CLAMP ON ULTRASONIC METER APPLICATIONS AND INSTALLATIONS

SHANE DOLAR
AUTOMATION PROJECT COORDINATOR
QUESTAR GAS COMPANY

Introduction

The adaptation of ultrasonic measurement from liquids to gas has changed the way natural gas producers, shippers, and distributors measure their product. These meters are taking the place of some of the more traditional natural gas measurement equipment and they're adapting to new roles as well due to the inherent design qualities of the ultrasonic flow meter. This paper will illustrate some of the more common clamp on ultrasonic measurement applications and also some of the not so common. The basic similarities and differences between the clamp on meter design and the more traditional "wetted" transducer models will be discussed as well. This information is not intended to explain the science of ultrasonic measurement; it will be more of a general overview of the technology and be an introduction to the clamp on style meter. Before going any further we should define a few technical terms:

Ultrasonic terms and definitions

Transducer: The heart of ultrasonic measurement. The device used to transmit and receive ultrasonic signals through the medium to be measured, in our case natural gas.

Wetted Transducer: This refers to a transducer whose face (the front of the device) protrudes into the gas via a machined bore in a steel meter body. These are mainly used in permanent traditional installations where the meter would be flow calibrated and used for custody transfer measurement or process control. The precision of the manufacturing process allows for this. Measurements for face to face distances are very precise and transducer angles are machined to tight tolerances.

Clamp on transducer: Similar to a wetted transducer in that it transmits and receives ultrasonic signals. That is generally where the similarities end. These transducers are installed on the outside of the pipe. They transmit and receive signals through the pipe wall so no part of the device comes in contact with the medium to be measured. Although steps can and have been taken in some instances to increase the accuracy of clamp on ultrasonic meters such as factory installed clamp on transducers onto honed pipe and flow calibrated clamp on meter tubes, the inconsistencies in manufacturing like pipe wall thickness, pipe material, pipe roundness, and other variables usually disqualify this type of ultrasonic measurement from custody transfer quality and accuracy. Generally speaking, we don't use clamp on technology for custody transfer or critical flow control measurement.

Dampening material: This material looks like heavy plastic or rubber tape generally about 10" wide. The purpose for the dampening material is to dampen signal noise up and down the pipe wall. This is a side effect of transmitting ultrasonic signals through the pipe wall. These signals can travel to a flange or weld, reflect back, and be received by the transducer and may cause interference with the desired signal. Dampening material can be a specific type provided by the meter manufacturer or something more generic like Grace brand Ice and Water Shield roofing underlayment. (See meter manufacturer's installation instructions for use of anything other than provided material). Ice and water shield seems to work fine on meters that allow it. There are differences in color and appearance that may make one more desirable than the other for esthetic reasons.

Liquid couplant: Silicone grease sometimes applied between the transducer and pipe or transducer and dampening material. Its purpose is to increase signal amplitude.

Mounting hardware: Fixtures or brackets used to mount transducers to pipe.

Reflect mount: Transducers are mounted on the same side of the pipe in line with each other. The signal is transmitted into the pipe on an angle from the first transducer and reflects back up to the second transducer to be received. This is the most common installation method. Gas pressure and pipe wall material will be factors in the mounting method.

Direct or diagonal mount: Transducers are clocked directly opposite of each other (180 degrees or 3 o clock and 9 o clock on the pipe). Unlike reflect mounting, signals are transmitted and received directly.

Transit time: The time it takes for an ultrasonic signal to be transmitted and received.

Single path: A single pair of transducers mounted in either reflect or direct making one path through the pipe.

Multiple path or Dual path: Two or more pairs of transducers mounted on different planes to make multiple paths through the pipe. A redundant system to increase dependability and accuracy. Most if not all clamp on meter manufacturers offer up to two paths.

Advantages and limitations of clamp on ultrasonic technology

There are many advantages of clamp on ultrasonic measurement. One of the most valuable features is the possibility of little or no pressure loss through the meter (No loss with a clamp-on meter that has no inline flow conditioning equipment upstream). Another unique feature is the ability to pig through the meter (See fig A). Other advantages are ease of installation, onboard diagnostics of meter performance via the meter controller, clamp on measurement can be relatively inexpensive, they're not damaged by high velocities of gas flow (although they may not be able to measure it), bidirectional flow capability with no additional equipment and measurement can be permanent or portable. They are sometimes marketed as the do-all meter.

