Why reducing steam pressure

The main reason for reducing steam pressure is rather fundamental. Every item of steam using equipment has a maximum allowable working pressure (MAWP).

If this is lower than the steam supply pressure \(\rightarrow\) a pressure reducing valve must be employed to limit the supply pressure to the MAWP.

In the event that the pressure reducing valve should fail \(\rightarrow\) a safety valve must also be incorporated into the system.

This is not, however, the only occasion when a pressure reducing valve can be used to advantage.

Most steam boilers are designed to work at relatively high pressures and should not be run at lower pressures, since wet steam is likely to be produced.

For this reason, it is usually more economic in the long term to produce and distribute steam at a higher pressure, and reduce pressure upstream of any items of plant designed to operate at a lower pressure.

This type of arrangement has the added advantage that relatively smaller distribution mains can be used due to the relatively small volume occupied by steam at high pressure.

Steam distribution out of the boiler
Why reducing steam pressure

Since the temperature of saturated steam is closely related to its pressure → control of pressure can be a simple but effective method of providing accurate temperature control.

This fact is used to good effect on applications:
1. Such as sterilisers and contact dryers where the control of surface temperature is difficult to achieve using temperature sensors.

2. Such as plant operating at low steam pressure:
   - Can tend to reduce the amount of steam produced by the boiler due the higher enthalpy of evaporation in lower pressure steam.
   - Will reduce the loss of flash steam produced from open vents on condensate collecting tanks.

Most pressure reducing valves currently available can be divided into the following two main groups:
• Direct acting valves.
• Pilot-operated valves.

Direct acting pressure reducing valve

**Smaller capacity direct acting pressure reducing valves**

*On start-up and with the adjustment spring relaxed, upstream pressure, aided by a return spring, holds the valve head against the seat in the closed position.*

Rotating the hand-wheel in a clockwise direction causes a downward movement, which compresses the control spring and extends the bellows to set the downstream pressure.

This downward movement is transmitted via a pushrod, which causes the main valve to open.

Steam then passes through the open valve into the downstream pipework and surrounds the bellows.

As downstream pressure increases, it acts through the bellows to counteract the adjustment spring force, and closes the main valve when the set pressure is reached.

The valve plug modulates in an attempt to achieve constant pressure.

In order to close the valve, there must be a build-up of pressure around the bellows. This requires an increase in downstream pressure above the set pressure in proportion to the steam flow.
Direct acting pressure reducing valve

In order to close the valve, there must be a build-up of pressure around the bellows.
This requires an increase in downstream pressure above the set pressure in proportion to the steam flow.
The *downstream pressure will increase as the load falls and will be highest when the valve is closed*.
This change in pressure relative to a change in load means that the downstream pressure will only equal the set pressure at one load. The actual downstream pressure compared to the set point is the proportional offset; it will increase relative to the load, and this is sometimes referred to as 'droop'.
The total pressure available to close the valve consists of the downstream pressure acting on the underside of the bellows plus the inlet pressure acting on the underside of the main valve itself and the small force produced by the return spring.
The control spring force must therefore be larger than the reduced pressure and inlet pressure and return spring for the downstream pressure to be set.

Any variation in the inlet pressure will alter the force it produces on the main valve and so affect the downstream pressure.

Direct acting pressure reducing valve

NOTE:
This type of pressure reducing valve has two main drawbacks in that:
1. It suffers from proportional offset as the steam flow changes
2. It has relatively low capacity.

It is nevertheless *perfectly adequate for a substantial range of simple applications where accurate control is not essential and where steam flow is fairly small and reasonably constant*. 
Installation of
Direct acting pressure reducing valve

NOTE:
It is important for a strainer and drain separator to be installed immediately prior to any pilot-operated control valve → as clean dry steam will prolong its service life

Direct acting pressure reducing valve

- Smallest in size
- Lowest capacity per line size
- Least accurate ± 10%
- Lowest per cost unit
- Self-contained; no external piping
- Turn-down ratio 10:1
- Tight shut-off: Yes
Pilot acting pressure reducing valve

Where accurate control of pressure or a large flow capacity is required, a pilot-operated pressure reducing valve can be used. A pilot-operated pressure reducing valve will usually be smaller than a direct acting valve of the same capacity.

There are 2 types of pilot acting pressure reducing valve:

Diaphragm type pilot acting pressure reducing valve

A diaphragm type pilot-operated pressure reducing valve works by **balancing the downstream pressure via a pressure sensing pipe** against a pressure adjustment control spring. When we tighten the control spring adjustment \( \rightarrow \) this moves a pilot valve to modulate a control pressure.

