Static Pressure in High Air Velocity Tunnel Houses

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As the size of our broilers increase so does the need for higher and higher wind speeds to keep them cool during hot weather

Whereas in the past 500 ft/min was considered sufficient,

today many poultry companies are designing for 600, 700 and even 800 ft/min

The problem is that obtaining these higher air speeds is more difficult/expensive than many realize

Example
50' X 560' X 9.25' broiler house

- How much fan power do we need?
- Cfm = air velocity X house cross-sectional area
- = 800 ft/min X (9.25' X 49')
- = 362,600 cfm

How many fans?

- Choretime – 52" high capacity
- 0.05" = 29,100 cfm
- 0.10" = 27,300 cfm
- 0.15" = 25,000 cfm
- 0.20" = 22,700 cfm
- 0.25" = 20,200 cfm
- 0.30" = 17,000 cfm

How many fans?

- # of Fans = Total cfm/fan cfm
- = 362,600 / 27,300
- = 13 fans

How much pad area?

- Pad area = total cfm @ 0.05" / 350
- = 378,300 / 350
- = 1,080 square feet

- Pad length = Pad area / Pad height
- = 1,080 / 4.7'
- = 230 linear feet
- Or
- = 115 feet per side
- Let's put in 120' feet per side to be safe

Would we get the air speed/bird cooling we designed for?

- and if we don't, why?

Tunnel ventilation system performance study

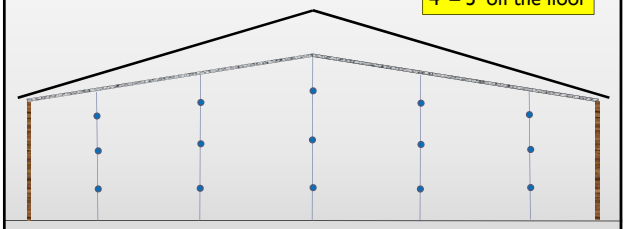
- Funded by USPAE, Choretime

Measuring house air speed

- 15 anemometers on 5 poles (3 anemometers per pole)

Air speed measurement grid

2' from the floor
2' from the ceiling
4' – 5' off the floor



Measuring house air speed

- Data loggers record average air speed every minute for 10 to 20 minutes under various

Multiple electronic static pressure measurements

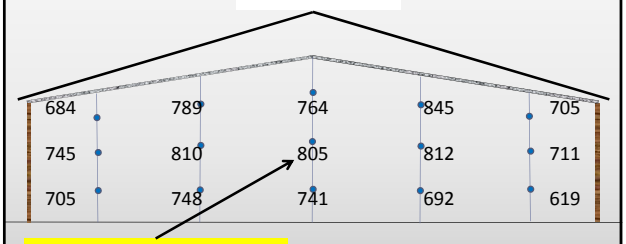
Over a dozen houses have been studied

The 15 anemometers…

allow an accurate determination of the air velocity profile

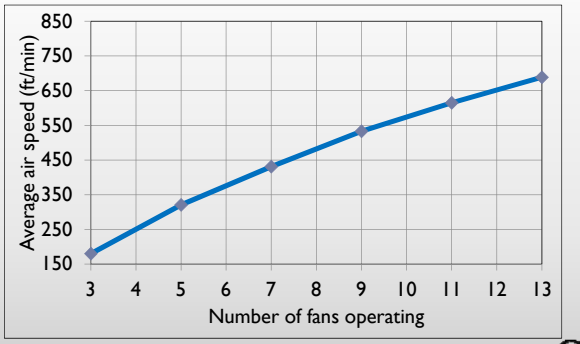
Air speed measurement grid
(50' X 560' house)

and to determine a very accurate average air velocity

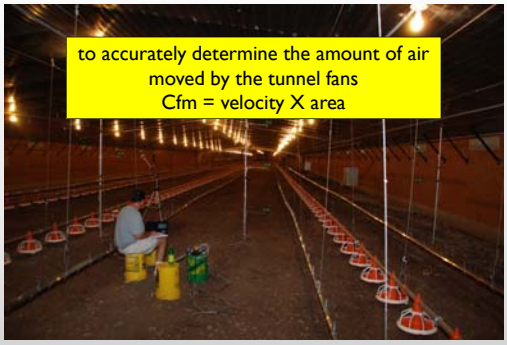


Center line velocity is 15 to 20% higher than the true average

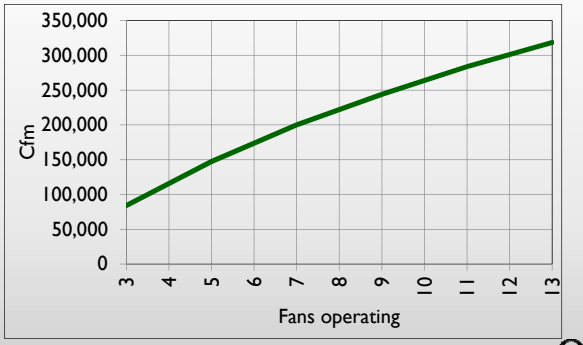
Allows an accurate determination of how air velocity changes with fan operation



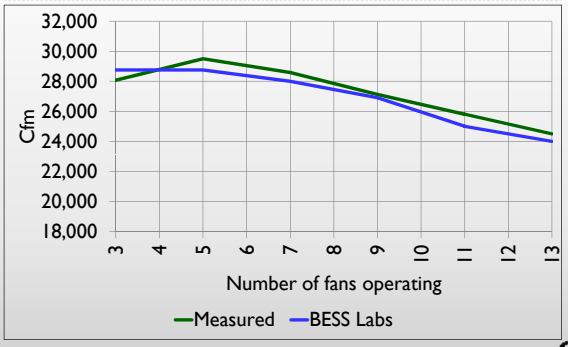
Last but not least…



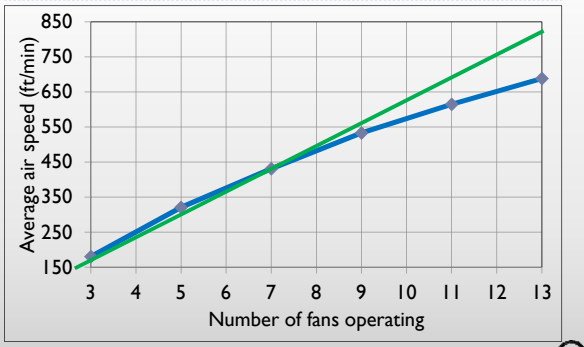
50' X 560' Broiler house
total fan air moving capacity



