return to contents page

MODERN GAS FLOW MONITORING PRACTICES:

A REVIEW OF ULSTR-SONIC SYSTEMS WITHIN CEMS APPLICATIONS

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1. Introduction

Originally TA LUFT and later USA EPA regulations required emissions reporting on a daily mass basis. This stimulated the development of continuous flow monitors to allow accurate determination of mass emissions.

At present in the UK, annual tonnages for particulates, SO_2 and NO_x are calculated using a factor for m³ flue gas per kg fuel burned. It is envisaged that future EC emission regulations will require monitoring of actual flue gas volumes discharged to atmosphere.

A new continuous flow standard, developed by ISO, has recently been adopted as a British Standard (BS ISO 14164:1999).The introduction of the UK MCERT scheme demonstrates the intention of the UK Environment Agency to enforce emissions regulations.

In this document, several technologies for gas flow measurement are introduced with the emphasis being on ultrasonic flow measurement. Some application examples are introduced by means of the SICK AG´s Flowsic instrument range..

The FLOWSIC instrument described in this paper complies with the new flow standard and is presently awaiting MCERT testing

2. The use of flow measurements in CEMS systems

2.1. Calculating the emission discharge

In most countries emissions reporting is carried out on a mass basis. The measuring instruments used for gas concentration, e.g. SO_2, produce output signals for concentration values (c) in ppm or mg/m³. These measurements are concentrations under actual conditions on a wet or dry basis. In-situ monitors deliver values on a wet basis, since they measure gas concentration in the stack without the water being removed. Extractive monitors give the values on a dry basis, the water being removed by a condenser in the sampling train. Additionally, the concentration is normalised for the effects of pressure and temperature.

$$c_{i.N.}(\text{wet}) = c_{i.B}(\text{wet}) \cdot \frac{T}{T_N} \cdot \frac{p_N}{p} \qquad (1)$$

$$c_{i.N.}(\text{dry}) = (1 - F) \cdot c_{i.N}(\text{wet}) \qquad (2)$$

$c_{i.N.}$ = Concentration under normal conditions
$c_{i.B.}$ = Concentration under operating conditions
F = Water Vapour
T =Temperature
T_N = Temperature norm (Europe:0°C, USA: 20°C)
p_N = pressure norm (1013 mbar)
p = pressure

To determine the mass basis, the normalised concentration is multiplied by the gas flow value, which as a rule is measured in m³/hr(or cubic feet/hr).

$$\dot{m} = \dot{Q} \cdot c_{i.N.} \tag{3}$$

It should be noted that all flow monitors principally measure on a wet basis during operating mode. Before the calculation to a dry basis can then take place with other concentration values, the gas flow and if necessary the O_2 values must firstly be corrected for the water vapour present in the gas.

To stop plant operators manipulating results, in several countries the result is calculated to a specified O_2 concentration (e.g. in Germany 13. BImSchV 6% O_2 for Incinerators).

In most countries it is normal to use plant specific substitute values for pressure and water vapour however the temperature is usually measured. For gas flow there are different philosophies. In some countries a substitute value is calculated from the fuel consumption (presently in the UK), in other countries measuring and substitute values are both used depending on the nature of the plant (Germany: plants which correspond to 13. BImSchV: use the appropriate substitute values). Furthermore, in other countries a measurement is used for the majority of plants (USA: plants corresponding to 40CFR part 75).

2.2. Calibrating CEMS systems

The calibration of CEMS measuring systems should ensure measuring results are to an approved standard. For this there are also differing, country specific procedures.

The German procedure

In Germany CEM measuring systems, which include flow monitors, are submitted to a qualifying examination according to the Federal Emissions Protection law. At least 2 instruments are tested in a laboratory and in the field for accuracy, reproducibility, permissible maximum drift and availability.

A calibration of the plant is not required for flow monitors if good plant conditions (adequate straight lengths of gas ducts) exist. Calibration is only necessary for dust monitors due to the measurement being dependent on the particle size (for all types of technology).

If flow monitors or gas velocity measuring monitors are calibrated, it takes place for example with standard Pitot tubes. The test procedure required is described in the DIN/VDI 2066 German standard.

The English procedure

There is a trend being set by the UK Environment agency to calibrate CEMS monitors to traceable national or international standards.

- BS ISO 10155 is used for dust monitors
- BS 6069.4.4 is used for SO_2 monitors
- ISO 10849 is used for NO_Y monitors
- BS ISO 14164 is used for velocity monitors

The American procedure

In the USA and in other countries which work to the EPA regulations, a so-called “relative accuracy rest” (RATA) is stipulated for every CEMS measuring system in the specific plant. There is no model test as in Germany. The RATA test results decide whether the device may be employed and how long the interval will be until the next RATA test. The better the achieved class of accuracy, the longer the interval is.

For calibrating flow monitors, standard Pitot tubes for example are used. The procedure is described in the ISO 14164.

2.3. CEMS flow monitors technology

Firstly, a short remark regarding the terminology. The language used in emissions technology sometimes quotes the term flow monitor and sometimes the term gas velocity monitor. For reasons of uniformity, the term “flow monitor” will be used here. Gas velocity monitors also determine gas flow by multiplication of the average velocity by the cross sectional area of the duct.

CEMS installations operate on combustion plant flue gas ducts or stacks, which as a rule have diameters from 0,5 to 10 m. Compliance with national or international standards are usually necessary for these applications (UK –MCERTS, US-EPA, D-BImSchG).

For gas flow measurement there are many types of technology, for CEMS applications however, essentially 3 types of technology are at the forefront:

- Differential pressure sensing
- Thermal sensing systems
- Ultrasonic flow monitors

Differential pressure sensing

Differential pressure sensors are classic measuring procedures, which have been used up until now in various specifications. The most comman of which are:

- Pitot tube
- Prandtl tube
- Ellison annubar flow probe

Both measured values produce the differential pressure.

$$p_{stau} = p_{ges} - p_{stat} \tag{4}$$

Which is proportional to the squared gas velocity.

$$p_{stau} = \frac{1}{2} \varsigma \cdot v_g^2 \tag{5}$$

p_{stau} = Differential pressure
p_{ges} = Total pressure
p_{stat} = Static pressure

v_g = Gas velocity
ς = Density

The gas velocity can be determined from the differential pressure by a suitable measurement method and a further calculation gives the gas volume.

