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MEASUREMENT USING ULTRA-SONIC TRANSIT-TIME METHOD - SOME ASPECTS OF GAS FLOW MEASUREMENT

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1. ABSTRACT

The objective of this paper is to show some characteristics of measurement of gas flows using ultra-sonic time of flight method. Also, USE-Ultraflux has developed a series of test on the IPT Anemometry facility to check the influence of several situations found on actual process plants on the ultra-sonic meter performance.

Keywords: flow metering, ultra-sonic, transit-time, high velocity gas flow

2. INTRODUCTION

The main objective of this paper is to show some characteristics in flow measurement using ultrasonic transit-time (time of flight) method and the influence of several factors and conditions found on actual process plants.

In the beginning of ultra-sonic measurement, only liquid fluids flows in closed conducts, in particular water, were measured by this method. Then, with some improvements, it was extended to liquid flows in open channel, gas flows at high pressure and finally to gas flows at low pressure.

It's important to observe that the velocity of sound in the fluid does not interfere in the expression used to obtain the average velocity of the flow, but it can influence the way the measuring device works.

The velocity of sound in fluids is a characteristic of each product. Basically, low-density materials have low velocity of sound and for high-density materials this velocity is higher. The velocity of sound shows how "easy" the ultra-sound pulse can travel through a material. This characteristic implies in using different types of probes for liquids and gases.

An important fact that shows the difference between flow measurement in liquids and gases is how it happens on actual production facilities.

The average velocity of liquid flows is quite lower than in gas flows but the velocity of sound is higher in liquid flows that in gas ones. In cases of large diameter and high flow velocity (20~30 m/s) and low velocity of sound (330 m/s - air or natural gas at low pressure, for example), the ultrasonic pulse made by one probe can be deflected by the flow velocity and, in consequence, it might not reach the other probe.

In the beginning, probes with low ultra-sonic frequencies (150~200 kHz) were employed, since long wavelength ultra-sonic pulses can travel on low-pressure gas easier than short ones. But there are some control valves and other apparatus that produce noises near this frequency, and some research and development was made to achieve good results using higher ultra-sonic frequencies.

To check the effects of high velocity flow range at low pressure, a series of tests was taken on IPT facilities on January 2000 by the USE-Ultraflux using a device specially built for this test and an ULTRAFLUX UF-322 G1 flowmeter.

3. APPLICATIONS OF ULTRA-SONIC GAS FLOW METERS

An ultra-sonic flow meter can be used in many situations found at production plants which may shave special characteristics that request special probes or special probe positioning.

Some typical situations are:

- Operational control;
- Fiscal metering;
- Flare gas metering.

These situations have different operational characteristics as follows:

Operational control:

- Low cost;
- Typical uncertainty: 1%;
- Medium to high pressure range requesting special probes;
- Single chord arrangement.

Fiscal metering (AGA-9)

- Very low uncertainty: less than 0,7%;
- High confidence;
- Medium to high pressure ranges requesting special probes;
- High quality spool manufacturing and measuring.
- Multi-chord arrangement.

Flare gas metering

- Low pressure ranges requesting large wavelength ultra-sonic probes;
- Very wide flow ranges with "surge" flow;
- Medium to large diameters;
- High uncertainty: less than 5%.
- Probe insertion without interrupt the process (Hot tapping).

4. THE TEST

The test was performed on IPT Anemometry lab. In this lab there is a wind tunnel with a test section of 0,5 x 0,5 m. It's possible to reach velocities up to 30 m/s. There are various velocity measuring systems like Pitot's meters, anemometers and hot-wire anemometers. There is also a laser-based velocity measuring system.

Test were performed in the wind tunnel because the velocity range desired was impossible to be reproduced in the gas flow laboratory.

Since the objective of the test was to get some qualitative data about the influence of high velocity flows on the ultra-sonic meter performance, the uncertainty of the velocity of the flow indicated by the ultra-sonic meter checked against a control meter was considered only as reference. Several control meters should be used to cover all ranges of flow velocity, masking a quantitative evaluation of the test.

The special device built by USE-Ultraflux permits two kinds of adjustments:

- The angle between the probe axle and the flow current;
- The tilt angle between the two probes.

Several adjustments on probe angle and electronic unit were made and some situations were simulated on the wind tunnel, to check how the meter would respond under various actual conditions.

Some of the situations simulated are:

- Very low flow velocity rates;
- Very high flow velocity rates;
- Rapid changes from low flow to high flow velocity rates;
- Rapid changes from low flow to high flow velocity rates and the, back to low flow velocity rates;
- Loss of echo at low flow velocity rate;
- Loss of echo at high flow velocity rate;
- Misalignment between probes;
- Preset angle between probes to compensate ultra-sonic path distortion at high flow velocity rates;
- Different angles between probe axle and flow direction.

To analyze the meter performance in such situations, the echo quality, waveform and amplification were checked through the built-in oscilloscope function screen.

Also, some configurations of parameters of the meter were tested to find how each parameter should affect the performance of the meter in the simulated situations.