Average fan air moving capacity can be compared against BESS labs data



In the 50' X 560' house the air velocity in the broiler house was much lower than expected…

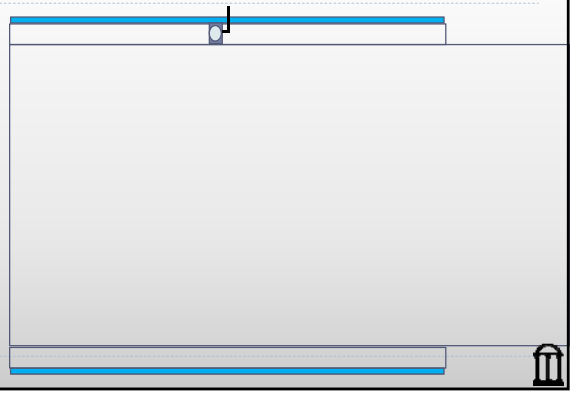


With all the fans operating we measured the static pressure…

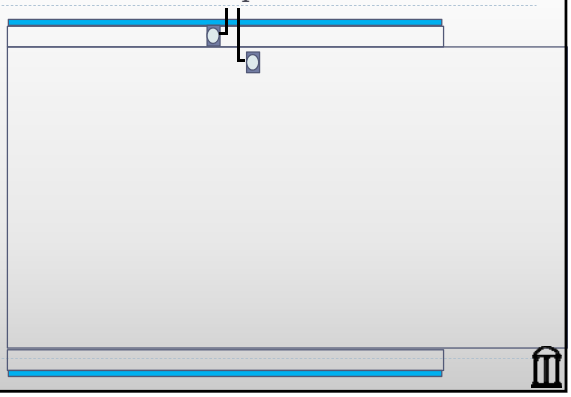
- controller (1/2 house) = 0.135"

- tunnel fans = 0.17"

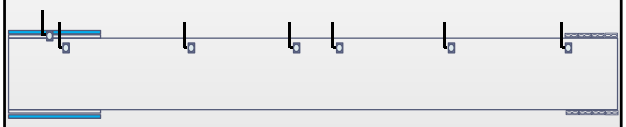
Pad pressure



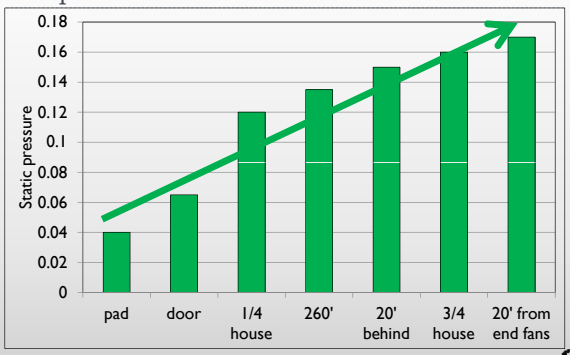
Pad + Tunnel door pressure



Then the static pressure was measured at:



Static pressure increased as we moved from the pads to the fans



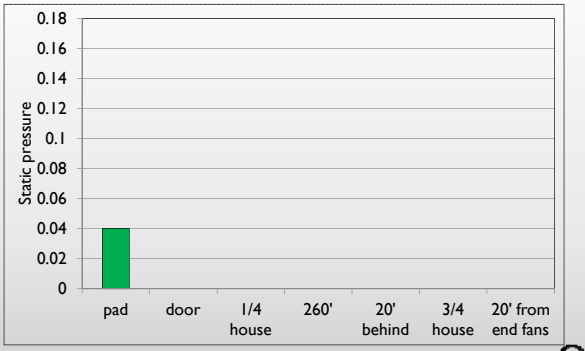
What are we really doing when we measure static pressure in a tunnel house?

- We are measuring how much work it takes the fans to move the air from outside to where you are standing inside the house.

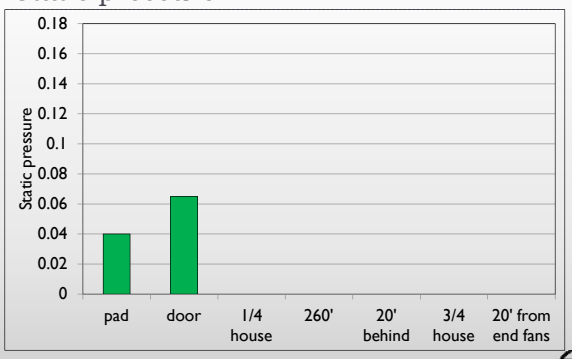
When we measure the static pressure in the center of the house…

- We are actually measuring the total of the amount of work it takes to…
  - Pull the air through the pads,
  - then through the tunnel doors,
  - into the cross-section of the house,
  - then down ½ way the house.
- Each action requires work (measured in pressure) of the fans

Static pressure

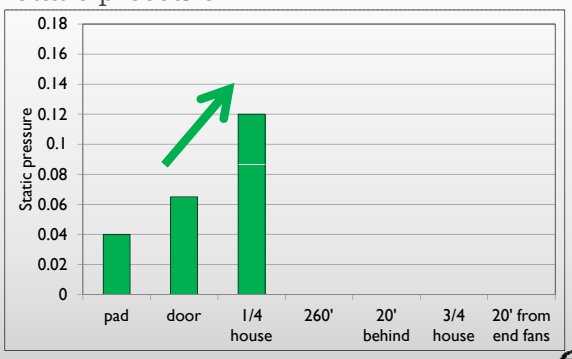


Static pressure



40" tunnel door opening on 5' tall pad

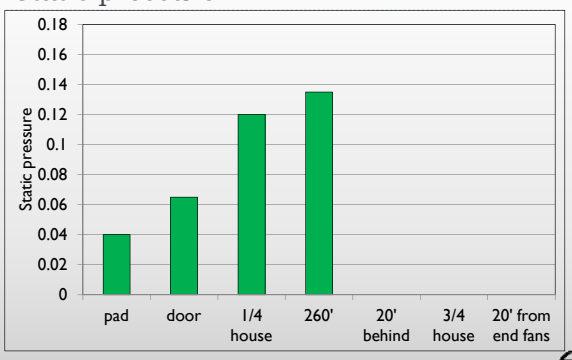
Static pressure



Transition or funnel pressure

- Pad area is much larger than the cross-sectional area of the house.
  - To obtain more air speed we add fans...
  - We add more pad as we add fans….
  - But the cross-sectional area (pipe size) remains the same
- You are taking air from over 1,000 square feet of pad and cramming it into a 450 square foot pipe

