
# DESIGN GUIDE

## - For the use of Frese OPTIMA

Frese

# FRESE OPTIMA PRESSURE INDEPENDENT CONTROL VALVES

## 1. INTRODUCTION

This guide describes the design and operation of the Frese OPTIMA pressure independent control valve (PICV). This single valve can be fitted to terminal units in heating and chilled water systems to provide:

- Flow regulation
- Automatic modulating control of heating/cooling output
- Differential pressure control

The OPTIMA valve is the ideal solution for modulating control of flow rates in systems incorporating variable speed pumps.

This guide explains:

- The principles of 2 port valve selection for modulating control
- Why it is often difficult to achieve accurate modulating control in conventional systems
- How the OPTIMA valve provides a solution to these problems
- How the OPTIMA valve operates under varying system conditions
- How the OPTIMA valve should be incorporated into systems
- How to undertake pre-commission cleaning and commissioning with the OPTIMA valve installed

## 2. TWO PORT VALVE SELECTION FOR MODULATING CONTROL

Forced convection terminal units, such as waterside controlled fan coil units, active chilled beams or air handling unit coils, require modulating control of heating or cooling output in order to maintain stable control of thermal conditions.

The valve characteristic (i.e. the relationship between valve opening and flow rate under constant pressure differential) needs to be such that flow reduces quickly when the valve begins to close, but then slows over the remaining closure.

This is because for most heating or cooling coils a large drop in design flow rate is required to influence heating or cooling output. Equal percentage characteristics (as illustrated in **Figure 1**) are recommended in CIBSE Guide H Building control systems. Linear or on/off (quick opening) characteristics are better suited to naturally convective or radiant emitters such as radiators, airside controlled fan coil units and passive chilled beams.

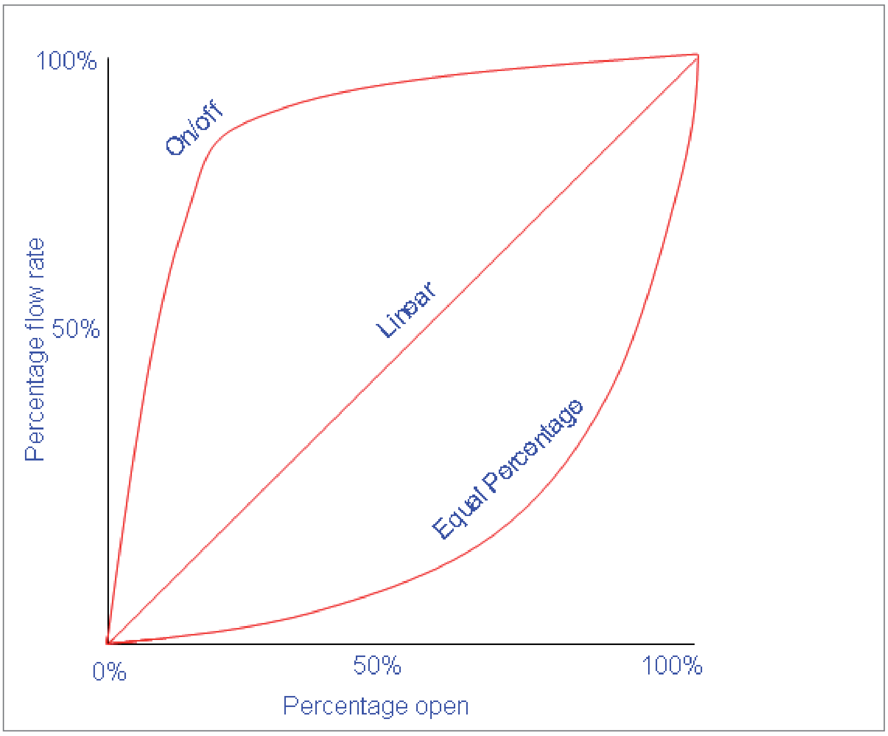


**Figure 1**: Alternative control valve

In order to achieve good modulating control, a control valve with an equal percentage characteristic must be sized such that the pressure drop across it when fully open, is a significant proportion of the pressure differential across it when closed. The higher this proportion, the more responsive the change in flow rate will be as the valve modulates between open and closed.

