

# ACOUSTIC EFFECTS IN METERING STATIONS; IMPACTS ON PERFORMANCE OF FLOW METERING EQUIPMENT

Dr. H.J. (Henk) Riezebos,  
(Gasunie Research, Energieweg 17, 9743 AN Groningen, The Netherlands  
email: h.j.riezebos@gasunie.nl)

**Abstract** Acoustics plays a central role in the current state-of-the-art gas metering equipment. In the last decade the benefits of ultrasonic techniques in fiscal metering of high gas volumes has become apparent. These metering technique expresses lots of advantageous features, like high accuracy, large rangability, low pressure drop and self-diagnostic capabilities.

Recently in addition to flow metering applications the acoustic techniques have also been applied in energy flow or Wobbe metering devices. An example of this is the Ensonic, a fast energy meter, which uses a correlative technique based upon measurements of the velocity of sound (VOS) at two different pressures and the CO<sub>2</sub> percentage. This technique yields a fast, low cost device, which is with respect to uncertainty (< 0,3%) and reproducibility (< 0,1%) fully comparable to the highly accurate field GC 担 which are used for custody transfer purposes. Because of its very fast measuring cycle of <~ 5 seconds this technique is excellently suited for gas quality control purposes.

Application of these techniques raises the question whether acoustic effects always present in piping systems can influence the reliability and accuracy of the measurements. Acoustic effects are present in any piping systems, either through sources like compressors or valves, but also through possible flow induced pulsations. All flow measurement devices in some way are affected by their presence. Orifice and venturi flow meters, based on measurement of differential pressure across a restriction experience a square-root error and/ or gauge line errors due to pulsations. Turbine meters experience so-called rotor-slip errors when operating in dynamic acoustical conditions. Moreover, practical experience at Gasunie shows that sometimes turbine meters are rotating under the influence of acoustic waves even when they are positioned in a standby metering run with closed valves! Some examples are shown in the paper.

How about the devices based upon the current state-of-the-art ultrasonic measurement techniques? Theoretically some aliasing errors can occur when the acoustical periods are close to the sampling time interval. In practice we have noticed some other effects. A serious drawback of the ultrasonic measurement technique is its sensitivity to noise of pressure reducing elements. It is somewhat ironical, that especially low-noise valves have more disturbing ability than regular valves. This ability originates in the fact, that low-noise techniques focus on the audible noise region and this sometimes implies a shift of the noise levels to the more ultrasonic part of the spectrum, where they can influence the signal-to-noise ratio of the US metering equipment.

Besides disturbing valves also certain flow straighteners can produce acoustic effects. These effects have been studied at Gasunie Research in bi-directional metering run tests at our flow facility in Westerbork. In such a setup always one of the two flow straighteners experiences an opposite flow direction. Such a flow straightener will produce whistling sounds at high flow velocities, which at a certain levels will affect the US metering performance.

As long as metering devices remain sensitive for all types of acoustic influences it is strongly advised to have an acoustic eye already in the design stage of metering or calibration facilities. Acoustic control is crucial in obtaining state-of-the-art quality and low measurement inaccuracy.

**Keywords** Natural gas metering, Acoustic design, Acoustic techniques, Flow and Energy Metering, Pulsations, Ultrasonic Noise, Metering Accuracy and Reliability

## 1. Introduction

Acoustics plays a central role in the current state-of-the-art gas metering equipment. Since the introduction in the market, about ten years ago, ultrasonic techniques are being used more frequently in fiscal metering of high gas volumes. These metering technique expresses lots of advantageous features, like high accuracy, large rangability, low pressure drop and self-diagnostic capabilities. These features make these metering systems also well suited for bi-directional applications. Recently acoustic techniques have also been applied to the gas industry in the area of gas quality properties. A correlative technique based upon measurements of the velocity of sound (VOS) at two different pressures and the CO<sub>2</sub> percentage yields a fast, low cost device. This device will briefly be described in section 2.

## 2. NEW ULTRASONIC TECHNIQUE IN GAS ENERGY ANALYSIS

### 2.1 IMPORTANCE OF GAS ENERGY ANALYSIS TECHNIQUE

Energy measurement is one of the main tasks of gas transport companies. New challenges in the gas world, confront gas transport companies with new requirements regarding energy measurement. (e.g. the variation in gas composition will be larger and will occur more frequently). These changes are the driving force for a number of new developments in energy metering. Present energy measurement systems for natural gas comprise of volume metering, volume conversion from field conditions to reference conditions and calorific value determination at reference conditions. The superior calorific value,  $H_{SR}$ , is mostly determined by compositional assay using a process gas chromatograph. The volume conversion factor can be determined from thermal equations of state, using the gas composition or some gas properties. The cost of ownership for accurate energy meters using a process gas chromatograph is high. These high costs were the main reason for Gasunie Research and Eon-Ruhrigas to join forces on the

### 2.2 PRINCIPAL OF THE METHOD

The correlation method is based on the assumption that a natural gas can be characterized as a four-component mixture consisting of nitrogen, carbon dioxide and an

Since along with new developments in ultrasonic technology the limits of acceptable accuracy are moving downward, we can also observe some unwanted impact of acoustic events, usually unexpected. We will show in this paper some examples about how acoustics can strike back.

Some general information will be presented about how acoustic pulsations can occur in piping systems and how these can affect measurement accuracy. In particular the focus will be first on turbine meters in section 3.1 and on ultrasonic measurement equipment in section 3.2.

In section 4 we will briefly describe how to deal with possible acoustic effects in the design stage of metering stations.

We will draw some conclusions in section 5.

development of new energy flow measurement methods.