The pitot tube produces a single point measurement and is therefore affected by stratification within the gas flow profile.

Another system which is widely used is the Ellison annubar flow probe.

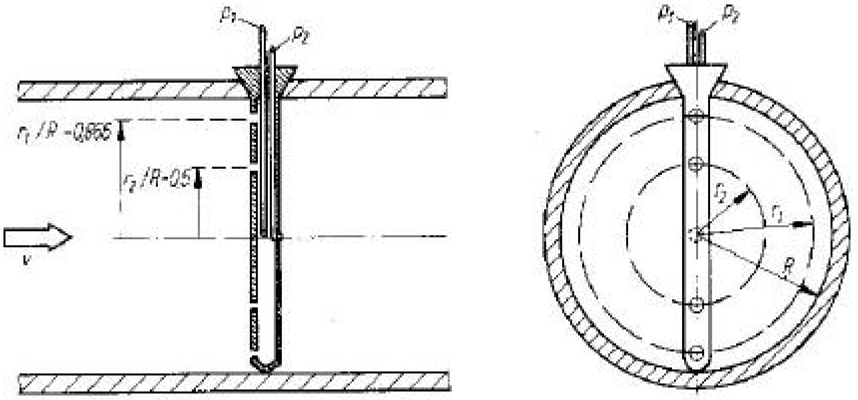


Fig1 Ellison-Annurbar-Flowmeter

This has several sensing apertures ie. it is a multiple point measurement (not to be confused with an integrating system along a measuring path). Therefore it is somewhat less susceptible to stratification within the flowprofite.

The differential pressure method can be evaluated as follows:

Advantages
- Well known technology, trained experts available
- Simple construction and manufacture, robust.

Disadvantages
- Non-linear characteristic curve, accuracy not so good for low levels of flow.
- Condensation or liquid droplets can lead to measurement errors, “blowback” systems can further improve availability (if necessary).
- Difficult to handle in large ducks due to weight, sometimes necessary to mechanically support on the both sides of the duct.

Thermal flow measurement

The measuring principle is based on the rate of cooling of an electrically heated sensor in the gas medium being dependent on the actual gas velocity.

A typical example is shown in Fig 2.

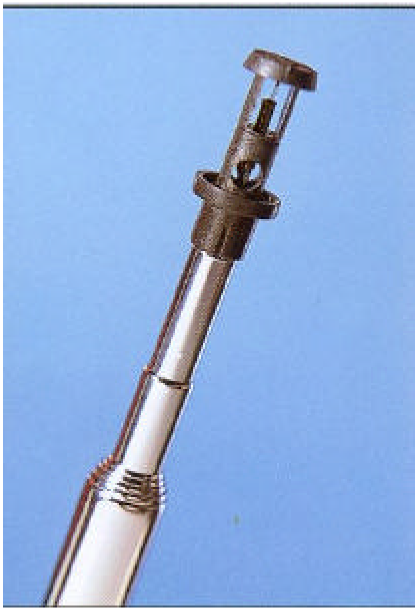


Fig 2 Hot wire anemometer

Two sensors are laterally located in the direction of flow. One of the sensors acts to measure the gas temperature, the other is electrically heated and is cooled dependant on the gas flowing past. When the temperature difference between both sensors is kept constant, the heat supplied is representative of the mass gas flow.

The thermal flow methods can be fundamentally distinguished from the pressure differential methods, as they deliver as primary measuring variable proportional to the mass flow [kg/h] as opposed to the gas velocity [m/s]. One must note that is concerns the gas mass flow here, not that of the pollutants!

Advantages:

- Measured value is directly proportional to the mass flow; no temperature or pressure signals required for normalisation.
  Multi-point measuring systems are relatively simple to produce and install.

Disadvantages

- The measuring signal is dependent on the density, deviations in the gas composition (O_2, H2O) will effect the result.
- Deposition or contamination lead to relatively large errors.

Ultrasonic flow monitors

Ultrasonic flow meters work on the principle of transit time measurement and the doppler principle. Since the latter has no application for the CEMS measuring systems, it will not be explained here in any more detail

On the flue gas ducts ultrasonic sensors are installed at a pre-determined angle, in most cases 45°

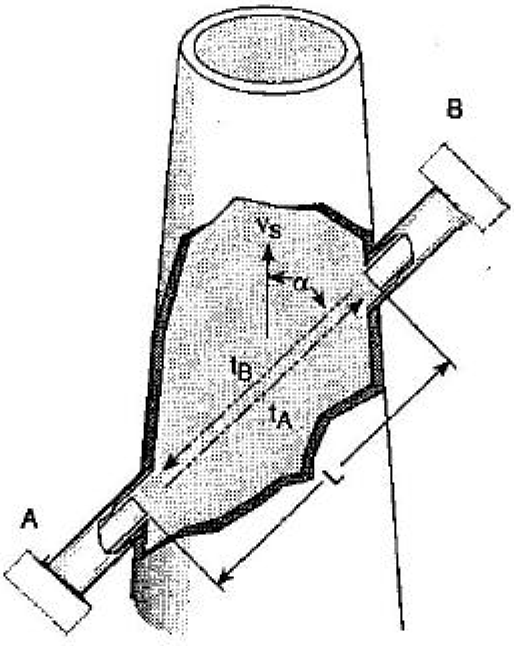


Fig 3 Principle of the time of flight measurement.