The ratio of fully open valve pressure drop (at design flow rate) versus the closed pressure differential i.e. $p_1 / (p_1 + p_2)$ in **Figure 2** is referred to as "valve authority" (denoted as α). Controls specialists usually accept that the control valve authority must be greater than 0.3 in order to achieve worthwhile control. If the authority is below this value then the equal percentage characteristic of the valve becomes more linear and reduces its ability to modulate flow accurately. **Figure 3** shows how the equal percentage characteristic tends to distort if the valve authority is reduced.

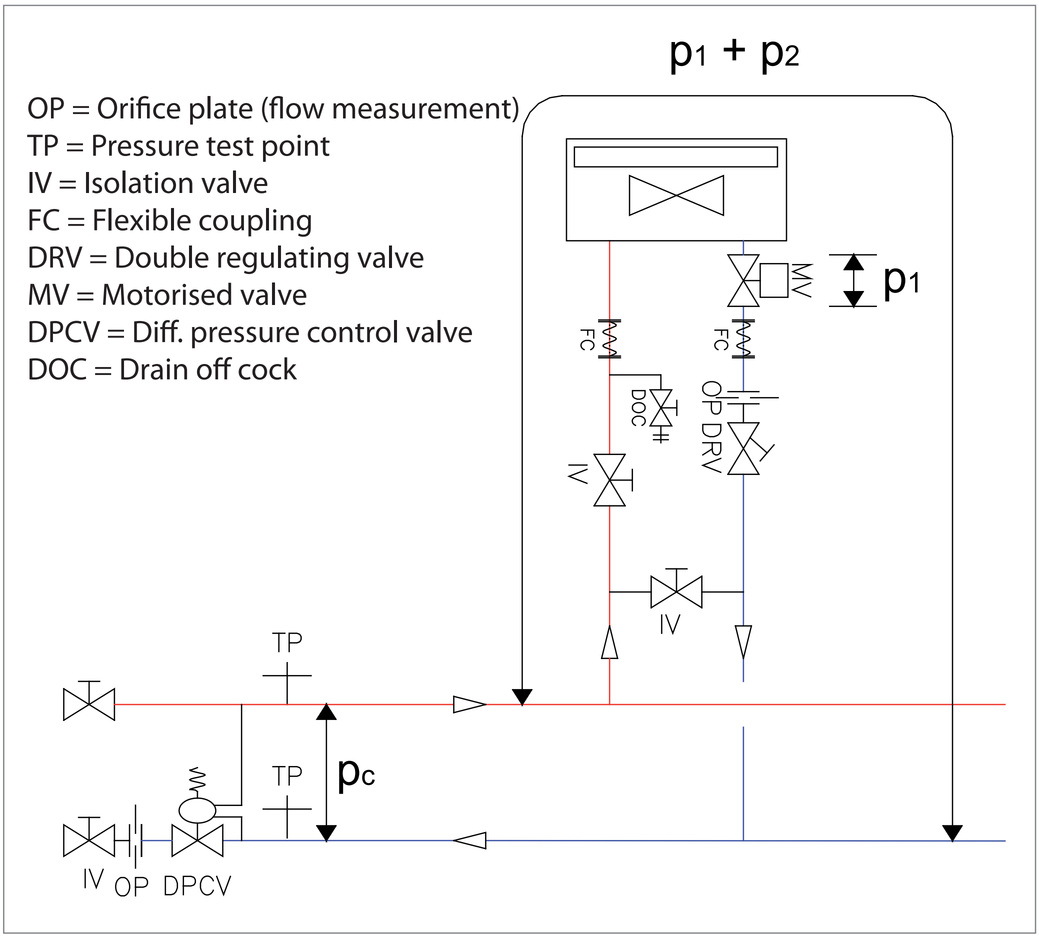


**Figure 2:** Valve authority in terminal branches with individual 2 port

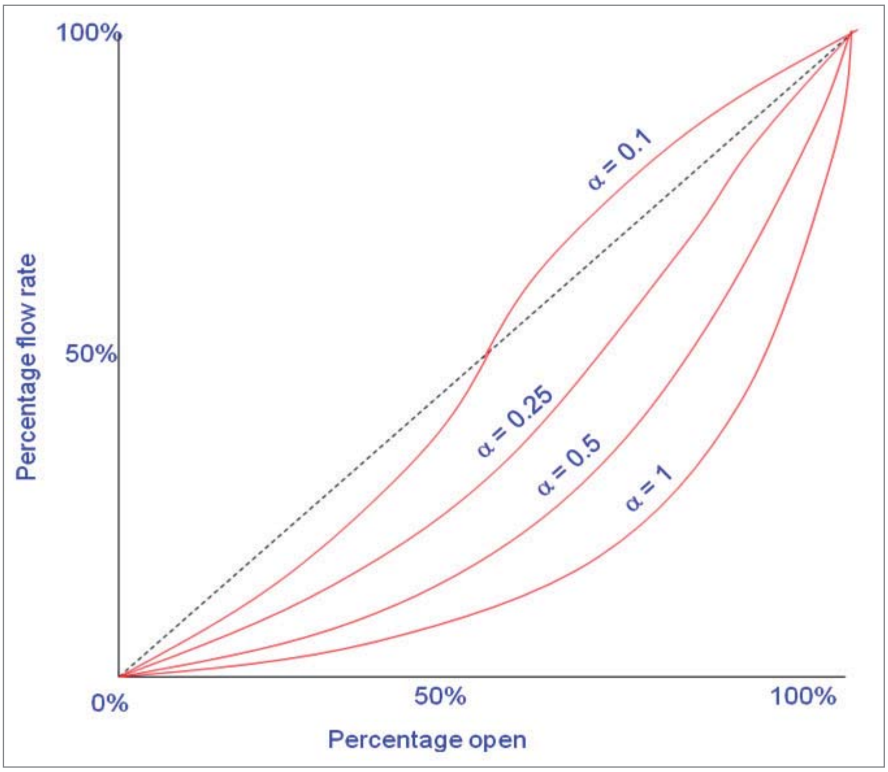


**Figure 3:** Effect of valve authority on an equal percentage valve

## 2.1 COMMON VALVE SELECTION PROBLEMS

There are two common problems that arise during control valve selection for systems with separately located regulating valves, two port control valves and differential pressure control valves (DPCVs).

**Problem 1: Valve selection is impossible due to low flow rates relative to high branch pressure losses**

As indicated in **Figure 2**, the value $p_2$ includes all pressure losses back to the branch connection including losses through the coil, pipework, flexible hoses, and regulating valve. If the branch is near to the start of a long run of pipework then the pressure drop across the regulating valve can be particularly high since the valve has to be throttled to increase flows to downstream branches. As a result, for low flow rates, it may be impossible to source two port valves with sufficient resistance to achieve the recommended minimum authority of 0.3.

**Problem 2: Control characteristics are distorted due to system pressure variations at part load**

Even when a valve has been selected with apparently good authority, the control characteristic may be distorted due to pressure variations in the system. As two port valves close, the pressure differentials across the terminal branches will increase towards the pressure held constant by the nearest upstream DPCV (i.e. pc in **Figure 2)**. This increase in pressure will be accompanied by an increase in flow rate through each terminal branch, hence reversing any flow reduction caused by the valves closing. Although the valves will, in theory, have the correct characteristic and be sized with good authority, they may often behave like on/off valves under part load conditions.

## 2.2 HOW OPTIMA SOLVES VALVE SELECTION PROBLEMS

The OPTIMA pressure independent control valve solves both of the above problems by integrating the functions of flow regulation, modulating control and differential pressure control. **Figure 4** shows the arrangement if the three functions of the valve are shown as separate symbols.

