REGULATOR & INDUSTRIAL METER STATION DESIGN

DAVE SMITH, PE
GAS DISTRIBUTION ENGINEER
AVISTA UTILITIES

Introduction

A regulator station is an arrangement of pipes, fittings, valves, pressure regulators, and other appurtenances designed to maintain a set outlet pressure while matching the flow requirements of a varying downstream demand. An industrial meter set shares many of the same features with the addition of a measurement device. This document refers to both types of facilities collectively as stations.

Whether it's referred to as a farm tap, high pressure service, industrial meter set, meter station, district regulator station, limit station, town border station, or gate station, they all have the same basic function described above that makes it a member of the regulator station family. Although having the same basic function, there's a wide variety of what these different stations can look like. Each location and set of circumstances will be unique. This paper will cover the steps necessary to design any of these types of projects.

Once the project parameters are determined, the calculations can be performed and the station layout started. Working closely with the construction and maintenance personnel makes this type of project very rewarding.

Unlike a pipeline project where the only above ground evidence is a swath cut in the tree-line or an asphalt patch in the road, a well designed station is a work of art any good utility-minded person will appreciate.

Federal and state codes dictate a lot of the design criteria. Company construction standards and personal preferences also enter into the decision making process.

Design Criteria

Before starting the design process, several pieces of information must be gathered and considered to properly design a station. These pieces include: inlet Maximum Allowable Operating Pressure (MAOP), minimum inlet pressure, outlet MAOP, outlet set pressure, and flow requirements.

<u>Inlet MAOP</u> – The inlet or upstream MAOP is required to properly specify the pipe, fittings, regulators, and relief valves. This maximum pressure is also to be used for calculating regulator failure capacity when sizing relief valves. The design pressure of the station must match or exceed the upstream

system MAOP, or it would become the limiting component in the system and therefore reduce the system's MAOP. Pressure ratings of the regulators and meters need to be carefully examined. Often times these devices can have a pressure limitation that is lower than the ANSI rating of the end connections, for example the pilot regulator may have a lower maximum inlet pressure than the main regulator body.

Minimum Inlet Pressure – The station minimum inlet pressure is critical for sizing the regulators and inlet piping diameter. The capacity of the regulators should be calculated using the minimum expected inlet pressure. This will ensure that the station will be able to satisfy the downstream demand when the overall gas system pressure is at its lowest, which often times occurs during periods of peak system demand. A useful tool for determining minimum system pressures are computer based piping network analysis programs. These programs are able to simulate the gas system's performance based on different system load demands and provide anticipated system pressures. Some companies may choose to use a standard minimum pressure for design. It's important to calculate the pressure drop through the piping upstream of the regulators and take that into account when sizing the regulators. Always refer to the manufacturer's literature to determine the proper sizing calculations and design factors. It is common for the regulator manufacturer to publish a computer program to assist in properly sizing their products. In general, regulators should not be larger than the pipe on either side, and are often one to two sizes smaller.

The inlet piping should also be sized using the minimum inlet pressure to ensure the gas velocity is within a specified range. Preferred maximum gas velocities are typically in the 70-125 ft/sec range (each utility company might have a different range). Velocities inside this range will keep pressure losses and noise to a minimum. Below is the formula for calculating velocity:

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

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

Outlet MAOP – The station outlet MAOP is required for determining the maximum set point of the regulator(s), sizing the relief valve, and sizing the outlet pipe. Outlet pipe sizing should be done using the velocity criteria discussed above.

Flow Requirements – What are the initial and future flow requirements for the station? This is normally stated in Standard Cubic Feet per Hour (scfh). For stations other than meter sets where the flow requirements can be easily determined, the use of a piping network analysis program can be very useful. Without one, an educated guess is required. A look at the upstream deliverability and downstream takeaway capacities can be a starting point. Table 1 can be used to estimate the takeaway capacity of the distribution system. It gives an approximate flow rate for a given pipe size, assuming a 20 psi pressure drop over a mile of pipe.

Pipe Size	**Flow (scfh) 55 psig → 35 psig, 1 mile**
2”	12,000
4”	70,000
6”	220,000
8”	460,000

Table 1- Flow Rate Estimates

If the only value available is a daily flow number, and the usage is primarily space heating load, then a 6% peak factor can be applied to the daily number to get an estimate of the max hourly flow. For instance, if the max daily flow is 100,000 scfd, that's roughly equivalent to a peak hourly flow of 6,000 scfh.

Overpressure Protection

With the above information gathered, we're now ready to start digging into the details. First let's select the type of overpressure protection (OPP). OPP requirements are covered in the Code of Federal Regulation (CFR) 192.195. Common (OPP) choices are summarized in Table 2.

Often the OPP choice is driven by the station's location or the downstream system requirements. Some questions to ask: Are the surroundings safe for a relief valve to be venting? Is it critical to maintain service to the downstream system or is it acceptable to shut off the gas service? How far is the station away for service personnel to respond to an abnormal operating condition? Does your company have a policy regarding working vs. standby monitors?

