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GI-EM-06-05

Final version
October 2006

Guidance note on energy determination: implementation of certain principles presented in relevant standards

Standing Committee Gas Infrastructure / Working Group Energy Measurement *

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Executive Summary

This MARCOGAZ *Guidance Note on Energy Determination* expresses the position of the gas distribution and transportation industry, clarifies some important concepts related to energy determination, and proposes some practical solutions for use by the gas industry, standardisation bodies and other national authorities.

Chapter 1 begins with the situation created by the liberalisation of the European gas industry. European Directives, as implemented in national regulations, have lead to increasingly demanding requirements to be met by companies acting in such a Single European Market and regulation and unbundling are critical issues for the gas industry.

European gas companies began preparing for the consequences of liberalisation at quite an early stage. This has led to the opening up of infrastructure systems to promote international gas trading. This has highlighted the importance of many technical aspects of the new market conditions.

One such technical aspect is gas measurement and metering technology, and it plays a central role in consumer billing. It lies at the heart of the gas industry; more so than any other technology. In a way, it is the bridge between the commercial and technical sides of the gas business.

The initial task of the Energy Measurement Working Group (WG-EM) was to conduct a survey of existing practices in this area, the results of which are summarized in **Chapter 2**. It shows that current practice differs across Member States in specific aspects, such as: network structure, company organisation and legal requirements. And yet - whilst the approaches may be different - the goal for all companies remains the same: to ensure high quality measurement and correctness of billing.

Gas companies take great care to ensure that gas delivered to consumers is measured and billed as precisely as possible at each point of change in custody. Large import stations often manage several million cubic meters per hour, whilst household diaphragm meters typically measure an average volume flowrate of less than one cubic meter per hour. It is evident, therefore, that metering strategies must strike a balance between accuracy and cost-effectiveness. **Chapter 3** provides the Marcogaz point of view, introducing basic concepts such as error, uncertainty and the MPE (maximum permissible error) in an energy determination context. These valuable concepts are often employed with differing terminology that reflects the intended use. In particular, Chapter 3 describes how the approaches of the GUM (ISO Guide to the expression of Uncertainty in Measurement), the OIML (Organisation Internationale de Metrologie Legale) and this guidance note are both linked and consistent with each other. In recognition that this topic is somewhat theoretical Chapter 3 also provides some practical and pragmatic examples of its use in the gas industry.

National and European Regulations and Directives, referring to national and international standards, represent the legal basis for all metering and billing activities. **Chapter 4** summarises the different approaches to Pattern Approval in Member States, which can trigger additional costs and additional time for manufacturers in obtaining approval /certification of measurement devices.

Chapter 1: Objectives

1.1 Introduction

Liberalisation of the European gas market has led to new and increasing demands on gas measuring systems. Price fluctuations and new allocation principles have resulted in the need for accurate energy determination over smaller and smaller time intervals (daily, hourly). Such demands are at present not dealt with adequately in International standards.

1.2 Background and Regulatory Framework

The OIML was created in 1955 and now numbers 57 Member States that are active in technical developments to promote global harmonisation of legal metrology procedures.

Technical Committee TC8 of the OIML (Subcommittee 7 «Gas Metering ») is preparing to publish a text setting out recommendations concerning "Measuring Systems for Gaseous Fuels". This text (hereinafter called the "OIML Recommendation" and at the time of this guidance note in its fourth draft) introduces several important and innovative concepts, such as:

- The idea of a measuring system, which is considered as all the equipment and documentary provision (see below) necessary to determine both volume of gas at base conditions (or, equivalently, the mass of gas) and energy (through the determination of calorific value).
- Use of different accuracy classes (A, B, C) to define performance of measuring systems in terms of an MPE (Maximum Permissible Error)
- A modular approach to permit determination the accuracy class of the overall measurement system from the MPEs of sub-systems (or Modules) for the three key functions necessary to determine energy: measurement at metering conditions, conversion of this volume to volume at base conditions, and conversion of volume at base conditions to energy.
- The use of documentary provision to justify assumptions or declarations of accuracy of non-instrumental processes.

Three classes of measurement system – A, B and C – are considered by OIML for achieving a specified accuracy in the determination of supplied energy. The class values for accuracy are set at 1%, 2% and 3% respectively (class A corresponding to the most demanding applications). Class values are defined on the basis of measuring device capacities and not actual consumption.

Table 1.1: OIML Accuracy classes

Accuracy Class	A	B	C
Determined energy	1%	2%	3%
Calorific value measurement (only CVDD)	0.5%	1.00%	1.00%
Representative Calorific value determination	0.6%	1.25%	2.00%

The OIML leaves it to national authorities to set their own class thresholds. In addition, OIML recommends that National Authorities should set the appropriate accuracy class for a particular application. OIML only gives an indication of these threshold values in an informative annex E.

OIML will also make recommendations on the accuracy of measured volume and of measured and determined calorific value.

The OIML Recommendation applies to measuring systems for gaseous fuel:

- With a designed maximum flowrate Qmax equal to or greater than 100m^3/h at base conditions and for operating pressures equal to or greater than 200 kPa (2 bar) absolute

- Not fitted with diaphragm gas meters.

In the period following its publication, the OIML Recommendation may be translated by each Member State into the framework of national regulations.

In this context, the Measurement Instrument Directive (MID) has recently been approved by the EU Council and comes into force in 2006. The MID's main purpose is to prevent trading barriers by restricting national demands to gas measurement equipment. This will extend the use of EC approved devices and harmonize methods of assessment of devices.

1.3 Consequences of the evolution in standards and regulations

The current framework of standards and regulations is essentially geared to the determination of volumes and based on approval of devices. The new approach, as embodied in the OIML Recommendation, is more global and recognises the quality of measured delivered energy. This could lead in some case in:

- Revision of some documented provisions and/or some existing measurement systems
- Adoption of systems for measurement and allocation of calorific value

Should a new regulatory framework arise from the OIML Recommendations, gas transmission and distribution operators may need to agree suitable implementation with their national authorities and to specify the main provisions of any new regulation, with due regard to its economic impact.

With the OIML Recommendations, the entire method used for the determination of energy is considered, which requires calculation of the global error in energy arising from each module of the measurement system.

1.4 Objectives of the guidance note on energy determination

It is in the interest of the gas companies to exchange information as early as possible about technical solutions and how the OIML approach could be translated in a regulatory framework. A common position should help harmonise the use of the OIML Recommendation within the regulatory framework of each Member State and assist in guaranteeing a defined degree of equality in the treatment of customers.

The Standing Committee Gas Infrastructure (SCGI) of MARCOGAZ constitutes an appropriate framework to organise these exchanges where representatives of many European gas companies can participate.

The Working Group Energy Measurement (WG-EM) held its first meeting in Brussels in September 2002 in which representatives of nine European gas companies participated. During subsequent WG EM meetings it became clear that a common Guidance Note was required on energy determination concerning implementation of those key principles presented in the OIML recommendation, other relevant standards and the MID.

