

BS 7965:2009



BSI Standards Publication

Guide to the selection, installation, operation and calibration of diagonal path transit time ultrasonic flowmeters for industrial gas applications

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 60, an inside back cover and a back cover.

Foreword

Publishing information

This British Standard is published by BSI and came into effect on 31 October 2009. It was prepared by Subcommittee CPI/30/5, *Velocity based methods*, under the authority of Technical Committee CPI/30, *Measurement of fluid flow in closed conduits*. A list of organizations represented on this committee can be obtained on request to its secretary.

This British Standard supersedes BS 7965:2000, which is withdrawn.

Information about this document

With this revision of BS 7965, this British Standard:

- offers improved guidance for each of the four classifications of meter;
- provides new guidelines and improved tables covering class performance and uncertainty criteria;
- where appropriate is aligned with revisions made to other USM documents such as AGA 9[4] ¹⁾, taking account of results from research and development projects and end-user experience;
- introduces performance specification summary figures for all four meter classes;
- introduces a new table presenting calibration options for all four meter classes;
- introduces additional guidelines covering the number of calibration data readings to be taken during a dynamic (wet) calibration of a meter;
- introduces new guidelines covering calibration relaxation;
- removes the informative annex covering uncertainty calculation for ultrasonic flow meters;
- removes the informative annex covering performance specification;
- includes a new informative annex covering application of flow calibration results;
- includes a new informative annex covering thermowell installations in bi-directional flow installations incorporating flow conditioners;
- has been updated in the light of research and user experience since 2000.

As a guide, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification or a code of practice and claims of compliance cannot be made to it.

Annex A, Annex B and Annex C are informative.

¹⁾ See Bibliography.

Presentational conventions

The provisions in this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is “should”.

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

1 Scope

This British Standard provides recommendations and guidance on the selection, installation, operation and calibration of transit time ultrasonic flowmeters (USMs) for industrial gas applications (including flare gas).

It is applicable only to those devices in which the entire gas stream flows through the body of the USM and the transducers (wetted or invasive type), or a wetted interface, are in contact with the fluid. This includes full-bore/reduced-bore and insertion type meters employing direct or reflective paths. It is also applicable to "dirty gases", i.e. those contaminated with solids and/or liquids in sufficiently small quantities, depending upon the application.

It is not applicable to clamp-on/externally mounted, domestic or stack/chimney (combustion exhaust) meters.

As an aid to selection, this standard incorporates an uncertainty classification for USMs. This takes into account the components of uncertainty relating to the meter plus those additional uncertainties associated with installation and operation effects. There are four classifications offered. These range from high accuracy applications (Class 1) to process flow indication and control applications (Class 4).

2 Normative references

Standards publications

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.

BS 7834, *Specification for turbine meters used for the measurement of gas flow in closed conduits*

BS EN ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

ASTM E 1002-05, *Standard Test Method for Leaks Using Ultrasonics, Book of Standard Volume 03.03.*²⁾

Other publications

- [1] A.G.A. Transmission Measurement Committee Report No. 8, *Compressibility Factors of Natural Gas and Other Related Hydrocarbon Gases*³⁾
- [2] API Manual of Petroleum Measurement Standards (MPMS), Chapter 21.1, *Electrical Gas Measurement*⁴⁾
- [3] A.G.A. Transmission Measurement Committee Report No. 10, *Speed of Sound in Natural Gas and Other Related Hydrocarbon Gases*³⁾

²⁾ Available from <http://www.astm.org/standard/>.

³⁾ Available from American Gas Association website (www.aga.org) or their official stockist at <http://www.techstreet.com>.

⁴⁾ Available from <http://api-ec.api.org/Publications>.

3 Symbols and abbreviations

Table 1 Symbols and abbreviations

Symbol	Meaning	Units
A	cross-sectional area of meter body	m^2
C_f	velocity of sound in a fluid	m/s
CI	confidence interval	—
D	diameter of meter spool	m
E_i	indicated flow rate error in percent	(%)
F	single calibration factor	—
f_r	frequency	Hz
f_i	variable weighting factor for i th velocity path	—
k_h	theoretical correction factor	—
k_r	uniform equivalent roughness	mm
K	meter factor typically the ratio of reference/meter flows	—
L	acoustic path length between two ultrasonic transducers	m
mA	current in milli-amps	mA
P	absolute static pressure of gas	Bar
q_i	flow rate	m^3/s
$q_{\max}$	maximum volumetric flowrate of meter	m^3/s
$q_{\min}$	minimum volumetric flowrate of meter, as specified by the manufacturer, as being the flowrate below which the expanded error limit for the meter class is exceeded.	m^3/s
q_t	transitional volumetric flowrate where the specified performance of the meter changes	m^3/s
q_v	volumetric flow rate	m^3/s
R_a	arithmetic mean deviation of the (roughness) profile	μm
T	temperature of fluid	$^{\circ}\text{C}$
t_{ab}	transit time for ultrasound to travel from transducer a to transducer b	s
t_{ba}	transit time for ultrasound to travel from transducer b to transducer a	s
USM_{tol}	predetermined tolerance	%
Δt	$t_{ba} - t_{ab}$	s
$\bar{t}$	mean of t_{ab} and t_{ba}	s
τt	average transducer/electronic delay time.	s
v_i	averaged axial component of velocity along the path between two transducers	m/s
$\bar{v}$	mean pipe velocity	m/s
V	voltage	V
w_i	constant weighting factor for i th velocity path	—
Wf_i	flow rate weighting factor	—
X	distance between transducers in the axial plane	m
Z	compressibility of fluid	—
θ	angle between the direction of ultrasound and the axis of the pipe	$^{\circ}$
a.c.	alternating current	—
d.c.	direct current	—
SNR	signal to noise ratio	—
SPU	signal processing unit	—
USM	ultrasonic flowmeter	—
USMP	USM package, including meter, meter tubes, flow conditioner and thermowell	—
VOS	velocity of sound	—
WME	weighted mean error	—

