

FOR INSTRUMENT AND PROCESS ENGINEERS

Tapping Orientation on Steam, Gas and Liquid Service

Where the tappings go on a horizontal line for each phase, why they change on a vertical line, and the impulse line slope that keeps the reading honest

A differential-pressure meter will measure any pressure difference presented to it. The primary element generates one; badly built impulse lines generate a second, add it to the first and hand the sum to the transmitter as flow. No calibration separates them, because nothing is out of calibration. The reading is the wrong quantity, faithfully reported.

Two decisions govern it. **The clock position** is where the tapping breaks through the pipe wall, measured around the circumference; it decides which phase can enter the impulse line. **The line direction** is whether the tubing rises or falls to the transmitter; it decides whether what entered can get back out. The first is fixed in steel — on an orifice flange union when the flange pair is welded in, and on a dual chamber fitting, where the flange tappings are integral to the body, when the body is set. The second is adjustable with tubing, within the headroom the layout left behind.

1. The horizontal line: one position per phase

ISO 5167-2 and API MPMS Chapter 14.3, Part 2 fix the geometry of the tapping itself: diameter, cylindrical length, flushness, freedom from burrs, and the 25.4 mm from each plate face for flange tappings. ISO 2186:2007 covers the rest of the connection: where the tapping sits around the circumference for each service, and the arrangement and slope of the impulse lines between the tapping and the transmitter. Its rule for the position follows what collects where: gravity sorts a horizontal cross-section, with liquid along the bottom, gas at the top and solids settled. Angles below are measured from top dead centre in the plane of the cross-section and apply either side of the vertical. Both tappings of a pair take the same position. On a dual chamber fitting the position is set by the body rather than chosen; Section 6 gives it.

SERVICE	POSITION FROM TOP DEAD CENTRE	TRANSMITTER	IMPULSE LINES
Gas, air, dry vapour	0° to 90° — the horizontal centreline or above it	Above the tappings	Rise continuously to the transmitter
Steam, condensing vapour	90° — on the horizontal centreline, never at the top	Below, through one condensate chamber per impulse line	Fall continuously from the chambers to the transmitter
Liquid	90° — on the horizontal centreline; 45° to 135° at the limits	Below the tappings	Fall continuously to the transmitter

Table 1 — Tapping clock position on a horizontal line, as ISO 2186:2007, Clause 5 gives it; the transmitter position and the condensate chambers are Inkotek installation practice. "Below" in the transmitter column means below the tappings; the angle is the only measure of position used here. No service takes the bottom quadrant, 135° to 180°, where scale and sludge collect and a drained line empties first.

Why each position

Gas, air, dry vapour. Liquid and settled solids collect in the lower half of the section, so the tapping stays on the horizontal centreline or above it (5.1). On a wet gas the position alone does not keep liquid out: the impulse lines rise continuously from the tapping so that what condenses in them drains back into the pipe.

Steam, condensing vapour. The lines have to stay full of condensate to a known level. On the centreline the tapping is clear of the sediment the pipe carries along its bottom (5.3), and away from the top, where non-condensable gas collects in the impulse tubing (Clause 8).

Liquid. Below the centreline a tapping collects solids; above it, air and the gas that comes out of solution. The centreline is the position, and in neither direction may the tapping sit more than 45° from the horizontal plane (5.2).

