

FOR OPERATIONS & MAINTENANCE ENGINEERS

The Meter That Bills You Every Hour

Permanent pressure loss is an operating cost — and it is fixed at the design stage, not by the vendor

A differential-pressure flow element works by taking energy out of the flow and then measuring what it took. Most of that energy comes back as the flow re-expands downstream. Some of it never does. The part that never comes back is the **permanent pressure loss** — Δp in ISO 5167 — and your pump or compressor pays for it, continuously, for the entire service life of the meter.

Nobody owns that number. It is not on the instrument datasheet in money terms, it is not in the maintenance budget, and it does not appear on any invoice. It is simply absorbed into the plant's electricity bill, where it is invisible. This paper puts a figure on it, and shows which decisions actually change it — because the two levers that matter are not the ones most specifications pull.

THE HEADLINE

On a single DN 200 water line carrying 400 m³/h for 8,000 hours a year, the permanent pressure loss of a conventional orifice installation costs **about €7,600 (TRY 197,000) a year in pumping energy**. Over a twenty-year plant life that is more than €150,000 — spent on one flow measurement, on one line.

1. What permanent pressure loss actually is

For an orifice plate, ISO 5167-1 gives the permanent loss as a function of the diameter ratio β and the discharge coefficient C . In practice the result is startling: a conventional orifice throws away most of the differential pressure it creates.

DIAMETER RATIO β	0.40	0.50	0.60	0.70	0.75
Permanent loss, as % of the measured Δp	82 %	73 %	63 %	51 %	45 %

Table 1 — Permanent pressure loss of a square-edged orifice plate, calculated from the ISO 5167-1 relationship at $C = 0.605$.

The trend is the right instinct — a larger bore loses proportionally less — but it is also the source of the most expensive misconception in differential-pressure metering, which is the subject of the next section.

2. The result most specifications get wrong

Ask any vendor and you will be told that a nozzle or a cone meter has a lower pressure loss than an orifice plate. Taken at face value, that is a reason to pay more for one. Taken carefully, it is only true under a condition that almost no real specification satisfies.

The reason is arithmetic. Write $K = C\beta^2/\sqrt{1 - \beta^4}$. The ISO 5167-1 loss relationship collapses to a function of K alone:

$$\text{Permanent loss} \div \Delta p = (\sqrt{1 + K^2} - K) \div (\sqrt{1 + K^2} + K)$$

But K is also exactly what the flow equation fixes. Once you have specified the flow rate, the pipe size, the fluid density and the full-scale differential pressure, K is determined — and so is the permanent loss. It no longer depends on which element you chose. An orifice plate at $\beta = 0.68$, an ISA 1932 flow nozzle at $\beta = 0.55$ and a cone meter at $\beta = 0.60$, all sized for the same duty and the same Δp , produce **the same permanent pressure loss**.

The elements with a higher discharge coefficient do not save energy; they simply reach the same Δp with a smaller bore. The saving that the marketing describes is real, but it only appears when β is held constant — the retrofit case in Section 4 — not when Δp is held constant, which is what a datasheet actually specifies.

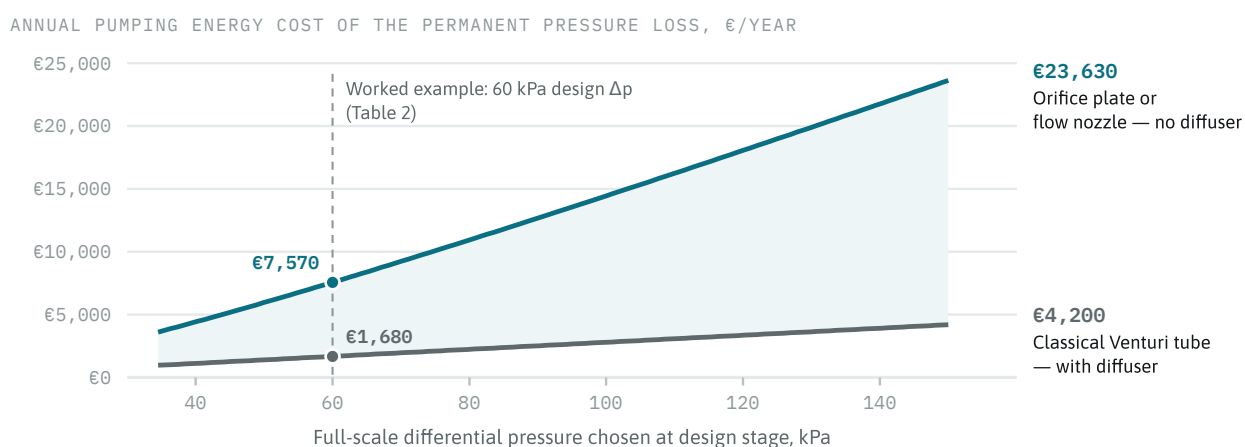
One family of devices genuinely escapes this: those with a **diffuser**. A classical Venturi tube recovers pressure gradually through a conical outlet rather than losing it to a sudden expansion, and its permanent loss is typically only 5–20 % of the differential pressure regardless of how the duty is specified. That is a difference in physics, not in marketing.