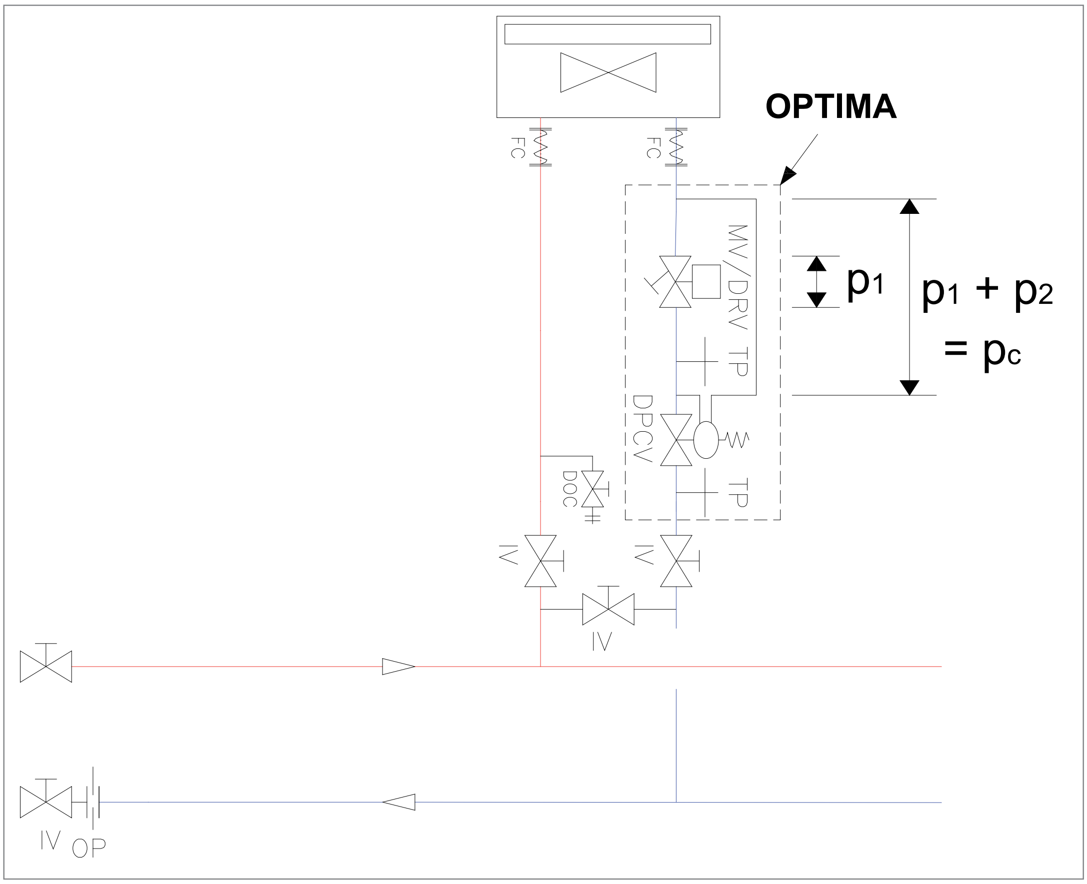


**Figure 4:** Valve authority in terminal branches with Optima valves

**OPTIMA solution for problem 1:**

It can be seen from **Figure 4** that the DPCV inside the OPTIMA valve holds the pressure constant across the two port valve and regulating valve. Therefore, the value of $p_2$ is minimized since it no longer includes pressure losses through the coil, connecting pipework, or flexible hoses. Furthermore, since the DPCV absorbs any excess pressure across the branch, the regulating valve does not have to be throttled to increase flows to downstream branches. Since the value of $p_2$ is almost 0 then the valve authority is always 1.

**OPTIMA solution for problem 2:**

**Figure 4** indicates that the pressure controlled constant by the DPCV is actually equal to the pressure loss in the controlled circuit i.e. $p_c = p_1$. Therefore, the overall pressure differential across the two port control valve can never vary so there is no possibility of the control valve characteristic being distorted.

## 3. OPTIMA VALVES - HOW THEY WORK

**Figure 5** shows a cross section cut of the OPTIMA valve in its closed and fully open positions.
The valve body contains two main components. In the top half of the body is the control valve and regulating valve component. In the bottom half of the body is the DPCV.

**Flow regulation:** Water entering the valve initially passes through a rectangular shaped opening. The length of this rectangular opening (and hence resistance) is variable and performs the regulating function of the valve. The flow setting dial at the top of the valve permits adjustment of the regulating valve; by turning the dial, the area of the opening through the slot varies. **Figure 5** shows how the slot would look at its fully open and minimum setting positions. The flow setting dial is marked from setting 0.2 (minimum) to setting 4 (full open). For each valve size, the settings correspond to a specific flow rate value as indicated in the product brochure. Once set, the corresponding flow rate indicated in the brochure will be maintained whenever the 2 port valve is in its fully open position. This is possible due to the function of the DPCV as explained below.

**2 port control:** The same rectangular opening is used to achieve modulating control of flow rate. As the actuator modulates the valve open and closed, the height of the rectangular opening varies to perform the temperature control function of the valve.

