Instant guide to flow profile

Reducing your Carbon Footprint

ABB Instrumentation
Flow profile explained

There are many different factors that can influence the final choice of flow meter for an application. Of these factors, the flow profile is one of the most important, but often least understood. We explain how flow profiling can help you choose the best flow meter for your application.

Flow meter selection would certainly be a lot easier if every application behaved in the same way. Unfortunately, every fluid behaves differently when flowing through the pipeline, meaning that there is no single flow meter suitable for every job. Understanding how this behaviour can affect flow meter performance is crucial to ensuring that you get a flow meter that matches your needs.

What is the flow profile?

The flow profile explains the way in which the flow of a fluid behaves or is likely to behave in a pipeline based on its velocity and viscosity. Once this is known, it is possible to start to decide which of the many different types of flow meter available is best suited to the demands of the application.

The term ‘Flow Profile’ is generally understood to refer to a vector diagram of the conditions within the pipe and an example is shown in figure 1.

The main cause of this is viscosity – an internal property of a fluid that offers resistance to flow. The degree to which the fluid resists flow in turn affects the velocity of flow through the pipeline.

Imagine stirring a spoon in a bowl of water, for example. With nothing to impede it, the spoon travels quickly and easily through the water. Now imagine stirring honey, which is more difficult to stir because it has a higher viscosity than water.

The same applies to the flow of fluid through a pipe. As the level of resistance, or shear rate increases, the way in which the fluid behaves will change.

By profiling the flow of a fluid through a pipeline, it is possible to find out how it behaves and from there to narrow down the choice of flow meters to those best able to cope with the conditions of the application.

What type of fluid do you have?

The viscosity and velocity of a fluid can significantly affect the way in which it flows through a pipeline. Fluids will behave differently and will flow at a different rate at the centre of the pipeline than they do at the sides, because of the resistance generated by the pipe walls.

Put simply, fluids can be categorised as either Newtonian or non-Newtonian. Most are Newtonian, and flow meters are generally designed for Newtonian fluids.

Newtonian fluids explained

Typical characteristics:
- Have a tendency to ‘stick’ to the pipe walls, resulting in the liquid moving more slowly at the sides of the pipe than in the middle
- Have a directly proportional relationship between the pressure of the liquid flowing through and the resistance, or shear force, caused by the fluid sticking to the pipe walls
- Examples of Newtonian fluids include milk, water, acids and mineral oils.

Non-Newtonian fluids explained

Typical characteristics:
- Behaviour is harder to predict as there is no relationship between pressure and resistance
- Behaviour varies either with time or as a consequence of changes in the shear force inflicted by resistance from the pipe walls
- For example paints, shampoos, yoghurts

What type of flow do you have?

There are three types of flow, each of which are linked to the velocity of the fluid.

Laminar flow
- Occurs at stable, low flow rates and is the most predictable type of flow
- The fluid settles into streamlined tiers which are prevented from merging by the viscous forces within the liquid and move in the same direction at a constant speed
- Fully Developed Laminar Profile is parabolic in form (see figure 1)

Transitional flow
- Occurs when an increase in velocity causes distortions in the flow
- This leads to mixing of the tiers within the fluid, resulting in the fluid exhibiting both laminar and turbulent characteristics at different points throughout the pipeline
- The profile is unstable and complex— it may be parabolic as in laminar, flatter as in turbulent flow or a combination of both

**Turbulent flow**
- This type of flow occurs at faster flow rates
  - Mass distortions in flow result through the formation of eddies and whorls which themselves randomly fragment into smaller distortions, causing blending of the tiers within the fluid
  - Fully Developed Turbulent Profile is not fixed, but changes with the Reynolds number, approximating a flatter shape than the parabolic, as also shown in figure 1

Turbulent flow is the flow regime found in almost all applications, and is the preferred condition for a flow meter installation as flow meters are all calibrated in such conditions and it provides the best situation for the flow meter to achieve repeatable and accurate flow measurements.

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**Which flow meter is best?**

To select the appropriate flow meter, it is necessary to calculate the Reynolds numbers of the application, which should take into account the full range of conditions under which the flow meter will be operating. These figures are the ratio of momentum against viscosity and can be obtained by calculating the minimum and maximum fluid flow and viscosity figures of the application using the following equation:

\[
R_e = \frac{V D \rho}{\mu}
\]

where:
- \( R_e \) is Reynolds Number
- \( V \) is mean velocity
- \( D \) is flowing Density
- \( \rho \) is absolute viscosity

**What does my Reynolds number mean?**

Once the Reynolds number is known it can be matched against a flow meter’s Reynolds range to help pick the one that is best able to meet the demands of the application.

- Less than 2,000 = Laminar flow
- 2,000 – 4,000 = Transitional flow
- 4,000 or above = Turbulent flow

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**Getting the most from your flow meter**

The best way to eliminate disturbance to the way in which a fluid flows through the pipe is to ensure wherever possible that the flow meter is situated with the requisite amount of straight pipe lengths upstream and downstream from the point of installation. Alternatively, where space is limited, flow conditioning equipment can be used to regulate the fluid stream and provide the ideal conditions required for flow meter operation, or the manufacturer can be asked to give an estimate of the effect of the less than ideal conditions on the performance of the flow meter.

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**Essential Flow Profile Facts**

- The flow profile explains the way in which the flow of a fluid behaves or is likely to behave in a pipeline
- The term ‘Flow Profile’ is generally understood to refer to a vector diagram of the conditions within the pipe and an example is shown in figure 1.
- Understanding the flow profile will enable easy selection of the correct flow meter
- All fluids fit in to one of two categories, Newtonian or Non-Newtonian, and will either have a Laminar, Transitional or Turbulent flow
- In order to figure out which flow meter is suited to a fluid, the Reynolds number must be calculated using the velocity, density and viscosity of a fluid
- Once this number has been calculated it can be easily matched to the Reynold number range of a particular flow meter

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**What ABB can offer**

Knowing how your fluid behaves in the pipeline can be an extremely useful first step in helping you to narrow down your choice of flow meters for your application and make a more informed choice. ABB can provide expert help and advice to help you find the best flow meter for your application.

**Recommended reading:**

- [Top Tips for flowmeter selection](#)
- [Process Flow Measurement wallchart](#)

**Tools:**

- [Online flow meter selection tool](#)