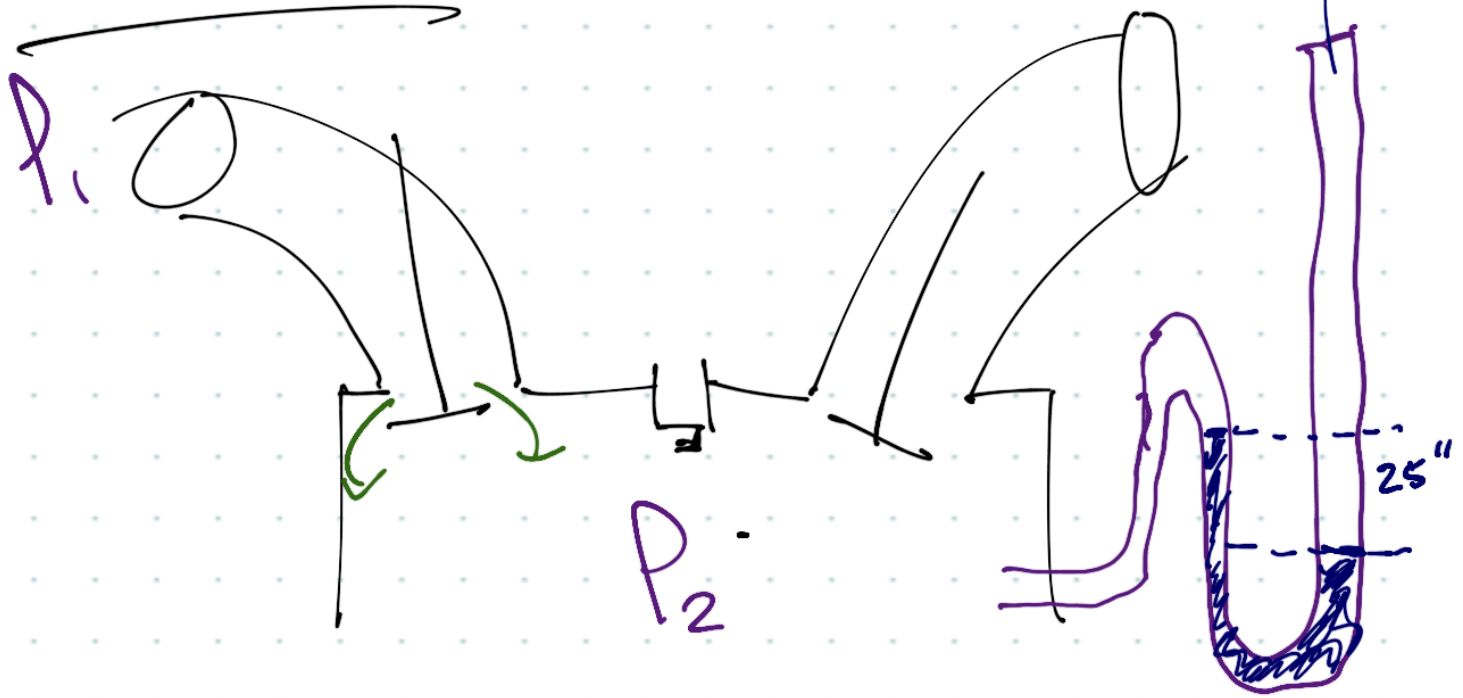


Flowbench



$$P_1 - P_2 = 25'' \text{ H}_2\text{O}$$

This is the pressure difference between the outside and inside

To control the pressure difference, we have a valve

Every time you change the lift, change the main flow valve to keep $P_1 - P_2$ constant

from the flowbench manual :

At 25" H₂O the pressure difference
for perfect flow $\Rightarrow$ 138 CFM/sq. inch
Cubic feet per min

Geometrically :

$$\text{Valve open area} = \frac{\pi D^2}{4}$$

D = Valve diameter

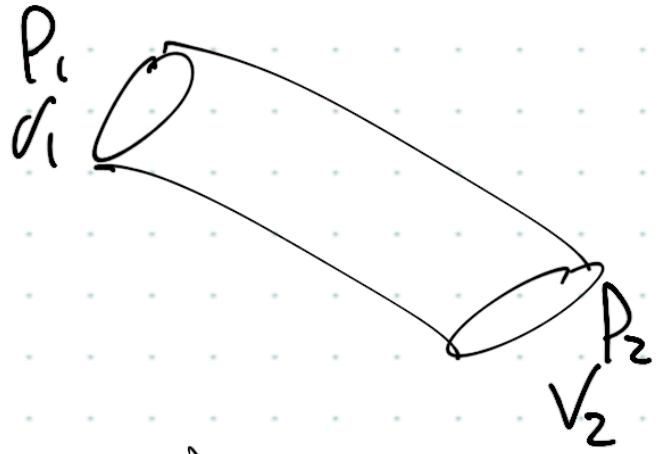
$$\text{for perfect flow} \Rightarrow 138 \times \frac{\pi D^2}{4} \text{ CFM}$$

At 25" H₂O

$$\text{Perfect flow is : } \frac{138}{2.1} \text{ litres/sec / sq. inch}$$

(28.3 litres in a cubic foot , 60 sec.)

