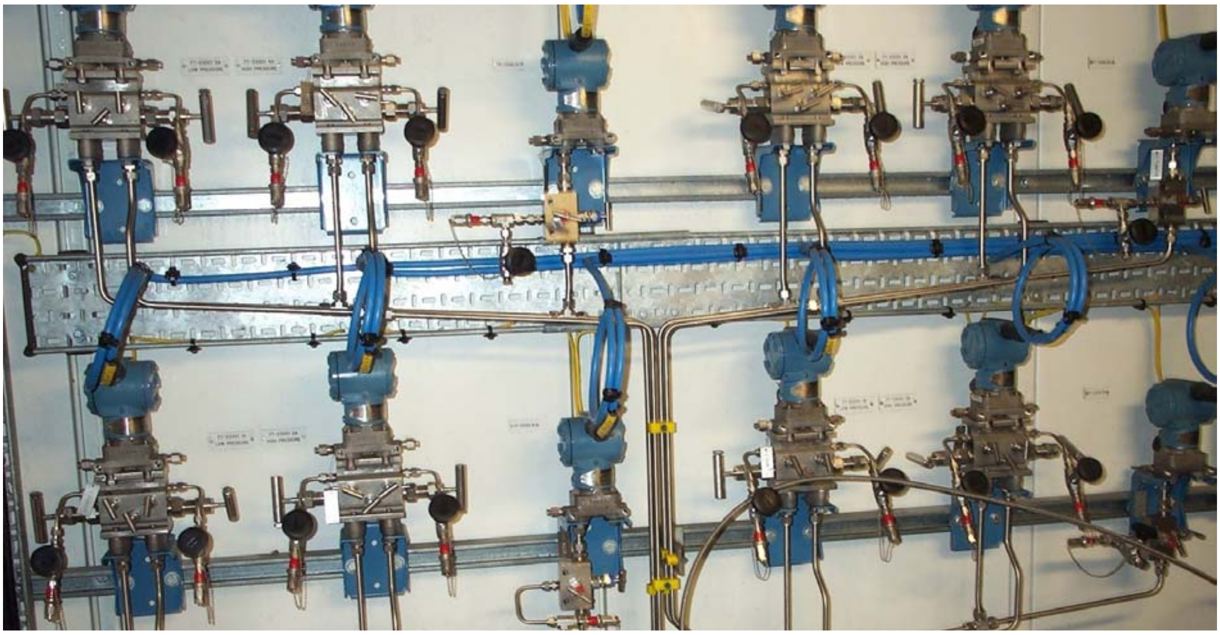
Best Practice Guide

Impulse Lines for Differential-Pressure Flowmeters



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Impulse Lines for Differential-Pressure Flowmeters
Best Practice Guide

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Executive Summary

This guide presents best practice in the design and installation of impulse lines that connect a differential-pressure flowmeter to the instrument for measurement of the pressure difference. It is intended to assist the designer to avoid known problems with impulse lines that can lead to incorrect measurement.

In general, the recommendations are to use short impulse lines of equal length, to use recommended configurations, to use trace heating and/or insulation if required, to ensure that the temperature is the same in both impulse lines, and to ensure effective venting of trapped gas in a liquid-filled line and draining of any liquid in a gas-filled line. Moreover, if the flow is pulsating it is also recommended that changes in impulse-line diameter should be avoided and that the pulsation and the impulse-line frequencies should not coincide.

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C O N T E N T S

1 INTRODUCTION

An impulse line is a small-bore pipe that is used to connect a point in a pipe at which pressure is to be measured to an instrument. In flow measurement using a primary device such as an orifice plate, a nozzle, or a Venturi meter, impulse lines are used to connect points upstream and downstream (or in the throat) of the meter to a secondary device for measuring the differential pressure.

The use of impulse lines is known to cause a number of problems that can lead to an incorrect measurement. The problems can arise from the following:

1. Damping of the pressure signal or resonances (this problem is exacerbated if a transient measurement is required or if the lines are of different length)
2. Blockage
3. Leakage at couplings
4. Different temperatures (and therefore different densities) in a pair of impulse lines
5. The fluid in the impulse lines being of a different composition from the fluid in the pipe (this causes a particular problem in a vertical meter when a gravity head correction or some other approach is required)
6. Condensation in an impulse line that is intended to be filled with gas
7. Gas bubbles being trapped in an impulse line that is intended to be filled with liquid, or boiling of a liquid with a bubble point below the ambient temperature.

Figure 1 below illustrates the potential problems listed above.

