Instromet®

# REGULATOR STATION HANDBOOK

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# INTRODUCTION

This manual is one of a series that Instromet has prepared for the gas industry. It describes the installations that are used to reduce the gas pressure to the operating pressure of the downstream system or appliances.

Regulator stations are required to supply a certain quantity of a gas at this specific operating pressure. They should meet this requirement for inlet pressures that may vary between a maximum and a minimum value. The minimum inlet pressure determines together with the required capacity the size of the fittings. These are therefore important parameters in the design of a regulator station. An overview of past and present distribution and transmission systems gives some background on the minimum inlet pressure that can normally be expected.

A general description of the specifications of a regulator station is given, followed by a short introduction to the physical process of pressure reduction and the cooling effect that it entails.

The next chapter is devoted to the main operational aspects, and this is followed by a description of the layout of the individual components and of their function.

Gas regulator stations are often also used for metering. This handbook concentrates on the regulator aspects. For the metering system the “Systems Handbook” should be consulted. The requirements for the installation of the meter vary with the construction of the particular type of meter. The handbook relating to the meter type selected for the station, provides information on this subject.

## DISTRIBUTION AND TRANSMISSION SYSTEMS

### History

In the early days of gas, its distribution was carried out at very low pressures, traditionally about 2 kPa or 20 cm water column (8" WC) and often even less. As the gas was locally manufactured at low pressure, this was the most economic solution. Additionally, the technology at that time did not permit the economic manufacture of pipes and fittings capable of withstanding higher pressures.

At the beginning of the twentieth century however, the use of natural gas was becoming very popular in the US, while in Europe manufactured gas from blast-furnaces became available in large quantities. In both instances the market was developing more and more remote from the place of production, necessitating the transmission of gas over some distance. As the distance that gas can be transported over, is directly related to the pressure at the source or production point, there was an increasing demand for higher pressures. This was met by the technological development of high pressure pipes, fittings and compressors.

### Present

At present, gas transmission over more than 100 km is normally at pressures of 50 to 100 bar and for distances over 20 km at pressures between 20 and 50 bar. Where the gas is being distributed through a gas grid to a number of customers in an area, the pressures would normally be less than 10 bar. In newly developed areas the minimum distribution pressure is often about 2 bar. Specifically in older systems, the minimum pressure can be as low as 10 mbar.

The capacity of a transmission or distribution system increases with the operating pressure. The operating pressure is limited to the maximum safe operating pressure of the weakest component in the system.

From the source to the user the pressure is reduced in stages, the maximum pressure in each stage being determined by the weakest component in the system subjected to the pressure of that particular stage. Regulator stations form the connection between the subsequent stages of the system.

An example of a practical system is given in figure 1.

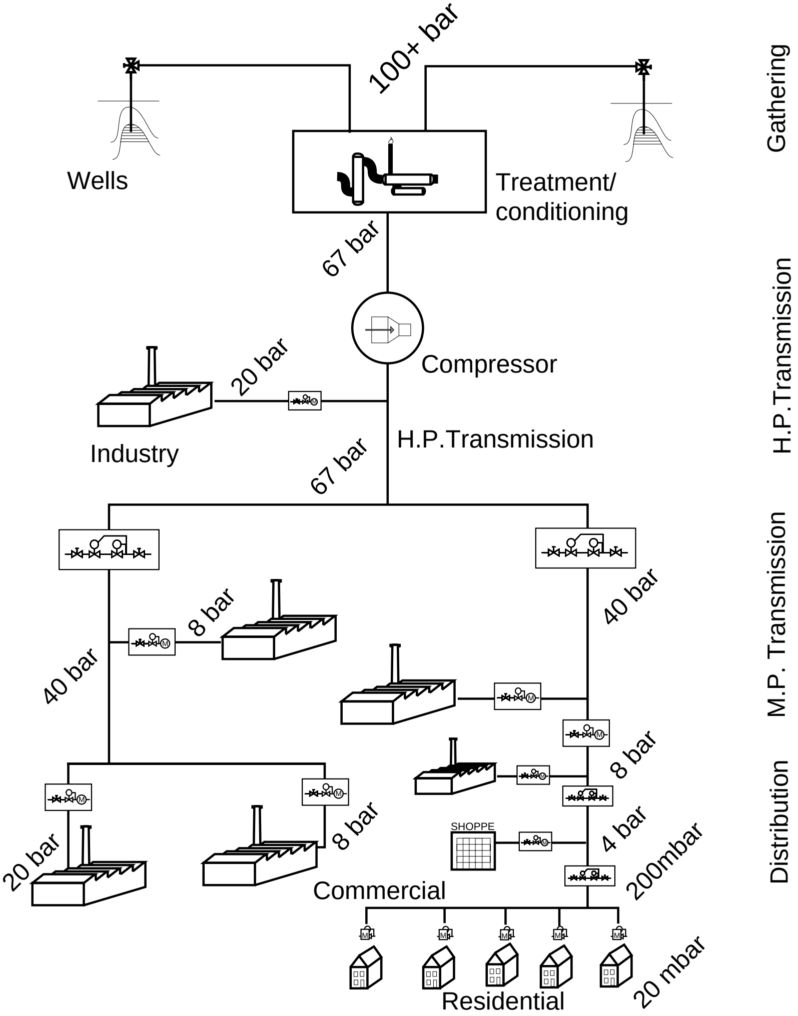

**Figure 1**
**Example of modern transmission and distribution system**

## Maximum allowable pressure loss

The design of transmission lines or distribution systems is outside the scope of this handbook. However, there is a simple rule for the maximum pressure drop that is normally acceptable in any pipeline system. As this governs the range of inlet pressures that a station is subjected to, it will be mentioned here.

