MODULE 138
HVAC&R SKILLS WORKSHOP

AIR MEASUREMENT TECHNIQUES

Skills summary

What?

A guide to different air measurement techniques used when undertaking air balancing of HVAC systems.

Who?

Relevant for those involved in the process of testing, adjusting and balancing air systems within the HVAC&R industry.

The accurate measurement and adjustment of airflow rates using a recognised and reliable process during commissioning ensures that plant and equipment are adjusted and set correctly to meet the specified design operating conditions.

Air distribution systems may be different from one another, but the fundamental principles remain the same. Fans move air through duct networks, either bringing in conditioned outdoor air or removing stale air and objectionable odour. In the case of supplying conditioned air to a room or comfort zone, the air temperature, volume, velocity, diffusion, induction ratio and the coanda effect all collectively interact to help provide a comfortable indoor environment.

For air conditioning systems, testing, adjusting and balancing (TAB) activities ensure that the system operational variables are adjusted and set correctly to create the design comfort conditions, including volume, temperature, humidity, pressure, air movement and air quality set-points or targets within the occupied space.

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In-duct air measurement

Airflow in ductwork is most accurately measured by pitot tube and electronic manometer. Hot-wire anemometers can also be applied to produce accurate results when calibrated and maintained in accordance with the manufacturer's instructions. Because airflow in ducts is typically non-uniform, a range of readings are taken and then averaged.

An accurate measurement of airflow in a duct section is possible by traversing the section using a pitot tube only where there is a portion of ductwork system that has a straight parallel section for at least seven duct diameters before the pitot traverse location and three duct diameters after the pitot location upstream of any bend, fitting, obstruction or abrupt change of section. The total pressure and static pressure connections are made to the opposite ends of the manometer, which will then indicate velocity pressure.

The device (pitot tube, velocity probe, aerofoil pitot tube, hot-wire anemometer, etc.) is inserted into the airstream via test holes drilled into the duct wall, and multiple point readings are taken in a pitot "traverse" and the results averaged.

At each test point of the traverse pattern, the velocity pressure is read after allowing sufficient time for the manometer fluid or digital reading to stabilise. The velocity pressure at each point is used to calculate the air velocity at that point. The mean air velocity across the entire duct section is obtained by averaging the individual air velocities calculated at each traverse point.

The flow rate through the duct is derived by multiplying the mean measured velocity by the cross-sectional area of the duct air pathway (i.e., minus any internal insulation). Remember, it is the internal dimensions of the duct, subtracting any area taken by internal insulation, that must be used when determining airflows.

Pitot test holes

Designers and installers need to consider the location of test holes for pitot tube measurements to ensure accessibility. The insulation and cladding materials also need to be considered in terms of being able to install test holes. Figure 1 provides the recommended dimensions. The best option is for pitot test holes to be pre-drilled and sealed so that they are reusable for the life of the plant.

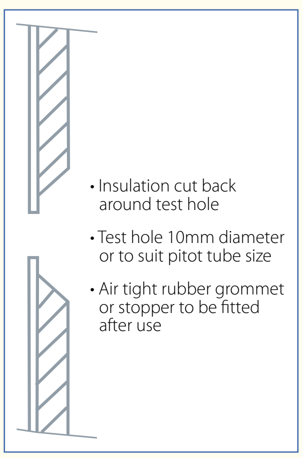


Figure 1 – Recommended test hole dimensions

Locating the pitot tube

Pitot tube traverses should only be carried out in areas of laminar or undisturbed airflow, well away from duct bends or fittings (take-offs, reducers, cowls) and duct-mounted components (dampers, filters, boxes).

To achieve laminar airflow, the pitot tube should be located as follows:

1. Distance of straight ducting before the pitot tube traverse location should be seven (7) duct diameters or greater
2. Distance of straight ducting after the pitot tube traverse location should be three (3) duct diameters or greater
3. The pitot tube tip must be facing at right-angles into the airstream.

For best measurement practices, BSRIA recommends the increased distances shown in Figure 2.

For circular ducts, a single test hole is required for ducts less that 150mm diameter, and for larger

