

FUNDAMENTALS OF ELECTRONIC FLOW METER DESIGN, APPLICATION & IMPLEMENTATION

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Introduction

Electronic flow measurement as applied to the natural gas industry has advanced considerably over the last 30 years. Applications to address Upstream, Midstream and Downstream gas measurement technologies have become more complex. Over time it has become necessary to understand the fundamentals that make up this ever changing environment.

This paper will discuss the important fundamental parameters to consider when designing an Electronic Flow Measurement (EFM) system. Please be aware of the many variances to each specific design and understand this is only a fundamental paper to give new gas industry members a first look at the technologies that are required when considering an EFM design.

Custody Transfer

Custody transfer gas measurement implies that a buying or selling transaction is taking place based on the flow computer calculated volumes. This normally requires high accuracy digital resolution and speed, but often custody transfer requires that the flow computer meet American Gas Association (AGA) and the American Petroleum Institute (API) standards. Since this paper is geared to the US market AGA 3, 7, 8, 10 and API 21.1 offer recommendations and or standards in assisting in the design.

Fundamentals of Electronic Meter Design

The following components make up the many sectors of the gas measurement industry. Referred here as Upstream, Midstream, and Downstream metering.

Upstream: This term is used commonly during the searching for, recovery of crude oil and natural gas - sometimes referred to as the exploration and production sector.

Midstream: After producing the fluid, a ways to move the product to market must be implemented. Pipelines are used to transport products and this sector is referred to as the Midstream portion of the industry.

Downstream: After the gas is produced (Upstream) and transported (Midstream) then delivered to the gas distributors (Downstream), the natural gas could have been measured at least 4 times once it hits your home. Downstream refers to the final delivery of the gas to homes, businesses, and industries.

We will investigate how the fundamental components fit together to help you design and understand the application and execution to each sector of the gas industry.

Components of Electronic Flow Meter

Primary, Secondary, Tertiary Devices

In the API 21.1 Document "Manual of Petroleum Measurement Standards – Flow Measurement Using Electronic Metering Systems" describes very fundamental principals in natural gas measurement:

- **Primary device:** Orifice, turbine, rotary, or diaphragm measurement devices that are mounted directly on the pipe and have direct contact with the fluids being measured.
- **Secondary device:** provides data such as flowing static pressure, temperature flowing, differential pressure, relative density, and other variables that are appropriate for inputs into the tertiary device.
- **Tertiary device:** is an electronic computer, programmed to correctly calculate flow within specific limits that receives information from the primary and/or secondary devices.



FIGURE 1. Primary Meters

Primary Measurement: Often orifice measurement is used for applications where extreme flowing products and conditions such as liquids mixed into gases, sand, paraffin, and many other foreign items – these are sometimes referred to as the “*blood, guts, and feathers*” in the producing world. A producing well often brings many bits of the earth up to the primary measurement device. Orifice measurement can generally handle the worse conditions for gas measurement. Turbine meters and PD (Positive Displacement) meters can be used where there is little or no foreign matter hitting the meter.

Today the hot meters for large volumes of measurement are the Ultrasonic meters, first meter as show above. These meters generate sound waves along transverse sections of a single spool section of pipe. These signals are monitored and when there is flow in the pipe the sound signals sent through the gas are delayed and the meter measures the delay of the signal. By measuring this delay precisely, the meter can determine the velocity of the gas and thus the flow rate. Ultrasonic meters are very cost effective when measuring great volumes of gas that vary in flow rate.



FIGURE 2. Secondary Measurement Transmitters and Gas Chromatograph

Secondary Measurement: The AGA-3 has written recommended practices for measurement of natural Gas when using orifice measurement. Three measuring devices in the form of transmitters or transducers for orifice measurement are the Differential Pressure which is often integrated with the Static Pressure transducer. These integrated transmitters are called Multi Variable Transmitters (MVT) shown above. For orifice measurement a flowing temperature is necessary. This signal is usually retrieved by using an RTD (Resistive Temperature Device) thus completing the required secondary elements to measure natural gas when using an orifice or differential head measurement. For Turbine meters, Ultrasonic and PD meters only the static pressure and flow temperature is required.

