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Measuring High Frequency Valve Noise to Evaluate Interference with Ultrasonic Flow Meters

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ABSTRACT

Ultrasonic flow meters are installed in lines with particular concern on the location of flow noise sources, such as valves and other geometry changes and restrictions in a piping system. The ultrasonic flow meter operates with a tone burst, typically in the range of 100 to 300 kHz. While, this frequency range is far above the typical range for noise control in piping systems, there is good evidence that the flow noise sources generate sound in the operating frequency range of the ultrasonic flow meter. The goal of the work was to establish a procedure to measure the noise generated by piping elements in the frequency range of the ultrasonic flow meter operation. The flow disturbance is placed upstream of the ultrasonic flow meter. The internal noise spectrum are measured at three locations, one upstream of the flow disturbance, one between the flow disturbance and the flow meter and one down stream of the flow meter. Some available results in the literature will be reviewed along with presenting the experimental setup and preliminary results. The results will show the capabilities of the measurements in this frequency range.

1.0 INTRODUCTION

Ultrasonic flow meters are being used in piping applications for the advantage that they create no disturbance to the flow as an orifice meter would. Thus ultrasonic metes have an advantage of limiting head loss in a piping system.

Ultrasonic flow meters operate on the concept that the travel time of a sound wave depends on the mean flow velocity of the fluid. Pierce [1] has a general development of this theory. However, since the ultrasonic flow meter is dependent on detecting a sound inside the pipe, other noise in the piping system can interfere with the flow meter. Case studies have been published, for example by Riezebos [2]. Control valves, flow straighteners, and pipe bends are flow noise sources of particular concern. In general, the manufacturers of ultrasonic flow meters have guidelines for the placement of the flow meter relative to potential flow noise sources. However, there appears to be a need for more measurements of the noise generated by these flow noise sources so that the guidelines for placing them near an ultrasonic flow meter are clear.

Much work with control valves and other piping flow noise sources are measured and analyzed below 10,000 Hz, since that is the segment of the audio range that they generate the most noise. However, a typical ultrasonic flow meter operates in the range of 100 kHz to 300 kHz, a frequency range far above most of the available test data and models of piping flow noise.

The goal of the work presented in this paper is to develop a test method and set of data that can be used to clarify the noise generated by flow noise sources in the range that interfere with the ultrasonic flow meter. The challenge faced in this work is developing the hardware to perform the measurements.

This paper will outline the equipment and measurement procedures used to acquire the high frequency noise from flow noise sources. Data for limited cases will be presented to show the trends that are being revealed by the data.

2.0 INSTRUMENTATION

Instrumentation was needed to measure the noise inside the pipe and to monitor the flow conditions in the line during each test.

The noise inside the pipe was measured with a PCB 132A32 pressure transducer, Fig 1, which have a sensitivity around 100 mv/psi and a resonance frequency of 1 MHz. The transducers were held in a custom built fixture that screwed into the pipe walls. It was critical to have the transducers well sealed, since flow through the fixture holding the transducer generated a characteristic signal when the line was pressurized. The transducer fixture was mounted in the pipe wall so that the fixture and transducer were flush with the pipe walls. Transducers were places at three locations in the flow line.