4 Selection

COMMENTARY ON CLAUSE 4

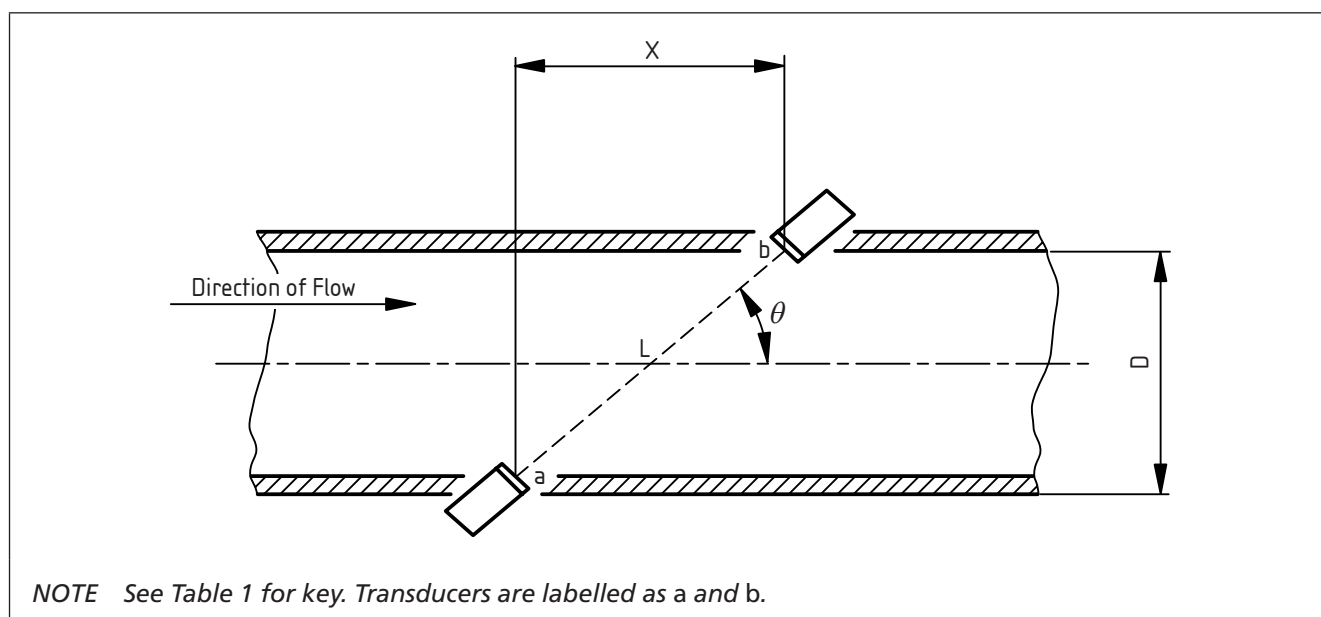
There are a number of USMs currently in service and under development. This clause aims to present a generic overview of the meters available and offer guidance as to their selection for specific applications.

4.1 Principle of measurement

USMs are based on the measurement of the propagation time of acoustic waves in a flowing medium. Generally, the assertion that the apparent velocity along a path is given by the velocity of sound in the fluid at rest C_f plus the averaged axial component of fluid velocity along the path between the transducers v_i is applied. To eliminate the velocity of sound from the subsequent derivation, transit times are determined both in the direction of flow and against it. Considering the general ray geometry shown in Figure 1, the upstream and downstream transit times are given by the following equations:

$$t_{ab} = \frac{L}{(C_f + v_i \cos \theta)} \text{ and } t_{ba} = \frac{L}{(C_f - v_i \cos \theta)} \quad (1)$$

