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 fundaments 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.

Basic Definitions

Custody Transfer: Custody transfer gas measurement implies that a buying or selling transaction is taking place based on the flow computer calculated quantities. 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, 9, 10 and API 21.1 offer recommendations and or standards in assisting in the design.

*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 way 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 the end consumer. Downstream refers to the final delivery of the gas to businesses, industrial sites, factories, power plants, homes etc.

The Components of an Electronic Flow Meter are described in the API 21.1 Document "Manual of Petroleum Measurement Standards – Flow Measurement Using Electronic Metering Systems":

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, flowing temperature, 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: Orifice measurement is typically used for applications where the flowing gas is not necessarily dry or clean; the gas could contain liquids, sand, paraffin, and many other foreign items – these are sometimes referred to as the “blood, guts, and feathers” in the production world. A producing well often brings many bits of the earth up to the primary measurement device. Orifice measurement can generally handle these difficult 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. As an alternative to the orifice plate, cone type meters can sometimes be used, particularly as they can be less susceptible to wear compared to the sharp edge that’s required on the orifice plate. However, few devices other than the orifice plate, can be easily removed from the process for inspection and replacement.

Recent technology advancements have seen an increasing use of both Ultrasonic Meters (USM) and Coriolis Meters, the former particularly for measurement in larger midstream applications. USMs utilize pairs of transducers mounted in the spool piece of the meter, with one mounted upstream of the other. These transducers produce pulses of sound which travel between the pairs of transducers, travelling both with the flow (downstream) and against the flow (upstream). Complex electronics use the difference in time to travel between the transducers to calculate the volumetric flow rate. Various designs exist with different patterns of transducers to be able to accurately measure flow locations affected by bends, valves etc. Coriolis meters use the Coriolis principle in order to measure the mass flow rate of the fluid. This technology is described in detail in many other papers, and can be applied to both gas and liquid measurement.

The benefits of preventative rather than reactive maintenance are now well understood; increased up-time, reduced costs, increased reliability, better overall measurement uncertainty, reduced trips to the field…… Both Ultrasonic meters and Coriolis meters can provide a host of diagnostic information to help achieve reliable operations. It should also be noted that recent advances now allow traditional DP meters, including the Orifice plate, to provide real time diagnostic information to help facilitate efficient preventative maintenance programs.

FIGURE 2. Secondary Measurement Transmitters and Gas Chromatograph

Secondary Measurement: The AGA-3 report covers recommended practices for measurement of natural Gas when using orifice measurement. Three process measurements are generally required for orifice measurement; these Differential Pressure, Static Pressure and Temperature. The Differential Pressure measurement 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 also required which 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 pressure measurement.

For Turbine meters and PD meters, which produce a pulse signal proportional to flow rate; only the static pressure and flow temperature is required. The AGA-7 report covers measurement of natural gas by Turbine meters.

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 the calorific value or energy content of the gas. 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 instruments that require planned maintenance and calibration to keep performing well.

FIGURE 3. Typical Flow Computer Systems

Tertiary Device: The flow computer is often referred to as the "glue" that pulls all the items together, or the "cash register" of the Oil & Gas industry. They are designed so that field operators easily can set them up using a configuration tool that runs on a laptop or tablet.

FIGURE 4. Typical Solar Panels

Power - Solar/Battery Systems: Power requirements for metering systems have changed and typically reduced over the years. Initially power requirements were much greater, with power hungry flow computers, radios and transmitters. Today we can lean on technologies that have been derived by many of our consumer products, such as Smart phones tablets 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 Radios

Radio Systems: The data generated by the flow computer in the field is often required at some other location on a timely basis. At remote installations Radio systems 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 readily available to many operations of the company, quick response by engineering and other sectors assure steady production helping to improve efficiency and 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 6. Typical Yagi Antenna

Antenna Systems: Without the proper design and orientation, 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 20 feet or more. All this is determined by a path study usually offered by the radio manufactures and some flow computer manufactures.

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 ensure records of what parameter was changed and when is available.

Today most 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 and just about all gas measuring systems have a means of editing the historical data generated by flow computers.

