BRITISH STANDARD

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Fluid flow in closed conduits — Connections for pressure signal transmissions between primary and secondary elements

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British Standards

National foreword

This British Standard was published by BSI. It is the UK implementation of ISO 2186:2007.

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A list of organizations represented on this committee can be obtained on request to its secretary.

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INTERNATIONAL STANDARD

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Fluid flow in closed conduits — Connections for pressure signal transmissions between primary and secondary elements

Débit des fluides dans les conduites fermées — Liaisons pour la transmission du signal de pression entre les éléments primaires et secondaires

Reference number
ISO 2186:2007(E)

Contents

Page

Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 2186 was prepared by Technical Committee ISO/TC 30, *Measurement of fluid flow in closed conduits*, Subcommittee SC 2, *Pressure differential devices*.

This second edition cancels and replaces the first edition (ISO 2186:1973), which has been technically revised.

Introduction

The primary devices are flow meters described in ISO 5167 (all parts).

A secondary device in this context receives a differential pressure signal from a primary device and can display the differential pressure value and convert it into a signal of a different nature, i.e. an analogue or digital signal, to transmit the value of the differential pressure to another location.

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Fluid flow in closed conduits — Connections for pressure signal transmissions between primary and secondary elements

1 Scope

This International Standard sets out provisions for the design, lay-out and installation of a pressure signal transmission system, whereby a pressure signal from a primary fluid flow device can be transmitted by known techniques to a secondary device safely and in such a way that the value of the signal is not distorted or modified.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4006, *Measurement of fluid flow in closed conduits — Vocabulary and symbols*

ISO 5167-1:2003, *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, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 2: Orifice plates*

ISO 5167-3, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 3: Nozzles and Venturi nozzles*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4006 and ISO 5167-1 and the following apply.

3.1
secondary device
device which receives a differential pressure signal from a primary device, may display the differential pressure value and may convert it into a signal of a different nature, i.e. an analogue or digital signal, to transmit the value of the differential pressure to another location

4 General principles

4.1 Safe containment

The differential pressure signal shall be transmitted in a safe manner within a pipe or tubing to the secondary device. This requires that the fluid between the primary and secondary device be safely contained. Safe containment of the fluid requires conformity to the applicable standards and codes and requires the selection of the proper materials of construction, the fabrication methods and practices and any required gaskets and sealing materials. For on-line maintenance or verification, design shall cover safe means for proof of isolation, depressurization, flushing and removal/replacement of secondary instrumentation.

4.2 Piping specification

The pipe or tubing installed between the primary and secondary device should comply with applicable national standards and codes of practice.

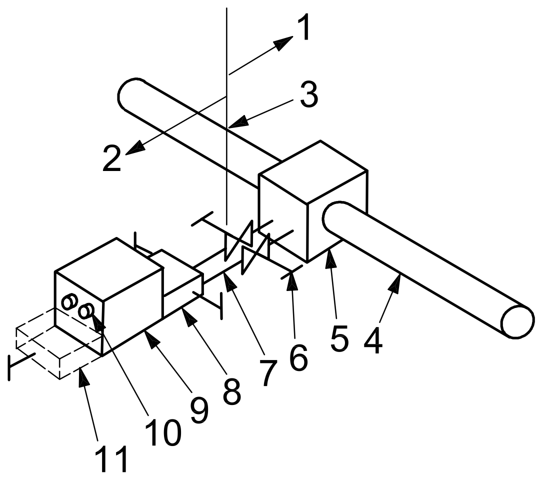
NOTE 1 National regulations can also apply.

A process-piping specification should include the specification for the isolation valve (or block valve) closest to the primary device. The specification for the piping or tubing between this isolation valve and the secondary device, including any additional valves in this piping, may differ from the piping specification for the isolation valve. This is because the small size, and often the more limited temperatures involved on the instrument secondary piping, justifies these differences.

The break (change) in piping specification between the process and the instrument (or secondary) side is normally at the process isolation valve on its secondary connection end (see Figure 1). If the process-piping specification requires flanged connections, then the process end of the isolation valve is flanged and the mating flange on the secondary side is an instrument connection or may have another approved fitting.

NOTE 2 An approved hydrostatic test can be required for piping systems to prove the integrity of the pressure-containing parts of the piping system.

NOTE 3 Some installations require provision for “rodding out” of the process connections. This is the use of a rod or other physical device to remove materials blocking the free flow of fluid in the impulse lines. Safety precautions apply.



Key

1 primary side
2 secondary side
3 specification break, where the piping specifications change between secondary and primary
4 conduit running full
5 primary head creating device
6 isolation valves
7 impulse line connecting pipe
8 manifold
9 secondary device
10 bleed valves, typical
11 alternative location of equalization valve

Figure 1 — Primary and secondary at same elevation, preferred installation

4.3 Isolation (block) valves

Isolation (block) valves are required to separate the entire measurement system from the main pipeline, when necessary, but they should not affect the pressure signal.

It is recommended that isolating valves should be located immediately following the pressure tappings of the primary element. If condensation chambers are installed, isolation valves may also be fitted immediately following the condensation chambers. However, if condensation chambers are used, it is important to check that they are emptied regularly and that they do not become a source of leaks due to corrosion.