For optimum modulating control of larger valves, the valve stem would be fitted with an actuator that could simulate an equal percentage characteristic.

It is important to note that regardless of the setting of the regulating valve, the 2 port valve lift remains the same (at approximately 5mm) under all conditions.

Comparable valves that use up part of the modulating stroke for regulating purposes are unlikely to retain an accurate control characteristic simply because, once regulated to any significant extent, there will be too little travel left in the valve to perform as anything other than on/off.

**Differential pressure control:** After the 2 port control valve, water then passes through the differential pressure control valve (DPCV). The DPCV automatically adjusts its position by sensing the differential pressure across the regulating valve and control valve combination i.e. between points A and B in **Figure 5**.

A small pressure tube transmits the pressure of the water entering the valve to a chamber at the bottom which forms one side of the DPCV diaphragm. Water that has passed through the 2 port valve is in contact with the other side of the diaphragm.

Hence the diaphragm will move in response to changes in the pressure differential between these two points thereby varying the opening through the DPCV. Similarly, if the overall pressure differential between points A and C in **Figure 5** should vary due to other valves closing or the pump varying its speed, the DPCV will again sense these changes and adjust its position such that the pressure drop between points A and B is unaffected.

It can be seen that by holding the pressure constant between points A and B with the 2 port valve fully open, the result is a fixed pressure differential across a fixed resistance resulting in a constant flow rate. This explains how it is possible to limit the flow to a specific value using the setting dial, and why this maximum flow rate will remain set unless the 2 port valve begins to close.