In first approximation the following equation (1) is for a pipeline with inlet pressure $P_1$ and outlet pressure $P_2$ and mass flow rate $q_m$:

$$\frac{P_2^2}{P_1^2} + \frac{q_m^2}{q_{mmax}^2} = 1 \qquad (1)$$

In this equation the pressures are absolute pressures and $q_{mmax}$ is the absolute theoretical maximum mass flow rate. This equation, when it is plotted, is a quarter circle as shown in figure 2.

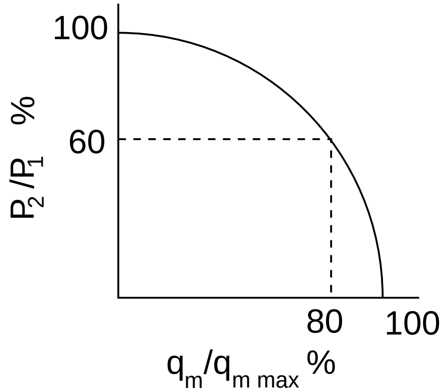

**Figure 2**
**Relation between pressure ratio and carrying capacity**

It is easy to see that if the flow is at 80 % of its theoretical maximum, the pressure at the end of the pipe has already reduced to 60 % of the inlet pressure. Any further increase in the flow rate has a large influence on the outlet pressure, and most operators would be very reluctant to operate beyond this limit.
The minimum inlet pressure of a regulator station would therefore rarely be less than 60 % of the operating pressure of its supply system.

# REGULATOR STATIONS

## Functions

The regulator station essentially performs a safety function: the limitation of the pressure in the downstream system to a safe value. In most instances this function is backed up by additional safety devices or even a second, redundant regulator. Regulator stations are therefore extremely reliable.

The regulators and other safety devices are normally powered by the gas itself so that these functions do not have to rely on the presence of external power.

In some stations the gas is also metered and this function usually influences the design.

## Essential design parameters

The following parameters are essential for the design of a regulator station:

- Maximum inlet pressure
- Minimum inlet pressure
- Maximum outlet pressure
- Minimum outlet pressure
- Maximum flow rate
- Maximum gas velocity

If the station also serves as a metering station, the following parameters should also be known:

- Range of flow rates to be measured
- Desired accuracy

Metering systems will only briefly be touched on in this handbook. For more details on metering, the “Systems Handbook” should be consulted.

In an existing transmission system the maximum inlet pressure is a given parameter. This determines the rating of the regulator body and the upstream pipework.

The maximum outlet pressure is given by the safety of the appliances or subsequent distribution system to be supplied. The rating and size of the fittings and therefore the cost of a station is determined by the maximum inlet pressure, the minimum inlet pressure and the maximum flow rate.

For the most economic design these two last values should be known accurately. However, in practice the uncertainty of these values is high and may change in time. Stations will therefore in general be sized somewhat larger than required to avoid having to change them too soon.

### Safety and environmental codes and regulations

With modern materials and proven operating principles present regulators and fittings are extremely safe and reliable. However, safety codes and regulations often demand additional safety devices. These codes have long traditions and vary considerably between countries. Before a station can be designed, all the relevant codes and standards valid for the particular site have to be known.

The quality control and assurance for pressure vessels and piping also vary considerably among countries.

Environmental concerns are mainly for the noise issuing from the station. The venting of gas to the atmosphere may also be restricted.

## PHYSICS AND THERMODYNAMICS

Pressure, temperature and volume of a gas are related by the equation of state. This is also known as the laws of Boyle-Gay Lussac or Boyle-Charles.

Usually this is formulated for one mole of gas as:

$$P \bullet V_m = Z \bullet R \bullet T \qquad (2)$$

In this equation P is the absolute pressure, $V_m$ the molar volume, Z the compressibility of the gas, R the universal gas constant and T the absolute temperature. The compressibility is dependent on the gas composition. Its value is equal to 1 at low pressures and normally drops to a lower value for higher pressures. For some natural gases it may drop as low as 0.6 or lower at pressures in the order of 100 bar (See "Systems Handbook" for more details on Z).

The capacity of a station is normally expressed in standard or base cubic metres per hour. This is the volumetric flow rate that would occur if the pressure would be reduced to standard or base pressure and temperature (usually 1013 mbar and 15° or 0° C). The actual or line flow rate $Q_l$ for a station capacity of Q $m^3/h$ is equal to:

$$Q_l = Q \bullet \frac{P_b \bullet Z \bullet T}{(P \bullet Z_b \bullet T_b)} \qquad (3)$$

with $P_b$ and $T_b$ the base pressure and temperature, P the outlet pressure of the station and T and Z the absolute temperature and compressibility of the gas leaving the station.

For pressures up to about 15 bar this can be approximated by:

$$Q_l = \frac{Q}{P} \qquad (4)$$

where P is the outlet pressure in bar.

Thermodynamically, pressure reduction is an isenthalpic process. The enthalpy H of the gas before and after throttling is the same. There are many equations and tables giving the enthalpy for different gases in a wide field of pressures and temperatures [1,2].

As a rule of thumb one can assume that for natural gas the temperature drops by 0.5° C for every bar of pressure reduction.

For large pressure drops the temperature can therefore drop to well below freezing point when the gas has not been preheated before reduction.

