Introduction

Scope

This section contains an account of why it is necessary to balance a water distribution system for the distribution of heating or cooling effects, the considerations that should be made before the system is designed, the result of balancing and the difference between a static and a dynamic balancing valve.

What is a balanced system?

Definition:
A distribution system is in balance when the flow in the whole system (through the component terminal lines, distributing lines and main distributing lines) corresponds to the flow rates that were specified for the design of the system.
The dimensioned "hydraulic" condition of operation can be simulated by means of the opening of all the valves regulating the flow depending on the temperature (room temperature, outdoor temperature or medium temperature) either as manual radiator valves, self-regulating thermostatic valves or electrically actuated valves.

In practice it is recommended that balance is established by means of a number of balancing valves that can be pre-set individually to an assessed orifice dimension. Together with the rest of the system they will then establish the exact flow resistances to ensure a correct distribution of the flowing medium.

Figure 2.1 shows an outline of a minor section of a balanced water distribution system. Referring to the figure below the distribution system is in balance when the system contains a number of regulation valves that have been pre-set to be mutually dependent so that the flow through the component terminal lines, distributing lines and main distributing lines corresponds to the flow rates that were specified for the design of the system.

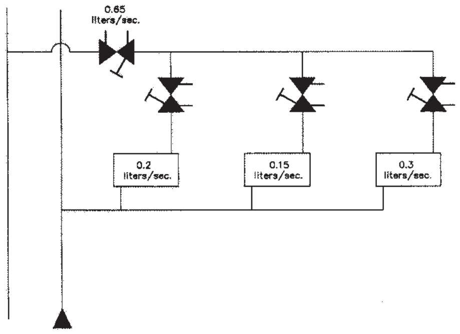

Figure 2.1 A balanced section with a distributing line for three terminals.

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In an analogue electric system the balancing valves are comparable with a variable resistance, and the resistance of the pipes with the corresponding wiring resistance, and the effective heating-/cooling surfaces with a load resistance (fig. 2.2). The distribution of the electric power through the component load resistances, distributing lines and main distributing lines, depends on the distribution of the resistance in the circuit, similarly to a water distribution system.

The need for Balancing

If the correct balancing of the system has not been established, this will result in an unequal distribution of the flow, so that there will be a surplus effect in some of the terminals, whereas the effect will be inadequate in others. The result of this will be that the wanted heating/chilling will not be ensured in all parts of the installation.
In practice it is not possible to make a correctly balanced system by manipulation of the piping or alteration of the pipe dimensions only.

Only a correct adjustment of the balancing valves shown in figure 2.1 will ensure the correct distribution of the flow in the system.

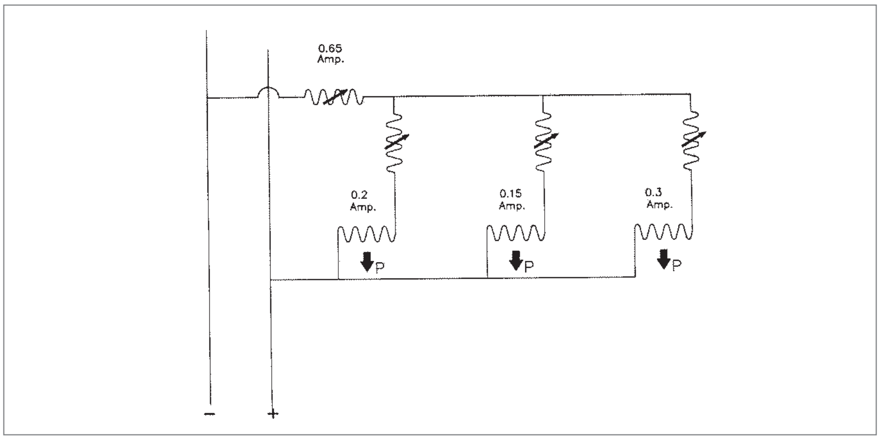

Figure 2.2 An analogue electric system

Design Considerations

The engineer in charge of the design and installation of a system should aim at:

- Substantial operating effectiveness
- Achievement of the required comfort at the lowest operating costs possible
- Avoiding unnecessary waste of energy resources.