ELEMENT SIZED FOR 60 kPa Δp	β	PERMANENT LOSS	PUMP POWER	ENERGY COST
Orifice plate	0.68	32.4 kPa	5.15 kW	€7,570 / TRY 196,500
ISA 1932 flow nozzle	0.55	32.4 kPa	5.15 kW	€7,570 / TRY 196,500
Cone meter	0.60	32.4 kPa	5.15 kW	€7,570 / TRY 196,500
Classical Venturi tube	0.55	7.2 kPa	1.14 kW	€1,680 / TRY 43,600

Table 2 — DN 200 water line, 400 m³/h, 8,000 h/yr, 70 % pump-and-motor efficiency. Cone-meter loss is calculated on the same sudden-expansion model; measured cone performance is often somewhat better, which is exactly why test data — not a brochure — should settle the question.

3. Lever one — choose the differential pressure, not just the element

If the element type does not set the energy cost, what does? The full-scale differential pressure. That single number, chosen early in a project by someone who will never see the electricity bill, determines the operating cost of the meter for its whole life.



DN 200 water line, 400 m³/h, 8,000 h/yr, 70 % pump-and-motor efficiency, €0.1837/kWh (EU non-household average, second half of 2025). β falls from 0.75 at 34.5 kPa to 0.56 at 150 kPa; below 34.5 kPa the orifice would exceed the ISO 5167-2 limit of $\beta = 0.75$.

Figure 1 — Annual pumping energy cost against the full-scale differential pressure selected at design. Moving the design Δp from 100 kPa to 50 kPa on this duty takes the annual cost from €14,450 to €5,960 — a 59 % reduction, with no change of element type.

The habit of specifying a generous Δp comes from a good instinct: a large differential gives good resolution at low flow and a comfortable turndown. But modern differential-pressure transmitters have far better low-range performance and far better turndown than the transmitters that habit was formed around. Specifying 100 kPa where 50 kPa would serve is a decision that costs real money every hour of every year.

4. Lever two — buy pressure recovery, in the right situations

The second lever is the diffuser. Where it is worth paying for depends on how the question is asked. In a *retrofit* — replacing a worn element in an existing meter run, keeping the same bore — the recovery devices win twice: they produce a lower differential pressure for the same flow, and they lose less of it.

SAME BORE ($\beta = 0.68$), SAME 400 m ³ /h	Δp PRODUCED	PERMANENT LOSS	ANNUAL ENERGY COST
Orifice plate	60.1 kPa	32.5 kPa	€7,590 / TRY 197,000
Cone meter	34.4 kPa	15.4 kPa	€3,590 / TRY 93,200
ISA 1932 flow nozzle	22.5 kPa	8.4 kPa	€1,960 / TRY 51,000
Classical Venturi tube	22.2 kPa	2.7 kPa	€620 / TRY 16,100

Table 3 — The retrofit case: identical bore, identical duty. Here the high-recovery elements do save energy — but the transmitter must be re-ranged, and the lower Δp must still give acceptable resolution at minimum flow. The orifice figure differs slightly from Table 2, €7,590 against €7,570, because Table 2 sizes every element to exactly 60 kPa while this table fixes the bore and lets the differential pressure fall where it will, at 60.1 kPa. The headline figure rounds the same case to €7,600.

On gas the same arithmetic applies to compressor power. A DN 300 transmission line carrying 150,000 Nm³/h at 50 barg, metered at 25 kPa full scale, loses about 13.4 kPa permanently through an orifice — roughly 14.6 kW of recompression duty, or €21,400 a year. A classical Venturi tube on the same duty loses about 3.0 kPa: €4,800 a year. **The difference, €16,600 a year, is larger than the price of the meter.**

5. What the cheap answer costs you elsewhere

Raising β to reduce pressure loss is the obvious move, and it is not free. Four penalties arrive together, and an operations engineer feels all four.

PENALTY	AT $\beta = 0.50$	AT $\beta = 0.75$
Discharge-coefficient uncertainty (ISO 5167-2)	0.50 %	0.75 %
Upstream straight length after a single 90° bend	≈ 20 D	more than twice that
Sensitivity to an imperfect velocity profile	Moderate	High — flow-conditioner territory
Practical turndown at a given Δp range	Good	Reduced — the meter runs lower on its range

Table 4 — The cost of chasing low pressure loss with β alone.

This is why a Venturi tube is often the better answer than a large- β orifice: it delivers the low permanent loss and a shorter straight-length requirement — typically 5 D after a single bend against 20 D for an orifice — rather than trading one against the other.