If the gas is not sufficiently dry, water and / or liquid hydrocarbons (condensate) may form at low temperatures. Specifically the presence of liquids is a risk, as it may lead to the formation of hydrates.

Hydrates are ice-like substances consisting of water and methane which may cause blockage of the installation. It has to be borne in mind that wet gas may result from inadequate treatment but also from hydrostatic testing of newly commissioned pipes.

For sufficiently low outlet temperatures, condensation will also occur on the exterior of the installation, and for very large pressure reduction, parts of the installation will even be covered with ice. To prevent this, the gas can be heated before pressure reduction.

However, a considerable amount of energy may be needed. The energy needed for the heating of the gas can be roughly approximated by:

$$W = 0.5 \bullet V_n \bullet \Delta T \qquad (5)$$

In this equation W is the required energy in kcal, $V_n$ the gas quantity in base or standard $m^3$ and $\Delta T$ the temperature difference. Similarly the capacity of the heater can be estimated by:

$$H_c = 0.5 \bullet Q_n \bullet \Delta T_{max} \qquad (6)$$

where $H_c$ is the required heating capacity in kcal/h, $Q_n$ is the maximum flow rate in base or standard $m^3/h$ and $\Delta T_{max}$ the maximum required temperature rise.

Apart from the heating costs, the investment in heaters and heat exchangers and their maintenance contribute to the cost of ownership. The advantages, however, are:

- Always access for maintenance (no ice)
- More tolerant for gas with higher water and / or hydrocarbon dew point

It is perfectly possible to operate stations with sub-zero outlet temperatures and save the energy otherwise required for heating.

This has a number of drawbacks as listed below:

- Difficult access for maintenance
- Gas has to have low water dew point and low hydrocarbon dew point
- Increased risk of corrosion
- Risk of blockage of vents and breathing holes by ice
- Moving parts in instruments may be locked (manometers, meter registers)
- Freezing of the ground surrounding the outgoing pipework

Advantages are:

- Savings in energy cost
- Simpler design and therefore potentially more reliable
- No investment in heaters and heat exchangers
- No maintenance of heaters, heat exchangers and ancillary equipment

By designing a special meter specifically for temperatures below 0° C that operates reliably and can be read even when thickly covered with ice, Instromet has eliminated one of the most critical barriers to achieving these savings.

The following example illustrates the above:

Inlet pressure : max. 40 bar (gauge) min. 30 bar (gauge)
Outlet pressure : 10 bar (gauge)
Capacity : 10,000 $m^3/h$

For the particular gas it is found from [3] that the values for Z are:

| | | | | | |
|---|---|---|---|---|---|
| P (bar abs.) | 41 | 31 | 11 | 11 | 1.013 |
| T (°C) | 10 | 10 | 10 | -5 | 15 |
| Z | 0.9194 | 0.9384 | 0.9778 | 0.9731 | 0.9981 |

Assume that the gas is heated so that after reduction the temperature is 10° C.

$$Q_l = Q \bullet \frac{P_b \bullet Z \bullet T}{(P \bullet Z_b \bullet T_b)} = 10{,}000 \bullet \frac{1.013 \bullet 0.9778 \bullet 283}{11.013 \bullet 0.9981 \bullet 288}$$

$$= 885 \text{ m}^3/\text{h} \qquad (7)$$

The approximate formula gives $\frac{10{,}000}{11} = 909 \text{ m}^3/\text{h}$. (8)

The heating capacity required is equal to:

$$H_c = 0.5 \bullet Q_n \bullet \Delta T_{max} = 0.5 \bullet 10{,}000 \bullet 15 = 75{,}000 \text{ kcal/h.} \qquad (9)$$

If no heating is applied, the temperature drop at an inlet pressure of 40 bar will be (40 - 10) • 0.5 = 15° C. The line flow rate is then equal to 856 $\text{m}^3$/h when calculated with the full formula.

## OPERATIONAL ASPECTS

### Gas quality

Most gases that are distributed are non-corrosive. Quantities of dust or sand left from the construction phase may however be present. Though most gases are treated to have a very low hydrocarbon dew point, it does happen that liquid hydrocarbons find their way into the system. Means for draining filters should therefore be provided. Gases should have a low water dew point to prevent hydrate formation. Water also increases the risk of corrosion.

### Availability and maintenance

Following safety, continuity of supply is in most instances of utmost importance. Apart from being reliable, a station should therefore be designed for maintenance without the need to interrupt the gas supply to the customer. A practical solution is to build the station using identical units of which one can be made stand-by for maintenance.

In some instances additional piping is installed to make it possible to temporarily connect meters in series for checking purposes.

## Electrical safety and hazardous areas.

In a well designed and constructed gas regulator station there should be no leakage. If any relief valves are present, their outlet shall be well above the installation or building. The only times when the occurrence of an explosive mixture can be expected is therefore during maintenance, and then only for short periods when a part of the installation is depressurised and taken apart. This would indicate that if a station is zoned at all, it should be rated as a very low hazard (zone 2 for the European CEN 50014 standard). Still, in practice stations are often zoned more hazardous (e.g. CEN 50014 zone 1).

The zoning of the station will have to be known before a proper design can be made.

## Construction

Most installations are presently designed to be skid-mounted. The complete system is assembled in the factory and tested. Construction work in the field is limited as much as possible.

## Noise

Most of the noise in a regulator station is generated by the gas travelling at high velocity through the regulator ports. The sound is transferred to the piping which in turn radiates it into the environment. The noise in a station therefore not only emanates from the regulator but also from the piping, in particular downstream.