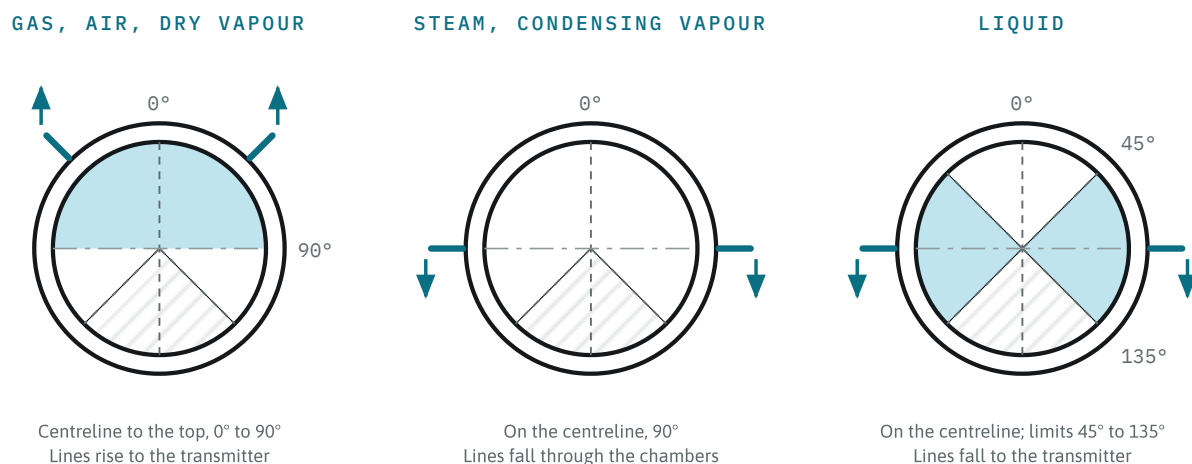


Figure 1 — Tapping positions on a horizontal pipe cross-section. Shaded: where ISO 2186:2007, Clause 5 allows the tapping; on steam the position is the centreline itself. Angles are measured from top dead centre and apply either side of the vertical; both tappings of a pair take the same position. The stubs mark the recommended position and the arrows the impulse line direction: rising to the transmitter on gas, falling on steam and liquid. Cross-hatched: the bottom quadrant, which no service takes.

Drain and vent holes in the plate

ISO 5167-2 permits a drain hole in the plate on a gas service that carries liquid, and a vent hole on a liquid service that carries gas. The drain hole sits at the bottom of the plate and the vent hole at the top, each in the phase it exists to pass, and the hole has to be clear of the pressure tappings: a hole in line with a tapping puts a jet where the tapping expects static pressure. With the positions of Table 1 that separation comes out automatically — the gas tapping is on the centreline or above it and the gas plate's drain hole is at the bottom, the liquid tapping is on the centreline and the liquid plate's vent hole is at the top. Take the permitted hole size and the required angular separation from the edition of ISO 5167-2 in hand; both are stated there, and neither belongs in a note from memory.

2. Slope, direction and symmetry

The clock position decides what enters the impulse line; the slope decides whether it leaves.

Slope every impulse line continuously at a minimum of 1:10, in one direction only, with no sag anywhere along it — 100 mm per metre, so 300 mm of vertical space over a 3 m run, which has to be there at layout. That is the figure published in White Paper 01, Section 4, and it meets ISO 2186, which recommends at least 8 % — about 1:12 — for lines that drain or vent themselves (5.1, 5.2). A sag in an otherwise correct line is not partial compliance: it holds whatever the slope was meant to clear. Where a change of direction cannot be avoided, ISO 2186 allows one, with a liquid trap at its low point on gas and a gas trap at its high point on liquid (4.5).

Which way the line falls follows the phase, and the two cases are opposites.

- **Gas, air and dry vapour.** The impulse line falls continuously back to the tapping, which is to say it rises continuously to the transmitter. Condensate forming in the tubing returns to the process line. The tapping is the low point of the run; the vent is at the transmitter end, and there is no drain at the tapping end to slope towards.

- **Liquid and steam.** The impulse line falls continuously to the transmitter, where the drain is. Gas coming out of solution works its way back up to the pipe.

Build both impulse lines as one pair, not two runs: equal length, internal diameter, elevation at every point, temperature, insulation, heat trace, valve arrangement and tubing. The transmitter responds to the difference between them, so anything present in one and absent from the other is added to the flow signal — a line routed past a steam line that the other does not pass is an asymmetry even when both are insulated.

Do not reduce the tubing below the tapping connection, ½" NPT as standard on Inkotek orifice flange unions, and keep the run short, because volume costs response time. Inkotek sets no house maximum length, and neither does ISO 2186, which asks for lines as short and direct as possible (4.5): the run follows the hook-up detail supplied with the element, and its slope follows this section and the standards that apply to the tubing installation.

3. What collects, and where

The three failures have one shape: a column of the wrong fluid standing in one impulse line that the other does not have.

Condensate in a gas line. Gas enters at process temperature, the tubing sits at ambient, and any gas near its dew point — wet gas, fuel gas carrying heavies, humid instrument air — condenses in the tubing and runs to the lowest point. A continuous slope back to the tapping returns it to the pipe; a sag keeps it.