For the design and selection of equipment for the balancing and control of a system the following should be taken into consideration:

(A) Type of application
(B) Type of the building in question
(C) The required room temperature/comfort
(D) Type of the hot domestic water supply
(E) Acceptable deviations from the comfort parameters
(F) Minimization of the primary energy
(G) Application of heat recycling
(H) Economic factors

The result of (C), (E) and (F) is very much dependent on the correct distribution of the flow in the system. Therefore the quality of the balancing should meet the the required comfort and energy efficiency.

The quality of the balancing is partly dependent on the type of the required balancing valves (static versus dynamic valves, ref. the following section), compared with the required adjustment method, and partly the design of the required components for the verification of the flow in the system.

The following quality parameters should be specified during the phase of design:

- Type of balancing valves
- Adjustment method
- Verification of flow, where and how?
- Acceptable deviations of the flow

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The Result of Balancing

A satisfactorily balanced installation will show the following results:

- Correct flow in boilers and chillers
- Correct distribution of flow and effect in the whole system
- Compatibility between all flow rates in primary and secondary lines

These results will ensure the following benefits:

- The room temperature is adjustable within the specific deviations
- Energy saving as a result of the favourable conditions of the requipment that controls the energy transfer
- Achievement of the required indoor climate.

Why are Balancing Valves Required?

We answer that question on the basis of figure 2.3

The figure shows a schematic outline of a simple installation that contains a boiler/chiller, three identical terminals with the same flow requirement, and a pump to make the heat transfer medium, i.e. water or water/glycol circulate in the system. The top half of the diagram represents the pressure distribution throughout the schematic layout shown in the lower half of the diagram. The branch 'nodes' are indicated on both the distribution diagram and the schematic by the smae lettering.

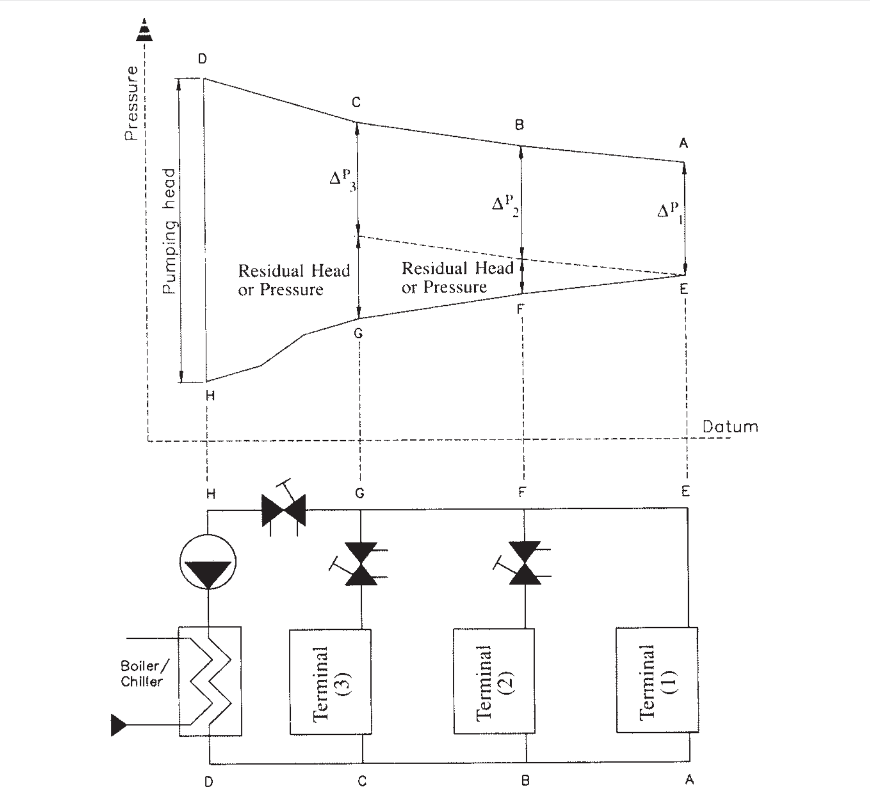

Figure 2.3 Simple installation and its pressure distribution

In the piping there will be friction between the flowing medium and the pipe wall. This frictional loss makes the pressure decrease along the pipe in the direction of the flow. This will be seen from the falling pressure line between the branching points.