Often the quality of the gas is important enough to have a Gas Chromatograph (GC) as part of the secondary devices. A GC will sample the natural gas being measured and feedback an analysis of the gas to the Tertiary Device or flow computer. The flow computer uses this analysis to determine the compressibility of the gas along with flow volume. The flow computer will take this data and with the use of a calculation from AGA 8 determine the compressibility of the gas under flowing conditions. Today’s GC’s are highly technical and expensive devices that need constant maintenance and up keep.



FIGURE 3. Flow Computer Systems

Tertiary Device: The flow computer is the “glue” that pulls all the items together. This factory programmed and user configured device is usually designed so that field operators can configure it via Web page displays on a PC or some other hand held device. More on this later.



FIGURE 4. Typical Solar Panels

Solar/Battery Systems: Today's power requirements for metering systems have changed greatly over the years. Initially the power requirements were much greater with power hungry flow computers, radios and transmitters. Today we have the pleasure of using technologies that have been derived by many of our own consumer products, such as cell phones and PDA's, IPod's and other very low power consuming electronics. The advents of improved battery system technologies and solar panels have also added to longer field autonomy. More on this later.



FIGURE 5. Typical Yagi Antenna

Antenna Systems: Without the proper designed and oriented antenna system designers take a risk in missing pertinent data from their metering location. Height and design of the Yagi antenna are important to assure good signal paths between the host tower antenna and the site location. Often the pole that the antenna is mounted on is usually 20 feet or more. All this is determined by a path study usually offered by the radio manufactures and some flow computer manufactures.



FIGURE 6. Typical Radios

Radio Systems: The data generated by the flow computer is often required at some other location on a timely basis. Radio systems today can bring the data quickly and efficiently back to an office or to the main company headquarters. This data often contains production information and other metering information that is used to determine if the well or pipeline is flowing properly. When this data can be made handy to many operations of the company, quick response by engineering and other sectors assure steady production thus improve the bottom line.

Radio systems can be of the licensed variety or un-licensed spread spectrum type. Spread Spectrum radios switch frequencies quickly while staying synchronized to each other, thus allowing multi-radio systems to co-exist in the same frequency spectrum. This means you get good radio distances without the hassle of registering the radios to the FCC.



FIGURE 7. Typical Gas Data Editing Systems

Historical Data Editing Systems: All flow computers for natural gas metering store historical flow data. This flow data is made up of specific measurement data parameters dictated by the API chapter 21.1. This comprehensive document contains sections that describe the methodologies used to meet minimum standards in all aspects of today's gas flow computers.

For historical data editing the parameters listed in the API 21.1 document are used to re-create the flow over a period of time. Why would we want to recalculate flow volumes? Often due to field operations or errors in the system the volumes can

contain some error that needs to be corrected. Sometimes the flow computer may have had the wrong orifice size entered for the past month and it is necessary to re-calculate the flow based on the correct orifice size. These editing systems allow users to change the final totals and keep complete audits to assure who and what parameter was changed.

Today most all flow computers meet the minimum requirement of data storage to satisfy API 21.1. Once the groups of data parameters are collected from the flow computers, via radio or manually, it then can be moved to a PC that contains this editing software program. These programs allow the users to re-calculate flows for a day or even a month based on certain conditions as stated above.

Today's historical data editing software can do this. Many other examples of re-calculating volumes make sense, and just about all gas measuring systems have a means of editing the historical data generated by flow computers.



FIGURE 8. Typical SCADA Host Systems

Host SCADA Systems: Most all gas measurement systems have a way to collect data remotely from metering sites. There is still the practice of manually driving to the sites and collecting the measurement data via a PC or some type of hand held device. Generally, overall the Host Supervisory Control and Data Acquisition (SCADA) system is a PC based program that resides in the corporate office or in the field office.

This PC system contains a polling software package that is designed to communicate via radio to the remote location (see *Radio Systems* above). Usually these systems communicate once an hour or on a more frequent basis to the well sites to be sure the processes are running at the site and to retrieve timely information.

Protocols are the means to which flow computers communicate to one another or to the Host system. Today the most common protocol is Modbus. This simple single layer protocol was developed in the early 80's and is still the most commonly used protocol in the business. Within the last 12 years or more the then Enron Company developed a means of transferring data with Modbus, known as Enron Modbus. By using a common protocol most vendors can communicate to one Host system.

As mentioned earlier on the importance of understanding the power consumption at the well sites, the Host SCADA system has to be designed to poll the flow computer on an interval that best meets the needs of the operators and other corporate directed requirements. Polling too often will drag down the battery/solar systems, and not polling fast enough might reduce the response team to fix any problems.

