"Ultrasonic Gas Meter Station Design Considerations and Validation with Advanced Diagnostics"

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Introduction

Gas flow meter station design using conventional flow meter elements such as orifice or turbine is a reasonably well-known subset of practices. Designing ultrasonic meter stations is now an applied practice by some but is still a new endeavor to many. There are many common sense practices that should be adhered to on any meter station designed and the ultrasonic station is no exception. Ultrasonic meters are very tolerant to some operating conditions that are very interruptive or offsetting to many meters. The ultrasonic flow meter (USM) has some considerations that are key to achieving optimum long-term performance. This paper will highlight some of the considerations that differentiate USM stations from conventional meter station practices. It is the subtle details that yield the big rewards. *Consideration checklists will be stated* and the prime importance items will then be discussed. There is more design detail than many people realize and *all items are important to a successful station.* These are generic checklist items. Designers will add specific code and corporate practice additions to their lists.

USM Meter Characteristics

Meters are chosen for their application by their performance characteristics. The USM is a high accuracy (custody transfer quality), wide flow range meter capable of high accuracy at high or low flow rates. USMs are large capacity meters for their diametric size. They are calibrated meters and commonly replace multiple parallel orifice meters with only one USM. They are more tolerant to tube wall build-up than most meters. They are full-bore with no restriction. USMs measure very low flow rates or rates as fast as you would operate a line without causing component erosion. The meter's wet-gas performance is excellent compared to conventional high accuracy metering technologies. Ultrasonic meters operate well at high pressures. They are in operation in gas injection applications up to 10,000 PSI. The characteristics alone offer a wide choice of applications, however, it is interesting that only a few **meter tube** design configurations are necessary to accomplish the entire range of applications. There are numerous site configurations possible. Designers should plan site tie-ins carefully.

Meter Design General Considerations

1. Is this application correct for using USMs?
2. Do I need custody level metering?
3. What is the area safety rating?
4. Does the meter need flow calibrated?
5. Is this unidirectional or bidirectional?
6. Sizing the meter/ minimum cost or maximum performance?
7. Space available-vs- meter lengths?
8. Control valve proximity considerations?
9. Flow conditioner selection/pressure drop?
10. Multi-run (low/high range)?
11. Multi-run (parallel) header sizing?
12. Meter tube specification/bore tolerance, surface roughness, t*ube-to-meter alignment, indexing?*
13. Special materials/stainless/nickel coated, etc.?
14. Special meter/tube paint spec's?
15 Special tests/documentation: I.E:x-ray/ H-stat/Charpy/material cert's.?
16. Where to calibrate/how many data points?
17. Cal'n test to include path out tests?
18. What is the max allowed ambient noise?
19. Test with abnormal approach piping in-place?
20. Isolation valves/full bore?
21. Manufacturer's piping recommendations?
22. Corporate or client piping recommendations?
23. RF or RTJ flanges?
24. Approach/discharge piping/bends?
25. Noise reduction Tees?
26. Mechanical compliance standards?
27. Measurement compliance standards?
28. Safety compliance standards?
29. Contractual special requirements?
30. Intermediate step inspection?
31. Calibration witnessing?

Site Design Considerations

1. Is there room to clean meter ?
2. Is there clearance to use extractor tools?
3. Is the meter installed absolutely horizontally or sloped, (but not drooped)?
4. Weight and support requirements?
5. Meter tube isolation (cathodic)?
6. Grounding considerations?
7. Service equipment/vehicle access?
8. Site area safety ratings met?
9. Header take-offs?
10. Meter isolation/blow down?
11. Conduit/isolation/grounding?
12. Security/fencing/access control, etc.?
13. Water run-off/grades/drains?
14. Shelters/lightning traps

Checklists of all considerations can help avoid missing a small design effort detail that may result in large measurement error, cause maintenance accessibility problems, a violated specification or safety issues.

Flow meter primary element choice -vs- application is vitally important and yet only the beginning of the total design effort for the whole "METER" station.

Temporary storage at a site is important. Make sure meter ends are sealed and meter protected from incidental damage.

The meter tube is as integral to the final performance of the meter. There is no easier way to **compromise your station's final performance** than by ***not*** using quality meter tube design and assembly procedures!

1. Full length honed?..not necessary per AGA 9 [ref.1].
2. Material spec./A106,X52, etc.
3. Meter bore match?..=/< 1.0% per AGA 9 [ref. 1].
4. Weld-grind/end hone?...welds should be ground.
5. Tube-to-meter alignment?..should be concentric.
6. Meter-to-tube indexing/pins?
7. Flanges/RF or RTJ?..removal ease?
8. Spool-to-spool alignment and orientation stamping?
9. Flow conditioner installation centering?
10. Thermowell T.O.L. located per AGA 9 [ref. 1].
11. Bolt and gasket spec's?
12. Vendor's procedures/calibrated torque wrenches/ torque patterns/verification?
13. Tube producers tube-to-meter offset measurement capability?
14. Additional T.O.L.s for test/sample/inspection?
15. Drain T.O.L.s/distance from meter considered?
16. Special paints/coatings?
17. Specifying mechanical tests/Hydro/x-ray/etc.?
18. Specifying documents/cert's/radiographs/certificates hydro-charts/heat lot reports/ etc.?
18. Specifying corrosion proofing/wrapping/end-caps?
19. Thermowell/s installed before shipment?
20. Are all T.O.L.s plugged/capped?

