AN01
Insertion probes – installation effects

1. Introduction

VPInstruments insertion mass flow meters can be used in various pipe sizes and offer great flexibility to the user. Depending on model and type, you can use insertion probes from 1 inch and up. However, it is important to be aware of the basic behavior of an insertion probe and which factors influence the total measurement uncertainty. In this application note we will explain which major factors there are and what you can do to optimize the performance of your insertion flow meter in the field.

2. Total measurement uncertainty (a.k.a. "accuracy")

The total measurement uncertainty is the official definition of accuracy. It consists of the sum of all possible errors in your measurement. In case of flow meters, these errors are:

- The stated calibration error, which you can find in the calibration report. This error can vary depending on brand and type of flow meter.
- Installation errors, due to flow profile effects. The flow is measured at one point, but you can never know the exact shape of the flow profile in the pipe. This applies to all single point insertion flow meters regardless of type and brand.
- Installation errors due to mechanical effects (alignment, insertion depth of your probe). This typically depends on the skills of the installation engineer.
- Pressure and temperature effects: some flow meters, especially non-mass flow meters, are sensitive to pressure and temperature effects. VPInstruments' flow meters are mass flow meters, meaning they compensate automatically for pressure and temperature changes.

Accuracy and precision are often used the wrong way. The figure below explains the difference between the two.

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3. The Pressurized calibration process

VPInstruments' insertion probes are calibrated by our proprietary pressurized calibration system, which is unique in the world. Pressurized flow meter calibration has many advantages:

- All flow meters deviate from their ideal behavior when the actual process conditions differ from the calibration conditions. It is best practices to calibrate flow meters as close as possible to the actual process conditions to obtain the highest possible accuracy.
- The flow profile in a tube is linked to a Reynolds number. It is good practice to calibrate a flow meter near the Reynolds number at actual operating conditions as the flow profile will be close to the real profile in the field.

As a result, our proprietary pressurized calibration process leads to the lowest possible measurement uncertainty. Pressure tests have been performed extensively over a range of 500 mbar abs to 8000 mbar. The pressure effect on the measurement results is less than 2% over this range (0.25% per bar). See application note 2, "pressure sensitivity of the VPFlowScope" for further details.

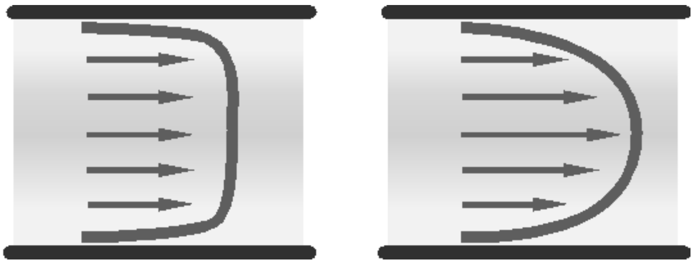
4. Installation in different pipe diameters

Insertion flow meters are very flexible to use and require little installation labor. However, they are single point measurement devices, which means they sense velocity at one point in the pipe. As theflow profile is not exactly known, this will always lead to additional measurement uncertainty.

VPInstruments has done extensive research on the behavior of insertion probes in different pipes diameters. We calibrated insertion probes in 2 inch pipes, then installed them into 3, 4, 6 and 8 inch piping. Based upon an internal formula in the flow meter, the mass flow is calculated by multiplying the cross sectional area of the tube with the velocity.

5. Flow profile effects - turbulent vs laminar

When air is flowing pipe, either of two types of flow may occur depending on the velocity and viscosity of the fluid: laminar flow or turbulent flow. Laminar flow tends to occur at lower velocities, below a threshold value, at which it becomes turbulent. Laminar flow is smooth while turbulent flow is more rough. The shape of the flow profile also differs. Laminar flow has a parabolic shape, and turbulent flow a more flat shape. This is beneficial for compressed air flow measurement, as with the flat flow profile, insertion depth is less critical.



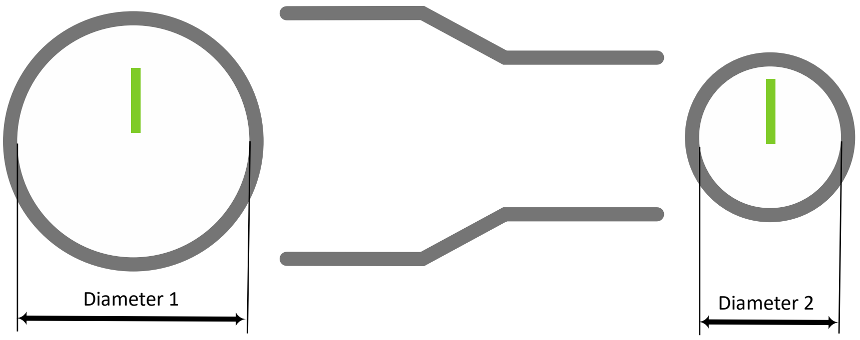
In this figure, the difference between turbulent flow (left) and laminar flow (right) is shown.