Figure 1 General ray geometry for transit time velocity measurement



There are four basic methods by which transit time velocity measurement may be performed: direct time differential, phase differential, phase control, and frequency differential as defined in BS ISO/TR 12765:1998, Clause 3 and Clause 5. In modern ultrasonic flowmeters the direct time differential method is most common. Short pulses are propagated upstream and downstream and the time interval for each excitation/detection is measured against an accurate

high-frequency clock. In this case, the expressions for the upstream and downstream transit times are then solved for v_i as follows:

$$\frac{1}{t_{ab}} - \frac{1}{t_{ba}} = \frac{(C_f + v_i \cos \theta) - (C_f - v_i \cos \theta)}{L} \quad (2)$$

$$v_i = \frac{L}{2 \cos \theta} \times \left(\frac{1}{t_{ab}} - \frac{1}{t_{ba}} \right) = \frac{L}{2 \cos \theta} \times \frac{\Delta t}{t_{ab} t_{ba}} = \frac{L^2}{2X} \times \frac{\Delta t}{t_{ab} t_{ba}} \quad (3)$$

where

$$\cos \theta = X/L$$

To obtain the volumetric flow rate q_v , individual velocity measurements are combined by a mathematical function to yield an estimate of the mean pipe velocity and multiplied by the cross-sectional area of the measurement section, A , as follows:

$$q_v = A \bar{v} \quad (4)$$

where

$$\bar{v} = f(v_1, \dots, v_n); \quad (5)$$

where

n is the total number of paths.

Even for a given number of paths, the exact form of $\bar{v} = f(v_1, \dots, v_n)$ differs due to variations in path configuration and different proprietary approaches to solving Equation 5 (see 4.3).

4.2 Factors affecting performance

The performance of a USM is dependent on a number of intrinsic and extrinsic factors.

Intrinsic factors (i.e. those related to the meter and its calibration, as applicable to the class of meter, prior to delivery) include the:

- geometry of the meter body and ultrasonic transducer locations and the uncertainty with which these are known;
- accuracy and quality of the transducers and electronic components used in the transit time measurement circuitry (e.g. the electronic clock stability);
- techniques utilized for transit time detection and computation of mean velocity (the latter of which determines the sensitivity of the meter to variations in the flow velocity distribution);
- calibration applicable to the class of meter (for static calibrations this includes proper compensation for signal delays in electronic components and transducers);
- thermal expansion coefficient of the meter body;
- pressure coefficient of the meter body.

Extrinsic factors (i.e. those related to the flow and environmental conditions of the application) include the:

- flow velocity profile;
- temperature distribution;
- flow pulsation;
- gas composition;
- noise (acoustic and electromagnetic);
- solid and liquid contamination;
- impurities in the gas.

4.3 Description of generic types

4.3.1 General

This subclause is a generic description of USMs for gases. It recognizes the scope for variation within commercial designs and the potential for new developments. For the purpose of description, ultrasonic meters are considered to consist of several components, namely:

- transducers, see 4.3.2;
- meter spool (and acoustic path configuration), see 4.3.3;
- electronics, data processing and presentation unit(s), see 6.5.

4.3.2 Transducers

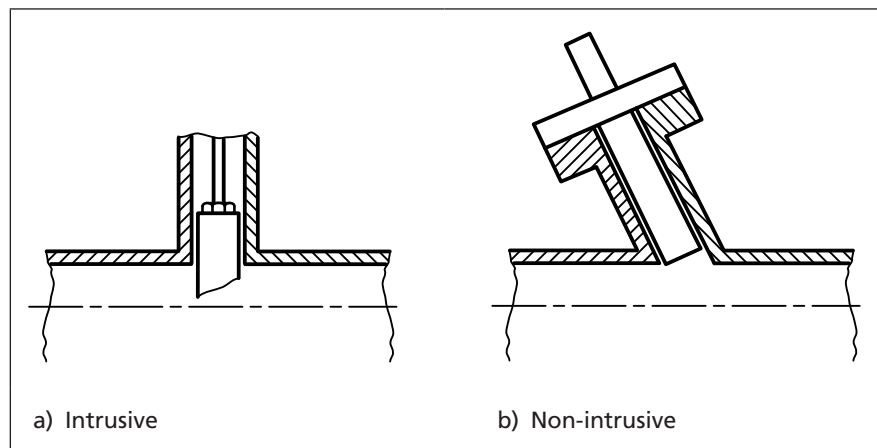
Transducers can be supplied in various forms. Typically, they comprise a piezoelectric element with electrode connections and a supporting mechanical structure with which the process connection is made. The process connection can be welded, flanged or threaded, or can be more mechanically complex, for example, to allow removal of transducers from a pressurized line. When inserted in the line, the active element transmits ultrasonic waves at an angle to the meter spool axis in the direction of a second transducer or reflection point in the meter spool interior. The active element is usually isolated from the fluid by a mechanical barrier.

