COMMERCIAL METER SET DESIGN

BRYAN PHILLIPS
SENIOR GAS ENGINEER
AVISTA UTILITIES

Introduction

Natural gas is a valuable resource that our customers have come to rely on for a variety of uses. The meter set is a critical element in the delivery of natural gas. It is the point at which the gas facilities directly connect to the customers piping. This "connection point" is really a combined system that provides the regulation, metering, over pressure protection. It also records a customer's gas usage and, in some cases, transmits that information back to the utility for billing.

For most utilities, the largest population of meters are typically residential. There are also many commercial customers that have loads that can be supplied by meter sets that are essentially a residential design but with a larger, diaphragm meter. This allows a similar configuration to be used for many applications. There are other commercial and industrial customers whose load requirements necessitate a solution that is more specific than one of the standard designs. Some examples are higher delivery pressures, higher gas loads/higher volumes, inlet piping limitations, etc. If a standard design cannot be used, a solution tailored for the customer's conditions will be required.

The intent of this paper is to discuss some of these requirements and to provide guidelines regarding commercial meter set design, specifically situations that require a custom solution for metering at a customer's facility. We will be discussing metering that is downstream of the gate station in a distribution system, we will not be discussing transmission meter set design in this paper.

There are many items that must be considered when designing a meter set. This includes information related to the design, siting, layout as well as factors related to the selection and sizing of the associated equipment. There are also federal and state codes, industry standards, company standard/specifications and practices as well as preferences from design and construction personnel. These paired with the customer's requirements direct and influence the design of the meterset.

Safety:

Incorporating safety in operational practices is a key initiative of many utilities. Designing meter sets to be safe is critical to protect our customers and to sustain the delivery of energy to their dwelling or facility. Most buildings that have gas facilities connected to them have a human present in it for some amount of time. Safety needs to be first on the mind of the designer to protect the facility's occupants and users.

Codes and Standards:

There are many requirements associated with the design of natural gas piping installations. The most notable is the Code of Federal Regulations 49 CFR part 192. This is the federal code that details the requirements for systems that transport natural gas. ASME B31.8, another important and widely used standard that deals with pressure piping for natural gas systems. It has many similarities to 40 CFR 192. State requirements, company standards and manufacturer's instructions also influence the design of natural gas piping systems. Learning how these codes, standards and specifications are practically applied to meter set design is critical.

Design Considerations:

When beginning a meter set design, it is important to determine the following information early in the design process.

Inlet MAOP and Pressure:

Determining the Maximum Allowable Operating Pressure (MAOP) of the system that is upstream and that will be providing gas to the meter set is an important first step. Understanding what pressure is available will help determine what equipment may be used. This pressure will be used in sizing the inlet piping, fittings, regulator and reliefs. The inlet MAOP should be used as the maximum pressure that the meter set could see. This is also used to calculate the regulator failure flow (if necessary) - the maximum flow that will pass through the regulator if it fails. The inlet MAOP is also used to establish the pressure test requirements for the piping and components that will be used in the system. It is also used to select piping components that are properly rated for the pressures they will be exposed to. This is vital to establish early in the design.

The inlet pressure to the meter set is often the operating pressure of the piping system that is in the area. There are situations where new piping and regulation may be added to serve a large industrial customer but often a new service will be added to existing gas facilities. It is critical to know what the Maximum Allowable Operating Pressure is for the piping system that will be connected to the meter. The inlet portion of the meter set will need to be designed to handle this pressure up to the point where the pressure is regulated down to the delivery pressure. This can occur before the meter or after the meter, depending on the pressure (upstream/downstream) that is used to select the meter. It is possible to meter before regulation; this allows the use of a smaller meter operating at a higher pressure. The meter can also be located after the regulation which will require a larger meter and piping.

Minimum Inlet Pressure:

It is important to determine what the lowest delivery pressure to the meter set will be. This pressure is used for design purposes so that the regulator and other components that make up the meter set will be able to meet the downstream demand at the lowest delivery pressure. In other words, if the pressure gets low, can you get the flow you need to serve the customer? This minimum inlet pressure is critical to determine. Gas planning experts and software packages exist in the industry to help provide engineering analysis to address this type of question. There is a lot going on in the system, knowing what the lowest inlet pressure may be for a worst case is very helpful. If gas planning calculation methods are not available, actual system data and estimation may need to be utilized. Use what your organization has available.

