DESIGN OF DISTRIBUTION METERING AND REGULATING STATIONS

Class #1060

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INTRODUCTION

The design of natural gas distribution metering and/or regulating stations is a mixture of science and art, of knowledge and judgment. The process requires four areas of knowledge: product, application, components, and communication. The goal in design is to use judgment to select and combine compatible components to create a safe, effective, and economical unit.

PROPERTIES OF NATURAL GAS

BASIC. The first area of required knowledge concerns the product being delivered; in this case, natural gas. It is lighter than air and rises if released. It is odorless and colorless, which is why odorant is added to aid in leak detection. It is flammable, which is why customers will pay for it. It can accumulate and explode, which is why it must be treated with care and respect. All of these basic properties will influence the selection of equipment at stations.

While these characteristics are important, they are not enough to properly design a station. Knowledge of the specific natural gas to be used at a particular location is also needed. The hope is for clean, dry, "pipeline-quality" natural gas, with consistent composition, but the reality is often something else.

HIGHER HYDROCARBONS AND OTHER IMPURITIES. Natural gas is usually produced with higher hydrocarbons such as propane, butane, and pentanes. These "heavies" can cause problems in a station, dropping out in liquid form to damage regulator seats and boots, turbine meter blades, and customer equipment. If it is not economical to remove the liquids by gas processing, stations can be protected by pipeline drips and separators. These, in turn, add to inspecting and operating costs. A lesser-known problem of such hydrocarbons is their ability to "mask" or remove many commonly-used odorants from the gas stream, with potentially disastrous effects.

Another consideration in sizing equipment is wide swings in gas composition, as from gasoline plant upsets. A regulator passing 1200 Btu/ft^3 natural gas may adequately feed an industrial boiler, but it may fire improperly if the natural gas heating value drops to 950 Btu/ft^3.

Natural gas often carries with it producing formation sand, welding slag, pipeline scale, and other solids which can damage equipment. These can be handled with properly-sized strainer baskets or disposable element filters. If used, however, these items must be included for inspection and maintenance.

Water vapor is another common impurity. It can cause pilot or main regulator freezing, loss of control, loss of flow capacity, and internal corrosion. Water vapor can be controlled by either removing it, with glycol dehydrators or desiccant adsorbers; or by limiting its detrimental effects, using pilot regulator heaters, line heaters, or alcohol injection. If alcohol injection is chosen, attention must be given to the rubber compounds used in the equipment, as some are deteriorated by methanol.

Finally, hydrogen sulfide (H_2S) is a problem in some areas. This source of internal corrosion can be treated by removal from the gas stream or by selection of equipment resistant to H_2S attack; for example, stainless steel regulator trim.

PHYSICAL CONDITION OF THE GAS. As any gas expands, as by a reduction in pressure through a regulator, it cools. For natural gas, this Joule-Thomson or "refrigeration effect" is about 7°F for every 100 psi pressure change. For example, a pressure cut from 350 psig to 150 psig would be expected to lower the gas temperature by 14°F.

Normally, this is not a problem, but when coupled with heavy hydrocarbons in the gas stream, a regulator setting can become a miniature gasoline plant, to the dismay of customers downstream. If coupled with a high water dew point, regulator freezing and/or hydrate formation can occur. If the soil is moist, frost heaving can occur as the moisture freezes and expands around the downstream underground piping. Paved roads have been buckled by this phenomenon! Besides the refrigeration effect, as differential pressure increases, gas velocity, noise, and seat wear typically increase as well.

Equipment must also be selected to handle the temperature extremes to which they will be subjected. For example, one might select a different rubber compound for a component in winter use on Alaska's North Slope than for the same component downstream of a west Texas gas compressor in July.

FAMILIARITY WITH THE APPLICATION

While knowledge of the product being delivered places some demands on the designer, the particular application being considered makes even more. These include regulatory, physical, load characteristics, operation and maintenance (O&M), and economic demands.

REGULATORY. Designers must always ensure that their designs satisfy applicable codes and standards. Design of natural gas facilities is subject to the requirements of the Department of Transportation (DOT) as expressed in the Code of Federal Regulations (CFR) Title 49 Part 192, Subpart D. State regulations, as from utility commissions, may also apply. Even local codes must be considered, particularly regarding end-user piping and equipment. The final source of requirements is often overlooked--the company O&M manual! If a company's requirements are more stringent than the code requires, the fact that the code was satisfied (while the company's requirements were not) will carry little weight with code officials.

PHYSICAL. In many cases, a field trip is helpful to see the physical layout of the proposed station site. Cameras, notebooks, and tape measures are often useful accessories. One can determine any space or setting arrangement limitations and identify potential hazards to, or from, the station. Common potential safety hazards include vehicle or heavy equipment traffic, vandals, flooding, or hazards that may arise from venting gas to the atmosphere.

Although less hazardous, noise can cause damage and reduce customer satisfaction and so should concern designers. The high velocities that cause it are associated with high pressure drops and vibrations which may cause cracking and other equipment failure. Noise is directly proportional to flow velocity, which is estimated by[1]:

$$V = (0.75 \times Q) / (d^2 \times P)$$

with, V = velocity, ft./sec (fps),

Q = flow rate, scf/h,

d = pipe ID, inches, and

P = absolute pressure, (psia).

