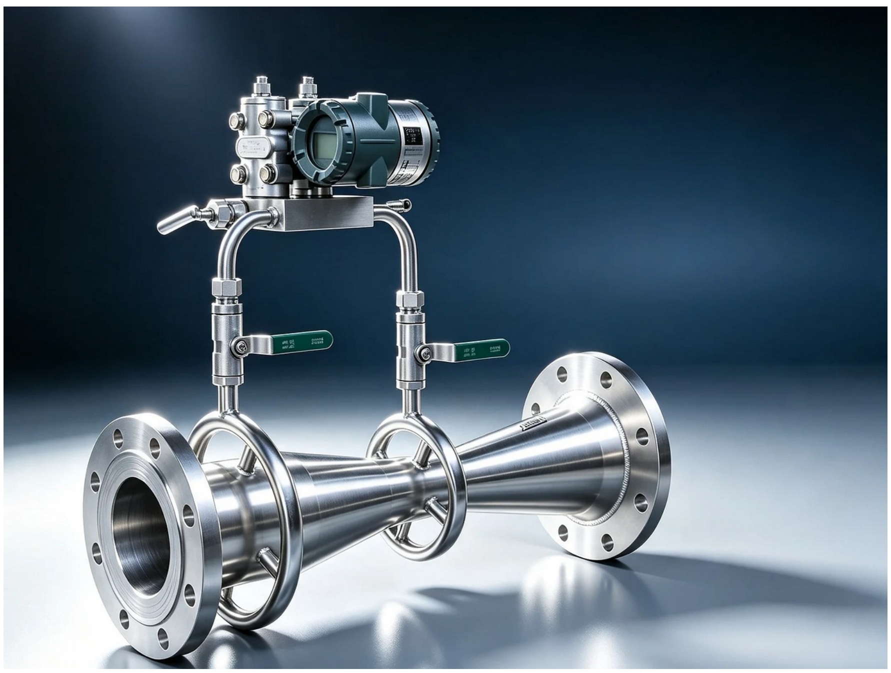
ISO 5167 DIFFERENTIAL-PRESSURE PRIMARY ELEMENTS

# Venturi Tube
# Product & Selection Guide

Principle · ISO scope · Sizing · Installation · Commissioning



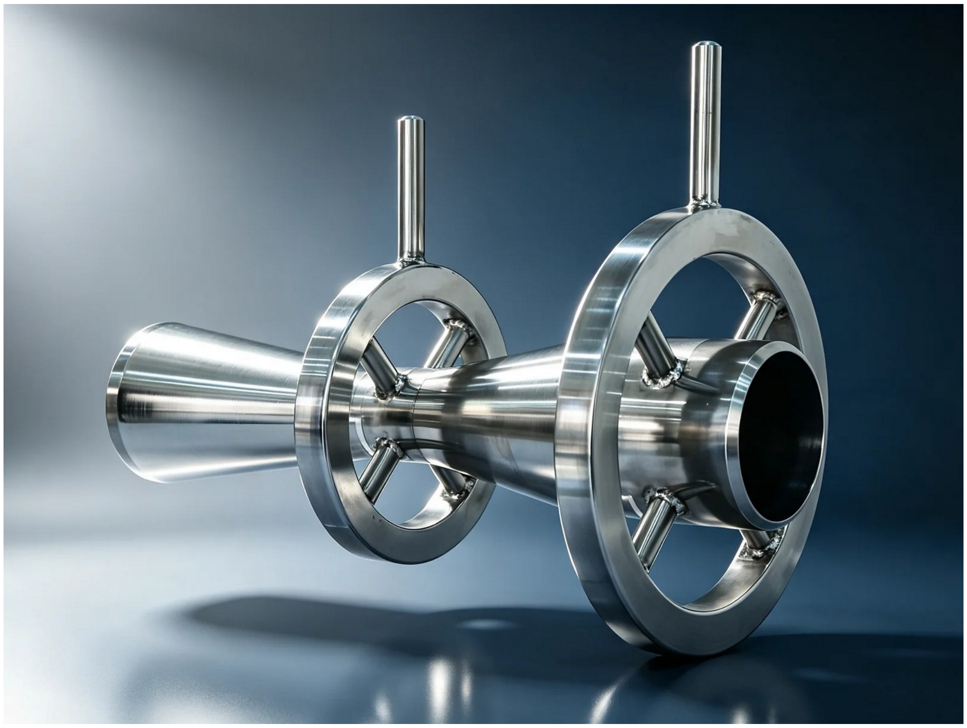
*Integrated Venturi tube flow-meter assembly*

| Cd uncertainty | Reference standard | ISO uncalibrated size scope |
|---|---|---|
| **0.5%–1.0%*** | **ISO 5167-1 / ISO 5167-4** | **DN50–DN1200** |