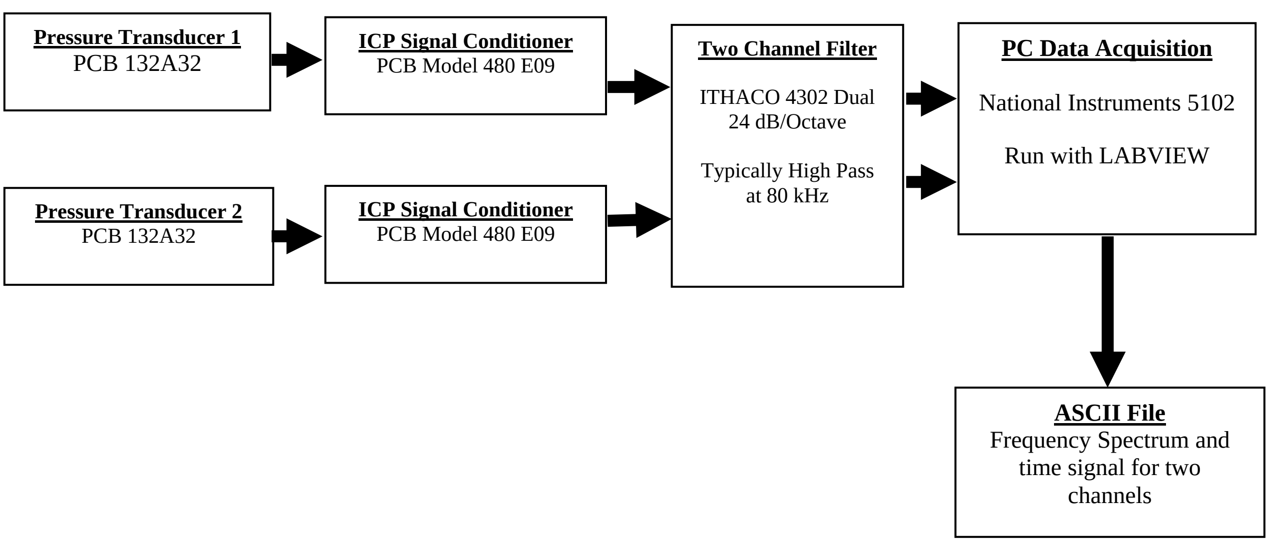


Figure 1: Diagram of the data acquisition system.

The transducers were connected to PCB Model 480 E09 signal conditioners, Fig 1. Each signal conditioner provided 100 times gain in the transducer signals. The signals were then passes through a high pass filter. Since the noise signal was dominated by sound below 50 kHz, the digitizer would use little of its resolution on the high frequency noise if the signal level was set based on the low frequency levels. Therefore, the high pass filter allowed the resolution of the digitizer to be used on the high frequency data being investigated. This was especially important since the digitizer, a National Instruments 5102, was an 8 bit digitizer. The digitizer was chosen for its maximum sampling rate of 15 MHz. With two channels that provides up to 7 MHz per channel. The filter also provided post filter gain of 10 times.

The digitizer was controlled by a Labview program that acquired the time signals and calculated the average auto spectra for each channel. For all measurements the digitizer sampled the signals at 2 Mhz. The average autospectra each consisted of 50 samples of 4096 point time signals. The data was amplitude calibrated after acquisition.

It is important to note that there was no anti-aliasing filter in the system. To avoid the expense of an anti aliasing filter, the signals were sampled at such a high rate, that above the niquest frequency, the noise floor of the digitizer was above the signal level. Data shown later will confirm this choice.

3.0 TEST SETUP

The ultrasonic flow meter was installed in an 8" line in the R.A. Engel Technical Center flow lab. Figure 2 shows a schematic of the test setup with distances shown in pipe diameters, and Figure 3 show a picture of the flow line. The red dots labeled, P_{DM}, P_{Dv}, and P_U represent to pressure transducer locations down stream of the ultrasonic meter, down stream of the test noise course, and upstream of the test noise source respectively. In the case of testing valves, the valve is placed where flow noise source is indicated and some dimensions change because of the valve length.

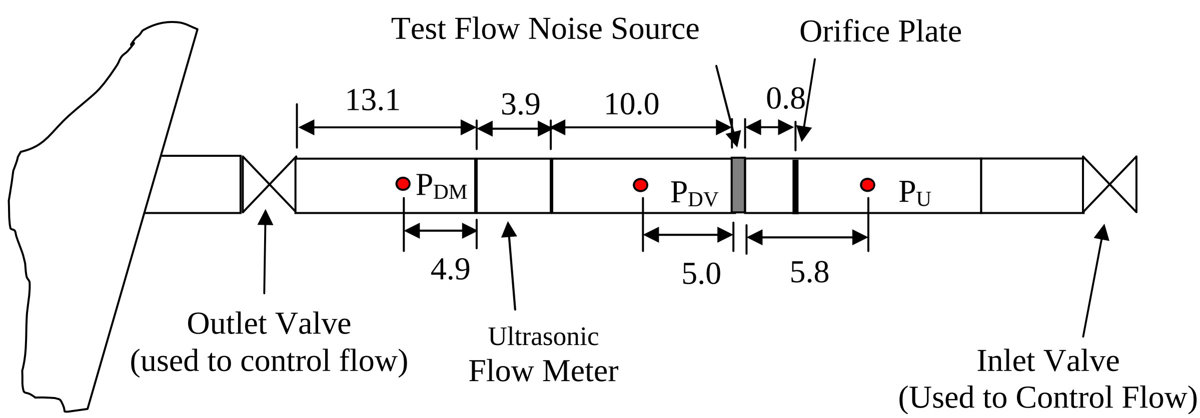


Figure 2: Schematic of the flow line. Dimensions are relative to a duct diameter

The flow rate in the line was controlled using either the upstream or down stream valve. In the case of controlling the flow from the upstream valve, the flow line was at a pressure near atmospheric pressure. However, the ultrasonic flow meter needed over 100 psi of static pressure to operate consistently. Therefore for the valve testing, the flow rate was controlled by adjusting the down stream valve, with the upstream valve kept open.

