Article AT/FLOW/002–EN

Flue gas measurement and control
Partial-insertion pitot tubes in CEMS applications

Measurement made easy

Specifying the most appropriate pitot flowmeter design in stack applications

Introduction

When metering stack gas flowrates within CEMS applications, a number of factors can influence a supplier or end user to consider the use of a pitot flow probe that spans only part of the stack diameter. This article discusses these factors and considers the circumstances under which partial insertion probes are an acceptable alternative – plus (as importantly) where they may not be acceptable – by discussing the advantages and limitations of the technique.

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How pitot tubes work

A simple pitot tube is typically a probe inserted into the process pipe with the open end pointing upstream into the flow. This approach is used on aircraft for basic airspeed indication. The process stream impacts on the opening (port) in the probe and creates an elevated pressure depending, among other factors, on the velocity and density of the fluid. The static pressure is measured by a separate port that does not face directly into the flow stream. The two ports are connected to (for example) a DP transmitter that measures the difference between the two pressures; that itself is a measure of the flowrate.

One disadvantage of this 'single point' pitot is that it measures only the velocity (and therefore the flowrate) at a single point in the pipe, at whatever depth into the pipe it is inserted into.

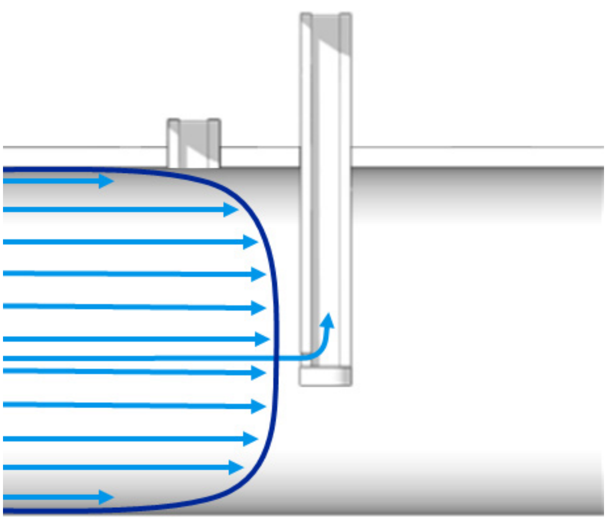

Fig. 1: Fully-developed flow profile

If the flow velocity profile across the pipe is symmetrical and fully developed (see Fig. 1), the average flowing velocity (and hence the average flowrate) can be established from this single reading, if the probe is inserted to a predicted specific depth. However, this typically occurs only if the pitot is used following long, straight, uninterrupted lengths of pipe.

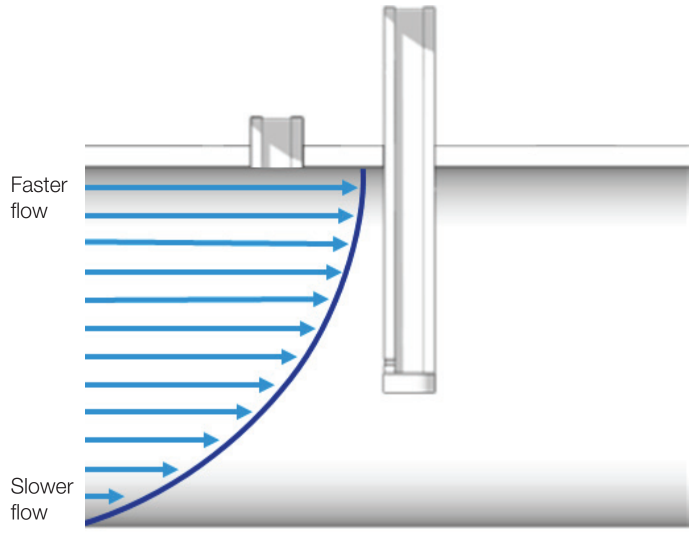

Fig. 2: Asymmetrical flow profile (not fully-developed)

However, if the flow profile is not fully-developed (for example as shown in Fig. 2), then the relationship between the velocity measured (at that point) and the average pipe velocity (that is what is required to be determined) cannot be predicted. Consequently any flow measurement produced using a single point device is poor.

To improve the measurement of flow with such a device in these cases, it is necessary to establish the actual velocity profile across the pipe by a process known as 'traversing' or 'flow profiling', where the probe is inserted at different points across the pipe and the velocity measured at each point; all while maintaining a constant flowrate. The insertion point (depth) at which the point velocity has the same value as the average velocity is established from the data and the probe can then be installed to that insertion depth. However it is important to note that this is valid only if the flow profile has the same shape and characteristics at all application flowrates. In practice this may well not be the case.

The optimal solution is a pitot that inherently measures the mean fluid velocity without the need for traversing. Multipoint or averaging pitot tubes (Figs 3 and 4) have multiple upstream holes at specific points across the whole pipe diameter. These holes measure the flow at several specific points across the pipe diameter and flow profile. The impact pressures across the pipe are combined within the probe to give an average upstream impact pressure. A separate hole, not facing into the flow stream, measures the static pressure alone and the difference between the impact (high) and static (low) pressures is proportional to the flow rate.

