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BASICS OF HIGH PRESSURE MEASURING AND REGULATING STATION DESIGN

Class # 1010

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Introduction

This paper will present a review of criteria necessary for designing high pressure natural gas measuring and regulating stations. For the purpose of this discussion, high pressure is assumed to be gauge pressure values above typical distribution mainline pressures, and therefore, is most applicable to station designs of gathering, midstream, and transmission operations.

The design engineer has many factors to consider when designing a metering facility. These factors must include considerations for their impact on measurement accuracy, facility capital cost, environmental stewardship, public stewardship, and long term maintenance cost. The successful designer will seek to achieve high accuracy at an appropriate capital cost, while minimizing the risks for environmental hazards, public nuisance such as noise, and provide the operator with a facility that minimizes maintenance requirements.

Regardless of the haste with which a meter station is constructed, it is most commonly in place for a number of years. It is not unusual for a facility to be in place for more than 30 years. Considering this, the facility must meet the purpose for which it was intended regardless of whether gas flow rates might increase or decrease over time. It is, therefore, prudent for a designer to consider the potential for expansion or flow rate reduction and how that might affect the facility design. Later modifications are likely to be more costly than initial construction.

Standards

Several codes and standards are applicable to measuring facilities. The following is a list of regulatory agencies and standard writing entities which are applicable:

1) American Gas Association (AGA)
2) American Petroleum Institute (API)
3) American Society of Mechanical Engineers (ASME)
4) U.S. Department of Transportation (DOT) Office of Pipeline Safety (OPS)
5) U.S. Department of the Interior (BLM, BOEMRE, BSEE)
6) National Fire Protection Association (NFPA)
7) National Electric Code (NEC)
8) U.S. Environmental Protection Agency (EPA)
9) U.S. Occupational Safety and Health Administration (OSHA)
10) Applicable local, state, and federal requirements not governed by the previous agencies

Initial Data

In order to properly design a measuring facility, some initial data is needed for equipment sizing and selection.

One of the classic challenges of the designer is trying to interpret the commercial representative's statement of range. For example, consider a station with a range stated as 0 – 250 million standard cubic feet per day (MMscfd). The first consideration is that this will be a rather large meter station. Secondly, there is no indication of what is being fueled so that range requirements can be verified. Also, it is appropriate for the design engineer to advise that zero is not a flow rate and determine what the minimum station flow rate will be.

To aid with these types of discussions, let's consider what data is necessary to do a proper design. Table 1 provides a list of items to consider as one is beginning the design process. Note that it is important for all parties involved to pay attention to the units for each value. It is normal for transmission companies to describe flow rates in terms of daily values and distribution companies to use hourly values.

By considering each of the items in Table 1, one can best arrive at the necessary design requirements. It is best to talk to the other party's engineers and learn about exactly what is being connected and how it will likely be operated. Note that one needs to know the maximum, minimum, and expected normal flow rates for proper sizing. For instance, a power plant design engineer will have precisely worked through unit fuel requirements and the staging of units by operating plan. This will be critical information for determining station turndown and range.

Table 1: Design Considerations

Design Consideration	Units
Expected flow rates (maximum, normal, minimum)	MMscfd
Peak hourly flow rate	Mscfh
Projected growth	MMscfd
Pressure (maximum, normal, minimum)	psig
Maximum Allowable Operating Pressure (MAOP) of both systems	psig
Maximum Operating Pressure (MOP) of both systems	psig
Overpressure protection (type, method, responsibility)	
Expected flowing temperatures (maximum, normal, minimum)	ºF
Base pressure	psia
Base temperature	ºF
Atmospheric pressure	psia
Gas relative density	unit less
Gas heating value	Btu/scf
Hydrocarbon dew point temperature	ºF
Water content	lbs. / MMscf
Maximum carbon dioxide, nitrogen, and oxygen (diluents)	mole %
Maximum hydrogen sulfide	grains/100 scf
Gas composition and gas quality determination method	
Maximum delivery pressure (downstream of meter)	psig
Maximum allowable noise	dBA
EGM software and hardware specifics per operating company	
Control method requirements (e.g., flow control with pressure override)	
Remote monitoring and control requirements (SCADA)	
Frequency of monitoring required (real-time/daily/weekly/monthly)	
Location (onshore/offshore/wetland/residential area, etc.)	
Availability of utilities (electricity, telephone, etc.)	
Local building or other permitting requirements	
Liquid removal, measurement, and re-injection requirements	
Condensate removal/storage/handling requirements	
Criticality of service (shutdown of service for inspection allowable or not)	
Filter separator requirement	
Heating requirement	
Odorization requirement	
Requirements for meter proof or reproof	

Another sizing consideration is that city gate stations may have peak hourly rates that are about six times as great as the daily total demand. In that case, all of the flow is needed at peak demand time, once in the morning and once in the evening. Sizing on daily demand would cause the facility to have inadequate capacity.