Many polling/Host systems have features to allow retrieval of data along with editing of historical data.

Upstream Electronic Measurement Design

We will look specifically to the production of natural gas and the fundamental components that make it up.



FIGURE 9. Typical Upstream Site



FIGURE 10. Low Powered Flow Computers

Figure 10 displays some typical low powered flow computers that are used for the measurement and calculation of natural gas. Notice, they contain the secondary and tertiary devices (transducers) assembled into one package. Inside is the battery system, flow computer circuit boards - all attached to the solar panel with a built in solar regulator. Typical installations in the Upstream measurement industry contain the following items:

Flow Computers

There are more choices today for flow computers used in the Upstream metering or production areas. Not only are there many calculations and meter standards to choose from, many times the application requires selection of the right packaging. In the Upstream production sites, classification of hazard or non-hazard service is critical. Many packaged systems as shown in Photo 2 meet Class 1 Division 2 hazardous service. Class 1 Division 2 hazardous service means there is natural gas present sometimes. Usually this means the flow computer systems is located some specific distance from the primary meter or flange on the pipe. Other instances exist where it might make sense to mount the flow computer directly on the meter run (see the first product on Photo 2). This device can be located directly on the primary device and meet a more stringent hazardous service where the presence of natural gas is always present and is referred to as Class 1, Division 1.

Photo 2 shows a flow computer assembly that resembles a small transmitter package. It is important that these products are both explosion proof and intrinsically safe in design. Explosion proof means that if the natural gas got inside of the device and somehow it was ignited, it would explode within the enclosure and not allow any of the fire to get out, thus containing the explosion/fire.

Items such as:

- Solar/Battery Systems
- Secondary and Tertiary devices
- Radio Systems
- SCADA Host

Are used in satisfying Upstream production Electronic Metering Systems.

Application and Implementation for Upstream

When all the parameters are known of what makes up the production site, the components can be assembled so as to be sure each is applied properly.

Site Requirements for Upstream Applications

Primary Device – How clean is the gas being measured? By knowing the amount of foreign debris rising up through the pipe users can determine the type of meter that makes sense. As stated earlier often “*blood guts and feathers*” are produced from dirty wells and orifice measurement is the best way to measure it properly.

Flow Computer –When applying a flow computer to a production location it is important to look out for a few major points. Ease of use, low cost, environmentally safe, and compact. Today there are many manufactures of flow computers that cover a broad spectrum of applications. When considering a flow computer field support and technical assistance are very important factor to consider.

Communications – Radio? Satellite? How do you plan on getting the measurement data back to the office? Radio systems and Satellite transponders take large amounts of power. Likely these power hungry radios use 90+ percent of the power at the site. It is very important to know if the radio will be powered up full time or on a power cycle basis. Remember when a radio transmits it uses the highest amount of energy. Power cycle radio systems allow the radio to stay powered off and only

turn on when it is needed. Sometimes the Host system knows when the flow computer has its radio on. This is done by synchronize the Host to the flow computer clock and the flow computer will turn on its radio to listen when it knows the Host will poll it. If handled this way, the power consumption can be tremendously reduced and therefore reduce the overall cost for the site. Always consider the amount of time the radio systems have to operate when applying a radio at a production site.

Antenna systems are easy once the radio technology is determined. Most all radio manufactures can recommend the type of antenna that works best with their systems.

Power Systems – After you have determined the type of meter and what type of communications is being used, a power cost can be determined. Solar systems along with battery systems can be sized to fit the radio and flow computer needs, and taking into account any external transmitter or tank monitoring devices.

Determining the autonomy of a system is very important. How many days does the system have to communicate to the Host when the solar power system was stolen or destroyed, or just not enough sun to recharge it?

Normally 14 days of autonomy is good enough for most regions. Sometimes in the far north into Alberta, Canada, it is very difficult to get to some sites due to extreme cold or in the summer when most of the sites might be surrounded by marshlands. Autonomy is an important design and implementation stage in designing a production site.

Host Systems – For today's Upstream production locations users have many choices. There are simple packages supplied by the flow computer manufacture that can poll the product and also offer editing packages so as to incorporate all functions into one software bundle.

It is important to know who may use the data once it is retrieved from the field production sites. Is it just for gas measurement? Who else needs to see the data, as discussed earlier?