Static pressure



"Pipe flow" pressure

- When every a fluid flows down a pipe there is a resistance/friction
- In water pipes we use the following equation to determine how much work/pressure is required to move water through a pipe:
  - Loss = PSI Loss Value x Pipe length / 100

PSI loss value table for water flowing through a PVC pipe

Flow (gpm)	¾"	1"	1 ¼"	1 ½"	2"	2 ½"	3"
5	2.5	0.8	0.2	0.1	0	0	0
6	3.4	1.1	0.3	0.1	0	0	0
7	4.6	1.4	0.4	0.2	0	0	0
8	5.9	1.8	0.5	0.2	0	0	0
9	7.3	2.3	0.6	0.3	0.1	0	0
10	8.9	2.7	0.7	0.3	0.1	0	0
11	10.6	3.3	0.9	0.4	0.1	0	0
12	-----	3.8	1.0	0.5	0.1	0	0
13	-----	4.5	1.2	0.6	0.2	0	0
14	-----	5.1	1.4	0.6	0.2	0	0
15	-----	5.8	1.5	0.7	0.2	0.1	0
16	-----	6.5	1.7	0.8	0.3	0.1	0

How much work/pressure does it take…

- To move water down a 500 long pipe at a flow rate of 5 gals/min?

PSI loss value table for water flowing through a PVC pipe

Flow (gpm)	¾"	1"	1 ¼"	1 ½"	2"	2 ½"	3"
5	2.5	0.8	0.2	0.1	0	0	0
6	3.4	1.1	0.3	0.1	0	0	0
7	4.6	1.4	0.4	0.2	0	0	0
8	5.9	1.8	0.5	0.2	0	0	0
9	7.3	2.3	0.6	0.3	0.1	0	0
10	8.9	2.7	0.7	0.3	0.1	0	0
11	10.6	3.3	0.9	0.4	0.1	0	0
12	-----	3.8	1.0	0.5	0.1	0	0
13	-----	4.5	1.2	0.6	0.2	0	0
14	-----	5.1	1.4	0.6	0.2	0	0
15	-----	5.8	1.5	0.7	0.2	0.1	0
16	-----	6.5	1.7	0.8	0.3	0.1	0

"Pipe flow" pressure

- When every a fluid flows down a pipe there is a resistance/friction
- Friction:
  - Loss = PSI Loss Value x Pipe length / 100
  - = 0.8 X 500/100
  - = 4 psi

Poultry house is basically a pipe… and the same laws of physics apply

Pressure loss for air flowing in a tunnel house

Air Speed (ft/min)	Pressure Loss
100	0
200	0.001"
300	0.002"
400	0.0035"
500	0.006"
600	0.008"
700	0.012"
800	0.016"

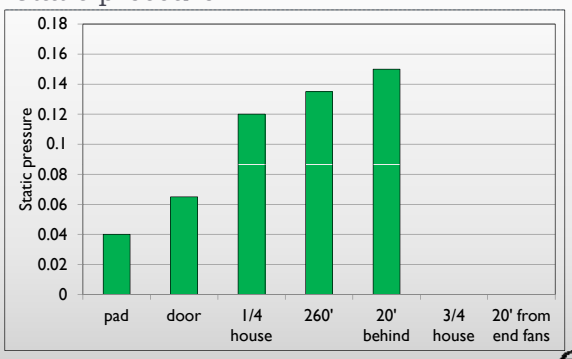
How much work/pressure does it take…

- To move air down a 500 long house at a flow rate of 500 ft/min?

Tunnel "Pipe flow" pressure

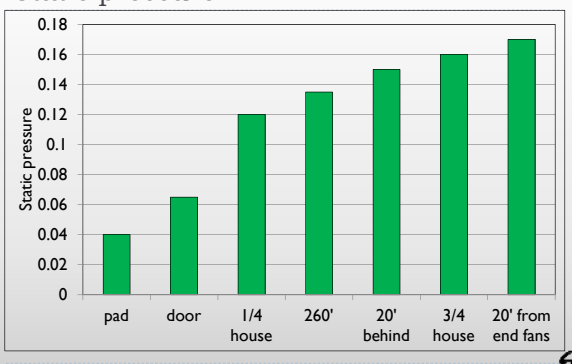
- When every a fluid flows down a pipe there is a resistance/friction
- Friction:
  - Loss = Pressure Loss Value x Pipe length / 100
  - = 0.006 X 500/100
  - = 0.03"

Static pressure



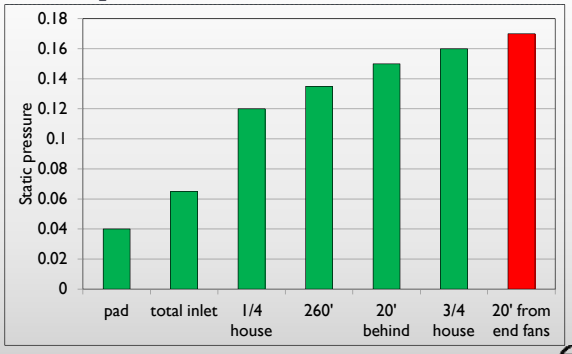
Half house curtain

Static pressure

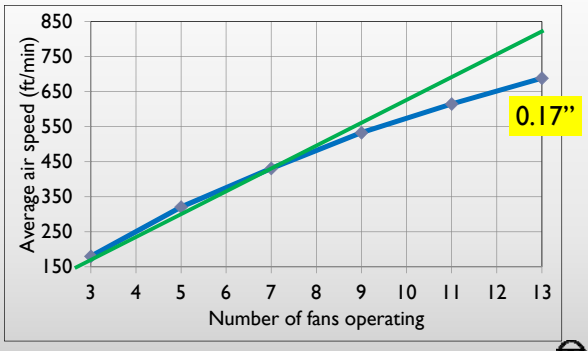


From a fan's perspective the critical pressure is that at the fan

Static pressure



Air velocity was lower than expected because the pressure was higher than expected



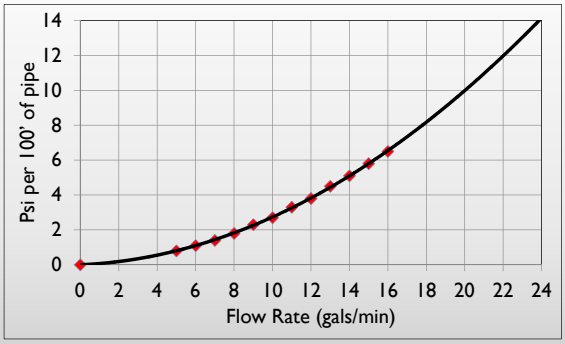
Does this large of a change in pressure from the pads to the fans occur in all houses?

