SAIOH Tutorial

Ventilation 2 – converting pressure units, system measurement and fan laws

Acknowledgement

- This tutorial was provided by SAIOH as an assessment support aid for prospective candidates.
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Measurement of pressure

- In ventilation it is usual to express ventilation pressure in Pascal's, Pa (N/m^2)
- When you stand facing the wind you feel pressure on your face, the higher the wind speed the greater the pressure.
- If a pressure gauge faces into this flow this pressure would be measured.

Measurement of pressure

- The equation which governs the relationship between air velocity (V) and velocity pressure (p) is:

$$\mathbf{P_v = \rho \frac{v^2}{2}}$$

ρ = Density of air (kgm^{-3}) = 1.2 at std conditions
v = Air velocity ms^{-1}
P_v = Velocity pressure (Pa ie Nm^{-2})

Measurement of pressure

- So if the air density is 1.2 kgm^{-3} what is the velocity pressure of air flowing at 20 ms^{-1} ?
  - $p_v = \frac{1.2 \times (20)^2}{2} = 240 \text{ Pa}$

Measurement of pressure

- So assuming air density to be 1.2 kgm^{-3} calculate the velocity pressure (Pa)for the following air speeds (ms^{-1})?

6	3	25

Measurement of pressure

- So assuming air density to be 1.2 kgm^{-3} calculate the velocity pressure (Pa)for the following air speeds (ms^{-1})?

6	3	25
21.6	5.4	375

Measurement of pressure

- The above calculation can be rearranged to allow the air velocity to be calculated from the velocity pressure measurement
- Why would this be useful?

$$V = \sqrt{\frac{2p_v}{\rho}}$$

Measurement of pressure

- The velocity pressure is measured at 100 Pa, what is the air velocity assuming air density is 1.2 kgm^{-3} ?

- $V = \sqrt{\frac{2p_v}{\rho}}$ $\quad V = \sqrt{\frac{2 \times 100}{1.2}} = 12.91\ ms^{-1}$

Measurement of pressure

- So assuming air density to be 1.2 kgm^{-3} calculate the air speeds (ms^{-1}) corresponding to the following velocity pressures?

32	126	535

Measurement of pressure

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32	126	535
7.3	14.5	29.9

Air density

- Is the weight of air per unit volume measured in kgm^{-3}
- As used in the previous calculations at standard conditions of temperature and pressure (20°C and 1013 mb) air density is 1.2 kgm^{-3}

Definitions

Air Density :

$$\rho = \frac{\text{Mass}}{\text{volume}}$$

Units – kg m^{-3}

(Varies with temperature and pressure)

Standard Conditions

STP

1 atmosphere

- 101.325 kPa
- 760 mm Hg
- 1000 mB
- 10^5 Pa

0^0 C (273K)

NTP

1 atmosphere

20^0 C (293K)

In ventilation STP is normally taken as being 20^oC and 1 atmosphere

Air density

- To Calculate air density at non-standard temperatures (t °C) and pressures (b mb) use the following equation:

$$\rho_{bt} = \frac{1.2 \times 293 \times b}{(293 + t) \times 1013}$$

Air density

- What is the air density at a temperature of 28°C and a barometric pressure of 1002 mb?:

Air density

- What is the air density at a temperature of 28°C and a barometric pressure of 1002 mb?:

$$\rho_{bt} = \frac{1.2 \times 293 \times 1002}{(293 + 28) \times 1013}$$

$$= 1.08\ \text{kgm}^{-3}$$

Addition of pressures

Remember - Total Pressure - P_t

- Algebraic sum of static and velocity pressure at any point
- May be +ive or –ive depending on flow direction

$$P_t = P_s + P_v$$

P_t = total pressure

P_s = Static pressure

P_v = Velocity pressure

All in Pascal's, Pa (Nm^{-2})

Exercise 3

The total pressure measured in a duct is -150 Pa

If the static pressure is -200 Pa, what is the velocity pressure?