This MARCOGAZ Guidance Note expresses the position of the European gas distribution and transportation industry, clarifies some important concepts related to energy determination, and proposes some practical solutions for use by the gas industry, standardisation bodies and other national authorities. This guidance note is consistent with general principles of relevant International Standards, the MID, the OIML Recommendation and the commercial demands brought by liberalisation.

In comparing the OIML Recommendation against common EU gas measuring practice, WG-EM considers that measuring periods must also be declared for each accuracy class and the justification for this is given in Chapter 3 and Annex B.

An additional accuracy class D should also be considered for smaller gas measurement systems (e.g., domestic, commercial applications).

Chapter 2: Current practice determined from the benchmark survey

This chapter summarises the main results of a benchmark survey, made through use of a questionnaire, concerning the current practices in every European country/company.

The questionnaire gathers information concerning items such as: general information on each company's network, legal aspects (organisation of gas metrology, patterns approval, verification procedures, etc.), energy determination methods, delivery point installations (RTU, ECVD, GC, etc.), acquisition systems, architectures of data processing system, contractual aspects, organisation of gas metering for billing and approved devices.

2.1 General information

The following general conclusions were drawn from consideration of the information volunteered by each company and where appropriate, a range from the lowest to the highest value is presented.

The amount of gas transported varies between companies and is generally between 7 and 110 billion m^3/year[1] with a range of pressure from 103 to 10 000 kPa.

The number of entry points to each country is between 3 and 64 including those from fields and storage, whilst the number of exit points is between 45 and 7000 considering connection with other transmission network, distribution network and end users (excluding domestic).

Companies receive gas from a minimum of 2 and a maximum of 12 sources of natural gas with differing quality type, with a maximum annual variation in calorific value of 2.5 – 7.5 MJ/m^3. To determine gas quality, companies mainly utilise gas chromatographs – the number of which varies from 5 to 150 depending on the size and complexity of the network.

2.2 Legal aspects

From the questionnaire it emerged that for most European countries, gas companies have discussed the OIML Recommendation with their National Authority but only about half of them have discussed the classification (A, B, C) proposed by the document. In comparison companies in around half of the countries have discussed the MID with their National Authority.

There are differences amongst countries in the approach to legal metrology. In a few cases the National Authority does not require approval or certification either for all or certain types of devices (either flow measurement or GCV measurement).

Legal verification for almost all countries is made by a National Authority or by a certified organization.

The pressure used for initial calibration of flow meters and for subsequent periodic verification/calibration differs between countries, ranging from 60-70 bar starting from atmospheric pressure. Direct connection between flow computer and GCV device is not always allowed.

The time period over which metering information are validated is common among countries (monthly) as is the practice of recalculation of billing data when metering data is missing or invalid.

2.3 GCV assignment

The energy content of gas is determined by multiplying measured volume and gross calorific value (GCV). Ideally, if technically achievable at reasonable cost, every customer would have an energy meter and be billed on the actual energy consumed. In practice, for most consumers GCVs are not directly determined and an assignment method is used, because of the high cost.

In general gas networks are divided into charging areas in which each consumer is assigned a common GCV value that - in conjunction with volume measurement - is used for billing purpose. The number of charging areas varies from country to country, ranging from 7 to about 200 depending upon the amount of gas transported and distributed, the variation in gas quality, and the number of entry and exit points.

The methods used to assign the GCV for energy determination for invoicing often differ and depend on the network structure, the regulatory framework, the possibility of blending gases of different quality, the number and type of customers, and the size of gas network.

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[1] Volumes quoted in this guidance note are given for gas at reference conditions of 0°C and 101.325 kPa unless stated otherwise.

The assigned GCV value is calculated by averaging of GCVs determined by one or more devices installed at the entry point into that charging area. The average GCV can be averaged either daily, monthly or annually, often depending on whether it is used in a transmission system, distribution system or local system.

If an area is supplied by more than one entry point, a flow weighted average GCV is calculated from gas flows at each entry point.

Different approaches are taken when gases of significant different quality supply a charging area. The following approaches were reported:

- If the difference between the average GCVs of the entry points to the charging area exceeds ±2% of the total flow weighted average GCV (over the charging period) the grid operator can refuse the gas.
- If the flow weighted GCV average exceeds the lowest source GCV by more than a representative value (typically 1 MJ/m^3) the billing GCV is capped at this level.
- If the difference between the average GCV determined within the area and the average GCV determined at any entry point to the area exceeded ±2%, then the borders of the area are adjusted to compensate and the charging GCV is recalculated.
- The lowest GCV value is used, irrespective of differences in gas quality.

Some companies are using or plan to use simulation programs to assign a GCV for billing individual consumers. However in all cases such simulation software has been or will have to be certified by the National Authority.

Chapter 3: Technical approach adopted in this guidance note

3.1 Introduction

The OIML Recommendation introduced two key concepts in the area of energy measurement which are adopted in this guidance note:

(i) Employing classes of measurement system of differing accuracy. The introduction of accuracy classes serves two main purposes. Firstly, it offers means of ensuring minimum accuracy requirements are met (i.e., appropriate accuracy of measurement are employed). Secondly, it permits installation of a cost-effective measurement system (i.e., not at excessive cost).

(ii) Treatment of an energy measurement system as comprising a number of modules, each of which serve to perform a specific function within the global energy measurement process. Each module could be either an instrument (e.g., a meter or a calorific value determining device) or a calculation or functional process (e.g., assignment of a calorific value, or conversion of quantity of gas to energy using a representative calorific value).

The global accuracy in energy measurement is related to the accuracy of the individual modules that make up the measurement system and this chapter addresses how modular accuracies are combined to derive global accuracy. It also addresses how minimum accuracy requirements can be defined either globally or on a modular basis, how classes and their corresponding threshold values might be set, and suggests a technical approach to selecting equipment to meet a given accuracy class.

Note: A number of examples are offered for clarification of the approach set out in this chapter. However, these examples are informative and should not be taken as evidence that any particular equipment or provisions meet a particular accuracy requirement.

3.2 General Principles

The principle adopted in this guidance note is to set accuracy classes in terms of a maximum permissible error (MPE). MPEs are the extreme values permitted by a specification or standard for a given accuracy class.

At the individual module level, the error displayed by a module may depend on the value of one or more input parameters. The MPE is the most extreme value in error that is permitted by a specification or standard for all values of the input parameters for which the MPE applies. So for instance:

(i) The error in volume at metering conditions from a gas meter may depend on the flowrate of gas passing through the meter. A gas meter compliant with Accuracy Class B will therefore show a distribution in errors in volume, but - over the operational range of flowrates for that meter - no error in volume is likely to exceed the MPE permitted for this class of meter (± 1.2%).