- No…the large pressure changes primarily occur in high air velocity houses.
- Due to a law of physics discovered by Daniel Bernoulli in the early 1700's
  - Pressure increases with the square of velocity
- More simply put, if you double the velocity of a fluid in a pipe, the pressure/work required to move the fluid through the pipe increases four fold

PSI loss value table for water flowing through a PVC pipe

Flow (gpm)	¾"	1"	1 ¼"	1 ½"	2"	2 ½"	3"
5	2.5	0.8	0.2	0.1	0	0	0
6	3.4	1.1	0.3	0.1	0	0	0
7	4.6	1.4	0.4	0.2	0	0	0
8	5.9	1.8	0.5	0.2	0	0	0
9	7.3	2.3	0.6	0.3	0.1	0	0
10	8.9	2.7	0.7	0.3	0.1	0	0
11	10.6	3.3	0.9	0.4	0.1	0	0
12	-----	3.8	1.0	0.5	0.1	0	0
13	-----	4.5	1.2	0.6	0.2	0	0
14	-----	5.1	1.4	0.6	0.2	0	0
15	-----	5.8	1.5	0.7	0.2	0.1	0
16	-----	6.5	1.7	0.8	0.3	0.1	0

Pressure loss vs. Flow rate
(1" pvc pipe)



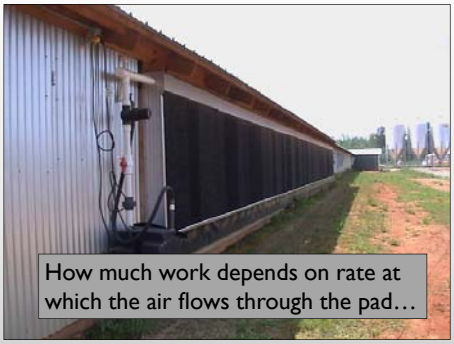
Similar things happen when a fluid flows through fittings…

- 90 degree elbow - 1" PVC pipe
  - For instance, the pressure required to move water through a single 1" PVC 90 degree elbow at 5 gals/min. is 1.5 psi.
  - Double the flow rate to 10 gals/min. and the pressure required increases four fold to approximately 6 psi.

or water filters…

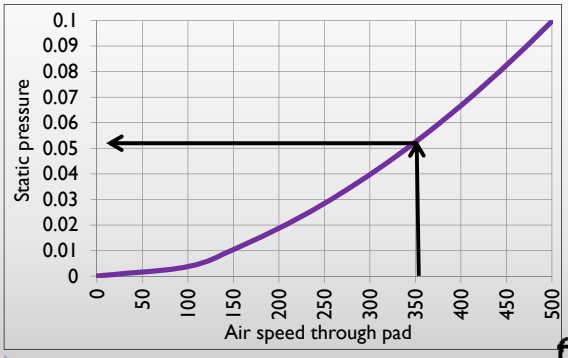
- Double the flow rate (5 vs 10 gals/min)….quadruple the pressure.

A pad is in a sense a filter….



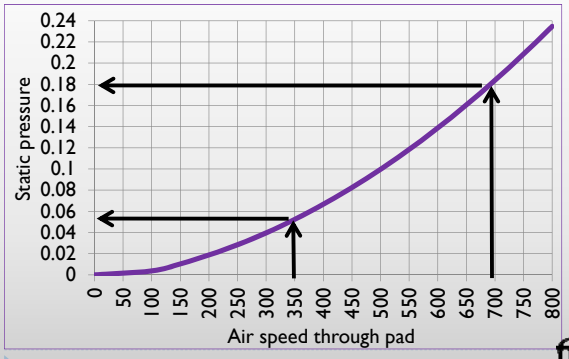
Pad pressure curve

(typical air velocity = 350 ft/min)



If we double the air speed through a pad

(by installing half as much)

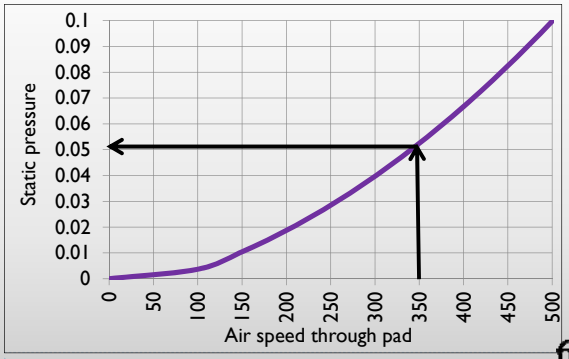


In the past air speeds were relatively low…static pressures were low

- Air speed through pad = 350 ft/min
  - Relatively minimum pressure/work

Pad pressure curve

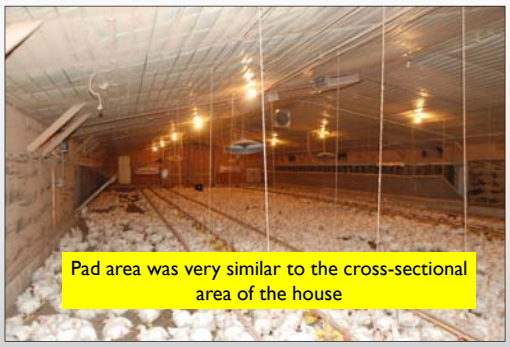
(typical air velocity = 350 ft/min)



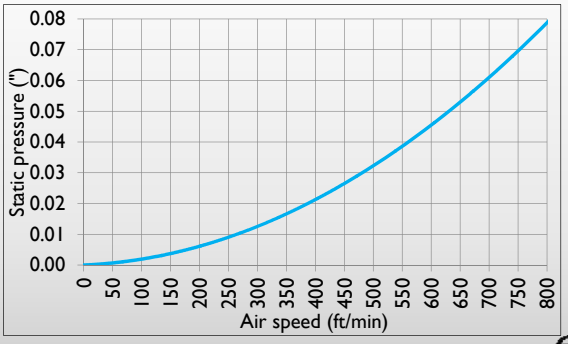
Total pressure

- Pad pressure = 0.05”

