GAS METERING - STATUS AND TRENDS ON TECHNOLOGY AND APPLICATIONS

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ABSTRACT

This paper deals with the development of fiscal gas metering systems recently observed and some of the reasons for this developments.

Three main headlines are used to describe the trend: Increase of cost effectiveness, increase the accessibility to metering systems and increase of confidence.

A few examples of this development are given both of what have been achieved as well as what potential there still are.

1 INTRODUCTION

I guess the words "The times they are a-changin'" has never been more true than now in every aspect of life, gas metering included.

Of course the general development with increasing speed in development of IT-technology and digital technology also influences the development of gas metering related area. This means that the possibilities are there for development in terms of "intelligent" devices and remote communication.
But also specific changes in the gas business demands for development: Liberalisation of the gas market and international competition between the gas suppliers.

In general, this takes us along a path towards devices and systems that are more (1) cost effective, (2) accessible and (3) confident to all parties.

Companies and countries have realised the importance of cooperation to achieve these goals. Knowledge-building programs and research programs are set up both on their own but also to an extensively degree in cooperation.

In UK for example National Measurement System (NMS) has set up a Science and Technology Programme on measurement science to meet users' ever-more demanding need for accuracy and to help users take advantage of leading-edge measurement techniques. Part of this programme is the Flow Programme.

Among the themes covered in this programme are:

- Developments of calibration facilities

- Intercomparison of standards facilities
- Research on DP meters
    - Venturi Tubes – Design Optimisation
    - Orifice plate – Flow compliance testing
    - Generation of database for revision of ISO 9300
    - Assessment of flow conditioner
- Research on mass meters
    - Evaluation of Coriolis meters for gas flow
    - Effect of mechanical vibration upon Coriolis meters
- Research on ultrasonic meters
    - In service performance of ultrasonic flowmeters

Among the issues that will be further addressed are:

- Use of meter diagnostics to provide additional flow information
- Composition measurement on-line
- Data analysis and uncertainty
- Technology to eliminate invasive processes like sampling

These themes reflects to a high degree both the needs and the realistic possibilities within gas flow measurement.

There are of course also other specific needs that individual companies are working on, either by themselves or in cooperation. For example within GERG, a number of programs have been established to achieve more knowledge about ultrasonic gas flow meters, calibration facilities and the abilities of CFD-models.

This paper will focus on the following items:

1. Development of more cost effective devices and systems.

   For a metering system the term “cost effectiveness” shall refer to the ratio between the cost of a system and the ability of the system to produce accuracy and reliability. The combination of accuracy and reliability can be named “*accubility*”.
   Among items that affect the “*accubility*” are:

   - Development of new basic technology utilised in gas flow metering
   - Improvement of existing technology
   - Lay-out and design of metering systems
   - Condition based maintenance
   - Implementation of existing technology in new application
   - Utilisation of computational tool (i.e. CFD)

2. System accessible by all involved parties

3. Systems more trustful to all parties:

   - Mutual accepted calibration and standards
   - Standardised uncertainty analysis.

2 MORE COST EFFECTIVE SYSTEMS

2.1 New Basic Technology

The most widely used types of flow meter for fiscal applications are orifice plate, turbine meter and more recently also ultrasonic flow meters and Coriolis meters. To a less degree vortex meter and swirl meter, and for special applications, venturi tube and V-Cone meter are used.

Is there any so-called ideal meters coming up ?
By an ideal meter one could think of a meter which remotely, from the outside of the pipe and not even in touch with the pipe, gives information about flow rate, density, energy and other quality parameters: CO_2, Sulphur component, water etc.
I think a realistic answer for the time being is "no" – at least not when speaking about high pressure gas within thick-walled steel pipes.

Reviewing papers from recent FLOMEKO conferences indicates no breakthrough in the near future.[1].

There is a lot of research on for example technology based electromagnetic radiation, for example optical technique.
The laser-doppler technique is in itself technology which measures the speed of motion of a particle very precise. However, it is far from being realized as a practical device for high pressure gas flow.

Other technique based on radiation is possible. For example by utilization of radiation from radioactive sources and making use of some sort of correlation technique. Technique based on some sort of radiation has the advantage of also being the base for analyzer of many kind. But again, no reports yet indicate a break-through of such techniques yet applicable for practical use.

However, despite the ultrasonic technique in itself is not new, I think a clamp-on ultrasonic device shown in fig. 1 deserves a place in this section. A manufacturer has recently come up with this device. [2] If this keeps its promises perhaps this is as far we for the moment can come to an ideal meter, at least from a design point of view.