When specifying an isolation valve, practical considerations include the following.

a) The valve shall be rated for the pipe design pressure and temperature.

b) There shall be a careful choice of both valve and packing, particularly in the case of dangerous or corrosive fluids and with gases such as oxygen.

c) Valves shall be chosen that do not affect the transmission of a pressure signal, particularly when that signal is subject to any degree of fluctuation.

Ball valves or gate valves should be used where possible, as globe-style block valves can create a pocket of gas or liquid if they are installed with the valve stem in the vertical plane.

NOTE This pocket can result in a distortion of the pressure difference, which can result in an error in the indicated measurement. Installation with the valve stem at an angle of 90° from the vertical normally solves this problem.

4.4 Valve manifolds

Valves are often installed to permit operation, calibration and troubleshooting of the secondary device without removing it. Some typical valve manifold configurations are shown in Figure 2.

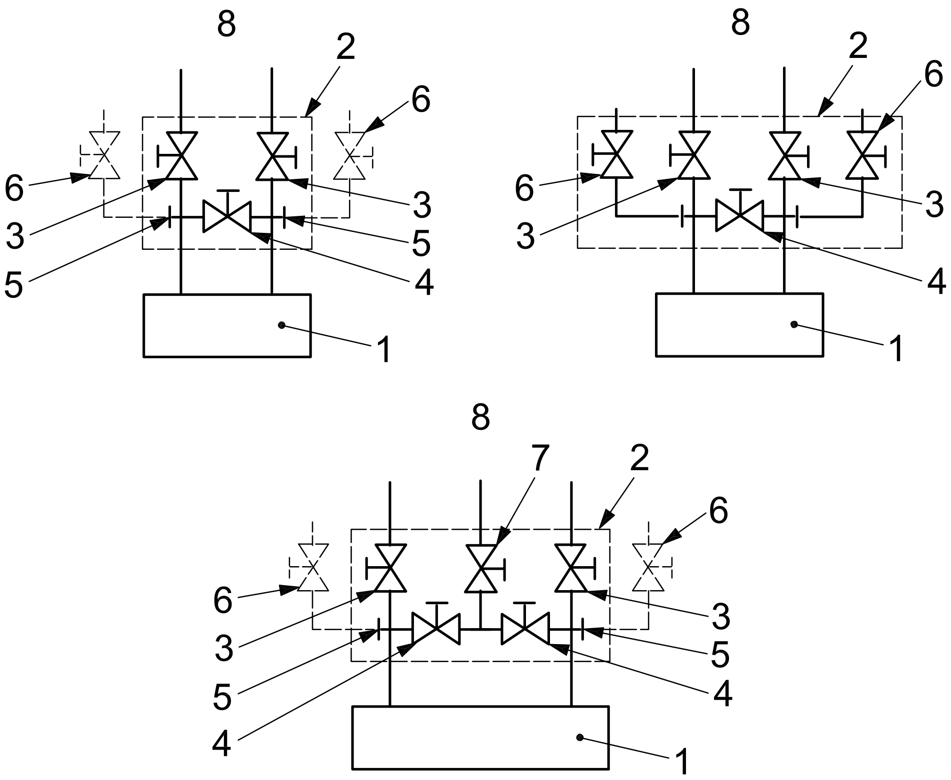
These valves are used

a) to isolate the secondary device from the impulse lines;

b) to open a path between the high and low pressure sides of the secondary device. The secondary device zero (no flow signal) can be adjusted at operating pressure with one block valve closed and the bypass valve(s) open;

c) to drain or vent the secondary device and/or the impulse piping to the drain or to atmosphere.

Manufactured valve manifolds can reduce cost and save space. Valve manifolds integrate the required valves and connections into one assembly. Valve manifolds shall be installed in the orientation specified by the manufacturer to avoid possible errors caused by trapped pockets of gas or liquid in the body.



Key

1 secondary instrument
2 manifold block
3 block valve
4 equalizer valve
5 vent, drain and calibration plug
6 vent, drain and calibration valve (optional if dashed)
7 vent, drain and calibration valve
8 process side

Figure 2 — Typical manifold configurations

4.5 Installation

The installation design should minimize the separation between the primary and secondary devices. The connecting piping is variously referred to as “impulse lines”, “gauge lines”, “instrument tubing” or “instrument piping”.

The detailed design for the installation of the flow meter secondary system should consider instrument troubleshooting and calibration. To accurately convey the pressure difference, the instrument lines shall be as short and direct as possible and the two lines should be the same length.

NOTE 1 For circumstances where the instrument lines are necessarily long, guidance on the preferred line diameter is given in Annex A. See additionally 4.7.1, 4.7.2 and 4.7.3.

Access to the impulse lines, the valves, the valve manifold and the secondary device is required to enable maintenance and calibration. Installations providing this access shall not increase measurement uncertainties by being excessively long with excessive fittings.

Any difference in elevation between the primary device pressure taps and the secondary device results in a pressure difference between the two ends of the impulse lines due to the hydrostatic pressure of the fluid column in the impulse lines.

NOTE 2 This effect is usually greater for liquids than for gases.

The impulse lines shall be installed in such a way that the hydrostatic pressure in the two impulse lines is identical. If the fluids in the two lines are not identical in density, a difference in pressure is generated. Density differences arise when there is a temperature difference between the fluids in the two impulse lines. It is recommended that, if possible, the two impulse lines be fastened and insulated together, when it is required to avoid significant temperature differences between them.

NOTE 3 Non-identical fluids in the two impulse lines can also give rise to density differences.

