Fundamental Principles of Clamp-on Ultrasonic Flow Meters

Overview of selection, Installation, Operation and maintenance of clamp-on meters.

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This paper is aimed at ultrasonic natural gas meters that use transit time across the gas pipe as the measurement variable. Custody transfer meters using sensors wetted with gas are the more familiar meter format. Clamp-on meters are quite similar.

General

Clamp-on meters are specified to achieve two to three per cent uncertainty. Manufacturers cannot control the quality of a given field installation and must provide latitude. Lab testing has demonstrated most installations perform at an accuracy level range of 1%. If a reliable installation technique is maintained, the clamp-on meter will often perform better than manufacturer standards. Further the meter control units have piecewise linear error correction schemes such that they can be adjusted to reference flow rates as afforded at a flow lab.

Clamp-on repeatability is very precise. Often the exact flow volume is not as important as repeatable data before and after an experimental change such as a meter cleaning. Changes as small as 0.1% can be detected.

There is a learning curve or experience effect. New users often have no confidence in the clamp-on technology. Training helps and repeated installation in known settings aids user confidence.

Clamping on at a flow lab where flow rate is known is helpful. In fact, a useful application is clamping on a custody meter as it is flow calibrated at a lab and collect clamp-on data at the same time. The clamp-on can later be installed in the field setting and compared to the custody meter to identify shifts between the two meter relationship at the flow lab.

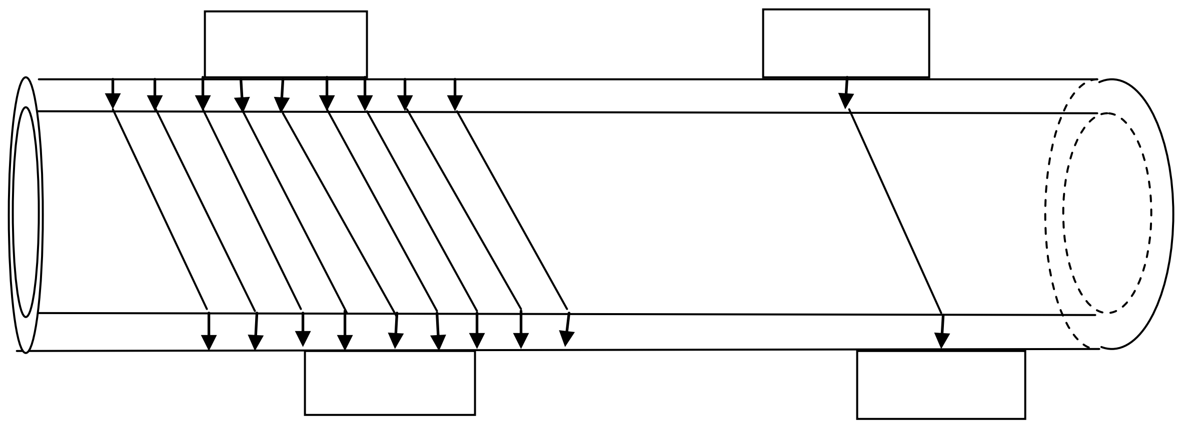
Meter Basics

Both wetted sensor and clamp-on meter types send ultrasonic pulses across the gas stream at an angle to sense the flow field. Both use quartz crystal as a sound impulse source.

The difference is the mount. The clamp-on is outside the pipe and is not exposed to conditions within the pipe. It can't be fouled as wetted sensors have a tendency to do.

While wetted sensors are fixed at an angle to the pipe axis, clamp-on meters rely on physics to establish the angle. There is a bend of the ultrasonic pulse as it enters the gas stream caused by the index of refraction between the steel pipe and the gas within the pipe. The angle across the pipe rather than a normal square diameter path is necessary to develop a component of gas velocity in the transit time. The gas velocity makes the transit downstream travel faster than simple speed of sound in the gas. Similarly, the gas velocity makes transit time longer when the ultrasonic beam is traveling upstream. In fact the ability to send pulses both downstream and upstream cancels out many gas variables and simplifies gas measurement to just measurement of time.

There are two types of clamp-on transducers, Lamb wave and Shear wave. Lamb wave transducers sometimes called wide beam, are easier to work with. Refer to Figure 1.



LAMB - WIDE BEAM **SHEAR WAVE**

Figure 1. Transducer Types.