These new methods are based on the measurement of three suitable properties (e.g. physical properties or component concentrations) and an accurate correlation between these properties and the gas composition. The inferred gas composition is used to compute a variety of gas properties like the superior calorific value, the density, the compression factor under reference and field conditions and the Wobbe-Index.

Within the joint project Gasunie Research focussed on the development of an energy meter based on velocity of sound measurements. The new meter is based on the measurement of the velocity of sound at high pressure ( $VOS_{high}$ ), the velocity of sound at low pressure ( $VOS_{low}$ ), and the molar fraction carbon dioxide ( $X_{CO_2}$ ). This combination is particularly suitable for stations with high pressure gas available ( $P > 40$  bar).

equivalent hydrocarbon gas (methane + higher hydrocarbons). A dedicated iterative method was developed on the basis of this correlative method. Using three input parameters, the

composition of the twelve main components in natural gas can be inferred. Especially the combination of velocity of sound at low pressure, velocity of sound at high pressure and molar fraction carbon dioxide appeared to be attractive, because it is simple, reliable and it is able to give accurate results.

Depending on the differences, the composition is adjusted and the calculation loop is repeated

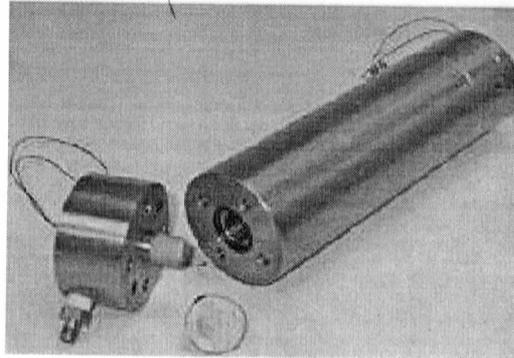
### 2.3 ACOUSTIC TRANSDUCERS

Application of velocity of sound as a measurement in correlative energy metering implicates the following requirements for VOS-meters: (a) high accuracy (better than 0.03%) and very high reproducibility (better than 0.005%); (b) because the VOS-meters need to operate with a continuous gas flow, a small internal volume is important for low gas consumption; (c) the temperature and pressure of the gas in the VOS-meter have to be known accurately and thus only changes in temperature and pressure at a time scale relative large to the measurement time (seconds) are allowed. Besides, the temperature and temperature profile of both VOS-meters should preferably be identical.

Therefore, in cooperation with Instromet [2] a new low volume, highly accurate VOS-meter has been developed. The new VOS-meter is based on transducers and electronics of the new Q.SONIC-3S compact ultrasonic flow meter of Instromet Ultrasonics. A picture of the new VOS-meter is shown figure 1. Two identical

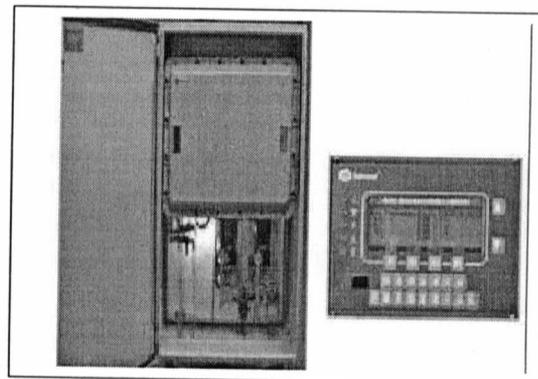
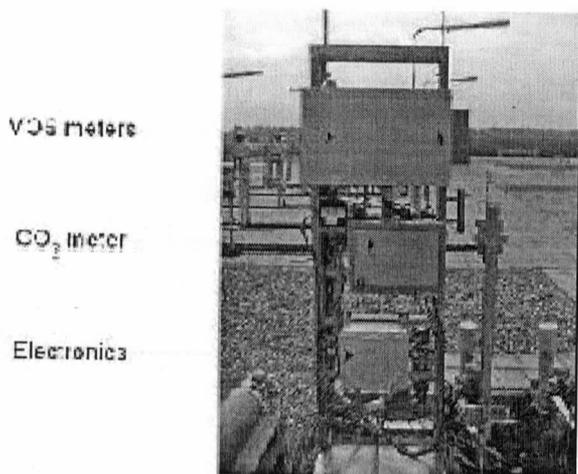
until the absolute value of the differences between computed and measured velocities of sound (VOS) are less than 0.002%. The final gas composition is used to compute the superior calorific value, the densities and the compressibility factors under reference and field conditions, respectively.

**Figure 1: The low volume, highly accurate velocity of sound meter**



meters were applied, one for high pressure VOS measurements and one for low pressure VOS measurements. The volume of the VOS-meter is roughly  $20 \times 10^{-6} \text{ m}^3$ , and the path length is approximately 0.12 m. The reproducibility of the velocity of sound measurements,  $2\sigma$ , with these type of VOS meters turned out to be better than 0.002%.

### 2.4 THE ENERGY METER ENSONIC



**Figure 2: (a) Field prototype of the correlative energy meter based on double VOS-measurement and (b) inside of ENSONIC, the commercial product of INSTROMET**

On the basis of the correlative principle Instromet [1] has started the production of the commercial product, the ENSONIC. Using highly accurate, state of the art ultrasonic technology the velocity of sound at high (approx. 30 ~ 40 bar) and low (approx. 2 ~ 3 bar) pressure is measured. The high accuracy of +/- 0.3 % for the Wobbe Index and +/- 0.1% for the (relative) density and the fast response (< 5 sec) open up new ~~theoretical~~ applications were currently available gas chromatography is either too slow or too expensive. Furthermore, this stand alone system is ideally suited for field mounted applications without the need for any additional conditioning. All measurement data can easily be accessed via the MODBUS protocol and up to 8 freely programmable analog outputs can be provided by connecting

### **3. PIPING ACOUSTICS INFLUENCING FLOW METERING EQUIPMENT**

By using more and more acoustic techniques as described above in metering systems and new developments in ultrasonic technology driving the limits of acceptable accuracy downward, we can observe some unwanted impact of acoustic events, usually unexpected. All these metering systems operate as part of a metering station. The acoustics present in connecting process piping can surely influence the accuracy and reliability of the metering. Acoustic phenomena are known to influence more traditional flow metering equipment as well. The phenomenon of rotor slip occurring

#### **3.1 SPURIOUS COUNTS OF TURBINEMETERS**

Spurious counting occurs in standby metering runs in which the flow pulsation levels occur above certain critical levels.