(ii) The error in calorific value of a (gas chromatography based) CVDD may depend upon the composition of the gas. A CVDD compliant with Accuracy Class A will show a distribution in errors in calorific value, but - over all compositions for that CVDD - no error in calorific value is likely to exceed the MPE permitted for this class of meter (± 0.5%).

At the overall measurement system level, however, the error in energy for the measurement system will depend upon all of the input parameters that affect the errors arising from the individual modules that comprise the measurement system. A measurement system will therefore show a distribution of errors in energy that results from combination of distributions of errors arising within the individual modules, but - over the operational range for the measurement system (flowrates, compositions, etc.) - no error in energy is likely to exceed the MPE permitted for a given class of measurement system.

Estimation and combination of distributions of errors of individual modules to achieve a distribution of errors in energy for the overall measurement system can be carried out by full application of the principles and approach of the GUM (*ISO Guide to the Expression of Uncertainty in Measurement*).

However, in many circumstances it is appropriate simply to calculate a mean error for each module and combine the estimates of such mean errors for each module by arithmetic addition to achieve an overall error in energy for the measurement system. The uncertainty in the overall error in energy for the measurement system is obtained by combining estimates of the uncertainty in the module mean errors by addition in quadrature. Uncertainty in module mean errors arises from the distribution of individual module errors as well as the uncertainty in the individual errors themselves.

If overall error in energy is no greater than the MPE for the measurement system, then the system complies with that accuracy class. However, in making that comparison, account has to be taken of not just the overall error in energy, ε(E), but also the uncertainty in overall error in energy, U(ε(E)). Compliance with a given accuracy class requirement is therefore denoted by the following criterion:

$$\left(\left|\varepsilon(\mathrm{E})\right| + \mathrm{U}(\varepsilon(\mathrm{E}))\right) \le \mathrm{MPE}$$

Demonstration of compliance with the above criterion involves two steps:

(i) Estimation of overall error in energy. In this Guide we recommend that overall error is estimated by combining estimates of mean error for each module. Mean module errors are combined by **arithmetic** addition.

(ii) Estimation of uncertainty in overall error in energy. In this guidance note we recommend that uncertainty in overall error is estimated by combining estimates of uncertainty in mean error of each module. Uncertainties in mean module errors are combined by addition **in quadrature**.

To illustrate this point, the simplest approach of a measurement system comprising individual modules known to comply with a particular accuracy class is considered below.

***Example 3-1**: An energy measurement system comprises an Accuracy Class A metering module, an Accuracy Class A volume conversion module and an Accuracy Class A CVDD. From the module MPEs given in Chapter 1, Table 1-2 the overall error in energy and its uncertainty are calculated as follows*:

Table 3-1: Calculation of overall error in energy and its uncertainty (simple approach)

Module	***Accuracy Class***	***MPE***	***Mean error***	***Uncertainty in mean error***
Metering	*A*	*± 0.7%*	*0%*	*± 0.7%*
Volume conversion	*A*	*± 0.5%*	*0%*	*± 0.5%*
CVDD	*A*	*± 0.5%*	*0%*	*± 0.5%*
Overall error in energy for the measurement system *(obtained from arithmetic addition of module mean errors)*			*0%*	
Uncertainty in overall error in energy for the measurement system *(obtained from addition in quadrature of the uncertainties in module mean errors)*				*± 0.995%*
(rounded to 1 dp)				*± 1.0%*

The above approach has two advantages. Firstly, it is consistent with the agreed methodology outlined in GUM. Details of this consistency are given in Annexe A. Secondly, in general the approach adopted when designing and building energy measurement systems is to ensure module errors can be assumed to be zero with an uncertainty estimated from the accuracy class of the module MPE. Under these circumstances, the approach is mathematically equivalent to that suggested by the OIML Recommendation (i.e., addition of module MPEs in quadrature).

It must be stressed, however that in reality it is not module MPEs that are being combined in quadrature, but estimates of uncertainty in mean module errors (which are derived from module MPEs).

In situations in which one or more mean module errors may not be assumed to be zero, then arithmetic addition of module errors may give rise to non-zero overall error in energy for the measurement system. An example of such a situation is application of a fixed factor for volume conversion, where the fixed factor may not be optimised for the range of operating conditions of the measurement system.

Justification for arithmetic addition of module errors and addition of uncertainties in module errors in quadrature is given in Annexe B of this guidance note.

3.3 Time period for energy determination

Energy generally relates to a time period during which gas flows, and yet the OIML Recommendation does not specify time periods for which each of its accuracy classes apply. In general this approach is acceptable provided that constant relative module errors can be demonstrated. In situations where constant absolute error(s) exist, then relative global error in energy may accumulate with time and a time period should be associated with an accuracy class. Justification for this important concept is given in Annexe B of this guidance note.

3.4 Deriving module errors and uncertainties in module errors

In some circumstances, a more detailed approach to demonstration of compliance with a measurement system accuracy class may be appropriate. This may be achieved by demonstration of actual module performance, rather than assumption of performance (i.e., mean error and uncertainty in mean error) from the MPE given for the module class. Below, the various approaches to energy measurement are outlined and guidance is given on estimating mean module errors (and their uncertainties) and combining them to estimate overall measurement system performance.

Generally, energy measurement can be characterised as following one of four approaches:

By totalising uncorrected volumetric flowrate:

(a)

$$E = K_a[C_a]\int_{t=t_1}^{t=t_2} F(t).dt$$

Where:

F is the volumetric flowrate at (varying) metering conditions of temperature and pressure.

[T], [P], [Z] are constants, representative of the (varying) parameters T, P and Z.

K_a is a constant, representative of the conversion factor to convert volumetric flowrate at metering conditions to a volumetric flowrate at standard conditions over the period of totalisation.

$$K_a = \frac{T_b}{[T]}\frac{[P]}{P_b}\frac{Z_b}{[Z]}$$

$[C_a]$ is a constant, representative of the calorific value of the gas metered over the period of totalisation.

By totalising volumetric flowrate that is corrected to a standard temperature (“T conversion”):

(b)

$$E = [K_b].[C_b].\int_{t=t_1}^{t=t_2}\left[\frac{F(t)}{T(t)}\right].dt$$

Where $K_b = T_b\frac{[P]}{P_b}\frac{Z_b}{[Z]}$

By totalising volumetric flowrate that is corrected to a standard temperature and pressure (“PT conversion”):

(c)

$$E = K_c[C_c]\int_{t=t_1}^{t=t_2}\left[\frac{P(t).F(t)}{T(t)}\right].dt$$

Where $K_c = \frac{T_b}{P_b}\frac{Z_b}{[Z]}$

By totalising volumetric flowrate that is converted to volume flowrate at standard conditions (“PTZ conversion”):

(d)

$$E = K_d.[C_d]\int_{t=t_1}^{t=t_2}\left[\frac{P(t).F(t)}{T(t).Z(t)}\right].dt$$

Where $K_d = \frac{T_b Z_b}{P_b}$

By integrating power:

(e) $$E = K_e \int_{t=t_1}^{t=t_2} \left[C(t).\frac{P(t).F(t).Z_b(t)}{T(t).Z(t)} \right].dt$$

Where $K_e = \frac{T_b}{P_b}$

Error and uncertainty in error will arise from the instrumentation associated with measurement of flowrate, temperature, pressure, compression factor and gross calorific value, as well as performing calculations set out in the above equations (e.g., totalisation or integration, volume conversion, etc.).