For specific applications, special transducers might be needed to cope with the conditions below. These special transducers can differ from the norm in terms of frequency, construction materials and mechanical arrangement. Transducer specification and mounting should be given careful consideration for extreme or difficult application conditions, such as:

- high gas flow velocities;
- high, low and/or rapid cyclic temperature;
- high, low and/or rapid cyclic pressure;
- corrosion/erosion;
- wet or "dirty" gas;
- close proximity to high ultrasonic noise sources;
- the gas composition.

Two general examples of transducer design are depicted in Figure 2.

Figure 2 Transducer designs



4.3.3 Meter spool and acoustic path configurations

4.3.3.1 General

The meter spool is a conduit comprising one or more pairs of ultrasonic transducers. An acoustic path is the transmission link between two transducers through the flowing fluid. USMs are available in a variety of path configurations. A particular configuration is generally chosen based on a requirement with respect to variations in velocity distribution and/or built in redundancy requirements.

As well as variations in the chordal location of the measurement paths in the cross-section, the path configuration can be varied in orientation to the pipe axis. By utilizing reflection of the ultrasonic wave from the interior of the meter spool or from a fabricated reflector, the path can traverse the cross-section several times.

4.3.3.2 Elementary acoustic paths

Elementary acoustic paths are illustrated in Figure 3. The number of traverses and three-dimensional geometry of each traverse describe an arbitrary path.

Certain path configurations might offer reduced susceptibility to disturbed flow profiles; claims for any such reduced susceptibility need to have been demonstrated by the manufacturer with appropriate supporting test data.

Figure 3 Variations in path configuration

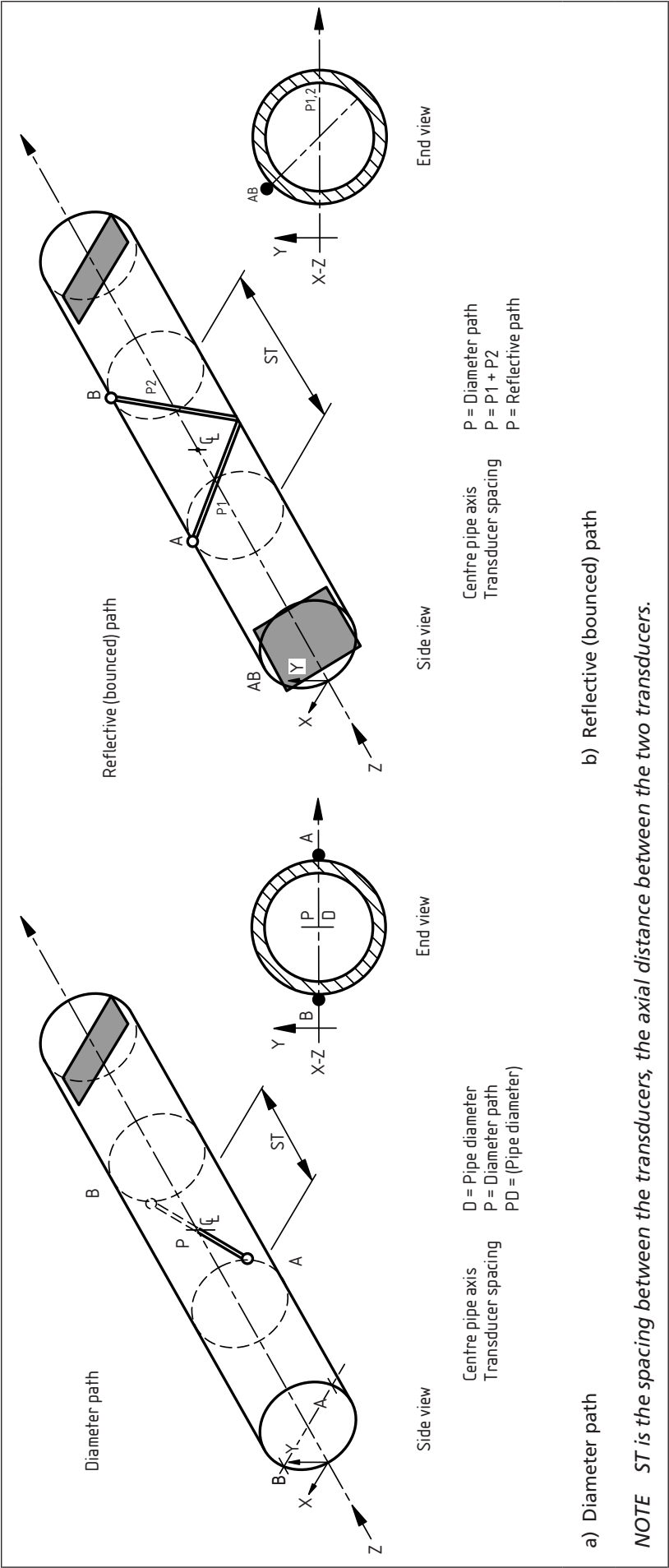
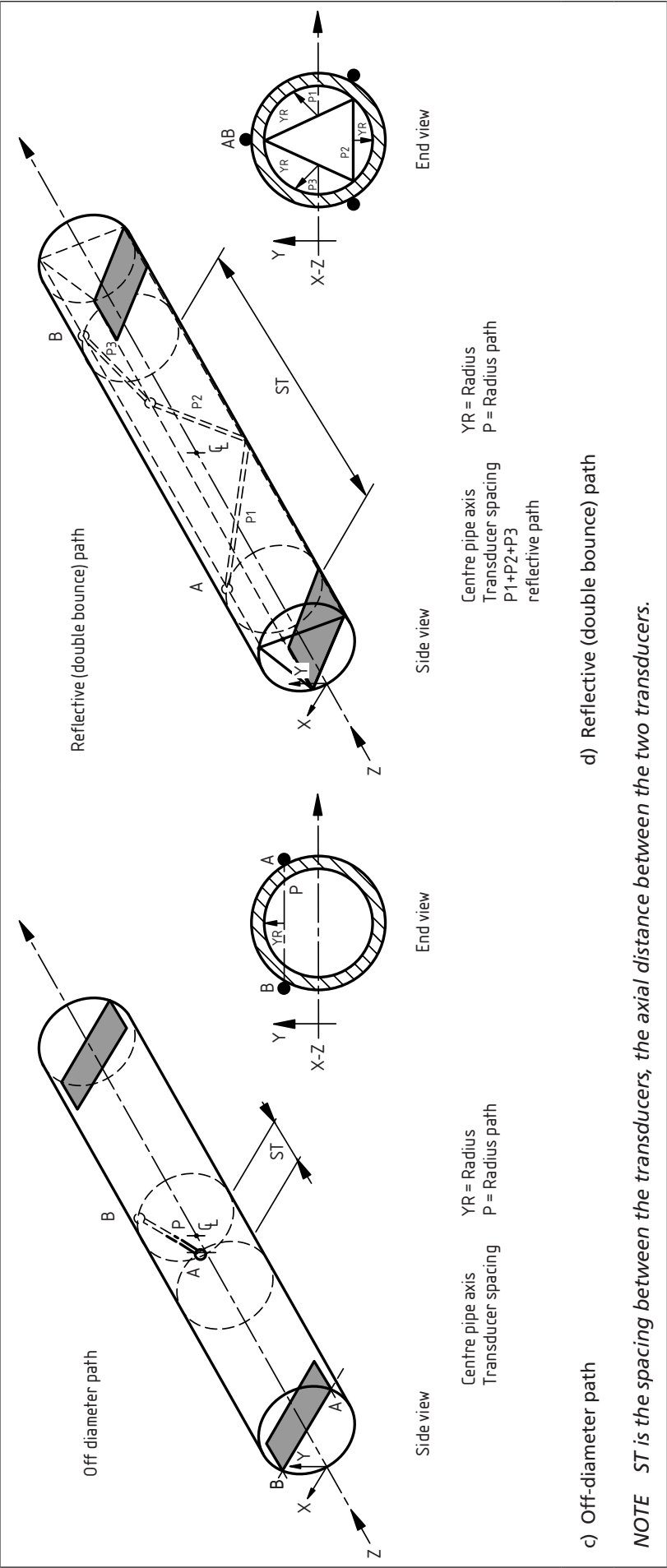