Bernoulli's equation



P_1 = Pressure in room

V_1 = Velocity in room

P_2 = Pressure past valve

V_2 = Velocity past valve

(cylinder)

It is the pressure difference that accelerates the air

$$P_1 + \frac{1}{2} \rho V_1^2 = P_2 + \frac{1}{2} \rho V_2^2$$

Potential
energy

Kinetic
energy

By conservation of energy $\rightarrow$

In the room $V_1 = 0$ at $P_1 = \text{atmospheric Pressure}$

So we get :

$$P_1 = P_2 + \frac{1}{2} \rho V_2^2$$

$$P_1 - P_2 = \frac{1}{2} \rho V_2^2$$

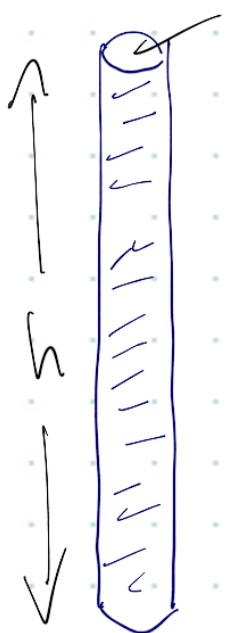
$$V_2^2 = \frac{2}{\rho} (P_1 - P_2)$$

So

$$V_2 = \sqrt{\frac{2}{\rho} (P_1 - P_2)}$$

V_2 = perfect flow velocity

ρ = air density (1.2 kg/m^3)



Area = A

Cylinder of water, h meters tall

Weight of water in column

Pressing down, we have $= h A \rho g$

This is a force (N)

$$\text{Pressure} = \frac{\text{weight force}}{\text{Area of Column}}$$

$$= \frac{\cancel{h} \cancel{A} \rho g}{\cancel{A}} = \underline{h \rho g}$$

So $P_1 - P_2 = h \rho g$ from flukebench

$$= \frac{25 \times 25.4}{1000} \times 1000 \times 9.81$$

← to get meters
← ρ of water

$$= 6229.35 \text{ N/m}^2 \text{ (or Pa)}$$

$$1 \text{ Bar} = 10^5 \text{ N/m}^2$$

$$25'' \text{ H}_2\text{O} = \frac{6229.35}{10^5} = \underline{0.06 \text{ Bar}}$$

Back to Bernoulli:

$$V_2 = \sqrt{\frac{2}{\rho} (P_1 - P_2)}$$

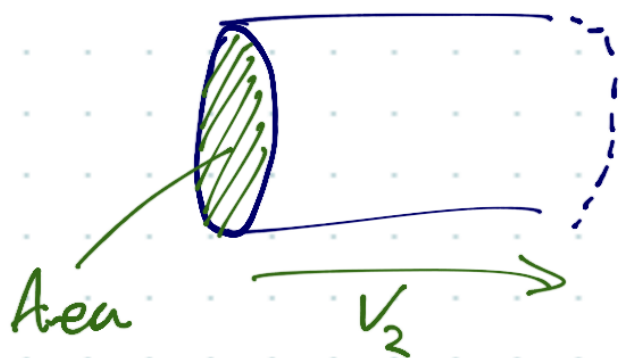
at 25" H₂O
(P₁ - P₂)

$$V_2 = \sqrt{\frac{2}{1.2} (622 \text{ g})}$$

$$V_2 = 101.9 \text{ ms}^{-1}$$

$$\Rightarrow \underline{210 \text{ mph}}$$

Imagine 1 square inch of area



Volume of air per second
 AV_2

Area = 1 sq. inch

$$\text{So } \frac{25.4 \times 25.4}{10^6} = 0.00645 \text{ m}^2$$

So perfect flow per square inch

$$\Rightarrow 0.00645 \times 101.9$$

$$\Rightarrow \text{at } 25'' \text{ H}_2\text{O } (P_1 - P_2) = 0.657 \text{ M}^3/\text{sec}$$

lets look at 1 cubic foot

$$1 \text{ cubic foot} = \frac{(12 \times 25.4)^3}{(1000)^3}$$

$$1 \text{ cubic foot} = 0.0283 \text{ m}^3$$

$$\Rightarrow \underline{28.3 \text{ litres}}$$

So,

$$138 \text{ CFM} = 138 \times 28.3$$
$$= \frac{138 \cdot 28.3}{60} \leftarrow \text{for seconds}$$
$$= 65.1 \text{ litres/sec}$$

So, the perfect flow per sq. inch

$$65.1 \text{ litres/sec/sq. inch}$$

This means if the valve diameter is D

we would expect a flow of

$$101.9 A \text{ m}^3/\text{sec}$$

$$\text{or } 101.9 \times A \times 1000 \text{ litres/sec}$$

This leads to $\rightarrow$ flow coefficient

$$C_f = \frac{\text{Measured flow} / S_q \text{ inch}}{\text{Perfect flow} / S_q \text{ inch}}$$

$$C_f = \frac{\text{Measured flow} / S_q \text{ inch}}{65.1}$$

$\Rightarrow$

lift	Measured litre/sec	$\rightarrow$	C_f
1 mm			
2 mm		$\rightarrow$	
3 mm			

To measure flow, measure a pressure difference across a hole.