A gas pocket in a liquid line. Gas leaves solution when pressure falls or temperature rises, and an incomplete fill leaves air behind. It rises to the highest point, where a continuous fall to the transmitter works it back into the pipe and a hump keeps it.

Unequal condensate on steam. Here condensate is wanted: both lines run full of water to a known level, and the failure is that the two levels differ or that one boils out and refills. That is why the chambers go in as a pair at one elevation — Inkotek condensate chambers are supplied matched, so both impulse legs sit at the same height. Chamber volume and elevation are outside the scope of this note.

In every case the error is a static head, $\Delta p \text{ error} = g \times h \times (\rho \text{ line} - \rho \text{ displaced})$, and it gives the three offsets of Table 2. With water at 20 °C at 998.2 kg/m³ and $g = 9.81 \text{ m/s}^2$, **100 mm standing in one line is 0.979 kPa** against a displaced fluid of negligible density. On natural gas at 50 barg and 15 °C the displaced density is about 39 kg/m³ — pure methane with a compression factor of 0.88, which is where that figure comes from, and a real pipeline composition is calculated to ISO 12213 or AGA Report No. 8 — so the same column is worth 0.94 kPa there. Table 2 carries 0.979 kPa, the value at negligible displaced density, because it is the larger of the two. **Two 2 m runs 40 °C apart**, 998.2 against 983.2 kg/m³, give 0.294 kPa with no standing column at all. **An untrimmed vertical elevation term** gives 2.92 kPa, from Section 5.

4. What a wrong position does to the reading

A standing column adds a **constant** differential pressure, while flow varies with the square root of the differential. Together they give the signature that makes this fault hard to see: small at full flow, very large at turndown.

FLOW, PERCENTAGE OF FULL SCALE	DIFFERENTIAL PRESSURE	ERROR FROM 0.294 kPa	ERROR FROM 0.979 kPa	ERROR FROM 2.92 kPa
100 %	25.00 kPa	+0.59 %	+1.94 %	+5.68 %
70 %	12.25 kPa	+1.19 %	+3.92 %	+11.28 %
50 %	6.25 kPa	+2.32 %	+7.55 %	+21.13 %

FLOW, PERCENTAGE OF FULL SCALE	DIFFERENTIAL PRESSURE	ERROR FROM 0.294 kPa	ERROR FROM 0.979 kPa	ERROR FROM 2.92 kPa
30 %	2.25 kPa	+6.33 %	+19.80 %	+51.58 %
20 %	1.00 kPa	+13.75 %	+40.68 %	+97.99 %

Table 2 — Flow error from a constant differential-pressure offset, calculated from the square-root relationship between flow and differential pressure in the ISO 5167-1 flow equation. **All percentages are referred to the true flow:** +51.58 % means the meter indicates 1.5158 times the true rate, which is 34.0 % of the indicated reading. The three offsets are the worked cases of Section 3 and come from three different services; they do not belong to one duty. The 25 kPa full scale is used here only as a common reference range — it is the full scale of the gas duty in White Paper 02, Section 4, a DN 300 line carrying 150,000 Nm³/h at 50 barg. Sign: with the transmitter below the tappings, an extra column in the high-pressure line reads high and in the low-pressure line reads low; with the transmitter above, which is the gas arrangement, the sign reverses, because a column standing in a rising line subtracts from the pressure reaching the transmitter instead of adding to it. The magnitude is the same either way.

Two things follow, and they are how the fault is recognised. **The zero moves:** a standing column does not disappear when the flow does, so it is still there with the process line shut in and no flow through the element — provided the manifold equalizer valve is closed, so that the transmitter still sees one impulse line against the other. **The error grows as flow falls:** a meter plausible at rated load and implausible at turndown is behaving as Table 2 predicts, and White Paper 01, Table 4 lists the same signature.

Opening the manifold equalizer valve connects the two transmitter chambers, which makes the differential zero by construction. A standing column is short-circuited there and can never show, so what remains with the equalizer open is the transmitter's own zero — that is the dry-zero check of White Paper 01, Table 4, and it is a check on the transmitter, not on the lines. Close one block valve before the equalizer is opened: ISO 2186 takes the zero with one block valve closed and the equalizer open (4.4), so the manifold never joins two impulse lines that are both open to the process, and on steam no more than two manifold valves are open at any time (5.3). The two valve states answer two different questions, and taking them in the wrong order is how a standing column gets signed off as an instrument matter. Neither reading is a calibration finding: a transmitter that passes calibration reports the offset faithfully.

