

Optical Flow Sensor Cold Air Performance

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I. Introduction

Airflow sensing in an industrial process control environment such as a duct is a difficult challenge. Existing technologies like ultrasonic and Pitot tubes require significant maintenance and have installation limitations. Both can suffer from nonrepresentativeness leading to a misreporting of flow rate. For example, Pitot tube devices only measure at one point and may under or over report the true flow. Ultrasonic devices must be installed at two cross sections along the duct, which may not be available for a short run of the duct. In addition, both ultrasonic and Pitot devices are intrusive to the media and may affect the flow rate and lead to degraded system performance.

II. OFS vs Pitot Tube and Ultrasonic Sensor

The Optical Flow Sensor (OFS) using a non-intrusive atmospheric scintillation technology was designed to solve these problems. The OFS is installed at one cross section and measures through glass windows across the duct. The configuration is perpendicular to the flow across the duct on the same cross-sectional plane. The user simply places the transmitter and receiver on flanges on opposite sides of the duct. The path-averaged result of the OFS provides a more representative reading of the flow characteristics in a duct. The sensor makes a true cross-duct measurement of the velocity along the entire path. The instrument does not require straighteners or additional ductwork like Pitot tubes often do in more challenging flow environments. Another advantage to the user is that fewer sensors are required to measure complex flow fields. One optical flow sensor could replace an entire Pitot tube array. True representativeness of the data is assured due to the path-averaged nature of the measurement. Unlike the Pitot tube and ultrasonic techniques, this velocity measurement is completely independent of temperature, pressure, humidity, and opacity.

The optical technology allows the sensor to sit behind windows “looking” through the duct. No part of the instrument is exposed to the direct flow of the duct. Therefore the OFS does not affect the flow field because of its non-intrusive nature. The OFS can be utilized in very extreme conditions such as explosive and high heat application. The sensor can be installed behind protective windows or flange extensions if needed. Avoiding direct exposure to duct effluent helps reduce maintenance and increase durability. Pitot tubes must be located directly in the duct environment where aggressive conditions (such as excessive heat, acidic gases, particulate, etc.) can degrade performance or damage the unit irreparably. Ultrasonic sensors whose transducers are exposed to the direct flow as well face the same problem.

III. Optical Scintillation Technology

The optical flow sensor uses optical scintillation as the detection method. Scintillation is a general term, which describes changes in the apparent position or brightness of an object when viewed through the atmosphere. Starlight twinkling is a common example of scintillation. Scintillation effects are caused by optical refraction occurring in small parcels of air whose temperature and density differ from their surroundings. Figure 1 shows the effect of scintillation or optical turbulence on an optical beam after traveling through the atmosphere. If there is no atmosphere, the beam pattern should be a uniform circular disc. The atmospheric turbulence produced the intensity fluctuations as shown. The receiver detects this beam and reconverts it to an electronic signal. Intensity variations of the detected signals caused by the scintillating air parcels provide the basis of the turbulence measurement. The twin modules in the receiver furnish the capability of measuring cross wind by detecting the temporal correlation between the two signals as the air parcels move across the beam path (covariance). The movement of the scintillation from one receiver to the next is related to the flow rate.



Figure 1 – Effect of Scintillation or Optical Turbulence on an optical beam after traveling through the atmosphere.

Optical scintillation technology has a proven track record and history. It has been used for nearly 30 years to measure crosswind outdoors. This same technology is used for industrial airflow monitoring in the aluminum industry. This instrument measures the air velocity along a pot room roof vent typically 500-700 m long. The EPA approves the optical anemometer for Method 14 (as an equivalent method in air monitoring compliance rule for the aluminum industry.) The optical anemometer is widely used in the aluminum industry for air velocity monitoring to comply with EPA regulations. Most of the aluminum smelters in the US and Canada rely on this technology to provide air velocity measurements.

The optical flow sensor uses the same technology as the optical anemometer. The major difference is that the OFS uses smaller optics to measure the flow over shorter path lengths (stack and duct diameters). The OFS has been certified for Part 75 airflow measurement in stacks and ducts. The optical flow sensor affords the user a distinct combination of advantages which the other methods do not offer. In addition, the optical technology is proven and tested. It is patented, approved by the EPA for airflow monitoring (Method 14 equivalent), NIST Wind Tunnel calibrated, relied on for almost 30 years to make atmospheric and environmental measurements, and has virtually no drift. No other flow sensor currently available in the environmental monitoring industry meets these conditions. Many OFS' have been installed at the stacks, passed RATA tests and are continuously measuring the flow rate for years.