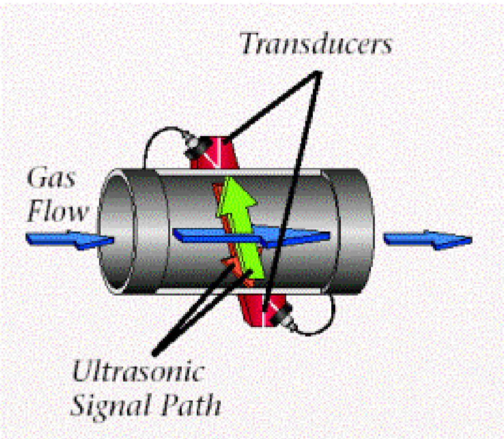

Fig. 1 Clamp-on ultrasonic meter for gas application

2.2 Improvement of existing technology

Lots of effort is made on improving existing technology to make systems more cost effective.

This mainly covers research and testing to reduce investment cost by reducing size and weight of systems.

For most of the current ‘energy extractive’ meter technologies, including differential pressure (DP) meters, positive displacement, turbine and vortex flowmeters, the designs appear to have reached a plateau where there is very limited scope for further improvements, other than those that will arise from advances in material science and manufacturing technologies. The latest revision of ISO-5167 for DP meters is supposed to be due in 2001 and the main changes relate to upstream lengths and the effect of pipe roughness rather than changes to design. Similarly, mechanical meters may only be improved by tighter manufacturing tolerances and addition of electronic characterisation and processing.
However, turbine meters have recently been improved to reduce the flowprofile sensitivity.

The other group of meters, the ‘passive’ meters includes electromagnetic, ultrasonic, Coriolis and cross correlation flowmeters. These meters have the distinct advantage that they can be designed to have a wide frequency response and hence they have a much greater potential to benefit from the huge advances that are taking place in signal processing and computational techniques.

By using algorithms from raw line density using a Coriolis meter, it is possible to produce a range of high accuracy property values including referred density.

Improving turbine meters and ultrasonic meters to reduce the flowprofile sensitivity is another example. If it can be proven that the meter does not loose accuracy when installed close to pipe disturbances, the whole system can be more compact.

Also, by improving ultrasonic meters to reduce the influence of noise generated by control valves, again the system can be more compact without long length of pipe between the valve and the meter.

Especially should be mentioned work going on to utilise the information provided by ultrasonic flowmeters:
There has been a growing interest in the use of measurements of the speed of sound in gases to determine other parameters including density. Speed of sound measurement enable ultrasonic meters to operate as mass flowmeters or, with one additional measurement parameter, energy meters. The advantage for natural gas metering is that the dependency on densitometers and gas chromatographs is reduced.

Also devices outside the flowmeter itself can help to improve the cost benefit. One example is development and verification of effective flow conditioners making the mechanical part of the system more compact by reducing the upstream straight length of the inlet pipe section.
Among other devices are silencer that can dampen the noise that otherwise can damage the functionality of ultrasonic meters.

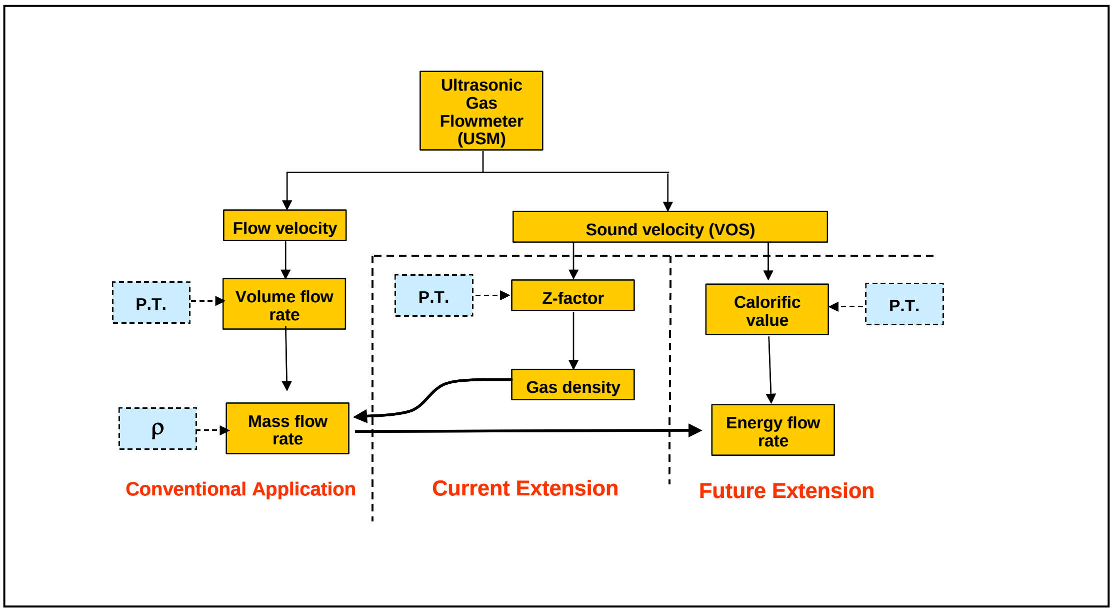

Fig.2 Current and future development of ultrasonic meters utilizing the information in VOS

2.3 Lay-out and design

A very cost adding element is the design requiring parallel meter runs. The reason for parallel meter runs is partly to have redundancy and partly to obtain necessary measuring range.