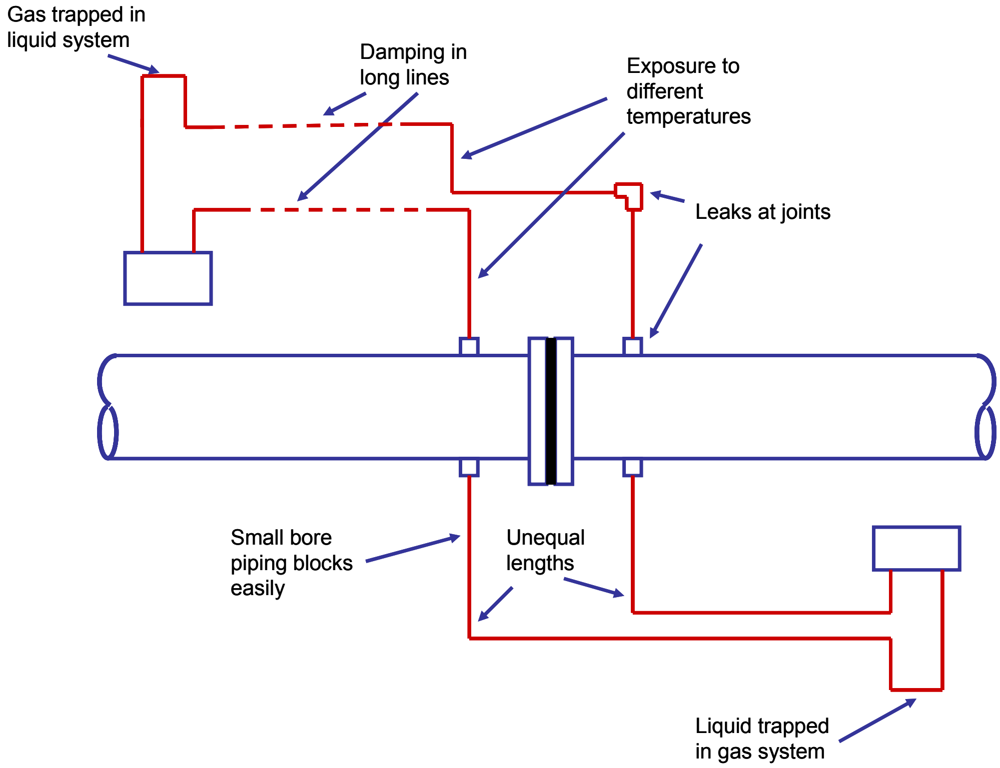

Figure 1: Diagram of potential problems and bad practice in impulse lines

This document provides general guidance for the design and installation of impulse lines. It covers impulse lines but not the pressure tappings (their diameter, edge sharpness etc.)

themselves. It applies to a range of applications including liquid, gas, two-phase, steady and pulsating flows. It does not cover safety issues in general: appropriate materials, manufacturing techniques, and sealing should be used, and applicable standards should be followed.

The key international standards relating to flow measurement using differential-pressure meters and to impulse lines are ISO 5167[1] and ISO 2186[2] respectively; ISO 2186 is currently being revised, and further reference is made to it in subsequent sections of this report. Further information on flow measurement can be found on www.flowprogramme.co.uk, which, in addition to other links, has a link to the ISO website.

2 GENERAL PRINCIPLES AND GUIDELINES

2.1 Introduction

The design of a typical differential-pressure flow-measurement installation involves consideration of a number of issues related to the impulse lines:

- Impulse-line diameter and length
- Location of the secondary device relative to the primary device
- Routing of the impulse lines between the primary and secondary devices, including the slope
- Location of pressure tappings
- Effects of ambient temperature, temperature gradients and fluctuations, and the associated need for heating or insulation
- Fluid in the impulse lines
- Valves and connections for venting and draining
- Isolation valves
- Avoiding impulse-line blockages

These issues are considered below for steady flows. Special considerations that apply to pulsating flows are discussed in Section 3.

2.2 Geometry

Most of the problems described above can be minimized or avoided by the use of impulse lines that are as short as possible. The main limitations are the possible need to isolate a secondary device from a high-temperature fluid in the pipeline and the need to include valves between the primary and secondary devices to make possible removal or replacement of the secondary device and to make it possible to open a path between high- and low-pressure sides with no differential pressure. A typical arrangement is shown in Figure 2 below. Additional valves, often in a single manifold, may be required to permit draining, venting or calibration.

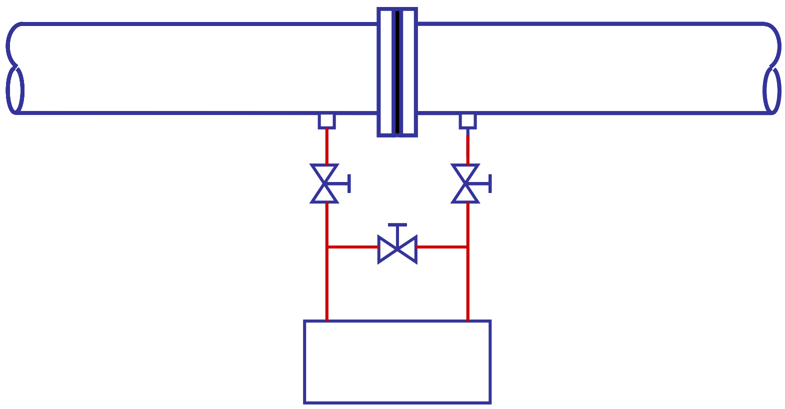

Figure 2: Typical valve arrangement to isolate the secondary device and to provide equalization

Similarly, it is usually best to select the smallest possible impulse-line internal diameter, but this will be limited by practical constraints such as avoiding damage and blockages, capillary effects, and the need to avoid trapped bubbles in liquid lines and trapped liquid in gas-filled lines. Generally impulse-line diameters in the range 4 mm to 25 mm are used. The smallest sizes are used for unsteady flow and for research. The international standard ISO 2186[2] is being revised, and the current draft (ISO/CD 2186:2004) recommends an internal diameter of not less than 6 mm and preferably at least 10 mm if condensation is likely to occur or if gas bubbles may be liberated from a liquid. It recommends a minimum internal diameter of 10 mm for industrial process applications in which reliability is the primary concern. Generally it recommends a maximum internal diameter of 25 mm.

ISO 2186:1973, which is still in force, contains a table giving very long impulse-line lengths and very large impulse-line diameters, included as Table 1 below. In ISO/CD 2186:2004 the largest lengths and diameters have been removed, and the table shown as Table 2 below is in an informative (i.e. not a normative) annex. This table is introduced with the words '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 D.1' (which is equivalent to Table 2).

Table 1: Impulse-line diameters from ISO 2186: 1973

Type of metered fluid	Impulse line length		
	0 to 16 m	16 to 45 m	45 to 90 m
Water/Steam and Dry air/Gas	7 to 9 mm	10 mm	13 mm
Wet air/Wet gas	13 mm	13 mm	13 mm
Oils of low to medium viscosity	13 mm	19 mm	25 mm
Very dirty fluids	25 mm	25 mm	38 mm

Table 2: Impulse-line diameters from ISO/CD 2186:2004

Type of metered fluid	Impulse line length	
	0 to 16 m	16 to 45 m
Water/Steam and Dry air/Gas	7 to 9 mm	10 mm
Wet air/Wet gas	13 mm	13 mm
Oils of low to medium viscosity	13 mm	19 mm
Very dirty fluids	25 mm	25 mm

If long lengths of impulse piping are required, it is important to ensure that the piping is well supported so that the possibility of damage due to vibration is eliminated. The natural frequency of the longest unsupported length should not coincide with any potential exciting frequencies in the system.