Monitor regulators can be set up in one of two different ways: standby or working. Standby monitors are set at a higher pressure than the worker and only regulate when the sensing pressure rises to the set point of the monitor. Otherwise they rest in the wide open position with gas flowing through them. The standby monitor can be installed either upstream with a sensing line plumbed downstream of the working regulator (Figure 1, next page) or it can be installed downstream of the working regulator (Figure 2, next page). The downside to these two configurations is the monitor does not get exercised during normal operations.

	Relief	**Working Monitor**	**Standby Monitor**	**Shut off**
Keeps downstream system on?	Yes	Yes	Yes	No
Vents to atmosphere?	Yes	No	No	No
Manual reset required after operation?	No	No	No	Yes
Reduces capacity of regulator?	No	Yes	Yes	No
Constantly working during normal operation?	No	Yes	No	No
Demands emergency action?	Yes	No	No	Yes
Annual review required?	Yes	No	No	No
Need additional alarm to signal over-pressure condition?	No	Yes	Yes	May-be

Table 2 – Summary of Overpressure Protection

Some believe the static monitors have the propensity to get "stuck" in the open position and not be functional when an overpressure condition is present. Additionally there is a loss in capacity of approximately 30% due to the gas having to flow through the monitor regulator. Also, it's critical to ensure the downstream pressure rating of the first regulator and the inlet rating of the second regulator is equal to or greater than the upstream MAOP. With the Figure 1 arrangement, the worker and monitor regulator can be switched annually to exercise each regulator. A benefit to this set up is a simple pilot configuration that is easy to tube. Testing regulator flow (the pressure setting while flowing gas) and lockup (the pressure at which the regulator completely closes when downstream demand is zero) pressures is also simple. If using the setup in Figure 1, the first regulator must have an external control line. The upside to Figure 2 is neither regulator has to have an external control line.

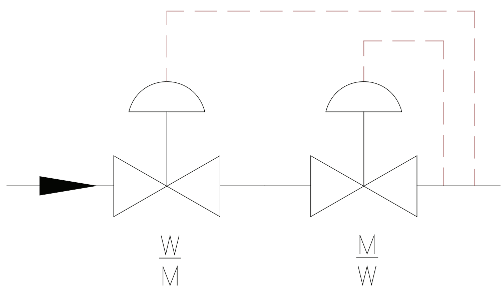

Fig. 1 – Standby Monitor: Either upstream or downstream of the worker

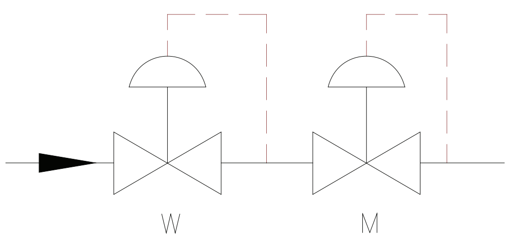

Fig. 2 – Standby Monitor: Worker first, monitor second

There are two typical methods used as indicators when the station is in an abnormal operating condition or "monitor mode". One way is to install a token relief valve downstream of regulator #2 set to go off in between the worker and monitor regulator set pressures. The sound and gas smell generated from the token relief valve will often prompt a neighbor or passerby to call the utility company. Another way is a pressure monitoring device installed downstream of regulator #2, either telemetry or pressure chart, that requires review to ensure the pressure is at the "working level" and not the "monitoring level". Companies with a Supervisory Control and Data Acquisition system (SCADA) can have real time pressure data can be inputted into SCADA and made visible via a computer to the gas control room, engineers, and other personnel.

The other monitor configuration is a working (active) monitor (Figure 3).

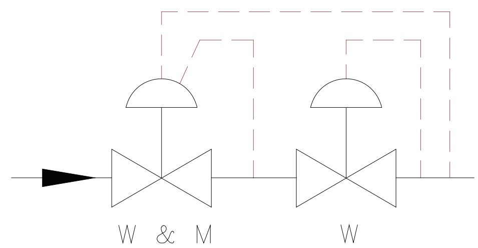

Fig. 3 – Working Monitor: Worker & monitor first, worker second

In this case, the first regulator pulls double duty with two pilots. The first pilot is controlling the first stage pressure cut, and the second pilot is monitoring the pressure downstream of the second regulator. If the first regulator fails, the second regulator takes over pressure control. Because of this failure scenario, both the outlet pressure rating of the first regulator and the inlet pressure rating of the second regulator must be equal to or greater than the inlet MAOP. If the second regulator fails, the monitor pilot on the first regulator will sense this and take over pressure control. The second regulator does not have to have an external control line with this configuration. This set up is sometimes favored because it keeps both regulators exercised and the noise is reduced because the pressure is reduced in two stages. However, the initial costs are slightly higher due to the second pilot and additional alarming. Furthermore, the capacity is reduced due to the lower pressure differentials. To alert of an abnormal operating condition, the pressure at both the interstage point and downstream of regulator #2 must be monitored. As described previously, this can be accomplished with token relief valves, charts, or telemetry to alert the operator.

Relief valves (Figure 4) come in four styles; pop, direct-operated, pilot-operated, and internal. The pop relief valve is the simplest. This is a straightforward spring loaded device that opens when the gas pressure reaches the set point. Typically the set points are factory set and not adjustable. Pop reliefs are prone to chatter since they typically go wide open as opposed to modulating. They are also not very accurate and the set point can tend to drift over time. This requires a larger than normal spread between the operating pressure and the MAOP to account for the imprecise set point of the relief. Example: Fisher H202/203.

