SOLUTIONS WITH DIFFERENTIAL PRESSURE IN HEATING WITH RADIATORS

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Abstract: Currently, many building managers record complaints from homeowners regarding the indoor climate. The main issue is that some rooms never have the desired temperature. After changing the load, room temperatures vary, particularly at small and medium loads. The design capacity can not be transmitted during the start of the heating system after setting and operation under a week-end or night. Such problems arise when the installation has an incorrect heat flow which prevents proper functioning of regulators. Considering that flow and pressure regulators ensure effective control when flows prevail in the plant project, this paper presents two solutions with differential pressure in heating with radiators. These solutions consist in the use of automatic differential pressure regulators or proportional relief valves.

Keywords: flow, regulator, differential pressure, valve.

1. INTRODUCTION

A careful and systematic analysis of ventilation and heating behaviour made possible the identification of several issues that arise in rooms to be heated or ventilated. And allowed the identification of several issues that arise in rooms to be heated or ventilated. Correcting these failures is possible if three key conditions are met: the designed flow must be available to all terminals; flow rates to be compatible to the system interfaces; differential pressure control valves must not vary too much.

Hydraulic calculations of heating with radiators is based on a number of simplifying assumptions which, unfortunately, are harmful to the actual operating conditions of such a heating system (constant flow and hydraulic resistance elements, although in reality they are highly variable).

To make hydraulic calculations more precise, it is necessary to consider a variable flow of heating water, which requires, in order to achieve a quantitative adjustment, using two-way valves to consumers. Unfortunately, the current operation of this type of control equipment, leading to the registration in the heating system of certain flow and differential pressure variables that require hydraulic balancing of the system.

The hydraulic balancing can be achieved by installing equipment capable of reacting based on changes in differential pressure, such as automatic or differential pressure regulators or proportional relief valves.

2.USE OF THE AUTOMATIC DIFFERENTIAL PRESSURE REGULATORS

Automatic differential pressure regulators are often used in heating with radiators equipped with thermostatic radiator valves, thus designed to ensure the tuned circuit, maintaining an available pressure at a constant value. These regulators are mounted in tandem with a partner valve at the base of each heat column. The role of this valve is to ensure the intake pressure impulse tube.

Being equipped with nipples for pressure the regulators also offer heat flow measurements [1], [5], [6], [8]. To ensure a stable and precise adjustment of control valves, the differential pressure should be less than the variable. This can be done using a STAP automated control valve for differential pressure in a variable flow distribution.

For systems with variable flow distribution the control valves must be sized so that in the most disadvantageous conditions, to obtain at least 0.25 of the nominal flow. This is possible by using variable speed pumps with pressure variation sensor correctly placed.

Depending on the structure of the plant, the differential pressure available on some circuits can vary greatly with load, in which case for obtaining and maintaining a feature proper control valves, differential pressure of the control valves Δp (Figure 1), can be maintained practically constant with a regulator combining the control valve with a local differential pressure regulator [2], [3].

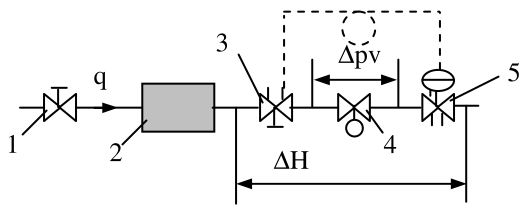

Fig. 1. Regulator Δp to maintain constant differential pressure valve: 1 - valve; 2 - coil; 3 - position valve; 4 - balancing valve; 5 - automatic differential pressure regulator

In this case, the procedure for balancing (Stabilisation pressure) involves the following algorithm [4]:
Step 1. Open the control valve (4);