Tube alignment is more important than (within reason) the exact bore match. For example: AGA 9 [ref. 1] allows the tube-to -meter match to be within +/- 1.0%. For a bore of 11.75 inches....that is +/- 0.117 inches....almost 1/8th inch! That is a huge difference and most good tube manufacturers will match to within a few thousandths. The USM will cope well with the mismatch if the registration is concentric. Recent tests have shown that eccentric connections which leave underlap/overlap edges can cause significant error...on the order of 0.1 to 0.2 %. The common culprit is using no forced alignment techniques and ending with misalignment by resting spools/meters on the bolts during make-up. The cumulative tolerances of flange hole I.D.s and bolt O.D.s with all the slack in one direction can allow significant eccentricity. A 12" USM with tube I.D.s of +/- 0.1inches of the meter bore will perform better if installed concentric than a perfectly tube-to-meter-bore matched (diametrically) make-up that is eccentrically offset by that amount! A huge consideration is: Can I disassemble the meter for cleaning and reassemble without altering the calibration?? Physics dictates that if you alter the airfoil you alter the flow the flow patterns.

Meters that are carefully designed and are built correctly may incur transit damage unless properly cradled and restrained for transport. The transport load specification is commonly overlooked. Inexperienced transporters can set back a whole project by "final damage".

Completed meter: Tubes factory aligned; meter-to-tube, conditioner plates and approach/discharge spools are concentrically aligned and bolts are drawn up in sequence... torque is measured. Meter is aligned with precision pins. Offset gauges are used to measures joint flushness, thereby guaranteeing concentricity.

Inner bore weld protrusions should be carefully ground/honed such that there is no flow discontinuity on tube walls.

Several USM meter station sites have reported very loud audible noise coincident with distorted profiles (on the path designs which allow cross-sectional profile viewing). Flow disturbances were observable by viewing or logging the consecutive transducer timing's deviations. In each case a spiral type metal gasket was used which did not have the inner retention ring. The flange torque (or possible over-torque) had squeezed the metal spirals into the bore and active flow. These are the type of performance problems that a designer must be aware of and avoid by proper component selection, and assembly specification. Attention to detail as shown on the two pictures and captions on the right are mandatory to successful meter stations. **Specify well**....***inspect anyway!*** If the meter station project designer or project manager cannot logistically visit the meter tube assembler to inspect these points....there are many reputable third party inspectors who are very knowledgeable about these considerations.

Adjoining Piping Considerations

1. Piping on each end of meter/tube?
2. Elbows in-plane...out of plane?
3. 5D min. between elbows?
4. Elbows wide radius/short radius?
5. Concentric reducers/expanders?

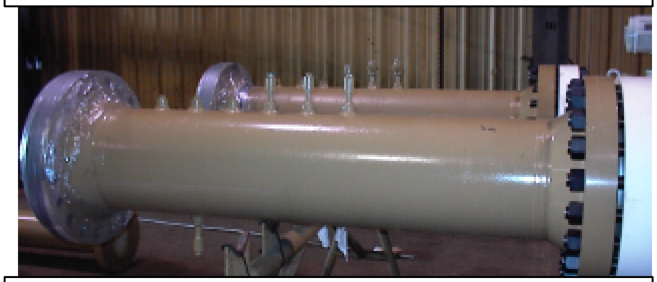
Note: Most USM research testing was done with One of the following three configurations:

100D straight pipe ahead of meter
2x 90's in-plane (5D+ between)
2x 90's out-of-plane (5D+ between)

Significant departure from these should evoke the consideration of calibrating with unusual piping-feeds in place. Short radius 90's or Tees spaced closely together ahead of a meter tube may cause high levels of swirl and profile distortions. Unusual piping should require use of a flow conditioner, but a conditioner may not be enough in some cases.

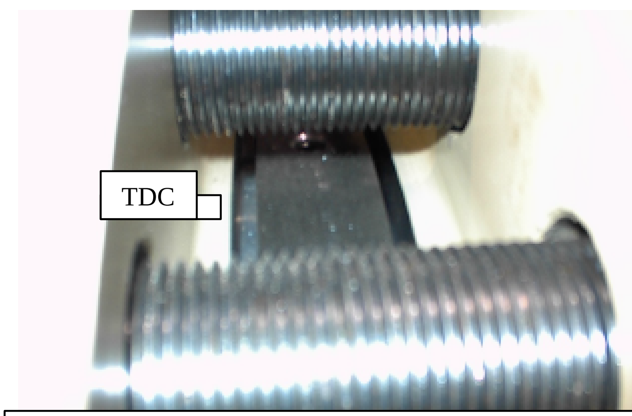
6 Location of regulator/control valves?
7. Header diameter-vs-tube/s diameter ?
8. Header take-off 's/sharp 90 or radius?
(additional data in subsequent pages)
9. Adjoining isolation valves/ full bore?
10. Meter by-pass valves/tight seal?

Shown below are the discharge tube sections of two unidirectional 12" USMs. Note the installed thermowells/sample probes and drain.



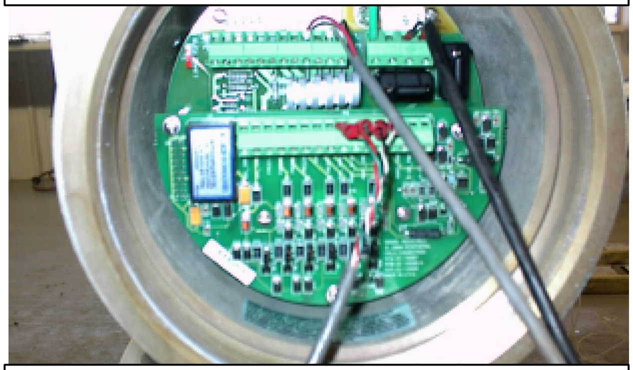
The flanges are precision aligned with the flow conditioner concentric. Gaskets are concentric with no protrusions!... into the bore.

