

FOR INSTRUMENT AND PROCESS ENGINEERS

Reading a plate that was installed backwards

What a reversed plate does to the indicated flow, how to recognise it from trend data alone, and the tag orientation convention that prevents it

A reversed orifice plate is one of the very few metering defects that a maintenance activity creates, that produces a double-digit error, and that leaves no symptom other than the number itself. It does not alarm. It does not move the zero. It does not add noise. It does not break the square-root relationship between differential pressure and flow. Every check that can be made without opening the line will pass, and the meter goes on reading low for as long as the plate stays in that orientation.

That makes it a documentation defect rather than an instrumentation defect: the error is decided in the two minutes before a joint is closed, and it is then invisible for months. This note gives the size and the sign of the error, three trend tests that identify it without opening the line, the marking convention that prevents it, and the installation check list that closes it out.

1. Why a reversed plate reads low, and always low

The measuring feature of an orifice plate is the sharp square edge on the upstream face, together with the land of thickness e behind it. ISO 5167-2 puts e between $0.005D$ and $0.02D$, and the plate thickness E between e and $0.05D$. Where E exceeds e — that is the criterion, not the line size — the downstream side is bevelled at $45^\circ \pm 15^\circ$ to restore the land. The bevel is a manufacturing necessity, not a measuring feature: as WHITE PAPER 01, Table 2 puts it, the land thickness, not the bevel, is the measuring feature. The discharge coefficient of ISO 5167-2 and of AGA Report No. 3 / API MPMS 14.3 is the coefficient of that geometry and of nothing else; the geometry itself is specified in ISO 5167-2 and in API MPMS 14.3.2 / AGA Report No. 3 Part 2.

Turn the plate round and the approaching flow meets the chamfer instead of the square edge. A chamfered inlet contracts the jet less than a sharp one, so the effective discharge coefficient rises and the plate produces less differential pressure at the same true flow. The flow computer still holds the coefficient of a square-edged plate, so it returns a number that is too small.

Two properties of that error matter more than its size. **The sign is fixed:** for a concentric bevelled plate, reversal can only under-read, and unlike deposits, which bias either way, a reversed plate never reads high. **And it is a scale error, not an offset:** the bias is very nearly a constant percentage over the range in which the discharge coefficient of a compliant plate is itself flat, and within that range no operating point reads correctly. Below that range the bias moves with Reynolds number, because the chamfered inlet a reversed plate presents does not share the coefficient-against-Reynolds characteristic of the square edge the flow computer assumes; how far it moves there is not established by published data.

QUANTITY	WHAT A REVERSED CONCENTRIC PLATE DOES TO IT	BASIS
Indicated volumetric or mass flow	12 to 15 % low	WHITE PAPER 01, Table 1, compiled from published orifice-meter troubleshooting literature
Differential pressure at the same true flow	23 to 28 % low	From the row above: flow varies with the square root of Δp , so the Δp ratio is $(1 - \text{error})^2$; $0.88^2 = 0.774$ and $0.85^2 = 0.723$

QUANTITY	WHAT A REVERSED CONCENTRIC PLATE DOES TO IT	BASIS
Direction of the bias	Low, at every flow	Mechanism above; WHITE PAPER 01, Table 1, gives the direction as low
Behaviour across the range	Constant percentage where the compliant coefficient is flat; not established by published data below that	A scale error on the coefficient, not a head error
Δp at a reference flow the process holds	Steps 23 to 28 % low on the date of the plate handling	Second row read as a step; the reference flow must be fixed independently of this meter — see Test 2

Table 1 — What a reversed concentric orifice plate does to the measurement. The first two rows are the numbers to test against; the last is the one that can be read from plant records, and only where the reference flow is held by the process rather than taken from the meter under test.

THE SIZE OF THE NUMBER

On the reference stream of WHITE PAPER 01 — natural gas at 10.55 kWh/Nm³ gross calorific value and €35/MWh, where 100 million Nm³ a year is worth about €36.9 million and a 1 % bias about €370,000 a year — a plate reading 12 to 15 % low on a stream **metered** at 100 million Nm³ a year leaves 14 to 18 % of the billed quantity unbilled: **€5.0 to €6.5 million a year**. The seller under-bills and the buyer under-recovers, from the day the joint was closed.