[1] American Gas Association, Gas Measurement Manual, Design of Meter and Regulating Stations, Part No. Nine, p. 9.5.1

For noise control, the American Gas Association (AGA) suggests maximum velocities of 50 fps in header piping, 200 fps in aboveground piping, and 400 fps in underground piping. As the formula indicates, one of the easiest ways to lower velocity is to increase the pipe diameter, often by expanding through a conical reducer. The "d^2" term helps here, since doubling the diameter will quarter the velocity.

Although reducing gas velocity is the preferred manner of reducing noise, there are other options available. Perforated control valves, elastomeric element regulators, underground regulator vaults, and heavy-wall pipe are commonly used. Various types of sound-deadening walls, fencing, and landscaping can be used at existing sites. A designer can also make use of a relationship between sound and distance similar to that between diameter and velocity. By doubling the distance from a noisy setting, the apparent noise level will be quartered.

LOAD CHARACTERISTICS. The designer must certainly consider the present estimate of maximum and minimum flows and pressures, but estimates of future values should also be considered. If growth of load is expected, additional length may be built into the setting to handle larger future equipment. Oversized inlet and/or outlet headers and valves can be installed for some additional initial cost. At a minimum, regulators with provisions for larger orifices or increased capacity trim can be specified.

However optimistic, the designer should also consider the effects of load loss. One example is designing a regulator to feed a low-pressure (LP) area. As the area is rebuilt and converted to medium-pressure, demand from the LP setting will decline. Vastly oversized settings may exhibit poor pressure control or measurement and will involve larger, more costly equipment than necessary. In these cases, a designer might select equipment that can be reduced in capacity over time.

A final consideration is the variation in the load over both short and long periods of time. A snap-acting boiler should be treated differently than a combined central heat load of the same size. Likewise, seasonal variations should be considered.

OPERATING AND MAINTENANCE. In selecting a setting configuration, at least an informal risk analysis must be performed. The designer should consider the consequences of various possible failures. How soon can a technician get to the location? How often is the site visited? A station installed an hour from the nearest technician or seen only at its annual inspection will probably be different than one installed next to the service center. Similarly, a redundant regulator feeding into a distribution system will differ from one solely serving a major industrial customer.

The most well-designed station will fail if not properly installed, operated, and maintained. Designers will help themselves by considering the technician who will take care of the station. Be sure to include enough sense line and pressure gauge taps and solicit feedback on making settings easy to work on and selecting equipment the technician prefers.

ECONOMICS. One of the major challenges to the designer is to meet all these constraints within another limitation--the budget. A perfectly-functioning station is a failure if it costs too much, either initially or for O&M. The designer must judge, for instance, whether the protection of costly equipment is worth the additional expense of a filter and its upkeep. Again, the risk assessment process is useful. Where safety is involved, it is helpful to remember that the money spent on a single lawsuit would likely buy many of the items in question!

COMPONENT HARDWARE

MEASUREMENT. The purpose of the measuring station is of interest to the designer. Metering is the "cash register" for the company in such cases as gas purchase, sales, transportation, or exchange. In designing measurement for internal use, however, the same AGA-specified measurement accuracy may not be necessary. These uses include lost and unaccounted for gas, custody transfer among company subsidiaries, driving odorization, or telemetry for system operations.

The goal in designing a measurement station is to accurately measure the flow over the full range of operating conditions without hindering system operations. The most challenging conditions are large swings in pressures and/or flow rates. These conditions are occurring more often as our companies replace leaky systems and our customers install pilotless gas-fired equipment.

There are two basic types of meters: positive displacement and inferential. Positive displacement meters physically confine volumes of gas. This type includes diaphragm and rotary meters. Inferential meters measure other characteristics of flow and from them "infer" the flow rate. For example, an orifice meter actually measures pressure differential across an orifice plate. We then infer that the higher the differential, the higher the flow rate. Other inferential meters include turbine, ultrasonic, and thermal mass-flow meters.

Rangeability or "turndown" is the maximum capacity of a given meter divided by the minimum capacity and is often used to select among the choices. Diaphragm meters are the proper choice for very low flow conditions. Inferential meters are the choice for high-volume conditions. Rotary meters can bridge the gap from low flow to relatively high flow rates.

Turbine and ultrasonic meters typically have rangeabilities of from 10:1 to 100:1 or more, depending on the application. Orifice meters have similar rangeabilities <u>over the full range of allowable orifice plates.</u> With a single plate however, turndown is only about 3:1. Other inferential meters suggest even higher rangeabilities than 100:1. Manufacturers' catalogue data are critical to making informed selection decisions.

Meeting peak demand is not the only factor in meter selection. Uniformity of flow or "mileage" and load diversity should also be considered. For example, at a particular site, diaphragm meters required replacement every 18 months, even though sized properly for the peak load. It turned out the meter served a boiler that ran 24 hours a day until it wore out the meter. Once the diaphragm meter was replaced with a rotary meter of similar peak capacity, the problem did not recur.