The impulse lines shall be installed so that the slope is in one direction only (upward or downward depending on the fluid; see Clauses 5 and 6. If a change to the slope direction is unavoidable, then only one such change shall be made. In this case, a liquid trap shall be installed at the lowest point in gas service and a gas trap shall be installed at the highest point in liquid service.

Where possible, the impulse lines should be “bled” or “vented” after installation to clear the impulse lines of fluids left during construction or after hydrostatic testing or cleaning. Bleed valves may be included in the valve manifolds or in the secondary device body, or installed as needed.

NOTE 4 Periodic bleeding can be required if the characteristics of the fluids in the impulse lines change over time with fluid ageing and with diffusion or leakage into or out of the impulse lines.

It is good practice to design the installation to allow for natural draining of liquids or venting of gases.

Errors caused by tap-elevation differences and pressure and temperature effects on the secondary device are reduced if the zero flow indication and transmission secondary instrument signal output is adjusted while the system is at the operating pressure and temperature and there is no flow through the system.

NOTE 5 Depending on the installation and materials used, non-flowing fluid in the piping can exchange sufficient heat to the environment to change the temperature up to tens of degrees Celsius towards ambient over a distance of hundreds of millimetres and hundreds of degrees Celsius over a distance of a metre.

4.6 Pressure taps

The pressure tap is part of the primary device. The requirements for the pressure tap (hole size, orientation, etc.) found in ISO 5167-1:2003, 5.4.3, which also makes cross reference to ISO 5167-2 (orifice plates), ISO 5167-3 (nozzles) and ISO 5167-4 (Venturi tubes), shall be used.

NOTE In very dirty services, diaphragm seals mounted flush with the internal surface of the pipe have sometimes been used. To ensure measurement sensitivity, diaphragms are typically a nominal 80 mm or 100 mm in diameter. These diaphragm seals are not within the scope of ISO 5167 (all parts).

4.7 Impulse line size

4.7.1 General

The required diameter of the impulse line depends on the service conditions. Lines having an internal diameter less than 6 mm do not easily allow gas bubbles to flow up and out of a liquid system, nor allow liquid drops to flow down. In smaller impulse-line sizes and with liquids, capillary effects can become significant. If condensation is likely to occur, or if gas bubbles are likely to be liberated from a liquid, the bore diameter shall be not less than 6 mm and should preferably be at least 10 mm. The internal diameter should not exceed 25 mm.

4.7.2 Process industries

In most process-control applications, the primary concern is reliability. If the pressure taps or the impulse lines plug, then the flow-rate information is lost. The automatic control system manipulates the controls and attempt to control the flow. This can result in a dangerous or expensive variation from the desired operating conditions. High reliability is required for flow signals used in the process safety management. A minimum internal diameter of 10 mm is recommended in industrial applications. For specific fluids and requirements, some users specify 18 mm as the minimum internal diameter. For high-temperature condensing-vapour service, 25 mm has been specified to aid in the flow of condensate. Large tubing diameters are not recommended for accurate measurements in clean fluids. In small piping and with clean fluids, smaller sizes may be used as appropriate and with proper care for draining and venting.

4.7.3 Research and special applications

See Annex B for a consideration of impulse-line dynamics. For special applications where fast dynamics are important and where fluids can be kept clean, special transducers with very small internal volumes are used. In this situation, it is necessary that the installation has been engineered to suit the application and then tested to ensure that the data collected are accurate and suitable for the application.

NOTE 1 Lines as small as 4 mm have been used.

The lines shall be short and carefully arranged. Testing and proving of special installations should be carried out.

NOTE 2 See also Annex C for an example calculation of the head created by a difference in elevation between the primary and secondary devices.

4.8 Insulation

Some hot or very cold lines require thermal insulation for personnel protection. It can also be necessary to insulate and "heat trace" the impulse lines to avoid freezing or unintended condensation. The amount of heat used shall be such as not to cause undesired vaporizing of liquids in liquid-filled lines or the prevention of condensation with condensable vapours. It is recommended to bundle the impulse lines together so that they are at approximately the same temperature.

5 Horizontal piping installations

5.1 Gases

Wall pressure taps on the primary device shall be on the horizontal centreline or up to the top of the pipe, unless the measured fluid is a vapour that is intended to condense in the secondary system (see 5.3). However, if the fluid is a "wet gas", i.e. a gas containing small quantities of liquids, the connecting lines from the point of breakthrough on the primary device to the point of entry to the secondary device shall slope upwards. The recommended slope for self-draining is a minimum of 8 %. See Clause 8 for special cases.

5.2 Liquids

Wall pressure taps shall be on the horizontal centreline. Taps below the centreline can accumulate solids, while taps above the centreline can accumulate air or non-condensing gases. In neither case should the taps be more than 45° to the horizontal plane. In liquid service, the connecting lines from the primary device shall slope downward to the secondary device with no upturns or pockets. The minimum recommended slope for self-venting is 8 %. See Clause 8 for special cases.

5.3 Condensing vapours, e.g. steam

The wall pressure taps shall be on the horizontal centreline of the primary device. In condensing hot-vapour service, such as steam, the fluid in the impulse lines is liquid condensed from the vapour. In this case, the wall pressure taps should be horizontal with the impulse lines sloping downwards to the secondary device; see Figure 3.