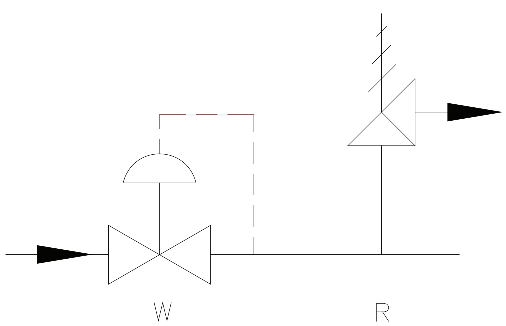

Fig. 4 – Typical worker and relief configuration

Direct operated relief valves provide higher capacity and more accuracy, however they typically require a fair amount of pressure buildup to fully open. They tend to modulate better, are more stable than a pop relief, and are relatively inexpensive. Examples: Fisher 289H and Anderson Greenwood Type 83.

More complex and expensive alternatives are the pilot-operated relief valves. They have the highest capacities with the lowest amount of pressure buildup over set point to fully open. These units are very accurate and repeatable. Typically they are designed to either modulate or go wide open once the set point is reached. Examples: Anderson Greenwood Series 200 & 400 and Fisher EZR.

The last common option is an internal relief valve (IRV) built into the regulator. These are customary options on the smaller regulator styles and are basically a pop relief built into the regulator. They open when the downstream pressure reaches a point above the set point of the regulator to relieve the downstream system. IRVs are great for certain applications but care must be taken when sizing to ensure the pressure and orifice combinations will provide proper relief capacity. Examples: Mooney FlowTap-R, Fisher 627R, and most service regulators.

Per CFR 192.201, relief valves must be sized and set to properly protect the downstream system from experiencing a pressure greater than the MAOP plus an allowable amount of buildup. This means the capacity of the relief valve at its set pressure must be greater than the failure flow of the largest regulator directly upstream. The inlet MAOP and wide open gas sizing coefficient (C_g) value should be used to calculate the failure flow of the regulator. If wide open C_g values are not available, manufacturer recommendations should be sought. Mooney, for example, recommends adding 5% to the regulator capacity value for determining the failure capacity. Be mindful of buildup pressures required to fully open the relief valve. These buildup values are often stated in the product literature. This means to protect a downstream system with a 60 psig

MAOP, the relief would have to be set no higher than 66 psig (system MAOP + 10% per CFR 192.201) minus the buildup pressure to fully open the relief valve. Care must also be taken to account for any buildup of pressure caused by the length of pipe between the working regulator and the relief valve. That pressure buildup would also have to be taken into account to determine the set pressure.

In general, for relief protected stations, pressure charts or telemetry are not required to alert the operator of an abnormal operating condition. Without telemetry however, your company is relying on a neighbor or passerby to call in the odor or noise complaint to the local gas company or authority.

In instances where it's not critical to maintain service to the downstream system, an overpressure shut off (OPSO) valve may be appropriate. These devices are typically installed upstream of the regulator and monitor the downstream pressure. If the working regulator fails and the downstream pressure rises to the set point of the shut off valve, the device is activated and the flow of gas stops. Sometimes these OPSO's, or slam-shuts, can be incorporated into the body of the working regulator. If the OPSO is installed downstream of the regulator, care must be taken to ensure the downstream pressure rating of the regulator is not less than the upstream MAOP. In this case, if the OPSO trips, full upstream pressure might be sensed on both sides of the regulator.

Regulator Sizing and Layout

It's now time to choose the layout of the regulators: multiple run (regulators piped in parallel with each other) versus single run. Multiple run stations are effective with relief valve OPP because the relief valve only has to be sized for the largest regulator failing, not all of them. They are also convenient where there is only one station feeding into a system or if gas flow can't be shut down. This allows maintenance to be performed on one run while the other continues to serve. There are different thoughts on how to size a dual run station, anywhere from 100% redundancy to 0%. It is usually a safe bet to fall somewhere in the middle; size the station such that one run can handle 60%-75% of the max capacity. This is a good balance that allows one run to be shut down during all but the most extreme flow conditions. It also keeps the costs down as compared to 100% redundancy. Normally the run would only be shut down for maintenance, which doesn't usually occur during cold weather, i.e. high flow demands.

For multiple run stations, the set points are often tiered so that one run is the primary or lead run and the other(s) are the lag runs. If the regulators were set to the same pressure, they might "fight each other" to see which one gets to flow gas, causing erratic pressures and high wear on the internal components. It's common for the lead and lag runs to be swapped every year during maintenance to ensure equal wear on the equipment.

Single run stations are typically less expensive but a bypass must be installed if the gas flow cannot be shut down. Manual bypassing (valve throttling) must be carefully monitored to ensure the downstream pressures stay within a prescribed range. A single run station with no bypass may be acceptable if the downstream system is back fed by another station or gas flow can be shut down while maintenance is performed.