There are several ways to reduce the noise.

Some regulators have special cages to break down the velocity more gradually. Some have different valve constructions with the same objective. All “silent” regulators are bigger and more expensive.

Heavier pipe walls and larger diameters generally help to reduce the noise as does external insulation, specifically of the downstream pipework.

Burying the installation is a very effective way of insulating it from the environment. If the regulator is housed in a building, sound-insulating the building can be very effective. Particular attention has to be paid to the ventilation apertures.

Pipe silencers can be effective. However, in many cases the intense vibration that the sound absorbing material is subjected to, destroys it mechanically and the loose materials may damage the downstream meter.

## LAYOUT AND COMPONENTS

### Station layout

In figure 3 a general layout of a station and its components is given. There are an infinite number of possible variations of which the most common are given below.

A valve is usually installed in the supply pipeline to the station making it possible to install the station without depressurising the supply network. If the station is used to supply a distribution network, a similar valve will be installed in the outlet line. The inlet and outlet of the station proper are connected to these valves by headers and risers.

The station configuration may vary depending on the circumstances, the application, and the codes and regulations that apply. In all cases there will be an inlet valve and a regulator, and in most cases also a relief valve and a safety shut-off valve. The regulator valve is equipped with a soft seat to give a complete shut-off when there is no gas being used. As even a slight weeping of the regulator could increase the pressure to dangerous levels, a relief valve has to be present. This relief valve can be small as it only has to blow off the possible leakage through the regulator. Some regulators can be equipped with a small built-in relief valve for that purpose. The relief valve can only be dispensed with when it is absolutely certain that a no-consumption situation will never occur.

If the gas supply has to be maintained at all times, a second installation is mounted in parallel. In that case both installations have to be equipped with outlet valves as well.

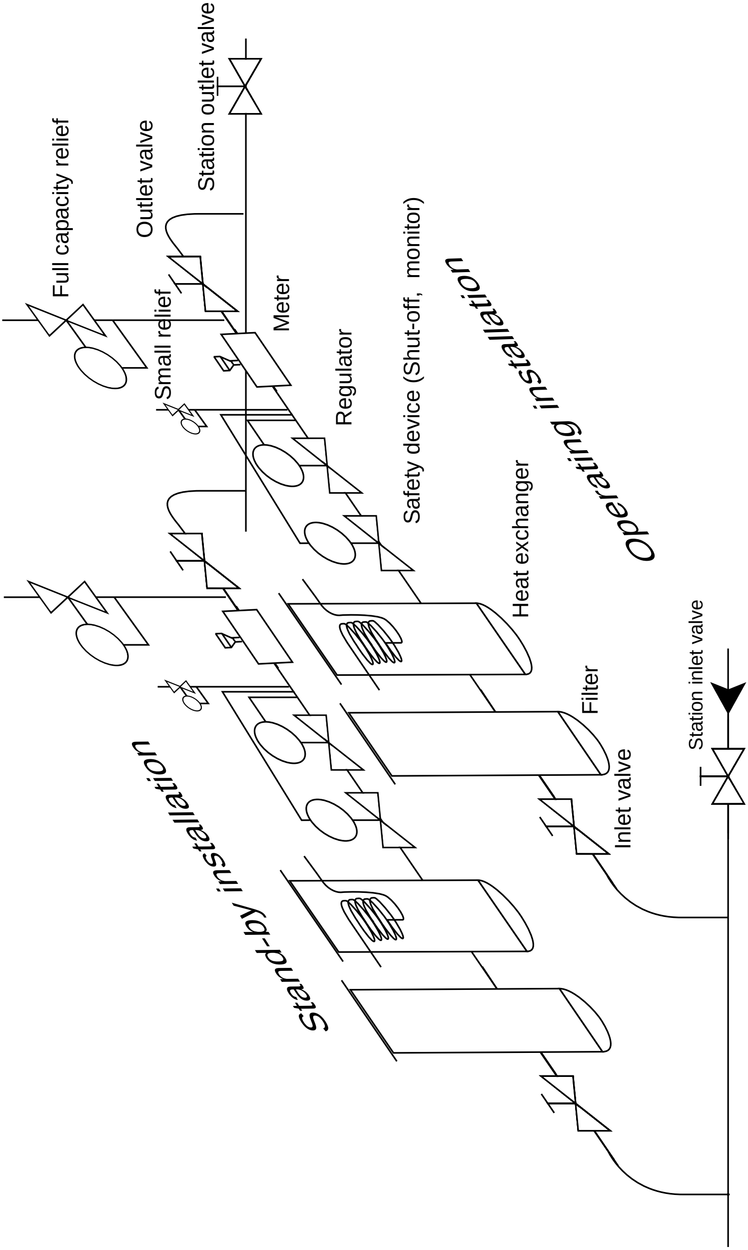

**Figure 3**
**Typical station layout**

Depending on the condition of the supplying network and on the reliability required, a filter may be installed. The filtering can be very simple, only needed to prevent debris damaging the regulator. However, especially if the station is used for metering, sophisticated dust filters that eliminate particles as small as 3-5 microns are used.

For larger stations a separate safety device will usually be installed. In some countries another, independent safety device is also required for stations from a certain size upward as back-up for the first. This second safety device may even have to operate on a different principle. The safety device will have to be able to prevent the outlet pressure from exceeding safe values in the case of complete failure of the regulator to the open position. It can be:

- a monitor regulator, taking over the function of the primary, normally active regulator,
- a slam shut valve, blocking the complete gas flow,
- a full capacity relief valve designed to release all gas passing through the failed regulator at maximum inlet pressure,
- an actuator operating on the inlet valve.