5. Vertical lines: one rule survives, the other does not

On a vertical run every point around the circumference is at the same elevation. Gravity no longer sorts the cross-section, so **the clock positions in Table 1 do not apply**. Choose the position for access and routing instead, keeping both tappings on the same side so the impulse lines run together at one temperature (6.1). The line rule survives unchanged: transmitter above with rising lines on gas, below with falling lines on liquid and steam, 1:10 minimum, both lines a matched pair.

What replaces the clock rule is an elevation term. The tappings are separated along the pipe axis, so on a vertical run they are separated in height — 50.8 mm plus the plate thickness for flange tappings, and 1.5 D for D and D/2 tappings, where the figure to use is the one on the approved drawing. The impulse line from the upper tapping is longer by that height, and what stands in it is not what is in the pipe: **offset = $g \times \Delta h \times (\rho_{\text{line}} - \rho_{\text{process}})$** .

Two worked cases, both on **D and D/2 tappings on a DN 200 run, so $\Delta h = 300$ mm**. On water at 80 °C in the pipe against impulse lines at 25 °C — 971.8 against 997.0 kg/m³ — the term is 0.074 kPa, which set against Table 2 is not worth an argument. Put saturated steam at 10 bar absolute in the same run, 5.15 kg/m³ against condensate at 20 °C at 998.2 kg/m³ in the lines, and the same 300 mm is worth 2.92 kPa: read against the 25 kPa reference range of Table 2, an error of 52 % of the true flow at 30 % of full scale.

Change only the tapping arrangement and the magnitude changes with it. Flange tappings on that same steam run separate the tappings by 50.8 mm plus the plate thickness — 53.8 mm with a 3 mm plate — and the identical process condition is then worth 0.52 kPa, about one fifth. It is the tapping arrangement, not the phase, that sets the size of this term, so carry the 2.92 kPa figure onto a drawing only where the drawing says D and D/2.

On steam and other condensing vapours the term can be built out. ISO 2186 gives two installations for a vertical run (6.4). In the first, the line from the lower tapping is formed upwards to the height of the upper tapping before both turn down to the transmitter, so the condensate stands to the same level in both lines and no correction is needed (6.4.2). In the second, both lines leave the pipe horizontally and turn down, and the difference in height is taken out of the zero, electrically (6.4.3). On liquid there is no such choice: both lines are full of liquid along their whole length, and the term stays.

Where the term stays, the vertical rule is procedural rather than geometric. **With the process line full, no flow, and the manifold equalizer valve closed, the transmitter reads the elevation term alone: measure it, record it, trim it out of the zero.** Its sign follows the flow direction, because that decides which tapping is the high-pressure one: with upward flow the upper tapping is the downstream, low-pressure one and the meter reads low; with downward flow it is the high-pressure one and the meter reads high.

The trim holds only at the density it was taken at, and how strong that condition is depends on the service. On saturated steam it is weak, so a recorded fixed trim is adequate: the condensate in the lines is about two hundred times denser than the steam, and dropping the run from 10 bar to 6 bar absolute moves the term from 2.9226 to 2.9284 kPa — 5.8 Pa, 0.2 % of the term. What moves it on steam is the temperature of the impulse lines, not the pressure of the steam. Where the process density is a material fraction of the line density and swings, the trim stops holding: on a water run whose process temperature moves between 80 °C and 150 °C — 971.8 to 917.0 kg/m³ against lines at 25 °C — the same 300 mm moves from 0.074 to 0.235 kPa, which at 30 % of full scale is the difference between a 1.6 % and a 5.1 % flow error. There the term belongs in the flow computer as a calculated correction rather than in the transmitter as a fixed zero. Take the tapping point on an upward-flowing run where the piping gives the choice: a run carrying liquid downwards can go slack unless the back pressure keeps it full, and ISO 5167 applies to conduits running full.

6. What to do with this

At layout stage one question decides the subject: at what clock position will each tapping sit, and does the transmitter go above or below? Ask it before the pipe is routed, and on a dual chamber fitting before the body is set in the line, whether it is welded or bolted. Both answers belong on the general arrangement drawing issued for approval.