Major Piping Design

All piping assemblies in the high pressure facility must meet the codes for pressure piping design, such as API Specification 5L, API Specification 6D, ANSI B16.5, and ANSI B16.9. In accordance with DOT 49 CFR Part 192, pipe used for measurement facilities must be designed with a Class 3 design factor of 0.50 (50% of SMYS) or a factor of 0.40 in a Class 4 location.

Tap valves and interconnect piping are sized on the basis of a velocity limit. This velocity limit is usually assigned by company convention; however, it is common practice to use a velocity limit of 70 feet per second. It is important to consider whether liquids might be present in the flow stream in order to avoid erosion velocity. Erosion velocity values may be very high for clean dry natural gas, but will be below the 70 feet per second value when free liquids or particulates are introduced.

Headers are necessary for multi-tube meter stations to ensure velocity balance across the parallel runs. If properly sized, headers will allow for velocity reduction prior to meter tube entry. This velocity reduction is necessary to reduce turbulence intensity in the meter tube entry.

Upstream piping design is an important part of ensuring accurate measurement. The metering technologies currently used in the natural gas industry were designed assuming homogeneous, steady state, non-swirling, axi-symmetric, and bulk turbulent flow. Another way to say the same thing is that the inlet velocity profile is assumed to be a function of the "law of the wall" that assumes that the velocity profile shaping occurs as a function of pipe wall roughness and radial position.

Perhaps the best way to think about this is to make flow direction changes in a gradual manner that will provide long flow streamlines. Compact meter station design having close coupled pipe fittings will make smooth streamlined flow a challenge. Too much turbulence caused by convoluted piping may cause ultrasonic meter problems in transmitting acoustic signals across the flowing gas stream.

Another consideration for station piping is pressure drop. Under sizing pipe and piping elements will create excessive pressure drop and a waste of horsepower in compression.

Check valves are a necessary item for unidirectional flow stations and should always be located at the tap rather than being installed in line with the meter tube. This practice avoids the distortion of velocity profiles in the meter tube which will produce bias errors.

Metering

The selection of meter type will be a function of the application and flow range required. Prudent design practice limits the applied range to flow rates for which the transduced flow transmitter inputs are limited to an operating range of 10 – 90 percent of calibrated span or frequency range. Typical differential pressure span values are 300 inches water column and typical input frequency span value is 5000 Hz.

Normal velocity maximum values for different inferential meter types are as follows:

1) Orifice meter = 30 feet/second
2) Turbine meter = 45 feet/second
3) Ultrasonic meter = 70 feet/second

Each company will have its own preference for meter type as a function of application. Some will almost exclusively use orifice meters for production receipt measurement. Others might use turbine meters as the meter of choice for city gate applications. Ultrasonic meters may be preferred for mainline to mainline high flow, interconnect facilities.

Rarely is one meter tube going to be adequate for an application. The problem is that with one meter tube, the station turndown is limited to the flow range of that particular metering technology.

Gas Quality

Gas quality criteria are established by the operating companies' tariffs. Limitations on non-hydrocarbon components, hydrocarbon dew point temperature, and other contaminants are defined. A customer may choose to reject a gas source if they find that the gas has materials which are commercially objectionable. This could include compressor lube oil or seal oil.

Two phase flow may produce metering bias errors in excess of 2%. For most operations, this magnitude of error is unacceptable. The solution is to include separation in the meter station design to eliminate free liquids from the gas stream. Separators are necessary on the downstream side of glycol dehydration processes and where operating conditions may allow for condensation of hydrocarbon liquids in the pipeline upstream of the meter station.

Compression

The use of gas compressors in close proximity to the meter station may lead to unacceptably high measurement bias errors. As mentioned earlier, one of the primary assumptions of currently applied metering technologies is steady state flow. If pulsation is expected or determined to exist, an engineering study must be made to design pulsation dampening equipment. The pulsation dampeners may be installed either on the compressor piping or at the meter station. Either way, the dampening must be positioned between the meter station and the compression to be effective. Pulsation dampening can be expensive to implement, and eliminating the pulsation at the source is the preferred method.

Station Control, Control Valves and Regulation

Station design would be incomplete without the installation of either flow control valves or pressure regulators. Many transmission pipelines will decline the maintenance requirement of regulation. However, one of the two parties must take on the responsibility.

There are several different control valves to choose from. Some examples of control valves are globe valves, noise-attenuated ball valves, axial-flow plug or boot type regulators, and diaphragm and grid-type regulators. Usually the selection is a matter of operating company choice.

Most meter stations are installed as a part of a SCADA system that allows a gas control center to remotely control the facility. The majority of facilities are simple flow control stations in which the gas controller can write a remote set point to the unit, and it will throttle a control valve to deliver the prescribed nominated quantity of gas for the desired length of time.

Certain control philosophies are important to understand. If the application is the only feed to a power plant, it must be fed as a pressure control supply. Power plants cannot tolerate limitations on the unit speed or unit starting sequence. A steady pressure during the sequence of load changes is desirable. The amount of pressure drop that is permissible will be a function of the sizing of the unit fuel gas regulators. Usually control within 10 psi is desired.