Ultrasonic sensors are installed on a flue gas duct at a determined angle, usually 45°. These can work as both sender and receiver. Intermittantly they transmit ultra-sonic pulses through the gas; once in the direction of flow from transducer A to transducer B, once against the direction of flow from transducer B to transducer A. The pulses sent in the flow direction are accelerated ; the pulses in the opposite direction are delayed. The transit time difference is calculated from the two measured values.

$$v_g = \frac{L}{2 \cdot \cos\alpha} \cdot \left(\frac{1}{t_{AB}} - \frac{1}{t_{BA}} \right) \tag{6}$$

v_g = Gas velocity
t_{AB} = Transit time with direction of flow
t_{BA} = Transit time against direction of flow
L = Measuring path
α = Installation angle

The measured gas velocity is proportional to the difference between both transit times. From the mean value of both transit times, the sonic velocity is derived and through this the gas temperature can also be deduced.

$$c = \frac{2L}{t_v + t_r} \tag{7}$$

$$T = 273°C \cdot \left(\left(\frac{2 \cdot L}{t_v + t_r} \right)^2 \cdot \frac{1}{c_0^2} - 1 \right) \tag{8}$$

c = current sonic gas velocity

c_0 = reference sonic gas velocity
T = current temperature [°C]

Ultrasonic measurement can be evaluated as follows:

Advantages:

- Linear characteristic curves, highest accuracy(2%)
- High measuring range dynamic, no drag reduction
- Independent of pressure, temperature and density
- Temperature measurement available as additional measuring variable
- Good possibilities for an automatic self-test

Disadvantage

- In large ducts a second platform in sometimes necessary

Ultrasonic measurement has experienced a rapid growth in use due to its technology-inherent advantages. According to /3/ , up to 1998, 64,7% of all 40 CFR part 75 flow monitors deployed in the USA used ultrasonic technology .

3. Ultrasonic model variations

In order to serve the many demands of modern industry, different instrument versions have been developed. These can be classified according to various criteria. Two which are relevant for the practice of CEMS measuring are set out here.

- Differentiation according to the characteristics of the measuring gas.
- Differentiation according to the site of the measuring path.

Obviously there would be considerably more differentiation and classification variants. We only want to examine 2 aspects here which are seldom featured in the subject-specific literature.

3.1 Differentiation according to the characteristics of the measuring gas

Here each of the following parameters have a role

- Gas temperature
- Degree of gas contamination
- Pressure

Pressure will not be more closely examined here, as it does not have an effect on applications in ducts or stacks where relative pressures in mbar range (typically +/- 20 m bar maximum) are present.
On the other hand, gas temperatures and particulates can vary over a broad range. In order to serve all applications, two instrument versions have been developed.

- Systems with purge air
- Systems without purge air

3.1.1 System with purge air

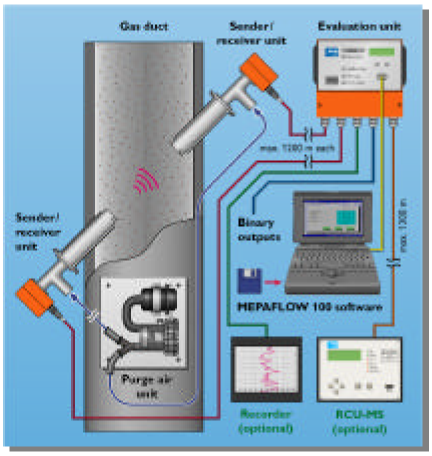


Fig 4 Standard System Overview

Fig 5 Purge air unit with blower and filter

As a rule, systems with purge air use filtered, ambient air to clean and cool the ultrasonic transducer . Because of this, the device can be subjected to temperatures of up to 500°C. This temperature range limit is not because the temperature is too high for the transducer or the measuring system; it is due to the physics of sound transmission. Furthermore the use of systems with purge air show a boundary effect, as the measuring medium and the transducer's surface area are separated by the purge air. The limitations for the range of use are once again dictated by the physics of sound transmission. When the dust concentration is too high, the ultrasound is attenuated so much that the signal-noise ratio falls short of the lowest permissible value, thus making a measurement impossible.

A disadvantage of purge air systems is the additional expenditure for a purge air blower, as well as the required regular maintenance. Furthermore, not all processes allow the introduction of purge air.

There are several forms of design for cleaning the transducer (as shown in Fig 6). In the 6-2 version the purge air's outflow path is located parallel to the ultrasound dispertion direction. The advantage here is that the transducers can be built into recesses, and as a result the structural factors determining the mounting situation(e.g. probe lengthening) can simply be adapted. As a disadvantage, the sonic dispersion is quite severely disturbed due to diffractive boundary layers from hot and cold air. Statistical methods can even this out, which can, however, lead to additionally necessary integration time for a delayed reaction of such systems. In the variant 6-1, the transducer is located directly in the gas current, protected by the probe, and is only separated from the duct gas by a thin cushion of air, this versions response times are much faster.

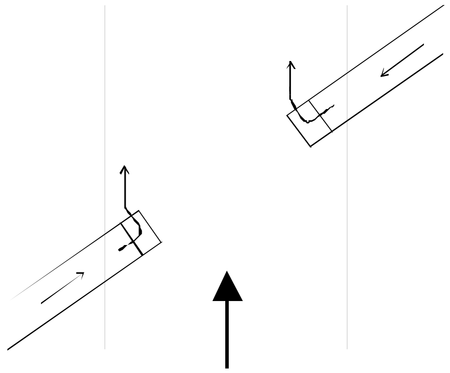


Fig 6 -1

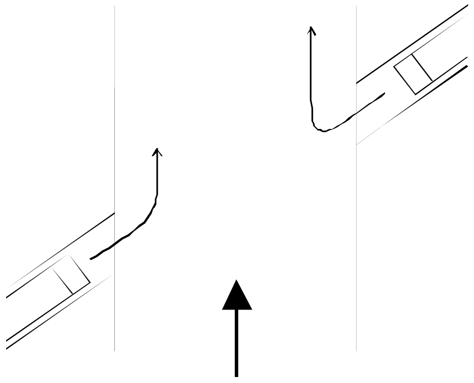


Fig 6-2

3.1.2 Systems without purge air

Systems without purge air are easier to maintain. In such systems the ultrasonic transducers must be made of upgraded materials to avoid corrosion, as they come into direct contact with the flue gas. As a rule, titanium or stainless steel are used. These systems can only be used in applications where temperatures of 260°c are present. The reason being; practically all ultrasonic transducers used in industry contain piezo ceramic. This ceramic may only be exposed to temperatures which do not considerably exceed 50% of the curie temperature. The permissible operating temperature can only be further increased when the piezoceramic is moved away from the direct influences of gas temperatures . Up until now this has been successful for measuring steam under high pressure, by using wave transmission. The ranges and accuracies which are capable of being attained are for not suited for use in the applications described here.