With an air speed down the house of 400 ft/min transition pressure was minimal



Transition pressure as a function of average house air speed



Transition pressure as a function of average house air speed

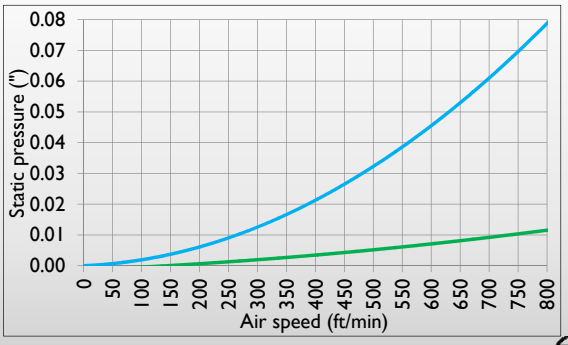
Air speed (ft/min)	Pressure gain
100	0.00”
200	0.01”
300	0.013”
400	0.02”
500	0.03”
600	0.045”
700	0.06”
800	0.08”

Total pressure

- Pad pressure = 0.05”
- Transition pressure = 0.02”

With an air speed down the house of 400 ft/min pipe pressure was minimal

Transition and pipe pressure as a function of average house air speed



Pressure gain for air flowing down tunnel house

Air speed (ft/min)	Pressure gain per 100'
100	0
200	0.001"
300	0.002"
400	0.0035"
500	0.006"
600	0.008"
700	0.012"
800	0.016"

Pipe pressure

- 0.0034" per 100 ft X 450/100 = 0.015"

Total pressure

- Pad pressure = 0.05"
- Transition pressure = 0.02"
- Pipe pressure = 0.015
- Total = 0.085"

Broiler breeder houses – pipe pressure?

Commercial layer?

Pressure gain for air flowing down tunnel house

Air speed (ft/min)	Pressure gain per 100'	Layer house
100	0	
200	0.001"	
300	0.002"	**0.007"**
400	0.0035"	**0.015"**
500	0.006"	**0.025"**
600	0.008"	**0.037"**
700	0.012"	
800	0.016"	

4.5 X

New houses…

- Air speed through pad = 350 ft/min
  - Pad pressure has remained relatively minimal

- But tunnel air speeds have increased = 600 - 800 ft/min
  - High transition pressure
  - High pipe pressure
- For example…

40' X 500' with an air speed of 700 ft/min

Pad pressure

- 350 ft/min = 0.05"

Transition pressure

Transition pressure

Air speed (ft/min)	Pressure gain
100	0.00"
200	0.01"
300	0.013"
400	0.02"
500	0.03"
600	0.045"
700	0.06"
800	0.08"

Pipe pressure

Pressure loss for air flowing down tunnel house

Air speed (ft/min)	Pressure gain per 100'
100	0
200	0.001"
300	0.002"
400	0.0035"
500	0.006"
600	0.008"
700	0.012"
800	0.016"

Pipe pressure in 500' long house (400' pipe past pads)

- 0.012" per 100 feet X 400/100 = 0.05"

Total pressure

Pressure sources	
Pad	0.05"
Transition	0.06"
Pipe	0.05"
Total	0.16"

Tunnel air speed vs. Total static pressure

- 700 ft/min = 0.16"
- This is for smooth walled houses, without tunnel doors, and clean pads
- Realistically you would probably need one to two points of pressure to determine the true operating pressure.

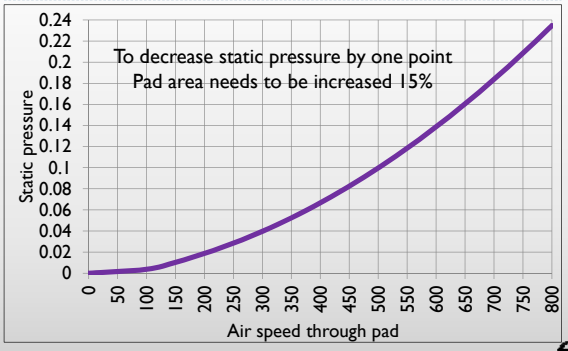
Tunnel air speed vs. Total static pressure

- 400 ft/min = 0.09" - 0.11"
- 500 ft/min = 0.10" - 0.12"
- 600 ft/min = 0.13" - 0.15"
- 700 ft/min = 0.16" - 0.18"
- 800 ft/min = 0.18" - 0.20"

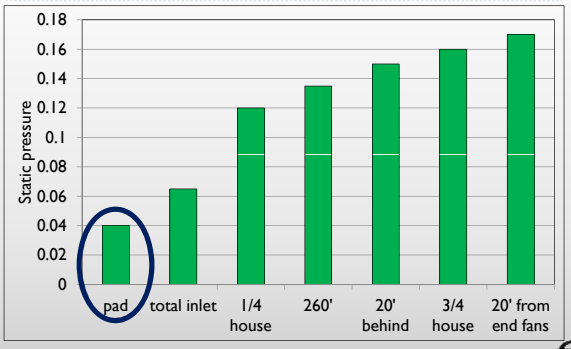
High air speeds = High static pressure

Can't we just add more pad

Adding pad will do little good



Static pressure

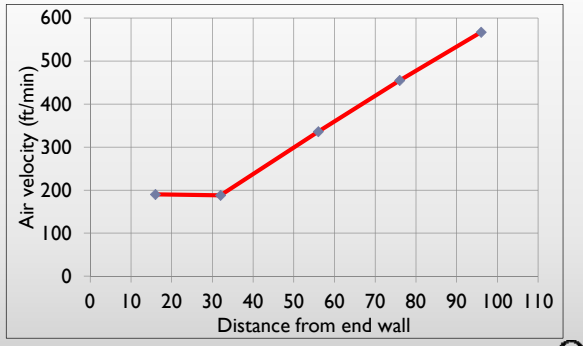


Longer the pad the larger the "dead spot" becomes…

54' X 560' – 5' tall pad with curtains

Measured air velocity 20' from side wall

Air velocity 20' from side wall



Longer the pad the longer the "dead spot" becomes…even with tunnel doors

66' X 600' – 110' of 6' tall pad

66' X 600' House with tunnel doors

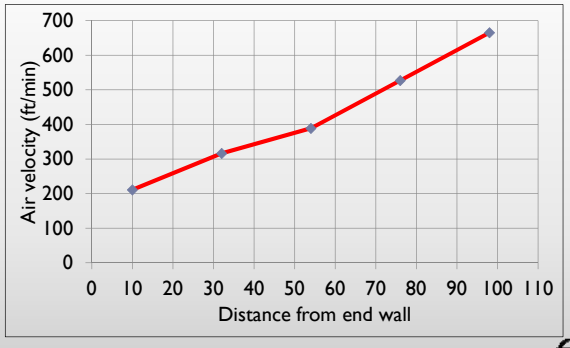
Air speed 18" above floor

98'	76'	54'	32'	10'	
752	542	383	298	131	6'
681	578	439	374	284	14'
563	460	344	276	218	24'

