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Flow Metering Calculations

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Revision History

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Disclaimer

This manual is provided for information only, and is intended as a reference for those attending the training course. No warranty expressed or implied is made regarding the accuracy of the contents.

Contents

Chapter 1 Introduction

1.1 Objective

The main objective of this course is to familiarise delegates with the calculations most commonly used in flow computers and in high-accuracy flow measurement in general. The many options that some calculation standards provide are explained in detail. On successful completion of the course delegates will be able to:

- Identify the most appropriate calculations for a particular application or activity
- Review the calculations for a particular application critically, and identify errors and inconsistencies
- Understand the available calculation options, and select the appropriate ones
- Understand the main parameters needed for correct calculation, and find suitable values
- Identify the likely reasons for problems in a calculation check
- Understand the evaluation routes and alternatives for complex calculations, and use this knowledge to locate calculation problems

These objectives may be modified as required for specific presentations of the course. These course notes include details of relevant equations and methods for future reference.

This course may be presented in two forms. The briefer introductory presentation is purely a class session, and uses only these notes. A more extended version with practical examples is also available if there is sufficient time and the conditions noted in the following section can be met. The extended version usually requires some customisation, depending on the available resources.

1.2 Course Versions and Requirements

1.2.1 Introductory Version

Delegates should already have a general appreciation of flow metering systems, in particular the instruments used and the information that the instruments provide. This can, for example, be achieved by attending our "Introduction to Flow Metering Systems" course.

1.2.2 Extended Version

Delegates should bring a laptop with Microsoft Excel or equivalent installed in order to complete the examples.

Some form of calculation checking software is also necessary. Kelton FloCalc or FlowSOLV can be used if delegates already have sufficient licences, or are able to negotiate them on a temporary basis. Alternatively, delegates could download and install Spirit Flow-Xpert to a Smartphone or (preferably) an iPad or Android tablet before attending the course, see http://www.spiritit.com/products/product/flow-xpert-calculations/. Flow-Xpert is free for such devices.

It is desirable for one or more flow computers with an application that is relevant to the delegates to be available for use during the course, and it is even better if simulation can be provided. The presenter is familiar with the following flow computers:

- Emerson S600

- Omni
- Spirit Flow-X
- Krohne Summit 8800 / Ex-I SFC 3000

Other flow computers and calculation checking software can be supported by agreement.

1.3 Overview

The vast majority of fiscal flow measurement applications are for crude oil, refined products, natural gas, and LNG/LPG. They are therefore covered in the most detail. All of these products are mixtures of many components, so density or composition measurement is normally necessary.

Pure products such as Ethylene are measured from time to time, and pure water can be relevant to prover calibration. In these cases the product properties can be deduced from temperature and pressure alone. Notes and references are included in this course to give a general awareness of methods that can be used in these and other less common cases.

Standards are central to this course, and wherever possible standards references of some kind are given. This is because it is highly desirable for every calculation that is used for a particular purpose to be supported by a well-known standard. This approach avoids errors as well as minimising argument and discussion.

The standards covered here are generally the latest versions, most of which have been in place for ten years or more. Some old versions of standards are still commonly used, are therefore also considered. A few relatively new standards that have not yet found widespread use are mentioned. Considerable detail is given of the main calculations that may be used, together with the options that the associated standard allows, which can be extensive in some cases.

Current international standards provide methods of calculating nearly everything that is needed for flow measurement. There are a few areas, however, where it is necessary to resort to one or more of the following:

- National standards
- Matters of definition
- Basic physics
- Historic standards
- Reference books
- Manufacturer's proprietary equations

National standards may have to be used in areas that are not covered by international standards. For example, a few calculations from ASTM (USA), GOST (Russia), and VDI (Germany) are used when necessary. For UK presentations, we will consider the implications of the Oil & Gas Authority (formerly DECC) guidelines though they do not specifically define any calculations.

An example of a **matter of definition** is that volume multiplied by density gives mass. All the proof that is needed for this result can be found in the dictionary, but see below.

An example of **basic physics** is the law of conservation of mass. Again, this hardly requires proof and in principle it needs no reference, but see below.

Occasionally a useful result is removed from a standard, and it is necessary to refer to a **historic standard** to justify its use. This can be dangerous, as the result was presumably removed for a reason.