6. Installation depth and blockage

An insertion flow meter blocks a part of the tube area. Blockage leads to an increase of the local velocity around the probe. This means that the deeper you insert a probe into a tube, the higher the reading will be. The VPFlowScope has a built-in correction table which compensates for blockage effects.

In small pipes (less than 80 mm / 3 inch), the blockage effect can cause a 10 … 30% higher reading. Therefore, it is very important to insert your probe as precise as possible to match the calculated blockage correction. Some manufacturers claim that their probes with laser-engraved markings are more accurate to install, but in fact this is misleading, as the installation points will always have different lengths and the installation depth is always relative to this. The only way to install a flow meter at the right depth is using a fine point permanent marker and a caliper.

In large pipes, above 3 inch, you will find that installation depth is less critical, since blockage does not play a significant role anymore in these pipes.



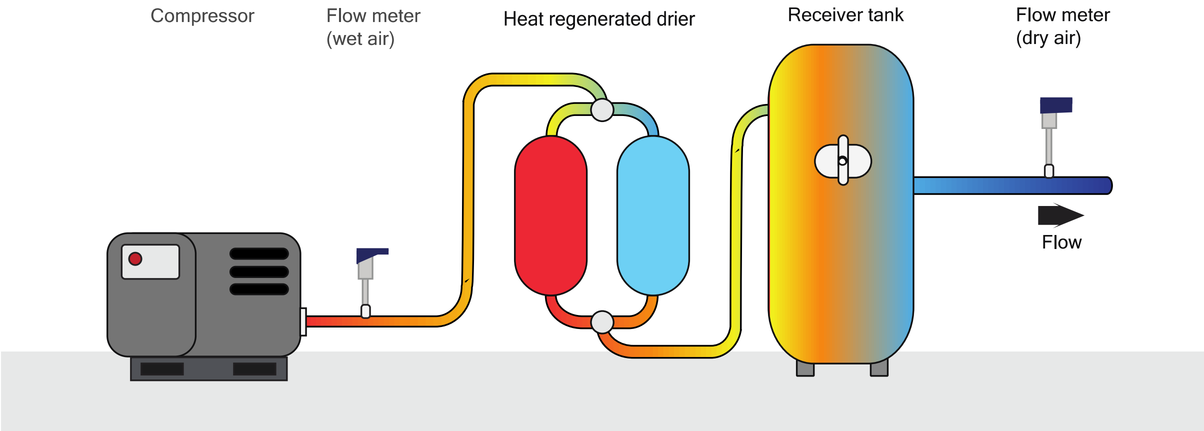
This figure shows when installed in a pipe, the probe will block a part of the pipe area. This will result in a higher local velocity around the probe. VPInstruments insertion probes automatically compensate for this blockage effect.

7. Alignment effects

The aerodynamic shape of the VPFlowScope probe is optimized to minimize alignment error. You can try it out yourself: the output of the flow meter will not change significantly within +/- 5 degrees.

8. Temperature effects

Temperature can influence your measurements, especially when it rapidly varies over time. The VPFlowScope has a certain thermal mass, which takes some time to accommodate. This causes the sensed temperature to lag the real process temperature. To minimize these effects, install the flow meter at a location with stable temperature and avoid places with rapid changes, for example, directly downstream of a heat regenerated drier.



The figure above: Typical temperature distribution in a compressed air system. Depending on the intercooler and post-cooling, the discharge temperature of the compressor will be 10 … 15 degrees C (20…50 degrees F) above ambient. When a heat regenerated drier switches between columns, hot air may enter the downstream piping. A receiver tank allows cooling down of the air. Further downstream the air will cool down to ambient temperature.

9. Conclusions

- The total measurement uncertainty of an insertion flow meter consists of the following components:
    - calibration uncertainty
    - installation effects (depth and alignment)
    - pressure and temperature effects
- The Flowstone compensates automatically for pressure and temperature variations. However, rapid temperature changes should be avoided.
- The VPFlowScope automatically compensates for blockage effects.
- A caliper and permanent marker are the best tools for accurately positioning the VPFlowScope in a pipe.