Different design is in use: “Multiple run single meter”, “multiple run dual meter”, “single run single meter” and “single run dual meter”.

Recently, more metering systems are now designed as single run systems. Many of them with two flow meters in series and dual instrumentation. One reason for making this possible, is the reliability (or availability) of the meter themselves and also the wide measurement range which now is possible with new type of flow meters, e.g. ultrasonic flow meters.

The choice of concept is dependent on the application. Questions like “What happens if the meter is out of service” have to be asked. In some cases there might be other alternatives to estimate the quantity. Even if this alternative is less accurate perhaps its contribution to the overall uncertainty over a period of time is insignificant.

There is a trend towards more “freedom” in the the selection of design.

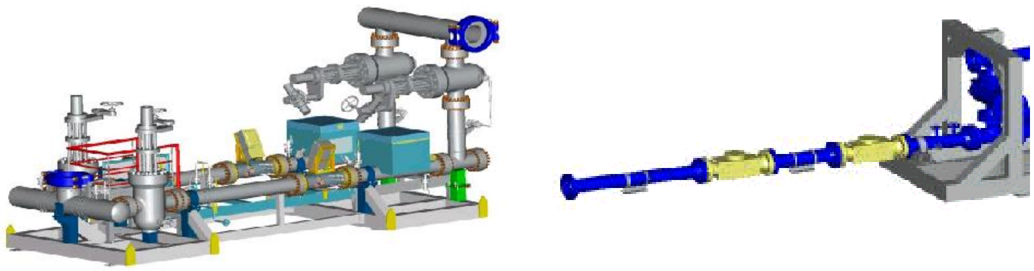

Fig. 3 Left: “Dual run single meter” design and right: “Single run dual meter”. Each of the meter in these cases is designed for 100 % of needed capacity.

2.4 Condition based maintenance

A great deal of the operating costs related to fiscal metering systems is the regular or preventive maintenance in form of regular calibrations and checks.

From statistics collected from such regular calibrations it turns out that the need for adjustment is very limited. This has led to the idea that it should not be necessary to perform (re)calibrations at all or at least not so often. But somehow there is a need to verify that the accuracy is maintained.

A general description of conditioned based maintenance can be found in the NORSOK standard. [3]

Condition based maintenance is basically based on comparison of values produced by the metering system itself. It could for example be comparison between two independent measured temperatures. Between those values there should be a well defined relation, for example they should be equal. It is however required that the values are determined independent of each other. As long as the expected relation is maintained the philosophy is that there is no need for “human interference”.

From time to time one of the component in the comparison chain will be calibrated with traceable equipment. This means that the demand for traceability is fulfilled.

Example of systems where condition based maintenance has been presented [4].

The experience has shown that the operational cost has been reduced by as much as 60 % compared to the conventional maintenance program based on regular calibrations.