The velocity of the flow in the inlet piping should be calculated. If the project is a rebuild or an increase in capacity, it is still necessary to verify that the existing piping is sufficient to supply gas to the new meter set at a reasonable velocity. A rule of thumb is to keep this velocity at 70 fps or less. The velocity can be higher than this, but care should be taken to understand the potential impacts to the portion of the system that will carry the higher velocity. Keeping the velocity under or around 70 fps will reduce the potential for erosion Validating if erosion is a potential concern can further be explored with the calculation procedure detailed in API RP 14E.

Velocity in the piping can be calculated with:

$$V = \frac{Q \times 0.748}{P \times D^2}$$

V = Velocity (ft/s)
Q = Flow rate (scfh)
P = Actual Pressure (psia)
D = Internal Pipe Diameter (in)

Outlet MAOP:

The outlet MAOP of the meter set is used to determine the setpoint of the regulator, any required reliefs and the size of the outlet piping. The outlet MAOP from the regulator should be delivered well below the customer's MAOP so that the customer's piping is not at risk of being over pressurized, and the gas load is properly delivered. Most customers rely on the utility to protect their piping from over pressurization.

Customer Load:

Determining the load required by the customer is a critical part of designing the meter set.

Determining the customer's load is important to appropriately sizing the meter, regulator and piping. It is necessary to know what volumetric flow rate and operating pressure the customer will need to run their equipment. It is helpful if actual cutsheets for the customer's equipment can be obtained. When this is not possible, discussions with a customer representative, engineer, or facility maintenance staff can also be helpful in determining the customers gas load. The meter should be selected to accurately meet the anticipated load condition. It is very possible that there may never be a condition where all the devices are on simultaneously. Often the total combined load is used as the criteria to size the meter. This is chosen so that should this load ever occur, the meter will have the capacity to handle the customer's load. This can lead to a meter that is oversized for the actual load that the customers appliances are drawing. Will there be more load added in the future and what, if any, provisions should be made for that consideration? There may be some diversity in how the various appliances that make up the load utilize gas. This is the consideration that not all the appliances are in use at the same time, all the time. If there is accurate, verifiable data on how the customers' loads and appliances can be operated, a diversified load can be determined and potentially validated, allowing a lower gas flowrate to be used as the customer's required gas load. Interval data from various communications solutions, advanced meter infrastructure (AMI) can help provide this.

The piping in the customer's facility and the piping that supplies the facility with gas will also need to be analyzed to verify it can meet the customer's load. The delivery pressure may be selected to keep the pipe size smaller, saving material and installation costs; smaller pipes will require a higher pressure to move the same amount of gas. This is often a cost tradeoff and dependent on what delivery pressure and load capacity is available in the area.

Meter Selection:

There are several considerations for sizing and selecting meters. Often the meter is the limiting device for flow so properly sizing the meter to the load is very important.

Picking a meter is similar to the selection of other devices in the meter set. The meter must deliver the flow required by the customer and meet the pressure requirements of the system. Each manufacturer has a sizing process for the meters they produce. Often, a utility may have guidelines and sizing criteria that they will use to determine to size a meter they use for a given pressure and flow requirement. These pre-established guidelines can be helpful in sizing and selecting equipment, but they should not be a substitute for verifying if a meter is suitable for a specific application.

Variations in load over the course of the day, low flow conditions, peak demand, process loads vs. intermittent loads are also factors. All of this should be considered to pick an appropriate technology that is sized to supply the load to the customer.

Many meter technologies have ideal ranges of operation. Accuracy is best for these technologies when they operate in the range defined by the manufacturer. Operating at the extremes of their ranges or exceeding those limits will often impact accuracy. There are also considerations regarding flowrates that may be above the ideal range for the meter. In many cases, exceeding the upper or lower range of the meter for a short time is acceptable but it will impact the accuracy of the reading. It is vital to develop an understanding of the load, the delivery pressure and any factors that may change the sizing of the meter or impact the accuracy of the meter.

