
**Hydrometric determinations — Liquid flow
in open channels and partly filled pipes —
Guidelines for the application of
Doppler-based flow measurements**

*Déterminations hydrométriques — Débit des liquides dans les canaux
découverts et dans les conduites partiellement remplies — Lignes
directrices pour l'application de mesurages du débit basés sur l'effet
Doppler*



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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.ch
Web www.iso.ch

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In other circumstances, particularly when there is an urgent market requirement for such documents, a technical committee may decide to publish other types of normative documents:

- an ISO Publicly Available Specification (ISO/PAS) represents an agreement between technical experts in an ISO working group and is accepted for publication if it is approved by more than 50 % of the members of the parent committee casting a vote;
- an ISO Technical Specification (ISO/TS) represents an agreement between the members of a technical committee and is accepted for publication if it is approved by 2/3 of the members of the committee casting a vote.

An ISO/PAS or ISO/TS is reviewed every three years with a view to deciding whether it can be transformed into an International Standard.

Attention is drawn to the possibility that some of the elements of this Technical Specification may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TS 15769 was prepared by Technical Committee ISO/TC 113, *Hydrometric determinations*, Subcommittee SC 1, *Velocity area methods*.

Annexes A and B of this Technical Specification are for information only.

Introduction

Flow measurement using Doppler-based flowmeters fall into the category of velocity-area methods and, as with all variants of this approach, flow estimation is a two-stage process. Measurements are made to derive estimates of:

- a) mean channel velocity, using the principle of Doppler shift,
- b) depth, from which cross-sectional area is computed with a knowledge of the relationship between depth and area (i.e. the profile of the cross-section).

Most difficulties governing this method relate to the estimation of mean channel velocity and the degree to which computed velocities can be assumed to be representative of the true mean velocity through the measurement section. The accuracy with which the calculated velocities represent the mean velocity is influenced by various factors which are considered in clause 4. This guide focuses on the process of velocity estimation and the conditions and practices which may help to deliver optimum results. However, it should be recognized that the accuracy of overall flow determination also depends on the accuracy of depth measurement. The influence of meter location and sensitivity of cross-sectional area to depth variation will have a bearing on performance.

Hydrometric determinations — Liquid flow in open channels and partly filled pipes — Guidelines for the application of Doppler-based flow measurements

1 Scope

This Technical Specification gives guidelines for the selection and use of Doppler-based flowmeters for the measurement of liquid flow in small open channels and partly filled pipes. It is applicable to whole-channel flow measurements using a single meter at a fixed point in the cross-section.

It is not applicable to flow measurements made using Doppler-based current meters for point velocity measurement nor using mobile profiling systems.

A limitation of this technique is that measurement is made of the velocity of particles or other reflectors being transported by the liquid rather than that of the liquid itself.

NOTE Though the title refers to liquid flow in general, the main use of flowmeters which use the Doppler principle is for water or water-based liquid and particular reference is often made in the text to water.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this Technical Specification. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this Technical Specification are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 772, *Hydrometric determinations — Vocabulary and symbols*.

ISO/TR 8363, *Measurement of liquid flow in open channels — General guidelines for selection of method*.

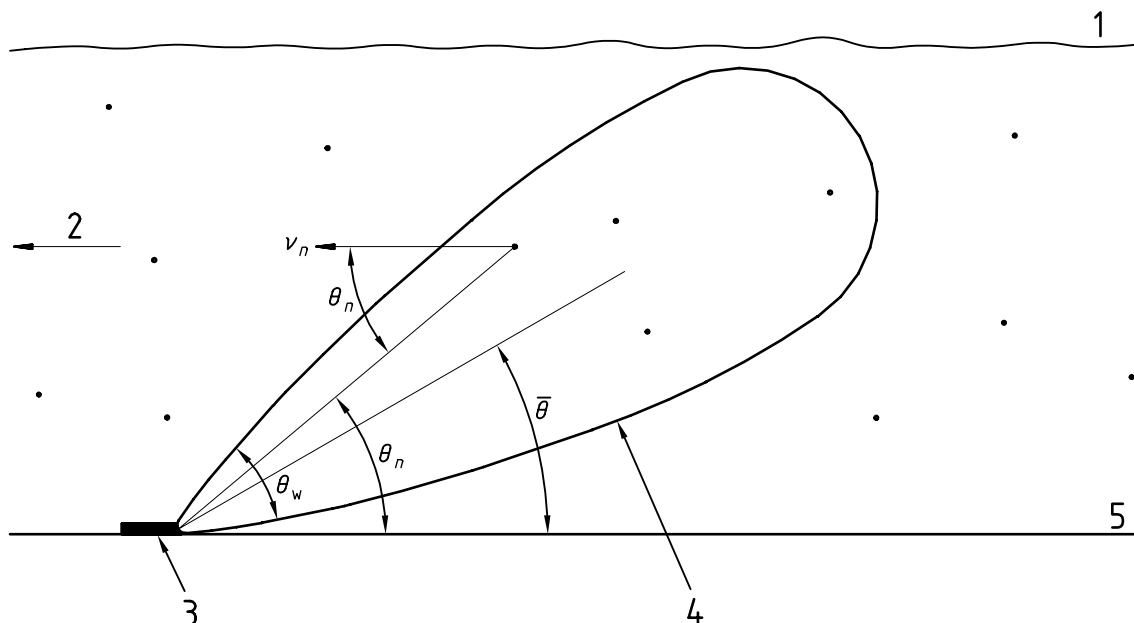
3 Terms and definitions

For the purposes of this Technical Specification, the terms and definitions given in ISO 772 apply.