The presence of particulates can also be another limiting factor for the employment of systems without purge air. Particularly sticky, resinous or wax containing gases can lead to sediment on the membranes which hinder the sonic dispersion and consequently make the maintenance cycle shorter. This contamination phenomenon was previously seldom able to have an effect, since a component of this type were not present in most combustible flue gases. In dry and humid dusts(but not in sticky dusts), the concentration does not have an important role, as both the gas velocity and the membranes surface area vibration lead to a self cleaning effect. On the whole one can comment that the systems without purge air are increasing in popularity. Everywhere where the conditions allow them to be used , a simple system is available to the plant operator.

3.1.3 Several application examples

The following applications shown are not CEMS applications, in other words the measuring site was before the filter and gas cleaning (normal applications). These examples were chosen to show that monitors used for CEMS applications can also be utilised under considerably less favourable conditions than those normally typically present for CEMS. These applications also require little maintenance.

Systems with purge air

Fig 7 shows the measuring head of a system with purge air, with tar condensates for 6 months without maintenance. Despite the probes being extremely contaminated, the transducer is still in-tact without any contamination.Using a system without purge air is not an option here to due to the condensates sticky nature.

Fig 7

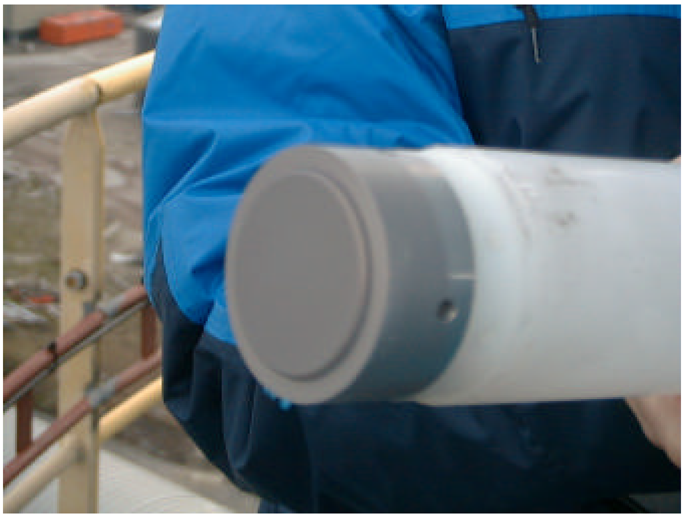
Fig 8 shows an ultrasonic transducer which was subjected to an high dust concentration (approx. 200g/m³) with temperatures of up to approx. 350°C (raw cement gas). Systems without purge air could not be used here, simply because the temperature is too high.

Fig 8 Use in raw cement gas

The vibrating membrane has kept itself free of dust.

Systems without purge air

Fig 9 shows a measuring head which was in use for a year at an aluminium plant, subjected to dust concentrations of approx. 100mg/m³ and was not cleaned at all. The typical example of a CEMS application (combustible gas measurement, gas temperature <180°C) can be operated almost maintenance-free using a system without purge air.



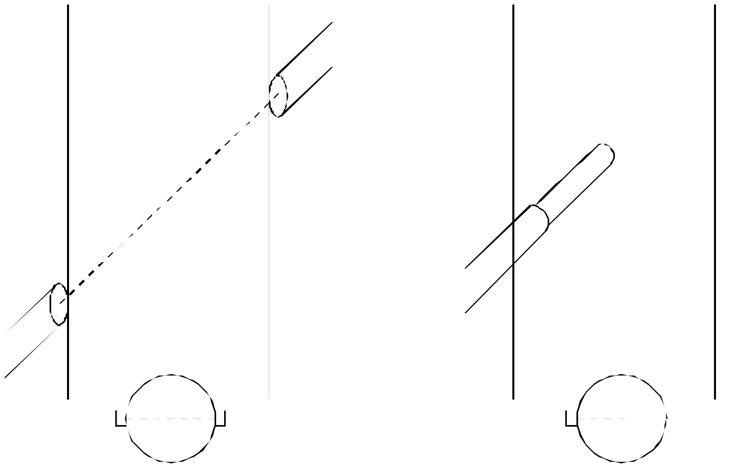
Measuring probe used without purge air, with titanium transducer.

3.2 Differentiation according to the site of the measuring path.

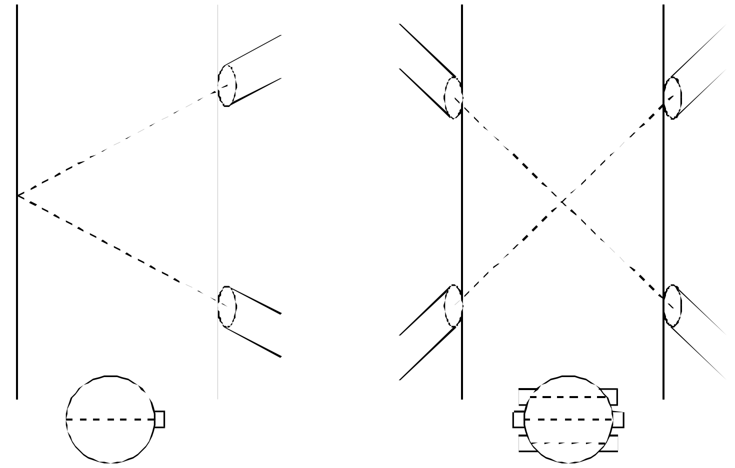
3.2.1 Overviews

The location of the measuring path dictates how representative the flow profile is examinedand consequently how accurate the flow measurement is. There are principally 4 different versions here:

a) Single path cross stack
b) Single path, reflection
c) Single path, probe
d) Multi-path



Version a) Version c)



Version b) Version d)

Fig 10 Various options for measuring path locations

Reflection directions are unimportant for stack applications, because the energy wastage during reflection in large diameters is unacceptable and the slight improvement in accuracy which can be achieved is of little value.

Several path adjustments play a positive role in stack applications, in order to compensate for an originally unfavourable mounting situation, (see /1/ for example). Particularly when several tubes are brought together, this method is often the only possibility for attaining representative results. For reasons of time we will not go into any more detail here, because as opposed to one path solutions, they are seldom used due to their considerably higher costs.

However, there are also disadvantages here. In large, vertical ducts a second platform is reguired, since the second probe is mounted at a higher level due to a 45° installation angle.