A station bypass can be either regulated or unregulated. On most stations, an unregulated bypass is sufficient; however, on larger stations the extra expense of a regulated bypass may be justified. An unregulated bypass can be useful to gain a little more capacity from the station during periods of high demand and low inlet pressures. In such cases when the downstream pressure may droop due to the low inlet pressure, the bypass valves can be manually throttled while keeping a close watch on the downstream pressure. This may be enough to keep the downstream system strong through the typical high flow morning peak.

As another bypass option, a station may just have taps and valves in place so a temporary “soft bypass” can be installed when maintenance needs to be performed. This usually involves valves and regulators attached to the station via high pressure flexible hoses. This is a low cost alternative for smaller stations.

How many stages (regulators in series) of pressure cut are required? The primary driver for this is related to how high of an overall pressure cut the station is making. There are no rules for this but a good guideline is no more than 500 psi pressure cut per stage of regulation. Of course there are other considerations; how much real estate is available, the minimum vs. the maximum vs. the average inlet pressure. For a given flow and pressure condition, two stage pressure regulation is quieter than a single stage.

For regulator sizing, a prudent design assumes the worst case: minimum inlet pressure at the highest flow rate, for pipe and regulator sizing. If the gas sizing coefficient Cg and the liquid sizing coefficient Cv are available from the manufacturer, then the Universal Gas Sizing Equation can be used for calculating the regulator capacity:

$$Q_{SCFH} = \sqrt{\frac{520}{G \times T}} \times C_g \times P_1 \times sin\left\{min\left[\frac{\pi}{2}, \left(\frac{59.64}{C_1}\right) \times \sqrt{\frac{(P_1 - P_2)}{P_1}}\right]\right\} \ (in\ radians)$$

Q_{SCFH} = Gas Flow Rate (SCFH)
G = Gas Specific Gravity (air = 1.0)
T = Inlet Gas Temperature (Rankine)
C_g =Gas Sizing Coefficient
C_v = Liquid Sizing Coefficient
$C_1 = C_g/C_v$
P_1 = Regulator Inlet Pressure (psia)
P_2 = Regulator Outlet Pressure (psia)

Some manufacturers provide different equations for sizing their regulators and some manufacturers provide tabular data listing regulator capacities for different inlet and outlet conditions. Sometimes interpolation is required if the tabular data does not cover the specific variables you are designing for.

For relief valve sizing, the regulator wide open failure capacity should be calculated at the maximum inlet pressure

Regulator droop is the deviation from the outlet pressure set point as the flow rate increases. Droop occurs when the flow rate increases beyond the flow rate that was present when the regulator’s outlet pressure was originally set. Because of this pressure deviation, it is important to set the regulator’s outlet pressure at a flow rate that is as close as possible to the typical flow conditions of the station.

Pilot operated regulators are regulators that have a small regulator that controls the larger main regulator. The pilot regulator controls the main regulator by applying a loading pressure to the flexible element inside the main regulator. One advantage of a pilot operated regulator is that they are able to respond quickly and more accurately to changes in the downstream demand. This is achieved by gain. Gain is the amount of change in the loading pressure for a given change in the downstream (sensing) pressure. It is common for a pilot operated regulator to have a gain of 20, meaning if the downstream pressure changes by 1 psig, the loading pressure will change by 20 psig therefore causing the main regulator to respond faster.

When sizing regulators, keep in mind their pressure limitations and also those of the pilot. Maximum inlet, outlet, differential, and sensing pressures can all be potential limitations to a particular regulator/pilot combination. Also be aware of temperature and pressure limitations on the internal parts such as springs, boots, orifices, and diaphragms. If two different spring ranges are available to meet desired pressure, choose the one with the lower range for better accuracy. Similarly with orifices, select the smallest one necessary.

If the differential pressure across the regulator is high and relief OPP is desirable, the size of the relief can be reduced by installing a single first stage regulator, see Figure 5. As long as the entire station has the same MAOP, OPP for a first stage failure isn't required. If it fails, the second stage regulators see the full inlet pressure, telemetry or a token relief will notify the operator of the abnormal operating condition, and the second stage regulators will continue to operate as designed. This allows the failure capacity of the second stage regulators to be based on P2 instead of P1, greatly reducing the size of the required relief valve. The first stage can either have a bypass valve or a second regulator in parallel to aid in maintenance.

Many states go above and beyond the federal codes. Washington, for instance, has added a "50 foot separation between stages of pressure regulation whenever practical" to help protect the station from physical harm (WAC