4 Principle

This method of velocity measurement is based on a phenomenon first identified by Christian Doppler in 1843. The principle of “Doppler shift” describes the difference or shift which occurs in the frequency of emitted sound waves as they are reflected back from a moving body.

The sensors of Doppler systems normally contain a transmitting and a receiving device (see Figure 1). A sound wave of high frequency (f_s) is transmitted into the flow of water and intercepted and reflected back at a different frequency by tiny particles or air bubbles (reflectors). A typical reflector “ n ” produces a frequency shift $f_{D,n}$. The “shift” between transmitted and reflected frequencies is proportional to the movement of particles relative to the position of the sound source (i.e. the sensor).



θ_n is the angle between direction of motion of particle n and the sensor

$\bar{\theta}$ is the angle between centre of beam and assumed flow direction (this is referred to as the "beam angle" or "projection angle")

θ_w is the beam width or spread

Key

- 1 Surface
- 2 Flow
- 3 Sensor
- 4 "Envelope" of ultrasonic beam
- 5 Bed

Figure 1 — Principle of Doppler-ultrasonic flow measurement

Doppler shift only occurs if there is relative movement between the transmitted sound source and the reflected sound source. The velocity of moving reflector " n " can be calculated from the following:

- a) the magnitude of the Doppler shift;
- b) the angle between the transmitted beam and the direction of movement;
- c) the velocity of sound in the water.

It can be shown that:

$$v_n = \frac{f_{D,n} \cdot c}{2 f_s \cdot \cos \theta_n}$$

where

v_n is the relative velocity between transmitted sound source and reflector n ;

$f_{D,n}$ is the Doppler frequency shift produced by reflector n ;

- f_s is the frequency of sound with no movement;
- c is the velocity of sound in water;
- θ_n is the angle between the reflectors' line of motion (the assumed flow path) and the direction of the acoustic beam.

A Doppler flowmeter measures the resultant frequency shift produced by a large number of reflectors of which reflector n is typical and from which the mean velocity can be computed. Consequently, the velocity of moving particles, and not the velocity of water, is measured. By measuring the velocity of many particles, the mean water velocity in front of the sensor can be estimated. Although the particles, if small, travel at almost the same speed as the water, sampling errors may occur. These errors depend on the spatial and velocity distribution of the particles as well as the extent of penetration of the ultrasonic beam. Instruments are neither point-velocity meters nor whole-channel meters. The area sampled by the ultrasonic beam can be visualized, by analogy, to shining a torch in front of the sensor. The purpose of using such an approach is to obtain a representative sample of the full cross-sectional velocity.

The cross-sectional area is also required for the velocity-area calculation of discharge. Most systems incorporate a pressure transducer in their sensors and by combining water depth with knowledge of the cross-sectional profile, the flow can be calculated.

5 Factors affecting operation and accuracy

5.1 General

The factors affecting the performance of Doppler flowmeters may be broadly divided into:

- characteristics of the instrument,
- characteristics of either the channel or the liquid flowing in it.

However, these factors interact and shall be considered together.

5.2 Characteristics of the instrument

5.2.1 General considerations

The characteristics of the instrument and in particular the sensor have a bearing on its performance in any given situation. There is no optimal set of characteristics. Certain characteristics may make a particular instrument perform better under certain conditions but worse under others. A list of characteristics and their influence on the performance of the instrument are given in 5.2.2 to 5.2.6.

5.2.2 Ultrasonic beam angle

The ultrasonic “beam” is usually transmitted in the approximate shape of a cone. The term “beam angle”, or “projection angle” in this context, refers to the angle between the cone axis and the flow direction. The effects of beam “angle” should be considered together with those due to beam “width” (5.2.3).

The sensor has to be installed so as to remain beneath the surface of the liquid under all conditions and is positioned so that the beam cone reaches the lateral extremities of the channel as far as possible. The installation position is often a compromise and the installer is frequently obliged to install the sensor on the channel bed, somewhere near the centre of the cross-section. An off-centre position is also sometimes used.

Assuming the sensor is installed on the bed of the channel, a high angle between the flow direction and ultrasonic beam (e.g. between 30° and 50°) enable signals to be obtained throughout the depth up to the limit of the penetration of the beam. However, no signals are obtained close to the bed on either side of the sensor. Serious sampling errors can occur particularly when the ratio between the depth of water and width of the channel is low.