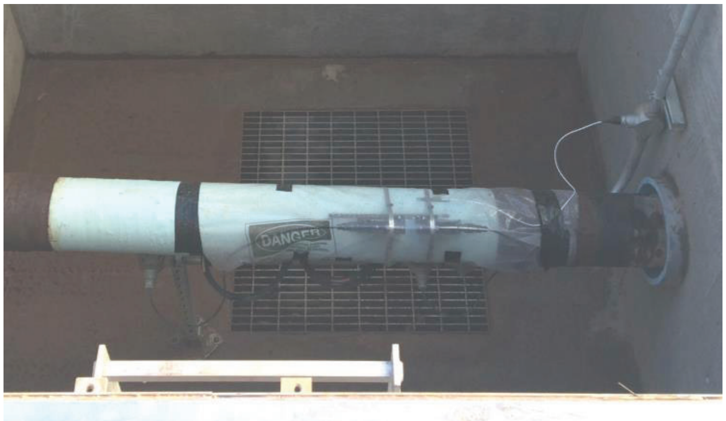

Fig A. *A Clamp On ultrasonic meter in a concrete vault. Single path transducers are mounted in reflect. The pipeline remains piggable due to the non-invasive clamp on transducers and a pipe wall mounted RTD for temperature. The pressure transmitter is installed in a nearby regulator station. A plastic cover is wrapped over the transducers and RTD to protect them from water dripping through the vault lid. A sump was installed in the bottom of the vault to drain off standing water.*

Like any form of flow measurement and with any technology there are limitations and some of these limitations are the same as those of the more traditional meter types. First of all, a fully developed flow profile through the meter is key for accurate gas measurement. This is true for most natural gas meters. Clamp on installations can be especially affected by this due to the nature of the work they're intended for. By design, most clamp-on installations will have no flow conditioning equipment upstream. Swirling or turbulent gas may become too inconsistent for the meter to measure accurately and may also render the meter inoperable. For all clamp on installations, a location that would provide the best flow profile should be considered first. Clamp on meters are commonly installed in less than ideal locations that may or may not be successful. With the portable nature of the meter, the problem could be easily remedied by moving to a different location. In applications where measurement is deemed critical, a more traditional meter run with a flow conditioner is preferred. If an ultrasonic is used, a manufactured meter body with wetted transducers would be best.

A possible weakness unique to this technology is noise. Ultrasonic signals can match the frequency of noise generated by other pipeline equipment. The meter can lose the ability to discern good signals from bad. This is referred to as "Signal to Noise" or "Signal to Noise Ratio". As the frequency of outside noise reaches the frequency of the meters signal, the ability to measure gas is limited or lost. Noise generating equipment such as regulators, flow control valves, gas compressors, or anything that generates noise or vibrations can affect meter performance. The interference isn't always audible.

Natural gas meters are not designed for measuring a gas/liquid mix or "wet gas". Ultrasonic meters are no exception. There are clamp-on meters designed specifically for measuring liquids but again, not both at the same time. In fact, ultrasonic gas meters are an adaptation from liquids meters. Hydrocarbon condensate, water, oils, etc., conduct sound differently than gas so their presence in the pipeline can cause a loss of signal or poor signal quality. An example would be rich gas with condensate travelling down the bottom of the pipe or inside pipe walls coated with water or oil. It is for this reason that clamp on transducers should never be installed on the top or bottom of the pipe (12 or 6 o clock). This arrangement would be more likely to send the ultrasonic signal through standing liquids on the bottom of the pipe or through accumulated dirt which could interfere as well.

On steel pipe applications, 100 psig seems to be the lower pressure limit for dependable performance. There may be exceptions to the 100 psig limit especially when using plastic (poly) gas pipe. Check with each manufacturer for lower pressure installation limits and gas quality requirements.

Dedicated or permanent installations

A dedicated installation is one whose location on the pipeline would be long term and would use the most permanent hardware for mounting transducers and the meter controller. There are meter controllers that are specifically designed to be installed in a permanent application. Most clamp-on manufacturers offer meters in permanent and portable configurations with applicable equipment. Some will include a weather proof enclosure with available 120v AC or 12v DC to 24v DC power. This meter installation will require a permanent power supply and any associated hardware to protect it from the elements. Although the transducers can technically be mounted on pipe that will be exposed to the elements, it's been shown that sheltering these devices from rain, snow, wind, ice, etc. has been worth the effort and probably pays for itself in the long run due to fewer weather related equipment failures. The meter hardware is generally robust and isn't overly sensitive to the elements, they actually perform well in adverse conditions, but they'll do this longer if simple means are used to keep them dry.