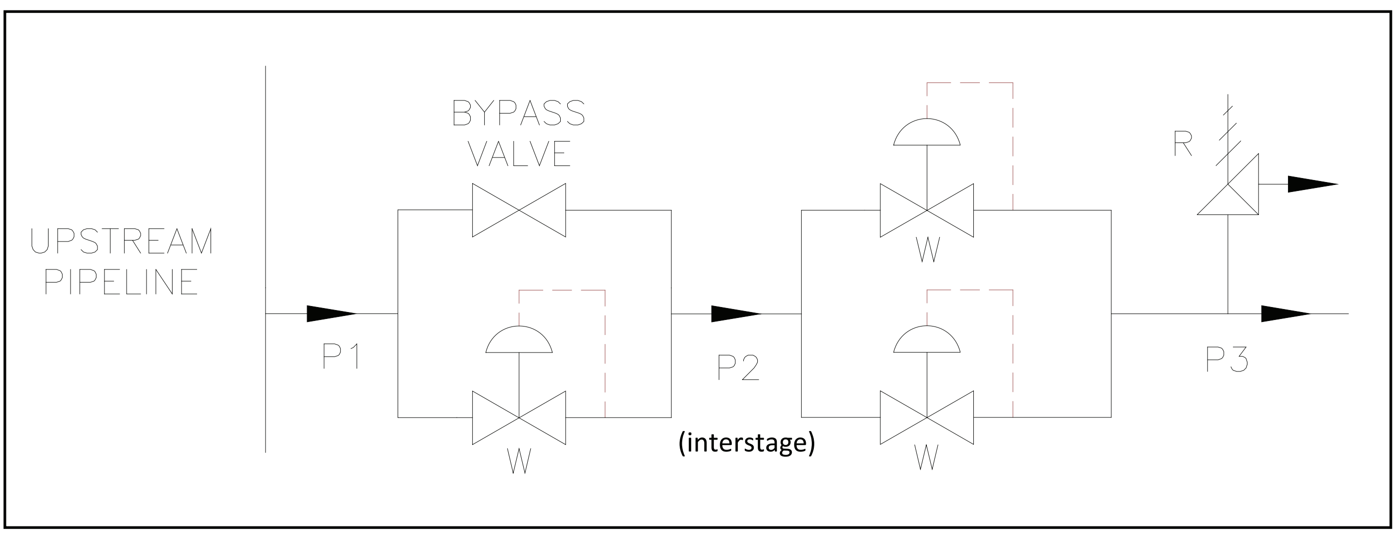

Fig. 5 – Two stage regulation option

480-93-130). This rule has obvious impacts to the size of the station and may force a change in the overall design. Be aware, states may have additional design considerations beyond the federal rules that must be adhered to.

The location for regulator control (sense) lines also requires thought. There are two common locations used. One is to install them 8-10 clean pipe diameters downstream of the regulator, on the regulator runs, before the outlet header valve. This is the simple option and least expensive. The second location puts the taps underground, 8-10 clean pipe diameters downstream of the last fitting, see Figure 6. Typically the last fitting is the elbow at the bottom of the outlet riser and transitions the pipe from vertical to horizontal. The advantage to this method is it adjusts for any pressure losses in the outlet header to the point where the sense lines are attached. It's also more complicated because the control lines have to split and be plumbed into the header between the regulator and the outlet header valve so that regulator lockup can be checked. Refer to the manufacturer's literature to determine the size of the control lines. Typically, the lines should match the tap size on the regulator, and should be upsized one size for each additional 20 feet of length. If a valve is used in the control lines, it should be full port. Under sizing the lines or using a reduced port valve could cause a delay in response time, leading to an increased chance of instability.

Station Plan

After the regulation layout is decided, the rest of the station needs to be arranged. First you must decide what other equipment will be needed. Is the gas already odorized, or will an odorizer need to be installed? Are the gas flows and pressure cuts great enough to require heating? Will pilot heaters suffice or will a line heater be required? What level of particulate removal is required? Will strainers be sufficient or is a filter required? Most often we're dealing with "pipeline quality gas" so a liquids separator won't be required unless there is a unique situation. What type of station inlet and outlet valves should be used and where should they be located? Do the maintenance personnel have adequate room to work on the station? Are the future flow requirements and pressure conditions taken into account to make expansion easy?

Odorization requirements of gas are outlined in CFR 192.625. There are two basic types of odorizers, bypass and injection. Bypass odorizers are completely mechanical devices that force a portion of the gas stream through a wick saturated with odorant. This diverted gas stream picks up odorant and is then blended back in with the main gas stream. These are very simple devices and are ideal for very low to medium gas flows. Injection style odorizers are more complex but allow for greater flow rangeablity, higher gas flows, and greater

