2.8 Jet Deflection Flow Detectors


Maximum Process Pressure  10 PSIG (0.7 bar)
Design Temperature  450°F (232°C) standard and up to 1200°F (650°C) special
Standard Materials  Type 316 stainless steel
Connection and Insertion  Standard connection is 3 in. flanged; insertion depth is adjustable from 0 to 60 in. (0 to 1.5 m).
Air (Nitrogen) Requirement Pressure  10 to 90 PSIG (0.7 to 6.2 bar) over process pressure
Flow  2.5 and 5.0 SCFM (71 to 142 l/min)
Velocity Ranges  0 to 50 ft/sec and 0 to 85 ft/sec (0 to 15 m/sec and 0 to 26 m/sec)
Output Differential Range  0 to 80 in H₂O and 0 to 130 in H₂O (0 to 20 kPa and 0 to 32 kPa)
Inaccuracy  ±2% of full scale (if sensor is inserted to average velocity point in the duct)
Rangeability  20:1
Cost  About $2500 to $5000; varies with accessories
Partial List of Suppliers  Fluidynamic Devices Ltd.
United Scientific/Monitor Labs (formerly Lear Siegler Measurement Controls Corporation)

OPERATING PRINCIPLE

Volumetric flow rate in a pipe or duct can be inferred from a measurement of gas velocity, and one of the methods to measure this velocity is jet deflection detection. The operation of this sensor requires the blowing of air (or some other gas that is compatible with the process) through a nozzle, which forms a jet as shown in Figure 2.8a. The jet is centered between the two receiver ports when there is no flow in the process pipe or duct. In that case, the differential pressure between the two ports is zero. As a process flow is initiated, the jet is deflected, and the amount of this deflection will be related to the velocity of the flowing process stream. Figure 2.8a shows how the pressure profile of the jet shifts as the velocity of the process stream increases.

The deflection of the jet will cause an increase in the pressure at the downstream port and a decrease at the upstream port. The geometry of the ports is so designed that, over the useful

FIG. 2.8a
Pressure profile generated by a jet deflection-type flow detector.
range of the element, the change in differential pressure is linearly proportional to the velocity of the process stream. The actual value of this pressure differential is a function of the product of the process velocity and the square root of the gas density. If the density is constant, the pressure drop varies linearly with gas velocity. If the particulate concentration in the process fluid (flue or stack gases) is separately measured, this reading will yield the mass emission rate of particulate materials.

In some respects, this flowmeter is similar to the conventional pitot tube. Similarities include the negligible pressure drop created, the high speed of response, and the retractable design, which can be used for wet tapping or to measure flow profiles by traversing the cross section of the pipe or duct. On the other hand, the jet-deflection sensor has features that are superior to those of conventional pitot sensors.

These advantages include the existence of a continuous back-purge and of the auxiliary cleaning jets, which keep the receiver ports clean. Another advantage is that the element is heated to a temperature above the dew point, so condensation is avoided. In addition, the output signal is not only linear but is also much stronger than that of a conventional pitot element. At a supply pressure of 50 PSIG (345 kPa), the output differential-pressure signal generated about 1.5 in of water column per each ft/sec (0.3 m/sec), which is about 100 times what is generated by a pitot tube.

The relationship between process gas velocity and flow rate is

\[ Q = 60VA \]  \hspace{1cm} 2.8(1)

where

- \( Q \) = flow rate, in actual cubic feet per minute (ACFM)
- \( V \) = velocity, feet per second (ft/sec)
- \( A \) = pipe or duct cross-sectional area, square feet (ft\(^2\))

In case of laminar flow in a circular duct, the profile is parabolic with the maximum velocity at the center and zero velocity at the walls. In this case, the maximum velocity is twice the average; therefore, the reading taken at the center of the duct will be twice the average for the laminar flow case.

In turbulent flow in a circular duct, the average velocity point is located at approximately 25% of the radius as measured from the duct wall. The accurate determination of average velocity in rectangular ducts is more complicated, and no simple rules of thumb can be given. The point velocity, in general, is inaccurate, because the velocity profile is not uniform.

In many actual installations, the point of average velocity will not be located at the predicted insertion depth because of disturbances introduced by the upstream piping configuration. For proper operation, the upstream piping should be straight for at least 20 pipe diameters to allow for the disturbances to smooth out. When this upstream straight run requirement cannot be met, an average velocity point can sometimes be found by traversing the duct and making a number of measurements at a number of points across the cross section.

A traverse should always be made on rectangular ducts, if accurate measurement is required. Traversing rectangular ducts is time consuming because of the need for traversing in two or more planes. In addition, the average velocity points can shift as flow rates vary in both the rectangular or circular ducts.

### HOT-TAPPING

Probe-type instruments, such as the jet deflection type element or the pilot tube, can be installed so that they can be removed for inspection without shutting down the process. Figure 2.8b shows the detail of such a hot-tapping installation, which makes it possible to remove the probe while the pipe is under pressure. To remove the sensor, first the gland nut is loosened sufficiently to allow the withdrawal of the shaft of the element until it is outside of the gate valve and in the “outside chamber.” The valve is then closed, the outside chamber is vented, and the gland nut is removed to allow the safe removal of the element.

Normally, the jet deflection element is installed in piping that is under low pressure or vacuum; thus, the risk of having the element blow out during removal is slight. Nonetheless, it is recommended to install stop rods or safely chains so as to completely eliminate the possibility of injury caused by a blowout.

The step-by-step hot-tapping procedure is shown in Figure 2.8c. The first step is to weld a flanged nozzle to the pipe that is to be tapped. As the second step, a flanged gate valve is attached to the weld neck flange. The third step is to bolt a hot-tapping drill to the downstream side of the gate valve. After the gate valve is opened, the hot-tapping machine drills through the wall of the process pipe. Rigid safety procedures must be enforced during hot-tapping operations, particularly if the process is flammable or hazardous. Hot-tapping can be performed only if the piping specification does
not require that welds be stress relieved and if there is flow in the pipe so that the heat of welding and drilling is removed.

The pressure seal on a hot-tap machine is similar in its design to that of a control valve packing box and it allows the tapping of pipes under relatively high pressures. A hand-operated drilling assembly is shown in the figure, but units are also available with pneumatic or electric drives. A scale is provided on the machine, showing the depth to which the operator has drilled into the pipe. After the drilling is done, the bit is retracted, the valve is closed, and the hot-tap machine is removed. The tap is now ready to accept the gland nut and outside chamber, which is provided with the flow element as shown in Figure 2.8b.

CONCLUSION

Jet deflection flow detectors can be considered for flow measurement in low-pressure, circular, or rectangular ducts. They can be periodically purged or flushed and can be removed for inspection and cleaning. They are suitable for dirty, abrasive, corrosive, and plugging services. Their accuracy of ±2% of full scale is usually acceptable for making flow measurements around flare headers, stacks, and air ducts. It should be remembered that the actual installed accuracy is dependent on one’s ability to insert the element to a depth at which the velocity is the average of the velocity profile across the duct.

Bibliography

Brooks, E. F. et al., Continuous Measurement of Total Gas Flow Rate from Stationary.

Other Sources