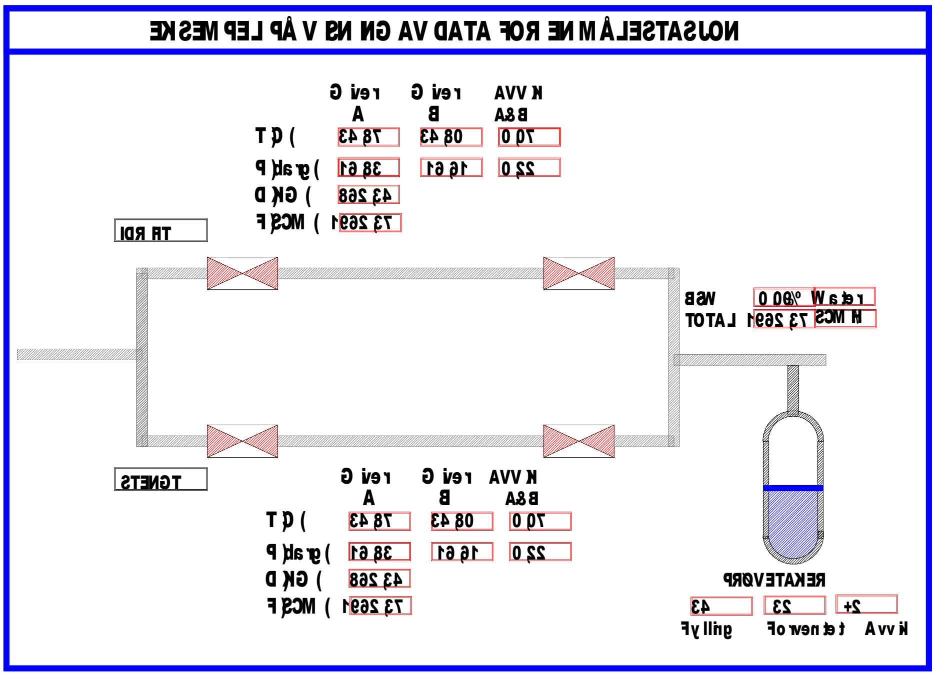

Fig. 4 Example of information from a metering system that can be used in condition based maintenance.

2.5 Implementation of existing technology in new application

There is a tendency to use more “fantasy” in the selection of type of meter, especially for special applications.

An example: Coriolis meter used for a special gas export metering station.

Some Coriolis meters are already approved for custody transfer of natural gas by PTB (Germany) and NMi (Holland). [5]

A special application should be mentioned:
From an offshore platform, high pressure (160 bar +) gas is exported. The gas is extremely heavy, relative density is approximately 1.15 and the methane content is approximately 45 mol %. For other reason than for metering, the gas is separated in a condensate stream and a gas stream before being commingled to a single gas phase export stream. The density of the gas phase is in the order of 340 kg/m³ and in the condensate phase 570 kg/m³. Typical flowrate is approximately 100 tonnes/hr, corresponding to 250 m³/hr in gas phase.

A skid is installed with four 3” meter runs equipped with Coriolis meters, two dedicated for gas, one dedicated for condensate and in order to be flexible, one meant for either gas or condensate,

Coriolis meter were tested for the effect of different medium. Testresults are shown in fig. 5. These results told the operator that a KF found by calibration by diesel would be valid within acceptable limits also for gas.
So a fifth meter acting as mastermeter was installed. The mastermeter is regular calibrated versus a compact prover with diesel and further used to check both meters acting as gas meter as well as condensate meter.

One special item to be aware of seems to be the limitation in flow rate. When used at gas, the limitations seems to be determined by the flow velocity in the meter tubings inside the meter rather than the mass flowrate. Fig. 6 shows what happens as the flowrate increases toward the meter’s full capacity given in mass flow.

Tests performed at different pressures indicated that the unstability in readings is a function of flow velocity inside the tubings in the meter (or volume flow rate). Fig. 7 illustrates this point. One could also suspect differential pressure to be the reason for the unstability, but the relation seems to be much more related to flow velocity.

So when sizing Coriolis meter for gas applications this effect must be kept in mind.

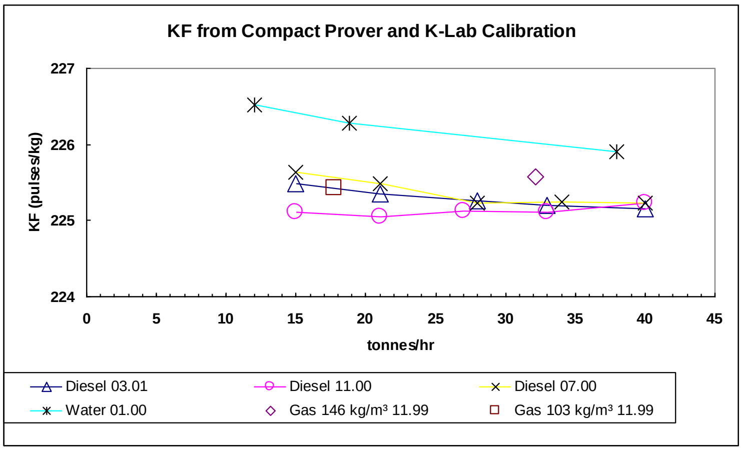

Fig. 5 Test results of a 3" Coriolis meter with different fluids.