Meter Types and quick description of features:

The following is a concise description of meter types, and the advantages and disadvantages to help develop an understanding of the most common technologies used for distribution metering today.

Diaphragm: Diaphragm meters are positive displacement meters. They are what many people think of when gas meters come to mind. They are ubiquitous as the residential and light commercial meter. They are used in lower pressure applications, are a durable and reliable technology and have a long history of use in the utility industry. Typically, the pressure capabilities of diaphragm meters increase as flow capacities increase; larger capacity meters have higher pressure ratings (MAOP). It is the lowest cost option of the meter types discussed here.

Rotary: Rotary meters are positive displacement, accurate, dependable, and low maintenance. Rotary meters provide accurate measurement over a wide range of flow rates as well as pressure and temperature conditions. For a given capacity, they have a smaller footprint than diaphragm meters and can handle higher pressures. Often, they will require more piping than a diaphragm meter. Care should be taken to protect the meter with an inline strainer or filter. Keeping weld slag or other debris out of the meter during or after fabrication of the piping will help preserve the condition and tolerances of the meter's internals.

Turbine: When used for natural gas, these are good for medium to high flow rates. They are accurate and offer good cost to performance for higher flow applications. Care should be taken to select the correct turbine blade pitch for the application and to make sure the installation in the piping allows for proper maintenance. Older variations of turbine meters that "pinch" a meter between two, flat faced flanges can bind the turbine blades and should be avoided.

Ultrasonic: Ultrasonic meters are accurate and reliable. There is a low pressure drop with these but in many cases, there is a higher cost solution when compared to the other meter technologies discussed here. They also require specific inlet and outlet piping conditions. Typically, this involves longer segments of straight piping on the inlet and outlet of the meter. Flow conditioning may be necessary. They are typically used in high pressure transmission pipeline applications because of their high accuracy and low pressure drop. They are the standard for custody transfer applications. They are available in bi-directional and uni-directional options. There are smaller devices that can be used in lower flow, higher pressure applications. Some of these have a flow conditioning device built in. They have large measurement ranges due to high turn down and they have reduced maintenance requirements.

Coriolis: Coriolis meters are a true mass flow measurement device. They have high accuracy, are unaffected by pressure, temperature, or viscosity and do not require specific inlet/outlet conditions. This can be a big advantage when used for retrofits or when dealing with challenging piping arrangements. They can be utilized in a variety of pressure conditions but are higher cost than diaphragm, rotary and turbine meters in comparable sizes. Care should be taken to avoid applications where debris or moisture may collect in the meter.

Corrections:

Gas meters measure the gas volume passing through the meter based on the gas temperature, metering pressure, and elevation. It is necessary to correct the actual measured gas volume to standard metering conditions to calculate the Standard Cubic Feet per Hour (SCFH) delivered to the customer. Standard conditions for natural gas are 60º F, atmospheric pressure (14.73 psia), and 0 feet of elevation. Often the process of correction is coordinated across various aspects of the organization so the meter shop will address this when preparing meters for installation in the field and billing can apply any corrections to meter data for a given installation. It is important to understand how the measurement is taken and if there are any corrections that need to be made with the equipment selected for the project.

Corrected flow is calculated as follows:

Corrected Flow (SCFH) = (Metered Flow)*(Pf+Pe)*(Tf)

Where:

Metered flow = Actual Cubic Feet of Gas per Hour (ACFH)

Pf=Pressure factor (Corrects metering pressure to standard conditions (14.73 psia)

Pe=Elevation factor (Corrects metered volume to zero feet elevation)

Tf=Temperature factor (Corrects gas temperature to standard conditions (60ºF). Tf is only used when metering a non-temperature compensated meter. Tf=1 for a Temperature Compensated meter

Elevation Compensation:

The factor to compensate for elevation is the atmospheric pressure where the meter is located divided by the base pressure (Tabular values for elevation factors are not included in this paper).

Elevation Factor Pe = Paz/14.73

Where: Pe = Elevation Factor

Paz = Absolute Atmospheric Pressure (psia) at actual location

14.73 = Standard Base Pressure (atmospheric pressure at sea level in psia)

Fixed Factor:

Fixed factor measurement is not typically used for industrial meters. Fixed factor measurement requires a regulator be used that can hold the pressure to +/- 1% absolute pressure. Because of the narrow range of acceptability, pressure correction is utilized more often.

