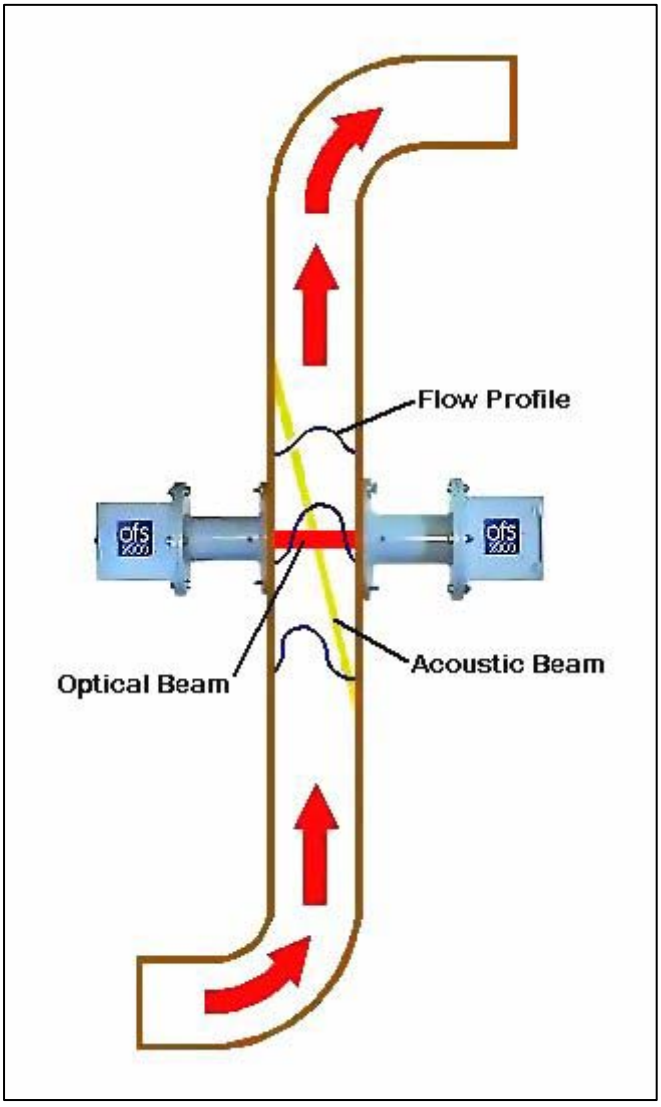
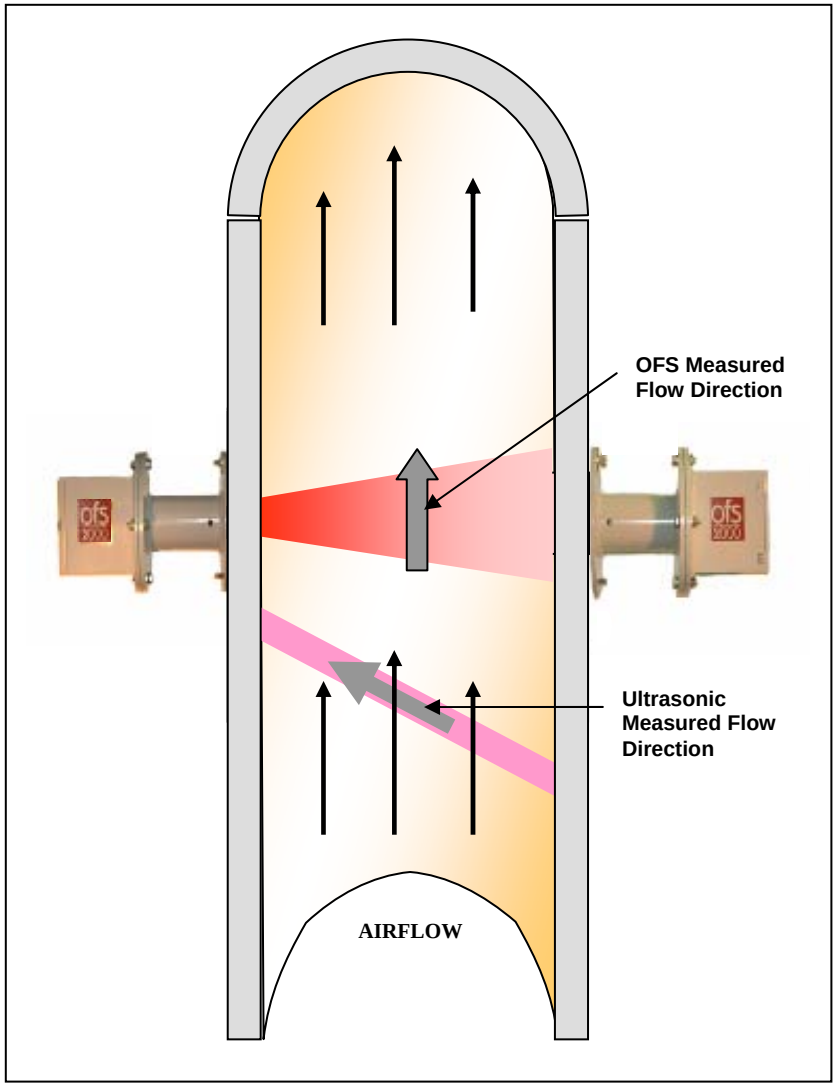
# Pipe & Stack Linear Placement Requirement for OFS