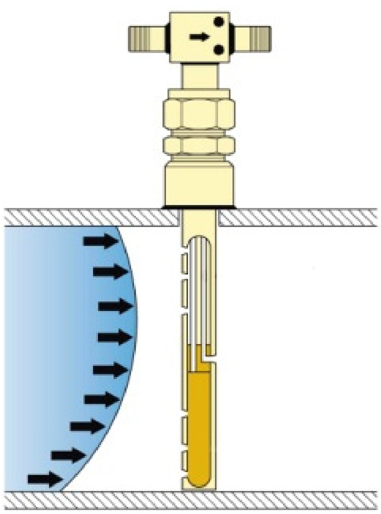

Fig. 3: Averaging pitot tube

This construction overcomes the main disadvantage of a simple pitot tube as it averages the velocities across the pipe diameter, instead of just taking a single point measurement. This removes the requirement to know the existing flow profile because effectively the unit continuously infers an average of the flow profile. In the ABB Torbar the static pressure sensing is at a point on the back of the sensor, removing the need to create a separate hole in the process pipe.

Fig. 4: Typical ABB StackFlowMaster full-insertion averaging pitot tube

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Full-insertion averaging pitot tubes

Full-insertion probes span the whole diameter of the stack and incorporate strategically spaced pitot sensing holes to measure a number of point velocities simultaneously. Subsequently the flow average is taken across the complete stack diameter. The probe tip is often supported on the 'far' side of the stack, especially with large diameter stacks. The ABB approach with CEMS flow meters is to offer full-insertion probes wherever possible, primarily for performance-related reasons, whereas the drivers for the use of partial-insertion probes are economic and / or for reasons of installation constraints.

The key advantage of full-insertion probes is that they provide acceptable flow measurement performance even with flow profiles that are not fully developed, which is why ABB prefer them.

The limitations are:
- probe can be expensive in large diameter stacks
- probe can be difficult to install (long and heavy)
- a platform may need to give access to the complete stack circumference for access to the end support mounting

Partial-insertion averaging pitot tubes

Partial-insertion flowmeter pitot tubes are a shortened version of the full-insertion tube and typically span only approximately $^1/_3$ to $^1/_2$ of the full stack diameter. The number of velocity sensing holes is reduced to take only an average velocity across that portion of the stack diameter.

Where allowed by the relevant legislative authority, partial insertion probes can be used and offer the following advantages in purchase cost:

- lower cost in large diameter stacks
- easier to install (shorter and less weight)
- platform can be smaller as it only needs to give access to part of the stack circumference, for access to the single mounting assembly.

However, they do have a serious limitation in that they are likely to give unacceptable readings for non-fully developed flows. The question often asked as a result of this is:

How do I know if a partial-insertion is suitable?

The answer to this depends on the flow profile at the measurement point. If the flow is fully developed and the flow profile is therefore uniform across the full diameter of the stack, then measuring across almost half of the stack diameter gives an acceptable reading that is representative of the whole stack diameter. However, if the flow profile is not uniform, then it is not acceptable to measure part of the flow profile only.

The status of the flow profile depends on a number of parameters such as the pipe layout at the bottom of the stack and the straight lengths available upstream and downstream. The profiles below are clearly very different in the 2 applications shown above (Figs 5 and 6). Consequently it is only possible to establish the shape of the flow profile by carrying out a test, either in situ (for example, a 'traverse') or by computation

Fig. 5: Stack with few upstream straight stack diameters available

Fig. 6: Stack with many upstream straight stack diameters available

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What the standards say

European Community Standards are in place governing the application and practice of flow metering and gas analysis in CEMS applications within the EC. Other countries often rely on these standards for guidance.

These standards are:

EN 14181
Stationary source emissions.
Quality assurance of automated measuring systems

EN 15259
Measurement of stationary source emissions.
Requirements for measurement sections and sites and for the measurement objective, plan and report

EN15267
Certification of automated measuring systems.
  Part 1 – General principles
  Part 2 – Initial assessment of the AMS manufacturer's quality management system and post certification surveillance for the manufacturing process
  Part 3 – Performance criteria and test procedures for automated measuring systems for monitoring emissions from stationary sources

EN16911
Stationary source emissions – manual and automatic determination of velocity and volume flow rate in ducts:
  Part 1 – Manual Reference Method
  Part 2 – Automated Measuring Systems

EN16911 is a new standard that includes advice on whether a 'probe AMS' (that is how the standard includes reference to a partial-insertion probe) can be used. Section 7 of the standard recommends that, unless the AMS can be positioned at a point where the flow profile is both fully developed and does not change over the complete operational flow range, a pre-investigation should be performed in order to characterize the flow.

For this pre-investigation (traversing / flow profiling) to be deemed unnecessary, a number of onerous conditions must be satisfied:

–	The meter must be located at a distance of at least 25 stack diameters downstream of any flow disturbance
–	There must be no movable dampers in the stack run
–	There must not be any multiple feeds into the stack

Table 1: Condition-specific requirements

Suitable methods for performing the pre-investigation are described in Section 8 of EN16911. Note that part of the pre-investigation process is identical to the investigation required to meet EN 15259 and could be combined with that to minimize costs. The pre-investigation establishes the flow profile that, if found to be fully developed, may permit the use of a partial insertion meter. However, it should be noted that the final decision on this rests with the competent legislative authority, not with the end user.

Recommendation

Under EN16911, ABB strongly recommend that, unless the specific conditions described in Table 1, page 6 are all satisfied for the application, a pre-investigation should be carried out to establish the flow profile in the stack. This profile should then be included in the submission to the competent legislative authority for their decision as to the type of instrument that can be used and its positioning on the stack.

If the flow profile is sufficiently fully developed, the legislative authority may approve a partial insertion probe in the selected position. If such a pre-investigation is not carried out and the specific conditions do not exist, there is a serious risk that when the inspection of the installed equipment is performed, the installation may be deemed unacceptable.

Therefore ABB will normally offer full insertion probes, unless we are advised that partial insertions are acceptable. Providing there is a statement from the customer confirming that the flow profile is fully developed over the full flow range at the proposed installation, ABB can propose a partial insertion flow probe.

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