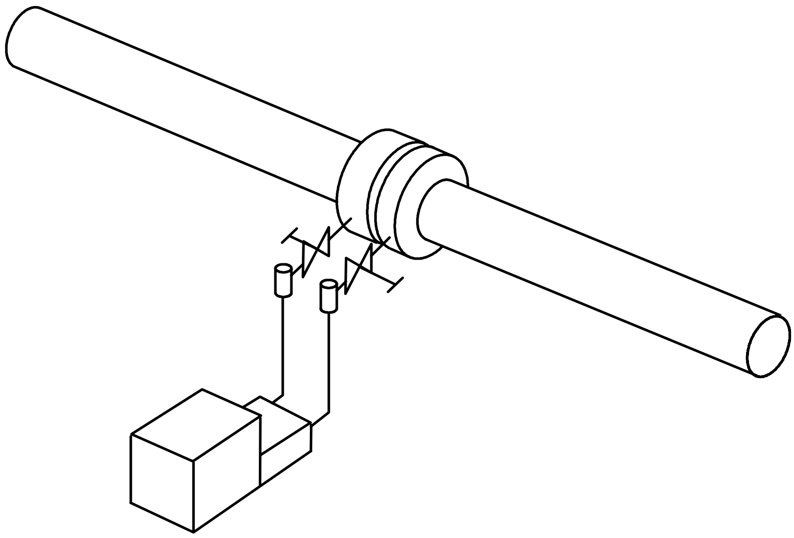


Figure 3 — Steam service, secondary below primary (with condensate pots, which may be installed, shown)

NOTE At start-up, the secondary device can be exposed to the vapour temperature before the lines fill with condensed liquid and cool. In this case, it is prudent to have a plugged Tee-fitting in the impulse line to enable the impulse line and secondary device to be filled with liquid (water for steam service) prior to start-up. Where possible, this problem can be mitigated by a careful start-up procedure, slowly filling the system and allowing sufficient time for pressure-transmitting lines to condense the vapours. See Clause 8 for special cases.

Equalizing manifold valves should not be operated with more than two valves open at the same time, as the resulting fluid circulation can exceed the temperature rating of valves and secondary instrumentation.

6 Vertical piping systems

6.1 General

In the case of vertical pipes, there are generally no problems as far as the radial position of pressure taps is concerned. Both taps should face in the same radial direction.

6.2 Gases

In dry, non-condensing gases, the connecting lines from the primary device shall slope upwards to the secondary device, as described in 5.1 above.

6.3 Liquids

For liquid service in horizontal lines, the piping shall be as described in 5.2 above.

6.4 Condensing vapours, e.g. steam

6.4.1 General

In condensing vapour service there are two choices for impulse-line design for flow in a vertical line. These are discussed in 6.4.2 and 6.4.3.

6.4.2 Equal impulse tubing height installation

The lower impulse line shall be formed upward before turning horizontal to become at the same height as the upper impulse line and then down to the secondary device. This provides an equal head of liquid in both vertical impulse lines leading to no requirement for a special calibration correction.

6.4.3 Calibration compensated installation

The two impulse lines shall leave the pipe horizontally and then turn down to the secondary device. The zero of the secondary device shall be adjusted to account for the difference in heights of the two impulse lines and the contained liquid. Zeroing should be done only electrically, as it is both simpler and safer.

7 Piezometer ring

The requirements and recommendations given in Clauses 5 and 6 shall apply to piezometer installations.

A piezometer ring may be used to physically average the pressures from the several pressure taps in the plane of the primary device. There can be a requirement to periodically vent or drain the ring.

8 Special cases

Any system to which the above requirements and recommendations cannot apply requires careful design and attention to details to avoid errors.

NOTE See Annex D for examples of special cases.

As an example, it is possible to install a primary element in a buried liquid line with the secondary device above it if any accumulated gases are removed from the impulse lines before they accumulate enough to depress the liquid level in the impulse lines (see Figure D.7). In condensable service, such as steam, orientation at the top of the pipe should be avoided to reduce the collection of non-condensable gas in the impulse tubing. Primary elements in gas service with the secondary mounted below the primary require provision for accumulation and removal of liquids before the liquids rise above the secondary device pressure taps (see Figure D.8). The same installation may be used in two-phase liquid service, but a close, coupled installation as illustrated in Figure 1 is preferred. This applies to single-phase operation but for situations where there is a risk of gas being present in the liquid (or liquid in the gas), Figures D.3 and D.4 are applicable. For condensing vapours with the secondary device above the primary, see Figure D.9. A clean fluid can be used to purge the system and to keep dirt out (see Figure D.10).

Pre-filled, physical barrier-diaphragm seals, called remote seals, or chemical seals are used in certain applications. Deflection of the diaphragm requires some small force, which it is essential to consider in the calibration process. Errors are reduced with larger diaphragms and good design. It is recommended that the impulse lines or capillary tubes to remote seals be of identical length and be arranged to reduce the exposure to different temperatures.

Cryogenic systems may require special designs not considered here. The liquids in the lines isolate the secondary device from the temperatures of the primary flowing fluid. The temperature difference can be considerable over a short distance of, for example, 100 mm to 200 mm.

Maintenance of special systems can be labour-intensive and require special care and knowledge. The recommended installations require less maintenance to ensure accurate measurement.

Annex A
(informative)

Guidance on pipe diameters for long impulse lines

It is always recommended that the shortest possible impulse-line lengths be used. Where it is not possible to conform with this, guidance on the preferred line diameter may be obtained from Table A.1.