Production SCADA systems are important to save costs in field operations and safety reasons.

Midstream Electronic Measurement Design

The Midstream metering systems often have a much greater volume of flow than the Upstream production wells. True, offshore production can produce larger volumes of gas than many main stream metering locations have, but in general the pipeline metering systems are in more populated areas thus gaining widespread criticism when something goes wrong.

Midstream measurement systems often consist of a means of measuring the gas content directly. This is often accomplished by two methods. Sampling systems and natural gas chromatograph systems. This detailed analytical information is useful in determining the compressibility and gravity of the gas. Sampling systems usually are based on either a timed basis or a volume basis. If based on volume, often the flow computer sends a digital contact closure to the sampler so that it can grab a sample of the gas and keep it in an enclosed cylinder to be analyzed later.

Gas chromatographs take a sample of the gas to analyze immediately resulting in a digital output of the specific gravity of the gas along with the full analysis determination. The digital information of the analysis is passed on to the flow computer to be used in the gas volume calculations.

Understanding the actual composition and known volume of the gas in a pipeline environment is very critical to moving large volumes.

Once the flow computer collects the proper information, next this data has to be sent over a communication network to the Host system. Many systems use radio or satellite network systems to move this data in a timely fashion to the Host system

Components of a Midstream Measurement system -consist of Primary, Secondary and tertiary systems as described earlier. Gas Chromatograph and or sampler system will likely be used for analysis purposes. Often radio/power system have to be sized to collect the data from the flow computers in likely a very fast scan rate.

Midstream SCADA hosts often need the data from large customer sites very quickly. This allows for balancing the pipeline pressures and flows, thus eliminate or reduce the number of physical breaks or leaks within the system. Pipeline modeling software package that look for problems in the integrity of the pipeline before there is a real problem are often standard in these systems. All these components are crucial in maintaining a high integrity for Midstream measurement.

Application and Implementation for Upstream–

Once all the components are assembled for site, installers follow proper practices in installations. Safety is always an issue when dealing with a flammable product such as natural gas.

After installation the SCADA engineers get to work making sure all the data is collected properly back to the Host system. This process once pre-tested back at the shop, should not take much time.

One of the major issues that come up is training of the field operations. This has to be well planned out and executed in a timely fashion. If training of the field techs is not done efficiently then often the complete project is at risk.

Downstream Electronic Measurement Design

Downstream measurement is different in that it often is located at private homes or private companies. Metering can range from very small volumes of gas to large volumes. Home usage is certainly the small volumes, and private companies like glass or concrete manufactures or power plants can use large volumes of gas. The Downstream metering systems have to address all these needs.

Components of a Downstream Measurement System – Primary element meters used in the low and large volume sites are shown below:



FIGURE 11. Typical Positive Displacement Meters

Calculations are supplied by AGA 7 for linear type meters. These meters generate a pulse output that represent a portion of the flow, if so configured, and these pulses are sent to a flow computer for accumulating and finally calculated to a finished volume. The flow computer for the Downstream business is known as a Corrector.



FIGURE 12. Typical Meter Correctors

The typical flow computers for the Downstream business comprise of built in pressure and temperature transmitters or transducers along with a pulse input mechanical drive device. Located on the bottom of each of the meter correctors shown above you can see the mechanical totalizer. This totalizer counts the number of rotations coming from the positive displacement gas meter and the count can be read off the mechanical display.

Each of these corrector flow computers have the ability to communicate over phone lines or radio back to a Host SCADA system.

Application and Implementation for Downstream–

Once the application is known the user can chose the type of Corrector that mounts properly to the flow meter. Different mounting brackets are required to fit properly on the gas meters.

Once these details are attended too, the next step is to select a host collection system. In the Downstream business there are many offerings know as Automatic Meter Reading (AMR). Some of these work through phone lines and others through very short wireless applications. It is important to keep in mind the power requirements at the remote sites. Radio's and phone modems again will take power to work properly and if the meters are located within buildings and or houses, often difficulties of installation become apparent.

Downstream systems also require editing of the historical data similar to the Up and Midstream business.

Summary

When considering the varied applications many factors make up the process of determining the type of meter, flow computer, radio, Host and power/solar system. Installations can become a difficult process and often the manufacture has to support this process.

Addressing the fundamentals of electronic meter design can cover many technical aspects and it is important to understand how all these technologies tie together to make up a successful system.

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