In addition, error and uncertainty in error will arise from the use of constant, representative, values for volume conversion (i.e., the K_i) and for gross calorific value (i.e., $[C_i]$). The error and uncertainty in error will depend on how gas quality varies over the period of time that totalisation or integration is performed.

Depending on what approach, (a) to (e), is taken to measure energy, different methods of estimating of error and uncertainty in error may be employed:

(i) By measurement and calibration of an instrument

(ii) By inference, using knowledge of the module accuracy class for an instrument

(iii) By documentary provision, in support of estimates of fixed factors

In this situation, and in accordance with the GUM, it is recommended that uncertainties in module errors are estimated and combined at the standard deviation level (standard uncertainty). In the absence of information about the distribution of errors, the GUM requires that standard uncertainty is derived from MPE by division by √3. If information on the distribution of errors is available then a divisor other than √3 (e.g, 2) may be appropriate. The combined standard uncertainty in error is then expanded to a probability level of around 95% by multiplication by a coverage factor, k. Where the overall error in energy is near zero a value of k=2 may be assumed. However, if overall error in energy is significantly non-zero, then an alternative value for k may be more appropriate. This is discussed in more detail in Annexe A.

Use of these different methods is illustrated by the examples given below.

***Example 3-2**: An energy measurement system comprising a rotary or turbine meter, employing error correction across the operating flowrate range, an electronic volume conversion device and a process gas chromatograph whose sampling point is located close to the volume measurement point.*

Module	Mean error	Standard uncertainty in mean error	Justification
Metering	**0%**	*± 0.15%*	*Unconverted volumetric flowrate using a rotary or turbine meter may generally be assumed to give zero mean error with a standard uncertainty in mean error of around ± 0.577% (u(ε(V) = 1.0 / √3 = ± 0.577%) if compliant with EN 12480 (rotary meters) or EN 12261 (turbine meters). Correction for meter error across applicable flow range should reduce the standard uncertainty to a value of around u(ε(E) = ± 0.15% (typical flow calibration laboratory expanded uncertainty is ± 0.3%).*
Volume conversion	**0%**	*± 0.577%* *(± 0.5%,)*	*Volume conversion (employing PTZ conversion) using electronic systems compliant with EN 12405 may be assumed to give zero mean error with a standard uncertainty in mean error of around ± 0.577% (u(ε(V_b) = 1.0 / √3 = ± 0.577%).* *(If documentary provision justifies a divisor of 2, a standard uncertainty in mean error of ± 0.5% may be assumed.)*
Energy conversion	**0%**	*± 0.063%*	*Determination of calorific value using a local gas chromatograph can be demonstrated to give zero mean error with a standard uncertainty in determined calorific value of around 0.025 MJ/m^3, i.e., u(ε(GCV_{gc}) = ± 0.025 MJ/m^3 or ± 0.063%, assuming an average GCV of 39.5 MJ/m^3. This uncertainty includes uncertainty in the response of the gas chromatograph and uncertainty in the composition of the calibrated standard.*
	0%	*0%*	*Assuming that sampling and analysis times are short (typically 5 minutes) there is no uncertainty associated with location.*
	0%	*0.147%*	*Uncertainty in bias error also arises from the choice of calibration gas and the variation in composition of the gas metered. Performance evaluation to ISO 10723 demonstrates that bias error over the analytical range of the instrument does not exceed ± 0.1 MJ/m^3, i.e., u(ε(GCV_{bias}) = 0.1 / √3 = ± 0.058 MJ/m^3 or ± 0.147%, assuming an average GCV of 39.5 MJ/m^3).*
Overall error in energy	**0%**		*Arithmetic addition of mean module errors*
Standard uncertainty in overall error in energy		*± 0.617%* *(± 0.545%)*	*Addition in quadrature of standard uncertainties of mean module errors* *(Assuming a divisor of 2 in volume conversion)*
Expanded uncertainty in overall error in energy		*± 1.2%* *(± 1.1%)*	*Using a coverage factor of k=2 and rounding final result to 1 dp* *(Assuming a divisor of 2 in volume conversion)*

Example 3-3: *An energy measurement system comprising a rotary or turbine meter, not employing error correction across the operating flowrate range and a PT conversion device which employs a fixed factor to correct for non-ideality of gas (Z_b/Z). Conversion to energy is carried out daily by use of a charging area calorific value calculated from the net energy flows and net volume flows into the charging area ("flow-weighted average calorific value").*

Module	**Mean error**	**Standard uncertainty in mean error**	**Justification**
Metering	0%	*± 0.577%*	*Unconverted volumetric flowrate using a rotary or turbine meter may generally be assumed to give zero mean error with a standard uncertainty in mean error of around ± 0.577%* $(u(\varepsilon(V) = 1.0 / \sqrt{3} = \pm 0.577\%)$ *if compliant with EN 12480 (rotary meters) or EN 12261 (turbine meters*
Volume conversion	0%	*± 0.577%*	*Volume conversion (using PT conversion) using electronic systems compliant with EN 12405 may be assumed to give zero mean error with a standard uncertainty in mean error of around ± 0.577%* $(u(\varepsilon(V_b) = 1.0 / \sqrt{3} = \pm 0.577\%)$.
	0%	*± 0.36%*	*Non-ideality of gas: The single fixed factor is selected so as to give zero mean error in* Z_b/Z*. The standard uncertainty in mean error in* Z_b/Z *is estimated from the variance in gas quality entering the charging area (standard deviation = 0.36%).*
Energy conversion	0%	*± 0.60%*	*Conversion to energy using a representative CV: Documentary provisions should justify the assumption that conversion to energy using a representative CV gives a zero mean error* $(\varepsilon(GCV)=0)$*. When gas flows into a charging area are measured using Accuracy Class A measurement systems the uncertainty in error in representative GCV is dominated by the variation in source GCV. Typical variation in GCV of gas sources to the charging area gives a standard uncertainty in GCV error of 0.60%.*
Overall error in energy	0%		*Arithmetic addition of mean module errors*
Standard uncertainty in overall error in energy		*± 1.075%*	*Addition in quadrature of standard uncertainties of mean module errors*
Expanded uncertainty in overall error in energy		*± 2.1%*	*Using a coverage factor of k=2 and rounding final result to 1 dp*