We describe here a few of these cases on a phenomenological basis. The plausible origin of the spurious counts is discussed. In all of these cases the spurious counting is related to the intensity of existing acoustic pulsations in the neighborhood of the turbine meters. The acoustic pulsations originate either from flow induced acoustic resonances or from pressure reducers or gas expansion units.

The theoretical background to explain how a rotor blade is rotating under the influence of an acoustic oscillation is the fact, that turbine rotors have a round leading edge and a sharp

the system to an Instromet FC2000 flow computer (displayed at the right of the energy meter).

Advantages of the new instrument are: (i) unlike a GC it does not require a conditioned analyser building, (ii) it can be positioned near the pipe, so there is a short sample line, (iii) a fast response time (<5 seconds) (iv) unlike a Wobbe meter also density and CO<sub>2</sub> are determined, therefore no instruments for these measurements are required anymore. Furthermore, the costs of ownership for the new system are considerably lower compared to current energy meters and Wobbe Index meters.

More information about the ENSONIC and its development background can be found in reference [2].

when the rotor of a turbinemeter has been exposed to acoustic pulsations in the pipe systems is well-known. This phenomenon has been described in literature over the last thirty years. We will first report here about a more recently described acoustic phenomenon on a turbinemeter, namely the fact, that spurious counting of the meter can occur under the influence of acoustic pulsations (ref. [3] and [4]).

trailing edge. This asymmetry is the cause of the spurious counts due to the vortex shedding at the sharp trailing edge. For more information about the background we refer to reference [3]. We will show some illustrations of this phenomenon below:

#### CASE 1 FLOW INDUCED PULSATIONS

In a gas delivery station the spurious count phenomenon occurred. The metering run with a turbine meter is placed in the standby mode. In such a case the outlet valve of this metering run was closed. The inlet valve remained open. The station flow passes the inlet side of the metering run to be measured at other metering runs. At certain flow conditions pressure pulsation amplitudes at three different positions in the metering run (at locations p1, p2 and p3 respectively) in combination with the spurious

counts from the HF-signal of the turbinometer were simultaneously recorded. A schematic sketch of the setup of the run and the locations

of the pressure transducers is shown below in figure 3.

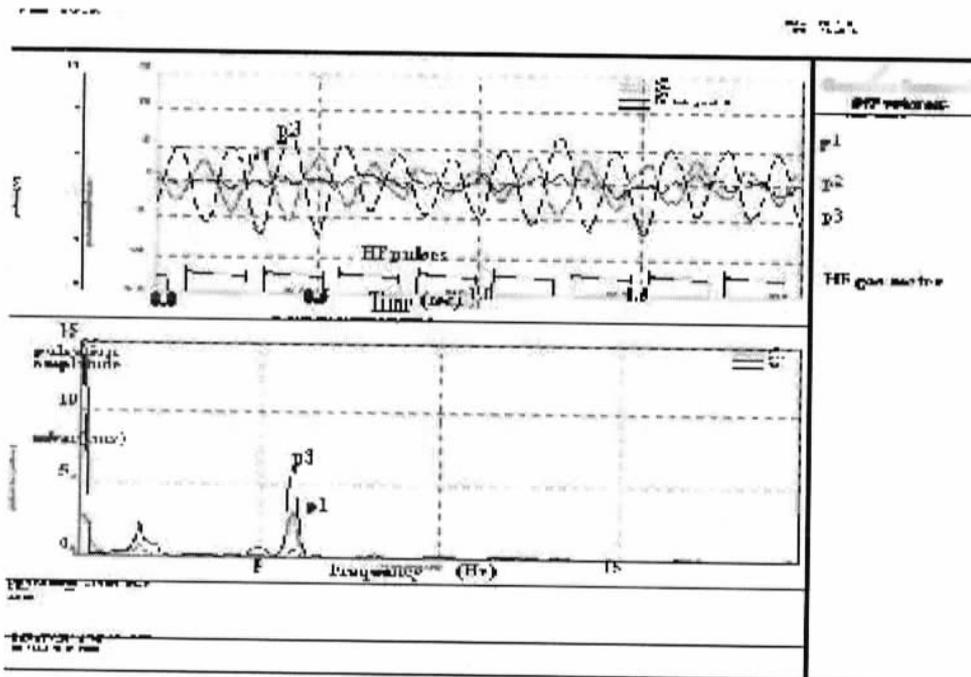
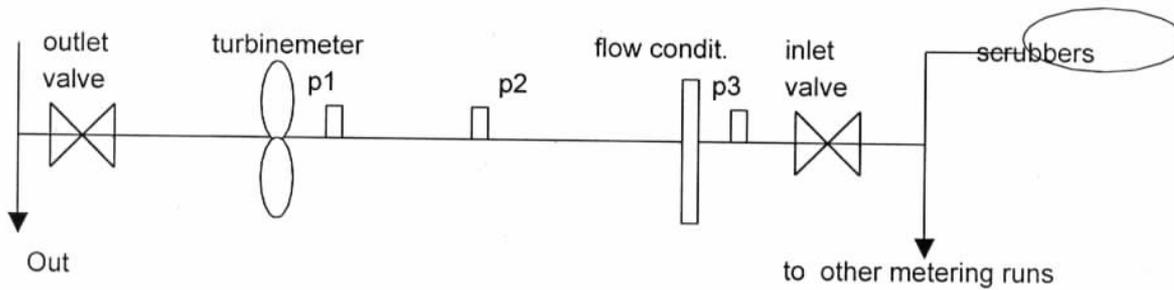