The flow rate between two points is determined by the pressure differential between the points and the resistance of pipes, valves and terminals against the flow. The arithmetic coherence can be expressed by the equation below.

$q_v^n = \Delta p / (R \cdot \rho^n)$, in whic

q_v = flow
Δp = pressure drop
R = resistance of pipes, single resistances (fittings, terminals etc.) and valves
n = exponent
ρ = density

The resistance of value R can be read from tables, please see appendix A3.5, and from the respective product catalogues. The exponent n varies in relation to the pipe sizing, please see appendix 3 table A3.5

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The pressure drop $\Delta p1$ is referred to as the 'index circuit'. The index circuit is the circuit that has the highest resistance to flow. It is normal for this to be the circuit most remote from the pump. This pressure drop can be found by means of the equation $\Delta p1 = R_1 \times (q_v \times \text{Þ})^n$, in which the resistance of the terminal R1 and the wanted flow q v are known values.

The pressure drop across the three identical terminals will be the same, provided the same flow is required through all of them, i.e. $\Delta p_1 = \Delta p_2 = \Delta p_3$.
In order to bring about this identical pressure drop across the terminals and associated piping it is necessary to connect another resistance in series with the resistances of the terminals, so that the residual pressure drop between branching points BF and CG can be absorbed.

If the installation in question is not equipped with balancing valves after terminals (2) and (3), the flow through the three terminals will vary so that terminal (3) will be exposed to the major flow, terminal (2) to a smaller flow, and terminal (1) to the smallest flow. In that case the system will not be in the required state of balance.

Figure 2.4 shows the distribution of the pressure drop between branching points BF. From this you will see that the adjustment of the regulating valve to the required resistance value has to be carried out with regard to not only the terminal but also the connecting pipes.

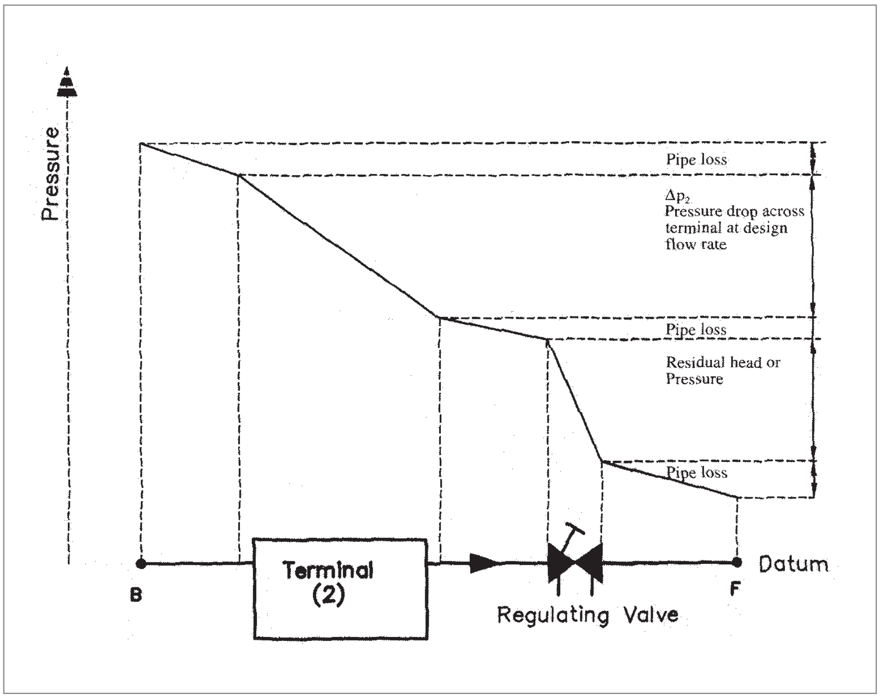

Figure 2.4 Absorbing 'residual' pressure

The final adjustment is usually carried out by indirect measurement of the flow through the regulating valve (ref. chapter 6) simultaneously with measurement of the flow through terminal (1).
The regulating valve to terminal (2) is to be adjusted to ensure that the proportion of the measured flow rates through terminals (1) and (2) is the same as the one between the indexed flow rates between the two terminals.