3.2.2 Cross-Stack-Version

This is the classic installation which is nowadays found in the majority of applications. This has good to excellent results.

However, there are also disadvantages here. In large, vertical ducts a second platform is required, since the second probe is mounted at a higher level due to a 45° installation angle.

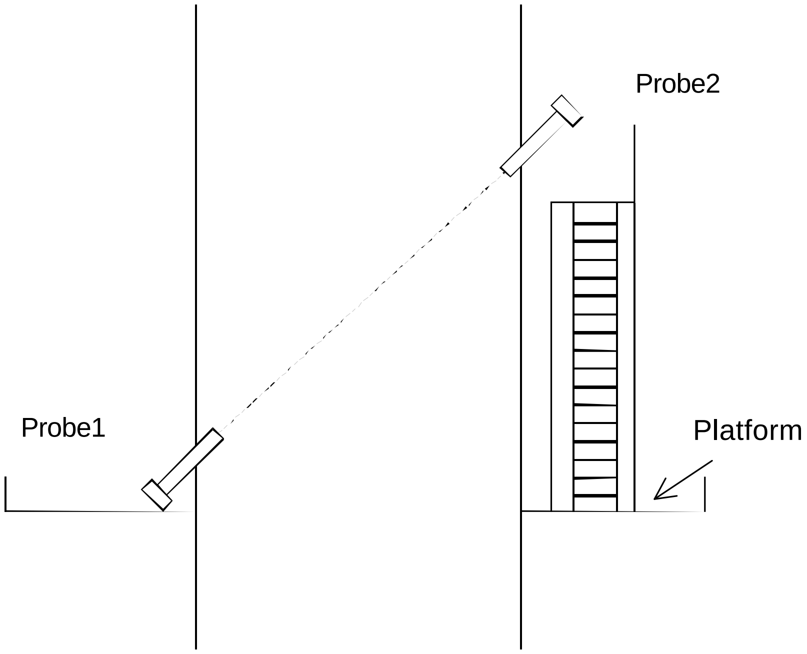


Fig 11 Platform construction for large, vertical ducts

In many plants the structural requirements are already in place. If this is not the case, costly additional construction may need to be built, which could undermine the whole economic efficiency of the measuring system.

Reducing the angle can be the solution in many cases, which in turn leads to a reduction in the vertical distance between both probes. This solution is not always acceptable however, as reducing the angle can lead to a reduction in the measurement accuracy. There are also plants where the structural conditions do not allow a cross-stack installation, e.g. if the opposite side is not accessible or internal supports prevent through line of sight for the sensors.

The probe version was developed to further expand the instruments potential.

3.3.3 Probe version

This new version benefits from most of the advantages associated with classic ultrasonic monitoring technology and is also very user-friendly. Because of the probe form, mounting is only required on one side. This overcomes the requirement for a second measuring point and the structural work and electrical installation associated with this. The costs associated with this extra work are also avoided.

With the probe version, both ultrasonic transducers are fixed to a support arm .

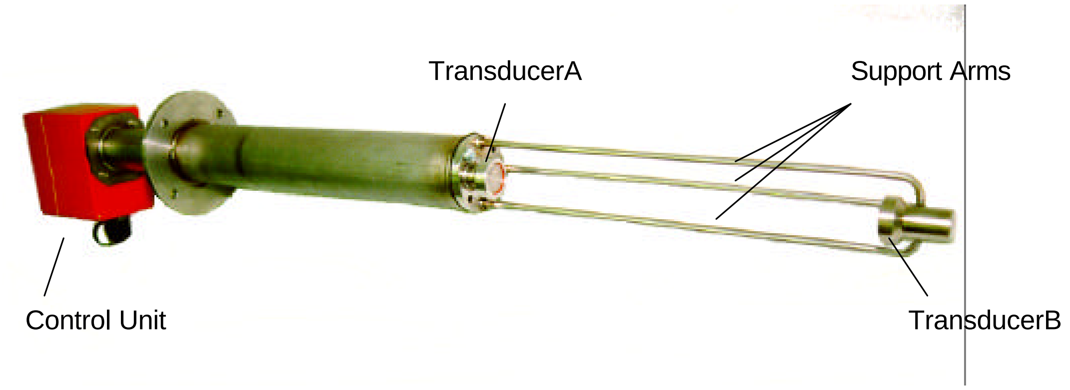


Fig 12 Probe version

This Support arm is designed so that it does not hinder the flow, therefore enabling a representative measurement. Installation should be carried out the same as for cross-stack version, generally at an angle of 45° to the flow stream. The ultrasonic transducers which are used here have a higher frequency than those in the cross-stack version, so as the same time resolution and consequently the same accuracy can be attained, even when used in a short measuring path. As both transducers are connected by the support arm, a special impact sound isolator is required. This ensures that the sonic dispersion only passes through the gas and not the fixed body.

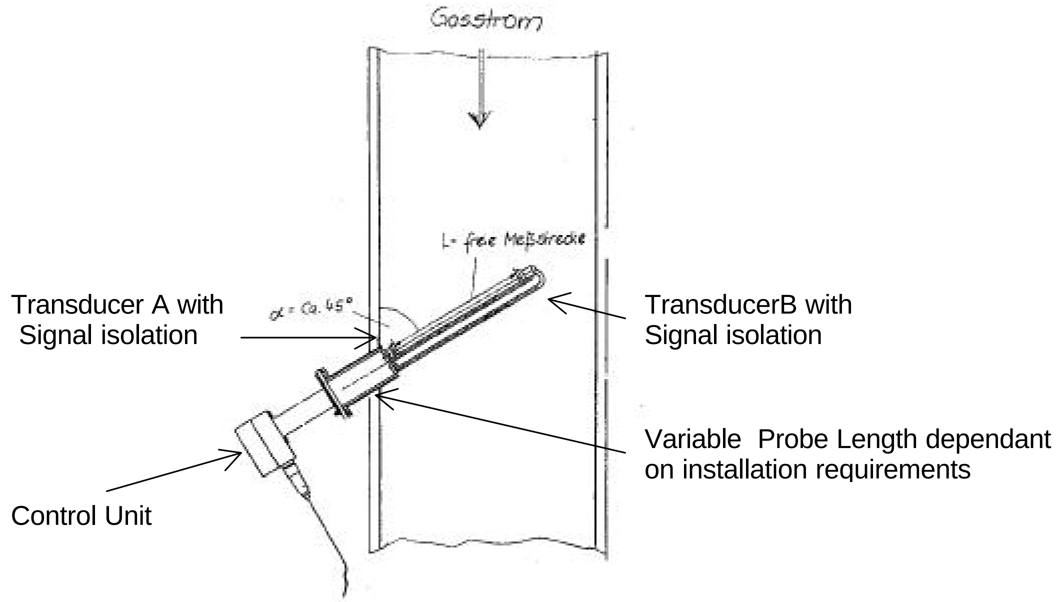


Fig 13 Installation site

The measuring path site is vital for the measurement accuracy. Therefore particular attention should be paid to this factor.