IV. OFS Cold Air Performance

For most of the stack applications, because the air flow inside stack is relatively warm, there is plenty turbulence to produce optical scintillation to measure the flow rate. However, for some combustion air monitoring applications, cold ambient temperature air is used. In this situation, sometimes the air contains very weak turbulence for OFS to provide a reliable flow measurement. A recent breakthrough on the algorithm enables OFS to reliably detect the flow rate for extremely weak turbulence condition. Therefore, OFS is now able to detect flow rate even for ambient air flow inside a duct. Figure 2 indicates a measurement record of close to eight hours for an OFS installed on a duct. Before the turbine fired up, only cold air was provided in the duct. For more than five hours of cold air, OFS did not miss a single minute of flow data. When hot air was fired, OFS' readings were used to adjust the flow speed inside the duct as indicated by the step nature of the flow speed.

BP Amoco Data (05/21/03)

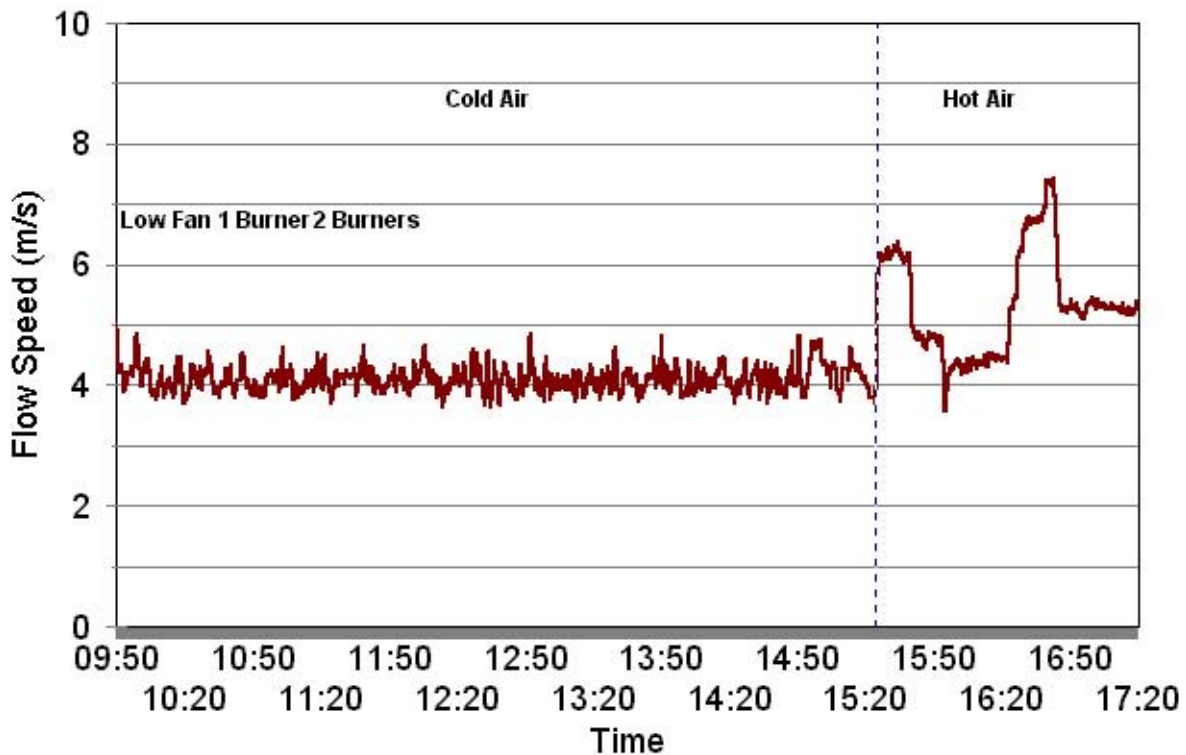


Figure 2. OFS performance records for a duct flow rate from cold air to hot air.