One of the biggest advantages to clamp on meters could be the ability to install fairly accurate measurement on an existing pipeline without cutting into the pipe to install a primary device. This is especially desirable for pipelines that require routine pigging which is becoming commonplace in our industry. With a more traditional meter, complex piping and equipment would need to be installed to keep the line piggable. That is no longer the case with clamp on technology. None of the devices used to measure a corrected volume need to protrude into the pipe. In Figure A, you'll notice the RTD mounted on the pipe wall along with the ultrasonic transducers. The pressure transmitter typically uses a thread-o-let for a pressure tap which doesn't affect pigging. In Figure B, a single path clamp on meter has been installed with a more permanent mounting bracket. Notice the pressure tap is a 2" thread-o-let with a ball valve. The reason for this is so the meter could be installed on a live pipeline. A 2" hot tap was installed for the pressure transmitter that will report to the flow computer. So in this case, a bi directional flow meter was installed without taking the line down. Information on gas volumes, pressure, and direction of flow provided by the meter help gas controllers manage gate station volumes and transmission pipelines that feed the distribution system all while keeping the line piggable and in service. Custody transfer levels of accuracy are not required in this installation although every reasonable effort was made to make it as accurate as possible.

Most clamp on meter control modules have the capability to correct volume with temperature and pressure inputs. The controller can also provide an uncorrected volume output to a remote flow computer. This could be the preferred method for permanent installations or at sites with an existing flow computer that already has pressure and temperature inputs and telemetry.

Fig B*. Single path meter transducers mounted in a permanent fixture. A 2" hot tap was installed with the line in service for the pressure transmitter and a pipe wall mounted RTD is used for temperature. The meter controller is located in another building in the same yard along with a flow computer and communications equipment. Notice the liquid couplant is being leached out by dust on the top of the pipe. Removal of the couplant by outside forces whether it be dust, rain, heat, dripping water, etc. is one of the most common causes of clamp on meter failure. Fortunately, it can be easily repaired by removing the transducers and adding more couplant.*

Fig C*. A metal building over a piggable high pressure gas distribution pipeline and clamp on meter.*

Fig D1*. A dual path installation with permanent transducer mounting fixtures. This model uses armored cables to connect the transducers to the meter controller. While robust, they do require that the meter controller be installed at a predetermined distance from the transducers due to the fact that the cable length cannot be modified. Generally this isn't an issue because the controllers are electrically classified for hazardous areas (check manufacturers specifications on electrical class location rating). It may be a concern when mounting the meter in a less than ideal environment like a damp vault.*

Fig D2. *A meter controller mounted near the clamp on transducers in a metal building. The controller sends a pulse output to a flow computer mounted remotely.*

Fig E1. *A meter controller mounted remotely in a Hoffman box. This model uses cable TV type coax to communicate with the transducers. Advantages are that this cable is fairly inexpensive, readily available, and can be cut to length and pulled through conduit. The disadvantage is that you need to install the ends on the cables. This may be a concern for those who aren't experienced with this task. It's also more vulnerable than the armored cable when outside of the conduit.*

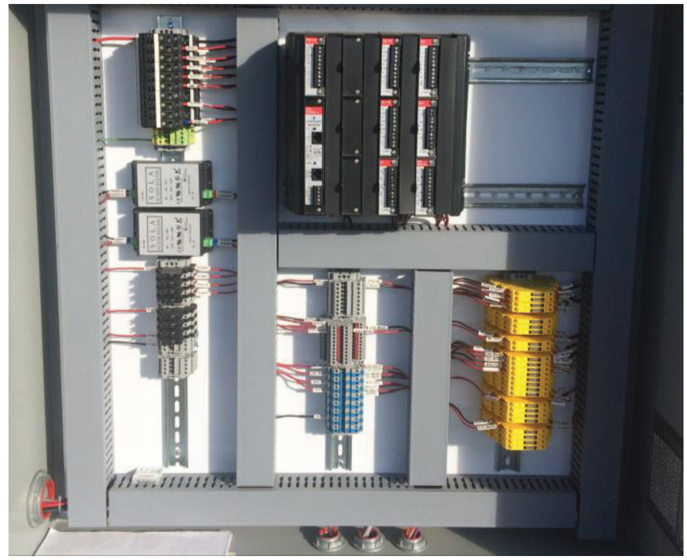

Fig E2. *A typical flow computer layout with associated automation equipment. The meter controller reports an uncorrected volume via pulse input to the flow computer for volume correction along with pressure and temperature inputs.*

Fig F. *An example of a clamp on meter installed with less than ideal upstream piping. Flow of gas is from left to right. The dual path meter was installed after the fact so no preparation was made for developing a good flow profile.*

Temporary measurement installations with a portable clamp on ultrasonic.