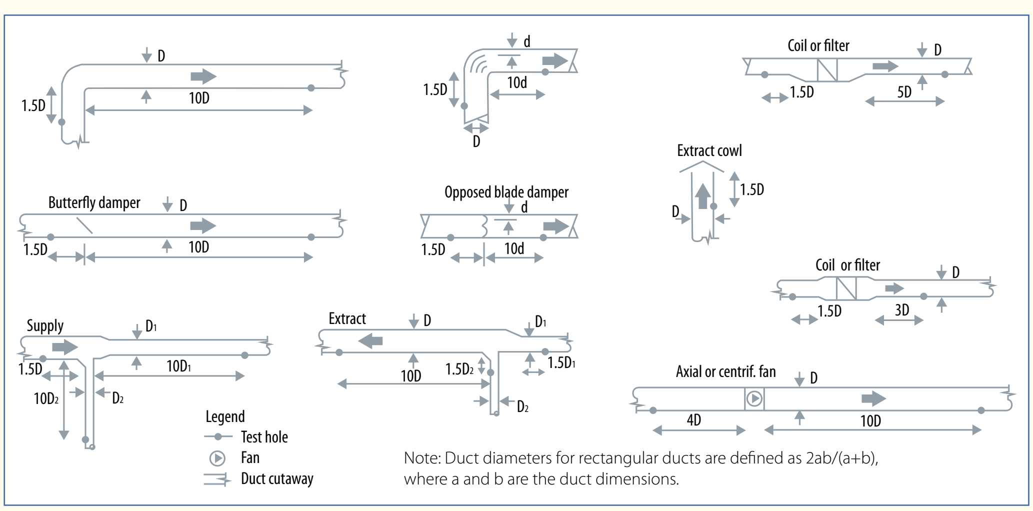


Figure 2 – Best practice pitot test hole distances

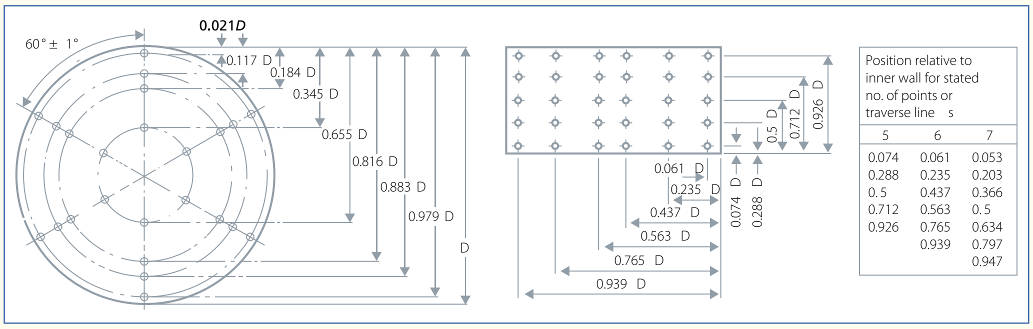


Figure 3 – Circular duct traverse locations – NEBB approach

ducts, two holes spaced 90-degrees apart are required. For rectangular ducts, the number of test holes depends on the duct dimensions.

Pitot on FRL protected ductwork

If it is necessary to pitot fire-protected or enclosed ducting to ascertain the actual airflow rate of the system, any holes created when performing the airflow measurement task will need to be reinstated to achieve the required fire rating (FRL) of the ductwork after the airflow readings have been taken and recorded. Refer to AS 1668.1 and AS 4254.2.

Pitot tube traverse patterns for circular duct

The required number of readings for a pitot traverse of a circular duct can be determined by the following information.

The number of pitot tube readings or test points for circular duct changes depends on the size of the duct.

Air moves through different sections of the duct at different velocities, so multiple readings are taken and an average generated. To determine the pitot tube location, the duct is divided into concentric annular zones of equal area, with readings taken in two directions and at right-angles to each other.

Two acceptable pitot traverse patterns for circular ducts are shown – the NEBB approach in Figure 3, and the BSRIA approach in Figure 4. Flat oval ducts are also covered in the BSRIA approach.

In the BSRIA approach, for circular ducts less than 200mm diameter, a single reading can be taken in the middle of the duct, with the measurement multiplied by 0.8 to obtain a reading.

In the NEBB approach, the number of readings to be taken and averaged is based on the size of the duct in accordance with Table 1.

Table 1 Number of readings for circular duct

Circular duct diameter	Number of readings required
Less than 250mm	6
250–300mm	8
Greater than 300mm	10

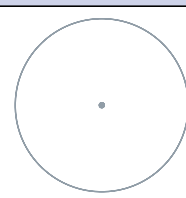
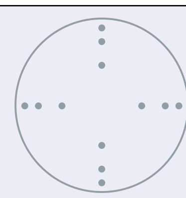
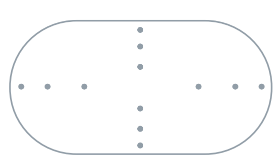
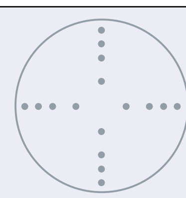
Diameter range and application	Distance of pitot tube from duct wall as a percentage of duct diameter								
	1	2	3	4	5	6	7	8	Test holes and measurement points
Up to 150mm diameter	50%*								
* Multiply this single point reading by 0.8 to obtain an average velocity									
Over 150mm diameter	3%	13%	32%	68%	87%	97%			
All sizes of flat oval duct	3%	13%	32%	68%	87%	97%			
For ducts 300mm to 1200mm diameter when measuring immediately upstream or downstream of a fan	2%	12%	18%	34%	66%	82%	88%	98%	
Note: Where flows measurements are unstable, additional measurement points should be included either on the same traverse or on additional traverses.									