Unused T.O.L.s are full pressure plugged in preparation for high pressure flow calibration



The flanges of the inlet tube (inlet-to-conditioner) and the approach tube (conditioner-to-meter), which mate to the conditioner plate, are precisely aligned. The TDC (top-dead-center) alignment mark is visible between the bolts shown.

USM transmitter terminations for serial and discrete information to FCs, RTUs, PLCs, DCSs.



PC cards contain surge protection components for each I/O line. Shown above: Meter under test with power, serial RS-232, pressure and temperature hook-up.

USM Transmitter DataConsiderations:

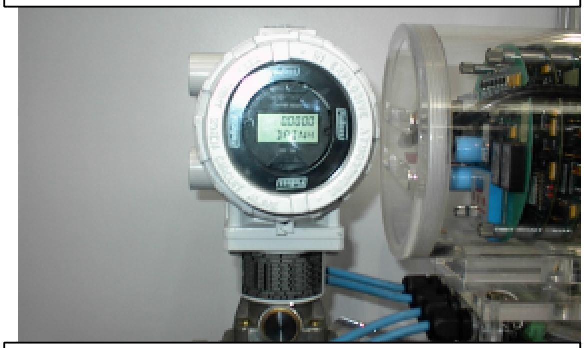
The following is a typical list of data that can be retrieved directly from the *USM Transmitter:*

1. Volume rates? ACF or SCF?
2. Volume totals? ACF or SCF?
3. Energy rates?
4. Energy totals?
5. Hourly Logs?
6. Daily Logs?
7. Audit Logs?
8. Error Logs?
9. USM configuration verification?
10. Data Quality Status?
11. Meter Temperature?
12. Meter Pressure?
13. Meter Average Velocity
14. Meter Average S.O.S.?
15. Meter Frequency?
16. Flow Direction ?
17. Meter Frequency?
18. Diagnostics?

USM Transmitter Hook-up

1. Power wiring/ gauge/ vendor recommendations?
2. UPS system......Yes/No?
3. Signal wiring/ gauge/ vendor recommendations?
4. Discrete transmitter wiring (P&T)?
5. Communication wiring/ gauge/ shields/ distance?
6. Cathodic avoidance/ isolation conduit couplings?

This is a complete flow computer, which ties directly to the USM transmitter, GC, Pressure and Temperature



The Flow Computer "marshals" the USM Energy/Volume system. It can be polled for archives, live values, alarms, discrete closure status and various additional data categories.

Flow Computer Data Considerations:

The designer should first determine all of the data categories and measurement values that need to be retrieved from the flow metering system before specifying the hardware selection for the associated Flow Computer. The following is a typical list of data that can be retrieved directly from the *Flow Computer:*

1. Volume rates? ACF or SCF?
2. Volume totals? ACF or SCF?
3. Energy rates?
4. Energy totals?
5. Hourly Logs?
6. Daily Logs?
7. Audit Logs?
8. Error Logs?
9. Communication protocol?
10. Log formats?
11. Transparent GC component data?
12. Passed through USM alarms?
13. Battery level/status?
14. Modem/RS-232/RS-485 hook-up?

Flow Computer Hook-up

1. Power wiring/ gauge/ vendor recommendations?
2. UPS system......Yes/No?
3. Signal wiring/ gauge/ vendor recommendations?
4. Discrete transmitter wiring (P&T)?
5. Communication wiring/ gauge/ shields/ distance?
6. Cathodic avoidance/ isolation conduit couplings?
7. FC to discrete transmitter cables/conduit?
8. FC to control panel/center wiring?

Checklists of station design considerations have been given above. We will now examine some of the early station design phase decisions to be made before hardware specification or selection.

Sizing the USM

There are two primary size philosophies: Pipeline full bore matched or reduced diameter meter-vs-pipeline.

Full pipeline bore matched meters will deliver accurate performance over the whole operating range of the line, typically 1 to 100 fps. There is little economy or occasion for operating a pipeline below 1 fps. 100 fps should be considered a short- term maximum. Velocities above 80 fps result in long-term erosion, accelerated dirt build up on conditioners, potential thermowell vibration/failure problems, high ambient noise and potential for ultrasonic noise generated by flow conditioners or other objects that the flow directly impinges upon. Full bore meters impose significantly less pressure loss than reduced diameter meters. Reduced bore meter applications are occasionally specified when the main pipeline normal maximum velocity is low enough that the meter maximum will never be exceeded and the additional pressure loss is not a concern.

A good sizing rule-of -thumb for USMs-vs-orifice meters is that a given size USM will meter as much flow as the same size orifice meter per 200 psi of line pressure. I.E: for: 1,000 psig; one 12" USM will meter as much flow as five 12" orifice meters at maximum beta ratio. The USM is a velocity averaging device. The orifice is a mass inertial averaging device.

The USM can be precisely calibrated to the actual volume rates proportional to 1 to 100 fps. Typically eight (8) velocity data points are tested at the calibration laboratory. Some meters only use a single *Flow Weighted Mean Error* (FWME) meter factor. Some meters have a meter factor per data point available to avoid the compromise of a single factor and results in a calibration final "as left" error of only a few hundredths of a percent.

Sizing programs are available from USM manufacturers. They calculate velocity, actual volume rate and standard volume rate. The following calculation example of **ACFH** versus meter diameter may be helpful: **12" meter: Bore = 11.75"/2=5.875 squared = 34.515 * 3.14159 (pi) =108.433 sq. ins./ 144 = 0.753 sq. ft.* 100 (fps) = 75.3 actual cubic feet/second * 3600 = 271,080 actual cubic feet/hour**. The meter size dictates the meter tube size, flow conditioner size and full bore isolation ball valve size.