Table A.1 — Internal diameter of pressure pipe (diameters in millimetres**)**

Type of metered fluid	**Pressure signal transmission distance** mm	
	0 m **to** $<$ 16 m	16 m **to** 45 m
Water/steam Dry air/gas	7 to 9	10
Wet air/wet gas [a]	13	13
Oils of low to medium viscosity	13	19
Very dirty fluids	25	25

[a] i.e. risk of condensation in pipes.

Annex B
(informative)

Impulse-line dynamics

The pipe or tubing between the primary element and the secondary device is a complex and imperfect dynamic-pressure transmission line.

At a constant pressure or with slow changes, the difference between the primary and the secondary devices are due only to elevation effects.

Compressible fluids inside impulse lines have acoustic resonant frequencies with standing waves and pressure maxima odd multiples of 1/4-wavelength apart.

Depending on the properties of the flowing fluid, the geometry of the pressure tap and the tube connecting the pressure transmitter, certain frequencies can be amplified in the lead line. Amplified pressure pulses can affect the secondary device. The magnitude of this effect varies with the type of secondary device, the geometry of the meter, flowing conditions, frequency response of the pressure transmitter, etc. Significant errors are reported with meters in reciprocating gas-compressor discharges when pressure pulsation is in excess of 10 % of the static pressure.

The problems are minimized with the use of short and direct pressure-transmitting lines of constant inside diameter and with a minimum of extra fittings.

ISO/TR 3313[1] gives more details on pressure pulsation effects.

Annex C
(informative)

Elevation head example calculation

C.1 General

As shown in Clause C.2, a difference in elevation of 2,54 m between the primary and secondary element with a 10 °C temperature difference between the two water-filled tubes creates a pressure difference of 0,619 mbar. This error is independent of the secondary device calibration span or the actual flow. With a relatively small span, and at low flow rates, the error caused by the impulse line temperature difference can be substantial.

Errors due to liquids standing in gas-measurement impulse lines, or due to air in liquid meters, can be much larger.

C.2 Example calculation

The example is based on the following conditions:

a) elevation difference: 2,54 m;

b) service: water;

c) ambient temperature: 20 °C.

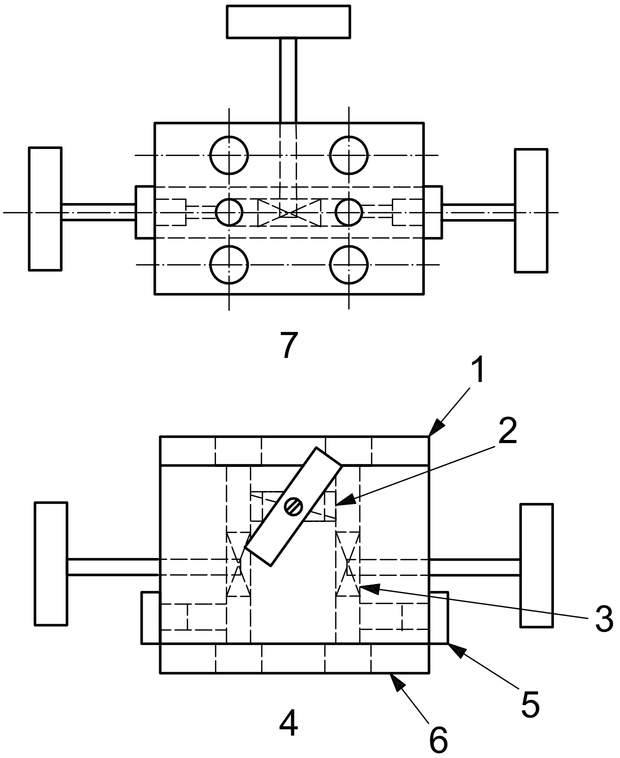
Table C.1 — Example calculation for two cases

Conditions	Tube temperature °C	Specific volume m^3/kg	Density kg/m^3	Density ratio	Pressure difference Pa (mbar)
Base	20	0,001 002	998,035	1,000 00	—
Case 1	30	0,001 004	995,554	0,997 514	61,9 (0,619)
NOTE The specific volume values were obtained from ASME Steam Tables, Fifth Edition [2].					

Annex D
(informative)

Supplementary figures

The figures in this annex depict specific valve and service configurations that can be encountered in pressure-signal transmission between primary and secondary elements.



Key

1 secondary connection flange matches instrument taps
2 equalizing valve
3 block valves
4 plan view
5 drain or purge connection shown plugged
6 process connection flange
7 front view