**Selected/configured product target; construction type, Reynolds number and calibration basis apply.*

# 1. Product Overview

A Venturi tube is a differential-pressure primary element with a convergent inlet, a cylindrical throat and a divergent recovery section. The contraction accelerates the fluid and lowers static pressure at the throat. Upstream and throat pressure taps measure the resulting differential pressure, which is converted to flow using the discharge coefficient, diameter ratio, fluid density and, for gases or steam, the expansibility factor.



*Classical Venturi tube primary element with upstream and throat pressure connections*

**Primary advantage:** The gradual diffuser recovers a large proportion of the velocity head. A Venturi tube therefore normally has substantially lower permanent pressure loss than a sharp-edged orifice plate at a comparable flow duty.

## Where it fits

- Water, gas, steam and process services with a full pipe, stable single-phase flow.
- Large lines or continuous operation where pumping or compression energy matters.
- Dirty or mildly solids-bearing services when the open throat is preferable to a thin orifice edge.
- High-pressure and high-temperature applications with project-specific materials and pressure class.

## 2. ISO 5167-4:2022 Scope and Construction Types

ISO 5167-4:2022 is used together with ISO 5167-1:2022. Its uncalibrated standard scope covers full-pipe, subsonic, single-phase flow without pulsation. The stated overall size envelope is DN50 to DN1200 with pipe Reynolds number ReD at or above $2 \times 10^5$. Each construction class has its own tighter diameter, beta-ratio and Reynolds-number limits.

| Construction | Standard envelope | Cd basis | Relative Cd uncertainty |
|---|---|---|---|
| As-cast convergent | D 100–800 mm; β 0.30–0.75; ReD $2\times10^5$–$2\times10^6$ | C = 0.984 | 0.7% |
| Machined convergent | D 50–350 mm; β 0.40–0.75; ReD ≥ $2\times10^5$ | C = 0.995 below ReD $10^6$; 1.000 above | 1.0% or 1.8%, per ISO clause |
| Fabricated convergent | D 200–1200 mm; β 0.40–0.70; ReD $2\times10^5$–$2\times10^6$ | C = 0.985 | 1.5% |

**Important accuracy distinction:** The website value “Cd uncertainty 0.5%–1.0% (type dependent, per ISO 5167-4)” is a selected/configured product target. It must not be treated as the universal uncalibrated ISO value for every construction. Outside the applicable ISO envelope—or when tighter uncertainty is required—use a documented calibration.

### Standards boundary

- The pipe must run full and the fluid must remain single phase through the meter.
- Pulsating flow is outside the standard basis unless the pulsation is controlled or separately evaluated.
- Geometry, surface condition, pressure tapping, pipe condition and straight runs are part of the metering system.
- Sizes or operating conditions outside the stated scope require an engineered and normally calibrated basis.

# 3. Geometry, Pressure Recovery and Pressure Taps

| Feature | Engineering requirement / guidance |
|---|---|
| Convergent section | Included angle 21° ± 1° within the ISO geometry basis |
| Throat | Cylindrical, concentric and dimensionally controlled; throat diameter defines β |
| Divergent section | Included angle 7°–15°; 7°–8° is preferred when low pressure loss is a priority |
| Upstream tap | Located in the cylindrical inlet section at the prescribed position |
| Throat tap | Located in the cylindrical throat; tap edges must be clean and free from burrs |
| Permanent pressure loss | Common ISO guidance is approximately 5%–20% of measured differential pressure |

A smaller diffuser angle improves pressure recovery but increases meter length. A shorter, steeper diffuser saves installation space but generally increases permanent pressure loss and sensitivity to flow separation. The final geometry is therefore a balance among energy, available length, fabrication and metrology.

## Diameter ratio and differential pressure

The diameter ratio β = d/D links the throat diameter d to the upstream pipe bore D. Lower β creates more differential pressure and can improve low-flow signal strength, but increases velocity and pressure loss. Higher β reduces differential pressure and pressure loss, but requires careful transmitter ranging and normally longer or more demanding straight-run qualification.