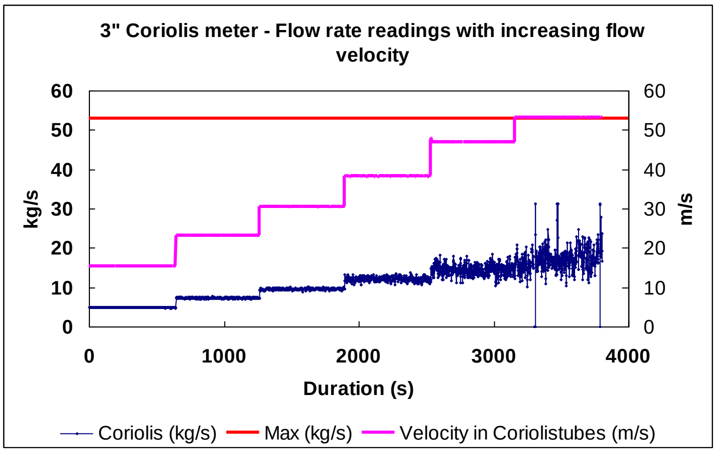

Fig. 6 Flow reading from a 3" Coriolis meter with increasing flow rate.

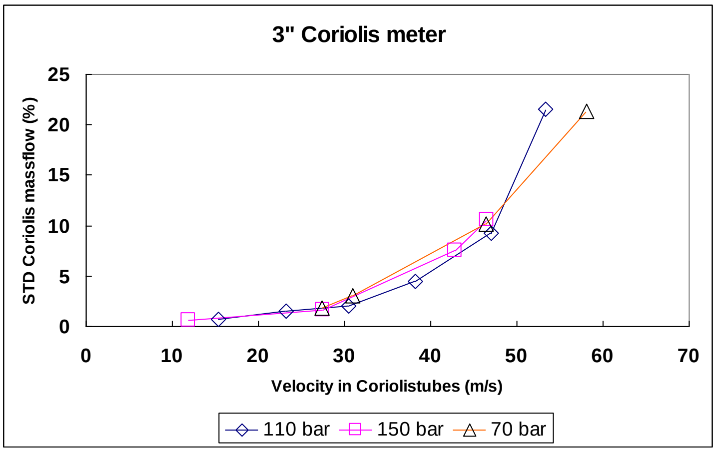

Fig.7 Unstability in flow readings from a 3" Coriolis meter expressed as standard deviation as function of flow velocity in the meter tubings.

2.6 Utilisation of computational tools

During the past 10 years or so, computational tools, Computational Fluid Dynamics (CFD), have been developed to calculate the flow patterns inside the pipe given its geometry and operating conditions.

Also, a reliable CFD code can be used to check that the velocity pattern is inside what a specified meter requires to be regarded as being inside its specified range of uncertainty.

Applications of CFD include verifying and optimising meter design, understanding physical phenomena, predicting meter performance and sources of error. CFD ca be a vital tool to predict the performance of mechanical meters before proceeding to prototype design.
The design of USM will also benefit from CFD. Ultrasonic meter can be strictly mathematically modelled and the effect of flow velocity pattern on an ultrasonic meter can be estimated. Special tools for USM have already be developed. [6].

CFD can also be used in design of flowconditioners [7].

Now, whether or not existing CFD codes are reliable enough is still an open question. Investigations seem to indicate that in most cases the simulated velocity pattern is very similar to experimental data with one exception: Velocity pattern out of a sharp T-bend is still a problem to simulate correctly (probably due to the high turbulence level). At least, impressive visualization program are developed, like the one shown in fig. 8.

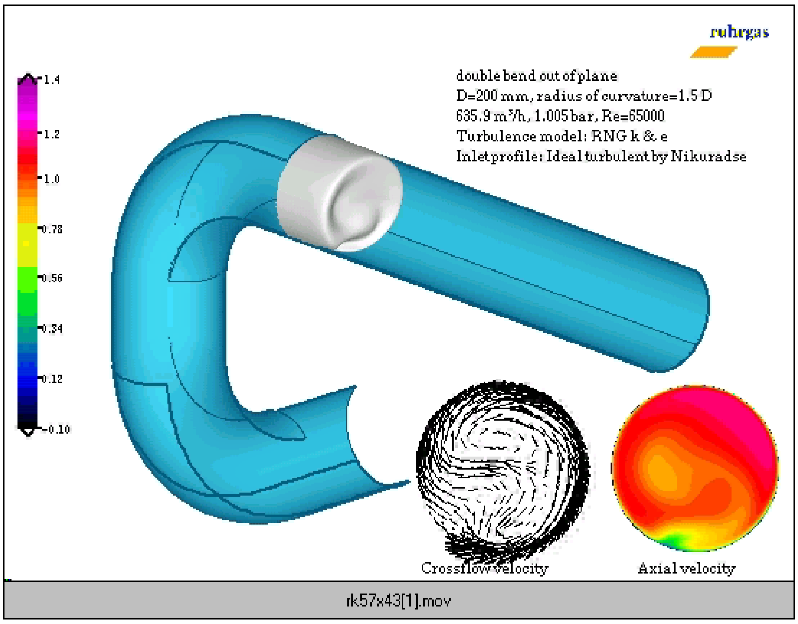

Fig. 8 Example of the possibility with CFD simulations

3 ACCESSIBILITY

3.1 Remote monitoring – internet

A key element in future measurement and process control systems will centre on remote system integrity management. Smart technologies with self-diagnostic capability coupled with rapid development in data communications means that the engineer will be able to perform his condition based monitoring routines from the desk top PC.