Figure 3 Results of the pressure pulsation measurements in the metering run at a velocity of about 6 m/sec in the header. In the top the time signal is shown. At the bottom the result of an FFT-operation on the pressure time data resulting in a frequency spectrum

Strong acoustic pressure pulsations occur at the frequency of 2 Hz and 6 Hz in the measuring run along with the spurious counts of the turbine meter.

The origin of the pulsation amplitudes is found in acoustic pipe resonances, which are in general standing wave patterns in the longitudinal direction. Depending on the sound velocity and length of the closed side branch acoustical resonances occur at certain frequencies

The resonance modes are fed by the gas flowing along the closed side branch giving rise

to vortices being shed with a shedding frequency. It has been verified, that for these type of vortex shedding a fixed Strouhal number relation exist by which the vortex shedding frequency can be determined. When vortex shedding frequency and acoustic resonance frequency coincide then the mode will be excited.

If we apply this to the specific situation at the metering run we expect the acoustic frequencies to be  $f_0 \sim 2$  Hz around a velocity of about 2 m/sec and  $f_1 \sim 6$  Hz around a velocity of about 6.5 m/sec, since the length in between the

header and the outlet valve is about 49 m and the diameter of the run is about 0.5 m.

Based on the different pulsation pressure amplitudes and phases at different positions in the metering run, the characteristic resonance

pattern of a flow induced pulsation occurs. It is clear from this case, that the flow induced mode with frequency 6-Hz drives the turbinometer spurious counts.

CASE 2 ACOUSTICS FROM HELMHOLTZ RESONATOR

At a new gas delivery station (new design) the following configurations of meter and regulating runs was present

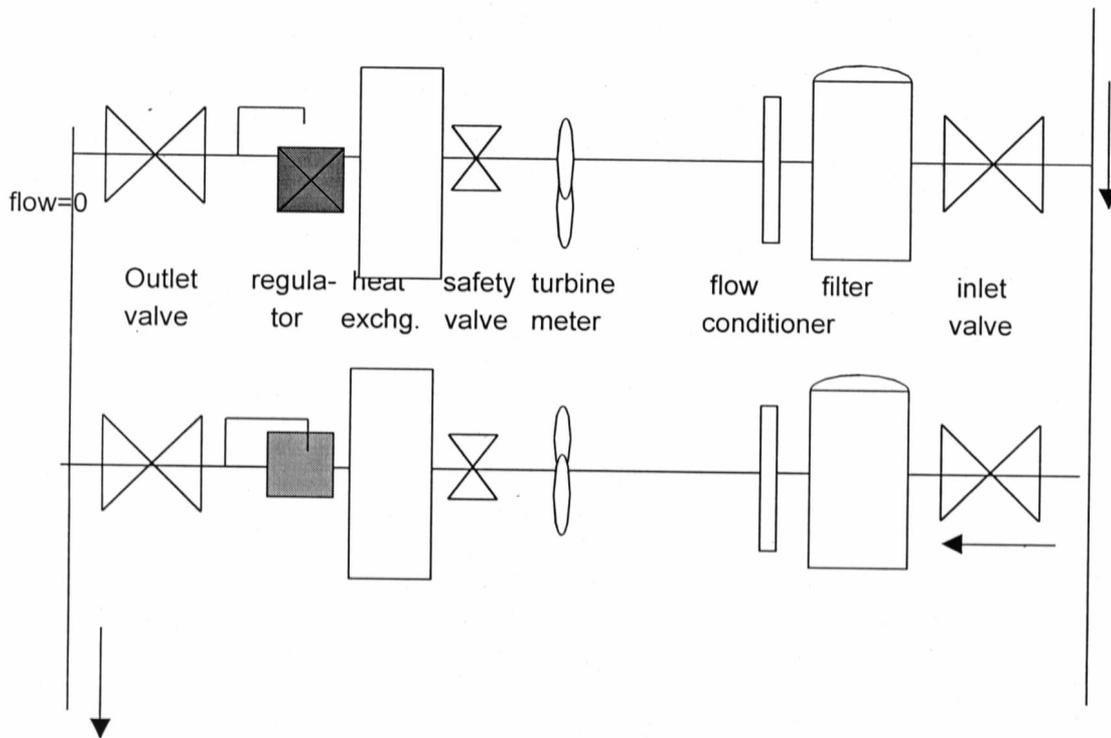


Figure 4 schematic representation of the new design regulating and metering run

The two vessels (filter vessel and heat exchanger) serve in combination with the connecting pipework as a Helmholtz resonator. The turbinometer has been placed in between the two vessels inside the connecting pipework. Making use of the geometric information we calculated in this way a theoretical Helmholtz frequency of 12 Hz. In the measured pulsation frequencies indeed a 12 Hz line dominated, although the amplitude was rather fluctuating.

In the graph below (figure 5) we plot the amplitude of the 12 Hz pulsation along with the spurious HF signals of the turbine gas meter. Although it is not clear how the Helmholtz resonant mode is excited in this case, we here again clearly observe the relationship between pulsation amplitude and the occurrence of spurious counts.