As meter tube lengths are chosen in units of tube/meter diameters then the meter size also dictates the overall length of the meter run. It becomes obvious that meter size determination is very important. Custom bores are available but the designer's best economy is achieved by using standard pipe schedules, I.E: sch. 40, sch. 80, etc.

The USM Material

Designers should note that USMs are readily available in LCC, SS316, SS304 and Duplex Stainless. LCC steel meters can be Nickel Plated.

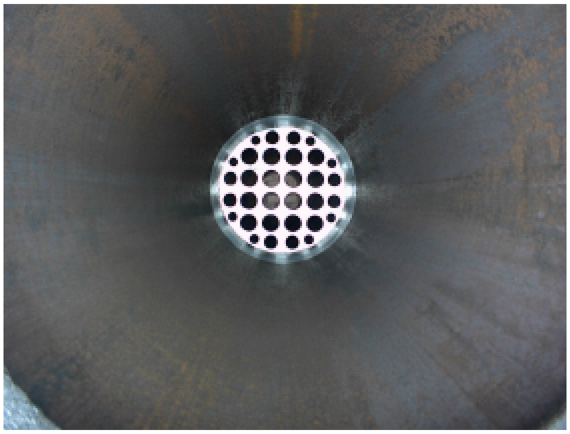
USM Features

Awareness of the primary available features is necessary to maximize the function of the metering system within the constraints of the project budget. The feature list below is typical for a quality USM meter product, although the designer should directly specify the exact items of interest.

1. Full Line Pressure Extractable Transducers?
2. Ability to achieve AGA 9 [ref. 1]accuracy with any one path out during online servicing?
3. Meter w/ integral Hourly/Daily data logs?
4. Meter w/ integral Audit "old value/new value"?
5. Meter w/ integral error log/reporting?
6. Meter electronics interchangeable for all sizes?
7. Multiple serial communication port?.
8. Multiple isolated frequency outputs?
9. Field selectable ASCII or RTU MODBUS?
10. USM transmitter w/ flow computer functions?

Many other features may be available for the selected USM. Specifying them avoids assumptions.

Flow Profile Conditioners



(thick-plate type)

Conditioners should be precisely centered with no gasket intrusion into the bore of the tubes

Multi-path USMs tolerate more flow disturbances than most flow meter technologies. But for ALL flow meters: ***"Good" flow is better than "Bad" flow***. Good flow is a flow approaching a flow meter that has a reasonably uniform, steady, symmetrical predictable velocity profile. "Bad" flow usually consist of any of the following: "Swirl" (angular momentum, usually rotational), cross-flow (angular to the longitudinal axis but not necessarily rotational), bulk rotation (rotating about the longitudinal axis, in a "corkscrew" fashion), pulsation (longitudinal relatively fast accelerations/decelerations), imbedded vortices and turbulence consisting of any portional combinations of the effects.

Flow conditioners for ultrasonic are generally of the "thick plate" type. These devices have the ability to stop low to medium levels of swirl and to "force-form" good velocity distribution profiles. The thick-plate devices are porous plates with various hole patterns (vendor or patent dependent}. The primary job of these conditioners is to isolate a meter run...in terms of flow stability...from the immediate upstream approach piping geometries that vary significantly as a function of the site piping / valves / layout / bends / reducers / expanders / headers, etc., and may result in approaching a flow meter with significantly disturbed flow patterns. This isolation and force-forming ahead of the meter gives the designer some added insurance that the meter will perform at the site extremely close to its performance at the calibration laboratory.

USMs vary in the different design's abilities to cope with flow disturbances. USM manufacturers have a lot of experience and test data. They usually know which ones are better for what type of application. Most will agree that although a 19 tube bundle has been used for decades with orifice metering....they should be avoided for USM meters. The "bundle" does an excellent job of stopping rotation or swirl but is not a velocity profile shaper. The bundle will "freeze" an incoming profile and you effectively loose that bundle's length of approach tube wherein natural profile recovery occurs.

Flow conditioners impose a slight pressure drop. Conditioner suppliers and USM suppliers typically have pressure drop data available. Some "no loss allowed" stations will need to operate without a flow conditioner. These stations should be built with 20D minimum approach tube lengths and wide radius 90s. The 90s ahead of the meter should have a minimum of 5D between the offset pipe centerlines. In-plane 90s produce much more stable flow than out-of-plane 90s. For no flow conditioner applications....longer meter tubes or straight pipe diameters ahead of the meter tubes....are better. Pipe is cheaper than errors!

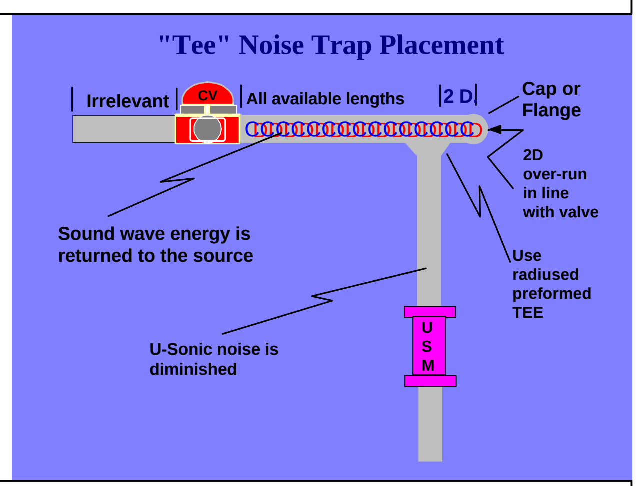
Control/Regulator Valve Considerations

Flow control and regulating valves can generate ultrasonic frequency range noise when a significant differential pressure (PSID) exists across the valve. Subsonic flow exit from a valve can still be a high frequency (ultrasonic range) noise that will propagate both upstream and downstream. High PSID on valves tightly pinched down may result in choke or Mach 1 exit velocity which will send a shock wave downstream (primarily) with a lesser energy level of the noise transmitted upstream as a result of the cage/ball assembly radiation [ref. 13]. This scenario is why it is generally better, when the option exists, to place a valve downstream of the meter. This is, of course, not an option on bi-directional stations. A 90-degree bend has significant attenuation to the highly directional ultrasonic noise spectrum. Dead-ended over-run Tees are very effective noise traps. Noise energy dissipates over line distance. Considering these precautions translates to some good rules-of-thumb about valve-vs-USM placement; as follows:

Valve/Meter Rules-of-Thumb

1. Place valves downstream of meters if possible.
2. Place all distance practical between valves and meters.
3. Bends between valves and meters help reduce noise.
4. Noise trap Tees are VERY EFFECTIVE noise-reduction devices.

Consult the USM vendor for Tee recommendations. Requirements may vary significantly between USM technologies.

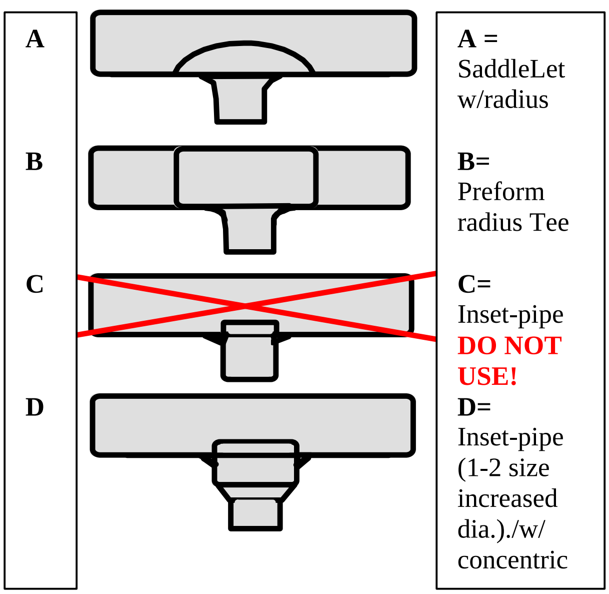


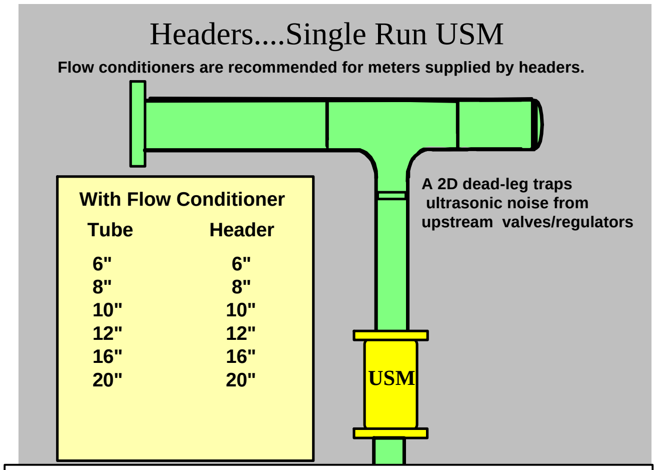
There are several piping configurations that accomplish the "Tee" over-run trap function. Consult vendors for drawings of typical, successful configurations.

Headers

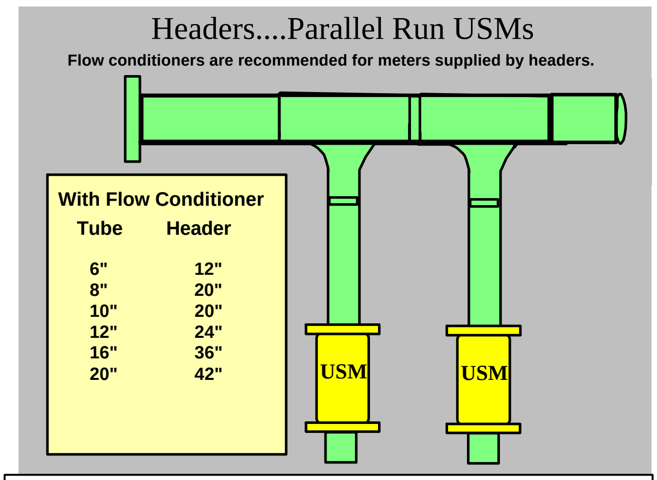
Headers are an opportunity to deliver excellent meter approach flows or seriously disturbed ones. Correct header size determination is vital in terms of both cost and performance. Cost increases rapidly as the header size increases. Marginal or undersized headers will degrade the meter performance significantly. Header sizing may sound like "old news that everybody knows", however you may be surprised by the number of incorrectly sized headers that the industry builds annually! Designers should be cautious about **"retrofit"** piping. Be sure that you acquire construction details of old headers being upgraded with new meters!

The four header take-off configurations shown below: **A, B, C, D** have all been used and produce interesting results when you evaluate the stability of the flow exiting the header into the meter.
A and **B** are clearly the best for smooth flow exit.
A is probably easier/cheaper for large headers.
B may be easier or cheaper for small headers.
C causes unstable flow. The cut-pipe sharp end (instead of a radius) causes severe turbulence.
D is a workable alternative to radius pre-forms.
Keep in mind as a designer that the header assembly technique results in a good or bad approach-to-meter flow pattern.....forever!