2.3 Fluid

In many applications, such as flow measurement of a gas that does not condense at ambient temperatures, the fluid in the impulse lines is the metered fluid. In other cases, such as measurement of steam flow where the steam saturation temperature is well above the ambient temperature, it may be advantageous for the fluid in the impulse lines to be in the liquid phase.

It is essential to avoid gas or vapour bubbles in liquid-filled lines, and liquid in gas-filled lines.

In some applications, for example steam flow with condensate (here meaning liquid water) in the impulse lines, it may be necessary to fill the impulse lines prior to start up.

2.4 Temperature Effects

The pressure head in an impulse line depends on the fluid density, which is in turn affected by the fluid temperature. It is therefore good practice to ensure that both impulse lines are exposed to the same ambient temperatures. For example it would be bad practice to have one impulse line exposed to solar radiation and the other in shade. For this reason it is recommended that the impulse lines are tied together, even when they are insulated.

Insulation and protection from solar heating is particularly important if the impulse lines contain a liquid that is close to its bubble point. It is also desirable to use insulation to minimize fluctuations in ambient temperature, which could affect the stability of the pressure head in the impulse line.

To give an indication of the effect of having the impulse lines at different temperatures, if the two impulse lines contain water and are at temperatures of 20°C and 30°C and there is a difference in height between the pressure tappings and the differential-pressure transducer of 2 m there will be an error in measured differential pressure of 49 Pa.

2.5 Location of Secondary Instrument

For gas-filled impulse lines the secondary instrument should be located above the primary instrument to facilitate drainage of any liquid that may form in the lines. Similarly the secondary instrument for liquid-filled lines should be located below the primary instrument to facilitate venting of gases.

With liquid-filled lines it is essential that the liquid heads in the two impulse lines are equalized or otherwise compensated. One way of achieving this where steam flow is being measured is described in 2.9.

If oil is being measured and there is the possibility of contamination with water, then the classic arrangement of the transducer below the tappings may not work well since water may enter the impulse lines. In this case it may be better to place the transducer above the tappings and to make additional provision for the possibility of gas in the impulse lines. This problem is not specific to oil and water but may occur with other immiscible pairs of liquids.

2.6 Location of Pressure Tappings

The recommendations of ISO/CD 2186:2004 for horizontal pipes are summarized in Table 3. The underlying rationale is that gas- or vapour-filled impulse lines should slope upwards to facilitate drainage of liquid, and that with liquid-filled lines tappings below the centre line can accumulate solids while tappings above the centre line can accumulate non-condensing gases.

Table 3: Recommended pressure tapping locations from ISO/CD 2186:2004 for horizontal meters

Fluid	Pressure Tapping Location
Dry gas	Between the top of the pipe and the horizontal centre line
Wet gas	Between the top of the pipe and the horizontal centre line, but so that the tappings are self-draining (see 2.7)
Liquid	On the horizontal centre line
Condensing vapour	On the horizontal centre line

In steam in horizontal pipelines tappings between the horizontal centre line and 45° below the horizontal may also be acceptable.

In vertical pipelines there is no restriction on the radial location of the pressure tappings.

2.7 Impulse Line Installations

The recommendations above on the location of the secondary instrument relative to the primary instrument imply that gas-filled impulse lines should slope upwards from the pressure tappings to the transducer and liquid-filled lines should slope downwards. ISO/CD 2186:2004 states that impulse lines shall be installed such that the slope is in one direction only, and that if a change in direction of slope is unavoidable, only one such change is made. In this event a liquid trap is required at the low point and a vapour vent at the highest point. The minimum recommended slope for self-draining or self-venting is 8 per cent.

Examples of impulse lines for dry natural gas are given in Figures 3 and 4. Figure 3 shows impulse lines leading from an orifice plate with horizontal tappings to an instrument room. The lines are sloped upwards towards the instrument room, and are insulated.

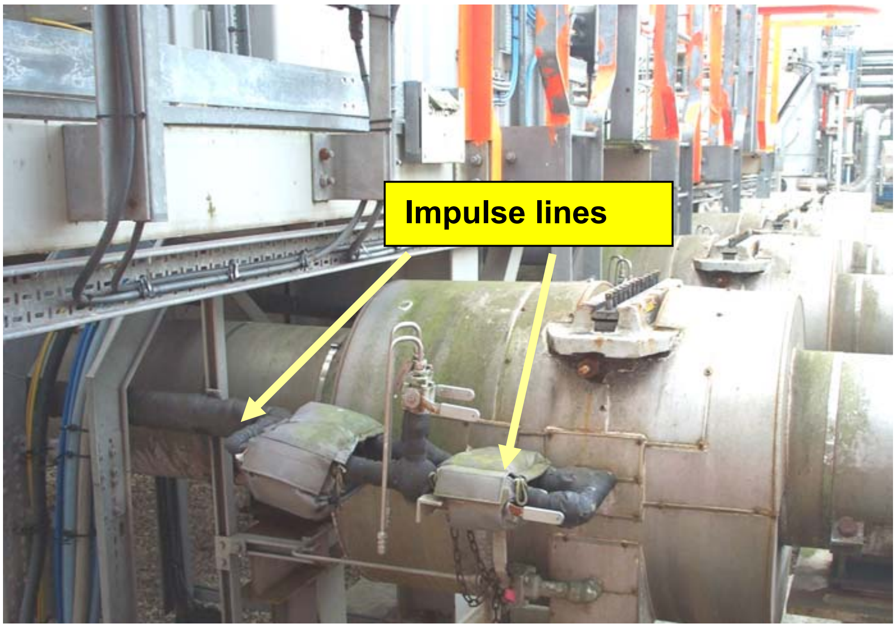

Figure 3: Gas metering installation showing insulated impulse lines
(Courtesy of CATS)

Figure 4 is a view of the interior of the instrument room. It shows the impulse lines again correctly sloping upwards towards the differential-pressure transducers so that any liquids that form in the lines will tend to drain downwards. Since the cabin is at a constant temperature which is above the dew point of the gas in the impulse lines, there is no need for insulation. The transmitters are calibrated *in situ*.