Step 2. Preset valve as STAM (3) to obtain at least 3 kPa for designed flow rate;
Step 3. Adjust the preset value Δp of STAP differential pressure regulator (5) to get the designed flow.
Step 4. If at least one of the flow rates of every network is not correct, it requires a new balancing procedure.
The STAP automatic control valve diaphragm (5) is connected to the inlet and outlet of the control valve (4). With an increasing differential pressure, the force acting on the diaphragm to close the automatic proportional control valve STAP increases. The differential pressure control valve is kept practically constant, being chosen so as to be able to get the designed flow. Differential pressure variations are compensated at balancing valve and designed flow can not be exceeded.
Differential pressure control valve (4) is detected on one side by connecting the capillary downstream of the valve position STAM and, on the other hand, using a membrane active directly connected to the controller automatically differential pressure STAP, the preset value which can be given by formula [7]:

$$\Delta \dot{p} = \left(0{,}01 \cdot \frac{q}{k_{vs}}\right)^2 \text{ [kPa]} \quad (1)$$

$$\Delta \dot{p} = \left(36 \cdot \frac{q}{k_{vs}}\right)^2 \text{ [kPa]} \quad (2)$$

where:
q – designed flow [l / h] - the relation 1 or [l / s] - the relation 2;
k_{vs} - constant of valve adjustment, the amount of which is known with an accuracy of 15%.

The designed flow value is obtained when the valve is fully open and is measured using the measuring valve STAM, which has an important role in diagnosis. Accordingly, control valve (4) is never oversized, its authority remains almost 1. As a result, the additional differential pressure is applied to the automatic pressure differential controller STAP, making it possible to reduce the pumping costs and the reduction of noise in the system by a combination of local differential pressure regulator with a variable speed pump.
The authority of a valve is the report between the differential pressure Δp_{min} producing the designed flow (with the valve fully open) and the differential pressure Δp_{max} when the differential pressure available is applied to the control valve.
If in the heating system there are several small terminal units (3) closely spaced from each other, the differential pressure can be carried out simultaneously on all the terminal units, bearing in mind that each terminal unit has to be provided with its own valve Balancing (Figure 2).
Sizing control valves involves the determination of pressure losses to the designed flow in each terminal unit and choosing the highest amount Δp_{maxT} so that each balancing valve to create (it is fully open and the designed flow), a pressure loss, given by:

$$\Delta p_V = \Delta p_{max\,T} + 3 = 0{,}25 \cdot \Delta p_{presetare} \text{ [kPa]} \quad (3)$$

Where:
$\Delta p_{presetare}$ - estimated preset differential pressure [kPa] value of automatic differential pressure regulator

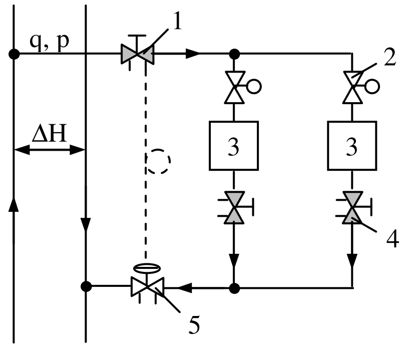

Fig. 2. Adjust differential pressure using balancing valves on each terminal: 1 - measuring valve STAM; 2 - balancing valve; 3 - terminal unit; 4 - STAD balancing valve; 5 - Automatic differential pressure regulator STAP [4]

Balancing procedure in this case involves the following algorithm:
Step 1. Maintain preset differential pressure of the automatic differential pressure regulator STAP to factory set value, control valves (2) being opened;
Step 2. Balances branch terminals on the method of balancing which not depend on available differential pressure ΔH;
Step 3. Adjust the preset value Δp of the Automatic differential pressure regulator STAP to obtain total design flow q_p through STAM measuring valve.
The differential pressure for systems with several terminal units can be set in the case where the heating system, are provided for each terminal unit, by a TRIM or STK control valve. However, this method does not offer flow measurement terminal units, thus imposing presets calculating control valves (Figure 3).

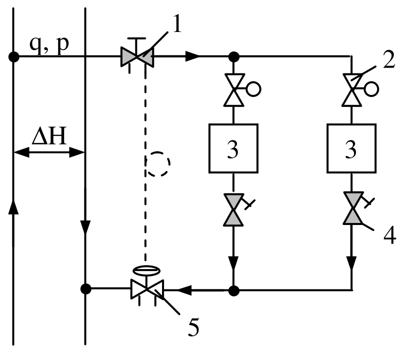

Fig. 3. Adjust differential pressure control using valves for each terminal: 1 - measuring valve STAM; 2 - balancing valve; 3 - terminal unit; 4 - TRIM control valve; 5 - Automatic differential pressure regulator STAP [4]

For this procedure, it is considered that the pressure losses in the pipes network of the downstream STAP regulator can be neglected, so that in order to achieve the balancing hydraulic if using TRIM control valves, will do the following:

1. It was estimated the required differential pressure for each circuit, which must be equal to the amount of pressure losses (for designed flow in control valve, terminal unit, accessories and control valve located in the fully open position), whichever is the maximum value Δp_{max};
2. For each circuit is calculated from the relationship (4), pressure loss which must be taken over control valve [7]

$$\Delta p = \Delta p_{max} - \Delta p_V - \Delta p_T - \Delta p_{Ac} \ [kPa] \qquad (4)$$

Where:

Δp_{max} – The maximum differential pressure for each network circuit, [kPa];

Δp_V – pressure loss across the control valve [kPa];

Δp_T – pressure loss across the network termination units, [kPa];

Δp_{Ac} – pressure loss through the accessories, [kPa].

Alternatively for the stabilizing differential pressure in cases of multiple terminal units is that the valves which are open-closed presetting (control valves pre-adjustable TRV) to which the drain outlet valve measuring STAM is downstream (Figure 4).

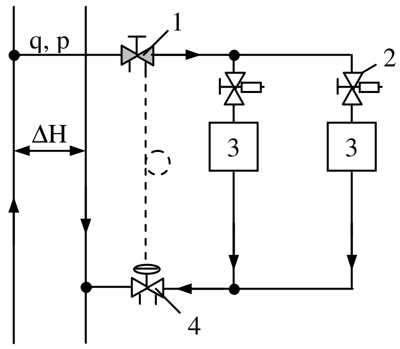

Fig. 4. Adjust of differential pressure using on-off pre-adjustable control valves , on each terminal: 1 - measuring valve STAM; 2 – pre-adjustable (presetting) TRV on-off control valves; 3 - terminal unit; 4 - automatic differential pressure regulator STAP [4]

This balancing solution is similar to that using TRIM control valves, with the observation that balancing valves in branches and columns are only required for diagnostics and serving as a closure.

3. HEAT PLANTS APPLICATIONS WITH RADIATORS FOR DIFFERENTIAL PRESSURE

A. Preset radiator valves

In a heating system with radiators, thermostatic valves are generally preset considering that the available differential pressure ΔH_0=10 kPa. In the balancing operation , the balancing valve STAD on the branch is set to obtain the correct total branch flow, the preset value of 10 kPa is obtained in the middle of the branch.

If the differential pressure applied to the thermostatic valves exceeds 30 kPa, there is a risk of noise in the system, especially when the air is trapped in the water. In this case it is recommended that the stabilisation of each branch with differential pressure should be achieved through a STAM automatic regulator valve (Figure 5). The main flow of the whole system is identical to project the total flow q_s,, as measured with a measuring valve STAM (1).

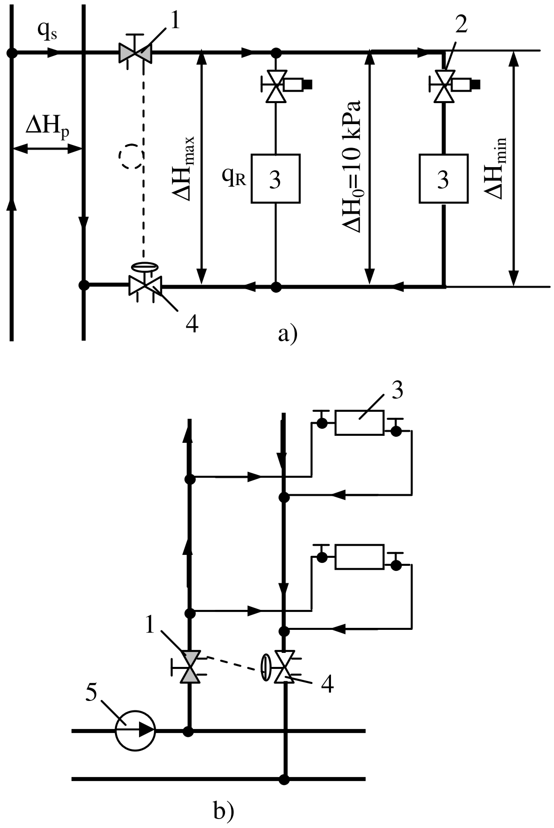

Fig. 5. Differential pressure regulator valve with an automatic STAP entry: a) inner horizontal distribution; b) inner vertical distribution; 1 - measuring STAM valve; 2 – pre-adjustable (presetting) TRV on-off control valves; 3 - terminal unit; 4 - Automatic STAP differential pressure regulator; 5 - pump

The procedure in this case involves balancing [7]:

Step 1. Complete opening by removing the thermostatic heads of all thermostatic valves;

Step 2. Preset these thermostatic valves for a constant differential pressure variation Δp=10 kPa;

Step 3. Adjust the preset pressure variation in the differential pressure controller STAP in order to obtain a total designed flow qs ;

Step 4. Apply the desired differential pressure of 10 kPa to the central area of the circuit.