## Cd uncertainty is not total meter accuracy

Total system uncertainty also includes differential-pressure measurement, static pressure, temperature, fluid-property uncertainty, dimensional measurement, installation effects, signal processing and any reference-condition conversion. A quotation should state whether a number refers to discharge-coefficient uncertainty, primary-element uncertainty or complete installed-system accuracy.

## 4. Flow Calculation and Instrument Sizing

For the applicable standard geometry, the mass-flow relationship is based on conservation of mass and energy. The ISO calculation is iterative because the discharge coefficient and Reynolds number depend on flow.

$$q_m = C \times \varepsilon \times A_2 \times [2 \times \Delta p \times \rho_1 / (1 - \beta^4)]^{0.5}$$

| Symbol | Meaning |
|---|---|
| $q_m$ | Mass flow rate |
| C | Discharge coefficient for the selected Venturi construction |
| $\beta = d/D$ | Throat-to-pipe diameter ratio |
| $\varepsilon$ | Expansibility factor for compressible fluids |
| d / D | Throat diameter / upstream pipe bore at operating conditions |
| $\Delta p$ | Differential pressure between upstream and throat taps |
| $\rho_1$ | Upstream fluid density at operating conditions |

### Transmitter range and turndown

- Check minimum, normal and maximum flow; do not size only at the maximum design point.
- Because flow is proportional to $\sqrt{\Delta p}$, a 10:1 flow turndown corresponds to roughly 100:1 differential-pressure turndown.
- Confirm overpressure/static-pressure rating, zero stability, rangeability and ambient/temperature effects.
- For wide ranges, consider dual-range transmitters or two DP ranges with a documented crossover strategy.
- For gases and steam, define pressure, temperature, compressibility and density compensation.

# 5. Selection Guide

| Decision item | Information required |
|---|---|
| Fluid | Phase, composition, density, viscosity, compressibility, solids, corrosion and fouling |
| Flow | Minimum, normal and maximum mass or volume flow with reference conditions |
| Line | Nominal size, actual bore, schedule, material, roughness and available straight run |
| Pressure / temperature | Minimum, normal, maximum and design values |
| Performance | Cd uncertainty or system accuracy target, turndown and allowable pressure loss |
| Construction | As-cast, machined or fabricated convergent; welded or flanged spool |
| Instrumentation | DP range, static-pressure rating, manifold, pressure/temperature compensation |
| Compliance | ISO basis, calibration, material certificates, NDE, pressure test and data book |

## Venturi tube versus standard orifice plate

| Criterion | Venturi tube | Standard orifice plate |
|---|---|---|
| Permanent pressure loss | Low; strong pressure recovery | Higher; limited pressure recovery |
| Installed length / cost | Longer and higher initial cost | Compact and economical |
| Dirty-service tolerance | Open throat; generally more tolerant | Sharp edge and plate bore need close inspection |
| Maintenance | Robust, but internal inspection may need access | Plate is readily replaceable |
| Best fit | Energy-sensitive and large-line duties | General-purpose standards-based DP metering |

**Selection principle:** Choose the primary element on life-cycle value, not purchase price alone. On continuous large-flow service, the energy saved by a Venturi tube can outweigh its higher initial cost.

# 6. Installation Requirements

## Piping and flow profile

- Install in the marked flow direction with the primary element concentric to the pipe.
- Maintain a full pipe; avoid high points that trap gas in liquid service and low points that retain liquid in gas service.
- Determine upstream and downstream straight-run length from ISO 5167-1 Table 1 for the actual β and disturbance combination.
- Do not replace the standard table with one universal straight-run number such as 5D or 20D.
- Locate throttling/control valves downstream where practical; elbows, reducers, tees and partially open valves must be reviewed.
- Inspect the adjacent pipe bore for steps, weld intrusion, scale, deposits, excessive roughness or ovality.

## Pressure taps and impulse lines

- Keep upstream and throat taps clean, square and free from burrs.
- Route positive and negative impulse lines together, as short as practical and with continuous slope.
- For liquids, prevent trapped gas; for gases, prevent condensate pockets.
- For steam, use equal condensate legs and consistent thermal conditions.
- Leak-test every fitting and manifold connection before transmitter zeroing.
- Protect against freezing, plugging, corrosion and vibration as required by the service.

**Straight-run evidence:** Final drawings should record the actual upstream fittings, their orientation, separation distance and β ratio. When the available layout cannot meet the applicable standard, engineering review or flow calibration is required.