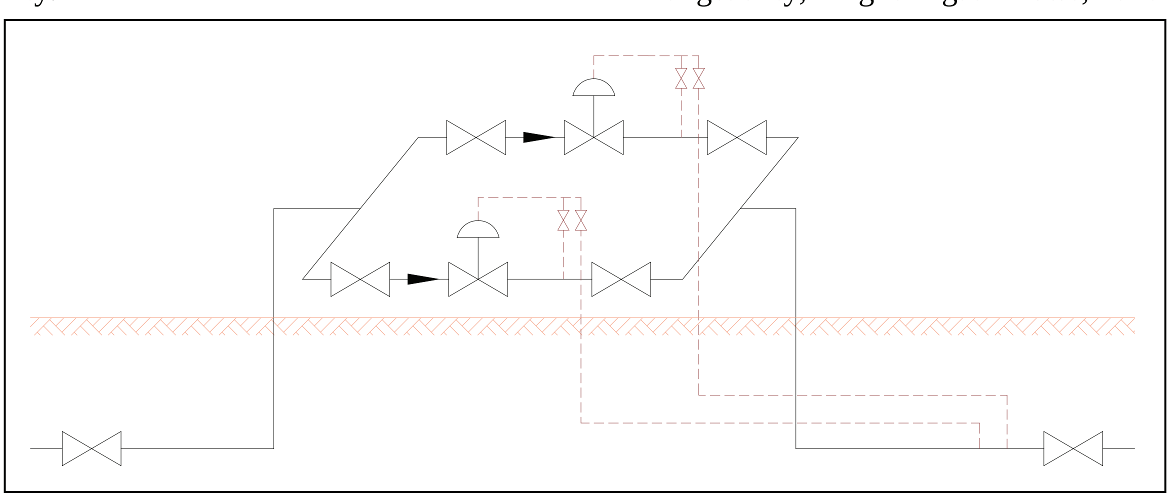

Fig. 6 – Long control lines

odorant storage capacity. These odorizers have electronics that cycle the odorizer pump once every time a preprogrammed amount of gas flows through the station. An odorizer should be installed on the upstream side of the station so that leaks can be easily detected throughout the facility.

The Joule-Thompson effect describes the temperature change of a gas when it is expanded through a flow restriction device. Gas temperature estimates can be made using the following rule of thumb: expect a 7° F temperature reduction for every 100 psi pressure reduction. Cold gas can be an issue if moisture is present in the gas stream. This moisture can freeze causing regulator controls to malfunction. External icing happens when moisture in the air freezes onto the cold pipe. External icing is usually more of an operational hazard. The gas still moves through the pipe, but there may not be access to the pilot controls or the downstream header valve if they are encased in ice. The gas flow rate will also influence the impact of the gas temperature on the station piping. Gas at lower flow rates may be warmed by ambient air temperatures acting on the piping, however the cooling effects at higher flow rates overcome the ambient warming and may cause frost and ice issues. Minor icing can be remedied by the use of catalytic type pilot heaters. If the heating requirement is greater, then an inline heater will be required. Regulator vent lines should be pointed down to avoid the accumulation of water and should be long enough to extend past a potential ice ball if freezing occurs. A complete station design will incorporate a bypass around an inline heater to make removal for service possible without a station shutdown.

Companies often have guidelines or standards around filtration. The nature of the upstream system and gas source will drive the level of filtering required. Generally a filter will provide a higher level of filtration as compared to a strainer. The primary intent is to protect the regulators and meters from internal damage caused by debris in the gas stream. This debris can clog small orifices in pilot regulators, damage sensitive meter parts, erode internal parts, and impinge themselves on soft parts making lockup difficult or impossible on regulators. Like the inline heater, consideration should be made regarding the ability to bypass a filter or strainer for maintenance purposes. Some stations may include one large filter or strainer ahead of all the regulation and heating, others may have individual units directly ahead each regulator run.

Station valve locations must be considered. CFR 192.181 requires one valve on the inlet of the regulator station at a safe distance. A valve on the outlet of the station is a wise idea as well to allow the station to be isolated from the downstream system. If space is available, it’s good to keep valves above ground. If this is not possible, then place them in an area where access will not be hindered by parked vehicles, vegetation, snow piles, etc. Avista spaces the inlet and outlet valves a minimum of 20’ from the station, but prefer to locate them at 50’ if possible.

Overall station layout for meter sets, farm taps, and district stations is rather straight forward. On larger stations, like city gate stations, there are more variables to consider when designing the layout. Adequate working room must be considered so that maintenance can be performed. Considerations should be made to make it easy to get vehicles close to equipment, allowing the technicians to drive the vehicles inside the fenced area. This keeps their tools and equipment close at hand. Line heaters should be internally inspected periodically per company standards. This typically means physically removing the heater from the piping and pulling out the gas tube bundles. The location of the heater and associated piping need to be designed with this in mind. Filling the odorizer sometimes requires a large vehicle and it is best to be able to park as close to the odorizer tank as possible.

It is important to layout the station so that the valves, meter, regulator, strainer, and other devices are within an average persons reach and are separated enough to allow for operation, disassembly, and reassembly. It's always a good idea to review the station plan with the technicians that will be building and maintaining it. If there are two options of doing something, the "engineer way" and the "operations way", and both end up with an acceptable result, choose the operations way. That relationship building with the field technicians is invaluable for an engineer's future. You may think you have a good design for a station, but if it can't be easily built or maintained, it's an inadequate design. See CFR 192.739 for station maintenance requirements.

Another goal of the station layout should be to make it simple enough such that one can make sense of the station piping without a drawing. The path and direction of gas flow, location of key valves, and location of bypass should all be readily discernable to someone unfamiliar with the station. In general, station piping should be above ground except where it makes sense to allow pedestrian and vehicle access to different parts of the yard.

Future growth plans for the station should also be considered. This might include expansion of the station capacity or additional pressure regulation requirements. Often the station piping would be sized for a 20 year forecast flow, but the regulators and meters might be sized for a 5 year forecast with the ability to upsize them easily when the need arises. One way to design for a future capacity increase is to install the regulators within a flanged end pipe section so that the original regulator(s) can be easily unbolted and replaced with a larger regulator(s). If this technique is used and a relief valve is used for over pressure protection, be sure to design the relief valve to handle the larger regulator capacity.