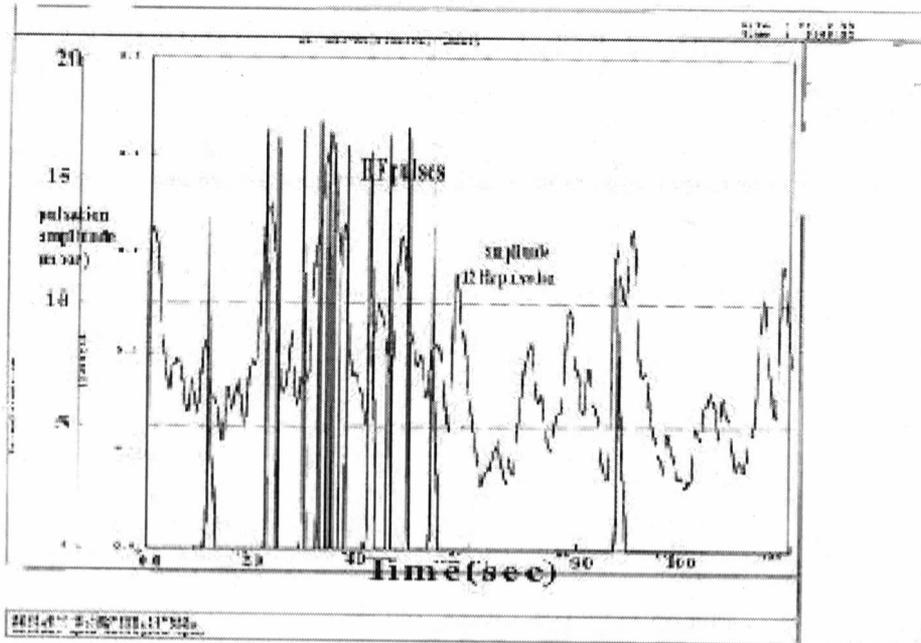


Figure 5 Amplitude of 12 Hz Helmholtz resonator pulsation and HF pulses from turbinometer

### 3.2 ACOUSTIC EFFECTS INFLUENCING US METERS

#### FLOW STRAIGHTENERS

Acoustic whistling phenomena have been observed in bidirectional metering run setups using Laws type flow straighteners (ref. [5]). Apart from the environmental sound problems due to the whistling, also the Ultra Sonic (US) flow meters are experiencing large measurement errors.

The reported experiments have been performed in two experimental setup lines at the Gasunie Bernoulli lab one on full scale (20) and one on reduced scale (12).

The Laws flow straightener is a perforated plate with concentric rings of holes, that have three different sizes. The Laws has a small upstream chamfer of 1 mm at an angle of 45 degrees. Hence there is a small difference between a normally placed Laws and one which has the chamfer at the downstream position. This asymmetry between a forward and backward placed Laws plate is the main reason, why the phenomenon occurs more pronounced in bi-directional runs. In these runs always one of the two straighteners will be positioned in the reverse direction.

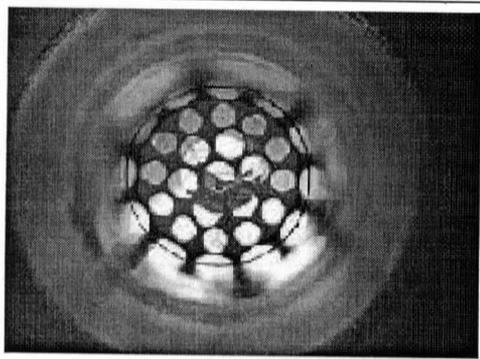


Figure 6 - photographic impression of a positioned Laws straightener

Besides the Laws type also a Zanker type consisting of a thinner perforated plate with holes and a honeycomb like structure with channels in the downstream direction. The acoustic spectra from low to very high (ultrasonic) frequency were recorded close to the US meter in the metering runs. The resulting spectra in 1/3 octave band values is shown in figure 7.

1/3 octave US spectra

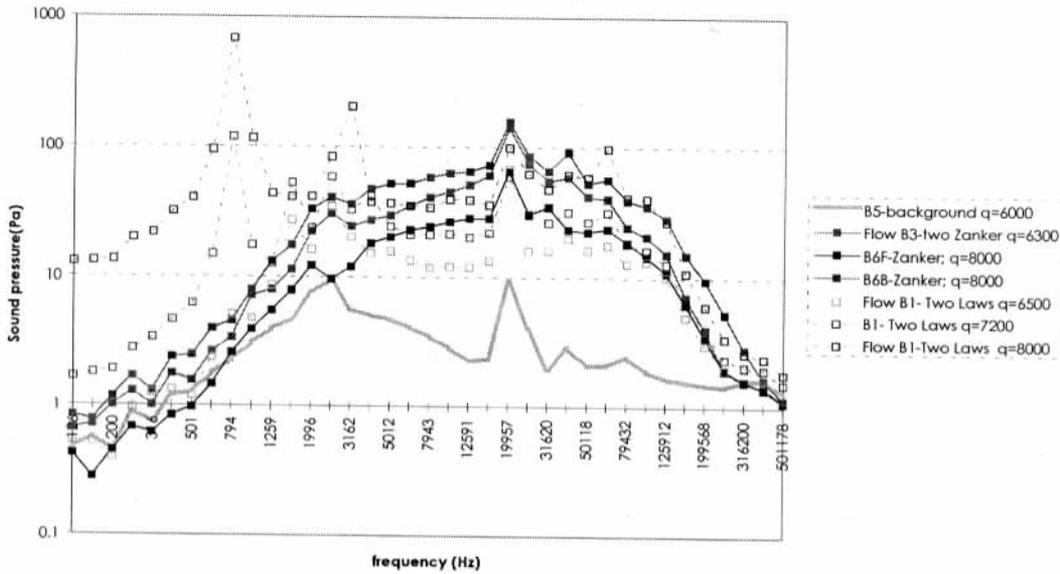


Figure 7 - one-third octave band spectra for configurations with Zanker (solid lines) and Laws straighteners (dashed lines) for different flow values.