WHAT THE BAND IS NOT

A reversed plate is a non-conforming installation. ISO 5167-2 and API MPMS 14.3 state a discharge-coefficient uncertainty — 0.50 % at $\beta = 0.50$ and 0.75 % at $\beta = 0.75$, per WHITE PAPER 02, Table 4 — only for a plate that meets every geometric and installation requirement, and neither gives a correction for this condition. The 12 to 15 % band is a diagnostic expectation, not a correction factor: the quantity for the affected period is settled by re-verification and the contract's mismeasurement clause, not by applying the band to past invoices.

Three limits on Table 1 are stated rather than glossed over. None is a value to estimate on the way into a purchase decision.

- An unbevelled plate is geometrically almost symmetrical, and reversing it biases the reading far less — but not by nothing, because only the upstream edge is manufactured and verified as the measuring edge and the opposite edge carries the exit burr. Its magnitude is not established by published data: it needs calibration data for square-edged plates tested both ways round, or one plate calibrated both ways in a flow facility. This is the second of the three cases in WHITE PAPER 04, Section 5, where flow calibration is the right answer — the geometry is not a standard one.
- For eccentric and segmental bores the concentric range does not apply and must not be borrowed: the bore sits against the pipe wall, and its relationship to the tappings changes the case. Its magnitude is not established by published data, and would differ by bore type and tapping position.
- The 12 to 15 % band carries no β or Reynolds number scope. Its dependence on β is not established by published data, and would come from calibration data rather than a correlation.

2. Every check that does not open the line will pass

A reversed plate survives a transmitter calibration, because the transmitter converts pressure to signal correctly; an as-found and as-left verification of the flow computer against a pressure calibrator, for the same reason; a zero check with the line shut in and the transmitter manifold's equalising valve open, because both legs are unaffected; venting and draining both legs at the manifold, because nothing is wrong with the legs; a check of the static-pressure and temperature inputs and of the compensation; and a check of the shape of the relationship between differential pressure and flow, because the shape is undisturbed.

A comparison against an independent meter gives the size of the bias but not its cause: a worn edge, a wrong bore, a stale coefficient in the flow computer and a reversed plate look identical in a single-point comparison. The only physical confirmation is withdrawal and inspection. On a dual chamber fitting that is the 20 to 40 minutes WHITE PAPER 03, Table 1 gives for a plate change under line pressure, following the seven-step sequence of WHITE PAPER 03, Section 2: equalizer valve opened first; the two opposing spring-loaded latches released by hand; the rotary valve opened; the carrier raised and confirmed fully above the rotary valve before that valve is closed to its closed limit with both latches engaged; the equalizer valve closed after it; the upper chamber vented to the approved safe location; and a verified zero at the upper-chamber gauge before the top seal block is loosened. No lubrication step is required at any point and none is to be introduced. On an orifice flange union the same confirmation waits for a shutdown, which is why the trend evidence below carries more weight there.

3. Recognising it from trend data alone

Three tests, in this order, all on data the plant already records.

Test 1 — the step at a known handling date. Take the plate-handling date from the tag history rather than the work orders. Extract indicated flow and differential pressure for a comparable period either side of it — two weeks where the data exist — filtered to matched conditions: same static pressure, same temperature, same independent indicator of load. Compute the ratio of the after-mean to the before-mean. A reversed concentric plate gives about 0.85 to 0.88 in flow and 0.72 to 0.77 in differential pressure, arriving as a step on the handling date. Erosion arrives as a ramp over months.

Test 2 — the reference differential pressure. This test works only against a reference flow the process holds and that is not read from the meter under test: a single compressor at full load, a fixed valve position, one pump at fixed speed, a tank level change over a timed period, or a second meter. At the same *indicated* flow the differential pressure does not move at all — the flow computer inverts the same square root the plate has shifted, and the error cancels out of the comparison. At the same *true* flow, a fall of 23 to 28 % is the signature. Where that number has never been recorded against the tag, Section 5 item 13 starts recording it.