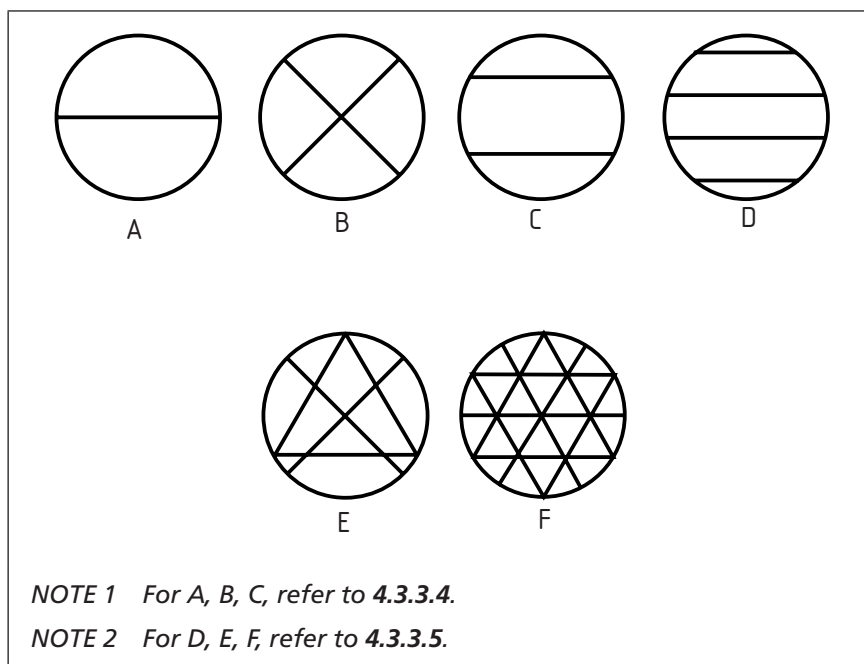
Figure 3 Variations in path configuration (continued)



4.3.3.3 Common cross-sectional path configurations

The cross-sectional configuration is important as this dictates what information about the axial velocity distribution is available for computation of the mean axial velocity. A selection of commonly encountered cross-sectional configurations is shown in Figure 4. It should be noted that the actual configuration selected by the manufacturer for a specific meter type can incorporate beams of equal radial displacement, paths at multiple radial displacements or a combination of both.