It can be seen from figure 7, that the configurations with Zanker straighteners have a much smaller low frequency component (< 10 kHz), whereas in the midfrequency range (10 kHz-50 kHz) the noise of the Zanker straighteners dominates. The high frequency part of the Zanker results is comparable with

the Laws results. The flow dependency of the path no-error percentage is shown in the graph below (figure 8) for the configuration with a single Zanker configuration (backwards directed), at 10D distance from the US flow meter and compared with a 指 histling Laws configuration

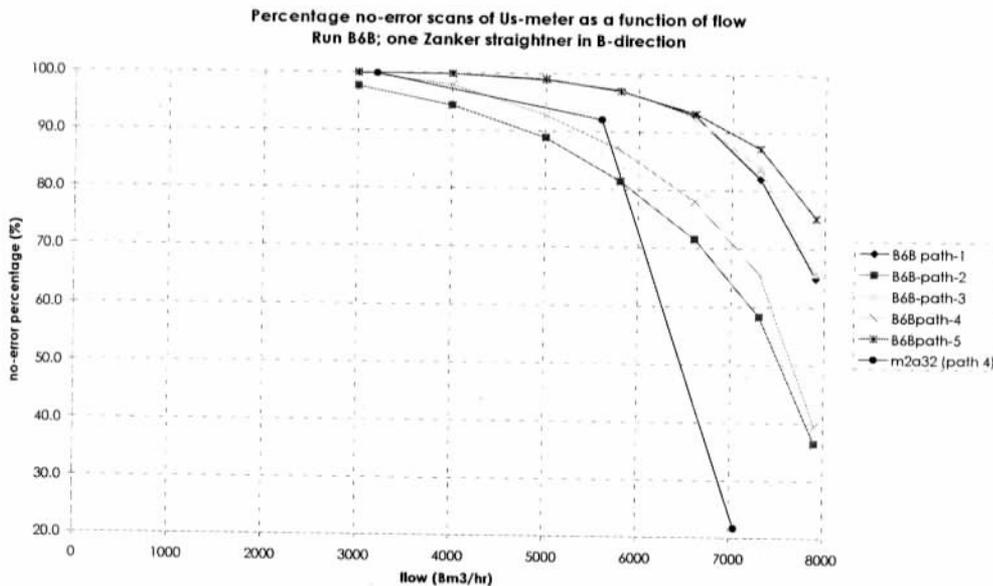


Fig. 8 - Flow path accuracy for the different paths as a function of flow. The no-error percentage of 5 different US paths for the single Zanker configuration B6B are shown. For comparison the measurement with a double Laws configuration has been added (US flow error 2% at q=7000).

The acoustical modes to which the flow through the holes in the Laws perforated plate couple mainly have a radial character.

On the basis of these trends we conclude, that the US meter error observed in the bidirectional runs with Laws straighteners does NOT

PRESSURE REGULATING VALVES

Placing a US meter close to a acoustic source such as a pressure regulating valve can be very harmful for its operation.

We performed some test in a compact metering run at our flow test facility in Groningen by placing a US meter upstream of a pressure regulator. The distance between the regulator and the US meter was 10D of straight piping, two 90 degree bends and 3D of straight piping. We varied some essential piping parameters like replacing one of the bends with a T-joint

originate from a high-frequency US component, but rather is caused by the pipe vibration imposed by low-frequency acoustic noise.

and changing the regulator type. We used one “normal” flow regulator and one with a low-noise trim. In several experiments flow and pressure were varied. The US noise close to the US meter was measured to check its sensitivity for acoustic noise. The results are summarized in the figure below.

**Relation performance US meter and US acoustic noise**

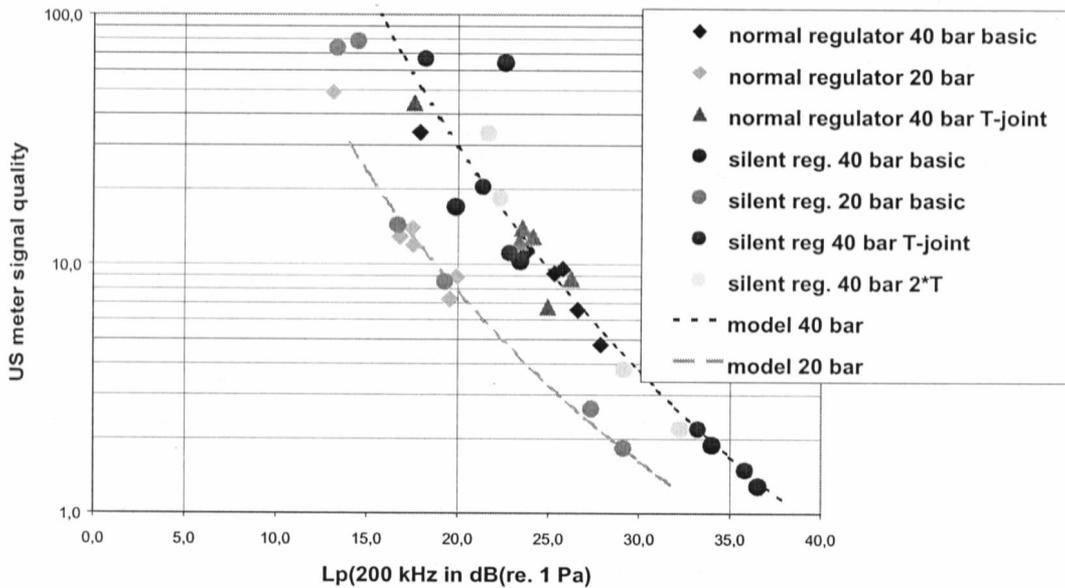


Fig. 9 – US signal quality as a function of measured sound pressure in the 200 kHz octave band .Measurement points are based upon different configurations (“basic”, T-joint), different pressure levels (20 bar and 40 bar) and different regulator type (silent and normal). The noise level of the “silent” regulator (the measurement points indicated as spheres) are higher than the comparable levels of the normal regulator