Metering Considerations

When designing an industrial meter set, many of the considerations mentioned above can be useful. The two most common industrial meter types are rotary and turbine. However, there are many other types that could be used based upon flow rates, metering pressure, turn-down ratios, and cost. The AGA document called "Meter Selection Guidelines for Natural Gas Measurement" is a great reference to compare the pros and cons of the various meters on the market today.

An accurate and detailed gas equipment load inventory is critical to sizing the meter set. It's important to understand each piece of equipment and how it will be used. This will help determine how much, if any, diversification (the percent of the time each piece of equipment will run at its full capacity) there will be on the total gas load. Not using diversification or not fully understanding how each piece of equipment is planned to be used could easily lead to over sizing the meter set. For example, is one of the boilers only used as a backup?

Determining the customer's pressure requirements is the next critical step. What pressures does your company normally offer? What is the customer's request? What is the maximum and minimum pressure the customer's piping and equipment can handle? Can the customer accept a shut down of gas? Is it safe to have blowing gas (relief valve) in the area of the meter set? Answers to these questions will help you determine the type of regulation and overpressure protection to choose.

Most industrial sized meters are not designed for fixed factor measurement. If fixed factor is selected, care must be taken to choose a regulator capable of holding a pressure typically to +/- 1% absolute pressure. For example, with a 5 psig delivery, the pressure must remain at:

14.7+5 = 19.7 psia (convert to absolute)
19.7 * 0.01 = 0.20 psia (1% of 19.7, rounded)
4.8 to 5.2 psig (+/- range of regulator)

If not using fixed factor, then pressure correction must be taken into account in the meter flow calculations.

Temperature compensation (TC) must also be considered. Some meters have TC built into them while others require external correction via a flow computer or electronic corrector.

The design must also account for maintenance requirements. Can the customer be shut down for maintenance or is a bypass required? Is the bypass permanently installed or just valves available to hook up hoses and a portable regulator? What are your company standards regarding meter proving? Do ports upstream and downstream of the meter need to be installed for a field prover? If the rotary meter is proven with a differential pressure test, do you need a port downstream to create additional flow?

There are also many AGA reports available for design guidelines and recommendations regarding straight pipe distances upstream and downstream of various types of meters. Meter manufacturers also publish design criteria. Avista installs rotary meters with flow in the vertical downward direction. This increases the chances of debris falling through the meter rather than being caught in the bottom and stopping the meter if it were installed with horizontal flow.

Telemetry considerations are important with meters. Depending on your company's tariffs, some classes of customers (transportation) may be required to have telemetry installed. It's important to know this ahead of time so power and communication plans can be thought through as well. More customers are requesting pulse outputs of the meter to feed into their energy management systems. This is something your company should have a standard on so that the proper barriers and electrical equipment are used if in a hazardous area.

Site Considerations

When selecting a site for a station, many factors should be taken into account, such as the shape and size of station. Is it in or adjacent to a public right of way? Stations located in public right of way can be susceptible for having to be relocated in the event of a road project. Securing an easement for the station is a wise idea to protect your company from costs associated with relocating the station. Is there room to park a vehicle adjacent to the station for maintenance? Does physical protection need to be installed to keep the station safe from people or vehicles? This may include jersey barriers, concrete filled bollards, a fence, or nothing at all. Some companies have fencing standards that may specify barbed wire around the top, slats in chain link, push bars on man-gates, size of posts and gates, etc. If space is limited, the piping design may have to get creative to fit within the constraints. Are there power lines overhead? If so, a monitor set up might be chosen rather than a relief valve for the overpressure protection to minimize the chance of gas ignition.

Will the station be in a vault (CFR 192.183 – 192.189)? Vault installations are no longer used at Avista. Stations designed into vaults are typically riddled with issues: corrosion from groundwater, limited working room inside the vault, potential “confined space” restrictions, and venting requirements to name a few.

Other Factors to Consider

When specifying the station fittings and piping, use the formulas listed in CFR 192.101-109. Company policy should dictate how the design factor will be used (i.e. whether or not to keep the hoop stress below 20% SMYS for the “transmission definition”). Testing requirements of the station must follow CFR 192.503 with documentation of the test per CFR 192.517.

When preparing the test procedure, try to minimize the number of individual tests required to test the entire station. This makes record keeping and documentation simpler. Consider designing everything up to the outlet valve to be able to handle the full inlet MAOP. This allows the outlet valve to be closed in the event of an emergency with no fear of damage to any components between it and the station. If this is not possible, then at least design up to, and including, the outlet header valves for the full inlet MAOP.

Tie-in fittings on both the upstream and downstream side need to be decided upon. Is the piping tying into an existing system where a hot tap will be required, or is it a new system that will have the tee already installed? Will the tap fitting require a reinforcement of the main?

What type of station valves will be used? Avista typically uses gate valves and floating ball valves for the inlet and outlet valves because they are nearly full port and don’t require grease. Header valves, the ones on either side of the regulator, are typically floating ball valves for the same reason. Trunion mounted ball valves are used on ANSI 600 designs because of the more robust design and double seat options. Plug valves are better equipped for throttling but require regular maintenance (greasing) to operate properly and have greater pressure drops across them. Over greasing a plug valve directly upstream of a regulator can cause grease to infiltrate the regulator. Each company is unique in regards to valve type selection.