Some **reference books** are held in such respect that they almost qualify as standards, especially those that are published by standards bodies. Examples include:

- The API Technical Data Book for Petroleum Refining
- The Gas Processors' and Suppliers' Association Engineering Data Book

- Perry's Chemical Engineers' Handbook

Manufacturer's proprietary equations apply, for example, to corrections for flow meters and particularly calculation of density from densitometer pulses. Some of these are so commonplace that they can almost be regarded as standards in their own right.

While it should not be necessary to justify matters of definition or basic physics, particularly zealous reviewers or inspectors may demand a reference for everything. A key function of flow measurement standards is to define exactly how the principles of physics should be applied in particular situations, using definitive data, to ensure that everybody consistently gets the same results. Because of this, they frequently refer to the equations of basic physics and can therefore provide references for them.

1.4 Field Equipment

Calculations do not exist in isolation: they are driven by the hardware installed in the field, and by the requirements of each project. So while field hardware is not the main subject of this course, it cannot be completely avoided. For example, the temperature correction for a gas densitometer depends on how it is installed. We will cover this briefly where necessary.

1.5 Parameter Values

A calculation will clearly give the wrong answers if it is fed with the wrong inputs! These notes therefore address the question of finding suitable parameter values. There is also a chapter on constants and conversions.

The flow computer will need a default for every parameter. Where a value is known and it is unlikely to change during the life of the system, it makes sense to use it as a default. Where a parameter is not known, there is no option but to use an estimate. The design should allow such data to be easily entered later.

Some values are available before the system leaves the manufacturer, but it is also known that they will be subject to change, for example when a prover is recalibrated or a worn orifice plate replaced. In this case, typical values can be used. Some end-users prefer these values to be obviously rounded, so there is no risk of mistaking them for similar actual values when a new flow computer is installed and configured.

1.6 Copyright

The calculation standards discussed in this course are copyright material. It would be convenient to provide copies to delegates, but that would be a breach of copyright. It is, however, common practice to quote equations and tables from standards in specifications and such, so this document does so.

Some of the standards mentioned here that do not relate directly to calculation are freely downloadable, for example the ISO/IEC Directives that define how standards should be developed.

1.7 ISO Terminology

It is not our purpose here to discuss how standards are made, but ISO in particular has a formal system that has a bearing on how its standards are applied. Parts of this system are gradually being adopted by the API as it issues new revision of standards.

Normative and Informative

ISO divides its recommendations into two types. **Normative requirements** are an integral part of the standard, and an implementation that does not follow them cannot claim to be compliant. **Informative requirements**, usually given in appendices, are advisory so an implementation that ignores them can still claim compliance. That is clear in principle, but the advice of an ISO standard is not something to ignore lightly. It would generally need either a lot of authority or another equally credible reference that says something else to justify such a course.

Technical Reports

ISO publishes Technical Reports (ISO/TR) where they have useful information to circulate but for one reason or another cannot publish it as a standard, or consider it best not to do so. The content of technical reports is therefore advisory rather than binding.

Technical Reports are much more likely to go unnoticed than full standards, but as we shall see they can sometimes resolve tricky questions.

1.8 Symbols and Units

Standards from different sources use different symbols, so it is difficult to be consistent. Partly because symbols are used in different ways in different equations, and partly because it is inconvenient to refer constantly to a symbols table in the back, each section defines its own symbols as they are needed. It is assumed that sections will be read as a whole, so symbols are not redefined constantly.

The following special symbols are used in the unit tables:

~	**Complex units that do not matter**
–	Dimensionless value
*	Any units may be used, as long all starred units are consistent

Units are usually shown for symbols where they are inputs and outputs of the calculation, although they are skipped for variables such as densitometer constants where the units are complex and irrelevant. Where intermediate values and constants have complex units that do not contribute to the discussion, they are not given. Dimensionless values have no units: for example, the ratio of two pressures falls into this category. Equally, the ratio of two absolute pressures does not depend on the units of the two values as long as they are consistent (and absolute), so that would be indicated by a star.

In the symbol tables, the inputs to each calculation or calculation step are shown first. The outputs are shown below, with a double line between them and the inputs. Where two double lines occur in a symbols table, the inputs are at the top, intermediate values provided by the standard are in the middle, and the outputs are at the bottom.