Example 3-4: *An energy measurement system comprising a rotary or turbine meter, not employing error correction, operating at a pressure of 100 mbarg and a T conversion device which employs a fixed factor to correct for non-ideality of gas (Z_b/Z) and pressure. Conversion to energy is carried out daily by use of a charging area calorific value calculated from the net energy flows and net volume flows into the charging area ("flow-weighted average calorific value").*

Module	**Mean error**	**Standard uncertainty in mean error**	**Justification**
Metering	0%	*± 0.577%*	*Unconverted volumetric flowrate using a rotary or turbine meter may generally be assumed to give zero mean error with a standard uncertainty in mean error of around ± 0.577%* $(u(\varepsilon(V) = 1.0 / \sqrt{3} = \pm 0.577\%)$ *if compliant with EN 12480 (rotary meters) or EN 12261 (turbine meters*
Volume conversion	0%	*± 0.577%*	*Volume conversion (using T conversion): Electronic systems compliant with EN 12405 may be assumed to give zero mean error with a standard uncertainty in mean error of around ± 0.577%* $(u(\varepsilon(V_b) = 1.0 / \sqrt{3} = \pm 0.577\%)$.
	0%	*± 0.36%*	*Non-ideality of gas: The single fixed factor is selected so as to give zero mean error in* Z_b/Z*. The standard uncertainty in mean error in* Z_b/Z *is estimated from the variance in gas quality entering the charging area (standard deviation = 0.36%).*
	0%	*± 0.259%*	*Meter inlet pressure: The single fixed factor is selected so as to give zero mean error in meter inlet pressure. The variation of meter inlet pressure for a pressure regulator of accuracy class RG5 is taken to be ± (0.05*100)/√3 mbar or ± 0.259% (inlet pressure 1113 mbar).*
	0%	*± 0.908%*	*Barometric pressure: The single fixed factor is selected so as to give zero mean error in barometric pressure. The variation of gas pressure is taken to be ± (17.5/√3) mbar or ± 0.908% (inlet pressure 1113 mbar). Documentary provision to justify this assumed variation should be provided.*
	0%	*± 0.143%*	*Altitude: The single fixed factor is selected so as to give zero mean error in altitude. The variation of meter altitude is taken to be ± (25/√3) m or ± 0.143% (mean altitude 25 m, inlet pressure 1113 mbar and a mean barometric pressure drop of 0.11 mbar/m).*
Energy conversion	0%	*± 0.60%*	*Conversion to energy using a representative CV: Documentary provisions should justify the assumption that conversion to energy using a representative CV gives a zero mean error* $(\varepsilon(GCV)=0)$*. When gas flows into a charging area are measured using Accuracy Class A measurement systems the uncertainty in error in representative GCV is dominated by the variation in source GCV. Typical variation in GCV of gas sources to the charging area gives a standard uncertainty in GCV error of 0.60%.*
Overall error in energy	0%		*Arithmetic addition of mean module errors*

Module	**Mean error**	**Standard uncertainty in mean error**	**Justification**
Standard uncertainty in overall error in energy		*± 1.438%*	*Addition in quadrature of standard uncertainties of mean module errors*
Expanded uncertainty in overall error in energy		*± 2.9%*	*Using a coverage factor of k=2 and rounding final result to 1 dp*

Example 3-5: *An energy measurement system comprising a diaphragm meter operating at a pressure of 22 mbarg, which employs a fixed factor to correct for non-ideality of gas (Z_b/Z), temperature, pressure and altitude. Conversion to energy is carried out daily by use of a charging area calorific value calculated from the net energy flows and net volume flows into the charging area ("flow-weighted average calorific value").*

Module	**Mean error**	**Standard uncertainty in mean error**	**Justification**
Metering	0%	*± 0.866%*	*Unconverted volumetric flowrate using a diaphragm meter may generally be assumed to give zero mean error with a standard uncertainty in mean error of around ± 0.75% ($u(\varepsilon(V) = 1.5 / \sqrt{3} = \pm 0.866\%$) if compliant with EN 1359 (excluding meters compliant with Annexe B of EN 1359).*
Volume conversion	0%	*± 0.36%*	*Non-ideality of gas: The single fixed factor is selected so as to give zero mean error in Z_b/Z. The standard uncertainty in mean error in Z_b/Z is estimated from the variance in gas quality entering the charging area (standard deviation = 0.36%).*
	0%	*± 2.204%*	*Temperature: The single fixed factor is selected so as to give zero mean error in temperature. The variation of gas temperature is taken to be ± ($11/\sqrt{3}$) °C or ± 2.204% (mean temperature 15 °C).*
	0%	*± 0.123%*	*Meter inlet pressure: The single fixed factor is selected so as to give zero mean error in meter inlet pressure. The variation of meter inlet pressure for a pressure regulator of accuracy class RG10 is taken to be ± ($(0.1*22)/\sqrt{3}$) mbar or ± 0.123% (inlet pressure 1035 mbar).*
	0%	*± 0.976%*	*Barometric pressure: The single fixed factor is selected so as to give zero mean error in barometric pressure. The variation of gas pressure is taken to be ± ($17.5/\sqrt{3}$) mbar or ± 0.976% (inlet pressure 1035 mbar).*
	0%	*± 0.153%*	*Altitude: The single fixed factor is selected so as to give zero mean error in altitude. The variation of meter altitude is taken to be ± ($25/\sqrt{3}$) m or ± 0.153% (mean altitude 25 m, inlet pressure 1035 mbar and a mean barometric pressure drop of 0.11 mbar/m).*
Energy conversion	0%	*± 0.60%*	*Conversion to energy using a representative CV: Documentary provisions should justify the assumption that conversion to energy using a representative CV gives a zero mean error ($\varepsilon(GCV)=0$). When gas flows into a charging area are measured using Accuracy Class A measurement systems the uncertainty in error in representative GCV is dominated by the variation in source GCV. Typical variation in GCV of gas sources to the charging area gives a standard uncertainty in GCV error of 0.60%.*

Overall error in energy	0%		*Arithmetic addition of mean module errors*
Standard uncertainty in overall error in energy		*± 2.670%*	*Addition in quadrature of standard uncertainties of mean module errors*
Expanded uncertainty in overall error in energy		*± 5.3%*	*Using a coverage factor of k=2 and rounding final result to 1 dp*

Chapter 4: Pattern Approval

4.1 European Regulation

This chapter presents the situation in Europe concerning type approval for gas energy measurement systems. As the thermal energy of a quantity of natural gas supplied is calculated from the volume (or mass) at base conditions and the relevant caloric value, an overview of the practices on gas meters, volume conversion devices, and calorific value determination devices (CVDD) is presented.

In past years, the lack of common European rules for most instrument pattern approvals triggered additional costs and significant time spent in obtaining type approval for a measuring device in every European country of intended use. Whilst this chapter cannot present the actual rules (laws, decrees, specifications, etc.) in all European countries, some figures given by gas companies are presented in Annexe C to show general differences in approach to pattern approvals in their respective countries.