In the case of controlling the flow from the up stream valve, the static pressure upstream and down stream of the inlet valve were recorded. Similar values were maintained for all test cases. In the case of controlling the flow using the down stream valve, the pressure drop across the test valve was measured, with the pressure down stream of the valve maintained at a constant value. For the valve testing, the travel of the valve was selected so that testing occurred at the same C_g values for each valves.

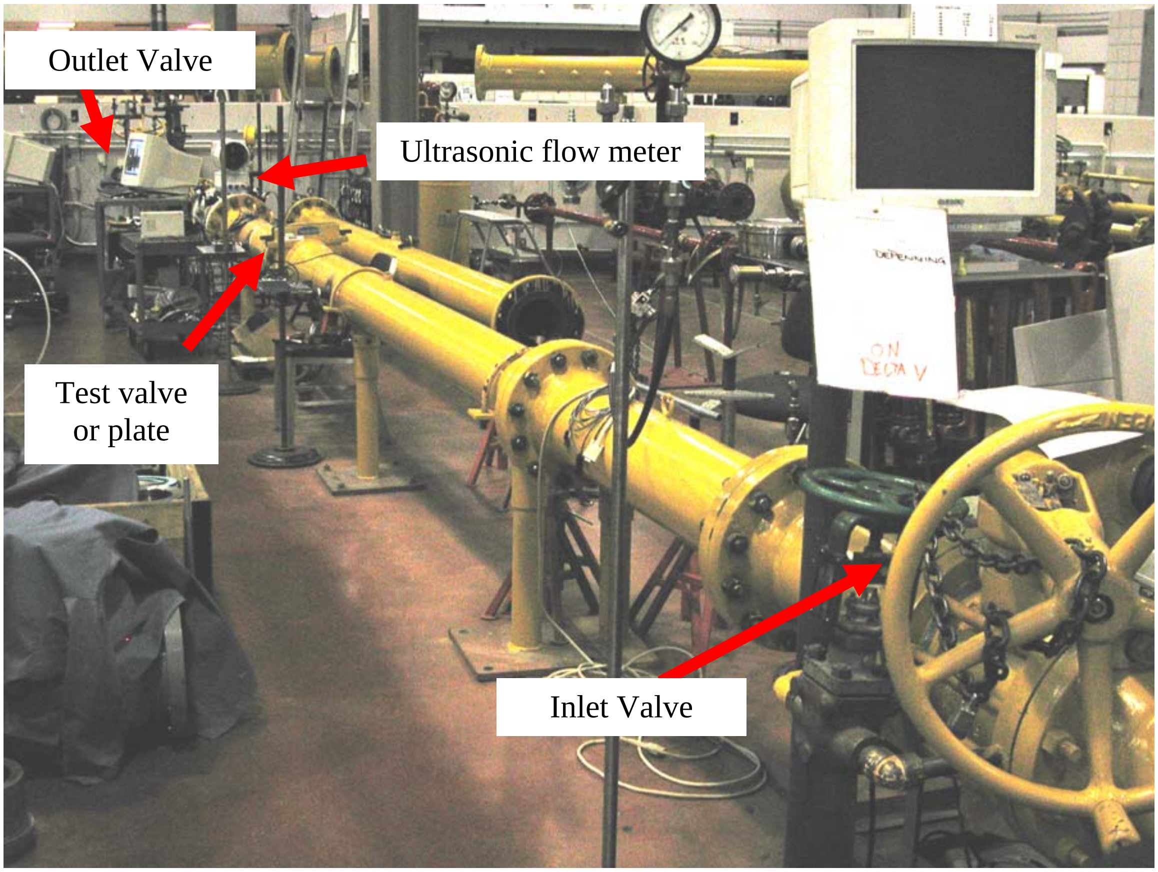


Figure 3: Picture of the flow line with key elements marked.

4.0 EXAMPLE TEST DATA

Figure 4 shows typical test data for a plate with thirty five one inch diameter holes. The tests were run at 5 flow rates, first with no flow to provide baseline data. Then the flow was increased and the pressure drop across the inlet valve was recorded. During measurements, the flow meter was monitored. As the flow rate increased, the meter would fail to provide a reading, a case caused by the flow noise being larger than the ultrasonic signal in the flow meter. These results are comparable to the values and frequency dependence reported by Riezebos [2].