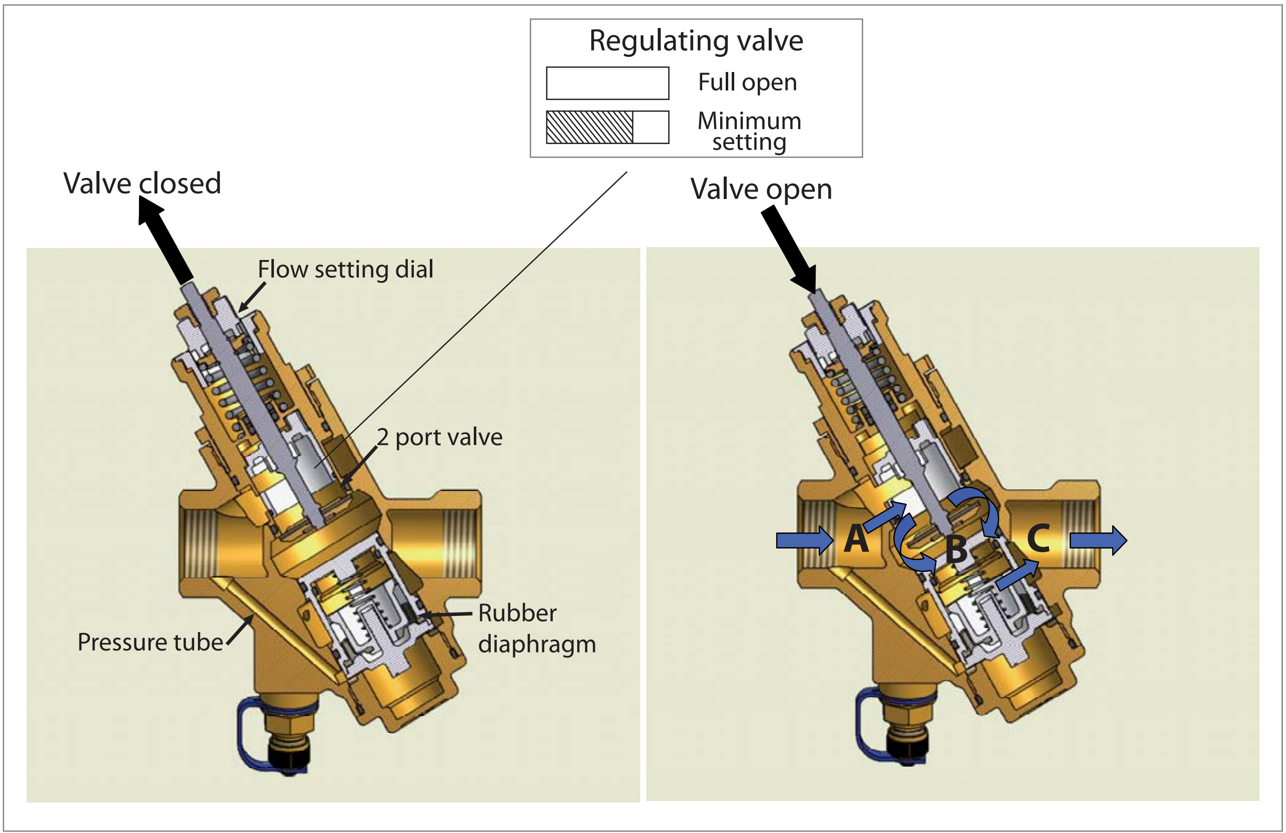


**Figure 5:** Cross section diagram of OPTIMA valve

## 3.1 OPTIMA VALVES IN OPERATION

The three elements of the OPTIMA valve described above behave in exactly the same way as if these functions were provided by a combination of separately located valves.

When the two port valve is driven closed by its actuator, the pressure build-up at the inlet to the valve is transmitted via the pressure tube to the bottom side of the DPCV diaphragm. This increase in pressure causes the diaphragm to flex inwards, with the result that the DPCV also moves to its closed position.

When the 2 port control valve begins to open, the reduction in pressure at the valve inlet is sensed by the DPCV causing the DPCV to open as well.
Under all part closed positions, the overall pressure differential across the regulating valve and 2 port control valve component is maintained at a constant value.

## 4. INCORPORATING OPTIMA VALVES INTO SYSTEMS

**Figure 6** shows a typical system layout incorporating OPTIMA valves and the accompanying components that are required on connecting branches. OPTIMA valves should be incorporated into a system with one at each terminal unit as a straight replacement for individual 2 port control valves and double regulating valves. The designer should be aware of the following issues during design.

**Valve selection**: Due to the function of the internal DPCV, OPTIMA valves can be selected simply on flow rate. Since the value $p_2$ in **Figure 4** above includes pressure losses across components that are all internal to the valve, the size of the coil and length of adjoining pipework are of no concern during valve selection.

**Minimum pressure differential**: In order to operate satisfactorily, the DPCV component of the valve must have enough pressure across it to enable the spring to move. This minimum is typically in the range 16-22kPa for 15 – 32mm diameter valves. Specific values are given in the product brochure. In order to determine whether there is sufficient pressure across each DPCV, OPTIMA valves are provided with pressure test points to enable the pressure differential to be measured.

**Flow measurement**: Since flows can be set without the need to measure the flow rate in the pipe, there is no need to locate individual flow measurement devices on every terminal branch. For checking purposes, flow measurement devices can be located on main branches and sub-branches upstream of the terminals.

**Upstream regulating valves**: Since the internal DPCV will vary its position depending on system pressures, there is no need for upstream regulating valves. In order to achieve a flow balance, the DPCVs inside OPTIMA valves located close to the pump will throttle the flow more than those located further away. Due to the action of the DPCVs, the flow balance will be maintained regardless of subsequent 2 port valve closures or variations in pump speed.

**Maximum pressure differential**: The DPCVS can control effectively up to a maximum differential pressure of 400kPa. They are therefore not suited to applications for which the full load pump pressure could exceed this amount.

**Pump speed control**: Pump speed must be controlled so as to maintain a minimum pressure differential at some selected point (or points) in the system. A differential pressure sensor should be located at the selected point and connected back to the pump speed controller.

One option is to control the differential pressure across the pump itself constant. However, reducing flow rate through a pump whilst keeping its pressure constant tends to result in poor pump efficiency at part loads with consequent loss of energy.

A more efficient approach is to locate a sensor at some point as far down the system as possible. As shown in **Figure 6**, a convenient location is at the top of the main riser. In systems with multiple risers serving branches with varying load patterns, multiple sensors may be required, the pump being controlled to maintain the differential pressure at all sensor locations above the set point value.

**Pressure relief at part load**: When all of the OPTIMA valves are approaching their closed positions, there needs to be some path open to flow to prevent the pump operating against a closed system. By-pass circuits at the top of the riser and at the end of each main branch are recommended. These locations should ensure that there are no potential stagnant pipework sections. Flow circulation is important in steel mains since it ensures that treatment chemicals are properly distributed, and speeds up the heating/cooling response when OPTIMA valves begin to open.