As far as the framework of European regulations is concerned, the only Directive to have any direct impact at the moment is Directive 71/318/EEC published on July 26, 1971 regarding the harmonisation of legislation in the various Member States concerning gas volume measurement systems. This directive will be replaced by the Measurement Instrument Directive 2004/22/EC (MID) of the European Parliament and Council, released in March 2004.

The MID establishes the requirements that devices and systems have to satisfy with a view to their being placed on the market. It is intended to help unify European rules for pattern approval and introduce conformity in assessment of instruments as soon as the MID is effective throughout all Europe. The MID comes into force in 2006.

Nevertheless, the MID does not cover all instruments in the energy measurement systems used by gas companies. Basically, for natural gas measurements, the MID describes the conformity of gas meters and volume conversion devices for residential, commercial and light industrial uses (MI-002). The upper limit in terms of flow rate or energy consumption is not definite and National bodies will set their own values. This situation therefore excludes CVDDs and all large metering systems. The MID introduces the concept of durability of instruments - not currently defined - for most of the gas meters and volume conversion devices. Finally, the MID does not describe periodic verification, which must be defined by National bodies.

4.2 OIML recommendation

All instruments not covered by the MID, could be type approved using the same international rules if the national authorities of Legal Metrology apply the OIML recommendations (R6, R31, R32 or the CD of TC8 SC7 and TC8 SC8). Nevertheless, there is no strict obligation for any national authority of Legal Metrology to follow the recommendations published by the OIML. It must be noted that the maximum permissible errors and the class of equipment are harmonised between OIML and the MID.

The OIML Recommendations of TC8 SC7 introduce requirements for energy measurement systems of different class of uncertainty, for larger applications (flow rate higher than 100 m^3/h and pressure higher than 2 bar) excluding diaphragm meters and mass to volume conversion. The concept of a measuring system can involve not only instruments, but also data and figures provided for documentary provision. This is necessary to carry out energy determination on the natural gas network.

The work developed by OIML TC8 SC8 is more dedicated to gas meters developed by manufacturers in which functionality corresponding to individual modules may be built in a single unit.

4.3 European and International standards

In order to ease the task of proving conformity, the MID and most of the National bodies recognise CEN (and CENELEC) as competent body for the adoption of harmonised standard in accordance with the general guidance of the EC or OIML.

Several standards published by CEN/TC237 related to products, specify the requirements and tests for the construction, performance and safety, and carefully describe the test procedures and requirements for type approval tests for the following instruments:

- EN 1359 – Diaphragm gas meters
- EN 12261 – Turbine gas meters
- EN 12480 – Rotary displacement gas meters
- EN 12405-1 – Gas volume electronic conversion devices

The EN standard relating to CVDDs is not yet released. CEN/TC237/WG4 is in charge of the prEN 12405-2 which specifies the requirements and tests for the construction, performance, safety and conformity of electronic conversion devices (volume conversion device, gas meter and CVDD) used to determine energy of fuel gases. This equipment may be integrated or not and they are separable. Moreover, conversion devices that can utilise either a fixed or periodically updated calorific value are included in the scope of this WG. The Committee Draft should be released at the end of 2006.

Several standards released by ISO are also widely used in Legal Metrology as reference:

- ISO5167 – 1 to 4 on pressure differential inserted in conduits
- ISO6976 – for the calculation of CV, density, Wobbe index of dry natural gas
- ISO12213 – 1 to 3 for the calculation of compression factor

Finally, ISO/DIS 15112 provides the means for energy determination of natural gas by measurement or by calculation, and briefly describes the techniques and measures that have to be taken. The general means of uncertainty calculations are given. This standard also gives an accurate list of normative references, which constitute provisions for this ISO standard.

No international specifications exist and no working group is in charge of the standardisation of the determination of CV on the delivery points from the CVDD measurements.

Annexe A – Consistency in approach of GUM and OIML

Use of mean error of measurement system and uncertainty in mean error

The OIML Recommendation is principally aimed at the performance of measurement systems and in particular specification of the maximum error that a measurement system may display over the range of conditions applicable to the measurement system. This is termed the MPE.

The GUM (*ISO Guide to the Expression of Uncertainty in Measurement*) is principally aimed at the measurement result and its uncertainty. Any errors in the measurement result are generally corrected by application of a correction, b, and the uncertainty in the correction, u(b), is included in the estimate of the uncertainty in the measurement result.

In situations where the required correction, b(t), is a function of an variable input parameter, t, then Section F.2.4.5 of the GUM recognises that in some circumstances it may not always be feasible to apply the individual corrections, b(t), and incorporate the individual uncertainties, u(b(t)) in the uncertainty of the measurement results. In such situations the GUM suggests that a single mean value of correction is computed:

[1] $$\overline{b} = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} b(t).dt$$

where t_1 and t_2 define the range of interest of the parameter t and the best estimate of the measurement result Y(t) is taken to be

[2] $$Y(t) = y(t) + \overline{b}$$

where y(t) is the best uncorrected estimate of Y(t). The variance associated with the use of the mean correction over the range of interest arises from two sources: firstly the variance in the corrections, b(t), and secondly, the variance associated with the uncertainty of the determination of the corrections, b(t).

When estimating the uncertainty in estimates, $y(t) + \overline{b}$, of the measurand Y(t), the GUM recommends use of a single value of standard uncertainty derived from the positive square root of:

[3] $$u_c^2(y') = \overline{u^2[y(t)]} + \overline{u^2[b(t)]} + u^2\left(\overline{b}\right)$$

where the second and third terms in equation 3 are given by:

$$\overline{u^2[b(t)]} = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} u^2[b(t)].dt \quad \text{and} \quad u^2\left(\overline{b}\right) = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} \left[b(t) - \overline{b}\right]^2.dt$$

It can be seen that the distribution in corrections, b(t), is equivalent to the distribution in errors in the measurement system, the mean correction, $\overline{b}$, is equivalent to the mean error of the measurement system, and the uncertainty in the mean correction (the second and third terms of equation 3) is equivalent to the uncertainty in the mean error of the measurement system.

Choice of coverage factor

In this Guide we recommend that the appropriate criterion for compliance with an accuracy class is determined by comparison of the mean error in energy with the MPE, taking into account the expanded uncertainty in the mean error in energy. This is denoted by the following criterion:

$$\left(\left|\varepsilon(E)\right| + U(\varepsilon(E))\right) \leq \text{MPE}$$

where the expanded (combined) uncertainty is calculated by multiplying the standard (combined) uncertainty by a coverage factor *k*.

When the distribution associated with a combined standard uncertainty in a measurement result can be assumed to be Gaussian, the GUM recommends the use of a coverage factor, k = 2, which gives a probability level of around 95%. This is appropriate for a distribution of errors of a measurement system when the mean error of the measurement system is zero or near zero - see Figure A-1. However, if the mean error of a measurement system is significantly far from zero, then a coverage factor of k = 1.64 is more appropriate, (corresponding to the one-sided normal distribution and 95% probability) - see Figure A-2. In intermediate situations it is more appropriate to compute the probability of compliance, by computing the area under the distribution between the limits of -MPE and +MPE.