If the power plant already has other suppliers, it is necessary to meet with the plant operators to determine the control requirements for the new feed. Given there are three suppliers to the plant, one (taking the swing) will be on pressure control, while the other two will be on flow control. Having all three on flow control will produce unsatisfactory results, as pressure on the plant header may drift if the scheduled flow rates do not precisely match the demand of the power generation.

There are several control options available such as flow control, pressure control, flow control with pressure override, pressure control with flow override, and flow control with pressure under ride. These are normally produced as a product of software controller interactions through a selector function. Figure 1 presents a diagram for controller interactions with override functions.

The best policy concerning controls is to keep it simple. Nesting of controls, devices, and complicated interacting scenarios leads to a technical support nightmare. Designs that require frequent ongoing outside-consultant support are costly to maintain and should be avoided.

Energy Measurement

Energy measurement requires proper gas sampling at the point of measurement. Some well-defined guidelines exist in API 14.1 and GPA 2166.

The goal should be to sample gas from the least turbulent point in the meter run. A location immediately downstream of an orifice plate is not an advisable choice since any free liquids may be atomized as they pass through the orifice plate and may bias the sample.

Good sampling practice avoids the opportunity for hydrocarbon dew point temperature to be reached in the sampling system. Attention to the installation of heated assemblies and heat traced sample tubing is necessary to maintain the gas temperature above the hydrocarbon dew point and thus eliminating condensation of heavier gas components.

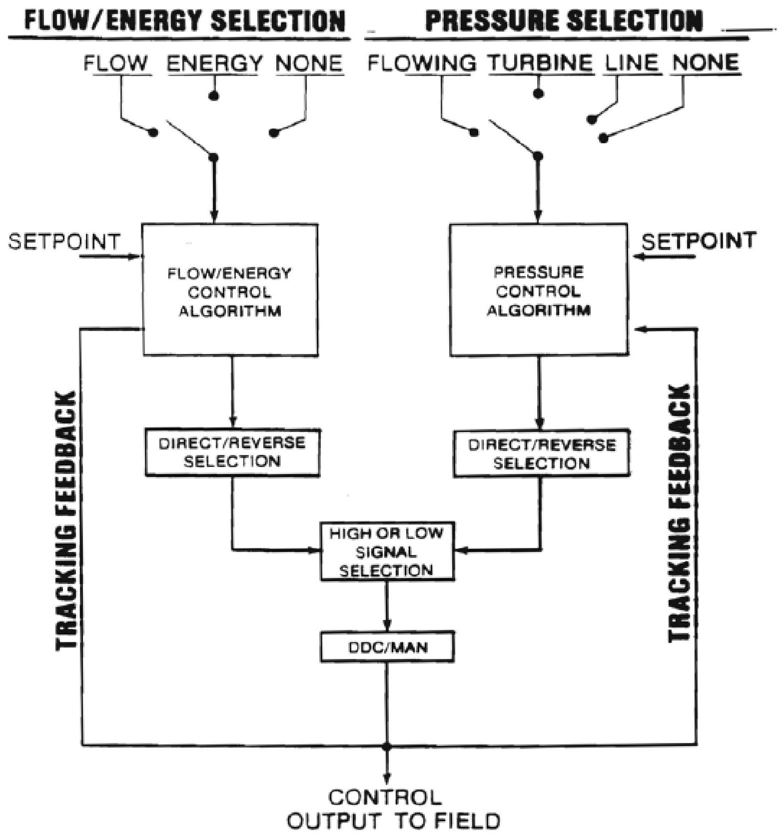
Sample probes need to be installed in a straight run of horizontal pipe. The sample probe should extend into the middle third of the pipe diameter.

Online gas chromatographs must be installed with attention to the same sampling criteria, with the additional concern of avoiding hydrocarbon dew point temperature in the calibration gas cylinder. The slightest condensation of hydrocarbon liquids inside a calibration gas cylinder will cause measurement bias if the cylinder is used for calibration without preheating.

Conclusions

Proper meter station design requires knowledge of several standards and regulations and requires experience to develop good practice. It is hoped that this paper has provided some insight into the basics of high-pressure measuring and regulating station design, but certainly does not eliminate the need to study and understand the reference material. For guaranteed success, the designer must maintain a current working knowledge of equipment and recent research that drives changes in industry standards.

It has been the experience of the author that industry members are most willing to share their knowledge and experience. The new station designer is encouraged to attend industry schools and ask questions of attendees for the best learning experience.



CONTROL CONFIGURATION DIAGRAM

Figure 1

References

1) API *Manual of Petroleum Measurement Standards*, Chapter 14 – *Natural Gas Fluids Measurements,* Section 1 – *Collecting and Handling of Natural Gas Samples for Custody Transfer,* American Petroleum Institute, Washington D.C., USA, 5th Edition, February 2002.
2) GPA Standard 2166-05, *Obtaining Natural Gas Samples for Analysis by Gas Chromatography*, Gas Processors Association, Tulsa, Oklahoma, USA, 2005.