SERIES 5000 TECHNICAL DESCRIPTION

Flow Measurement Principles

General: Flow measurement in open channels and partially filled pipes is generally more difficult than in full pipes due to the presence of a free water surface. Several methods of measurement have been established as practice in the past. These include:

1. Gravity Flow Measurements: This form of measurement involves a simple gravity-driven, friction retarded flow equation. The depth of flow may be related to flow rate through such equations as Chezy's or Manning's. The conditions of pure gravity driving forces and constant channel wall friction coefficients are quite vague so that high measurement accuracy is rarely obtained. In addition, free gravity flow dependence makes the measurements very susceptible to errors cause by backwater effects and channel stagnation.

2. Flume and Weir Measurements: Flumes and weirs are used to improve flow measurement accuracy in open channel applications. These devices produce depth versus flow (H/Q) relationships which are much more predictable and stable than gravity flow measurements.

The H/Q relationships are developed through these devices by restricting the flow thereby causing a hydraulic jump to occur. The improved accuracy does not come without some cost in the form of increased head loss. For the typical installation, the head loss will be the difference between the depth of flow in the unobstructed channel and the depth of flow with the flume in place.

The accuracy of flumes is affected by excessive submerged flow. Submerged flow begins to occur when the downstream depth approaches 60% of the upstream depth. This submerged condition is usually caused by backwatering and stagnation

3. Continuity Equation Measurements

The equation of Continuity in Flow can be stated as:

$$\oint_A V dA = O$$

Thus, flow into a region must equal flow out of the same region. If for each point in the area (A) the velocity (V) is known, the flow is stated as: $\oint = \bar{v}A$

where $\bar{v}$ is the average of all velocities. This equation describes the flow under any condition. To apply this technique, both area and velocity must be determined.

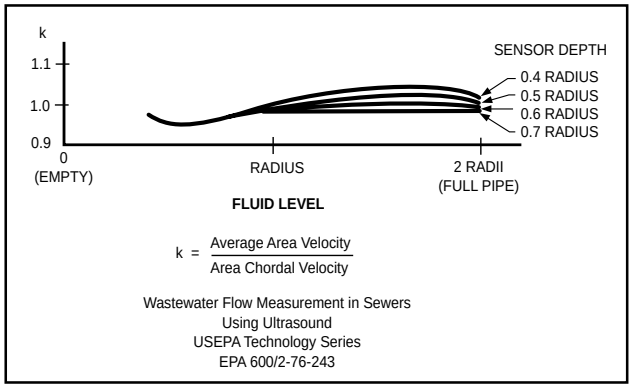
Area measurement can be obtained by measuring flow depth for a known channel shape. This is readily accomplished, provided the channel geometry does not change during scouring.

The measurement of average velocity however, is the major technical problem in using the Continuity Equation. Ideally, the requirement is to measure the flow velocity at each and every point within a given cross section of area occupied by the flow.

Chordal Measurements

The chordal measurement method, used in the Eastech Badger Series 5000 equipment, is the most viable technique for predicting average velocity. It requires detection of the chordal velocity along an entire path across the fluid. This chordal velocity more nearly represents the average area velocity over the entire flow-profile. Studies with turbulent flow profiles in various channel geometries have shown that for the region from 25% to 100% of maximum channel depth, there is a predictable correlation between chordal velocity and average velocity. This correlation permits accuracies within ±1% to ±3% depending on the channel geometry. This correlation factor has a slight variation from 0.96 to 0.98, as the channel level changes from 30% full to completely full. A typical correlation plot is shown below.

TYPICAL CORRELATION PLOT



Wastewater Flow Measurement in Sewers
Using Ultrasound
USEPA Technology Series
EPA 600/2-76-243

References
1. "Wasterwater Flow Measurement in Sewers Using Ultrasound", EPA-600/2-76-243. Municipal Environmental Research Laboratory; Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1976.
2. Chow, V.T. Open Channel Hydraulics, New York: McGraw-Hill, 1959.
3. Water Measurement Manual. United State Department of the Interior, Bureau of Reclamation. United States Government Printing Office, 1974.

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