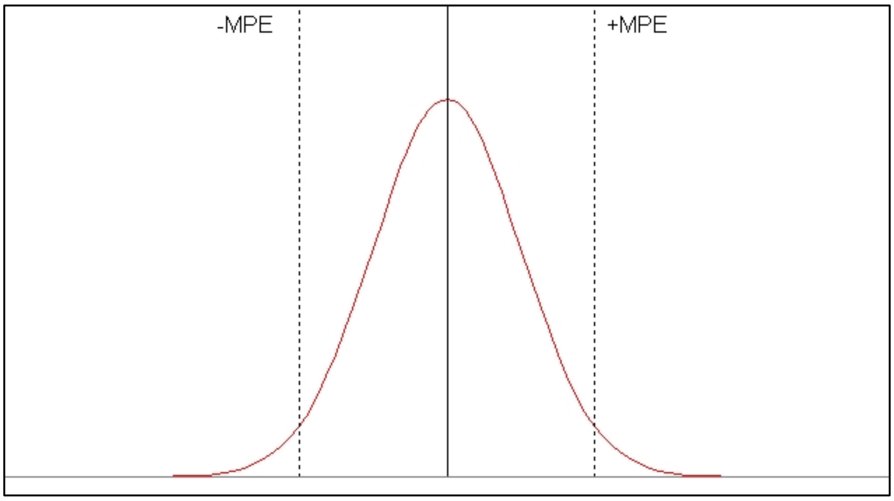

Figure A-1: Selection of appropriate coverage factor, k, (mean error = zero)

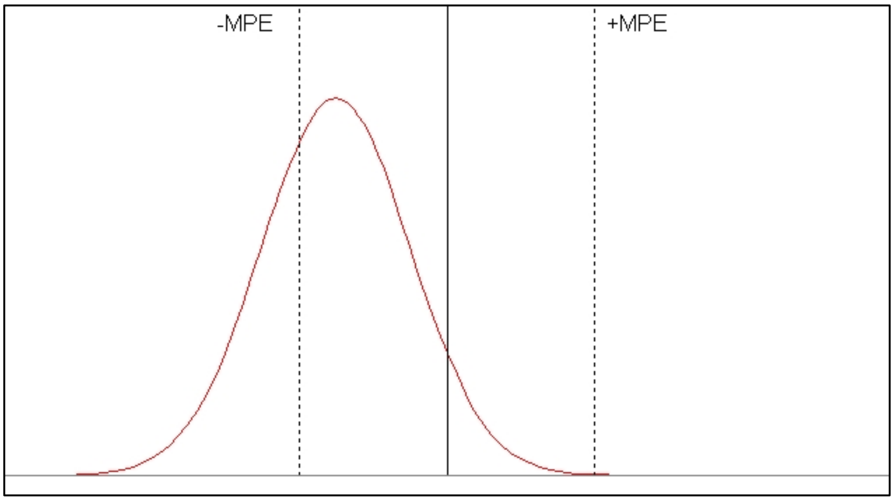

Figure A-2: Selection of appropriate coverage factor, k, (mean error ≠ zero)

Annexe B – Error and uncertainty in error in volume and energy

Error in volume

Volume is computed by integrating volumetric flowrate over time:

$$V = \int_{t=t_1}^{t=t_2} F(t).dt$$

in a flow computer, integration is achieved numerically as summation of flowrate over (relatively) short constant time increments:

$$V \approx \Delta t \sum_{i=1}^{i=N} F_i$$

In practice the F_i may be in error by $\varepsilon(F_i)$ and so the true volume is given by:

$$\mathrm{Vtrue} = \Delta t \sum_{i=1}^{i=N} (F_i - \varepsilon(F_i)) = V - \Delta t \sum_{i=1}^{i=N} \varepsilon(F_i)$$

(Not that error is here defined as the measured value minus a true value, in compliance with GUM practice.)

For high accuracy volume measurement, the Fi are corrected by use of k-factors, where the k-factors permit estimation of error in flowrate as a function of flowrate. K-factors are determined from meter calibration.

However if Fi are not corrected for error, then some assumption or knowledge about how $\varepsilon(F)$ varies with F is required. Assuming that $\varepsilon(Fi)$ can be expressed as a polynomial in Fi we can write:

$$\varepsilon(Fi) = a_0 + a_1 Fi + a_2 Fi^2 + \ldots$$

and

$$Vtrue = V - \Delta t \sum_{i=1}^{i=N} (a_0 + a_1 Fi + a_2 Fi^2 + \ldots)$$

$$Vtrue = V - \Delta t N a_0 - \Delta t \sum_{i=1}^{i=N} (a_1 Fi) + \Delta t \sum_{i=1}^{i=N} (a_2 Fi^2) + \ldots$$

For higher terms in Fi knowledge of how Fi varies with time is required, but for lower orders we may write:

$$Vtrue = V - a_0 t_{tot} - a_1 V$$

Where t_{tot} is the time period for integration or totalisation.

In addition to the situation above, two further simplifications in expressing error in flowrate are possible.

(a) Firstly, constant relative error across the application range in flowrate

$$\varepsilon(Fi) = a_1 Fi$$

which leads to

$$Vtrue = V + a_1 V$$

and

$$\frac{\varepsilon(V)}{V} = \frac{V - \mathrm{Vtrue}}{V} = -a_1$$

In these circumstances, relative error in volume is equal to the relative error in flowrate and time period would not have to be included in a specification that set maximum permissible error in volume.

(b) Secondly, constant absolute error across the application range in flowrate

$$\varepsilon(Fi) = a_0$$

which leads to

$$Vtrue = V - a_0 t_{tot}$$

i.e. absolute error in volume is equal to the product of the error and the time period for integration, and

$$\frac{\varepsilon(\mathrm{V})}{\mathrm{V}} = \frac{\mathrm{V} - \mathrm{Vtrue}}{\mathrm{V}} = \frac{a_0 t_{tot}}{\mathrm{V}}$$

Under some circumstances (e.g., constant flowrate Fi,) relative error in volume would be independent of the time period for integration. However unless this were known to be so, **time period would have to be included in a specification that set maximum permissible error in volume**.