Test 3 — multiplicative or additive. Plot indicated flow against an independent estimate — a second meter, a tank gauge, a heat-and-mass balance, a positive-displacement total — at three or more separated loads, and look at the ratio rather than the difference. A ratio constant across the loads is a coefficient or geometry error, and a reversed plate belongs to that family. A ratio that moves away from unity as flow falls, in either direction, is a static head error in the impulse legs: the Δp offset is constant, so it becomes a larger fraction of a falling Δp , and a positive leg imbalance drives the ratio above unity while a negative one drives it below. One caution: a ratio that is not constant does not by itself exclude a reversed plate at low Reynolds number, so check the Reynolds number at each load before using this test to clear the plate.

Trend data carries the diagnosis only as far as a multiplicative under-read that began on a known date. Naming the plate as the cause needs the exclusion list below, and then the plate.

CAUSE OF A CLEAN MULTIPLICATIVE STEP	HOW IT DIFFERS IN THE TREND	WHERE TO LOOK FIRST
Reversed plate	Flow step 12 to 15 % low, Δp step 23 to 28 % low at the same true flow, on a plate-handling date; ratio constant across loads	Tag history, then the plate
Transmitter re-ranged or respanned	The same multiplicative signature — the most common innocent explanation	Transmitter configuration change log, date for date
Bore, β or coefficient edited in the flow computer	Flow steps with no change in Δp at all	Flow computer audit trail
A different plate fitted in error	Multiplicative step of a size computable from the two bores, not confined to 12 to 15 %	Plate serial against the tag; store records

CAUSE OF A CLEAN
MULTIPLICATIVE STEP

HOW IT DIFFERS IN THE TREND

WHERE TO LOOK FIRST

Plate fitted off-centre	Multiplicative step, size set by the eccentricity, for which ISO 5167-2 gives a tolerance	Plate and carrier seating
Gasket intruding into the bore or across a tapping	Multiplicative step; may also disturb one tapping alone	Withdrawal and inspection
Unequal wet legs or leg imbalance	Ratio departs from unity as flow falls; not constant across loads	Leg slope, elevation, temperature; WHITE PAPER 01, Table 4, which gives no magnitude

Table 2 — Separating a reversed plate from the causes that share its multiplicative signature. The first three rows share that signature almost exactly, so the configuration history is cleared before any joint is opened; the off-centre plate and the intruding gasket are quantities ISO 5167 and API MPMS 14.3 specify, as WHITE PAPER 01, Section 3 notes. Defects with a different shape — a worn edge, deposits, a buckled plate, a deposit film — carry published magnitudes in WHITE PAPER 01, Table 1, and are not repeated here.