As has been described earlier, it may be desirable to heat the gas before reduction to prevent condensation of either hydrocarbon condensates or water from the gas or water vapour on the outside of the station. In that case a heat exchanger and boiler have to be installed.

The meter and its additional pressure and temperature sensors are usually installed downstream of the regulator. Guidelines for the installation of the meter are given in the handbooks for the respective meter types (Turbine Gasmeter Handbook, Rotary Piston Gasmeter Handbook and Ultrasonic Gasmeter Handbook). For further details on the instrumentation and the metering system, please see the “Systems Handbook”.

## Pipe sizing

The size of the piping in a regulator station is usually chosen to limit the gas velocities to around 20 m/s. The inlet piping is sized on maximum flow rate at minimum inlet pressure. For very low outlet pressures (< 25 mbarg), the gas velocities are limited to 10 m/s in order to avoid too high a pressure loss.

## Valves

Modern regulator stations are mostly equipped with ball valves. Improved production techniques have made these valves cheaper and more cost-effective than the earlier used plug valves.

Ball valves are normally of the same size as the piping, but a ball with reduced bore may be used. The additional noise generated by this restriction is small compared with the noise of the regulator, and is usually outweighed by the cost saving.

## Regulators

Gas regulators differ from control valves such as used in the process industry by the fact that they do not use any external energy source. Instead they use either a spring or the gas itself to generate the force to operate the valve. As a result they are faster and more reliable.

The other major difference is that gas regulators are always equipped with a soft seat making it possible to fully seal the inlet from the outlet when no gas is used.

Present regulators can mainly be divided into two main groups: spring-loaded (direct acting) and pilot-operated.

Figure 4 shows a simplified drawing of a typical spring-loaded (direct acting) regulator. The space under the diaphragm is connected to a suitable sensing point downstream, where the pressure is representative for the outlet pressure. The force exerted on the diaphragm is compensated by the spring. The lever causes the valve to close when the pressure under the diaphragm increases. In most cases the pressure downstream of the valve is internally connected to the space under the diaphragm. This is called internal control. External control is when the space under the diaphragm is connected to a suitable tapping downstream. Internal control is generally more sensitive, but less flexible than external control.

The space above the diaphragm has to be open to the atmosphere. The aperture should be small enough to prevent ingress of foreign matter. A small breathing aperture would limit the closing speed of the regulator. The Instromet 243 regulator pictured in figure 4 is equipped with a breather valve that opens for quick closure of the main valve.

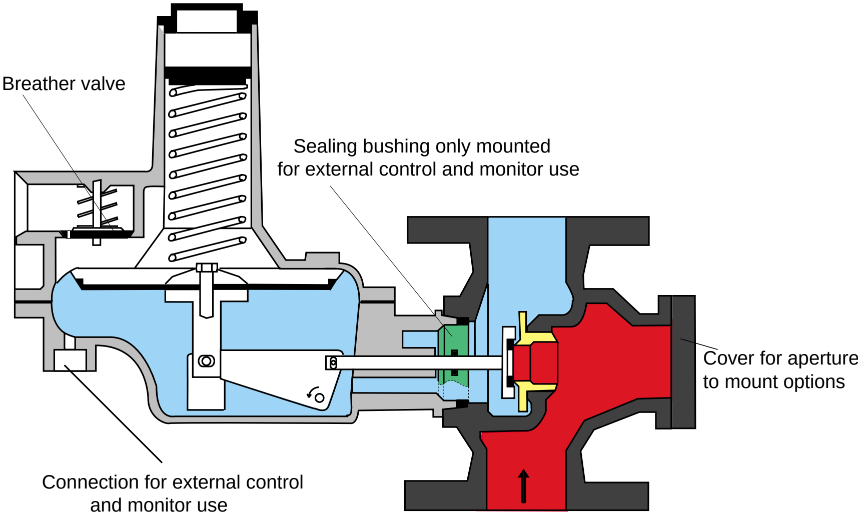

**Figure 4**
**Instromet 243 spring-loaded regulator**

The outlet pressure is somewhat dependent on flow rate and inlet pressure. Typical curves are given in figure 5. These curves are for one spring and one valve orifice. Other springs and orifices would give different sets of curves. For zero flow rate the pressure to push the valve sufficiently strongly onto the soft seat to obtain complete closure is called “lock-up pressure”.

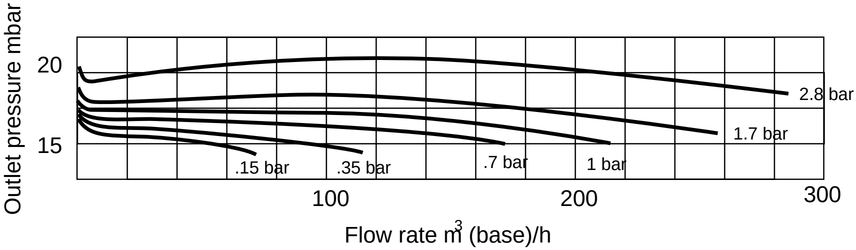

**Figure 5**
**The outlet pressure of a regulator as a function of flow rate for different inlet pressures**

An optional, small, internal relief valve is often incorporated as indicated in figure 6. This relief valve is only meant to relieve gas resulting from a slight weeping of the main regulator, for example as a result of a slightly damaged seal. It is set to a pressure slightly above the lock-up pressure.