The next point to note is that the probe should only be used in relatively uniform gas flow profiles. Severely stratified profiles should not be considered as probe applications. In these cases conventional cross-stack methods should be used.

For a probe version, the decisive factor for ensuring measurement accuracy is the correct alignment in the gas flow profile. One should therefore produce an error assessment regarding the flow profile observation.

To examine full-form, turbulent flow profiles (Re>2300) in tubes, the model according to Nikuradse is often used. The velocity distribution is described according to the equation (9).

$$v(r) = v_{\max}\left(1 - \tfrac{r}{R}\right)^{n} \qquad (9)$$

r = Spread of the points from the average value
R = Radius
v_{max}= Maximum Velocity

The potence factor n is a function of the Reynolds number.

$$\mathrm{Re} = \tfrac{v \cdot d}{\nu} \qquad (10)$$

d= diameter
ν = kinematic viscosity

to obtain the gasflow $\dot{Q}$, the velocity measured over the cross section is standard, which is shown in equation (11).

$$v_m = \frac{\dot{Q}}{A} = \frac{\dot{Q}}{\pi \cdot R^2} = \frac{2}{R^2}\int_0^R v(r) \cdot r \cdot dr \qquad (11)$$

v_m= velocity measured over the surface area
$\dot{Q}$ = gasflow

An ultrasonic monitor (cross stack) nevertheless obtains the path velocity across the measuring axis, which is different from the average velocity V_m.

$$v_p = \frac{1}{2 \cdot R}\int_{-R}^{+R} v(r) \cdot dr \qquad (12)$$

v_p = path velocity

The formula is valid in this from for the cross stack version; for the probe version the formula would be modified as follows:

$$v_p = \frac{1}{2 \cdot r}\int_{r_1}^{r_2} v(r) \cdot dr \qquad (13)$$

r = path length
r_1= transducer 1`s co-ordinates
r_2= transducer 2`s co ordinates

The measurement needed by a CEMS is the gas flow and, connected with this, the mean velocity v_m. The measuring system ascertains the variable v_p. Therefore the v_p/v_m ratio is the decisive variable for measurement accuracy. The absolute numerical value of this relationship is not the most important factor here, since all CEMS measurements are calibrated, as mentioned above. This factor is determined during a calibration and any deviations from the theoretical value are corrected. For accuracy then, the determining factor is the reproducibility of the measurement.

The influence variable flow profiles have on different flow velocities should be examined here, when using different tube diameters and different load conditions.

As examples, the typical Reynolds numbers and porence factors shall be used here for ducts of 3...7m and flow velocities of 10...30 m/s. The corresponding values will vary between

7m, 30 m/s: Re = $3,7*10^6$, n = 0,10 and
3m, 10 m/s: Re = $5,3*10^5$, n = 0,12

Fig 14 shows the theoretical current profile of the studied Reynolds numbers. Both tube and diameter and gas velocity were varied.

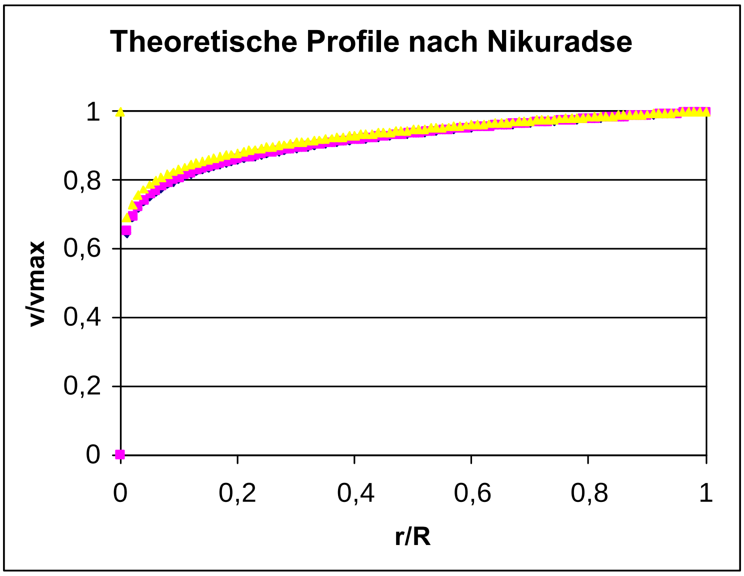


Fig 14 Theoretical profile according to Nikuradse

It can be seen here that even with theoretical flow profiles, a relativity low profile dependence is registered for a Reynolds number range.

A tubes' flow profile path is normally determined by the occurrence of frictions between the gas and the tube wall. In the case of high Reynolds numbers observed here, the frictional strength the inertia strengths which are predominant in the gas, so that a fully formed flowprofile only sets in after an intake path of 100...200 D. For a tube diameter of 0,5...1 Km would simply not be a viable option in normal, everyday plants.

Furthermore, the theoretical observation for fluidic, smooth tubes is relevant here, howeverthe ducts in CEMS applications are to be assumed to be relatively coarse tubes.

The profiles which are the closest to those found in use over a large number of measurements should be used here for error observation on topic, as well as many applied measured profiles are to be found in /1/. Fig 15 shows the practical profile adopted .