Figure 4 Some typical cross-sectional acoustic path configurations



4.3.3.4 Meters with paths of equal radial displacement

Meters with beams of equal radial displacement (e.g. A, B, C in Figure 4) essentially make the same measurement with respect to velocity distribution if the flow is axisymmetric, regardless of the number of paths employed. For this reason, the mean velocity is usually determined by simple average. In fully developed flow a theoretical correction factor, k_h , can be introduced to account for the known variation in velocity profile.

$$\bar{v} = k_h \frac{\sum_{i=1}^n v_i}{n} \quad (6)$$

where

n is the total number of paths.

The k_h factor is a function of Reynolds number, pipe roughness and radial displacement. In practice, it can be input as a single constant or can be calculated on the basis of static parameters and/or measured variables.

4.3.3.5 Meters with paths at multiple radial displacements

In the case of these meters (e.g. configurations D, E and F in Figure 4), the velocity is measured at different radial positions. Several methods can be used when combining the velocities to obtain the mean pipe velocity. These can be classified as follows.

- Summation with constant weighting:

$$\bar{v} = \sum_{i=1}^n w_i v_i \quad (7)$$

where the radial displacements of the paths and the constants w_i to w_n are determined on the basis of documented numerical integration methods. Or

- Summation with variable weighting:

$$\bar{v} = \sum_{i=1}^n f_i v_i \quad (8)$$

where the radial displacements of the paths are fixed at design and the variables f_i to f_n can be determined from input parameters and/or measured variables (e.g. velocities). To allow analysis of the sensitivity of this meter design to velocity profile, the function used to determine f_i should have been documented by the manufacturer.

In any of the given configurations, a multiplying or meter factor, K , (either constant or variable) can be applied after summation to correct for deviations due to manufacturing tolerances and/or incomplete assumptions (see Equation 9).

$$q_v = KA\bar{v} \quad (9)$$

4.4 Criteria for selection

The aim of this sub-clause is to aid the user in making a meter selection based on the overall uncertainty required for the measurement. This divides the meters available into (essentially) four classes of performance as outlined in Table 2.

Table 2 Class performance criteria – Meter requirements

Class	Total USM uncertainty (actual volume flow) %	Repeatability %	Reproducibility %	Resolution mm/s	Error limit (plus or minus) %	
					Large meters	Small meters
1	< ±0.7	< ±0.20	< ±0.30	< 1	0.7	1.0
2	< ±1.5	< ±0.25	< ±0.60	< 2	1.0	1.5
3	< ±3.0	< ±0.35	< ±0.90	< 4	1.5	2.0
4	< ±7.5	< ±0.50	< ±1.20	< 10	3.0	3.5

NOTE Large meters are defined as those meters with nominal bores equal to or greater than 254 mm (10 inches), whilst small meters are defined as those meters with a nominal bore below 254 mm (10 inches).

Actual meter performance, inclusive of total meter uncertainty, repeatability, resolution and maximum peak-to-peak error, depends upon a number of factors which include:

- pipe internal diameter;
- acoustic path length;
- number of acoustic paths;
- gas composition/speed of sound;
- meter timing repeatability (itself a function of transducer frequency); and
- actual flow velocity.

Class 3 and Class 4 meters are often retro-fitted to existing process plant where flow rates are uncertain and sometimes unknown, where piping geometry does not support a fully developed velocity profile, where meter spools are not third-party calibrated or indeed the transducer ports are welded to the parent-pipe section on site and the transducers inserted through hot-tap methods. The should provide the manufacturer with comprehensive process data and consult with them to assess actual meter performance versus required meter uncertainty for a given application, see Table 3.

Table 3 System uncertainties and applications – System requirements

Class	Typical system uncertainty	Maximum installation effect	Typical applications
	%	%	
1	$< \pm 1.0$	0.3	Custody transfer
2	$< \pm 2.0$	0.5	Allocation
3	$< \pm 4.0$	1.0	Utilities/fuel gas
4	$< \pm 10$	5.0	Process/flare gas

The four classes represent different measurement specifications commonly applied in UK industry. Depending on the importance of measurement with respect to regulatory or fiscal demands, the total uncertainty budget for the system is different, as outlined within Table 3. To aid the user in meter selection, an approximate uncertainty budget for the meter is suggested in order to meet the system uncertainty budget. A significant part of the total value for the USM uncertainty comes from the uncertainty of the calibration facility where the meter was flow calibrated. Typical uncertainty values from recognized gas flow calibration establishments are in the order of $\pm 0.3\%$.