Exercise 3 - Answer

$Pt = Ps + Pv$

Re arrange the equation:

$Pv = Pt - Ps$

$= -150 - (-200)$

$= -150 + 200$

$= 50$ Pa

Exercise 4

Complete the following table

Ps	Pv	Pt
-289	173	
58		298
-260		-153
	124	166

Exercise 4 - Answers

Ps	Pv	Pt
-289	173	-116
58	240	298
-260	107	-153
42	124	166

Exercise 5

If the velocity pressure measured in a duct at room temperature is 50 Pa, what is the velocity of the airstream? (assume STP)

Remember - Velocity Pressure

$$\mathbf{P_v} = \boldsymbol{\rho}\frac{\mathbf{v^2}}{\mathbf{2}}$$

ρ = Density of air (kgm^{-3})

v = Air velocity ms^{-1}

P_v = Velocity pressure (Pa ie Nm^{-2})

Velocity Pressure

If standard temperature and pressure conditions are in existence, i.e.:

$\rho = 1.2 \text{ kg m}^{-3}$

Then

$P_v = 0.6 v^2$

Exercise 5 - Answer

$P_v = 0.6\ v^2$ (at STP)

$50 = 0.6\ V^2$

$V = \sqrt{50/0.6}$

$V = \sqrt{83.3}$

$V = 9.1\ ms^{-1}$

Exercise 6

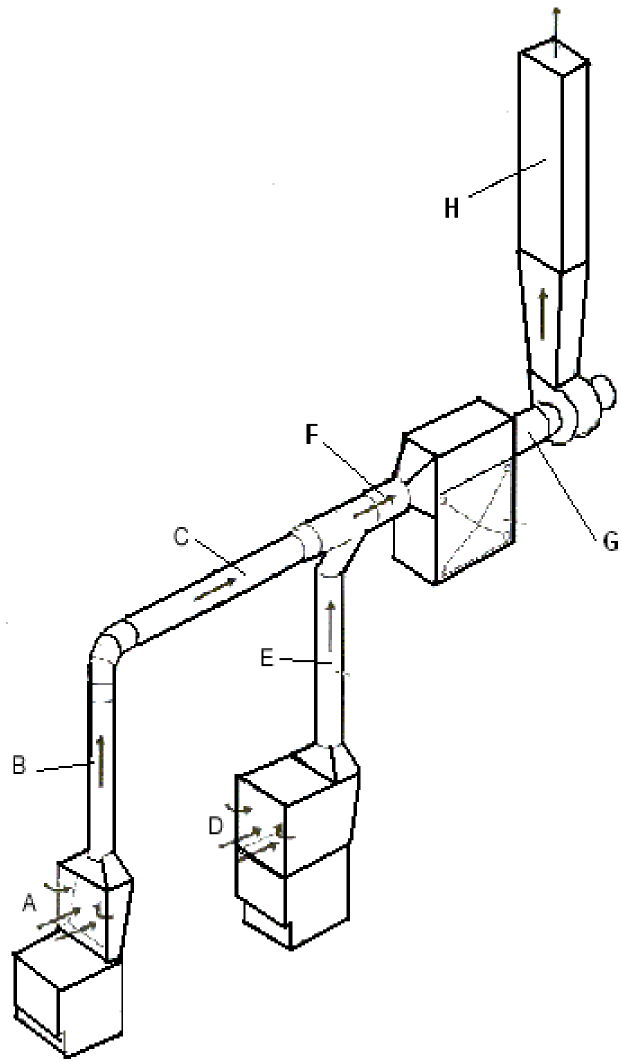
Complete the following table

Pv (Pa)	V (ms^{-1})
173	
240	
107	
124	

Exercise 6 - Answers

Pv (Pa)	**V (ms^{-1})**
173	17.0
240	20.0
107	13.3
124	14.4

Exercise 7



Exercise 7

Point	Dimensions	Pv (Pa)	V (m/s)	Q (m^3/s)
A	1 x 1 m	-	0.8	
B	0.3 m diam	75		
C	0.3 m diam	81		
D	1 x 1 m	-	1.0	
E	0.4 m diam	38		
H	0.8 x 0.4 m	19		