Figure D.1 — Three-valve manifold — Schematic

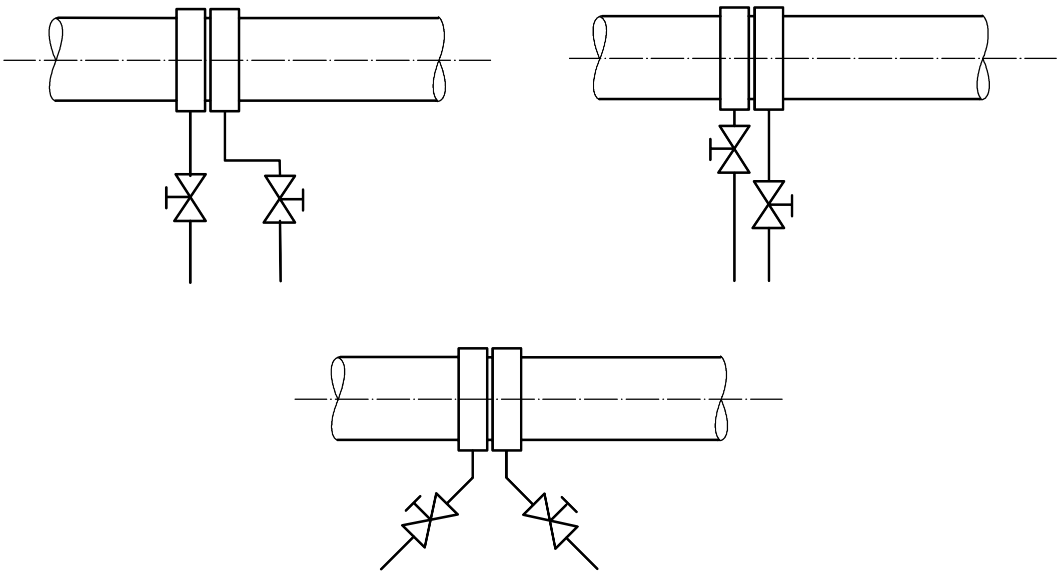
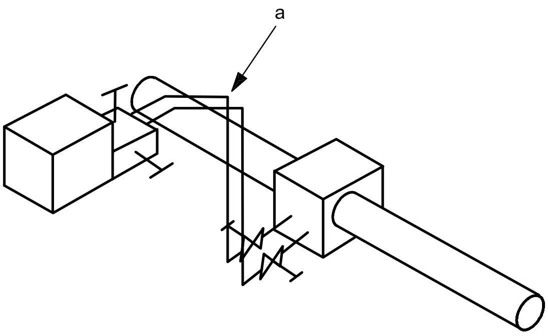


Figure D.2 — Details, block-valve interference



[a] Slope is 1:12.

Figure D.3 — Gas service, secondary above primary

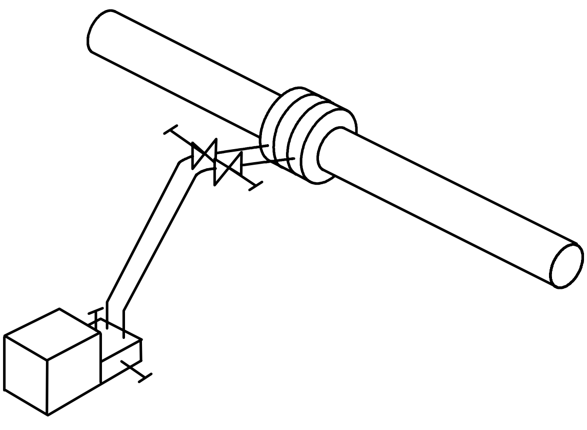
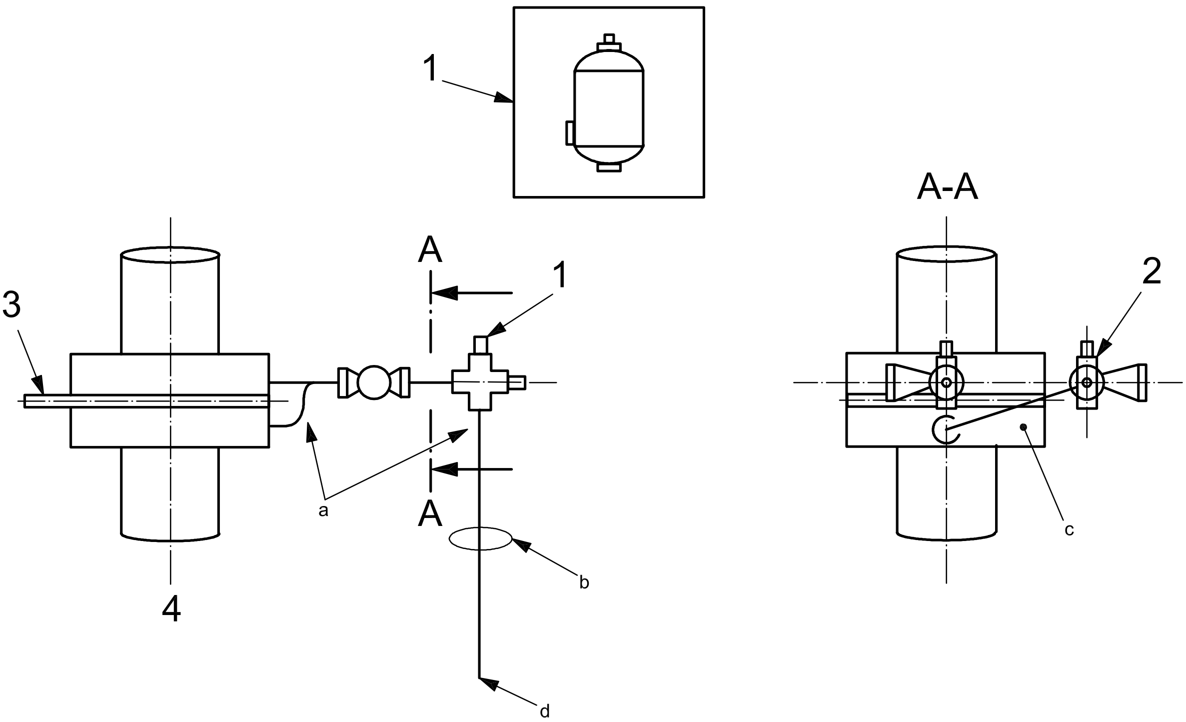