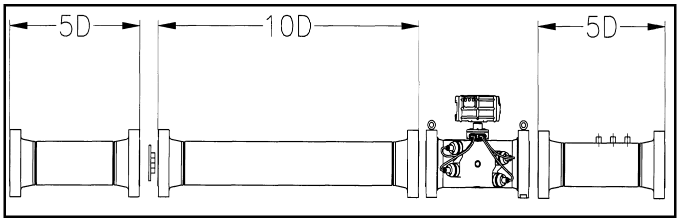
This configuration should have a radiused 90 Tee



This configuration should have radiused 90 Tees

Meter Tube Piping

The meter tube depicted below is a typical unidirectional USM requirement for a multipath meter with a single thick-plate flow conditioner. As can be observed from the checklists above and the captioned pictures; designers should seek USM meter tube experience based recommendations from the USM companies. As well as being aware of good practices, safety considerations and quality assembly techniques, designers should verify that any recommendation or drawing for a tube configuration complies with the recommended practices of AGA 9 [ref.1]. This document instructs the designer to produce a design that does not alter the calibrated results more than 0.3%. Further, it instructs the designer to follow USM vendor recommendations for meter tube requirement.
This is further governed by the requirement that the vendor must have tested the configuration recommended.



Unidirectional USM Typical Upstream Piping

The sketch above shows a USM/meter tube with a five diameter settling zone approach section ahead of the conditioner plate and a ten diameter approach section between the plate and meter. The 5D discharge section allows sufficient space to locate the thermowell 2-5D downstream (typically 3D) and additional T.O.L.s spaced 6" apart while allowing enough clearance for flange bolt make-up. A bidirectional meter would duplicate the approach 5D, conditioner, 10D section. The thermowell must be at least 3D from the meter inlet and is typically 3-5D from the inlet for bidirectional meters. USM companies typically offer readily available drawings that guide the usage of noise Tees or cleaning Tees associated with the meter and tube.

Ultrasonic meters are precision time, distance and geometry devices. Attention to detail pays the same dividends on a USM station as on any other flow technology station.

Flow Calibration Basics

The primary use for USMs today is custody measurement applications. As was discussed earlier, the introduction of AGA Report No. 9 has helped spur this growth. Section 5 of AGA 9 discusses performance requirements, including flow calibration. Currently AGA 9 does not require meters be calibrated for fiscal use, but it is expected to be required in the next revision. In the absence of a calibration requirement, AGA 9 does require that...“the manufacturer shall provide sufficient test data confirming that each meter shall meet these performance requirements.” The basic accuracy requirement is that 12-inch and larger meters be within ±0.7%, and 10-inch and smaller meters to be within ±1.0% for the flow range of q_t to q_{max} (low flow rate to maximum flow rate). Below q_t, the error limit is ±1.4%. These maximum error values are “prior” to flow calibration.

Initially USMs were installed without a flow conditioner. However, customers are using flow conditioners in the majority of applications today. Many feel that using a “high performance” flow conditioner (not a 19-tube bundle) further enhances performance. Even though data exists to support the supposition that some USMs perform quite well without flow conditioners, the added pressure drop and cost is often justified by assuming uncertainty is reduced. One thing that everyone does agree on is that if a flow conditioner is used with a meter, the entire system should be calibrated together.

It should be noted that one of the benefits of the ultrasonic meter is that it does not create a pressure drop. The pressure drop resulting from the flow conditioner is offset by the lack of pressure drop across the meter (when compared to orifice or turbine meters). As such, total pressure loss across the metering facility as a result of using flow conditioner is probably no greater than with other primary devices for the same given flow rate.

Most companies have standard designs for their meters that typically specify piping upstream and downstream of the flow conditioner(s) and meter. Usually these USMs are calibrated as a unit with either 3 or 4 piping spools. Calibrating as a unit helps insure that the accuracy of the meter, once installed in the field, is as close as possible to the results provided by the lab.

Most customers feel their applications deserve, and require, less uncertainty than the minimum requirements of AGA 9. To ensure these higher standards are met, virtually all users are flow calibrating their USM meters used in custody transfer applications. At the 2002 AGA Operations Conference a paper was presented that discussed the benefits of flow calibrating ultrasonic meters [Ref 6]. Summarizing from that paper, there are three main reasons users are calibrating meters.

Reduce uncertainty
Verify performance
Improve rangeability

Calibration Labs

There are several flow labs in North America that provide calibration services. Each will calibrate to any number of points the designer feels is necessary. Typically most designers are requesting 6 to 8 data points. Once all the “as-found” data points have been determined, an adjustment factor (or factors) is computed. Facility personnel enter the value(s) into the meter. Usually one or two verification points are used to validate the predicted “as-left” performance. That is, the lab will select one or two flow rates and verify the meter error is zero (or very close to zero). Generally the USM will repeat within ±0.1% of the predicted value.

During the past few years, two large-capacity calibration facilities have been commissioned in North America. These two laboratories permit users to cost-effectively calibrate larger (greater than 10-inch) USMs to full capacity, thus reducing the uncertainty related to measurement error when installed in the field. With the number of test results now in the hands of users, some have asked the question “How can I further reduce my risk in measurement when using an ultrasonic meter?”

Even with the substantial amount of data USM manufacturers have that shows meters to be linear to better than ±0.2%, many want to reduce this error further. Because of this, some users have implemented multi-point linearization, within their flow computers, to further reduce the uncertainty of their USM calibration results. This is not a new technique and has been often used for turbine meters in the past.