One of the major concerns for installing a flow sensor is its siting requirement for some amount of leading and trailing linear length from bends or flow disturbances in the pipe or stack. Because the flow is constantly changing its profile along the flow path, the best location for any flow sensor is always at the place where the flow profile is well developed (consistent). However, for different type flow sensors, the siting requirements are different. Some types need very long and straight runs while other types can tolerate a much shorter linear length.




The figure at right shows a typical pipe installation for two different types of flow sensors. The OFS (using an optical beam) is installed perpendicular to the flow direction. It shoots a light across the same cross-section area of the flow. The total amount of flow is the flow speed times the cross-section area at that location. The OFS provides a line-averaged flow measurement that is most representative to the overall flow profile across that cross-section area. Whereas the ultrasonic flow sensor is required to install at an angle (usually 45$^{o}$) to the flow. It is clear that the flow profiles change along the flow direction. The ultrasonic sensor shoots a slant-path sound wave across different cross-section areas with different flow profiles as shown in the figure. It is more sensitive to the profile changes along the path. Therefore, to obtain a representative flow measurement for an ultrasonic sensor, a more uniform (or well-developed) flow profile location is required. Usually the ultrasonic sensor cannot make a representative measurement unless there is a linear length more than 20 times the pipe diameter leading and 10 times the pipe diameter trailing from the elbow. However, this requirement can be relaxed for the OFS. **Because the OFS light beam shoots across the same flow profile cross-section, the OFS can make accurate representative line-averaged measurements, even for a less developed flow profile.** Usually linear lengths more than **two** times the pipe diameter leading and **one** times the pipe diameter trailing are good enough for OFS to make a representative flow measurement. For some extreme cases, OFS were installed right at the elbow of a pipe and provided satisfactory measurements.

Another consideration is the orientation of the installation of the flow sensor with respect to the direction of the flow. **Because OFS measures the flow across the optical beam, the best orientation of an OFS sensor is that the optical beam is perpendicular to the direction of flow** as indicated in the figure below. The measured flow rate is the line-averaged flow rate across the whole pipe or stack cross-section. This configuration will give the most representative flow measurements across that cross-section. In addition, the measured flow rate is insensitive to the cyclic flow pattern usually existed in the pipe especially near the bends. Therefore, the OFS does not need a long linear length to get a well-developed flow profile to make a representative measurement.




**For ultrasonic sensor, it measures the flow direction along the acoustic beam** (see figure at right). **Therefore, the best installation for an ultrasonic sensor is at the two ends of the pipe.** However, it is known this installation requirement is hard if not impossible to implement in a practical situation. As a compromise, the ultrasonic sensor usually installed in a slant configuration as indicated in the Figure. Because of this compromised installation, the measured flow velocity is not the true flow velocity; it needs a correction factor dependent on the actual angle between the acoustic beam and the flow direction. This correction factor (always larger than one) also amplifies the uncertainty of the flow measurement. The larger the angle between the acoustic beam and the flow direction will produce a larger uncertainty of the flow measurement. An even more critical problem of this configuration is that the measurement is contaminated by any flow not at the direction of mean flow direction such as a swirling flow. Therefore, it needs a well-developed flow profile to make a representative flow measurement. This is why the ultrasonic sensor is usually required to install far away from the bend of the pipe or stack. In some extreme situation, in order to shorten the linear length requirements, the ultrasonic sensor is installed at a large angle to the flow direction almost direct across the pipe. Unfortunately, this will only deteriorate the measurement accuracy to the extent it is no longer a reasonable representative measurement of the true flow rate.