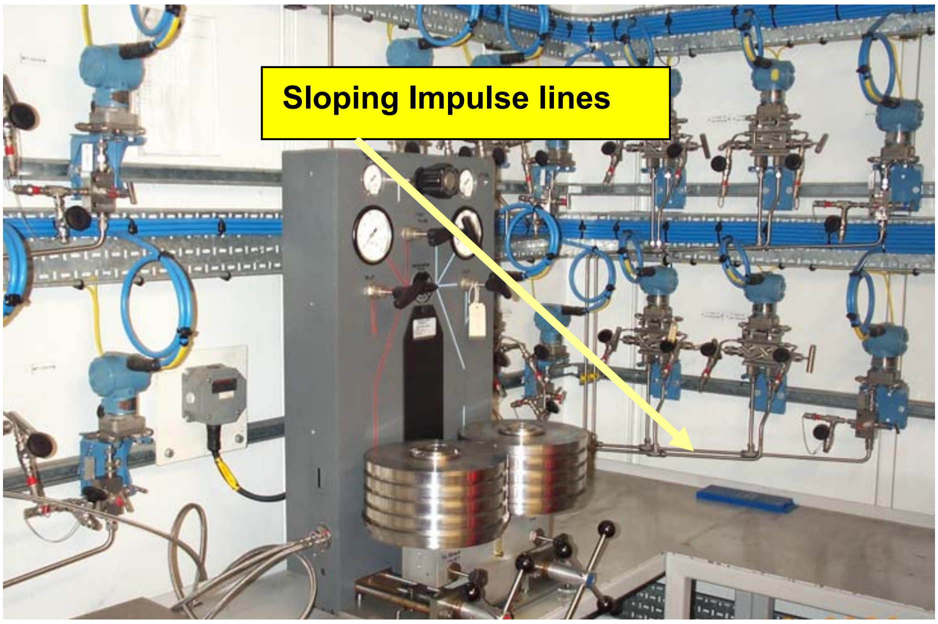

Figure 4: View of interior of instrument room for gas metering installation
(Courtesy of CATS)

Many instrument enclosures are much smaller than the room in Figure 4. Figure 5 shows an enclosure with three differential-pressure transmitters and one static-pressure transmitter. The enclosure contains a heater (behind the transmitters in the middle of the picture). The three differential-pressure transmitters are mounted on a mono-block. Where high-static calibration is performed off site and footprinting is the norm on site then small enclosures are not a problem since if the transmitters are mono-block-mounted the complete block with transmitters mounted is removed for remote calibration, and footprinting can be performed in situ on site with very little problem. The mono-block also has a stabilizing effect with regard to temperature. Where a number of transmitters are connected via pipework it is prudent to keep the distance between transmitters as small as possible. On some gas systems where three or more transmitters are used and the distance between the transmitters is about 1 m there is a problem with gas noise; the signal from the end transmitter may be reflected so as either to increase or to decrease the signal strength at the first transmitter. This causes problems where the accuracy of the measured differential pressures is checked by a comparison between pairs of transmitters, and alarms are set. So close coupling between such transmitters is very desirable (see Figure 5).

Figure 5: View of enclosure for three differential-pressure transmitters and one static-pressure transmitter *(Courtesy of PCD)*

The recommended slopes of the impulse lines for meters in vertical pipes are generally the same as for horizontal meters.

If liquid-filled lines are used to measure flow of a vapour or gas in a vertical pipe, there is a difference in liquid head between the tappings. Thus there is a pressure difference between the tappings under static conditions for which compensation can be made in one of two ways:

1. Form the lower impulse line upwards before turning horizontal at the same height as the upper impulse line, and then form both lines downwards to the secondary device. This arrangement equalizes the liquid head above the secondary device in the two impulse lines and avoids the need for a correction to the instrument calibration.

2. Both impulse lines leave the tappings horizontally and then turn down to the secondary device. The zero of the secondary device must then be adjusted to account for the difference in liquid head above the secondary device.

Option 1 is depicted in Figure 6 below.

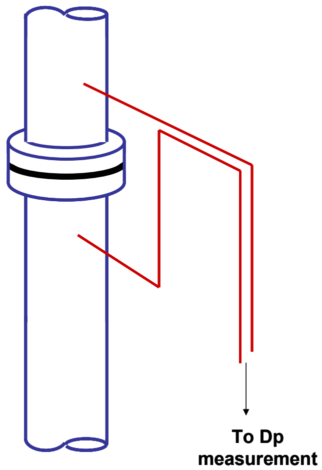

Figure 6: Handling the height difference between tapping points on vertical flow

ISO/CD 2186:2004 provides recommendations on impulse-line configurations with useful diagrams and should be the first place where information is sought. The new version (now at Committee Draft stage) will be an improvement on the 1973 version. The standard has a useful section on isolation valves, which are required in practice, though their use conflicts with the desirability of having as few joints as possible in the impulse lines and having no changes of diameter. Some choices of valve are better than others: globe valves with a vertical stem that may create a pocket of gas or liquid should be avoided. It is usually desirable to be able to join the high- and low-pressure sides of the differential-pressure transducer so that the signal from the transducer can be obtained with no differential pressure but at line pressure (see Figure 2); this is often called performing a high-static zero check.

Installations other than those recommended can be used, but will generally require more maintenance. If the transducer lies below the pressure tappings in gas, drain pots and valves will be required; if the transducer lies above the pressure tappings in liquids, vent valves at least will be required.