When using this multi-point linearization technique, external to the measurement device, at least two issues always surface. First, since this method has been traditionally applied in the flow computer, the output signals from the USM (serial, frequency and analog) are not adjusted. If the output signal from the meter is sent to two separate flow computers, care must be taken to ensure both computers are utilizing identically the same algorithm or their results may differ. Second, since the linearization is not taking place in the meter, there is no verification (such as a laboratory calibration certificate) of the linearization process, or the results it generates.

As good as the results are in Graph 5, some users have asked: "Why not incorporate a multi-point linearization in the USM to further reduce measurement uncertainty?" With all the capability of today's USM, this has now become a reality. Some meters now permit entering the multi-point correction directly into the meter. This technique is also called piece-wise linearization. Additional information on this subject can be obtained from an AGA 2002 paper titles "Benefits of Flow Calibrating Ultrasonic Meters [Ref 6].

Re-Calibration

AGA 9 does not currently require an ultrasonic meter to be re-calibrated (as mentioned earlier, initial flow calibration is not required). As USMs have no moving parts, and provide a wide range of diagnostic information, many feel the performance of the meter can be field verified. That is, if the meter is operating correctly, its accuracy should not change, and if it does change, it can be detected. This, however, remains to be proven.

The use of USMs for custody transfer applications began increasing rapidly in 1998. Thus, with little than 5 years of installed base, there is limited information to conclude USMs don't require re-calibration. Many companies are not certain as to whether or not they will retest their meters in the future. They are waiting for additional data to support their decision. Manufacturers are also trying to show the technology may not require re-calibration.

During the next several years, many meters will require re-calibration in Canada. Their governmental agency, Measurement Canada, requires USMs to be re-tested every 6 years. Many meters will be due for re-testing in 2003 and 2004. Once data is obtained from these meter re-calibrations, from random re-testing by customers, and long-term data from meters at calibration labs is analyzed, customers can better determine if they should re-calibrate their USMs in the future.

Several users have removed meters in the past year and returned them to the calibration facility for a quick verification. If the meter is clean, the performance on these has typically been within 0.1-0.3%. Unfortunately, there is very limited information to date and little if anything has been published. Over the next few years, the industry's knowledge base with respect to the long-term accuracy of the ultrasonic meter should grow significantly.

A few designers have chosen to incorporate a separate "reference" meter in their larger stations [Ref 7]. The purpose of this meter is to provide an in-situ verification against all the other fiscal meters at that location. The idea is to route all the gas from a given operational meter periodically through the "reference" meter and make any adjustment based upon the difference. In many ways this is exactly what the calibration facility is doing. However, this technique has several issues that must be addressed. First, if there are any installation effects on the reference meter, a bias could be introduced in the results. The installation effect could come from the upstream piping or pipeline contamination. Second, the addition of a reference meter adds significantly to the cost of the station. Not only is the designer paying for the additional reference meter, there is an additional cost for each meter run as a separate ball valve must be included to permit diverting the gas through the reference meter. Additionally, the extra reference run requires more space on the skid that adds to the cost. Also, using a reference meter on location somewhat limits the ability to verify performance over the entire range of operation. Finally, removing a meter and having its performance verified at a calibration facility provides an independent analysis of the meter's performance. This would most likely be required in the event of a dispute by the purchaser of the gas.

Other Design Issues

EMI/RFI

The USM is electronic in nature. As such some believe it is susceptible to electro-magnetic interference (EMI) from high voltage power lines. Today manufacturers enclose electronics in well-shielded metal housings that are virtually immune to any typical field EMI problems. Installations have been done where 200,000+ volt AC power lines are virtually overhead of the meter with no impact on operation.

Radio frequency interference (RFI) can also affect electronic devices. Again, all manufacturers provide a high degree of protection by enclosing the electronics in grounded metal housings. However, the designer is cautioned to insure that all the wiring that is attached to the meter is also grounded. There have been reported cases where high-power ratio transmitters, such as Ham radios, can interfere with a meter's operation. By installing shielded wiring, and following proper grounding recommendations, this potential problem can be eliminated.

Communication issues

Most USMs communicate using either RS-232 or RS-485. The general recommendation for serial communication varies by designer. For distances up to 250 feet, serial communication has been shown to be very reliable. This distance is substantially longer than the traditional 50-foot limitation that used to be the standard maximum recommended length.

The actual maximum distance is somewhat dependent upon communication speed. That is, for higher speed communication (beyond 9600 baud) the reliability may be less, necessitating shorter lengths, or switching to RS-485. For this reason, designers often choose to use RS-485 for lengths in excess of 250 feet. Here the distances can easily be several thousand feet with no degradation in communication performance.

Another feature many designers take advantage of is the ability to remotely access a meter. Some manufacturers provide software that supports remote, dial-up access. Attaching a serial port to a modem now permits remote monitoring and troubleshooting without the need to for a site visit. When designing an ultrasonic meter installation, consideration should always be given to utilize this technique as it can often provide substantial savings for a small monthly investment. Since other equipment at the measurement site, such as gas chromatographs and flow computers, also support remote access, it is not uncommon for all three to be accessed via the same phone number.

Remote access can be a very powerful tool. Since the USM provides significant diagnostic capabilities via the serial port, diagnosing potential meter problems can be done remotely. This may save a field trip, and with the proper installation, may also permit remotely performing the typical monthly or quarterly maintenance checks. This can be a very valuable tool in preventative maintenance program.

Ambient Temperature

Today's USM is designed to handle a wide range of ambient temperature conditions. Electronics typically can operate from –40 °F to a minimum of +140 °F. Thus, the meter can be installed in most applications without the need for a shelter or building. Typically if the designer has an application where temperature extremes are present, they may include a shelter more for the technician's benefit than the meter's requirement.