# 7. Commissioning and Verification

1. Confirm tag number, approved calculation, drawing, materials, pressure class and flow direction.
2. Inspect the throat, convergent, diffuser and pressure taps for damage, deposits or fabrication debris.
3. Flush or blow the line before exposing the meter to full flow.
4. Pressure-test the assembly and verify that both impulse paths are open and leak-free.
5. Equalize the manifold, apply stable static pressure and perform the transmitter zero check.
6. Open the positive and negative isolation valves in the specified sequence, then close the equalizing valve.
7. Verify DP range, square-root extraction, engineering units, damping and compensation inputs.
8. Compare indicated flow with process expectations at stable points and record the as-commissioned baseline.

## Baseline records

| Record | Purpose |
|---|---|
| Zero and static-pressure check | Separates transmitter bias from primary-element performance |
| Normal-flow DP | Provides a future comparison point for blockage, deposits or impulse-line faults |
| Pressure / temperature / density | Confirms compensation inputs and fluid-property basis |
| Valve and manifold position | Prevents configuration errors after maintenance |
| Photographs and tag data | Preserves installation evidence and traceability |

# 8. Maintenance and Troubleshooting

| Symptom | Likely causes | Checks |
|---|---|---|
| Flow reads low | Positive-line leak/blockage; low actual flow; density error; oversized DP range | Leak-test, purge, verify fluid state and range |
| Flow reads high | Negative-line leak/blockage; throat deposit; wrong density or DP range | Inspect negative path, throat and compensation |
| Unstable reading | Pulsation, two-phase flow, trapped gas/liquid, vibration or nearby valve | Review process, line routing and damping |
| Bias grows over time | Deposits, erosion, tap blockage, corrosion or zero shift | Compare with baseline; inspect bore/taps and zero |
| Poor low-flow response | DP near noise floor or ReD outside the selected basis | Recalculate minimum flow and transmitter strategy |

## Recommended periodic checks

- Review transmitter diagnostics, zero stability and manifold condition.
- Compare operating DP against the commissioning baseline at similar flow and fluid conditions.
- Inspect pressure taps and impulse lines for plugging, leakage, corrosion, freezing or condensate imbalance.
- Inspect internal surfaces when process contamination, erosion or corrosion is credible.
- After line modifications, recheck straight-run geometry and the calculation basis.
- Retain calibration, pressure-test, material and dimensional records with the meter tag history.

# 9. Ordering Data Checklist

Provide the following data for sizing, engineering review and quotation. Missing process or piping data can produce an unsuitable throat diameter, DP range, material or pressure class.

- Fluid name, composition, phase and any solids, droplets or corrosive constituents.
- Minimum, normal and maximum flow with units and reference conditions.
- Minimum, normal, maximum and design pressure and temperature.
- Density, viscosity, compressibility and isentropic exponent where applicable.
- Pipe nominal size, schedule, actual internal diameter, material and flange/weld standard.
- Required Cd uncertainty or installed-system accuracy, turndown and allowable pressure loss.
- Available upstream/downstream straight run and nearby fittings, valves or branches.
- Preferred construction type, connection, materials, DP transmitter and communication protocol.
- Required calibration, NDE, pressure test, material certificates and inspection plan.
- Documentation language and deliverables: calculation, GA drawing, ITP, certificates and data book.

## Typical deliverables

| Deliverable | Typical content |
|---|---|
| Engineering calculation | Throat/pipe bore, β, Reynolds range, Cd, DP range and fluid-property basis |
| General arrangement | Dimensions, pressure taps, flow direction, materials and connections |
| Inspection records | Critical dimensions, surface condition, NDE and pressure test as specified |
| Material documentation | Certificates and traceability per purchase order |
| Installation guidance | Orientation, straight-run, impulse-line and commissioning requirements |

# 10. References, Contact and Document Status

## Primary references

ISO 5167-4:2022 — Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 4: Venturi tubes.

Official ISO record: https://www.iso.org/standard/79181.html

ISO 5167-1:2022 — General principles and requirements for differential-pressure devices in full circular conduits.

NIST Technical Note 831 — Fluid Meters: Their Theory and Application, used for the classical discussion of pressure recovery and calibration practice.

NIST source: https://nvlpubs.nist.gov/nistpubs/Legacy/TN/nbstechnicalnote831.pdf

## Contact

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**Document status:** This guide is a product-selection and application reference. It does not replace the approved project calculation, GA drawing, purchase specification, calibration certificate or site safety procedure. Final specifications and performance commitments are confirmed per order.