Figure D.4 — Liquid service, secondary below primary



Key

1 optional detail: condensate pot replaces plugged cross as required

2 globe valve stem is horizontal to eliminate pocket, not required with ball valve

3 primary element

4 front view

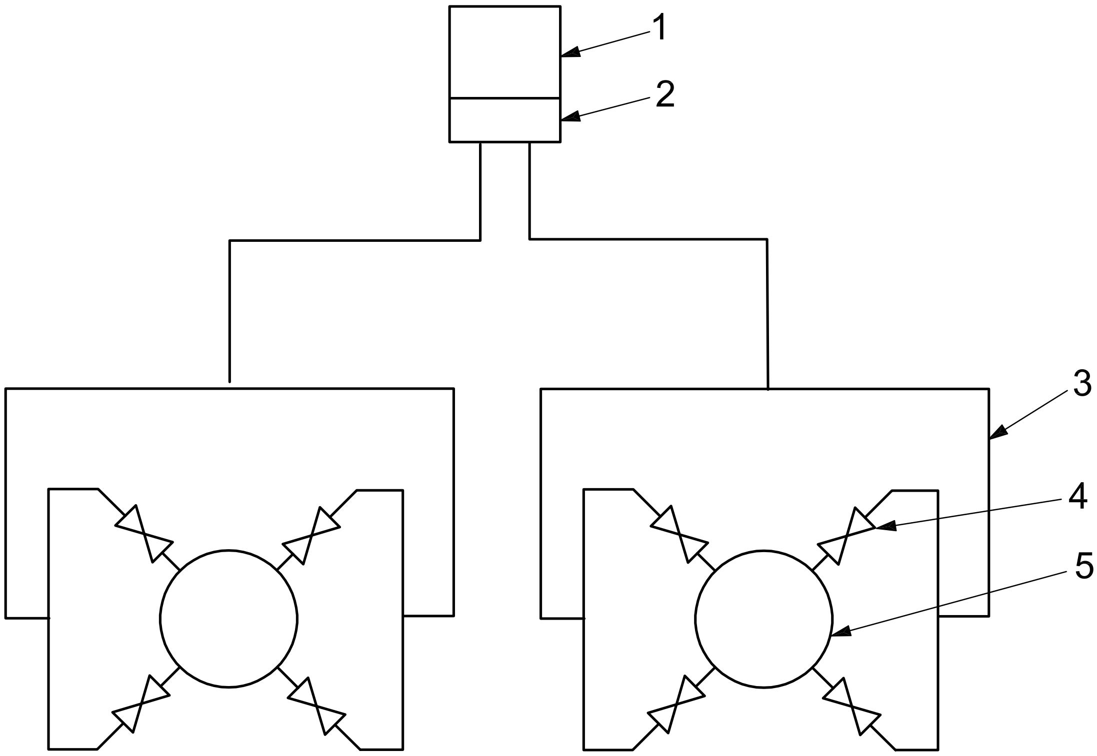
[a] The line between pressure tap and tee is filled with vapour, below the tee the fluid is liquid.

[b] Insulate lines together if required for personnel and freeze protection.

[c] Form the lower impulse line upwards to match the height of the upper pressure tap.

[d] To secondary device.

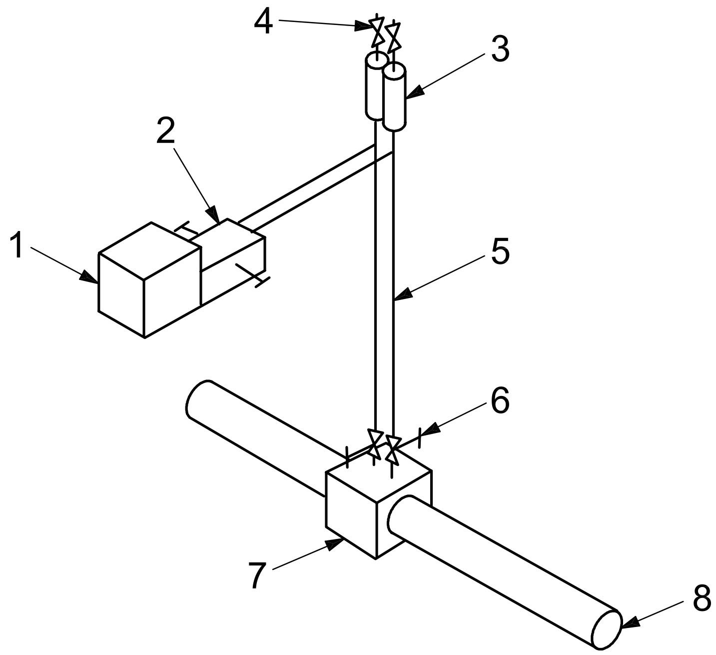
Figure D.5 — Vertical flow, condensing service, detail for equal head installation