Systems have been developed making it possible to sit anywhere and being connected live to metering stations and the individual instruments via internet. The health condition of the system can be monitored by specialists.

My guess is that in the near future this will be extensively used worldwide.

4 CONFIDENCE

4.1 Calibration and traceability

One condition to trust a meter's reading is that it is traceable back to standards for weight and measure.
There are several ways to fulfill this requirements. One possibility is to manufacture a device with so close tolerances that the device is known to repeat readings from similar devices. Once one of these devices is known to produce accurate results, other devices will do the same. So it is not need for an individual check or calibration. In a way, this is the case with orifice plates: When the orifice is manufactured and used according to recognised standards (ISO 5167), the result should be within given tolerances.

A development is now taking place to apply the same philosophy for other devices as well. To trust such a philosophy, all influencing factors must be known. There are work going on now to apply this philosophy for ultrasonic gas flow meters. As we learn more about these devices, I think it is possible to reach this goal, but we are not there yet. A great deal of work has been done. Especially I would like to mention GERG Project on Ultrasonic Gas Flow Meters, Phase II [8].

Until this goal is achieved, we have to live with the need of flow calibration. A number of flow calibration facilities and organisations exist around the world. Those facilities hold references which the user of flow metering devises has to trust.

There is continuous work going on to improve the accuracy and confidence of these references. There seem to be growing public interest in what these facilities can produce in terms of accuracy.

One condition for confidence is traceability. Between the fundamental quantities defined by BIPM and the flowrate measured there need to be proven and verifiable links. For every chain in this link, the uncertainty will increase. Work is going on to minimise the number of chains in this link and to improve the quality of equipment and procedures involved in the comparison and calibration taking place in each step. As an example of development on volumetric flowrate traceability taken place the recent years can the traceability chain at Pigsar be mentioned.
A piston prover for high pressure gas has been developed. Fig. 9 shows how this provers enters into the traceability chain.[9].
Other calibration facilities have different traceability chain.

Even though the different flow calibration facilities do their best to maintain accuracy, there is a trend towards search for even better verification of the different laboratories. One way of performing such checks is to perform intercomparison exercises or round robin tests. To do so, Transfer Standard Packages (TSP) have been designed. Normally, two flow meters of the same or different types are put in series. See fig. 10.
This TSP is transported between the facilities and characterised by each facility. The characteristics are finally compared. Provided no changes have occurred with the TSP, it can be checked if the results from the facilities are inside acceptable limits. Two major intercomparisons has recently been made: GERG Intercomparison Exercise [10] and CENTAUR (Canadian, European, North America Turbine And Ultrasonic Round robin) [11].

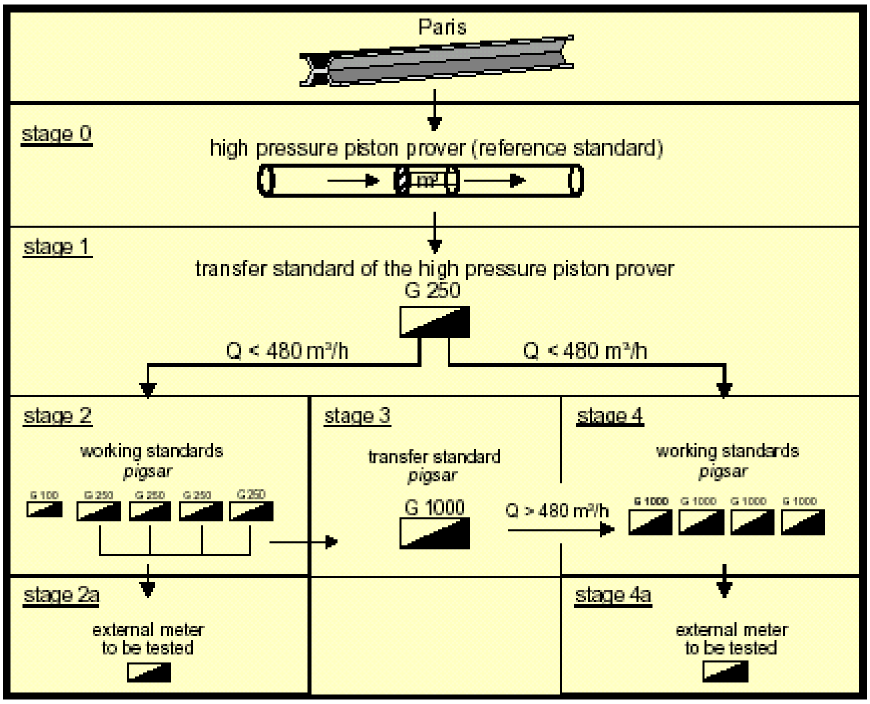

Fig. 9 Traceability chain at Pigsar including high pressure piston prover [9]