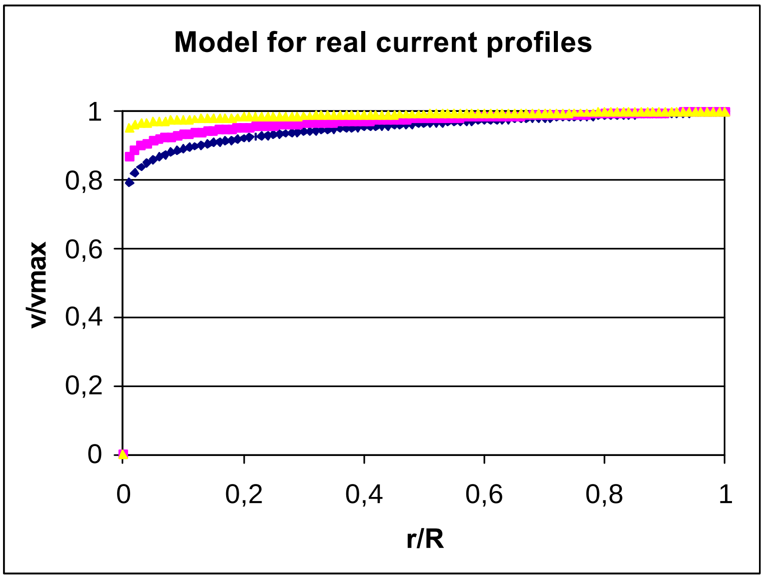


Fig 15 Model for real flow profiles

The relationship between v_m and v_p can be calculated from the profiles in Fig 15, according to the influence of errors on the profile, the following assumptions must be accepted:

- Both device variants, cross-stack and probe, work according to equation (6) without theoretical or practically determined calibration factors or correcting factors.
- For a probe version, a geometric specification is to be chosen as is shown in Fig 16.

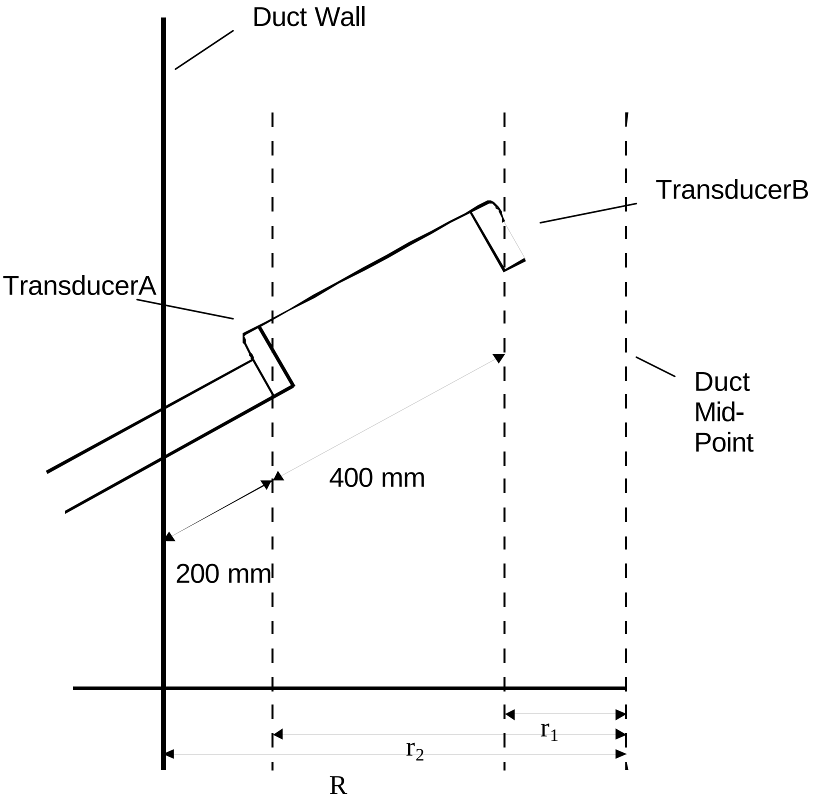


Fig 16 Geometric specification for the probe version

The v_p / v_m ratio is shown in Table 1.

	3m	5m	7m
Cross stack			
v_p/v_m	0,976	0,985	0,995
rel.error	-2,38%	-1,45%	-0,48%
Probe version			
v_p/v_m	0,973	0,950	0,930
rel. Error	-2,70%	-5,00%	-6,98%

Table 1

These results certainly compare to those which were expected. The increasing error when diameters get larger proves the fact that the measuring path is found nearer to the tube wall (relative to the radius). By lengthening the probe, this can also lead to less deviations. This is nevertheless usually unnecessary because of the calibration which follows anyway.

Interpretation of the results:

- The more the profile resembles a rectangle, the less influential the errors are using both methods (that which was anticipated).

- It only concerns the uncalibrated errors, the other errors cannot be studied after calibration using reference method.

- Both installation versions can be calibrated without any restrictions.

As expected, the cross-stack version was of higher accuracy. When the installation site is favourable calibration can be waived here assumong certain technical factors,.As the specific accuracy under the circumstances was no worse than that of the reference measurement.

3.4 An application example

Comparison measurements between the probe version and the cross stack version without purge air were carried out in a German power station. The plant can be regarded as a typical CEMS application.
Diameter: 7,5m
Gas temperature: ca. 130°C
Gas velocity: 15 .. 40 m/s
Duct gas pressure: - 5mbar
Combuston flue gas into flue gas desulphurisation plant
The measuring point here lies approx. 5D above the inlet.