These results also highlight one of the primary challenges in the measurements: maintaining enough resolution in the digitizer for the high frequency content in the signal. In the cases of 10 and 17 psi drop, the signal level above 600 kHz are constant and is 20 dB above the no flow data. In these two pressure drop cases the amplification was decreases by 10 times, a 20 dB change. Therefore, the level above 600 kHz are at the noise floor of the digitizer. In the cases of 40 and 65 psi drop, the signal above 600 Hz again appears to increase. However, for these three cases, the signal levels were high enough that the amplification needed to be decreases by an additional 10 times. Thus the 20 dB increase above 600 Hz is caused by the increased noise floor of the digitizer after calibration.

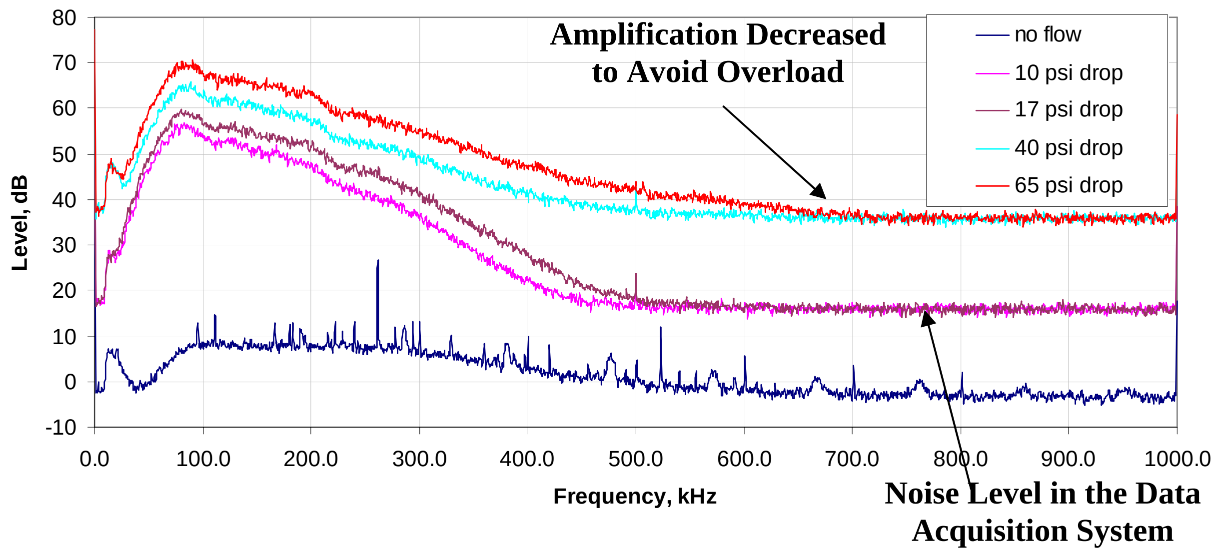


Figure 4: Example data down stream pressure, $P_{DV,}$ of a plate with thirty five 1 inch holes.

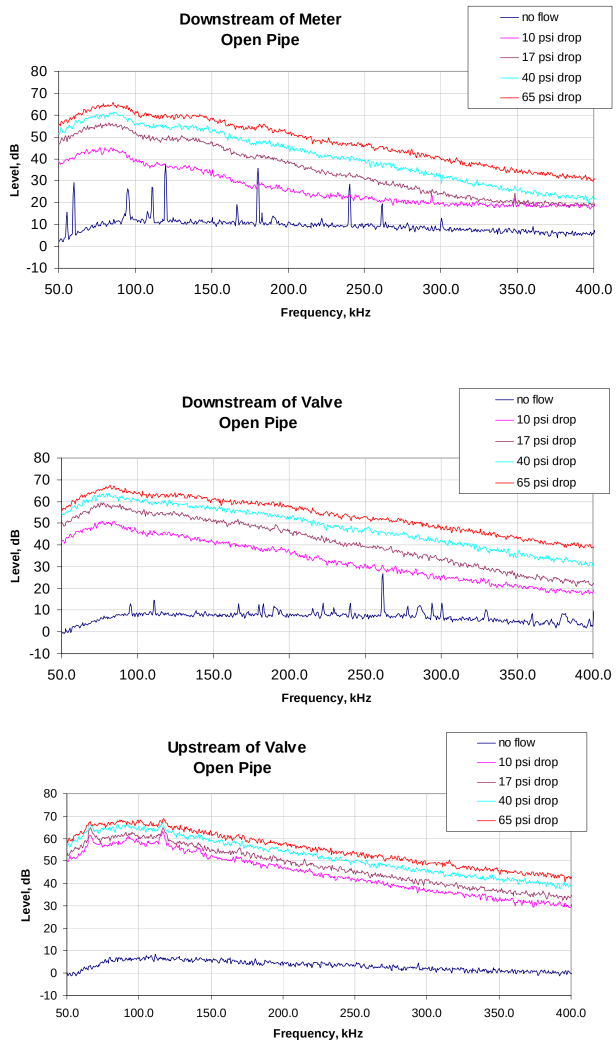
These results also show that the digitizer is sampling the signals at a rate that the broadband signals generated by the flow is below the noise flow of the digitizer. The data also points out the need for the high pass filter. Without it, the signals below 100 kHz would force an amplification level that would place the signal above 100 kHz into the noise floor of the digitizer.