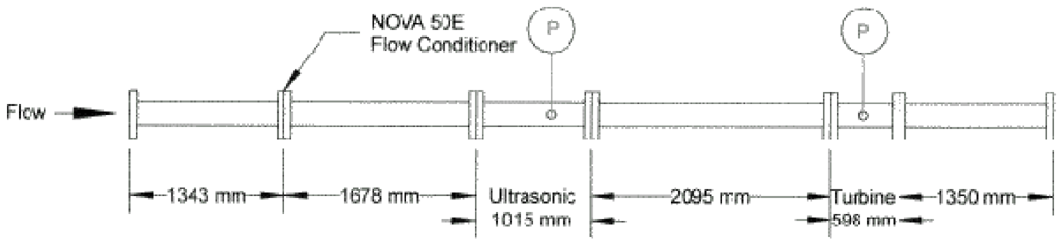

Fig. 10   The CENTAUR Standard Package.

Such intercomparisons can reveal need for harmonisation between facilities. If over the years systematic differences occur between facilities with different traceability chain, and the facilities have well controlled uncertainty budgets, it is possible to enter into harmonisation agreement. This was the case between NMi and PTB (Pigsar). An harmonisation agreement was signed on June 2, 1999.

The practical part of this harmonisation agreement is that three Transfer Packages each consisting of a pipe arrangement and two turbine meters in series are undergoing similar exercise at both places.

The result of this harmonisation is mutual accepted reference value with a lower uncertainty than their own individual uncertainties.
The harmonisation process is shown in fig. 11. [12]