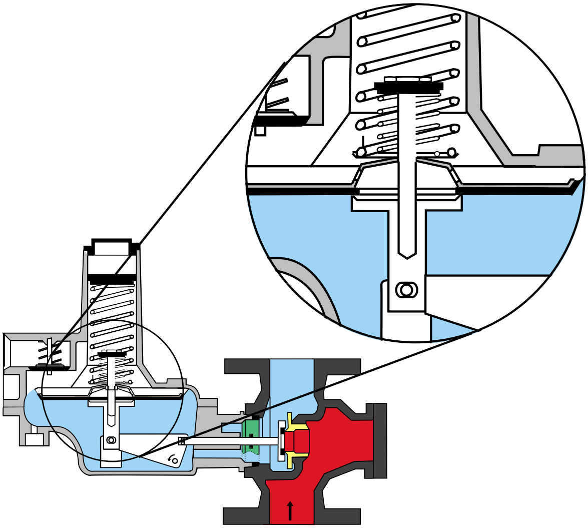

**Figure 6**
**Internal relief valve**

In a pilot-operated regulator, a small, spring-loaded regulator (the pilot) provides the gas pressure to control the main regulator. There are several designs of pilot-operated regulators, and a picture of an axially symmetric design is given as an example in figure 7. In this design a sleeve valve is connected to a spring-loaded diaphragm. When the pilot does not deliver any pressure, the spring pushes the sleeve against its seat. During normal operation the pressure under the diaphragm is higher than the outlet pressure to balance the force of the closing spring. When the outlet pressure drops, the pilot operator increases the pressure below the diaphragm. The outlet pressure setpoint is determined by the spring of the pilot. The deviation of the actual outlet pressure from the setpoint is amplified by the pilot to provide the force to open and close the main valve against the spring. The supply to the pilot regulator is stabilised by a special small regulator to a pressure that is a fixed amount above the outlet pressure.

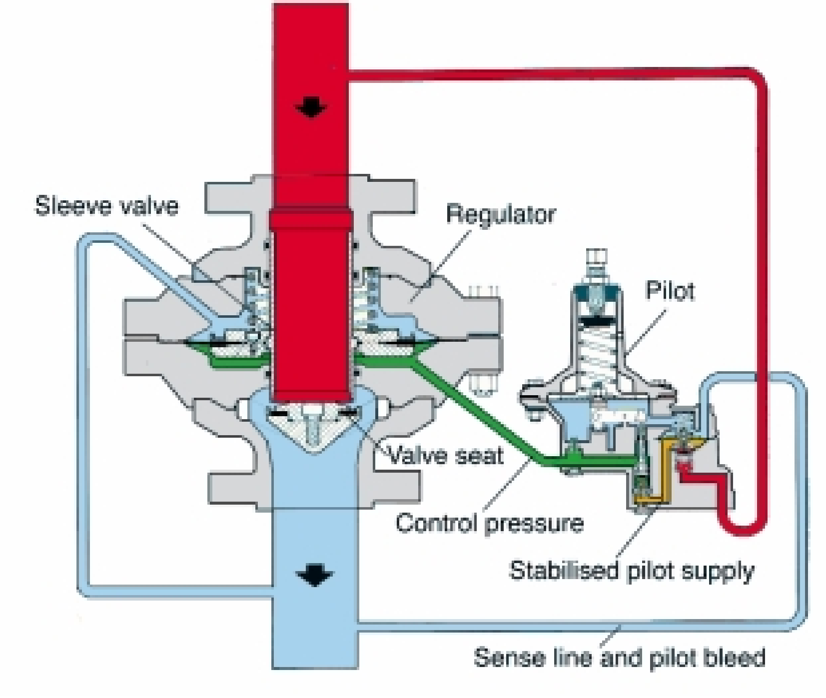

**Figure 7**
**Pilot-operated regulator**

Pilot-operated regulators are used for large capacities. They are fast, and their outlet pressure is, contrary to spring-operated regulators, practically independent of flow rate and inlet pressure.

Most regulators are of a modular construction. One regulator body can be equipped with a variety of valve sizes, springs, diaphragm sizes and additional options. These options are mainly safety-related such as shut-off valves and built-in relief valves. Some regulators can be supplied with a special low noise cage downstream of the valve, or with special low noise valves.

The capacity of regulators is fundamentally determined by the size of the valve orifice, minimum inlet pressure and minimum pressure differential. Low noise features reduce the capacity of a regulator.

The capacity of a gas regulator is dependent on its mode of operation. If the absolute outlet pressure of the regulator is (for natural gas) less than half the absolute inlet pressure, the regulator regime is “choked”. It means that the gas velocity in the restriction of the valve is equal to the velocity of sound. Under those conditions the flow rate does not increase anymore when the outlet pressure reduces further. The flow rate in terms of standard cubic metres is now:

$$q_b = K_c \bullet P \qquad (10)$$

where P is the absolute upstream pressure and $K_c$ a constant.

For lesser pressure differences, the flow rate can be expressed as:

$$q_b = K_v \sqrt{(P_1 - P_2)} \qquad (11)$$

where $P_1$ and $P_2$ are the upstream and downstream pressures respectively and $K_v$ a constant.

