The automatic flow rate regulators are able to keep a constant flow rate of the medium that passes through the circuit in which they are installed.

Variable flow rate systems are the most difficult to balance because the differential pressures, and therefore the network flow rates, vary continuously in relation to the opening or closing position of the 2-way valves. These variations can only be controlled with balancing devices that work in dynamic conditions, i.e. in variable positions. In variable flow rate systems, static devices can only limit the maximum flow rates, but they are not able to cope with the dynamism (i.e. with the continuous pressure and flow rate change) that characterizes the operation of these systems.

The regulation element of these devices is composed of a cylinder and a piston which has dedicated lateral openings with fixed and variable geometry through which the medium flows through. These openings are controlled by the piston movement actuated by the pressure of the medium due to the pressure differential persisting on the circuit.

Starting from a minimum load loss the regulator is able to maintain a constant flow rate by changing its bore cross section, specifically changing its Kv value to maintain the design flow rate \( G_{NOM} \) when the differential pressure (\( H \)) changes. Its operation can be divided into three specific configurations.
(A) Below the working range
Condition that occurs when the head that can be "used" by the regulator is lower than the minimum differential pressure value (15 kPa) and therefore the piston does not compress the spring and provides the maximum cross section to the medium.

In this case the valve acts as a static element and is characterized by a fixed Kv value (Kv,Δ) and therefore the passing flow rate depends on the differential pressure according to the formula:

\[ G = Kv_A \cdot \sqrt{\Delta P} \]

The basic design condition after choosing this type of balancing is to ensure a minimum operating head of 15 kPa, which can be used by the regulator.

(B) Within the working range
The valve works with a differential pressure higher than the minimum value and lower than the maximum value required. The piston compresses the spring and provides a free cross section for the medium flow, varying the Kv so as to maintain the flow rate constant at the nominal value when the load changes on the circuit.

\[ G_{constant} = Kv_{variable} \cdot \sqrt{\Delta P_{variable}} \]

(C) Above the working range
When the differential exceeds the maximum value of 200 kPa, the piston fully compresses the spring and provides the minimum cross section to the medium. As in the first case the valve acts as a static element and is characterized by a fixed Kv value (Kv,Δ) and therefore the passing flow rate depends on the differential pressure according to the formula:

\[ G = Kv_C \cdot \sqrt{\Delta P} \]
SIZE AND CARTRIDGE SELECTION

The device consists of body and cartridge:

- The body size is usually selected according to the pipe size. However, for economic reasons, in some cases it is possible to choose a valve body in a size smaller than the pipe size.
- The choice of the cartridge depends on the flow rate required for the circuit. Depending on the nominal flow rate, the cartridge closest to this value is chosen (not necessarily the one with higher flow rate).

SECONDARY CIRCUIT

Two identical circuits connected to a same primary circuit and calculated to have a nominal flow rate $G_{NOM}$ are subject to different heads ($H_1$ and $H_2$) that generate flow rates different from the design flow rates ($G_1$ and $G_2$) and therefore load losses ($\Delta P_1$ and $\Delta P_2$) different from the nominal design load loss.

The dynamic balancing of a secondary circuit flow rate consists in introducing in each circuit a regulator suitable to neutralize the influence of the primary distribution circuit, especially in the case of very variable loads.

In essence, in the previous diagram it is necessary to insert a regulator in every secondary circuit selected according to the nominal flow rate $G_{NOM}$. In this way, not only under static conditions but in any load situation, every secondary circuit is fed with the design nominal flow rate.
The elements that make up a limiting circuit that controls the flow rate are essentially: distribution lines characterized by distributed and concentrated losses, a zone valve, and the output terminal.

To illustrate the situation, a numerical example is introduced. The circuit in question has a \( G_{\text{nom}} \) of 300 l/h and a nominal load loss of the \( \Delta P_{\text{nom}} \) design flow rate of 12 kPa.

If at the circuits ends there is a head of 30 kPa \( H_C \), it is necessary to insert a regulator that absorbs the excessive differential pressure, to maintain a constant flow rate in the circuit.

\[
\Delta P_{\text{vb}} = H_C - \Delta P_{\text{nom}} = 30 - 12 = 18 \text{ kPa}
\]

The head to be absorbed by the regulator is greater than the minimum value (15 PPa) and therefore it works correctly within the adjustment range.

To ensure the nominal flow, the valve self-regulates itself in order to have a \( K_v \) value equal to:

\[
K_v = 0.01 \cdot \frac{G}{\sqrt{\Delta P_{\text{vb}}}} = 0.01 \cdot \frac{300}{\sqrt{18}} = 0.71 \text{ m}^3/\text{h}
\]

As shown in the diagram, the design load loss of the circuit is 12 kPa, the head persisting on the circuit is 30 kPa and therefore the excessive head must be absorbed by the balancing valve for 18 kPa.

**Graph for load loss**

**Circuit operating curves**
A head increase at the ends of the balanced circuit from 30 to 35 kPa would result in an increase of the flow rate passing through a dynamically unbalanced circuit; with the use of a regulator the excessive head is absorbed by the valve according to:

$$\Delta P_{VB} = H_c - \Delta P_{NOM} = 35 - 12 = 23 \text{ kPa}$$

The head to be absorbed by the regulator is greater than the minimum value (15 PPa) and therefore it works correctly within the adjustment range.

To ensure the nominal flow rate and absorb the head excess, the regulator has to introduce an additional load loss into the circuit, this is done by automatically reducing the Kv value according to:

$$Kv = 0.01 \cdot \frac{G}{\sqrt{\Delta P_{VB}}} = 0.01 \cdot \frac{300}{\sqrt{23}} = 0.62 \text{ m}^3/\text{h}$$

The regulator Kv value changes from 0.71 m$^3$/h to the condition in which it had to absorb a differential of 18 kPa at 0.62 m$^3$/h with a 23 kPa differential. To increase the absorbed load loss, the regulator has decreased its bore cross section dynamically decreasing its Kv.
In the event of a head decrease on the primary circuit (from 30 to 27 KPa), the regulator must decrease the load loss value introduced in the circuit (from 18 to 15 Kpa). Also in this case the valve automatically changes in its Kv value (in this case increasing) according to:

\[ Kv = 0.01 \cdot \frac{G}{\sqrt{\Delta P_{VB}}} = 0.01 \cdot \frac{300}{\sqrt{15}} = 0.77 \text{ m}^3/\text{h} \]

The regulator Kv value changes from 0.71 to the condition in which it has to absorb a differential of 18 kPa at 0.77 m³/h with an absorbed differential of 15 kPa.

To decrease the absorbed load loss, the regulator has increased its bore cross section dynamically increasing its Kv.

The installation of AutoFlow dynamic balancing devices in the plumbing circuits ensures it operation at the correct flow rate regardless of the load conditions such as switching on and off other circuits in the same system or excessive heads available at the circuit.

The ideal application is therefore related to circuits or zones that need to operate at a constant flow rate, with switching on or off typically controlled by a dedicated zone valve.