Error in energy

Energy is computed by integrating power over time:

$$E = \int_{t=t_1}^{t=t_2} F(t)C(t).dt$$

in a flow computer, integration is achieved numerically as summation of power over (relatively) short constant time increments:

$$E \approx \Delta t \sum_{i=1}^{i=N} \left(F_i C_c\right)$$

In a similar manner to volume determination, the Ci and the F_i may be in error by $\varepsilon(C_i)$ and $\varepsilon(F_i)$ and so the true energy is given by

$$\mathrm{Etrue} = \Delta t \sum_{i=1}^{i=N} [(F_i - \varepsilon(F_i))(C_i - \varepsilon(C_i)]$$

$$\mathrm{Etrue} = \Delta t \sum_{i=1}^{i=N} [F_i C_i - F_i.\varepsilon(C_i) - C_i.\varepsilon(F_i) + \varepsilon(F_i).\varepsilon(C_i)]$$

$$\mathrm{Etrue} = E + \Delta t \sum_{i=1}^{i=N} [-F_i.\varepsilon(C_i) - C_i.\varepsilon(F_i) + \varepsilon(F_i).\varepsilon(C_i)]$$

Expressing ε(Ci) and ε(Fi) as first order polynomials in Ci and Fi :

$\varepsilon(Fi) = a_0 + a_1 Fi$

$\varepsilon(Ci) = b_0 + b_1 Ci$

and

$$Etrue = E + \Delta t \sum_{i=1}^{i=N} [-F_i.(b_0 + b_1 C_i) - C_i.(a_0 + a_1 F_i) + (a_0 + a_1 F_i).(b_0 + b_1 C_i)]$$

which leads to:

$$Etrue = E + a_0 b_0 t_{tot} + (b_0(a_1 - 1)).V + (a_0(b_1 - 1)).\Delta t \sum_{i=1}^{i=N} (C_i) + (a_1 b_1 - a_1 - b_1)E$$

Two simplifications are possible to cater for lack of information about how Fi and Ci vary with time:

(a) Constant relative error in F and C (i.e., a_0 and b_0 are zero)

$$Etrue = E + (a_1 b_1 - a_1 - b_1)E$$

Provided a_1 and b_1 are relatively small, the cross-term $a_1 b_1$ may be ignored and relative error in energy is the arithmetic sum of the relative errors in flowrate and calorific value.

Note also that time period would not have to be included in a specification that set maximum permissible error in energy.

(b) Constant absolute error in F and C and average calorific value $\overline{C}$

$$Etrue = E - a_0 b_0 t_{tot} - b_0 V - a_0 t_{tot} \overline{C}$$

The average calorific value is more often estimated from samples taken over the time period for integration. This is commonly known as the “representative” calorific value and we can write

$$[C] = \frac{\sum_{j=1}^{j=M} (C_j)}{M} \approx \overline{C} = \frac{\sum_{i=1}^{i=N} (C_i)}{N}, (M \neq N)$$

With constant flowrate F and constant representative calorific value, relative error in energy would be independent of the time period for integration. However unless this were known to be so, **time period would have to be included in a specification that set maximum permissible error in energy.**

Uncertainty in error in volume

For constant relative error across the application range in flowrate (see 1(a)):

$$\frac{\varepsilon(V)}{V} = a_1$$

and we may simply write

$$U\left(\frac{\varepsilon(V)}{V}\right) = U(a_1)$$

Uncertainty in error in energy

For constant relative error in F and C (see 2(a)):

$$\frac{\varepsilon(E)}{E} \approx a_1 + b_1$$

and assuming that a_1 and b_1 are uncorrelated, we may write:

$$U\left(\frac{\varepsilon(E)}{E}\right) = \sqrt{U^2(a_1) + U^2(b_1)}$$

Under these circumstances, the uncertainty in error in energy is obtained by adding in quadrature the relative uncertainties in flowrate and calorific value.

Annexe C – Example of pattern approvals in European countries

Item	Denmark	Belgium	France	Germany	Italy	UK
Models of CVDD approved	None - no such certification required	85 Gas Chromatographs (GC) for border stations and gas quality (determination) stations	Daniel (GC Danalyser 570) ABB (GC 8100) MECI/Yamataké (HGC 303)	Calorimeter, GC (Daniel, Instromet, RMG, Marquis)	There is a draft document for the approval of GCs	Devices in current production GC - Daniel model 500 - 2251 Controller - 2551 Controller - 2350 Controller
Model of flow computers (or volume conversion device) approved	None - no such certification required	Border stations flow computers are under control of national authority	Flow computers, PTZ, PT, T are approved. Many models from : Meci, SIS, Emerson, Actaris, Instromet...	FlowComp, Elster, RMG, many models (>50)	4783 model of flow computer are approved by our NA FIMIGAS: VESCOM3C, VESCOM4 FIORENTINI: FIOMEC10, FIOMEC12 INSTROMET: 901, 999, 782/2XF, 782/10 O.M.T. TARTARINI: FLOWTI T500, FLOWTI T502, FLOWTI T600 SCHLUMBERGER INDUSTRIES: COMPLEX, PTZ EX	Main types in Use 6 Main Manuf: OMNI, SpectrateK, Instromet Bristol Babcock, Sension,
Gas meters approved	None - no such certification required	All installed Turbine, Rotary and Diaphragm gas meters are approved (National or European model approval)	Turbine, ultrasonic, rotary displacement and diaphragm gas meters	USM, GTM, Vortex, Orifice, Rotary displacement, Diaphragm	Turbine and rotary displacement meters	NA does not approve flow meters for network energy balancing. NA does approve meters for consumer supply points. Types in Use Orifice, Turbine, Ultrasonic for HP sites
Requirements for the configuration of gas- meters and CV measurement devices	No requirements	Secured direct and local connection between flow computer and GC.	No restriction if each device is approved.	no restrictions, when DSFG is used	No possibility to connect flow computers with gas chromatograph	We have agreed a generic design of CV and flow meter arrangement but NA does not have power of approval.
Connection between flow computer and GC	Yes	Secured direct and local connection between flow computer and GC.	Yes	no restrictions, when DSFG is used	No	Yes. But the CV measurement from the CV device must be used when calculating energy and daily CV's.
Periodical verification/ calibration frequency of flow meter, CV and energy measurement devices	Flow-meters (turbine) calibration every 8 years. Densitometers, pressure-, and temperature-transmitters calibration every 2 year, in situ 1	Turbine Flow meters : Border stations every six years (+ online control via 2 meters in series), End-users a functional control or verification in situ (2 meters in series -where ever possible-serie // is part of our prescriptions) every year	Periodical verifications: Flow meter: every 5 years CV: 1 by year Flow computer: 1 by year	flow meters: 8 to 16 years CV measurement 1 year converters: 5 years	Flow meter: no frequency Flow computer: 2 years	We undertake annual validation of our network energy balancing flow meters and until recently annual evaluations of our CV devices using 6 calibration gases. Since 2002, annual evaluations of CV

Item	Denmark	Belgium	France	Germany	Italy	UK
	(transmitters) - 2 (densitometers) times a year.	GC : at least once a year (Borders stations twice a year and online comparison between at least 2GCs), + control in situ every 3 month Other types of Flowmeters: Verification of the flow meters on statistical bases (legal imposition).				devices are no longer required by NA and we monitor the performance of the CV device using condition-monitoring software (principally analyzing the Relative Response Factor).