The Lamb wave transducer has its crystal parallel to the pipe wall. It produces a large coherent pulse with many rays launched at the same angle. The receiving transducer only needs one of the rays to operate so that exact transducer spacing is not critical.

Shear wave transducers have the crystal normal to the pipe wall or sort of vertical. That produces a small beam and alignment is important but this type will function on heavy pipe wall more than an inch thick.

The piezoelectric effect in quartz rock crystal is used to produce a short sound pulse. An electrical pulse excites the transducers and the crystal responds with a physical ringing response much the same as a hammer on a bell. That sound level is transferred to the pipe wall and throughout the gas stream.

An electronic control unit provides the transducer pulse excitation and allows for many forms of measurement output. Gas velocity is the base variable but this can be readily multiplied by pipe cross sectional area to develop actual flowing volume. An accumulation of actual volume is available and there are interface programs that run in a laptop to extract data and provide diagnostics. Some of the interface programs such as Siemens' Dataview and Flexim Snapview provide views of the operating waveforms with trigger points for help with measurement quality assurance. See the following figure 2. On the envelope waveform, the leading baseline should be clean and the pulse should have a well-defined sinusoidal form with an exponential rise and fall in about five cycles.

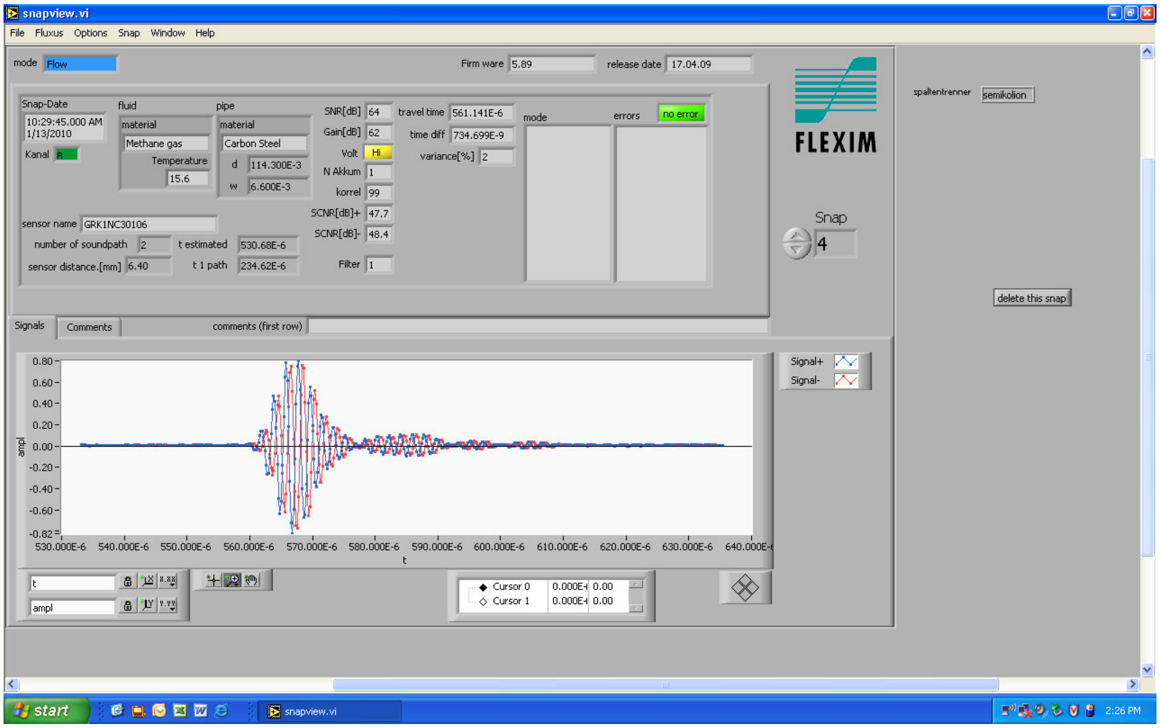


Figure 2. Clean Baseline, Pulse Waveform

To install a clamp-on meter, the pipe wall thickness must be measured. Use an ultrasonic thickness gage or Flexim provides the wall thickness measurement within the control unit. Transducers cover a range of wall thickness. A set of three of four types will cover common gas piping. Once a transducer is selected, pipe size and wall data is entered into the control unit and transducer spacing is determined. There may be damping material required for a given transducer. Damping material is a self-adhesive flexible membrane that provides an impedance match between the pipe and the high impedance transducer. Damping material also reduces synchronous noise that might be reflected from some pipe discontinuity such as a flange or weld and returned through the pipe to a sensor but at a random time. This kind of interference can be seen in the waveform as leading baseline noise.