From figure 9 it can be seen that the signal quality is rapidly decreasing as a function of increasing noise level. The variable "US meter quality" can be seen as the signal-to-noise ratio of the metering device. We observe some reduction in the US metering noise when replacing a bend by a T-joint connecting piece. Furthermore there seems to be a pressure effect since the sensitivity at 20 bar differs from the

#### 4. DEALING WITH ACOUSTICS IN DESIGN OF METERING STATIONS

Acoustic noise effects (pulsations) are visible in any gas station induced by the flowing medium. Usually the pulsation levels are low over a broad range of frequencies (broadband noise). In general all instabilities in the flowing medium generate flow noise, the most common one being pressure reducing elements. However, once and a while severe acoustic resonances occur in a piping system. Usually it is a coupling of flow instabilities through the gas velocity with acoustic resonances in the piping system. These are so-called Flow induced Pulsations or FIPs.

In general flow metering equipment, like orifices or turbinometers exhibit a measurement error, which is proportional to  $I_v^2$ , with  $I_v$  being the ratio of the acoustic velocity  $v\sim$  with respect to the mean velocity  $v$ . The best place for a flow meter positioned inside an acoustic resonator - each pipe segment can be considered as such - is at a position during an acoustic resonance for which the acoustic velocity is zero, i.e. a velocity node.

##### 4.1 CONTROLLING FIP PROBLEMS

In designing a complex pipe system many acoustic resonances are present, which can be induced by flow passing several type of objects in piping.

The background of a FIP study is described in a Gasunie directive OSW-17N, which is a guideline to be used by engineers when designing a manifold or complex pipe-system. A short summary is now presented below.

The origin of the pulsation amplitudes is found in acoustic pipe resonances, which are in general standing wave patterns in the longitudinal direction. Depending on the sound velocity  $c$  and length  $L$  of the closed side branch acoustical resonances occur at the frequencies

$$f_n = (2n + 1) * \frac{c}{4L} \quad \text{with } n=0,1,2,\dots \quad (1)$$

The resonance modes are fed by the gas flowing along the closed side branch giving rise to

sensitivity at 40 bar. Although being pushed to the limits the US meter didn't show any significant increase in flow error during all the tests shown above.

However, if it would be placed downstream of the flow regulator where noise levels are 15-20 dB higher any normal operation of the meter would be impossible.

vortices being shed with a shedding frequency  $f_s$ . It has been verified, that for these type of vortex shedding a Strouhal number relation exist:

$$f_s = \frac{Sv}{D} \quad (2)$$

with

- S Strouhal number ( $\sim 0.5$  here)
- $v$  the gas velocity in the pipe (m/sec)
- D the sidebranch diameter (m)

When Strouhal frequency  $f_s$  and resonance frequency  $f_n$  coincide then the  $n^{\text{th}}$  pipe-mode will be excited. The amplitude of the thus occurring pulsation is depending on specific conditions, which influence the damping or the leaking out of the resonance. Factors like rounding edge play a role, but in general it can be stated, that for single side branch resonances the pulsation amplitudes will be of the order of magnitude of

$$\tilde{p}_{\max, \text{single}} \approx \frac{1}{2} \rho v^2 \quad (3)$$

In combination with other resonance modes, like e.g. another single side branch the pulsation pressure amplitudes can be a factor  $\text{Mach}^{-1}$  or  $c/v$  larger, order of magnitude

$$\tilde{p}_{\max, \text{double}} \approx \frac{1}{2} \rho c v \quad (4)$$

These amplitudes can be compared with the maximum acceptable amplitudes according to the API-618 (ref. [3]) referring to mechanical integrity of the installation.

After having converted the pressure pulsation levels to flow pulsation levels -thereby making use of the acoustic impedance of gas inside a piping system we can estimate the possible implication on flow metering error  $\epsilon_{\max}$  for turbinometers:

$$\varepsilon_{\max} \approx \frac{1}{2} I_v^2 \quad \text{with } I_v = \frac{\tilde{v}}{v} \quad (5)$$

A similar relation holds for orifice meters, which are facing a square root error when subject to flow velocity pulsations  $I_v$

$$\varepsilon_{\max} \approx \frac{1}{4} I_v^2 \quad (6)$$

## 4.2 CONTROLLING VALVE ACOUSTICS

For US metering equipment in a design stage it is important to avoid acoustic noise from pressure valves which influence the performance of the meter. In general the performance is dependant on three important input parameters:

1. Ultrasonic noise generated by pressure regulating valve
2. Noise attenuation along the trajectory from valve to US meter.
3. Sensitivity of US meter to ultrasonic noise levels.