If the downstream distribution system is fed by more than one regulator station, then CFR 192.741 states that either telemetry or pressure recording gauges must be installed to monitor the gas pressure in the downstream system. When installing telemetry or pressure charts, consider monitoring the upstream pressure as well. This pressure information may be useful for troubleshooting if regulator droop or chatter becomes an issue. The Planning Department will also appreciate receiving data from the inlet side of the station to help validate capacity studies.

In general, welded connections are better than screwed or flanged, especially below grade. Mechanical connections are always a potential leak point, so minimizing them is often encouraged. Remember to include unions as appropriate when screwed connections are used to aide in fabrication and maintenance. Flanged connections do have their place though. They work great when attaching components that will need to be disconnected in the future for maintenance or replacement, such as line heaters. They also work great if a component or system needs to be electrically isolated by installing an insulated gasket, bolt sleeves, and washers. Flanges also make great lines of demarcation to delineate pipe ownership. Additionally they make testing easy with the use of blind flanges, it's then very clear where the extents of the pressure test are, as opposed to using weld caps that get cut off later leaving a tie-in weld to deal with. Another consideration is the skill sets of the personnel performing the maintenance. Are they certified welders? If not, the inclination might be to have flanged regulators and valves instead of weld ends.

Cathodic protection (CP) isolation needs to be considered so that the CP system is not inadvertently grounded or connected to another CP system. Electrical insulation/isolation should to be installed at the following points to prevent possible grounding: odorizer tubing, telemetry points, inline heater connections (if the heater is physically mounted to a concrete foundation), and pipe supports. Often there may be a CP isolation point such as a monolithic insulating joint (Zunt), insulated union, or insulated flange connection installed for troubleshooting the CP system. Under normal operating conditions the insulated joint can be shorted across by the use of wires, and then if necessary, disconnected to help isolate the systems and investigate shorts.

Another design consideration is a building. There are multiple benefits in having a structure built around the station. Weather protection can be a driver, especially in areas prone to heavy snow falls. Vandalism and noise abatement is another plus. Finally, if the station is located in an area where looks are important, it may need to be hidden behind four walls. The building materials should be non-combustible and care must be taken when installing electrical components within classified areas. Determine where the Class 1 Division 1 and Division 2 zones are and adhere to the electrical rules regarding seal-offs and explosion proof fixtures. Will the building be insulated or not? Heated or ventilated?

How are the set pressures of the regulators determined? Sometimes company policy will help make this determination, but here's some guidance. First determine what is meant by set pressure, is it the lockup pressure with no flow or is it a flowing pressure. Note that these two pressures could vary by 3-8 psig, depending on the situation. Lockup pressure is always higher, so if the station is running very close to the downstream MAOP and the station has the chance of "locking up" (no downstream demand), then it's important to ensure the lockup pressure is below the downstream MAOP. If the station is feeding a large enough system where gas demand is always present, then a flowing pressure can be used. This scenario should be used with caution if the pressure is set near the downstream MAOP because if flows are reduced, the downstream pressure will obviously increase, potentially nearing the MAOP. Keep in mind the reseat pressure for relief valves are always lower than the set pressure. So if a relief valve is the OPP device, the set pressure for the regulator must be below the reseat pressure of the relief valve.

CFR 192.161 describes pipe support requirements. Supports should be designed with vertical adjustments that allow for inspection of atmospheric corrosion between it and the pipe. A non-metallic material should be used in between the support and the pipe to provide electrical isolation.

Station drawings are a good place to document the following: inlet and outlet system MAOP, station MAOP, regulator and relief capacities, regulator failure flow (for relief calculations), pipe velocities, minimum inlet pressure, max regulator and relief pressure settings, and pressure test requirements.

Telemetry requirements also need to be included with the station design. Such items to consider include: the location of thermowells to monitor gas temperature, taps to install pressure transducers, power to drive the flow computer and communication devices, conduits to run wires in, and hazardous area identifications for electrical classifications.

If station noise is a concern, there are several ways to help mitigate it. Some manufacturers offer noise reducing trim for certain regulators. Using heavier wall thickness pipe downstream of regulators can also help absorb the sound waves and reduce decibel levels. Blocking the noise path is also very effective and can be done by installing a building over the regulators, by building a wall in front of the regulators, or by installing vinyl or wood slats in the station fence. Noise in the piping can be reduced by keeping gas velocities within 70-125 ft/sec.

Some companies design stations to be modular or skid mounted. This is a great idea if the station is not intended to be permanent or if an upsizing of the station is imminent. Skid mounted designs typically have flanged connections between the assemblies making for easier disassembly.

Conclusion

CFR 192 and company standards provide a lot of guidance for station design. Other drivers include personal preferences from field technicians based on operations experience and guidance from senior level design engineers. The guidelines and parameters discussed here will help future station designs to be functional, safe, easy to construct and maintain, and easily expanded for future growth.