Power

Most applications today utilize remote AC power to operate the USM rather than solar or thermal electric generators (TEG). Although solar and TEG are feasible, the typical installation also has other "higher-power" consumption components such as flow computers, gas chromatographs and communication equipment.

As with all electronic devices, providing a reliable power source is important. Designers typically utilize an uninterruptible power supply (UPS) to insure reliable service. Some USM manufacturers provide power loss alarms in the meters audit history. This can be very helpful in the event of intermittent power problems. First, it indicates there is a problem by logging an alarm. Second, by knowing the date and time of the event, determining the amount of downtime can assist in estimating the volumes missed. Also, knowing the date and time may be helpful in solving the power problem.

Dual or Multiple Meter Runs

For larger applications, many designers choose to use two similar sized meters in parallel. The break point often comes when the flow rate dictates a meter size of 16-inch and above. There are many variables to consider before choosing whether one meter is a better solution, or if two might be the best choice.

Two meters provide some redundancy. This might be important if company policy dictates removal and re-calibration periodically. Also, if maintenance policy requires internal inspection periodically, having two runs makes it much easier to perform this task without having to estimate volumes. Also, should one meter develop an operational problem, having a second meter may help identify the problem(s).

The disadvantage of using two meters is obviously the cost and additional maintenance required. Two smaller meters will require more capital expense in the beginning, and most likely more long-term O&M cost. Which design is best for any given application somewhat depends upon the operational requirements, space limitations, and many other factors.

Generally speaking, designers that choose to use two or more meters in parallel don't do it for rangeability requirements. Today's USM provides at least 30-1 rangeability, and many are flow calibrating to achieve in excess of 80-1 rangeability. The primary reason is to permit removal of a meter for maintenance while measuring all station flow through the other meter(s).

Pulsation

One problem for just about any measurement device is how accurate it performs when subjected to pulsation. The effect of pulsation on orifice meters has been studied for years, and many reports have been written. As the USM is a non-intrusive device, it might be assumed there would be little effect on its accuracy. However, this may not always be the case.

Some independent testing has been performed on several brands of USMs. To date very little has been published. However, it is safe to say that pulsation, given the right conditions, can impact the accuracy of an USM. More research is being done on this area, and it is expected that results will be published later in 2003 or in 2004.

Pressure Effect Issues

No discussion on calibration of USM would be complete without bringing up the issue of calibrating at one pressure and operating at another pressure. Testing conducted at SwRI, under the funding of the Gas Technology Institute (GTI), has shown some potential for a meter's performance to shift with pressure [Ref 8]. Additional testing is on-going and some separate tests have not supported this conclusion. At the present time the industry is trying to resolve this issue.

The results for different manufacturers do show somewhat different pressure effect results [Ref 9]. Currently USM manufacturers feel there is no pressure effect. Each has conducted testing at other facilities to show there is little, if any, effect. However, the issue still remains. Perhaps later in 2003 this will be resolved. At present the pressure effect, if there is one, is not more than 0.2-0.3% for meters calibrated at 1000 psig and operated at 200 psig. Since most transmission companies typically operate above 600 psig, calibrations done at the high-capacity facilities probably don't introduce any significant bias.

Dirty Meter Considerations

Just like any measurement technology, if the meter is not properly maintained, performance will suffer. Today's pipelines are generally relatively clean. However, there is always the potential for mill-scale and oil to coat the inside of a meter. This coating will impact the accuracy. The magnitude and impact on accuracy appears to be somewhat dependent upon meter design. Several papers have been published on this issue [Ref 7, 10 & 11]. The good news here USM's are probably less sensitive to performance changes due to contamination than other technologies. Maintaining a clean primary measurement element is just as important as calibration of ancillary devices. Many users have regularly scheduled inspections to insure optimum performance.

Today's powerful software also makes it much easier to identify problems potential dirty meter conditions. By collecting the data from the USM, indications of pipeline buildup can often be identified. Other issues, such as partial blockage of a flow conditioner, can easily be seen using the proper diagnostic techniques. The ability to diagnose potential problems, even remotely, is certainly one of the major benefits in using USMs, and should not be under-estimated when designing a station.

In a paper published at the 2003 AGA Operations Conference, examples were shown on how a meter's performance can be diagnosed using software [Ref 12]. The ability to recognize when problems are developing has helped many users to reduce their measurement uncertainty over the past several years, and thus lower their Lost and Unaccounted For (LUAF) volume. In many cases this has translated into a significant increase in a company's "bottom-line" revenue.

More applications than ever before are being designed today using this technology. Just like any measurement device, it must be installed and maintained properly to insure optimal long-term performance. The best of technologies will not provide the expected benefits if it's not installed and maintained properly. The designer must take into consideration all aspects of the station requirements in order to realize the potential for this technology.

Summary

The meter station designer has a very involved multi-discipline job. Considerations have been discussed for flow measurement hardware, data, piping and overhead basic flow calculating devices. The list of total considerations when designing a USM station or any other flow metering technology station, is enormous and cannot be entirely covered in the scope of one paper.

Managers should be cognizant of the magnitude of time, effort, coordination and detail needed to design, specify, procure, assemble and commission a station.

Numerous technical papers have been written on this subject [ref. 14] and the complexity of it insures that many more will be. Many excellent papers are available to the designer on the Internet and from various contributory industry sources.

Three custody transfer meters from three suppliers plus three multi-regulator pressure reduction skids.....a lot of serious design considerations for one small site!

As a designer, avail yourself of all the guideline data possible. Although a new day *IS dawning* for measurement hardware, the 90+% of meter tube station design "historical good practice techniques" will still apply.

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Note for Reference correlation:

Pages 1-8 by: Charles Derr
Pages 9-12 by: John Lansing, (Ref. 14 above)