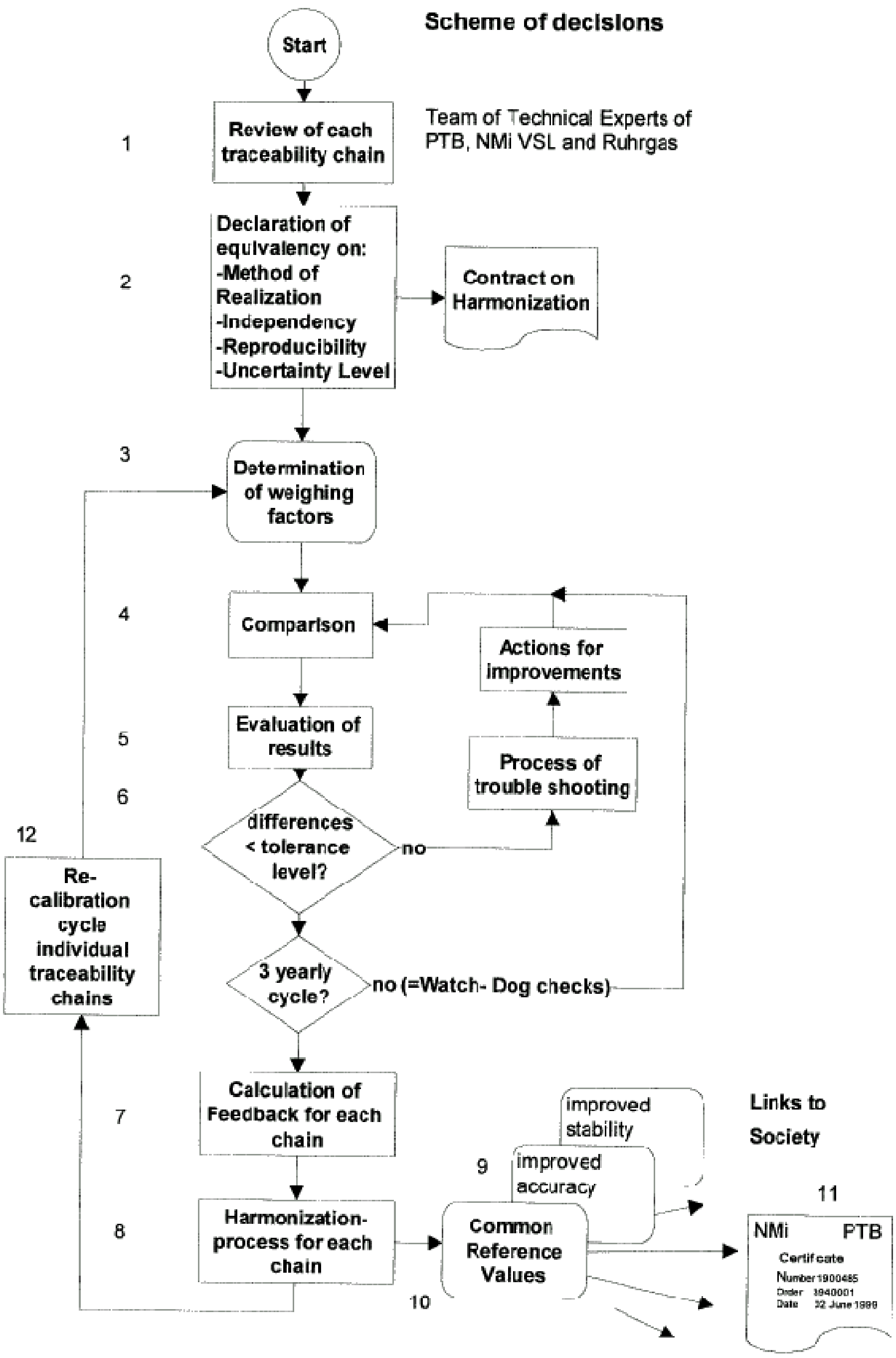

Fig. 11 The Harmonisation Process between PTB and NMi.

4.2 Standardised uncertainty analysis

A metering system consists of more components than just the flow meter. Despite the effort being made to improve confidence and accuracy in the calibration of the flow meter itself, this only partly helps to reduce the uncertainty of a metering system. The uncertainties of the other components such as instruments for pressure, temperature, density, specific energy etc need also to be maintained at a low level. And finally: What is the uncertainty of the whole system and on the final output being it mass or energy ? And how is it determined ?

What is needed is standard ways of estimating the uncertainty. When comparing uncertainty of different systems it should be certain that it is the same quantity that is compared.

During the past years, international recognised method of uncertainty analysis and calculation has been developed [13]. Based on general methods, practical tools for uncertainty calculation of flow metering systems are now being developed together with standardised report content [14]. And more is on its way [15].
With mutual accepted methods and reporting, all involved parties should be able to produce, review, evaluate and trust numbers, tables and graphs for uncertainties.
So when a graph like fig.12 is presented it will be trusted among involved parties.

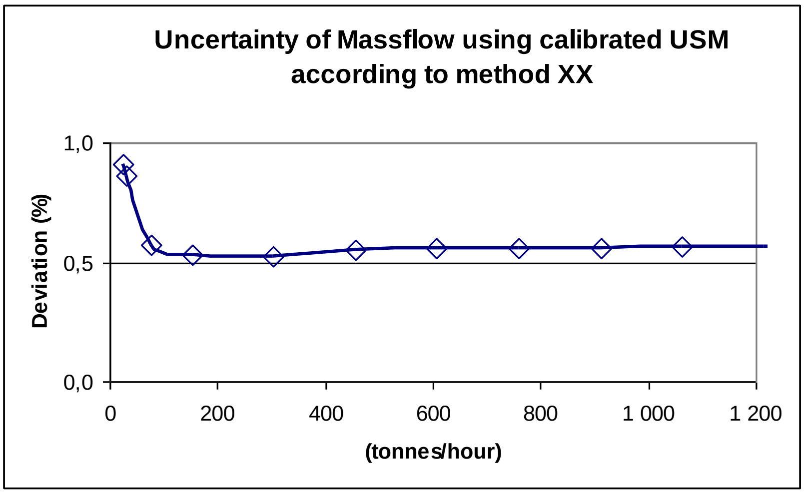

Fig. 12 Example of uncertainty of massflow for a system based on flow calibrated USM and densitometer.

5 CONCLUSION

For all types of flowmeters, users will be seeking more cost effective and more reliable, which have in-built self-diagnostic capabilities and are insensitive to the installation conditions as well as the physical properties of the fluid.

Clearly, the 'modern' flow metering instruments – in particular ultrasonic and Coriolis – will continue to lead the way owing to their potential to benefit from signal processing and computational techniques. However the older, well-established metering techniques such as orifice plates, Venturi meters and even turbine meters are all seeing a revival, in particular from the ability of computer modeling to maximize design.

Also procedures related to the operation of fiscal meters are believed to be greatly affected by the development of metering systems toward self diagnosing systems which tell the operator what the health condition is. This means that a great deal of the maintenance will be based on condition of the system.

Finally, confidence is a key word. One way to improve confidence in the end result is to improve the confidence in the base for the metering result: The calibration facilities. There is a trend towards more cooperation and comparison exercises despite the facilities also are competitors on the market. All part of society will benefit from this cooperation.

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