## ISO 3966:2020 (E)

## Measurement of fluid flow in closed conduits — Velocity area method using Pitot static tubes

## Contents

Foreword

- 1 Scope
- 2 Normative references
- 3 Terms, definitions and symbols
  - 3.1 Terms and definitions
  - 3.2 Symbols
- 4 Principle
  - 4.1 General principle
  - 4.1.1 Graphical integration of the velocity area (see Clause 9)
  - 4.1.2 Numerical integration of the velocity area (see Clause 10)
  - 4.1.3 Arithmetical methods (see Clause 11)
  - 4.2 Measurement of the measuring cross-section
  - 4.2.1 Circular cross-sections
  - 4.2.2 Rectangular cross-sections
  - 4.3 Measurement of local velocities
  - 4.3.1 Method of exploring traverse section
  - 4.3.2 Reference measurement
  - 4.3.3 Checking of velocity distribution
  - 4.4 Location and number of measuring points in the cross-section
  - 4.4.1 General requirements
  - 4.4.2 Circular cross-sections
  - 4.4.3 Rectangular cross-sections
- 5 Design of Pitot tubes
  - 5.1 General description
  - 5.2 Criteria to be fulfilled by the Pitot tube
- 6 Requirements for use of Pitot tubes
  - 6.1 Selection of the measuring cross-section
  - 6.1.1 Location of the measuring cross-section (of selection)
  - 6.1.2 Avoidance of asymmetry, swirl and turbulences
  - 6.1.3 Maximum flow deviation
  - 6.1.4 Preliminary traverse tests
  - 6.2 Devices for improving flow conditions
  - 6.2.1 Anti-swirl device
  - 6.2.2 Profile developer
  - 6.2.3 Positioning/Location of devices
  - 6.2.4 Provisional guiding installation
  - 6.3 Limits of use
  - 6.3.1 Nature of the fluid
  - 6.3.2 Range of velocities
  - 6.3.3 Nature of the flow
  - 6.3.4 Dimensional limitations
  - 6.3.5 Influence of turbulence
  - 6.4 Performance of measurements
  - 6.4.1 Measurement of differential pressure
  - 6.4.2 Differential pressure fluctuations
  - 6.4.3 Determination of fluid density
  - 6.5 Inspection and maintenance of the Pitot tube

- 7 Positioning of Pitot tube
- 8 Velocity computation

9

- 8.1 Verification of conditions for a measurement
- 8.2 Formulae for velocity computation
- Determination of the discharge velocity by graphical integration of the velocity area
  - 9.1 Circular cross-section
  - 9.2 Rectangular cross-sections
- 10 Determination of the discharge velocity by numerical integration of the velocity area
  - 10.1 Circular cross-sections
  - 10.2 Rectangular cross-sections
- 11 Determination of the discharge velocity by arithmetic methods
  - 11.1 "Log-linear" method
  - 11.1.1 Circular cross-sections
  - 11.1.2 Rectangular cross-sections
  - 11.2 Log-Chebyshev method
  - 11.2.1 Circular cross-sections
  - 11.2.2 Rectangular cross-sections
- 12 Corrections of local velocity measurements
  - 12.1 Correction for stem blockage
  - 12.1.1 Case where the correction can be neglected
  - 12.1.2 Estimation of the correction of local velocity measurement
  - 12.1.3 Estimation of the overall correction of the flow-rate value (application to arithmetic methods)
  - 12.2 Correction for transverse velocity gradient
  - 12.2.1 Correction for measuring point position
  - 12.2.1.1 Case of graphical or numerical integration
  - 12.2.1.2 Case of arithmetical methods
  - 12.2.2 Overall correction of flow rate
  - 12.3 Correction for turbulence
  - 12.4 Correction for head loss

## 13 Errors

- 13.1 Definition of the error
- 13.2 Errors in the estimation of the local velocity
- 13.2.1 Random errors
- 13.2.1.1 Error in the measurement of differential pressure
- 13.2.1.2 Error due to slow velocity fluctuations
- 13.2.1.3 Error in density
- 13.2.1.4 Error in the calculation of the compressibility correction
- 13.2.2 Systematic errors
- 13.2.2.1 Error in the Pitot tube calibration
- 13.2.2.2 Error due to turbulence
- 13.2.2.3 Error due to the transverse velocity gradient
- 13.2.2.4 Error due to conduit blockage
- 13.2.2.5 Error due to the inclination of the Pitot tube with respect to the flow direction
- 13.2.2.6 Error due to the head loss between total and static pressure tappings
- 13.3 Errors in the estimation of flow rate
- 13.3.1 Random errors
- 13.3.1.1 Error due to local velocity measurements
- 13.3.1.2 Error due to graph in graphical integration technique
- 13.3.1.3 Error due to evaluation of power law index, m
- 13.3.1.4 Error due to positioning Pitot tubes
- 13.3.2 Systematic errors
- 13.3.2.1 Error due to measurement of duct dimensions
- 13.3.2.2 Error due to numerical or arithmetic integration techniques
- 13.3.2.3 Error due to number of measuring points
- 13.4 Definition of the standard deviation 5 5 The standard deviation as defined here is what is more accurately referred to as the "standard deviation estimation" by statisticians.

- 13.5 Definition of the tolerance
- 13.6 Calculation of standard deviation
- 13.6.1 Standard deviation on local velocity measurement
- 13.6.2 Standard deviation on flow-rate measurement
- Annex A (normative) Pitot tubes
  - A.1 Different types
  - A.2 Sensitivity of Pitot tube to inclination
- Annex B (normative) Correction to the measuring position of Pitot tubes used in a transverse velocity gradient
  - B.1 Determination of the displacement of a measuring point
  - B.2 Determination of the overall correction for flow rate in a circular conduit
- Annex C (normative) Study concerning turbulence correction
  - C.1 Influence of turbulence on the total pressure tap
  - C.1.1 Pressure probe insensitive to orientation
  - C.1.2 Pressure probe sensitive to orientation
  - C.2 Influence of turbulence on the static-pressure tap
  - C.3 Evaluation of errors for an exploration with a Pitot tube
- Annex D (normative) Damping of pressure gauges
  - D.1 Damping procedure
  - D.2 Balancing of the damping
  - D.3 Checking of the damping
- Annex E (normative) Measurements with a Pitot tube in a compressible fluid
  - E.1 General
  - E.2 List of subscripts used in this annex
  - E.3 Determination of velocity calculation
  - E.4 Operating procedure
- Annex F (normative) Determination of coefficient m for extrapolation near the wall
  - F.1 Method of determination of m
  - F.2 Influence on the calculation of discharge velocity
- Annex G (informative) Example of calculation of the uncertainty on the flow-rate measurement by means of Pitot tubes
  - G.1 Error on the local velocity measurement
  - G.2 Error on the flow-rate measurement

Page count: 55