A temporary clamp on meter installation would be one that uses a simple to install transducer mounting fixture, a small portable meter controller capable of volume correction with a possible internal power supply, and portable pressure and temperature inputs. Most if not all portable ultrasonics allow temperature and pressure to be entered manually into the controller. Some applications include spot sampling regulator stations for IHP distribution system modelling, verifying a permanent measurement station's accuracy within the tolerances of clamp on technology, leak detection of a suspected bypassing valve, gas velocity measurements, and verification of direction of flow in tied through pipelines or systems with multiple feeds. Some companies are using this technology as a step in their welding procedure for live pipeline welding. They use gas temperature and gas velocity to determine the amount of weld quench they'll see in a flowing pipeline. This could prove to be useful information for weld engineers or others in the pipeline construction business.

Flow profile, gas pulsations, low gas pressure, gas velocity, turbulence, and signal to noise limitations apply to temporary installations as well. The advantage of a temporary meter installation is that it's simple to move to a new site if you have problems. A portable ultrasonic could also be used to survey a permanent meter location since a good flow signal should be attainable with clamp on or permanent transducers if conditions are right. There is no difference between the two types of clamp on transducers other than possibly mounting hardware.

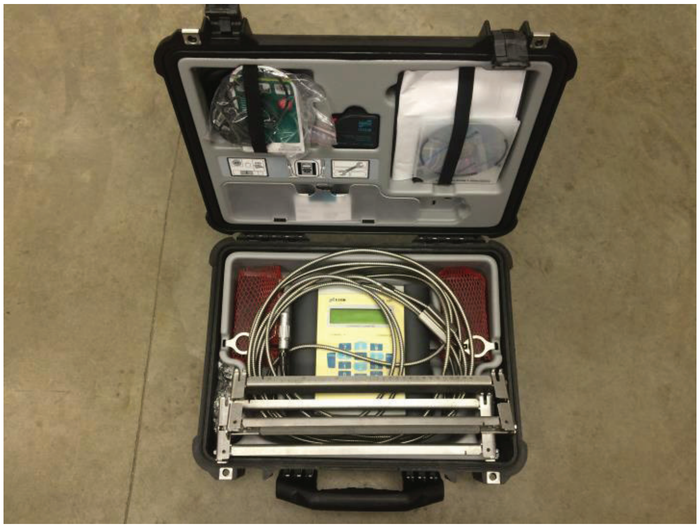

Fig G. *A portable clamp on package with an internal battery. The transducer mounting bracket is magnetic for faster installation to the pipe.*

The following data on Tables 1 through 4 *(Courtesy of Rick Spann, Measurement Coordinator, Questar Pipeline Company)* illustrates a meter station accuracy verification done with a portable clamp on ultrasonic against a single rotor turbine meter. The portable ultrasonic used in this case is more complex than a normal handheld model. It uses a permanent style controller adapted to portable service by installing it in a Hoffman box along with an industry standard flow computer for volume correction. Although portable, its size is much larger than the meter in Figure G. In fact, this particular meter is mounted on a small trailer for ease of transportation and storage. Full size 110 amp hour batteries are used to increase run time. A standard custody transfer grade pressure transmitter was used for a pressure input to the flow computer and a pipe wall mounted RTD for temperature. The single rotor turbine meter in question was installed in an acceptable meter tube and had flow conditioning upstream. It also used standard pressure and temperature transmitters with an RTD installed in a thermal well.

Using identical flow computers with the same volume correction configuration simplifies the data comparison between the two meters. The additional support equipment like larger batteries and an AC power supply (If AC power is available) make it possible for this portable meter to stay in the field unmanned for several days. The internally powered handheld models typically run for less than one day on a charge and require the operator to stay on site or at least come back in the same day to retrieve the meter.