Hereafter the valve is adjusted to terminal (3) to ensure that the proportion between the measured flow rates through terminals (3) and (2) is the same as the one between the indexed flow rates between the two terminals.

This adjustment method is called the 'proportional method'.

The Difference between a Static and a Dynamic Balancing Valve

Usually you will not find an indication of the resistance value of a valve in valve catalogues and data sheets. On the other hand, the producer always states a flow coefficient referred to as k_V or c_V (American products). This is also called the flow coefficient of the valve.

The flow coefficient of kv is defined to be the flow of water (density 1 kg/liter) through the valve, when the differential pressure across the valve is 1 bar. The designation of this flow is m^3/hour.
The flow coefficient of cv is defined as the flow of water (density 1 kg/liter) through the valve, when the differential pressure across the valve is 1 psi ($lb/inch^2$). The designation of this flow is GPM (US gallon/min.).

Hereafter the mathematic coherence between the flow and the differential pressure of the valve can be expressed as follows:

$q_v = k_v \sqrt{\Delta p/\rho_r}$ q_v in m^3/hour when Δp is in bar (gauge)

$q_v = c_v \sqrt{\Delta p/\rho_r}$ q_v in GPM (US) when Δp is in psi

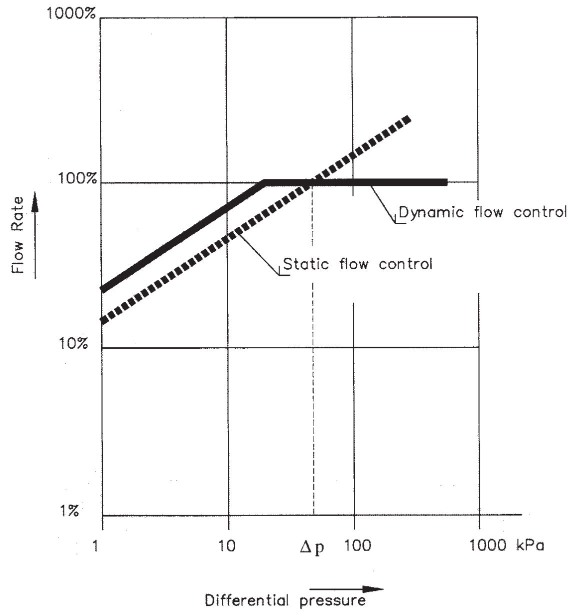

Figure 2.5 The valve features of a static circuit balancing valve and a dynamic circuit balancing valve respectively at a given pre-adjustment value.

As regards the 2-position and balancing valves, the indicated flow coefficient of k_V refers to the completely open valve.

A feature of a static circuit balancing valve is that the open orifice area (kv value) can be changed manually and fixed into a static value. The kv value can now be obtained by referring to the hand wheel position in relation to the calibration graph of the valve. The valve should be equipped with 2 pcs. isolation test plugs to which the measuring equipment for indirect flow measurement can be connected.
The valve can be pre-adjusted on the basis of a calculated pressure distribution in the whole HVAC installation. Please note that the calculation of large, complex installations may involve a considerable inaccuracy. Further, the valve can be pre-adjusted on the basis of an adjustment after the installation, e.g. according to the 'proportional method'.

A dynamic circuit balancing valve is a new balancing valve that was introduced on the market within the last few years. One of its features is that it can be pre-adjusted to a given flow and be locked to ensure this flow. The valve is an automatic regulator valve that with a reference to the differential pressure automatically adjusts to the k_V value necessary to maintain the required flow. The k_V value of the valve automatically compensates for any changes of the differential pressure, so that the flow will never exceed the pre-set flow.