Some installations may require the opportunity to 'rod out' the impulse lines. This is particularly important in steam flow as dirt is often a significant problem. In addition to the requirements in the previous paragraph, provision for draining or venting the impulse lines may be necessary, both immediately after installation (e.g. after hydrostatic testing) and subsequently. The specification of the piping for the impulse lines may be different from that for the process piping because of the more limited temperatures in the impulse lines.

For steam flow, plugged tees in the impulse lines may be required to enable the impulse lines to be filled with water at start up.

2.8 Specific Guidelines for Wet Gas Applications

The Department of Trade and Industry Licensing and Consents Unit Guidance Notes for Petroleum Measurement under the Petroleum (Production) Regulations December 2003, Issue 7 provide specific comments for wet gas applications and can be obtained through www.flowprogramme.co.uk/clubs/ogfg.

A particular concern is that liquid drop-out in impulse lines is likely to occur due to cooling of the gas towards ambient temperatures once it leaves the meter stream. In extreme cases, hydrates may form. To avoid measurement errors due to the presence of either liquids or hydrates in impulse lines, the Guidance Notes reiterate the general recommendations that impulse lines should be as short as possible and inclined upwards in order to drain entrained liquids. Other advice given in the Notes is that liquid or hydrate accumulation can be further countered by the insulation of the impulse lines and the application of trace heating, and that operators should consider placing the transmitters, and even the impulse lines if possible, in a heated, sealed enclosure.

The Notes advise that catchment pots located in the impulse lines may be effective at catching liquids, and that these should be drained frequently to avoid excessive liquid build-up. They may therefore not be effective on un-manned installations that experience significant liquid drop-out in impulse lines.

It is also recommended for wet gas applications that “the meter should be orientated horizontally such that the pressure tappings are located at the 12 o’clock position. In this way the potential for liquid becoming entrained in the tapping or impulse lines is minimized, and the tappings are kept as far as possible from the bulk of the liquid if stratified or annular flow regimes are present”.

2.9 Specific Guidelines for Steam

Specific recommendations for steam flow are provided in “A Review of Steam Flowmetering Technology”[3]. This is available from www.flowprogramme.co.uk/Publications/reports.asp. It is reported that impulse lines are usually designed such that they are filled with condensate at all times. This is usually achieved by a siphon arrangement or by including a low point in the impulse lines in which the condensate collects, insulating the transducer from the steam. Seal pots (also known as condensate pots) are often included in the arrangement and there is usually provision for venting or flushing the lines and filling with water.

It is recommended in the report that impulse lines should ideally be insulated and provided with trace heating to avoid condensate freezing in cold weather. Sometimes glycol is added to the condensate in the impulse lines for similar reasons. Gas bubbles in the impulse lines can cause a sluggish response from the pressure transducers and the impulse lines should be purged to ensure that no air is trapped in them.

Some manufacturers also recommend the use of condensate or seal chambers for steam flow. They are used when the instrument displaces a large volume of liquid as the measurement changes, which was much more common with older instruments. A seal chamber is a small pressure vessel that is mounted at the top of the liquid-filled impulse line. Each chamber acts as a reservoir in the impulse line in which large volume changes will result in minimal elevation change so that seal liquid is not dumped into the process line and elevation shifts of the wet-leg liquid do not cause measurement errors. The two seal pots must be at the same height. In general modern transducers with very small volumetric displacement do not need seal chambers. Spirax Sarco do not recommend the use of condensate pots except for superheated steam applications; moreover, they do not recommend the configuration shown in Figure 6: they always recommend removing the static-head offset using the secondary instrument.

Figure 7 illustrates the use of seal pots.

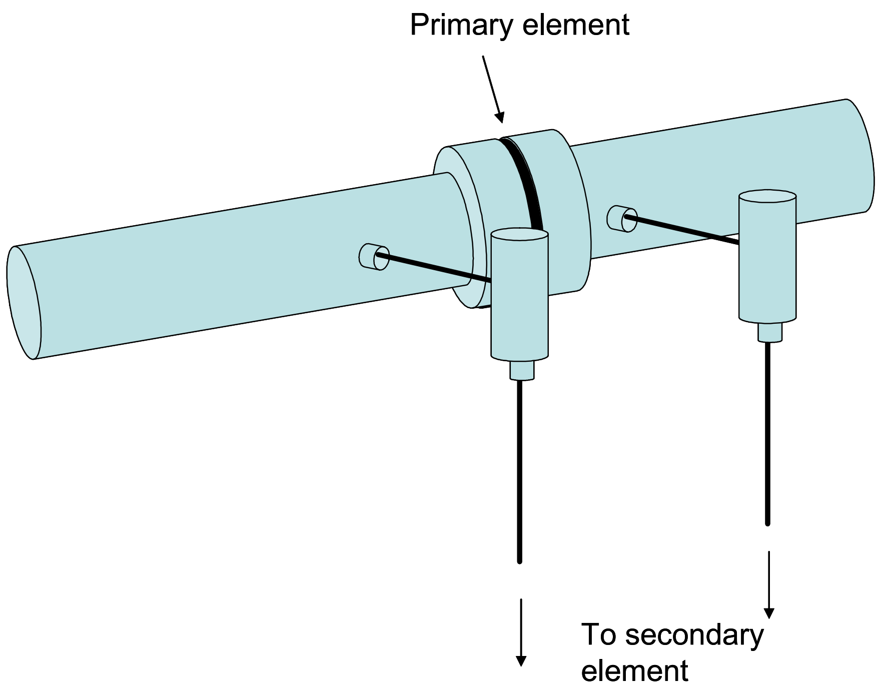

Figure 7: Illustration of the use of seal pots in steam flow

Figure 8, taken from Reference 3 (see also Mottram et al.[4]), shows some common arrangements for steam flow in horizontal and vertical pipelines. Figure C.5 of ISO/CD 2186:2004 is also very helpful.