On a dual chamber fitting the clock position comes with the body. The tappings are integral to it, so their angle is a property of the body as built rather than something the piping designer selects, and the body's orientation is constrained as well by the carrier travel and the clearance above it. Inkotek drills two pairs of tappings as standard, one pair each side of the body at the horizontal centreline, 90° from top dead centre; where three or four pairs are ordered, the extra pairs sit 30° below the centreline, 120° from top dead centre. The side tappings are on the centreline, the position Table 1 gives for all three services; the lower pairs fall inside the liquid limit but outside the gas and steam positions. On gas the impulse line rule of Section 2 is unchanged: the lines rise continuously to a transmitter above the tappings. Where the gas can condense in the lines, Inkotek recommends an external condensate chamber on each impulse line in addition. What layout still chooses is which side the transmitter sits on and at what elevation.

On an operating line, a walkdown in five steps.

1. Record the line orientation and the clock position of both tappings — the angle from top dead centre as a number, not "top" or "side". Record from the plate records whether the plate carries a drain or a vent hole, and at what clock position.
2. Compare against Table 1 for the phase actually in the line at the tapping point, not the phase on the datasheet. A gas line downstream of a cooler may be running wet.
3. Check the transmitter elevation against the phase, then each impulse line for a continuous 1:10 slope in one direction, with a level held along the run and the reference point taken from Section 2 for that phase. Look for a sag, a loop or a line carried over an obstruction.

4. Check the symmetry items of Section 2, line against line. On steam, measure the elevation of both chamber centres rather than judging by eye, and confirm both lines were filled before the zero was taken.
5. With the process line shut in and no flow, both root valves open and the manifold equalizer valve **closed**, record what the transmitter shows. That is the static head difference between the two impulse lines, and Table 2 converts it into the flow error it implies at minimum flow. Then close the high-pressure block valve at the manifold and open the equalizer valve: the reading should fall to zero, and what is left there is the transmitter's own zero rather than a standing column. Close the equalizer and reopen the block valve before going on. Finally vent, drain and refill both impulse lines and repeat the equalizer-closed reading — a value that changes with the fill is a standing column, one that does not is a manifold or transmitter matter.

Where the position is wrong and the line cannot be opened, fit the vent or drain at the unavoidable high or low point, trend the equalizer-closed zero, and put the position on the work list for the next opening with the target angle from Table 1. What does not help is re-ranging: a fixed offset is a larger fraction of a smaller range, so a lower full-scale differential pressure makes this error worse, and a higher one costs permanent pressure loss for the life of the meter.

Heat trace and insulation set points for the impulse lines are fixed for each project: they depend on the site minimum ambient temperature and the freezing point of the fluid standing in the lines, and both belong to the project rather than to the element.

SOURCES AND STANDARDS REFERENCED

ISO 5167-1 and ISO 5167-2, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full* · ISO 2186:2007, *Fluid flow in closed conduits — Connections for pressure signal transmissions between primary and secondary elements* · ISO/TR 9464, *Guidelines for the use of ISO 5167* · API MPMS Chapter 14.3, Part 2 / AGA Report No. 3, *Orifice Metering of Natural Gas and Other Related Hydrocarbon Fluids — Part 2: Specification and Installation Requirements* · IAPWS-IF97 for the water and steam densities used in Sections 3 and 5 · ISO 12213 and AGA Report No. 8 for natural gas density · İnkotek Enerji, White Paper 01, *The Silent Drift*, Section 4 and Table 4 · White Paper 02, *The Meter That Bills You Every Hour*, Section 4.

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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Worked examples are calculated from published standards and standard fluid property data; they are illustrative and do not replace an installation-specific calculation. The tapping positions in Table 1 are those of ISO 2186:2007, Clause 5, and clause numbers in brackets refer to that edition; they are not a requirement of ISO 5167-2 or of API MPMS Chapter 14.3, Part 2. The 1:10 slope, the transmitter positions and the matched condensate chambers are İnkotek installation practice within ISO 2186. Read the current edition of every standard cited. © 2026 İnkotek Enerji Sanayi ve Ticaret Ltd. Şti. · TN-01 Rev 02 · 28 September 2026