For residential buildings, the installation of the heating system by an automatic differential pressure regulator STAP in each apartment is absolutely necessary. In these conditions, the temperature of the heat radiators can be adjusted with a central regulator based on the external climatic conditions. The room thermostat is placed in a reference room where the radiator valves are fitted with thermostatic head, so as to ensure adjustment to a valve closed-open (Figure 6).

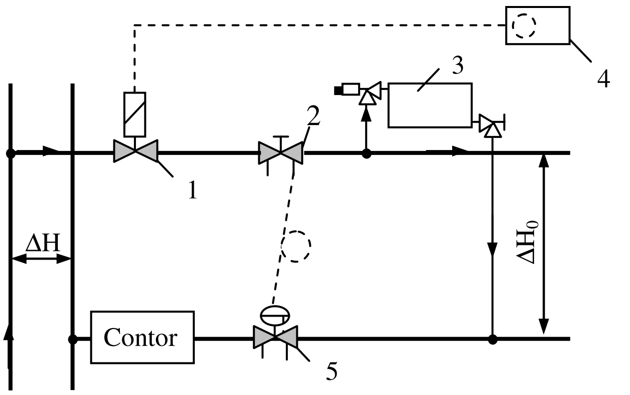

Fig. 6. STAP differential pressure regulator with automatic valve for each apartment: 1 - balancing valve closed-open; 2 – STAM measuring valve; 3 - terminal unit (radiator); 4 - room thermostat; 5 – STAP Automatic differential pressure regulator [4]

To prevent variable pressure losses the open - closed control valve (and possibly heat meter) must not be located in the circuit area where the differential pressure is controlled so that the differential pressure applied to the radiator is not affected.

B. Unfulfilled adiator valves

Valves of the old radiators are not preset but the differential pressure controllers can limit the differential pressure on each circuit. But without restricting flow in radiator valves, the flow can be several times higher in one or more circuits and too little in others, despite the differential pressure setting.

The best solution to this problem is to install the preset and adjusting radiator valves. Their balance principle corresponding scheme in Figure 5. Another solution is to use a STAD type balancing valve and connecting pipe test signal set point before STAD limit. The STAD balancing valve is also designed to measure the total designed flow qs, being included in adjusted circuit (Figure 7).

The preset value of the difference of pressure at the STAP controller is chosen to the minimum of its scope (the pressure delivery), which require minimum height of pumping. With all thermostatic valves fully open, the difference of pressure is adjusted to the STAD balancing valve so that flow to the total designed flow rate can be obtained.

During starting, when all thermostatic valves are open, the total flow is limited to the designed value. When the thermostatic valves close, the available differential pressure is automatically limited to the preset value of the STAP controller. This ensures the correct total flow and limit the given differential pressure value. Unfortunately, this method is not performed at the same time nor need a fair distribution of the total flow between
all the radiators