4. The marking convention that prevents it

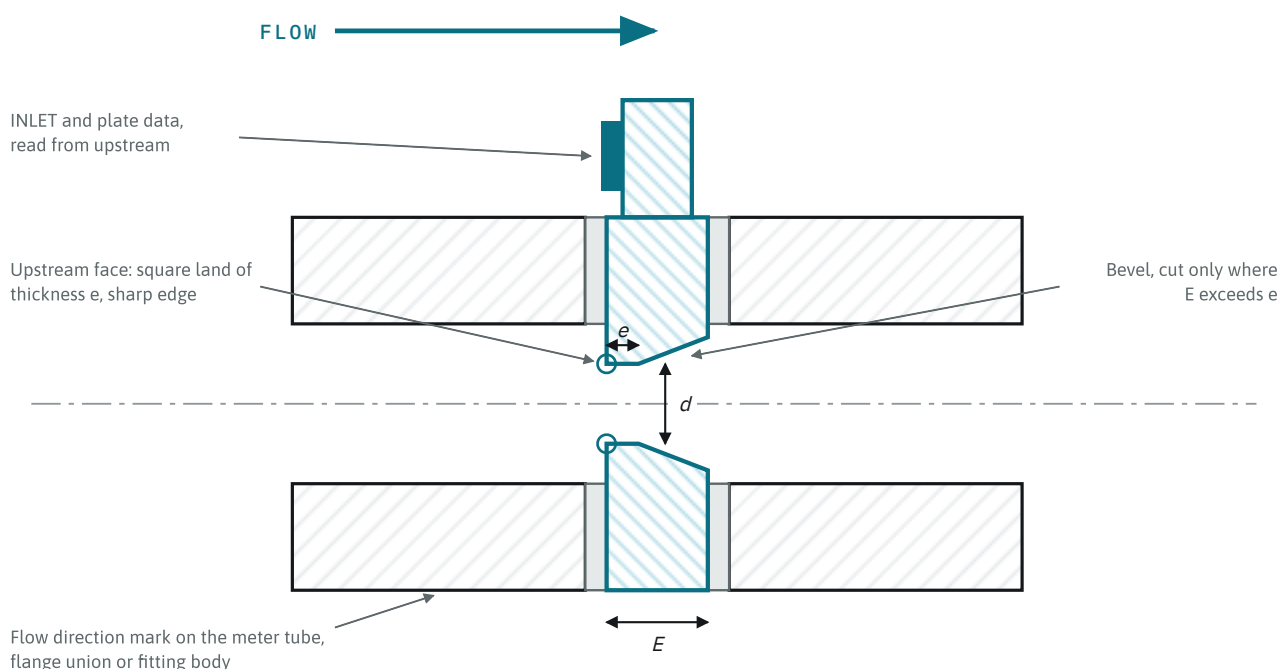


Figure 1 — Orientation of a paddle-type plate in an orifice flange union. INLET and the plate data are marked on the upstream face of the tab handle and read from upstream. The square land of thickness e carries the sharp edge that does the measuring, and the bevel is cut only where E exceeds e . Symbols only, not to scale: the plate thickness is exaggerated so that the land and the bevel can be seen, and the bevel angle is given in Section 1.

MARK

WHERE IT SITS

CORRECT READING WITH THE PLATE THE RIGHT WAY ROUND

The bevel, where E exceeds e	On the plate bore	Opens towards the downstream side; the square land takes the flow
The plate marking	On the upstream face of the tab handle	INLET, read from upstream. İnkotek plates are marked with INLET, tag number, serial, job number, bore and β on the upstream face; a flange union plate carries the rating as well

MARK	WHERE IT SITS	CORRECT READING WITH THE PLATE THE RIGHT WAY ROUND
The flow direction mark on the plate	On the tab handle or the plate edge	Agrees with the flow direction as confirmed from the process
The flow direction mark on the body	On the meter tube, the flange union or the fitting body	Agrees with the flow direction as confirmed from the process, not from the paint. Inkotek fitting bodies carry tag number, serial, job number, bore and flow direction

Table 3 — The four marks that must agree. Two marks agreeing is not a check: all four are read wherever all four exist, and any disagreement stops the job until it is resolved on the drawing rather than at the flange.

THE ONE-LINE RULE

INLET faces the flow. Standing upstream of the plate, you read INLET on the tab; if you cannot, the plate is the wrong way round.

Three notes on the convention. The word and its position say the same thing: INLET is marked on the face that meets the flow, so the legend cannot be read as naming the other side, and the rule is the one WHITE PAPER 01 states — the bevel faces downstream and the INLET marking faces upstream. Next, this is a marking convention, not a requirement of ISO 5167-2, which specifies the plate geometry but not which face carries the marking: where a plant operates its own convention, that convention governs and belongs on the approved drawing, and two conventions in one metering station is a defect in its own right. Last, an unbevelled plate has one mark fewer, so the INLET marking and the flow direction mark carry the whole check.

Plates without a tab handle. Inkotek fittings use a handle-free plate format across single and dual chamber bodies, held in a carrier matched to the fitting bore, so the two plate marks cannot sit on a tab. The body mark is unaffected. The plate marks move onto the plate itself, as they do on a flow conditioner plate, where the marking goes on the plate edge or the tab. The convention does not change: Inkotek marks INLET and the plate data on the upstream face of a carrier plate as it does on a tab, at the position shown on the approved drawing. Neither does the requirement: the fitter loading the carrier names the upstream face from the INLET mark on the plate, and signs for it, before the carrier goes down.