Host SCADA Systems: Most gas measurement systems have a way to collect data remotely from metering sites. However, the practice of manually driving to the sites and collecting the measurement data via a laptop or tablet still exists, particularly for remote isolated production sites. That said most sites general use Supervisory Control and Data Acquisition (SCADA) system that resides in the corporate office or in the field office.

The SCADA system will typically utilize 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 correctly 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 widely used protocol is still probably Modbus. This simple single layer protocol was developed in the early 1980's and is still used commonly throughout the industry. By using a common protocol most vendors can communicate to one Host system. Other proprietary protocols are available from different manufacturers; while other open protocols such as DNP3 are increasingly being employed particularly as they help address the increasing challenge of maintaining security.

As mentioned earlier, 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 frequently will drag down the battery/solar power systems, and not polling fast enough might reduce the response time to address any site issues.

Upstream Electronic Measurement Design

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

FIGURE 8. Low Powered Flow Computers

Figure 8 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 (Differential pressure and static pressure 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:

There are many choices today for flow computers used in the Upstream metering or production areas. Not only are there many calculations and metering standards to choose from, many times the application requires selection of the right packaging. In the Upstream production sites, the classification of the hazardous area is critical. Many packaged systems as shown above meet Class 1 Division 2 hazardous service. Class 1 Division 2 hazardous service means there can be natural gas present in the atmosphere occasionally and that the equipment must still operate safely.
Please note that Hazardous Area classification and requirements can vary in different countries and regions and advice from a qualified expert must always be sought.

Site Requirements and Considerations 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 often 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 by the local workforce, cost of ownership, environmental safety, and compact design/ease of installation. 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 100% of the 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 synchronizing 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 significantly reduced and the overall cost for the site also reduced.

Antenna systems are easy once the radio technology is determined. Most radio manufactures can recommend the type of antenna that will 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 requirement 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 if the solar power system is stolen or destroyed, or just not enough sun to recharge it?
Normally 7 to 10 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.

Midstream Electronic Measurement Design

The Midstream metering systems often have a much greater volume flow than the Upstream production wells and are typically located in more densely populated areas.

Midstream measurement systems often consist of a means of measuring the gas content or composition 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, energy and gravity of the gas. Sampling systems usually are based on either a timed basis or a volume basis. If based on volume, the flow computer often sends a digital contact closure to drive 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 automatically take a sample of the gas to analyze, and a few minutes later provide a digital output of the specific gravity of the gas along with the full gas composition analysis. The new analysis is then communicated 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 required information and calculates the necessary flow rates, totals, averages and periodic data, next it sends this data 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 with faster 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 eliminating or reducing the number of physical breaks or leaks within the system. Pipeline modeling software packages that look for potential problems in the integrity of the pipeline before there is a real problem are often included within in these systems. All these components are crucial in maintaining a high integrity Midstream measurement system.

Downstream Electronic Measurement Design

Downstream measurement is different, in that it often is located at different privately-owned facilities, factories, power plants or homes. As a consequence, the metering can range from very small volumes of gas to significant 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 differing needs.

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

FIGURE 9. Typical Positive Displacement Meters

Calculations are supplied by AGA 7 for linear type meters. These meters generate a pulse output that represents a fixed volume of the flow, and these pulses are sent to the flow computer for accumulating and calculating the final flow volumes. The flow computer for the Downstream business is known as a Flow Corrector.

FIGURE 10. Typical Meter Correctors

The typical flow correctors for the Downstream business have built in pressure and temperature transmitters or transducers, along with either a pulsed input or a mechanical drive device which is located on the bottom the flow correctors.

Each of these corrector flow computers can 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 has the necessary transducers and inputs and if required, the correct method of mounting directly to the to the flow meter.

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 EFM applications and the many factors that contribute to the process of determining the selection of the primary flow meter, secondary instruments/transmitters, flow computer, radio, host and power/solar system. Initially it can be quite daunting, but starting with a broad understanding of how these different technical aspects interact is a good starting point. This paper provides at starting point to this process, but becoming more familiar with and gaining a more thorough understanding of topics such as; Orifice plates, Ultrasonic Meters, Turbine Meters, EFMs etc. will contribute to your future success in selecting, installing and maintaining Electronic Flow Meter installations.