fans

Centerline

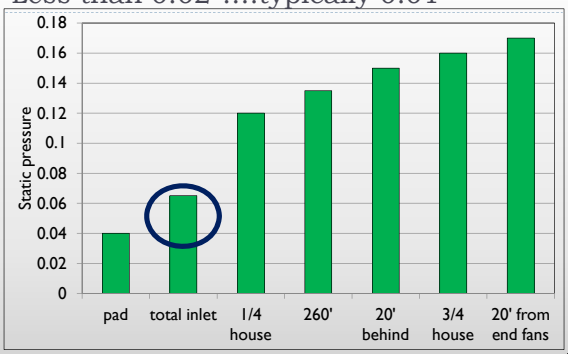
Average floor velocity



Tunnel doors may improve the situation…not solve the problem.

- After all worse case scenario they are only adding a couple points of pressure…

Less than 0.02"….typically 0.01"



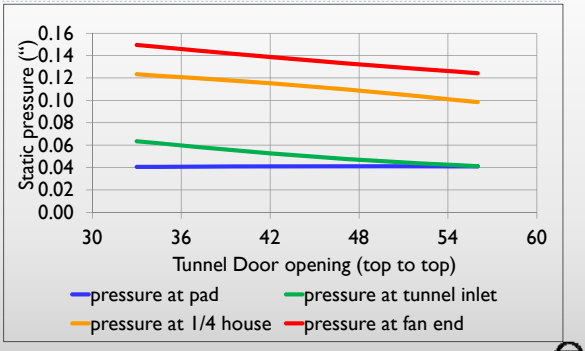
But we would end up with less air movement in the tunnel curtain area

Do we really need a 5' tunnel door on a 5' pad?

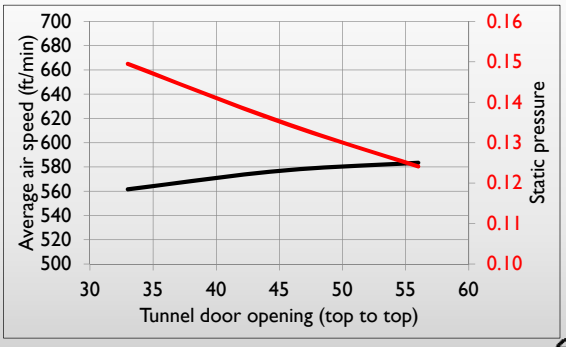
50' X 500' – 600 ft/min

92' of 5' tall pad

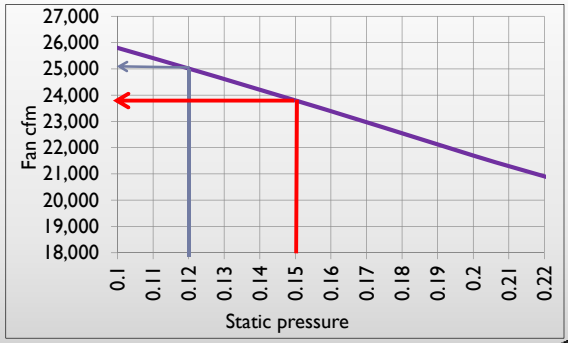
Static pressure as a function of door opening



Average air velocity vs. Tunnel door opening



Fan performance vs. Pressure

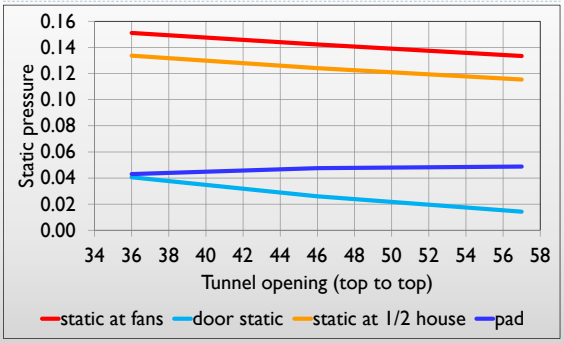


66' X 600' – 600 ft/min

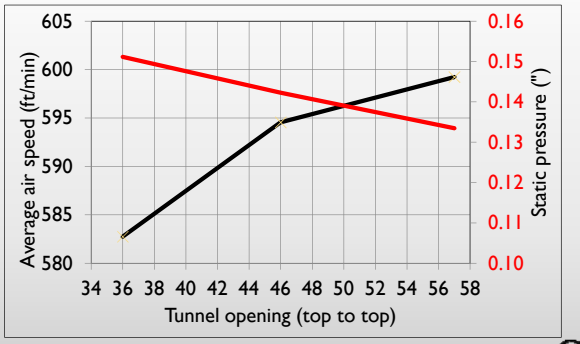
110' of 6' tall pad

5' tunnel door on a 6' tall pad

Static pressure as a function of door opening



Air velocity vs. Tunnel door opening



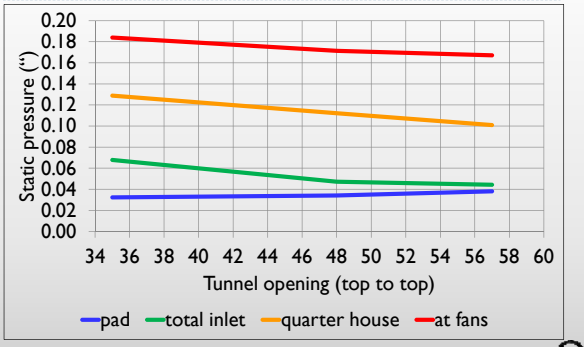
46' X 565' – 700 ft/min

110' of 5' tall pad

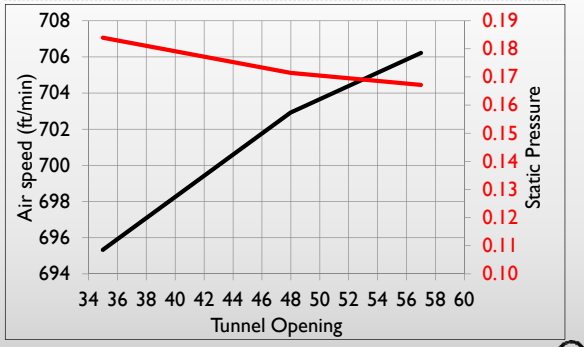
5' tunnel door on a 5' pad

46' X 565'