Figure 4 – Circular duct traverse locations – BSRIA approach

For convenience, the constants in Table 2 can be multiplied by the duct diameter to determine the pitot traverse points.

Table 2 Constants to determine the pitot tube points for a circular duct

Readings taken in duct	Constants – multiply by duct diameter for distance of pitot tip from the duct centre point location towards duct wall.				
	P1	P2	P3	P4	P5
6	0.241	0.3535	0.4564	—	—
8	0.1768	0.3062	0.3953	0.4677	—
10	0.1581	0.2738	0.3535	0.4183	0.4743

NEBB circular duct traverse locations

Up to 6, 8 or 10 readings may be required, depending on the size of the duct, in accordance with Table 1.

For 6 readings (using the constants from Table 2) = 0.241 / 0.3535 / 0.4566 x diameter = points from centre line of pitot (see Figure 4.8)

e.g., 125mm = 57.0 - 44.2 - 25.5 - (62.5) + 25.2 + 44.2 + 57.0

For 8 readings = 0.1768 / 0.3062 / 0.3953 / 0.4677 x diameter

e.g., 300mm = 68.49 - 53.02 - 36.15 - (150) + 36.15 + 53.02 + 68.49

For 10 readings = 0.1581 / 0.2738 / 0.3535 / 0.4183 / 0.4743 x diameter

e.g., 500mm = 114.15 - 88.37 - 60.25 - (250) + 60.25 + 88.37+ 114.15

NOTE: No readings are taken at the geometric centre of the duct, and the readings will be taken closer together as they approach the duct wall (see Figure 5).

Pitot tube traverse patterns for rectangular/ square duct

In the NEBB approach, rectangular ducts are divided into equal areas, with the maximum distance allowable between points being 150mm, with a minimum of 16 reading points for any size duct, up to a maximum of 64 reading points on large ducts.

For example, for a duct size = 400mm (X) x 350mm (Y)

Pitot tube setting via "X" profile = 400mm/8 = 50mm and (400/4 = 100mm)

Therefore, take readings at: 50mm, 150mm, 250mm and 350mm

Pitot tube setting via "Y" profile = 350mm/8 = 43.75mm and (350/4 = 87.5mm)

Therefore take readings at: 44mm, 131mm, 219mm and 306mm

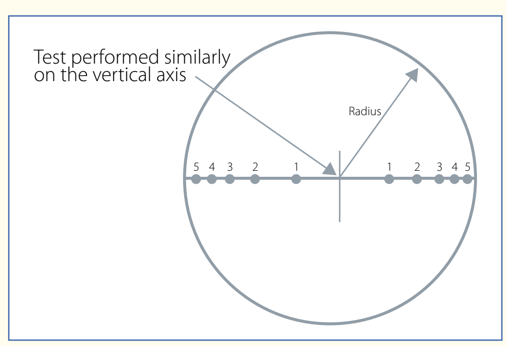


Figure 5 – Circular duct traverse locations – for 10 readings

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Readings are taken at each intersection point shown in Figure 6.

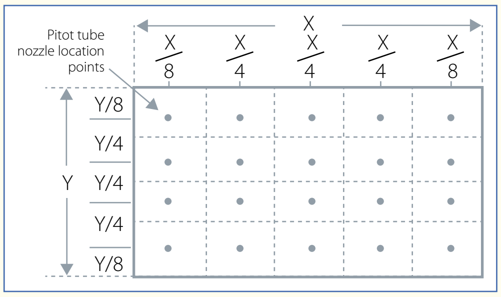


Figure 6 – Rectangular duct traverse locations

An alternative is the BSRIA Log-T method approach to pitot traverse averaging, using the grid as outlined in Figure 7. In the BSRIA approach, the number of readings to be taken and averaged is based on size of duct in accordance with Figure 7.