The transducers are usually fixed to the pipe with large hose clamps and mounting frames. The photograph below, figure 3, shows two transducer pairs in reflect mount. Each beam bounces off the opposite side of the pipe and travels through the gas twice. Each pass is in an opposite direction providing some cancellation of flow profile defects and is the best manner for accurate volume determination.

Figure 3. Transducers mounted on pipe in reflect mode.

The black material under the transducers is damping material helping to match the transducer to the pipe. A couplant grease is used on the active transducer face. Both the couplant and the damping material are used to improve signal transfer to the pipe.

Once the transducers are mounted, and wired to the control unit, measurement can begin. The control unit can provide data files as output to a laptop computer similar to log files on custody meters and it can provide pulse rate output to feed an RTU for correction to standard conditions.

The real challenge is in choosing the experiment. Often it is important to have a plan and know what is expected before data is recorded. Wise placement of the clamp-on meter can make use of its excellent repeatability for before and after kinds of test data.

Beyond simple volume measurement, the unit can detect flow profile defects through rotational analysis. This technique operates the unit in a direct single pass through the pipe and then measurements are taken at multiple positions around the pipe. If the flow is fully developed and symmetrical as required for custody transfer, all of the measurements at any position will produce the same flow rate. Profile distortions will show up as variable flow rate for the different positions around a pipe. Eight positions are recorded and flow rate must be held constant or the data can be normalized to average flow rate during the data collection period. The polar plot, figure 4, below shows typical field data for a twelve-inch meter. The clamp-on was mounted near the inlet to the ultrasonic meter. This data resulted from a side inlet elbow and short meter run lengths. Measurement error is likely for this profile.

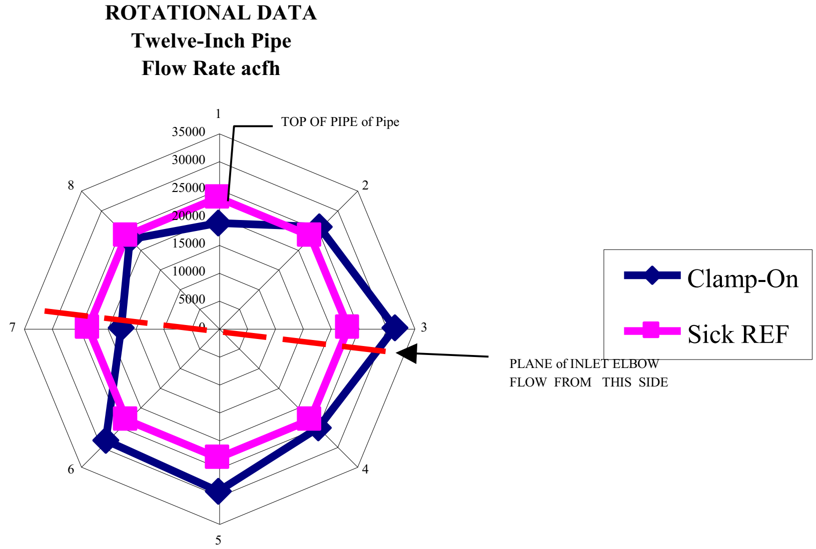


Figure 4. Rotational Data Looking upstream.

There are a few installations that are difficult. Paint can be a problem if it is extensively cracked and crazed. One epoxy coating was not fully cured and it absorbed ultrasonic energy. Even an ultrasonic wall thickness gage would not function with the spongy coating. Sometimes, it is necessary to re-grease the transducers and try again. Some pipe steel seems to have regions where the grain structure is a problem. Often moving a few inches corrects the problem.

But once an installation is working, it will function for a long time. Some have five years on line. There are some installations on mainline applications such as segmentation meters that must be made below grade. Invariably, the pit fills with water but the units keep on operating. The photograph below, figure 5, shows permanent transducers mounted on a submerged mainline and the clamp-on meter functions the same as when dry.

Figure 5. Siemens Installation in service under water.

Also in pipeline segmentation meter application and in storage fields, the flow may change direction. That is no difficulty at all. The flow just indicates flow direction with a plus or minus sign.

Clamp-on metering can do anything a wetted ultrasonic meter can do. The limit is user imagination.