Pressure Compensation:

A pressure factor is applied to adjust the volume of measured gas for meters that are measuring gas at a pressure higher than atmospheric conditions. The following formula is used to compute the pressure factor:

Pf = Pg/14.73

Pf = Pressure factor

Pg = Gauge Pressure (psig)

14.73 = Standard Base Pressure (absolute atmospheric pressure at Sea Level in psig)

Delivery Pressure:

The delivery pressure of the system is the pressure that will be provided to the customer from the meter set. The pressure from the inlet piping will be regulated down to a pressure than can be used by the customer. In some cases, a customer will request a higher delivery pressure and size their piping system to deliver this to regulators that are located at or near their equipment. They will then use their own regulators to further reduce the pressure at the appliances. Whether or not that is the case, a pressure cut is taken at the meter set and the pressure is then provided to the customer across the designated custody transfer point. The service agreement often reflects this agreed upon delivery pressure and the utility is contractually obligated to provide this along with the specified volumetric flowrate of gas. Selection of a regulation solution is critical to this. Many utilities have sized and selected equipment that they will use for certain applications and have their own sizing guidelines. Often these guidelines are based on manufacturer's data and engineer/ field testing and experience. Due to the procurement process associated with equipment that will be used and purchased in large quantities, there is a high amount of involvement from the purchasing group and field operations both of which help drive the need to standardize. Often a utility will have developed a list or table of pre-selected devices. These are devices that have been sized in advance for a range of use. This means that certain regulators for certain applications. The manufacturer can also be consulted for specific applications that fall outside of the typical requirements that a utility has defined. Knowing what your utility typically uses and why and when to deviate from that is necessary to tailor the solution to the pressure regulation needs of the project.

Overpressure Protection:

Providing over pressure protection is a code requirement and is part of ensuring system safety and longevity. A relief valve or a regulator with an internal relief valve is most often used in meter set applications. These perform the required function safely and reliably and are an affordable option for this type of application. Overpressure protection on a meter set is utilized to protect a piping system with a lower MAOP from a higher pressure. This is accomplished by the use of devices that reduce the pressure to an acceptable level if it rises above a predetermined level. This can be accomplished in several ways. Typically, a utility will use a device that releases pressure if it rises above a setpoint. Often this is a relief valve; a valve that has the ability to open, relieve pressure, and then reseat when the actuating pressure is at or below the setpoint.

The capacity and reliability of an internal relief will need to be considered to determine if the regulator's relief capacity is sufficient to cover the flow should a failure of the regulator occur. The method of relief should also be vetted by your organization to determine if it is acceptable for the application. If an internal relief does not have the required, calculated capacity or if it is deemed unacceptable for the application, a dedicated relief valve should be used. This valve should be sized to protect the meter set by limiting the pressure that the piping and equipment downstream from it can be exposed to. This relief should be sized to handle the full failure flow of the regulator that is upstream (the full failure flow is the flowrate that would go through the regulator if it were to fail in a fully open position). This will protect the system from the higher pressure that could cause damage. Typically, there is manufacturer guidance provided for how to size for this flow condition. For some regulators, the Universal Sizing Equation can be used to determine the regulator's flow for the given inlet conditions. Reference the manufacturer's literature for the sizing method to use and for the coefficient information.

General Configuration Considerations:

There are many requirements to balance when laying out a meter set to include all the necessary equipment in a configuration that allows for proper function and maintenance. The metering technologies and spatial constraints of the installation location will largely dictate how the piping will be designed and the meter and associated equipment will be configured. Many of the metering technologies mentioned above have installation requirements that influence how the upstream and downstream piping should be configured. There may also be recommendations on the piping configuration required for a particular model of meter. Some examples are: required diameters of straight pipe upstream and downstream, filtration, inlet pipe configuration, the use of flow conditioners, "system noise", pressure, temperature, and flow capacities.