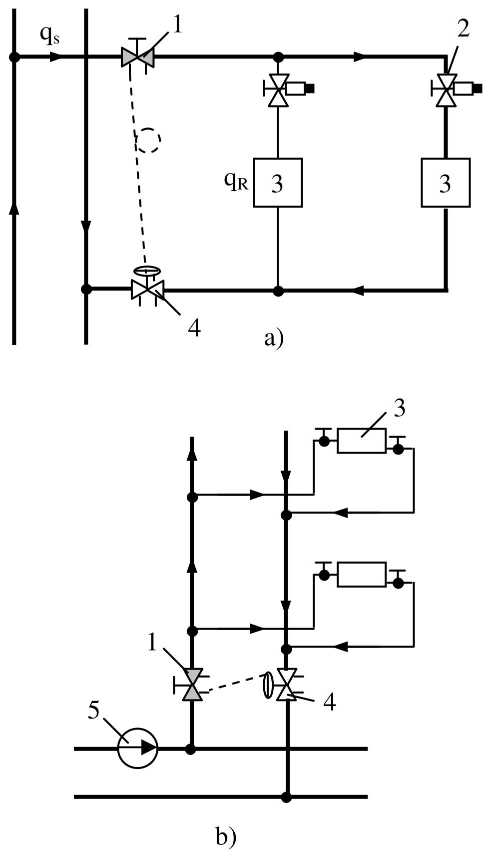

Fig. 7. STAD Differential pressure balancing valve using a STAP automatic differential pressure regulator: a) inner horizontal distribution; b) inner vertical distribution; 1 - STAD balancing valve; 2 – pre-adjustable (presetting) TRV on-off control valves; 3 - terminal unit; 4 – STAP automatic differential pressure regulator; 5 - pump

4. SIZING EQUIPMENT SET

A. Sizing measuring valve STAM

In view of the main functions of a STAM measuring valve (transmission pressure, flow measurement, draining and closing), these components of the distribution networks of heat for domestic heating are available in the size range D_n = (15 ... 50) mm with inner threads G_i = (1/2 ... 2) (Table 1). To accurately measure the flow, the preset is chosen to get, at designed flow, a pressure loss of at least to 3 kPa.

Table 1. Minimum flow rate in l/h and l/s needed to obtain a pressure loss of 3 kPa STAM [7]

No	STAM measuring valve Type	Setting and adequate minimum flow rate [l / h]				Setting and adequate minimum flow [l / s]			
		1	2	3	4	1	2	3	4
1.	DN 15	62	177	520	695	0,017	0,049	0,144	0,193
2.	DN 20	380	715	892	1030	0,105	0,200	0,248	0,286
3.	DN 25	532	1008	1300	1431	0,148	0,280	0,361	0,397
4.	DN 32	771	1689	2234	2529	0,214	0,469	0,620	0,702
5.	DN 40	1199	2321	3152	3585	0,333	0,645	0,875	0,996
6.	DN 50	1628	3187	4538	5698	0,452	0,885	1,260	1,582

Considering, for example, the flow of water in the tub to measure STAM DN 20 to 800 l / h in Table 1 to the flow values corresponding to the four settings of the valve, it is noted that the amount of 800 l / h is less than the limit value 892 l/h for the 3 and above a threshold value 715 l/h to position 2. Position 2 is the most convenient setting, taking into account the pressure loss created in the STAM measuring valve determined by Relations 1 and 2, according to k_v - the valve (Table 2) and the needed designed flow.

Table 2. Values of the k_v adjustment constant depending on the valve size and the setting position

No.	STAM measuring valve Type	STAM kV line with the positions set			
		1	2	3	4
1.	DN 15	0,35	1,02	3,00	4,01
2.	DN 20	2,19	4,13	5,15	5,95
3.	DN 25	3,07	5,82	7,51	8,26
4.	DN 32	4,45	9,75	12,9	14,6
5.	DN 40	6,92	13,4	18,2	20,7
6.	DN 50	9,49	18,4	26,2	32,9

B. Sizing STAD balancing valve

Considering the main functions of STAD balancing valve (transmission pressure, flow measurement, creating a pressure loss, emptying and closing) as a guide for choosing the STAD size can use Table 3. The size range in which such equipment is available from D_n = (15 ... 50) mm internal thread G = (1/2 ... 2). The determination of the appropriate control constant of a desired pressure loss may be performed using the relationship 1 or 2, where:

$$k_v = 0{,}01 \cdot \frac{q}{\sqrt{\Delta p}} \tag{5}$$

$$k_v = 36 \cdot \frac{q}{\sqrt{\Delta p}} \tag{6}$$

Table 3. Sizing STAD balancing valve when the pressure loss is known [4]

No.	Type balancing valve	k_{vs}	Entrained flow range	
	STAD		l/h	l/s
1.	10	1,47	100…430	0,028…0,119
2.	15	2,52	350…750	0,097…0,208
3.	20	5,70	650…1600	0,181…0,444
4.	25	8,70	1300…2400	0,362…0,667
5.	32	14,2	2000…3800	0,556…1,06
6.	40	19,2	2800…5700	0,778…1,58
7.	50	33,0	4500…11000	1,25…3,06
	STA-DR			
8.	15	2,00	200…450	0,056…0,125
9.	20	2,00	200…600	0,056…0,167
10.	25	4,00	600…1200	0,167…0,333

The values of the adjusting constant of balancing valves are shown in Table 4.