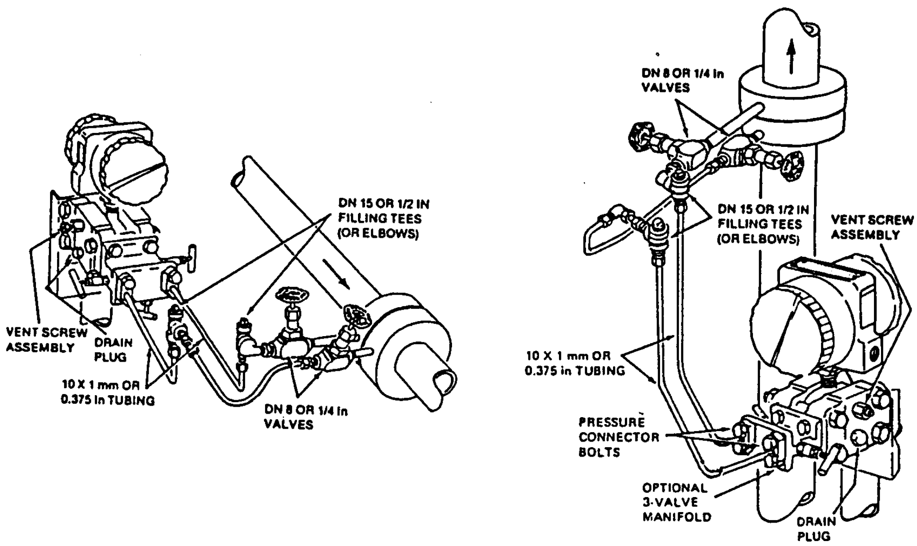

Figure 8: Impulse-line arrangements for steam flow

2.10 Condensing or Evaporating Fluids

In flow measurement of a fluid that is close to its bubble or dew point, the general aim is to ensure that both impulse lines are maintained full of either gas or liquid at all operating and ambient conditions.

The recommendation in Section 2.8 for steam flow applies to any condensable vapour for which the dew point is above the ambient temperature, in which case impulse lines will tend to fill naturally with liquid. In other applications alternative options may be appropriate depending on the dew and bubble points and the ambient temperature, on the mass fraction of the condensable vapour and on whether or not trace heating or cooling is employed. For example, if there were the possibility of condensation of only a small amount of a vapour component it would be better to follow the gas-flow recommendations.

If the ambient temperature is always above the dew point, the recommendations for gas flow should be followed.

Flow measurement of a liquid that evaporates at ambient temperatures can present similar problems. It may be necessary to provide insulation to prevent boiling of liquid in the impulse lines. Alternatively, if ambient temperatures are well above the bubble point it may be better to design for vapour in the impulse lines.

3 PULSATING FLOW

According to ISO 5167-1:2003[1], a flow is considered as not being pulsating when

$$\frac{\Delta p'_{\mathrm{rms}}}{\overline{\Delta p}} \leq 0.10 ,$$

where $\overline{\Delta p}$ is the time-mean value of the differential pressure

$\Delta p'$ is the fluctuating component of the differential pressure

and $\Delta p'_{\mathrm{rms}}$ is the root mean square value of $\Delta p'$.

With a pulsating flow the requirement may be to measure either the time-dependent flow or a time-average.

The occurrence of flow pulsations introduces the possibility of additional measurement errors. An extensive research programme on impulse lines in pulsating flows was performed at Southwest Research Institute in the USA, and another major research contributor was the research laboratory of the Nova Chemical Corporation.

In the SwRI Research Programme, the report by Sparks[5] describes results of an experimental programme to document and to describe pressure-measurement errors inherent in impulse lines when gas flow in the pipe is unsteady or pulsating. The report contains good descriptions of the effects of impulse lines on pressure measurements in pulsating flows. It is directed towards measurement of the time-average flow.

With a simple impulse line consisting of a straight tube of constant diameter its resonant frequencies will be excited when a pulsation frequency coincides with its quarter-wave resonant frequency or with any odd multiple of that frequency. For this simple geometry the acoustic resonance frequencies f_n are given by

$$f_n = \frac{(2n-1)c}{4L} \quad \text{Hz}$$

where

n = mode number (1, 2, 3,…………..)
c = speed of sound in fluid
L = impulse pipe length.

The experiments showed that at resonance the pulsation amplitudes in the impulse lines can be much greater than in the main pipe.

Further analysis showed that pulsation data from impulse lines cannot necessarily be relied upon unless impulse-line lengths are very much shorter than a quarter wavelength for the highest frequency existing in the piping, and then only if there are no constrictions or volumes in the impulse line that would lower its resonant frequency.

Moreover, the existence of pulsations can cause a shift in the mean pressure inside an impulse line. The average pressure transmitted by the impulse line is not necessarily equal to the average pressure in the piping system, even when impulse lines are not at resonance. The basic cause of the shift is stated to be oscillating flow through non-linear resistance elements such as contractions, enlargements, valves and transducer volumes. These elements may have a loss coefficient for flow into the impulse line that is different from the coefficient for outward flow. Oscillating flow is therefore partially rectified, and a net change in the mean pressure in the impulse line results. This flow rectification is greatly amplified if the impulse-line acoustic resonance frequency coincides with the pulsation frequency.

The main findings of Sparks[5] are:

- The acoustic response of the impulse lines can cause the pulsations in the impulse line to be many times higher or lower than in the main pipe, depending on the acoustic response of the impulse line.
- Impulse lines can distort mean-pressure measurements when there are pulsations in the piping system. These shifts can be either positive or negative, and are most severe when acoustic resonances are excited in the impulse line.
- Pinched valves, volumes and impulse-line filters can be used to provide damping and therefore attenuate the observed pulsations, but they do not totally eliminate the mean pressure shift.
- Differential-pressure measurements are particularly susceptible to impulse-line effects. A positive mean-pressure shift in one line and a negative shift in the other can cause a large shift in the differential pressure.