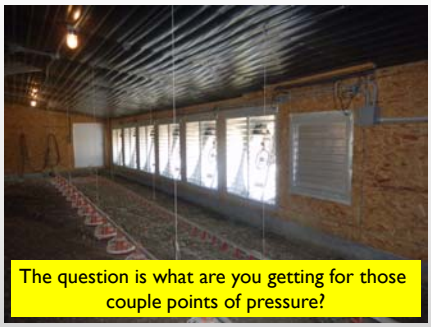
110' of 5' tall pad



46' X 565'



One or two points of pressure does not make that big of a difference in the air moving capacity of a quality fan



Do some of our houses have too much pad area?

- Originally….400 cfm per square foot of 6" pad,
- Then we increased it to 375 cfm/ft^2,
- Then to 350 cfm/ft^2,
- Now some people are using 325 cfm/ft^2
- As a result pad area per cfm has increased 15 percent or more.

Add to this the fact that traditionally we based our pad area on what the fans move at 0.05"

- Size fans at 0.10" and size pads at 0.05"
  - safety margin
- But today many of our fans are operating at a pressure of between 0.15" and 0.20" but we are still sizing our pads at the fans air moving capacity of 0.05"
  - more safety margin
- As a result pad area per cfm have increased another 10% or more

Is this really of benefit?

- 66' X 600' house (805 ft/min)

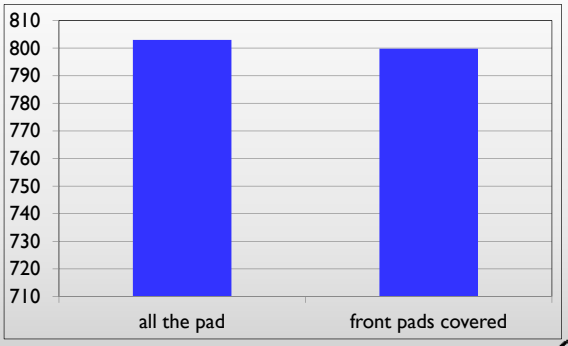
66' X 600' house – 805 ft/min

- 21, 52" fans (27,700 cfm @ 0.05")
- 27,700 X 21 = 581,700 cfm
- 581,700/350 = 1,662 square feet
- 1,662 / 6' = 271 total linear feet
- 271' / 2 = 136' feet per side of house

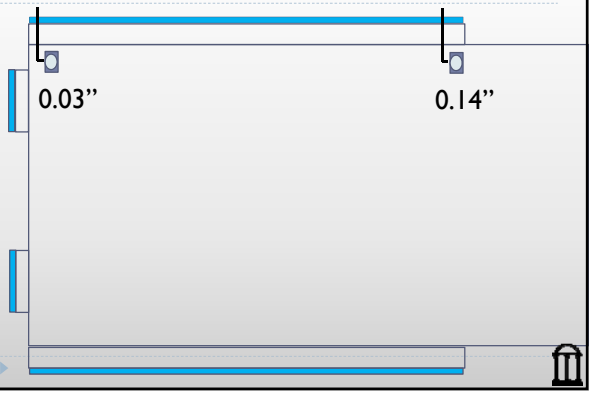
66' X 600' house – 805 ft/min

- 21, 52" fans
- 124' X 6' of pad on each side wall
- 2 X 12' X 6' of pad on the end of the house.