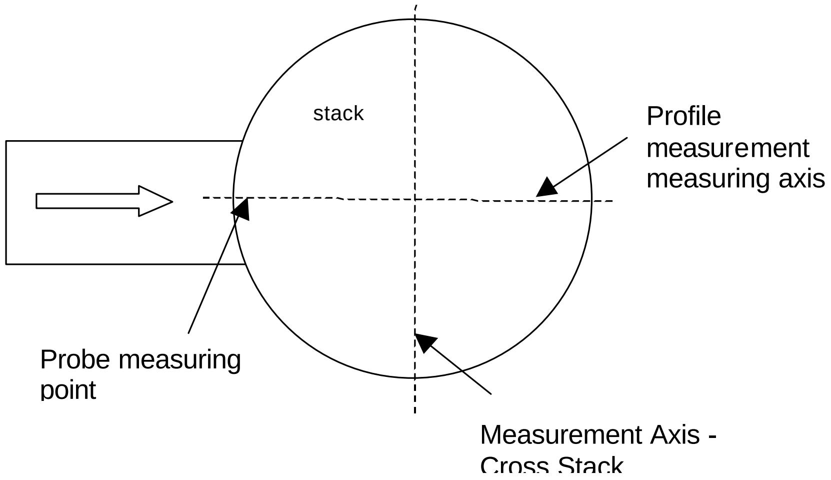
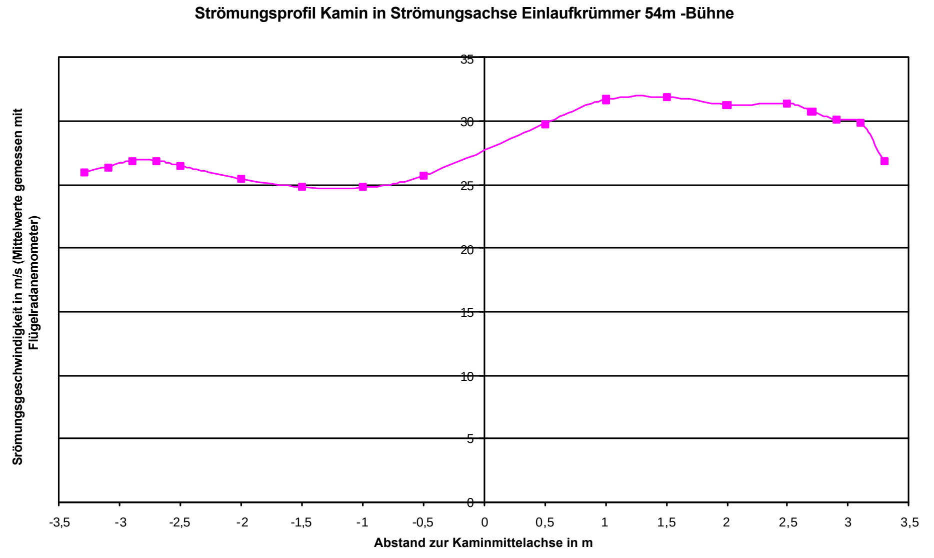


Fig 17 Measuring alignment

The following results were obtained:

The flow profile is slightly unsymmetrical (Fig 18) This is caused due to the last gas directional change not being great enough. Unfortunately this is a situation that frequently occurs in practice.

The deviation between the path velocity v_p of the cross – stack monitor and the mean velocity established from the measuring points totalled (full load) +0,65%, under medium load –1,2% (not calibrated)



Strömungsprofil Kamin in Strömungsachse Einlaufkrümmer 54m -Bühne

Fig 18

The probe version ´s uncalibrated measurement deviation came from the mean value of the measuring points on the measuring axis (path velocity) –0,7%, from which the velocity establish over the cross section Vm –8,0%. With a profile total this is immediately reasonable. The path velocity deviation is so little, since the comparison measurement was carried out on the same path. As a result the path curve makes allowances for this. The probe system was calibrated to the same value as the cross stack device by entering linear coefficients.

Timed course of the gas velocity in the stack

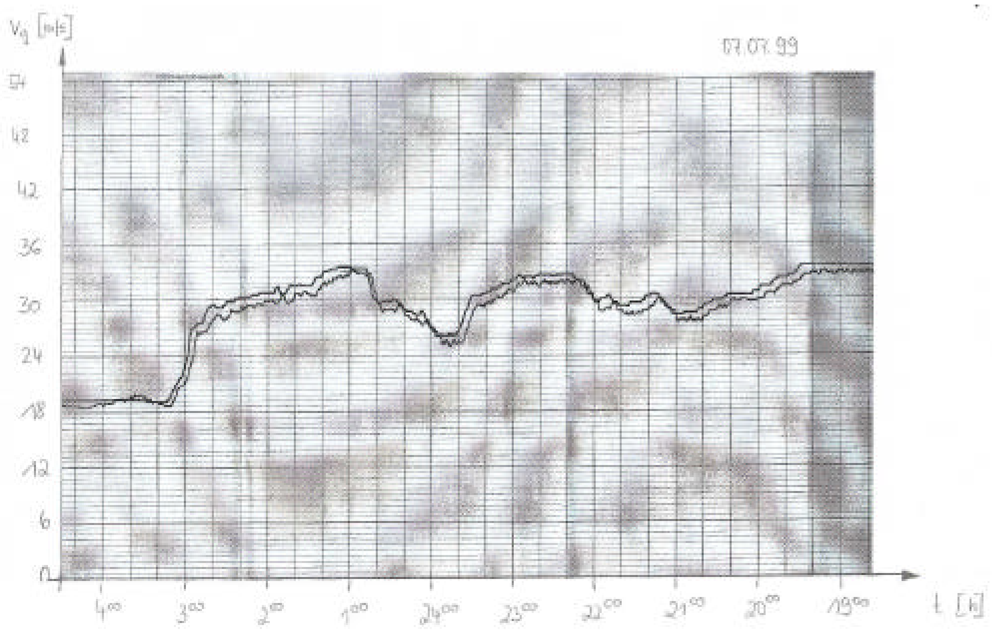


Fig 19 shows the measured values for both devices under fully load conditions and the correlations between both signals attained after calibration. Here it should be determined that it has been well reproduced. It is worth noting that the profile concerned is also unsymmetrical. Therefore the use of probe systems for CEMS applications after a calibration can also be recommend here, without losses in accuracy having to be tolerated.

4. Conclusions

Ultrasonic measurement for CEMS applications exists in various specifications, in order to decide the best possible design suited to a particular plant table 2 shows a summary for the scope of use.

	Cross Stack	**Probe Version**
Without purge air	Temperature <250°C, no sticky particles 2 nd platform available	Temperature < 200°C, no sticky particles 2 nd platform not required
With purge air	Temperature < 600°C, 2 nd Platform available	Not on option

Table 2

The gas flow measurement using ultrasonics has now reached a grade of maturity, in the sense that it is the preferred technology for determining volume flow in the CEMS measuring field. Low maintenance plus the simplest installation and commissioning, have helped lead the way, not to mention the technology – inherent advantages, favourable price range and operation which are closely related to each other.

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