Exercise 7 - Answers

Point	Dimensions	Pv (Pa)	V (m/s)	Q (m^3/s)
A	1 x 1 m	-	0.8	**0.8**
B	0.3 m diam	75	**11.2**	**0.79**
C	0.3 m diam	81	**11.6**	**0.82**
D	1 x 1 m	-	1.0	**1.0**
E	0.4 m diam	38	**8.0**	**1.0**
H	0.8 x 0.4 m	19	**5.6**	**1.8**

Exercise 8

- The velocity pressure was measured in a 350mm diameter duct to be 360 Pa. assuming the air density to be 1.2 kgm^{-3} calculate the quantity of air flowing through the system?

Exercise 8 - Answer

$A = 0.096\ m^2$

$p_v = 360\ Pa$

$$V = \sqrt{\frac{2 \times 360}{1.2}} = 24.49\ ms^{-1}$$

$$Q = 24.49 \times 0.096 = 2.35\ m^3s^{-1}$$

Pressure measured with a liquid filled gauge

- Traditionally liquid filled manometers were used to measure pressure in a system
- Simple ‘U’ tubes and difference in height in mm indicates pressure
- Modern commercial manometers electronically convert the result to Pa

Pressure measured with a liquid filled gauge

- Pressure from a liquid manometer in mm can be converted to Pa using the following formula:

$$p = \rho gh$$

Where: p is the pressure (Pa)

ρ is the density of the liquid (H_2O = 1000kgm^{-3})

g is acceleration due to gravity 9.81

h is the height of the liquid column in m

Pressure measured with a liquid filled gauge

- A gauge filled with water shows a difference in level between the two limbs of 100 mm, what is the pressure in Pa:

$$p = \rho gh$$

$$P = 1000 \times 9.81 \times 0.1 = 981 Pa$$

Pressure measured with a liquid filled gauge

- What are the following pressures measured on a liquid filled gauge?
  - 45mm of water =
  - 72 mm of paraffin (s.g.0.8) =
  - 130 mm of mercury (s.g.13.6) =
- (to correct for other liquids multiply their s.g. by the density of water (1000) to obtain their density)

Pressure measured with a liquid filled gauge

- What are the following pressures measured on a liquid filled gauge?
  - 45mm of water = 441 Pa
  - 72 mm of paraffin (s.g.0.8) = 565 Pa
  - 130 mm of mercury (s.g.13.6) = 17344Pa

Fan laws

- Used to calculate changes in flow rate, pressure and power due to a change in fan speed.
- Volume flow is proportional to Fan Revs (Q1 – flow rate ms^{-1})

$$Q_2 = Q_1 (N^2/N^1)^1$$

- Pressure produced is proportional to fan revs squared (P2 – Pressure Pa)

$$P_2 = P_1 (N^2/N^1)^2$$

- Power consumed is proportional to the fan revs cubed (W3 – Impeller power kW)

$$W_2 = W_1 (N^2/N^1)^3$$

N = Fan rotational speed rps or rpm

Fan laws

- A fan running at 560 rpm has the following duty: volume flow 4.4m^3s^{-1}, total pressure of 750 Pa and power 4.7kW. Find the new flow, pressure and power at:
  a. 659 rpm
  b. If the speed is increased by 30%

a b

$Q_2 = Q_1 (N^2/N^1)^1$

$P_2 = P_1 (N^2/N^1)^2$

$W_2 = W_1 (N^2/N^1)^3$

Fan laws

- A fan running at 560 rpm has the following duty: volume flow 4.4m^3s^{-1}, total pressure of 750 Pa and power 4.7kW. Find the new flow, pressure and power at:
  a. 650 rpm
  b. If the speed is increased by 30%

	a	b
$Q_2 = Q_1 (N^2/N^1)^1$	4.2 (650/560)= 4.88	4.2 (728/560)= 5.46
$P_2 = P_1 (N^2/N^1)^2$	750 $(650/560)^2$= 1010	750 $(728/560)^2$= 1267
$W_2 = W_1 (N^2/N^1)^3$	4.7 $(650/560)^3$= 7.35	4.7 $(728/560)^3$= 10.3