The main recommendation of the report was that impulse lines should be made as short as possible to give a high acoustic frequency, well above any pulsation frequency in the main piping. The lines should also be of constant diameter, and be free of constrictions and volumes.

In the Nova Corporation Research, Botros et al[6] made similar recommendations on impulse-line design to those arising from the SwRI research, i.e.

- Use short impulse lines.
- Avoid abrupt changes in diameter.

- Use a transducer with a very small chamber and with a flat frequency response to the actual frequency range of the pressure oscillation.

ISO/TR 3313[7] provides guidelines on the effects of flow pulsations on flowmeters. It encapsulates and adds to the impulse-line design guidelines in the literature described above, but distinguishes between the use of a slow-response and that of a fast-response transducer. A slow-response transducer is designed to indicate the time-mean differential pressure, whilst a fast-response transducer will be designed to follow the time-dependent differential pressure so that the square root of the measurement can be averaged to yield a true mean flowrate (i.e. the square-root error is eliminated).

Design guidelines for impulse lines for slow-response transducers to measure time-mean flowrate are:

- A piezometer ring should not be used. A piezometer ring is also called a "Triple-T" arrangement and is shown in Figure 1 of ISO 5167-1:2003.
- The distance between pressure tappings should be small compared with the pulsation wavelength.
- The impulse lines should be as short as possible, and of the same bore as the tappings, which should be greater than 3 mm in diameter.
- An impulse-line length close to the pulsation quarter wavelength should not be used.
- For gas-filled lines the sensor cavities or other volumes should be as small as possible.
- Vent points are required for liquid-filled lines to remove any gas bubbles.
- Damping resistances in the connecting tubes and sensing element should be linear. Throttle cocks should not be used.
- The device time constant should be about ten times the period of the pulsation cycle.
- If the above rules cannot be observed the secondary measurement system can be effectively isolated from pulsation by the insertion of identical linear-resistance damping plugs into both impulse lines, as close as possible to the pressure tappings.

Design guidelines for a fast-response transducer to measure the time-varying flowrate are:

- The mechanical and electronic frequency limits of the secondary measurement system should be at least ten times greater than the pulsation frequency.
- The impulse-line lengths should be as short as possible and less than 10% of the pulsation quarter wavelength.
- The bore of liquid-filled impulse lines should be greater than or equal to 5 mm.
- Fittings and valves should be of the same bore as the impulse lines.
- The secondary device must be geometrically identical on the upstream and downstream sides.
- Vent points are necessary for liquid-filled lines to remove any gas bubbles.

4 IMPULSE-LINE BLOCKAGES

Blockage of an impulse line will cause flowrate information to be lost, with potentially serious consequences in a process control application. The need to avoid blockages is a primary consideration in the specification of impulse-line diameter.

Blockage of impulse lines due to freezing is addressed by Daiber and Hughes[8], who estimate that 60% of trace-heating systems for freeze protection are not working as designed. They found a number of problems with installation, and transposition of the problems into the corresponding solutions yields:

1 Provide trace heating (generally by electricity or steam) whenever freezing conditions are possible.
2 Avoid exposure of trace-heating systems to excessive temperatures.
3 Avoid over-tightening or the improper clamping of the tubing bundle (consisting of the impulse lines and heating line) to its supports, which can cause the insulation to be compressed and prevent proper operation of the trace-heating system.
4 Do not exceed the tubing bend-radius limit.
5 Install effective trace-heating systems and insulation. The simple method of laying on insulating tape, applying an electric heater cable and then adding more insulation tape and sealing with mastic may not provide adequate protection.
6 Ensure correct slope of impulse lines.
7 Provide high-quality instrument enclosures, which, though expensive, are essential for reliable long-term frost protection.
8 Provide adequate weatherproofing.

The use of smart pressure transducers to detect and predict plugged or frozen impulse lines is described by Menezes[9]. An open impulse line has high frequency noise due to fluid turbulence. If a line plugs its signal becomes flat. A smart transducer can “learn” the frequency characteristics of open impulse lines and use them to establish an “OK” condition. The different frequency characteristics of plugged lines can then be detected and reported using software. It is possible to detect the plugging of one or both lines. This technique requires the use of a very fast pressure sensor.

Tests to assess the ability of smart pressure transducers to detect an impulse-line blockage in a refinery application are described by Szanyi et al[10]. Blockage in the impulse lines of pressure or differential-pressure transducers in fluid catalytic cracking (FCC) units can cause very expensive shutdowns.

Advice on trace heating using steam is provided by Harrold[11]. When trace heating is used, both lines must be equally protected. He recommends avoiding “splitting a single steam trace line into two lines, one for each impulse line, and then rejoining the lines ahead of the steam trap. Steam follows the path of least resistance. The line offering the most resistance will stop flowing, the steam will condense, freeze, and possibly rupture the trace-heating line. It's okay to split the lines, but provide each line its own steam trap”.

Trace heating must not be so great as to cause liquid to vaporize unintentionally or to prevent steam from condensing.

Waxing is another cause of blockage. Lagging or trace heating may be required to prevent this problem.

5 TWO-PHASE FLOW

With two-phase flows the impulse lines are generally designed to be filled with either liquid or vapour depending on the nature of the flow. Thus all of the comments in Sections 2 and 3 above apply equally to two-phase flows.

The location of the pressure tappings should take into account the probable two-phase flow pattern. For example with a stratified flow and gas-filled lines, the tappings should be located on the top of the pipe.

In addition it is important to avoid condensation in vapour-filled lines and boiling in liquid-filled lines; so trace heating or insulation may be required.

A pulsating two-phase flow will cause particular difficulty because of, for example, periodic pumping of gas bubbles into liquid-filled impulse lines.

A meter located in a vertical pipe length requires particular care because the fluid in the meter line between the two tapping points has a different density from the fluid in the impulse lines. The correction for the difference in height between the tapping points requires a calculation of the mean two-phase density in the pipe line, which is subject to some uncertainty. Moreover, although it is intended to have a known single-phase fluid in the impulse lines, in practice often the fluid in the impulse lines is in fact two-phase. For this reason it was found in Reference 12 that a horizontal orientation of a Venturi tube was preferred in multiphase flow.