Perfect velocity through a hole from Bernoulli

$$= \sqrt{\frac{2}{\rho}(P_1 - P_2)}$$

To get litres/sec through hole

$\Rightarrow$ Bernoulli velocity $\times$ Area

Geometry of a hole $= \frac{\pi D^2}{4}$

$\Rightarrow 0.6 \times \frac{\pi D^2}{4}$ for a sharp hole

So measured litres/sec

$$= \sqrt{\frac{2}{\rho}(P_1 - P_2)} \times 0.6 \times \frac{\pi D^2}{4}$$

Air flow past a valve

Air has to exit the part through a
Side area between Valve and part



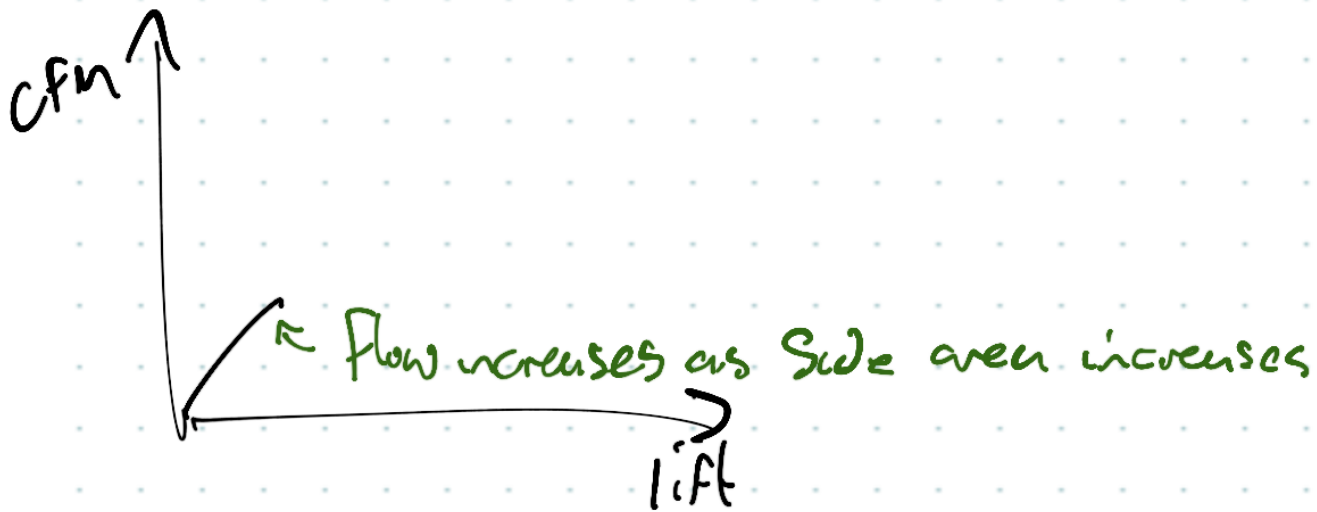
$$\text{Part Area} = \frac{\pi D^2}{4}$$

$$\text{Side Area} = \pi D \times L$$

↑ Circumference
↑ lift

The air flows through a part area of $\frac{\pi D^2}{4}$
and then through a 'curtain' side area
of $\pi D \times L$

At low lift, L is small, so the curtain area
is small



This continues until the Side area = Port Area
 i.e. when

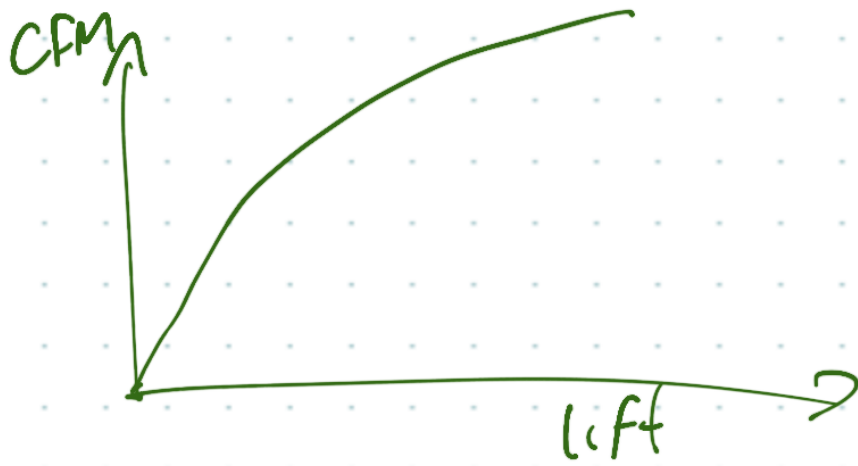
$$\cancel{\pi D L} = \cancel{\pi D^2} / 4$$

so $L = D/4$ the Port becomes
 the restrictor.

Remember

$$\text{Value area} = \text{Number of Valves} \times \pi D^2 / 4$$

Results $\rightarrow$



or CFM/Sq. inch