Maintenance and operations considerations:

Many locations may present space limitations and make it difficult to put a meter and equipment into place. When space is limited, creativity is required to make the meter set accessible for maintenance. Sometimes it is a challenge to include all the functionality and equipment required while also including designing for access. Both of these priorities must be considered when designing the meter set. Orient all valves and connections so that they can be easily accessed for service. Consider equipment mounted on the side of the pipe, bolt access, set screws, adjustment screws, and where indicators can be viewed or accessed from. Avoid wrench and equipment conflicts. Allow appropriate space to move tools, insert bolts and operate valves. Where possible, allow truck access so truck mounted cranes can be used.

Maintenance that may be performed involves everything from simple meter reads to removal and replacement of the meter set. Access to the meter set should allow operations personnel the ability to get close to the equipment and perform maintenance or replacement, this may include adjusting regulators, checking meters, removing equipment. Keep the outlet of relief vents, etc. away from an operators or and potential hazards during operation. The ability for an operator or person performing service to get to the meter set and associated equipment quickly, safely, and easily increases the likelihood of maintenance being performed consistently and on schedule.

It is likely that these installations will be in service for a long time, so it is important to get it right the first time. Involving experienced field service personnel in the design process will help develop a solution that incorporates their experience and preferences into the end product.

Meter protection:

Where meters are exposed to vehicular traffic, potential impacts, or other sources of damage, it is necessary to protect the meter set and any associated piping from anticipated threats. This requires the meter set designer to balance protection of the meter set with the ability to access it. Does the meter need to be protected? What are potential risks or hazards? Is a fence required? Does it need to be lockable? These are key questions for the engineer to consider during the design of the meter set.

Area Classification:

An understanding of how area classification is established and where class 1, division 1 or class 1, division 2 areas can occur is helpful for the designer to understand. This will help the designer understand where flanges, ports and reliefs can be located with respect to electrical equipment and other potential hazards. There should not be the potential presence of gas near sources of ignition, intakes, openings to buildings or other potential hazards. Electrical equipment used on or around the meter set should be properly rated for the installation type. In many cases this is at a minimum, a class 1 division 2 rating. Vents or relief outlets may need to be piped away from the area. NFPA 70 and AGA XL 1001 are the go-to references for our industry. In establishing the limits of classified locations, group D (from article 500.6) contains natural gas. The AGA document is solely concerned with the proper application of electrical equipment to avoid the ignition of flammable vapors and gases. For the designer, this means identifying the areas where gas will be present and locating piping components and electrical equipment so that a flammable mixture of gases does not encounter electrical gear that is not properly rated.

Bypass:

Providing a bypass allows gas to be delivered downstream while equipment relating to metering or regulation is taken offline. This helps reduce downtime to customer processes and facilities thus minimizing the impact of maintenance related activities. There are different types of bypasses. There can be permanent bypasses that are configured of pipes and fittings that route around the meter set and have valves that are dedicated to providing isolation during maintenance. There are also bypasses that can be set up from vents or dedicated bypass ports that allow a "soft" bypass to be utilized. These "soft" bypasses are temporary in nature and still require valves in order to temporarily isolate the meter set and equipment. Consideration for this type of feature is best included in the design. This can help make things easier for proving meters.

The flows required for verification of the meters calibration are often higher than the meter may be running at while service personnel are onsite to verify. The option to be able to utilize a bypass or port to vent flow to atmosphere to get a higher rate of flow to check meter performance while the meter is still installed in the piping (especially in the case of a rotary) is beneficial. There are equipment options to prove different meter types and this should be considered when designing a meter set.

CP:

Cathodic Protection (CP) needs to be considered in the design of the meter set. There may be connections associated with the meter set that require isolation to be included in the design. If the inlet piping is steel, it may be necessary to isolate the meter set from the CP system that is protecting the steel. Including the meter set and the customer's piping system on the utilities CP system will add unnecessary load to the system without providing any benefit. In some cases, it may short out the system and lead to troubleshooting challenges. Isolating the customer's piping from the meter set may also be required. This should be reviewed as part of the design, and it may be necessary to get help from someone within your organization who is a corrosion control technician.

Conclusion:

The design of commercial and industrial meter sets is a process. It is a practice in the balance of many different factors and priorities. It is a rewarding experience for the engineer and designer. The considerations mentioned here provide a framework to help the design process.