Pilot controlled valve
without auxiliary energy for
heating and cooling systems

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The parallel installation of two valves with different dimensions allows a wide positioning range also for controllers without auxiliary energy. So, high control stability for the low and partial load range can be assured. These ‘pilot controlled control units’ consist of a main valve, a nozzle and a pilot valve in the bypass line. This special combination enables a high control stability as well as multiple functions and safety functions and was patented for the Danfoss IWK Regler GmbH.

Introduction

Control valves without auxiliary power are still in wide use today. They are ideal where a separate power supply is not available and where the control task calls for variable positioning times. Control valves (‘controllers’) without auxiliary power can be used for general pressure, differential pressure, temperature and flow rate control duties, covering a wide range of straightforward control tasks. Most controllers without auxiliary power are proportional controllers, which means that any deviation in the momentary value from the setpoint is assigned a proportional output signal that counteracts the deviation provided the controller is within its operating range (P range). This P range is also a measure of the permanent deviation, and in control valves without auxiliary power it is approximately directly proportional to the valve lift. Large nominal valve diameters, i.e. high valve lifts, involve high proportional permanent deviations which often means that controllers without auxiliary power cannot be used to perform control tasks. Large bore P controllers are also prone to unstable operation in the light-load range. These drawbacks can be overcome by the use of pilot controlled devices with bypass control and regulation (Figure 1). These valves draw their auxiliary power direct from the controlled circuit, and so require no separate power source. The special design of these valves combine high rangeability with low proportiona offset.

Operation of pilot controlled valves

The control unit consists of a main positioning valve with diaphragm drive mounted in the main circuit, and a pilot controller in the bypass. A low pressure loss control nozzle similar to a venturi is connected in series with the pilot controller to control the pressure in the positioner (Figure 2).

At low flow rates the valve is held shut by the spring in the diaphragm drive, and the medium flows across the bypass.

At the same time a relative negative pressure compared with the inlet pressure at the positioning valve is...
generated as the medium flows across the control nozzle. This differential pressure is applied through control pipes to the diaphragm drive and is used to activate the valve. The differential pressure is a function of the flow rate through the bypass line.

As long as the differential pressure stays below a predetermined level the valve is held shut by spring force and the controller in the bypass regulates the variable, e.g. pressure. As the flow in the bypass and the associated pressure differential at the control nozzle rise above a given limit, the valve in the main circuit is progressively and smoothly opened. Should the flow rate fall back below its limit in the part-load range, the main valve is closed and the bypass takes over control once more.

Figure 3 shows the curve of the relative negative pressure over the flow rate. A relative negative pressure of approx. 330 mbar is required to activate the positioning valve, i.e. the valve in the main circuit starts to open when 45% of the maximum bypass flow rate is attained. A pressure differential of 1200 mbar at the diaphragm drive is needed to open the valve fully, i.e. over its full lift. This pressure differential is attained at maximum flow through the bypass.

Figure 3 also shows the characteristic of the pressure loss through the control nozzle. It can be seen that the remaining pressure loss is minimal compared with the relative negative pressure. This property is an important criterion for the selection of a suitable control element.

**Configurations**

A wide variety of connection and control options can be configured with this system. Depending on the particular control task, only the controller in the bypass normally needs to be changed - the ‘basic circuit’ consisting of positioning valve, diaphragm drive and control element is generally left untouched. As well as control valves without auxiliary power, valves with an electric actuator can also be fitted to the bypass. An electric master controller or central control system can be used to implement a wide range of control functions in this way. Some typical configurations are shown in Figures 4a to 4f. Figures 4d and 4e illustrate special cases: each uses two bypass controllers that are connected in series and in parallel respectively. Multiple circuits like this can be used to perform different functions with a single controller. In the series connected version (Figure 4d) the motor valve in the bypass does not perform any control function - it is always fully open in normal operation and is only used to shut off the entire control unit at a control signal from the central control system should this become necessary. The position of the bypass controller has no effect in this instance. The motor valve that is connected in parallel in Figure 4a has the opposite function - when it opens, the normally closed valve opens the entire control unit.

The flow controller (Figure 4) is yet another example.
This option uses a valve that has an adjusting throttle inside the actuator. The differential pressure tapped at this throttle is applied to the diaphragm of a differential pressure regulator in the bypass and limited to 0.2 bar max. As a result there is a certain maximum flow rate for each throttle position.

Advantages Of Pilot Controlled Automatic Controls Proportional system deviation

As stated above, large bore valves have a broad P range with a high permanent system deviation as a result. If we ignore the effects of friction and the closing force, a differential balance of forces in the valve can be expressed by the equation.

$$\Delta h = \frac{1}{C_s} \cdot A \cdot \Delta p$$

where

- \(h\) : Lift
- \(C_s\) : Spring constant
- \(A\) : Effective diaphragm area
- \(\Delta p\) : Pressure

We can see that for each change in pressure there is a matching proportional change in valve lift. A simple integration gives the maximum system deviation of a pressure regulator, for example:

$$\Delta \rho_{\text{max}} = \frac{C_s \cdot H_{\text{max}}}{A_{\text{diaphragm}}}$$

With the pilot controlled devices the valve in the main line is not affected by the momentary value of the variable, and so operates without feedback. The maximum system deviation is calculated with the lift of the pilot valve and not with the lift of the main valve. The lift and hence the proportional system deviation of the pilot valve is significantly less than that of the main valve. Figure 5 shows various characteristics of a pilot controlled pressure reducer as a function of flow.

Positioning range

In the light load range the medium flows through the bypass, while most of it flows across the main valve in the full load range. This means that the smallest possible flow through the complete unit is the flow through the bypass controller, whereas the maximum flow rates of the main valve as a function of the kvs value are achieved at full load depending on the system conditions.

Combination circuits

Given the combination of options described above, it is possible for a single valve to perform a number of different functions. Safety functions can also be added to any desired control functions. The system is part tested to DIN 32730.

Applications

The pilot controlled units can be used for all non-toxic and nonflammable fluids and gases. They are ideal for use in heating and cooling systems, and for energy distribution systems. Their main specifications are listed in Table 1.

<table>
<thead>
<tr>
<th>Applications</th>
<th>Heating and cooling systems</th>
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<tbody>
<tr>
<td>Flow media</td>
<td>Non toxic, nonflammable fluids and gases</td>
</tr>
<tr>
<td>Variables</td>
<td>Inlet pressure, outlet pressure, differential pressure, temperature, flow</td>
</tr>
<tr>
<td>Temperature range</td>
<td>Up to 300 °C max.</td>
</tr>
<tr>
<td>Pressure range</td>
<td>Up to PN 40</td>
</tr>
<tr>
<td>Nominal diameter</td>
<td>Valve: DN 100- DN 250</td>
</tr>
<tr>
<td></td>
<td>Bypass: DN 15 - DN 40</td>
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<tr>
<td>Housing materials</td>
<td>GG 25, GGG 40.3, GS-C 25</td>
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</table>

**TABLE 1**: Technical data of the pilot controlled control unit