The first item of US noise generated by the valves is most hard to control. One can make use of guidelines, such as VDMA-24422 or IEC 534-8-3 to obtain a rough order of magnitude. Applying it to natural gas systems practical deviations of 10 dB or more in the US range are common. This is because there are many regulator types which are not covered by the guidelines and the application range is broad. It is very tempting to ask for "low-noise" valves in this case, but remember very well, that "low-noise" usually means "low-audible noise". There is absolutely no guarantee that the ultrasonic noise components will also be low. On the contrary, it is our experience, that low noise valves sometimes have a higher ultrasonic noise component as compared to normal valves. This is because its low-noise trims –consisting of small channels and holes- usually shift the acoustic energy from audible noise frequencies (100-15000 Hz) towards ultrasonic frequencies (>20 kHz).

In order to really be sure about expected noise levels one can either ask the manufacturer of the

If the pulsation levels lead to unacceptable flow metering inaccuracies several options are present to reduce the FIP pulsation. For instance changing branch diameters or avoiding specific symmetry in the design will show a drastical change in FIP levels helping to improve the acoustic performance..

valve to provide his best guess, or –in case the manufacturer is not able to prove or guarantee his best guess- have US pressure measurements performed at actual conditions.

About the second issue, it is possible to calculate already in a design stage noise attenuation along the trajectory from valve to meter. Noise attenuation of all piping and piping components, such as elbows, tees, flow straighteners, etc. need to be taken into account. For real noise control in this stage, either the use of a ultrasonic silencer in the piping must be considered or the use of another type of meter like a turbinemeter or a Coriolismeter, whenever the valve and the meter are necessarily (too) close in piping distance. The best silencer exhibit S-type flow trajectories. In any case implementing a silencer at an US meter will affect the nice characteristic US meter properties of non-intrusiveness and low pressure drop.

The third issue of sensitivity of US metering equipment is solved by the manufacturers in two ways. Either performing advanced signal analysis techniques to lower the acceptable signal-to-noise ratios or by increasing the ultrasonic frequency of the transmitters towards the higher end of the spectrum, at which usually the background noise components are lower.

There is an increasing awareness among users and manufactures about these issues. In any case to avoid disappointing results beware of using US meters close to pressure valves, and if it is really unavoidable, ask for full guarantee of the manufacturers.

## 5 SUMMARY AND CONCLUSION

In this paper we have shown in retrospect some of the very recent developments in acoustics influence in gas flow and composition metering.

We have shown a recent application of new acoustic techniques in fast and accurate composition analyses. Furthermore the paper

described a number of possible way in which acoustics originating from surrounding piping components can influence the accuracy and reliability of turbine and ultrasonic flow meter equipment.

Acoustic techniques have been applied to develop an accurate and fast natural gas analysis system, which has an energy uncertainty ( $< \pm 0.3\%$ ) and reproducibility ( $\pm 0.02\%$ ) which makes it fully comparable to highly accurate field GC 组 used in custody transfer applications, nowadays. Advantages of the new instrument are: (i) it does not require a conditioned analyser building, (ii) it can be positioned near the pipe, so there is a short sample line, (iii) a fast response time ( $< 5$  seconds) (iv) compared to Wobbe meters also density and  $\text{CO}_2$  are determined, therefore no instruments for these measurements are required anymore. Furthermore, the costs of ownership for the new system are considerably lower compared to current energy meters and Wobbe Index meters.

On the basis of a few phenomenological cases of turbinometers operating in acoustic resonance conditions it has been shown, that spurious counting pulses can occur. The described cases show, that the plausible origin of the spurious counts is related to the intensity of existing flow pulsations in the neighborhood of the turbine meters. The origin is either related to flow

induced pulsations, or specific acoustic resonances imposed by reciprocating machines. Concerning the metering errors of US meters under the influence of acoustic phenomena we observe that there are two effects contributing to possible malfunctioning of a US meter (1) a *High vibrational background* which can result in pathfailure along many scans resulting in flow metering errors of  $> \sim 2\%$ . This effect is observed for high-flow Laws straightener configurations exhibiting severe whistling phenomena (2) a *High ultrasonic sound background*; this is especially apparent when a US meter is positioned in the neighborhood of a pressure reducing device.

In any design of metering stations acoustics is an aspect which has to be accounted for. Often this fact is neglected and acoustic problems occur unexpectedly. Gasunie has a long term experience with acoustic phenomena in pipework and have developed some engineering guidelines which in many cases help to prevent severe flow induced pulsations or other acoustic resonance phenomena.

As long as metering devices remain sensitive for all types of acoustic influences it is strongly advised to have 撰 acoustic eyes already in the design stage of metering or calibration facilities. Acoustic control is crucial in obtaining state-of-the-art quality and low measurement inaccuracy.

- [1] Instromet International N.V., Rijkmakerlaan 9, B-2910 Essen, Belgium.
- [2] H.J. Panneman, C.W. Koreman, S. Toonstra and F. Huijsmans, Development of an Accurate, Low Cost Energy Meter for Custody Transfer; The Last Step from Prototype to Commercial Product. Proceedings of the 22<sup>th</sup> World Gas Conference, Tokyo, 2003 and references therein
- [3] H.J.Riezebos, J.P.Mulder and R. Zwart, Influence of flow pulsations on turbinometers, paper presented at the 8<sup>th</sup> Int. Gas Research Conference (IGRC), Amsterdam, Netherlands, 2001
- [4] P.Stoltenkamp, S. Araujo, H.J. Riezebos, J.P.Mulder, A. Hirschberg, Spurious counts in volume flow measurement, Paper presented at the 10<sup>th</sup> international congress on sound and vibration, 7-10 July 2003, Stockholm, Sweden
- [5] H.J.Riezebos, J.P.Mulder, G.H.Sloet and R. Zwart, Whistling flow straighteners and their influence on flow metering accuracy, paper presented at the 18<sup>th</sup> North Sea Flow measurement workshop, Gleneagles, Scotland, 2000