5. Installation check list

1. Before the plate leaves the store, read the plate marking against the datasheet and the calculation sheet: tag, serial, job number, bore d , β , and rating where marked. A plate that does not match its paperwork is not installed while the question is open.
2. Check what the marking does not carry — outside diameter, D , plate thickness, material — against the datasheet and the material certificate.
3. Confirm the plate's inspection record covers upstream edge radius not greater than $0.0004 d$, flatness gap under a straightedge below $0.005 (D - d)/2$, upstream face roughness R_a below $10^{-4} d$, and bore roundness and concentricity, per ISO 5167-2 and WHITE PAPER 01, Table 2. None of the four can be judged by eye.
4. Confirm the actual flow direction from the process, not from the mark on the pipe, and record how it was confirmed.
5. Confirm the bevel side: square land upstream, bevel downstream.
6. Confirm the INLET marking will face upstream once the plate is in — on the tab, or on the face of a handle-free carrier plate.
7. Confirm the tab will project clear of the flange and stay readable after bolt-up. A tab trapped between flange faces removes the only mark that survives commissioning.

8. Where the plate has a drain or vent hole, confirm its position and its declaration: a drain hole at the bottom of the bore on gas service that may carry condensate, a vent hole at the top on liquid service that may carry gas; not in the plane of the pressure tapplings; one hole only; a diameter small enough for the flow through it to be negligible, to the limit ISO 5167-2 sets; declared on the datasheet and on the calculation sheet.
9. Fit new gaskets, and confirm no gasket intrudes into the bore or across a tapping.
10. Bolt up to the documented procedure, and do not hammer the plate into position. Any plate that has been dropped, hammered out of or into a flange, wire-brushed, grit-blasted, cleaned with an abrasive disc, or exposed to a differential pressure excursion is a suspect plate in the terms of WHITE PAPER 01, and is replaced rather than argued about.
11. **Have a second person verify the bevel direction and the marked face before the flange is closed or the carrier goes down, and sign for it.** This is the step that prevents the error. A single-person check does not, because the person who has just decided which way round the plate goes is the worst available reviewer of that decision.
12. Photograph the plate in the open flange, or in the carrier, with the plate marking and the flow direction visible, and log the photograph against the tag rather than the work order. Work orders are closed and forgotten; tag histories set inspection intervals and settle disputes.
13. After start-up, record the differential pressure at the first reference flow the process can hold independently of this meter, and compare it with the value recorded before the plate was changed. A step outside a few percent is investigated before the meter is handed back.

6. What to write into the work instruction

WHITE PAPER 03 already carries the re-entry line, quoted here rather than rewritten:

Confirm the plate tab orientation and bevel direction on re-entry — sharp bore edge upstream, bevel downstream.

This note adds two lines: a second signature before the joint is closed, and a number recorded against a reference flow the process holds.

Have a second person confirm and sign the bevel direction and the marked face of the plate before the flange is closed or the carrier goes down.

Record the differential pressure at a reference flow held by the process and not read from this meter, before the plate is removed and again after the replacement is fitted, and log both against the tag.

Those two lines cost a minute each. Section 1 prices the alternative.

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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Error magnitudes are taken from İnkotek Enerji WHITE PAPER 01, The Silent Drift, Table 1, where they are compiled from published orifice-meter troubleshooting literature; the differential-pressure figures are derived from them by the square-root relationship between flow and Δp . Discharge-coefficient uncertainties are from WHITE PAPER 02, Table 4. Geometric requirements are those of ISO 5167-2 and API MPMS 14.3.2 / AGA Report No. 3 Part 2. Gas valued at 10.55 kWh/Nm³ and €35/MWh. Figures are illustrative and do not replace a site-specific calculation. © 2026 İnkotek Enerji Sanayi ve Ticaret Ltd. Şti. · TN-06 Rev 03 · 3 October 2026