

## 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.
- The tutorial is free to use and share for learning and knowledge improvement for candidates preparing to sit SAIOH registration assessments.
- Please ensure that you acknowledge SAIOH as the author and source of this material.

# Measurement of pressure

- In ventilation it is usual to express ventilation pressure in Pascal's, Pa ( $\text{N/m}^2$ )
- 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:

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

$\rho$  = Density of air ( $\text{kgm}^{-3}$ ) = 1.2 at std conditions

$v$  = Air velocity  $\text{ms}^{-1}$

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

# Measurement of pressure

- So if the air density is  $1.2 \text{ kgm}^{-3}$  what is the velocity pressure of air flowing at  $20 \text{ ms}^{-1}$  ?

$$- p_v = \frac{1.2 \times (20)^2}{2} =$$

# Measurement of pressure

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

6	3	25

# 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  $1.2 \text{ kgm}^{-3}$  ?

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



# Measurement of pressure

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

32	126	535

# Air density

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

# Definitions

Air Density :

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

Units – kg m<sup>-3</sup>

(Varies with temperature and pressure)

# Standard Conditions

STP

1 atmosphere

– 101.325 kPa

– 760 mm Hg

– 1000 mB

–  $10^5$  Pa

0° C (273K)

NTP

1 atmosphere

20° C (293K)

*In ventilation STP is normally taken as being 20°C 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?:

# 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 ( $\text{Nm}^{-2}$ )

## 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 4

Complete the following table

<b>Ps</b>	<b>Pv</b>	<b>Pt</b>
-289	173	
58		298
-260		-153
	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

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

$\rho$  = Density of air ( $\text{kgm}^{-3}$ )

$v$  = Air velocity  $\text{ms}^{-1}$

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

# Velocity Pressure

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

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

Then

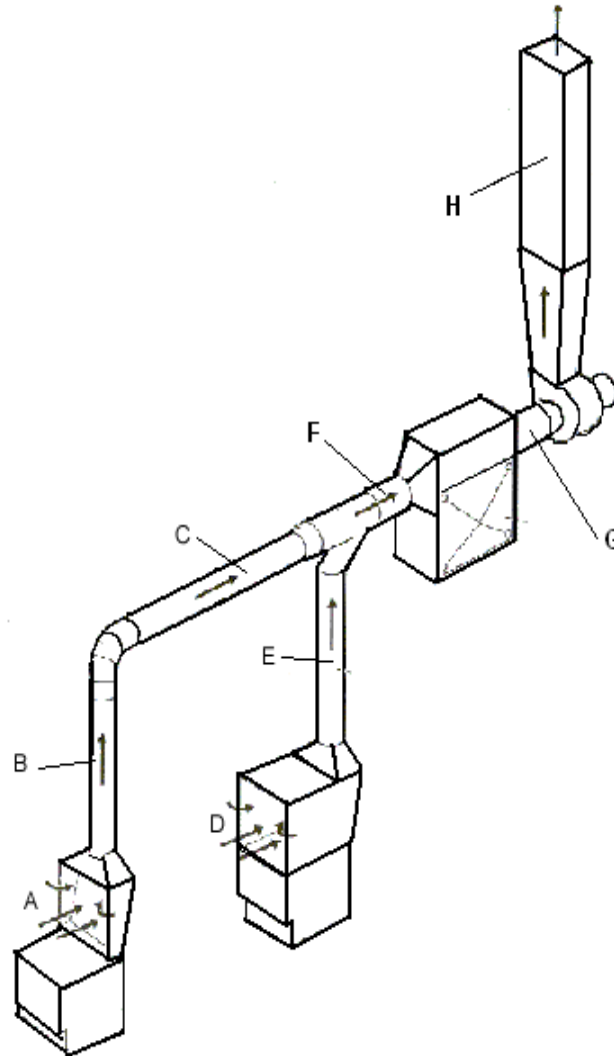
$$P_v = 0.6 v^2$$

# Exercise 6

Complete the following table

$P_v$ (Pa)	$V$ ( $\text{ms}^{-1}$ )
173	
240	
107	
124	

# Exercise 7



# Exercise 7

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

## Exercise 8

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



# 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)

$\rho$  is the density of the liquid ( $H_2O = 1000\text{kgm}^{-3}$ )

$g$  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:

$$p = \rho gh$$

$$P = 1000 \times 9.81 \times 0.1 = 981\text{Pa}$$

# 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)

# 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<sup>-1</sup>)

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

- 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  $4.4\text{m}^3\text{s}^{-1}$ , 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

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

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

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