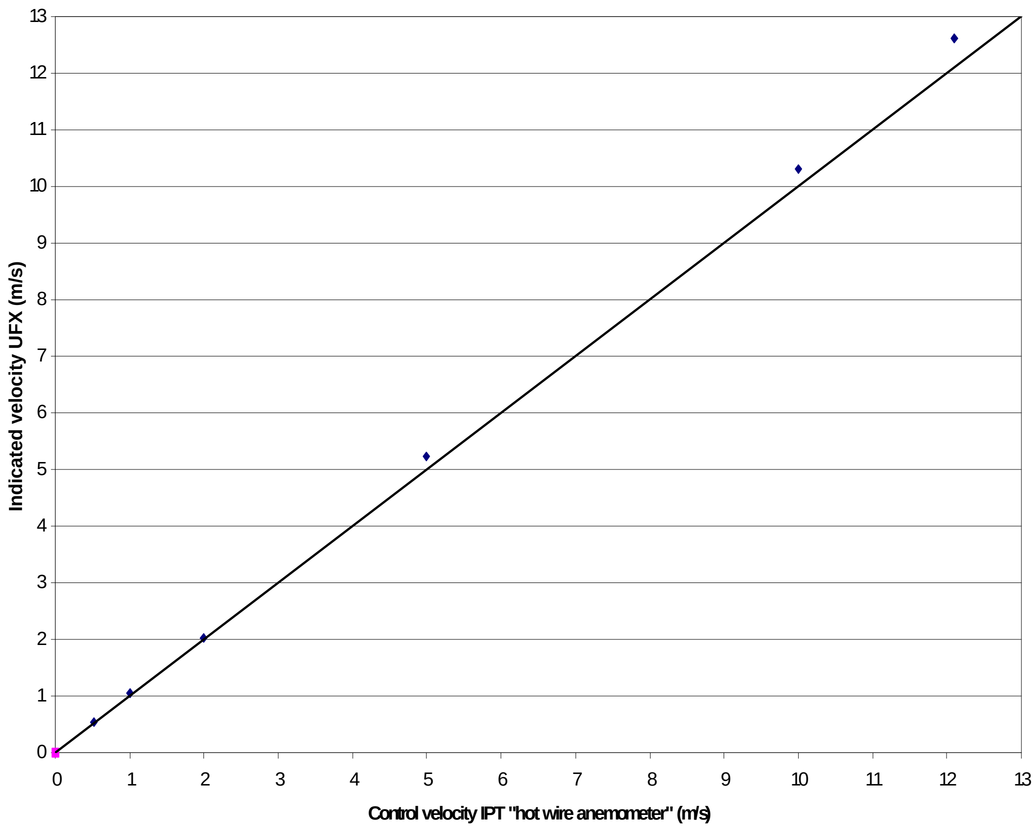

Figure 1 - Deviation of measured velocity

After several runs on the wind tunnel, some statements were observed:

- An increase of echo amplification when increasing the flow velocity shows a tendency of deviation of ultrasonic path. This effect is stronger at velocities above 12 m/s;
- There is also the increase of noise level at high velocities. One possible explanation is the turbulence caused by the ultra-sonic probe heads since it was an open flow device not installed on a pipe or spool piece;

- It is possible to have metering flow velocities up to 30 m/s (the maximum velocity reached by the tunnel) since the meter has a built-in DSP that reduces the influence of noise or distortions on the acoustic path;
- Jumps from low velocities to high velocities rates can be measured by the meter without any visible problem. When it's induced a echo loss (simulating, for instance, the passage of a debris on the acoustic path) the meter can operate as soon as the echo is established again;
- A preset angle between the probes does not improve the performance of the meter. There is a slight improvement at medium and high velocities but at low velocities that angle induces a lower performance that is not worth the benefits.

Device Angle 60°	**Angle between probes 0º**	
Flow Velocity (m/s)	**Sound Velocity (m/s)**	**Gain (dB)**
2,50	346,8	28
5,02	346,8	29
10,0	347,2	35
11,0	347,0	36
12,0	347,2	37
13,0	347,2	38
14,0	346,7	39
15,0	346,6	41
25,5	346,0	52
Programming: c=330 m/s ∆c=50 m/s		

Table 1 - Echo signal amplification

5. CONCLUSIONS

On the first instance, the objective of the test is to observe how a standard ultra-sonic flow meter would work at several conditions of gas flowing at low pressure.

Some situations that may occur in actual process plants were simulated in the wind tunnel to check the meter performance. Such situations include echo loss, low-to-high flow rates, misalignment of ultra-sonic probes and so on.

The maximum velocity reached by the wind tunnel is 30 m/s. Although there is a tendency of deviation of the acoustic path and the noise caused by high velocity flows, the meter can perform a stable measure since it has a built-in DSP that reduces the influence of the effects of flow velocity. Ultraflux flow meters do not need a tilt angle to get better performance at high flow velocities.

The velocity measurements are easy up to the limit of 12 m/s. Above this limit, the probe's geometry and positioning are critical for the quality and stability of the measurement.

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