NOTE 1 These applications are for guidance only, each application to be considered on its own merits.

NOTE 2 See Annex A for the application of flow calibration results and Annex B for methods of correcting flow measurement error.

The difference between the uncertainty figures of the meter and the system indicates the uncertainty budget permitted in determining additional uncertainties associated with the metering process e.g. secondary instrumentation, derivation of density and flow computers. For example, the composition, pressure and temperature of a gas might result in an uncertainty value for the derivation of density that causes the budget available for the system to be exceeded: for these

reasons it is important that this aspect is not neglected. For natural gas, A.G.A. Report No. 8 [1] should be consulted for guidance on the derivation of density and uncertainty.

When identifying a meter for a particular purpose, it is important for the user to have access to the information in Table 2 and Table 3. In respect of Table 2, this information should be obtained from the meter manufacturer and it is recommended that the user reviews actual test data regarding the meter performance when purchasing for the first time or from a new supplier or manufacturer.

Other criteria for selection can be determined by regulatory or statutory bodies, such as the Department of Energy and Climate Change (DECC) Energy Group:Energy Development Unit, and also agreements between companies for custody transfer/allocation metering. USMs have a large potential advantage over other forms of flowmeter owing to the availability of diagnostic software. This means that not only is a measurement made, but also information is gathered regarding the measurement process and the fluid itself. This can in turn allow for further criteria for selection. For example the accuracy of measurement in the event of a path failure is important in many custody transfer applications. For most other forms of flowmeter a major failure in the measurement process would lead to a complete shutdown while the meter is replaced. In the event of a path failure with USMs, it is possible for some meters to substitute values in place of the failed path measurements from knowledge of the velocity profile present in the meter prior to the failure. For Class 1 meters, the additional error owing to a path failure should, under stable flowing conditions, be less than 0.1%.

5 Installation recommendations

5.1 General

The guidance in this clause has been derived from comparable meter standards, good engineering practice and experience gained to date in the testing of these meters. Installation criteria should be considered in conjunction with specific recommendations from outside agencies such as the meter manufacturers, the statutory authorities and other interested parties.

5.2 Environmental considerations

5.2.1 Temperature

Some USMs might be sensitive to differences between ambient and line temperature and adequate insulation, heating and/or cooling should be installed in order to minimize the effects of extreme differences between ambient and line temperature.

The meter should be able to operate within specification within an ambient air temperature range of -25°C to 55°C . This temperature range applies to the meter body with and without gas flow, field mounted electronics, ultrasonic transducers, cabling, etc. The manufacturers should provide ambient temperature specifications for the USMs if different from -25°C to 55°C .

For Class 1 and Class 2 applications, where optimum accuracy is required or the gas temperature varies from the ambient temperature, the meter spool and the meter tube assembly, including the upstream and downstream pipework, should be fully insulated. This insulation should extend up to and include the thermowell housing of the temperature element and also any intermediate flanges and fittings.

Sudden large changes in temperature caused for example by compressor start-up or close proximity to a flare stack should be avoided. It is also important to insulate the meter spool when there is a deep cavity between the inner pipewall and the transducer fronts.

5.2.2 Vibration

The manufacturer should be consulted regarding the performance of the meter in a vibrating environment as there is a potential for measurement error. It is recommended that measures are taken to isolate sensitive equipment from the vibration source, such as the provision of anti-vibration mountings.

5.2.3 Electrical noise

Good wiring practice should be implemented to minimize the effect of electrical noise.

NOTE Readers are reminded of EMC-RF obligations for equipment used within the EU, some of which may be met by conformity to BS EN 61000-6-3 and BS EN 61000-6-4.

The meter and associated electrical conduits, cables and circuits should be designed and installed in accordance with applicable electrical codes and particular care should be taken with the type of screening and routing of interconnecting cable installed between the transducers and the control unit.

5.2.4 Mechanical noise

COMMENTARY ON 5.2.4

Additional information on gas control valve interference with gas USMs is available in Flow Guidance Note #43 [5].

Some installations, including for example pressure reducing control valves, which are specifically designed to reduce audible noise, can produce very high levels of ultrasonic noise under certain flow conditions. The ultrasonic noise from these control valves can interfere with the operation of a nearby ultrasonic flowmeter even when the valve is located downstream of the USM. The manufacturer should be consulted when planning to install a USM in the vicinity of a pressure-reducing component including control valves, reducers, etc.

If acoustic noise is considered to be a potential problem for the USM in service, a means should be provided to monitor its impact on the meter using the signal to noise ratio (SNR); an alarm facility might be needed to advise the operator when the ratio exceeds an acceptable level.