In practice manufacturers provide tables that enable the user to size the meter without the use of any formula. An example is given in table 1 for the 2” Instromet 243-12 regulator equipped with a spring, suitable for an outlet pressure of 70 mbar.

|  | Inlet pressure | Orifice size / valve angle |  |  |  |  |  |
|---|---|---|---|---|---|---|---|
|  |  | 1”/30° | 3/4”/30° | 3/4”/10° | 1/2”/10° | 3/8”/10 | 1/4”/10° |
| Regulator 243-12, internal control<br>Spring range : 70-140 mbar<br>Setpoint : 70 mbar<br>Max. outlet pressure variation : 14 mbar | 140 mbar | 80 | 53 | 50 | 32 | 26 | 13 |
|  | 350 mbar | 157 | 112 | 104 | 64 | 42 | 26 |
|  | 700 mbar | 267 | 202 | 173 | 109 | 74 | 38 |
|  | 1.0 bar | 320 | 248 | 221 | 149 | 101 | 45 |
|  | 1.75 bar | 400 | 440 | 293 | 226 | 141 | 64 |
|  | 2.8 bar | - | 534 | 373 | 333 | 200 | 90 |
|  | 4.2 bar | - | - | 413 | 360 | 267 | 122 |
|  | 6.4 bar | - | - | - | 373 | 320 | 149 |
|  | 8.0 bar | - | - | - | - | 456 | 213 |
|  | 10.0 bar | - | - | - | - | 640 | 286 |

**Table 1**
**Example of a capacity table for a 2” Instromet 243-12 regulator**

## Gas filters

A filter protects the rest of the station from any debris or dust that may be carried with the gas stream. Debris may for example consist of parts accidentally left in the pipe during construction. It could also result from swarf from drilling holes for taps, or it could be welding beads and sand from construction or fine iron oxide dust.

The filter elements of Instromet filters (figure 8) consist of polyester needle felt cloth that removes dust particles down to 3-5 micron. A drain is provided at the bottom for the event of liquids being present. The pressure drop over the filter elements should not be more than 100 mbar at maximum flow rate. The elements are however designed to withstand 0.5 bar. The pressure drop is indicated by a pressure differential gauge.

Filters are equipped with a cover plate on top that can either be bolted or secured by a quick closure device. For cover plates weighing more than 30 kg an optional lifting device (davit) is recommended.

Dust is transported with the gas stream when flow rates are high. If the velocity remains below a certain level, most of it remains dormant. If this level is exceeded, all that can move is transported. If the amount of dust and debris exceeds the capacity of the filter, the element will be blocked and collapses.

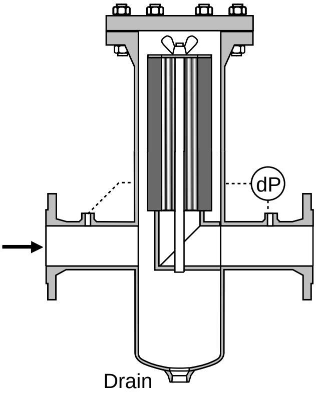

**Figure 8**
**Filter**

Minimising the amount of dust and debris is therefore the best approach and this can be achieved by observing the following:

- Protect stored pipe from corrosion. Internal coating prevents or minimises internal corrosion during storage and operation, and increases carrying capacity.

- Provide adequate gas treatment to prevent corrosive conditions. Carbon dioxide and hydrogen sulphide are the most common potentially corrosive constituents of natural gas, specifically if water is present too.

- Exercise care during construction to prevent the ingress of sand or dust.

- Blow and pig transmission and distribution feeder lines after construction whenever possible.

- Do not reverse the direction of the gas flow if not absolutely necessary.

- Maintain the lowest possible gas velocity.

## Monitor regulator

The monitor regulator is a second regulator, normally upstream of the primary regulator that takes over the function of the primary, active regulator in case the latter fails to open. Its sensing point is at the same location as that of the active regulator and its setpoint is a bit higher than the setpoint of the active regulator. During normal operation the monitor will therefore be fully open. However, if the pressure becomes equal to the setpoint of the monitor, the monitor will close to constrain the pressure.

The differences between a regulator and a monitor regulator are small. Sensing will have to be external and as the pressure under the diaphragm is normally considerably less than the outlet pressure, any leakage from the outlet into the space under the diaphragm should be prevented. In the regulator of figure 4 the linkage between valve and diaphragm is therefore led through a leak-tight bushing when it is used as a monitor.

## Safety shut-off valves

Safety shut-off valves close the supply when a variable exceeds a predetermined limit. In most cases this will be when the outlet pressure exceeds a maximum value. However, it is also possible that too low a pressure is deemed to create an unacceptable risk. This could be the case when a number of appliances without flame failure protection is supplied. The situation could then arise where the flame extinguishes and gas keeps flowing.

Another possibility is to make the device operate when its temperature becomes too high, indicating a fire.

Safety shut-off valves can either be separate units as in figure 9 or incorporated in a regulator body as in figure 10 that pictures a safety shut-off valve that can be attached to the Instromet 243 regulator from figure 4. Another possibility is to mount a valve operator on the inlet valve.

A safety shut-off valve can only be manually reset on site. A by-pass has to be provided to equalise the pressure before the valve can be reset. A small, normally closed push-button valve is a good solution.