Table 4. Values of the k_v adjustment constant of STAD balancing valves with the positions set [4]

No.	Type balancing valve	Rotations							
	STAD	**0,5**	**1,00**	**1,50**	**2,00**	**2,50**	**3,00**	**3,50**	**4,00**
1.	DN 10	0,045	0,090	0,137	0,260	0,480	0,826	1,26	1,47
2.	DN 15	0,127	0,212	0,314	0,571	0,877	1,38	1,98	2,52
3.	DN 20	0,51	0,76	1,19	1,90	2,80	3,87	4,75	5,70
4.	DN 25	0,60	1,03	2,10	3,62	5,30	6,90	8,00	8,70
5.	DN 32	1,14	1,90	3,10	4,66	7,10	9,50	11,8	14,2
6.	DN 40	1,75	3,30	4,60	6,10	8,80	12,6	16,0	19,2
7.	DN 50	2,56	4,20	7,20	11,7	16,2	21,5	26,5	33,0
	STA-DR	**0,5**	**1,00**	**1,50**	**2,00**	**2,50**	**3,00**	**3,50**	**4,00**
8.	DN 15	-	0,107	0,172	0,362	0,645	1,16	1,78	2,00
9.	DN 20	-	0,107	0,172	0,362	0,645	1,16	1,78	2,00
10.	DN 25	0,21	0,36	0,52	1,02	1,85	3,00	3,70	4,01

C. Sizing of STAP automatic differential pressure

Sizing of STAP automatic differential pressure is done for the acceptable value of pressure loss. This value is limited by the differential pressure. In these circumstances, the STAP automatic differential pressure controller is chosen so that this pressure loss does not exceed the following values [7]:

$$\Delta P_{STAP} < \Delta H_{min} - \Delta P_{STAM(STAD)} - \Delta P_v \tag{7}$$

$$\Delta P_{STAP} < \Delta H_{min} - \Delta P_{STAM(STAD)} - \Delta P_s \tag{8}$$

Where:

ΔH_{min} - Minimum admissible differential pressure, [kPa];

$\Delta P_{STAM(STAD)}$ - Pressure loss on the measuring valve (STAD) or balancing valve (STAM), [kPa];

ΔP_v – pressure loss on the control valve [kPa];

ΔP_s – pressure loss on the entire system with control and measuring valves, [kPa].

5. CONCLUSIONS

Heating and ventilation are designed for a maximum load, so if the total load is not obtained because the plant is not balanced for the designed condition, all investments for the whole system are not used.

Unfortunately, control valves, cannot solve this situation, because they are fully open when maximum load is required. Sizing the control valves with two paths is difficult, and some calculated valves are not generally available on the market, which means that they are generally oversized which means that hydraulic balancing is essential and usually represents less than 1% of the total investment for such a system.

A well-balanced plant quickly realized this, with beneficial consequences. 30 minutes to start earning (Gaining 30 minutes at the start), reported at 8 hours of operation, can save around 6% of daily energy consumption, which represents more than all pumping costs.

In a variable flow distribution, the pumping energy is usually less than 5% of the season consumption. This should be compared with the cost of 10 ... 16% for a temperature lower by 1°C in the rooms.

Getting a correct comfort is the best way of saving energy. Therefore, any action to reduce pumping consumption must be taken so as not to adversely affect the operation loops control terminal units.

Another way to reduce the pumping costs is to increase, where possible, the designed temperature variation (ΔT) using variable speed pumps with optimal location of the differential pressure sensor, Δp. PI proportional integrative regulators- require lower flow rates than on-off regulators type and thus reduce pumping costs.

The most important measure is the oversize compensation pump. Balancing valves set the compensation method, draw attention to the excessive size, in which case all excess pressure balancing valve is reported to the nearest pump. When the pump operates properly, with variable speed, this balancing valve is reopened.

Hydraulic balancing requires the correct equipments, modern procedures and effective measuring apparatus. Manual balancing valve remains the most simple and safe product that allows for accurate flow under the design conditions, enabling flow verification for diagnostic purposes. In special cases, differential pressure regulators can be used.

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