Figures 5 and 6 show test data for an open pipe and a plate with thirty five one inch diameter holes. In both cases the flow was controlled by the inlet valve, with the outlet valve fully open. In other measurements with valves, the flow was controlled by the outlet valve with the inlet valve fully open.

The results show an increase in the level at all measurement locations with the plate. There is however a base level in the system measured with the open pipe that will need to be compensated for. This noise appears to be generated in a large part by the inlet valve, since the levels decay down stream from the inlet valve. Also, in both data sets the pressure transducer upstream of the valve or orifice plate has a similar spectrum that is different from the other transducers. This appears to be caused by noise generates by the straightning tubes and inlet valve in the pipe just upstream of the transducer.

5.0 CONCLUSIONS

The work presented here shows some of the potential and challenges in measuring the noise generated by piping flow noise sources above 100 kHz. It is surprisingly difficult to develop a system that is immune to noise generated by the flow control systems in the flow line. Future measurements will be implemented on a longer line, so that the flow control devices will be further up and down stream of the transducers. On going studies are also investigating the noise generated by standard and low noise valves.



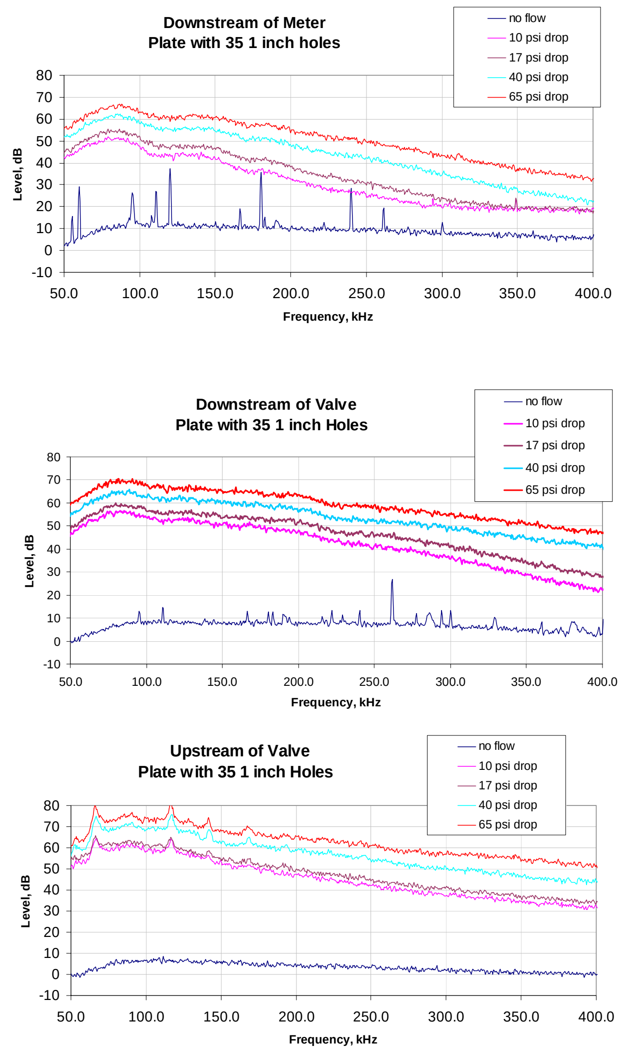


Figure 5: Example data for an open pipe. Flow rate controlled by inlet valve.

Figure 6: Example for a plate with thirty five. One inch diameter holes. Flow rate controlled by outlet valve.

6.0 ACKNOWLEDGEMENTS

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7.0 REFERENCES

[1] Pierce, A.D., Acoustics: An introduction to its Physical Principles and Applications, McGraw-Hill, 1981
[2] Riezebos, H.J., "Acoustic Effects in Metering Stations; Impacts on performance of Flow Meter Equipment," Flomeko 2004 Guilin, China