The best way to maintain flow in these by-passes is to install constant flow regulators that hold the flow constant regardless of pressure changes elsewhere in the system.

### 4.1 PRE-COMMISSION CLEANING

**Figure 6** indicates all of the design provisions required by BSRIA Application Guide AG 1/2001.1 Pre-commission cleaning of pipework systems. The main stages of the clean are exactly the same as for a conventional system.
In accordance with the BSRIA guide, the final stage of the clean is to back-flush through each terminal unit and control valve in order to remove any debris they might contain.

This procedure is exactly the same for a system with OPTIMA valves. When a reverse pressure differential is generated across the OPTIMA valve, the DPCV will move to its fully open position. In this position, and with the regulating valve and 2 port control valve also fully open, the resistance across the entire OPTIMA valve is low enough to permit adequate flushing velocities through the adjoining pipework and terminal unit.

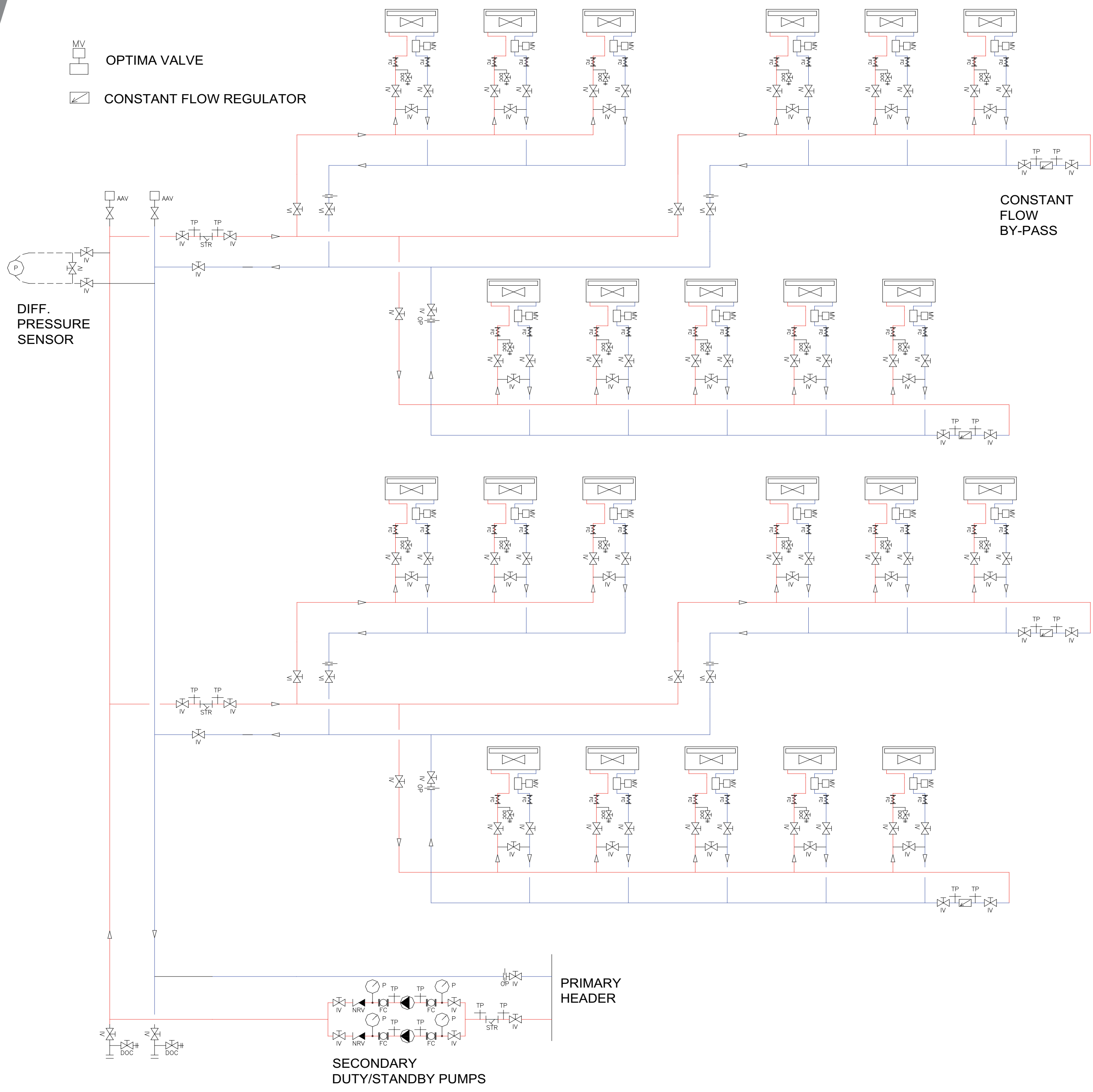


**Figure 6**: Typical system schematic incorporating OPTIMA

## 4.2 COMMISSIONING

Having flushed and cleaned the system flow balancing can commence.
Each OPTIMA valve can be set independently and in any order provided there is sufficient pressure available to enable its integral DPCV to operate. Branches close to the pump are most likely to have sufficient pressure at start up and are therefore an obvious place to start. The commissioning procedure is as follows:

**1.** For the selected OPTIMA valve, ensure that the 2 port valve is fully open. Measure the pressure differential across its pressure tappings and confirm that the value obtained is greater than the minimum value indicated in the product brochure. If this is not the case investigate the causes and, if necessary, report to the designer.

**2.** Adjust the flow setting dial to the specified design flow rate. Lock the dial in position and record the setting.

**3.** Repeat the above process for all of the OPTIMA valves on the branch.

**4.** Measure the flow rate indicated at the flow measurement device on the branch. Confirm that the value recorded is equal to the sum of the flows set at downstream OPTIMA valves. If this is not the case investigate the causes and, if necessary, report to the designer.

**5.** Repeat this procedure until all OPTIMA valves in the system have been set and their summated flows checked against upstream flow measurement devices.

**6.** Measure the differential pressure across the OPTIMA valve on the system index terminal (usually the most remote terminal from the pump). Adjust the pump speed until the pressure differential across this valve is equal to the minimum value indicated in the product brochure.