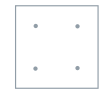
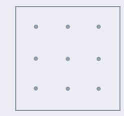
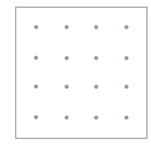
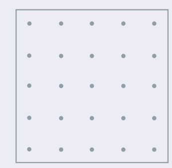
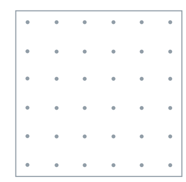
Diameter range and application	Distance of pitot tube from duct wall as a percentage of duct diameter						
	1	2	3	4	5	6	Test holes and measurement points
Up to 200mm	25%	75%					
200–500mm or when measuring immediately upstream or downstream of a fan where the duct area is <0.1m²	17%	50%	83%				
500–900mm or when measuring immediately upstream or downstream of a fan where the duct area is >0.1 and <0.4m²	13%	38%	63%	88%			
Over 900mm or when measuring immediately upstream or downstream of a fan where the duct area is >0.4 and <2.5m²	10%	30%	50%	70%	90%		
When measuring immediately upstream or downstream of a fan where the duct area is >2.5m²	8%	25%	42%	58%	75%	92%	
For rectangular ducts, numbers of test holes and measurement points depend on the width and height of the duct. For example, for a duct 700mm wide by 400mm deep measure at 4 points across the width and 3 points across the depth.							

Figure 7 Rectangular duct traverse locations – BSRIA approach

Main duct readings

Where it is not possible to find a suitable measuring point to determine total airflow on the main or branch ducts, velocity can sometimes be measured at the fan suction (if the flow is uniform, i.e., a fan suction box is fitted).

If the fan flow rate cannot be measured by either of these techniques, it can be calculated by summing the flow rates of all principal branch ducts.

Measurement of static pressure at the entry to a duct system

If a lower order of accuracy is acceptable, a meaningful measurement of airflow within approximately ± 10% can be made by measuring the static pressure or suction just downstream of the entry to a duct system that is exhausting from a space, provided the area of the wall in which the duct entry is located is much larger than the duct entry.

A considerable amount of reliable information is available for entry coefficients of many alternative types of entry, and using this data together with a static pressure or suction measurement, the flow can be calculated.

Note: Comprehensive data on fitting losses is provided in *AIRAH DA03*.

Measurement at duct discharge

Measurement by pitot tube

Measuring by means of a pitot tube at the air discharge point is relatively easy if the flow is uniform and straight, but if any outlet louvres or other obstructions are fitted, which is the normal situation, reliable readings are very difficult to obtain.

Measurement by anemometer

It is possible to use an anemometer at a duct discharge, but significant experience is necessary to obtain meaningful results. Unless the air being discharged is of substantially uniform velocity and flowing parallel to the duct axis (e.g., laminar), the anemometer readings will require extensive corrections and interpretation. As a result, this method is not very accurate, and multiple readings need to be taken and the average recorded to improve accuracy.

Table 3 provides recommended averaging grids for anemometer velocity measurements at grilles.

It is also essential than the anemometer is recalibrated regularly, as they can lose accuracy quite easily.

Measurement at grilles and diffusers

Each grille and diffuser type has a different amount of free or open area that the air must travel through. This free area differs from the nominal face area by a constant factor. This factor is known as the area constant, or A_k factor.

To accurately determine the air volume from a grille using air velocity measurements, the grille A_k factor must also be known or determined.

Electronic measuring devices, typically rotating-vane, hot-wire or hot-film anemometers, while accurate, convenient and portable, are highly dependent on measurement location, sensor tip geometry and temperature sensitivity, and there is no industry standard measurement arrangement. These devices provide a velocity that must be combined with the grille free area and the A_k factor to produce the actual measured airflow.

The flow through the grille or diffuser is calculated as follows:

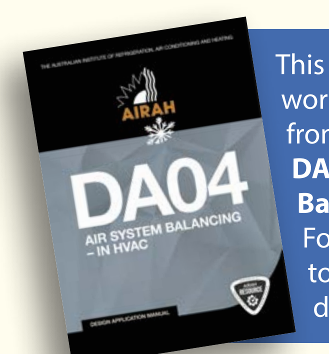
L/s = average velocity × grille-free area × A_k

The grille-free area is the measured actual free area of the grille. It is calculated by measuring the area inside the margin of the grille face and then subtracting the area of all the bars and blades, leaving only the open or free area. Grille-free area multiplied by A_k gives the effective area. The A_k factor accounts for the variations in airflow and pressure generated by the grille outlet, which are often designed to promote diffusion.

A_k factors depend both on the methodology and the device used to determine them. It is important that any proportional balancing using A_k factors is tied back to a pitot traverse to reflect this. ■

Table 3 Averaging grids – anemometer measurements at grilles

Depth of grille (mm)	Width of grille (mm) and number of readings							
	up to 150		150–300		300–460		Over 460	
	Down	Across	Down	Across	Down	Across	Down	Across
Up to 150	1 (centre)		—	2	—	3	—	4
150–300	2	—	2	2	2	3	2	4
300–460	3	—	3	2	3	3	3	4
Over 460	4	—	4	2	4	3	4	4



This month's skills workshop has been taken from the recently released **DA04 Air System Balancing – in HVAC**. For more information go to www.airah.org.au/da_manuals

Next issue:
Inverter testing and diagnostics

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