The difficulties in maintaining a single-phase fluid in the impulse lines in some two-phase flow applications where, for example, the dew or bubble point is close to ambient temperatures, may mean that it is preferable to have a horizontal meter with the secondary instrument level with the primary instrument. This arrangement minimizes the uncertainties associated with the static head between the tapping points and the secondary instrument.

6 IMPULSE-LINE PURGING

One solution to problems of impulse line-blockage, gas bubbles in liquid lines and liquids in gas lines is to maintain a continuous purge flow through the lines. Impulse lines can be purged with a dry gas to keep liquids or vapours out, and with a non-freezing liquid to keep the process fluid out. It is important to purge through equal lengths of the two lines and to equalise the two purging flowrates. Figure 9 below shows a typical installation with continuous impulse-line purging.

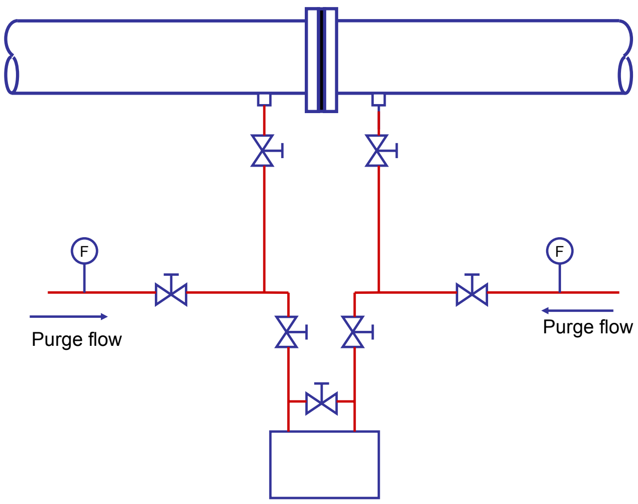

Figure 9: Impulse line installation with purge flow ("F" represents a flowmeter to measure the purge flowrate)

However (see Harrold[9]) there are disadvantages in terms of the requirements for additional hardware and piping and the need for tight control of the purge flowrate. It will be necessary to ensure that the frictional pressure drop due to the purge flow is negligible, and this may mean selecting a larger internal diameter of the impulse line.

Continuous liquid purging has been recommended as a method of avoiding undesirable effects of pumping of vapour bubbles into liquid lines in pressure measurement in two-phase flows, especially in research applications.

7 CLOSE COUPLING

Recently some manufacturers have developed transducer mounting arrangements so that the differential-pressure transducer is mounted directly on to the meter pipe, thus removing the need for impulse lines in the conventional sense, although there is still a length of tapping at least between the pipe and the differential-pressure transducer. This arrangement has significant benefits in that it greatly simplifies the piping and, most importantly, reduces the number of joints, and thus the number of leak paths at threaded connections and compression fittings. It reduces the need for insulation or trace heating and errors due to different densities of fluid in the different lines; it also minimizes problems with liquid drop-out or gas break-out in the impulse lines where the ambient temperature is very different from the line temperature. If short impulse lines are required because of pulsations, close coupling gives the shortest available lines. Close coupling also gives a good speed of response. However, it means that the transmitters have to be located in small enclosures beside the meter rather than in large cabins further away. This may make it more difficult to calibrate the transmitter *in situ* and may be less attractive to the operator. The small enclosures may provide shelter but not temperature control; however, modern transmitters are less sensitive to changes of temperature than earlier models. The use of impulse lines may be essential when the line temperature is too high or too low for the pressure transducer.

Figures 10 and 11 show examples of close-coupled installations.

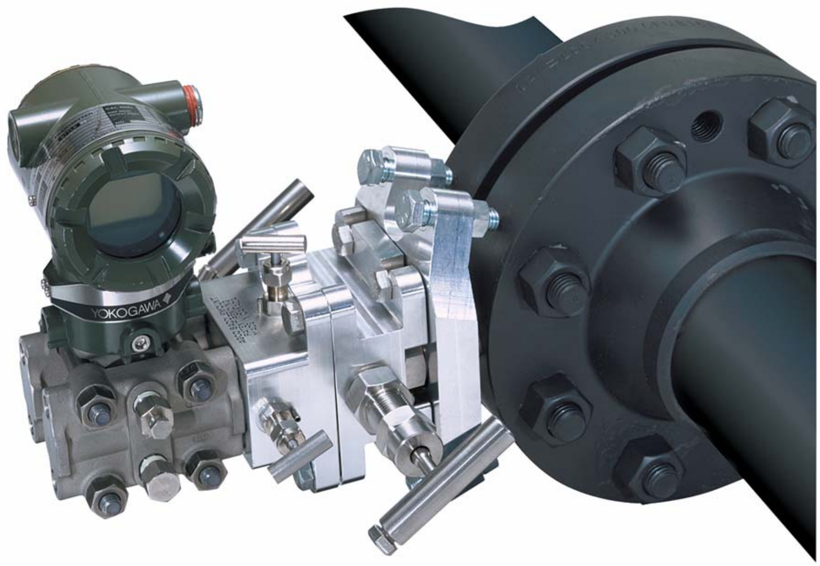

Figure 10: Example of close-coupled arrangement
(Courtesy of Anderson Greenwood)

Figure 11: Example of close-coupled arrangement
(Courtesy of Emerson Process Management)

8 SUMMARY

In general the recommendations are to use short impulse lines of equal length (close coupling is a way to achieve this), to use recommended configurations, to use trace heating and/or insulation if required, to ensure that the temperature is the same in both impulse lines and to ensure effective venting of trapped gas in a liquid-filled line and draining of any liquid in a gas-filled line. Moreover, if the flow is pulsating it is also desirable to avoid sudden changes in diameter and it is essential to avoid coincidence of the pulsation and the impulse-line frequencies.

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