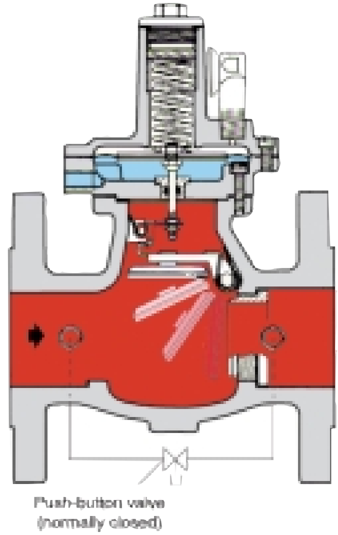

**Figure 9**
**Safety shut-off valve**

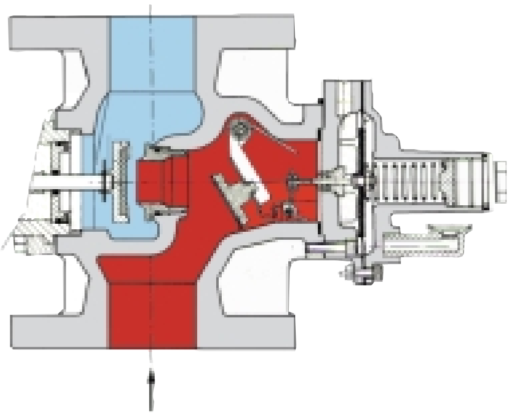

**Figure 10**
**Safety shut-off option installed on an Instromet 243 regulator as from Figure 4**

## Safety relief valves

In the preceding paragraphs we have already spoken about relief valves to release the small quantities weeping through an imperfectly closed regulator. As even the slightest leak could pressurise the downstream installation to the full inlet pressure, given enough time, it is imperative to have a small relief valve installed. These small safety relief valves can either be incorporated in the regulator or installed as a separate unit.

Large relief valves are used to take the full capacity of the station. They should be designed for worst case conditions: maximum inlet pressure and fully open regulator and monitor.

The outlet of a relief valve should be in a safe place. Normally this would be at a certain height above the installation or, in enclosed installations, at a certain height above the roof. Relief valves are very similar to regulators in construction. They can be spring-loaded or pilot-operated.

The sensing point for the pressure of a relief valve, however, is upstream of the valve rather than downstream. The valve opens when the sensing pressure is higher than its setpoint.

## Heat exchangers

The heat is normally supplied by hot water from conventional separate boilers located in a safe area. The water circuit is closed so that there is no risk of corrosion. The water temperature difference is usually chosen to be 90° C inlet / 70° C outlet. The heat exchanger has to be capable to supply the energy necessary to heat up the gas to the minimum desired temperature without causing a too high pressure drop in the gas part.

Very few instances are known of the heat exchanger tubing failing, thus pressurising the water circuit. Nevertheless, as a safety measure a safety device to prevent the boiler from being pressurised can be mounted in the water circuit. The simplest way is to use a rupture disc in the water circuit. Alternatively an ordinary relief valve can be connected to the water circuit. In some countries the regulations call for special security safety valves to isolate the boiler totally from the heat exchanger in case of a leak.

## Setpoints

In general the setpoints of the different regulators and safety devices are based on the following philosophy:

Normally the regulator is operating. The setpoint of the monitor regulator (if installed) is chosen somewhat higher so that when the regulator fails open, the monitor restricts the pressure. If there is no consumption, both the regulator and monitor close. If the system behind it is perfectly tight, even the slightest leak would in the long term pressurise the downstream system. A relief valve is therefore installed to operate at a pressure somewhat above the lock-up pressure of the monitor. This will be a small capacity relief valve. Safety shut-off devices are normally set highest to avoid closing down the customer’s supply unless absolutely necessary.

If two installations are mounted in parallel, the regulator of the second, stand-by installation is set at a lower pressure than the normally operating one. The safety devices, however, have to be set at the same value as or at a higher value than in the normally operating installation.

In figure 11 an example is given for a large station equipped with monitors and regulators.

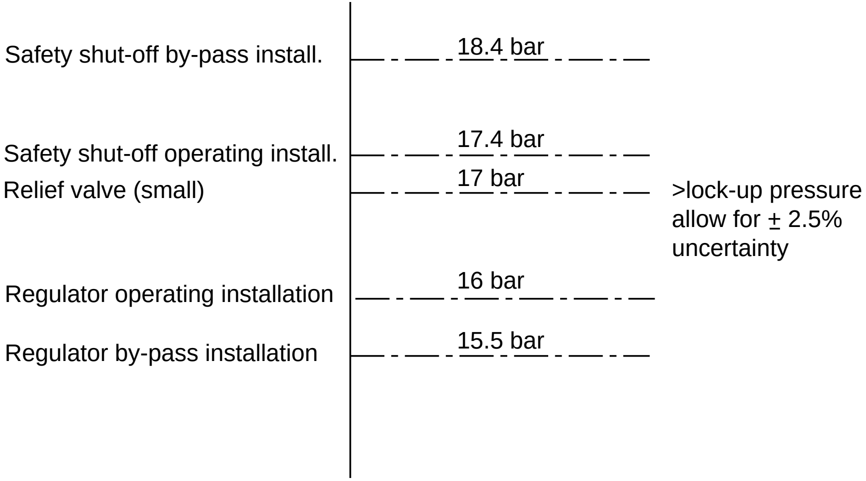

**Figure 11**
**Example of settings of regulator and safety devices**

The highest pressure in the downstream system is governed by the setting of the last safety device that will start operating. The setting of this last device should therefore be higher than the weakest part in the downstream installation. The actual operating pressure will be a considerable amount lower, depending on the margins between the settings. These margins are in turn determined by the tolerance, uncertainty and drift in the regulators and safety devices, or may be determined by the local codes of practice.

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