Pressures and temperatures were specific to each flow computer as well. This isn't always needed but isolating inputs may be beneficial in troubleshooting measurement errors. Examples of why this could be useful are illustrated in the following tables:

Tur SCF	USM SCF	Diff	% Diff
702.83	816.96	-114.13	-16.24
725.84	870.25	-144.41	-19.90
727.57	872.29	-144.73	-19.89
727.53	872.66	-145.13	-19.95
737.91	884.12	-146.21	-19.81
738.44	886.79	-148.35	-20.09
741.06	888.91	-147.84	-19.95
742.95	892.48	-149.53	-20.13
727.84	873.21	-145.37	-19.97
721.90	876.72	-154.81	-21.44

Table 1. *This table lists the recorded Standard Cubic Feet or Corrected Volume reported by the turbine meter (Tur SCF), the clamp on ultrasonic meter volume (USM SCF), the difference in volume (Diff), and the % difference (%Diff).*
Notice that the turbine meter is reporting about 19% lower than the ultrasonic meter.

Tur Vol.	USM Vol.	Diff	% Diff
573.59	663.69	-90.09	-15.71
591.95	705.51	-113.57	-19.19
595.97	710.17	-114.20	-19.16
594.55	708.56	-114.02	-19.18
600.19	715.34	-115.15	-19.19
600.88	717.10	-116.22	-19.34
601.68	717.73	-116.06	-19.29
603.73	721.43	-117.70	-19.49
593.40	707.07	-113.67	-19.16
587.47	710.88	-123.41	-21.01

Table 2. *In this table we see that the uncorrected volumes reported by the turbine meter are also about 19% lower than the volumes reported by the ultrasonic meter.*

Tur Press	USM Press	Diff	% Diff
250.06	249.98	0.08	0.03
249.90	249.38	0.52	0.21
250.05	249.48	0.57	0.23
249.96	249.33	0.62	0.25
250.03	249.43	0.60	0.24
250.03	249.40	0.63	0.25
249.96	249.33	0.63	0.25
249.99	249.39	0.60	0.24
250.03	249.45	0.57	0.23
249.95	249.41	0.54	0.22

Table 3. *This table shows a comparison of the pressure transmitters from each meter. It also illustrates why having separate pressure inputs can be beneficial. The individual transmitters are relatively close so we can probably assume that the turbine meter pressure is accurate.*

Tables 1 and 2 show that the % error is the same between corrected and un-corrected volumes and that in both cases the turbine meter is under registering. Tables 3 and 4 show a fairly accurate comparison between the pressures and temperatures. A problem with the volume correction from the flow computer can probably be ruled out as well since the % error doesn't change between corrected and uncorrected volumes.

Tur Tmp	USM TMP	Diff	% Diff
38.16	39.49	-1.34	-3.51
38.21	39.56	-1.35	-3.54
36.79	37.96	-1.17	-3.18
37.63	38.83	-1.21	-3.21
39.22	40.46	-1.24	-3.17
39.36	40.65	-1.29	-3.27
39.87	41.16	-1.29	-3.24
39.45	40.79	-1.34	-3.39
38.83	40.18	-1.35	-3.47
39.19	40.24	-1.04	-2.66

***Table 4**. This is a comparison of the two temperature inputs to each flow computer. The two temperatures are out a little more that the pressures were due to one of the temperature inputs being an RTD in a thermal well and the other being an RTD on the outside wall of the pipe. Factors like outside ambient air temperatures and sun load on the pipe will affect the RTD on the pipe wall. This error in temperature wasn't outside of what was expected due to ambient air temperatures of the day.*

Removal, testing, and inspection of the turbine meter module revealed a spin time that was lower than it should be. Disassembly of the meter also revealed a gear train housing that was full of liquid hydrocarbons or condensate. The liquid was putting excessive drag on the gear train which slowed the meter down and caused it to under register uncorrected volume. This error carried over to the corrected volume as well. Cleaning the meter repaired the low spin time problem. The repair was verified by an as left spin test and a follow up comparison of the turbine meter and clamp on ultrasonic.

Conclusion

This paper outlines a few of the possible benefits of having clamp on ultrasonic meter technology in the mix of a natural gas company's measurement equipment. This information is based on the author's personal experience with this technology, his personal study of ultrasonic measurement, available industry information, and experiences shared with him by others using ultrasonic meters similar to the models discussed. It would be wise to consult with manufacturers and industry experts for further knowledge and technical data before purchasing and installing any ultrasonic measurement equipment.