The **control pressure transmitted via the pilot valve is proportional to the pilot valve opening, and is directed, via the control pipe to the underside of the main valve diaphragm.**

The **diaphragm moves the pushrod and the main valve upward** in proportion to the movement of the pilot valve. Although the downstream pressure and pilot valve position are proportional (as in the direct acting valve), the mechanical advantage given by the ratio of the areas of the main diaphragm to the pilot diaphragm offers accuracy with small proportional offset.

Under stable load conditions, the pressure under the pilot diaphragm balances the force set on the adjustment spring. This settles the pilot valve, allowing a constant pressure under the main diaphragm. This ensures that the main valve is also settled, giving a stable downstream pressure.
Diaphragm type pilot acting pressure reducing valve

When downstream pressure rises → the pressure under the pilot diaphragm is greater than the force created by the adjustment spring and the pilot diaphragm moves up. This closes the pilot valve and interrupts the transmission of steam pressure to the underside of the main diaphragm. The top of the main diaphragm is subjected to downstream pressure at all times and, as there is now more pressure above the main diaphragm than below, the main diaphragm moves down pushing the steam underneath into the downstream pipework via the control pipe and surplus pressure orifice.

The pressure either side of the main diaphragm is balanced, and a small excess force created by the main valve return spring closes the main valve. Steam will prolong its service life.

When the downstream pressure increases a bit → the increasing steam pressure will go back through the sensing tubing to the bottom of the metal diaphragm below the spring chamber → the pilot valve will be closed a bit → resulting the downstream pressure will always be stable no matter the downstream pressure is fluctuated a bit.
Diaphragm type pilot acting pressure reducing valve

• Any variations in load or pressure will immediately be sensed on the pilot diaphragm, which will act to adjust the position of the main valve accordingly, ensuring a constant downstream pressure.
• The pilot-operated design offers a number of advantages over the direct acting valve. Only a very small amount of steam has to flow through the pilot valve to pressurise the main diaphragm chamber and fully open the main valve. Thus only very small changes in control pressure are necessary to produce large changes in flow. The fall in downstream pressure relative to changes in steam flow is therefore small, typically less than three hundredths of a bar (0.03 bar = 0.5 psi) from fully open to fully closed.
• Although any rise in upstream pressure will apply an increased closing force on the main valve, the same rise in pressure will act on the underside of the main diaphragm and will balance the effect. The result is a valve which gives close control of downstream pressure regardless of variations on the upstream side.

Installation of
Diaphragm type pilot acting pressure reducing valve

NOTE:
It is important for a strainer and drain separator to be installed immediately prior to any pilot-operated control valve as clean dry steam will prolong its service life
Diaphragm type pilot acting pressure reducing valve

- Largest capacity per line size
- Greatest accuracy ± 1%
- External sensing line required
- Turn-down ratio 20:1
- Tight shut-off: Yes

Piston type pilot acting pressure reducing valve

In some types of pilot-operated valve, a piston replaces the main diaphragm. This can be advantageous in bigger valves, which would require very large size main diaphragms. This piston type pilot operating valve is more robust to handle the water hammer (if the steam coming into the valve is wet) than the diaphragm type pilot operating pressure reducing valve.
Piston type pilot acting pressure reducing valve

A piston type pilot-operated pressure reducing valve has the same pilot construction as in diaphragm type pilot pressure reducing valve. It works by balancing the downstream pressure via a pressure sensing hole inside the valve body against a pressure adjustment control spring. This moves a pilot valve to modulate a control steam pressure coming into a piston located on top of a main valve plug. The control pressure transmitted via the pilot valve is proportional to the pilot valve opening.

The piston moves the pushrod and the main valve downward in proportion to the movement of the pilot valve. Although the downstream pressure and pilot valve position are proportional (as in the direct acting valve), the mechanical advantage given by the ratio of the areas of the main diaphragm to the pilot diaphragm offers accuracy with small proportional offset.

Under stable load conditions, the pressure under the pilot diaphragm balances the force set on the adjustment spring. This settles the pilot valve, allowing a constant pressure under the main diaphragm. This ensures that the main valve is also settled, giving a stable downstream pressure.

Piston type pilot acting pressure reducing valve

When downstream pressure rises → the rising downstream pressure will go up into a small hole in the downstream of the valve body and push the metal diaphragm below the spring housing a bit. Now the steam amount coming out of the pilot valve into the upper part of the piston become lesser than before.

Since less pressure coming to the piston → the piston will move upward a bit and the main valve will close a bit too.

Resulting the downstream steam pressure will always be stable even though the downstream steam pressure is fluctuating & increasing a bit.
Installation of
Piston type pilot acting pressure reducing valve

NOTE:
It is important for a *strainer* and *drain separator* to be installed immediately prior to any pilot-operated control valve → as clean dry steam will prolong its service life

Piston type pilot acting pressure reducing valve

- Self-contained; no external piping
- Larger capacity per line size
- Greater accuracy ± 5%
- More expensive than direct type
- Turn-down ratio 10:1
- Tight shut-off: No