Key

1 secondary element
2 manifold
3 impulse piping
4 isolation valves
5 conduit

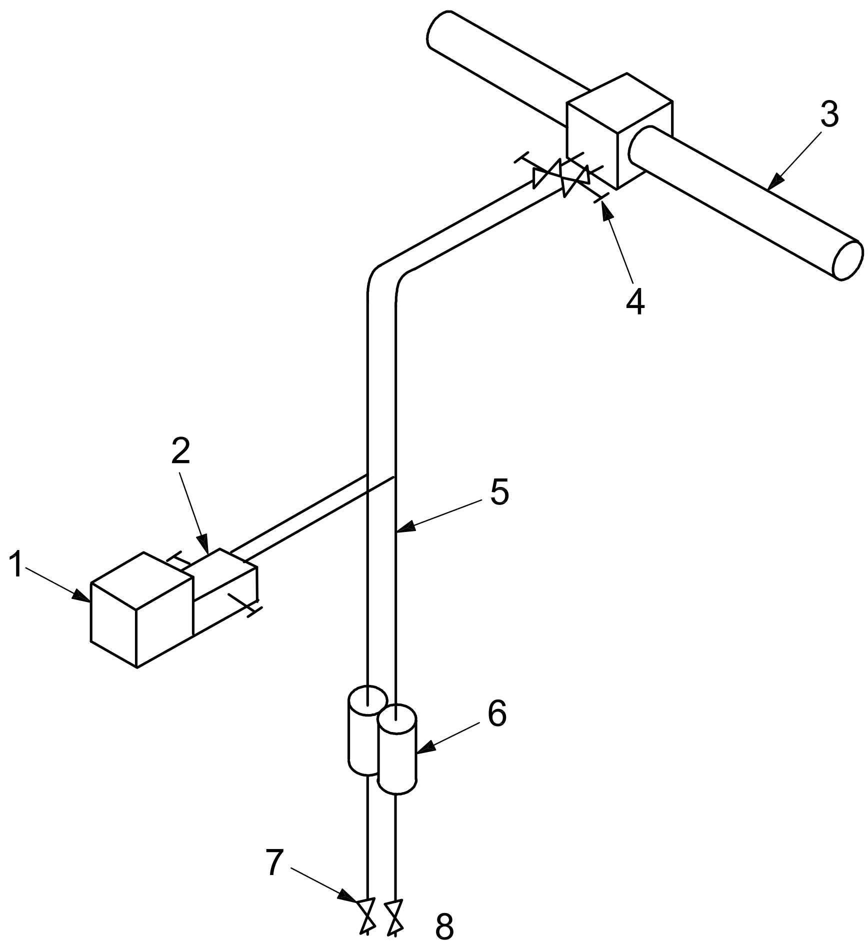
Figure D.6 — Piezometer ring, symmetrical



Key

1 secondary element
2 manifold
3 air or gas separator with vent valve
4 vent accumulated gases
5 impulse lines
6 isolation valves
7 primary element
8 conduit running full

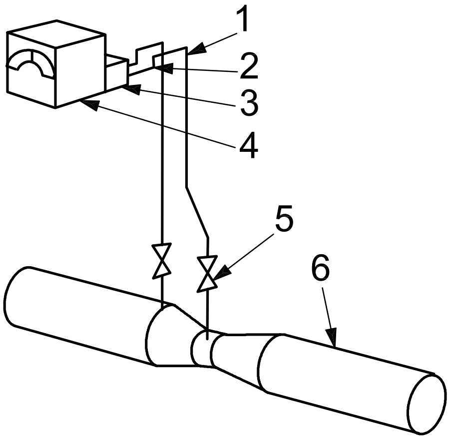
Figure D.7 — Liquid service, secondary above primary



Key

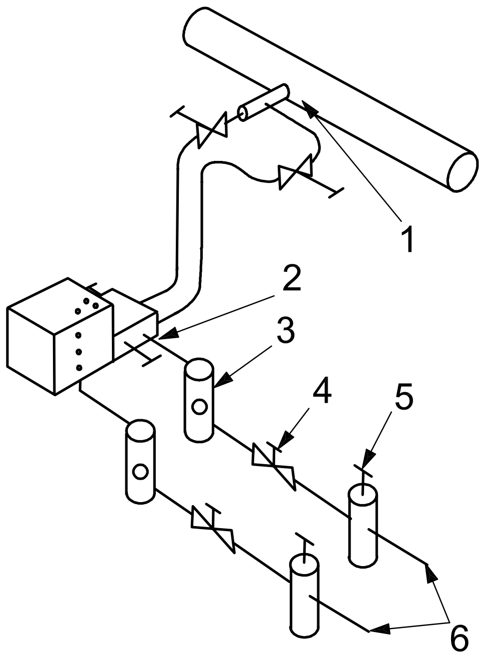
1 secondary element
2 manifold
3 conduit running full
4 isolation valves
5 impulse piping
6 drain pots
7 drain valves
8 drain for accumulated liquids

Figure D.8 — Gas or condensable vapours service – secondary below primary



Key
1 steam filled
2 condensate filled
3 manifold
4 secondary device
5 block valves
6 primary element, Venturi shown

Figure D.9 — Horizontal line, condensing service, secondary above primary



Key
1 primary element, Pitot shown
2 purge tap on manifold
3 flow indicator
4 needle flow valve
5 pressure regulator
6 supply of clean purge fluid

Figure D.10 — Purged secondary system, horizontal line, liquid service

Bibliography

[1] ISO/TR 3313, *Measurement of fluid flow in closed conduits — Guidelines on the effects of flow pulsations on flow-measurement instruments*

[2] ASME Steam Tables, 5th Edition

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