6. A decision guide you can apply this week

SITUATION	WHAT USUALLY WINS
Continuous duty, large line, high running hours, pumped or compressed fluid	Classical Venturi tube. At the numbers above, a price premium of €5,000 pays back in about ten months; €12,000 pays back inside two and a half years.
Intermittent duty, short running hours, or gravity flow	Orifice plate. With no pumping energy behind the loss there is nothing to recover, and the orifice's low cost and easy replacement dominate.
Existing meter run, worn element, energy cost under review	Retrofit to a recovery element at the same bore (Table 3), and re-range the transmitter. No pipework changes.
Erosive, abrasive or particulate-laden service	Nozzle or wedge meter. Here the driver is service life, not energy; a rounded profile survives what a sharp edge does not.
Short straight lengths available	Venturi tube, or an orifice plus a flow conditioner. Compare the installed cost of the spool you would have to build against the price of the element.
Custody transfer and fiscal metering	Whatever the contract and OIML R 140 / AGA Report No. 3 require. Energy is a secondary consideration where a 0.1 % uncertainty band is contractual.

Table 5 — Selection guidance. In every case the calculation should be repeated on your own flow, hours, tariff and efficiency; the arithmetic is simple and the result is usually larger than expected.

THE ONE-LINE VERSION

Ask your vendor for the **permanent pressure loss in kPa at your design flow** — not as a percentage, and not as a claim about the element type. Multiply it by your flow rate, divide by your pump efficiency, multiply by your running hours and your tariff. That number belongs in the purchase decision.

Appendix — running the number on your own line

This takes ten minutes with a calculator and is worth doing before the next flow-element purchase or replacement.

1. **Get the permanent pressure loss in pressure units.** Ask the supplier for Δp in kPa (or bar) at your design flow — not as a percentage. If they will only give a percentage, multiply it by your full-scale Δp .
2. **Convert to hydraulic power.** $P_{\text{hyd}} [\text{kW}] = \Delta p [\text{kPa}] \times Q [\text{m}^3/\text{s}]$. Use the actual volumetric flow at line conditions, not the normalised flow.
3. **Divide by efficiency.** $P_{\text{elec}} = P_{\text{hyd}} \div \eta$, where η is the combined pump-and-motor (or compressor-and-driver) efficiency — typically 0.65–0.75 for pumps, 0.70–0.80 for large compressors.
4. **Annualise.** Energy [kWh/yr] = $P_{\text{elec}} \times \text{operating hours}$. Use real running hours, not calendar hours.
5. **Price it.** Multiply by your own delivered electricity tariff, then compare against the price difference between the candidate elements. If the annual saving exceeds a third of the price premium, the payback is under three years and the case is usually made.

A SANITY CHECK

On a liquid line, 1 kPa of permanent loss at 100 m³/h costs roughly **€58 a year** at 8,000 h/yr, 70 % efficiency and €0.1837/kWh. The number scales linearly with flow, with loss, with hours and with tariff. So a proposal that saves 25 kPa on a 400 m³/h line is worth about €5,800 a year — and you worked that out without opening a spreadsheet.

SOURCES AND STANDARDS REFERENCED

ISO 5167-1, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 1: General principles and requirements* · ISO 5167-2, ... *Part 2: Orifice plates* · ISO 5167-3, ... *Part 3: Nozzles and Venturi nozzles* · ISO 5167-4, ... *Part 4: Venturi tubes* · API MPMS Chapter 14.3 / AGA Report No. 3, *Orifice Metering of Natural Gas and Other Related Hydrocarbon Fluids*; Part 2 covers specification and installation requirements · OIML R 140, *Measuring systems for gaseous fuel* · Management system certification: ISO 9001:2015, ISO 14001:2015 and ISO 45001:2018. Pressure-loss figures are calculated from the ISO 5167 flow equation at the stated β and the stated duty; the worked assumptions are in the footnote on the last page. Read the current edition of every standard cited.

ABOUT İNKOTEK ENERJİ

İnkotek Enerji is an Ankara-based engineering and manufacturing company specialising in differential-pressure flow elements and integrated metering systems: orifice plates, Venturi tubes, flow and Venturi nozzles, cone and wedge meters, averaging, grid-type and retractable Pitot assemblies, dual chamber orifice fittings, flow conditioners, meter runs, custody-transfer and fiscal metering skids, and SWAS sampling stations. Engineering is supported by CFD analysis, high-precision machining, precision welding, post-weld heat treatment, ultrasonic and radiographic examination and corrosion-protection coatings. Designs are prepared to ISO 5167, AGA Report No. 3 / API MPMS 14.3 and OIML R 140, under a management system certified to ISO 9001:2015, ISO 14001:2015 and ISO 45001:2018. Served sectors: natural gas transmission and distribution, power generation, petrochemicals, refining and general process industry.

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Figures are worked examples based on published standards and openly available industry data; they are illustrative and do not replace a site-specific calculation. Energy prices: €0.1837/kWh (EU non-household average, second half of 2025) and TRY 4.77/kWh (Türkiye business tariff, 2025). Water case: DN 200, 400 m³/h, 997 kg/m³, 8,000 h/yr, η = 0.70. Gas case: DN 300, 150,000 Nm³/h at 50 barg, 8,000 h/yr, η = 0.75. © 2026 İnkotek Enerji Sanayi ve Ticaret Ltd. Şti. · WP-02 Rev 01 · 27 September 2026