The designer should also remember that the design must be installed and maintained. Care should be taken that room for these activities is adequate, if not abundant. Proper gas flow conditioning (filters, strainers, and flow conditioners) should be used and maintained as recommended by manufacturers to ensure the proper operation of equipment.

Historically, the gas industry has been most interested in accurate measurement at the high end, but as pilotless ignitions and measurement-driven injection odorizers proliferate, more attention will need to be paid to low-end accuracy as well.

REGULATION. The purpose of regulation is to match pressure and flow to downstream demand under varied inlet conditions. As with metering, regulators must be matched to the requirements of the job, in terms of pressure rating, flow capacity, operating characteristics, and cost.

A regulator consists of a variable restriction, a sensing element, and a loading element. The variable restriction is commonly a moving seat/fixed orifice or an elastomeric element ("boot") and fixed body. The sensing element is generally the controlled downstream pressure acting over a diaphragm area to create a force. The loading element is another force that moves to oppose the sensing force. This can be a deadweight, lever and weight, spring, or pressure-loading element. The regulator operates by changing the restriction until the loading and sensing forces are in balance. At that point, the regulator is “in control” and delivering its set pressure to the downstream system.

Spring-operated regulators are the most common and would be expected at residential meter locations. They are relatively simple, reliable, and inexpensive, with accuracy and capacity adequate for low to moderate flows. Pressure-loaded regulators, which use a pilot regulator to control the loading element, are more accurate, but also more complex and expensive. Pressure-loaded control valves and boot-type regulators are generally used for much higher flows.

OVERPRESSURE PROTECTION. The purpose of overpressure protection is to limit downstream pressure to a safe level in the event of a "worst-case" regulator failure. The most widely-used methods of overpressure protection are overpressure shut off (OPSO) valves, relief valves, and monitor regulators.

OPSO valves sense downstream pressure and, if it rises above a set point, the valve closes, shutting down the station. They are relatively inexpensive, small, and simple, but they cause the loss of gas to the system or customer and so require a technician to service the system and reset the valve. This can upset customers and add to operating expenses.

Relief valves are installed downstream from a regulator. If they sense pressure above their set point, they open, relieving gas to the air. The simplest example is a "pop-off", which, like a rupture disk, is simple and inexpensive, but has the disadvantage of requiring attention even if the overpressure condition ends.

A true relief valve closes ("resets") when the overpressure condition ends. Relief valves can be relatively inexpensive and simple. They also have relatively high capacities, especially in pilot-loaded models. Relief valve sizing is based on the worst-case failure of the highest-capacity regulator in the setting. Manufacturers' data are used to determine this flow, generally at the highest possible regulator inlet pressure and the wide-open flow coefficient (C_g, C_v, or K factor). The downstream system also has a maximum allowable operating pressure (MAOP) and an allowable overpressure value established for it.

Once the regulator failure capacity, downstream MAOP, and downstream allowable buildup are known, a relief valve and set pressure can be selected. It must allow the regulator to close ("lock-up") above the regulator set pressure, open the relief valve, and flow the regulator failure capacity before exceeding the allowable downstream pressure.

Monitor regulators protect the downstream system without venting gas to the atmosphere. They may save the installation of a large, expensive relief valve. Their major disadvantages are the reduction of flow capacity of the setting, since the gas stream must pass through both regulators; added cost, particularly in a dual run configuration; added complexity; and that solids that cause internal damage to one regulator may damage both.

In passive (wide-open) monitors using boot-type regulators, it is common for the boot to conform to its wide-open position or "take a set." When called upon to operate, it may be slow to act. To prevent this, many designers use active (pilot-override) monitors, which add a second pilot regulator to the monitor. This installation normally acts as a two-stage regulator setting, which keeps both boots flexible. If the override pilot senses higher downstream pressure, however, it takes control of the monitor regulator and makes the entire pressure cut. This setting has been further enhanced by the use of small "tattletale" relief valves to signal when the override pilot is in control.

COMMUNICATION

The alliance between the field technician and the designer is critical. The technician must be aware of and accurately communicate the operating conditions, design parameters, and equipment preferences to the designer if the design is to be satisfactory. The designer must effectively communicate the final design and any other information useful to those who will construct, operate, and maintain the station. It is useful for the designer to visit the site before, during (if possible), and after construction to get feedback on the successes and shortcomings of the design and its execution. It is said, "Good judgment comes from experience; experience comes from bad judgment!"

Mechanical drawings, especially as produced by computer-aided drafting (CAD), are very common and useful for conveying the design. They also provide a starting point for making field changes or "as-built" drawings. If the limits of application are clearly understood, commonly-used settings may be designated as company standards to prevent "reinventing the wheel" and to allow the designer to focus on atypical stations.

CONCLUSION

The challenge of the station designer is to produce stations that: comply with applicable rules, policies, and codes; function properly under the foreseeable design conditions; provide easy construction, installation, operation, and maintenance; and provide all this at a cost acceptable to customers and shareholders. By remaining mindful of the many factors listed here, by drawing on others' and previous experience, and by listening to information and feedback from the field, it is a challenge that can be met.