In general, it is good practice to locate control valves, compressors, etc. downstream of the USM. If this is not possible then the maximum distance between the control valve and the USM should be targeted. Blind tees, baffles and other such fittings, which provide high attenuation, should be fitted between any source of noise and the USM. This precaution should be taken for both downstream and upstream sources of noise. These devices should be fitted at the

maximum distance from the USM that the pipework allows, given that some of them can and will produce distorted velocity profiles.

USM manufacturers recognize the potential for operating problems, and most USMs have diagnostic capabilities that indicate whether acoustic noise impairs meter performance while operating. Strategies have also been devised by users and manufacturers to estimate and/or limit a USMs susceptibility to noise interference, such as:

- evaluation of USMs response to acoustic noise prior to station installation;
- enhanced signal processing to improve ultrasonic pulse recognition and detection;
- signal filtering to narrow the bandwidth surveyed for better/faster pulse recognition;
- installation of fittings, such as blind tees or filters, to isolate the noise source from the USM;
- development of specialized silencers that are installed in the piping between the USM and the noise source to isolate the meter from the noise.

In general, noise sources upstream of USMs have a more adverse impact on meter performance than those installed downstream, although downstream installation of pressure reduction or other noise generating equipment does not guarantee interference will not occur. Also, greater separation between a noise source and the USM and the consequent increased number of fittings, provides more attenuation than would be the case if the meter and source were installed in close proximity to each other.

When considering installation of a USM, particularly in the vicinity of pressure or flow regulation (the most common noise generators), the factors that should be taken into account during the USM station design phase are:

- the installed position of valves (as potential noise sources) relative to the meter (upstream, downstream, distance between meter and source, number and type of fittings between meter and source);
- the operating frequency of the meter and the range of frequencies generated by the noise source (noise reduction trim valves are of particular concern since the design generates noise exceeding audible frequencies which is often in the ultrasonic range);
- whether additional attenuation between noise source and USM is required, which could include blind tees or other fittings or acoustic filters (see 5.2.4);
- whether enhanced filtering of digital signal processing has to be applied and, if so, whether it slows signal processing time beyond acceptable limits (limits are given for a linear measuring device in API MPMS Chapter 21.1 [2]);
- the cost/benefit of pursuing one or more strategies to limit USM exposure to offending acoustic noise.

When installation of a USM near a potential noise source is anticipated, it is recommended that users contact manufacturers for recommendations specific to their products and the proposed installation prior to finalizing USM station design. Cooperation between specifiers/users and manufacturers during the design of the facilities can avoid the need for potentially expensive remedial actions at a completed meter installation.

5.2.5 Gas composition restrictions

The presence of certain gases might impact on the performance of a meter (for example, high levels of carbon dioxide and hydrogen in a gas mixture can influence and even inhibit the operation of a USM owing to their acoustic absorption properties); meter manufacturers should be supplied with the expected constituents of the gases to be measured and the associated pressure and temperature range.

5.3 Installation conditions

5.3.1 Flow direction

Where the flow is in one direction only, the user should ensure this is clearly marked on the body of the meter. For bi-directional applications, both ends of the USM should be considered upstream and the markings attached to the meter spool clearly indicating the primary flow direction.

NOTE For example, plates may be affixed to the meter as a means of marking.

5.3.2 Upstream and downstream fittings

COMMENTARY ON 5.3.2

Various combinations of upstream fittings (valves, bends, expanders, tees, reducers, etc.) might produce velocity profile distortions and swirl at the inlet to the USM that could result in measurement errors. The magnitude of error is dependent on the type and severity of the flow distortion and the ability of the USM to compensate for this distortion. To a much lesser extent, downstream fittings could also affect the accuracy of the meter.

The manufacturer should be consulted to evaluate how upstream and/or downstream fittings and piping configurations can affect the performance of the USM. In the absence of performance data for a specific installation, and certainly where a Class 1 or Class 2 meter is involved, it might be necessary to use a flow-conditioner and calibrate the USM and flow conditioner together (see 5.3.3). Alternatively, it might be necessary to model the system by experimental means in order to determine its impact on the USM.

The general configuration of the pipework upstream of the meter tube assembly and the self-compensating features associated with the USM should be taken into account when assessing the potential impact of pipe geometry on the velocity profile of the gas. For Class 1 applications, the meters should only be installed where the impact of fittings and pipe-work configurations does not have a detectable effect on the performance of the meter. In all circumstances, the pipework should be designed so that swirl or poor velocity profiles that affect the installed uncertainty of the meter reading are not produced, i.e. that these effects are within the manufacturer's stated limits for the meter; this might be verifiable at site by on-board diagnostics in certain multi-path USMs.

To ensure that the USM, when installed in the user's piping system, will perform within the specified flow rate measurement accuracy limits, good metering practice should be followed.

The installer/user may choose to flow calibrate the USM in-situ or at a flow calibration facility in which the test piping configuration is identical to the planned installation. Alternatively, for Class 1 and