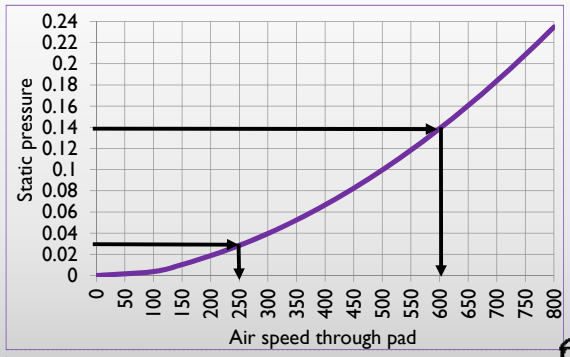
Average air velocity



Pressure at pads – 124' X 6' on side wall



Pressure vs. Air speed



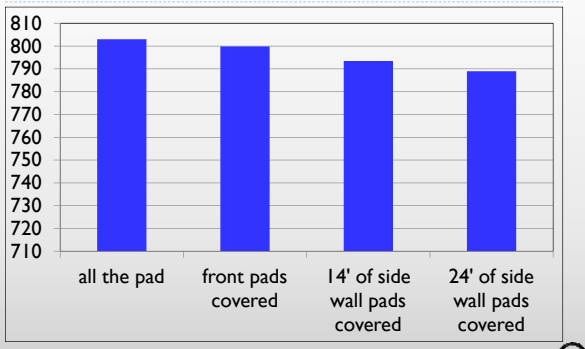
Top view – front pads in use

	1'	14'	26'
14'	287	207	61
46'	323	239	363

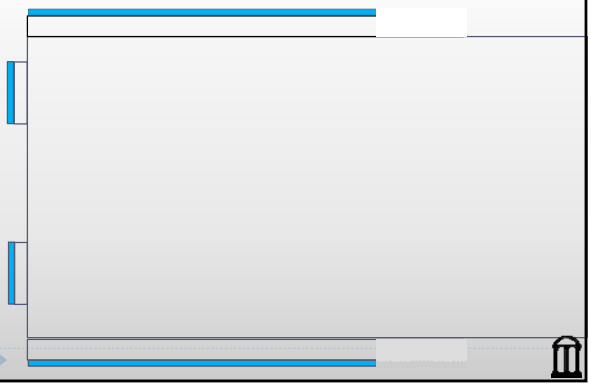
Top view – front pads covered

	1'	14'	26'
14'	329	250	68
46'	349	240	304

Average air velocity



Reducing pad area reduces the dead spot



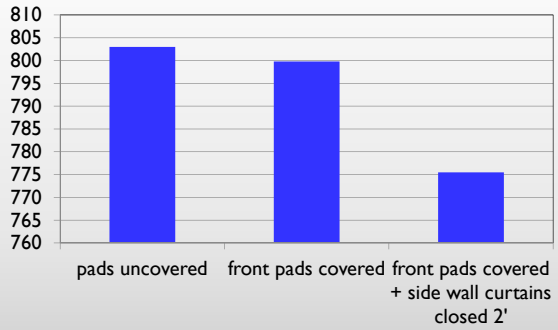
Top view – front pads in use

	1'	14'	26'
14'	287	207	61
46'	323	239	363

Top view – front pads covered, closed side curtains 2'

	1'	14'	26'
14'	554	294	103
46'	506	354	351

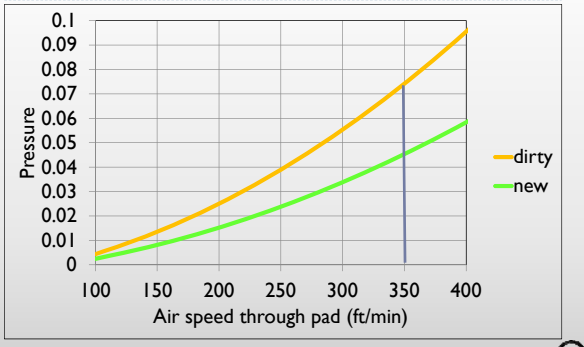
Average house air speed



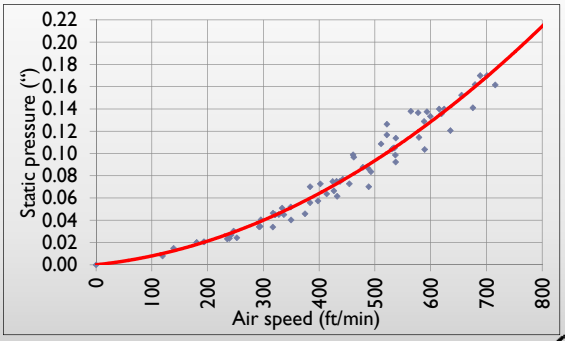
But the extra pad will help us when it gets dirty…right?

- To some extent but….

Static pressure – dirty vs. clean



High air velocity = High static pressures



High air velocity tunnel houses

- Determine the number of tunnel fans at a proper design static pressure.
- 400 ft/min = 0.10"
- 500 ft/min = 0.10"
- 600 ft/min = 0.15"
- 700 ft/min = 0.15"
- 800 ft/min = 0.20"

High air velocity tunnel houses

- Determine the number of tunnel fans at a proper design static pressure
- Fans should ideally have an air flow ratio of 0.80 or better
  - This typically requires more powerful (less energy efficient) tunnel fans

High air velocity tunnel houses

- Determine the number of tunnel fans at a proper design static pressure.
- Fans should ideally have an air flow ratio of 0.80 or better.
- Determine pad area based on the air moving capacity of the tunnel fans at 0.05" below the operating.

Pad area based on static pressure 0.05" below fan operating pressure

- 400 ft/min = 0.10"
  - Pad area @ 0.05"
- 500 ft/min = 0.10"
  - Pad area @ 0.05"
- 600 ft/min = 0.15"
  - Pad area @ 0.10"
- 700 ft/min = 0.15
  - Pads area @ 0.10"
- 800 ft/min = 0.20"
  - Pads area @ 0.15"

High air velocity tunnel houses

- Determine the number of tunnel fans at a proper design static pressure.
- Fans should ideally have an air flow ratio of 0.80 or better.
- Determine pad area based on the air moving capacity of the tunnel fans at 0.05" below the operating.
- Install pads as tall as possible
  - Ideally 6' tall

5' tunnel door on a 6' tall pad

High air velocity tunnel houses

- Determine the number of tunnel fans at a proper design static pressure.
- Fans should ideally have an air flow ratio of 0.80 or better.
- Determine pad area based on the air moving capacity of the tunnel fans at 0.05" below the operating.
- Install pads as tall as possible
  - Ideally 6' tall
- Maintain tunnel fans on a regular basis!

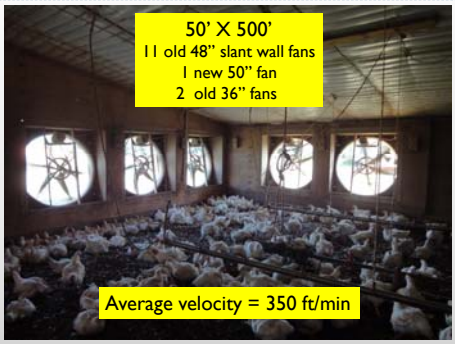
High air velocity tunnel houses

- Determine the number of tunnel fans at a proper design static pressure.
- Fans should ideally have an air flow ratio of 0.80 or better.
- Determine pad area based on the air moving capacity of the tunnel fans at 0.05" below the operating.
- Install pads as tall as possible
  - Ideally 6' tall
- Maintain tunnel fans on a regular basis!
- Clean evaporative cooling pads on a regular basis!

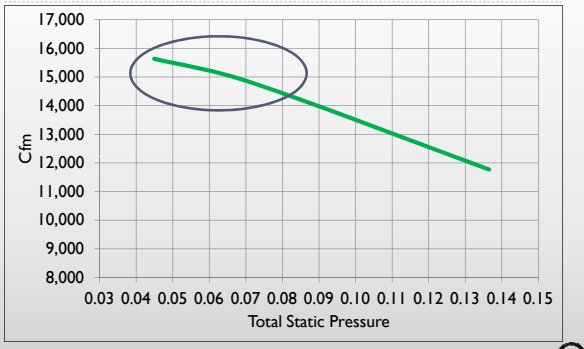
High air velocity tunnel houses

- When upgrading keep in mind that existing fans may not hold up well under high static pressures

Upgrading a house to 600 ft/min



Late 1980's 48" slant wall fan



What is required?

- The existing fan capacity @ 0.15" = 145,000 cfm
- Additional fan capacity required = 120,000 cfm

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