**7.** Determine the pressure differential at the sensor location. Set the pump speed to control such that the value indicated at the sensor is maintained constant under all conditions.

**8.** Measure and record the total flow rate, pressure differential and energy consumption at the pump.

**9.** Run all two port valves to their closed positions. Measure and record the total flow rate, pressure differential and energy consumption at the pump. Calculate and report the overall energy saving achieved i.e. between full load and minimum load operation.

## 5. FURTHER READING

Further details on system design and commissioning can be found in:

- CIBSE Guide H Building control systems
- CIBSE knowledge Series Guide KS7 Variable flow pipework systems
- CIBSE Knowledge series Guide KS9 Commissioning variable flow pipework systems

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# Full stroke modulation & automatic balancing:
# The new generation of combination valves is now introduced.

Frese Optima is designed to combine automatic balancing and absolute modulating control regardless the preset flow.

- ·Max diff. pressure: 400 kPa
- ·Temperature: 0 to 120°C
- ·Dimensions: DN15-DN32
- ·Material: DZR brass
- ·Static pressure: PN25
- ·For cooling and heating

The innovative design of Frese Optima introduces an intelligent control valve that adjusts automatically to the preset flow in order to provide full modulating control. When the installer presets the valve according to the maximum designed flow, the stroke of the control valve remains the same thus providing 100% modulating control. In practical terms, Frese Optima ensures that there isn't any overflow and that below the design flow the actuator has absolute authority.

Furthermore, Frese Optima combines all those features that are necessary to ease the work of designers and installers: flushing is possible due to the cartridge solution selected for the dynamic balancing part of the valve; the wide (up to 400kPa) differential pressure range meets the requirements of most applications; the compact design and the user-friendly presetting unit guarantee easy installation and commissioning.

Frese Optima is the best solution for all terminal units of cooling and hea-ting applications. It is the safe choice for the designers, the easy choice for the installers and the comfort choice for the end-users.

Frese balances efficiently HVAC systems all around the world. From cooling systems in the Middle East to heating systems in Scandinavia, Frese's products transform state of the art technology into every day solutions.

Danish production


Female/female threaded


Simple scale

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