These valves are available in types that have been calibrated in the factory to the rated flow, and in types the indexed flow of which can be pre-adjusted by the user before or after the installation of the valve in the system, or from the outside as the system is working.
The valve can be used on the basis of the calculated flow without regard to the distribution of pressure in the system.

Figure 2.5 illustrates the difference between the static and the dynamic application in the form of flow variation as a function of the differential pressure across the valves at a given pre-adjustment.

As will be seen from the chart, the flow through the static valve will increase as the differential pressure increases, and decrease as the differential pressure falls, whereas the dynamic balancing valve will maintain a constant flow (within the regulation range) independently of the differential pressure within the dynamic balancing valve.

Further, please note that the indexed flow (100 %) through a static balancing valve will not be achieved unless the differential pressure across the valve is equal to the indexed differential pressure $\triangle$p.

When are Flow Measurement Devices required?

Static Systems: During the adjustment it should be possible to measure the flow through each terminal (coil in air-condition, not radiators in heating systems), distributing line, main distributing line and supply line.
The measurements will typically be carried out as an indirect measurement, i.e. measurement of the differential pressure converted into a flow value in relation to the k v value of the measured device. The measurements are carried out across each circuit-balancing valve with the k v value relative to the valve setting and the associated flow chart.
The accuracy of the measured flow is not likely to be better than +/- 25 % dependent on the hand wheel position. This inaccuracy should be taken into consideration in connection with the verification of the flow. Still, it is of no particular importance to the relative comparison between the flow through the individual terminals and distributing lines during the balancing procedure.

Dynamic Systems: Dynamic valves will typically balance the system at an accuracy of +/- 5 % of the rated flow.
So, as direct measurements involve a degree of accuracy of +/- 25 %, it will be inappropriate to verify the flow through the individual terminals.
Instead, measurement/verification of the flow in the supply line is recommended.
For verification of the flow in the supply line it is recommended that a fixed orifice device is used with a specified accuracy which is +/- 5% above that of the measured flow.

Where are Balancing Valves required?

Figures 2.6 and 2.7 show a section of the same system, in which figure 2.6 has been designed as a static system, and figure 2.7 as a dynamic system. The section contains one supply line for 3 main distributing lines, each of which has 3 distributing lines with 3 terminals each (totally 27 terminals).

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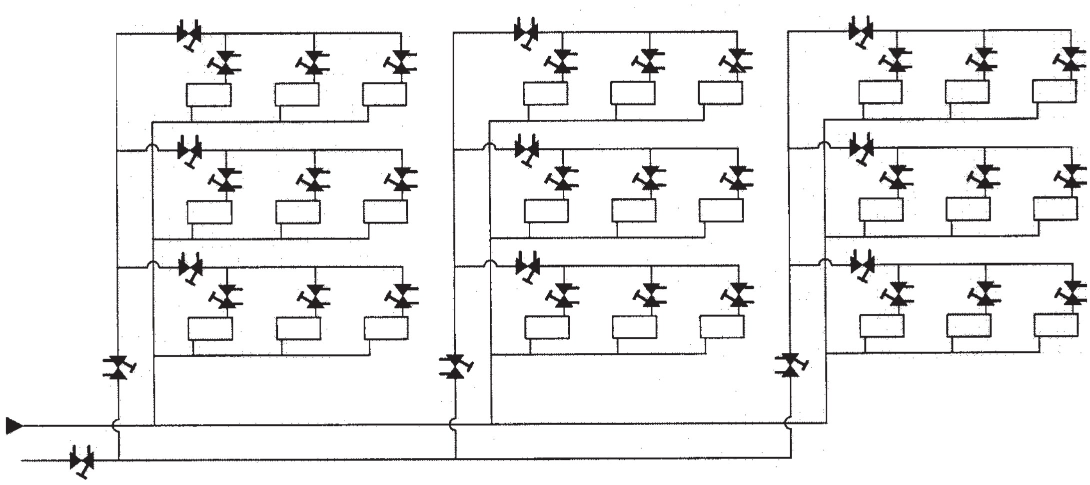

Figure 2.6 Water distribution system, static balancing

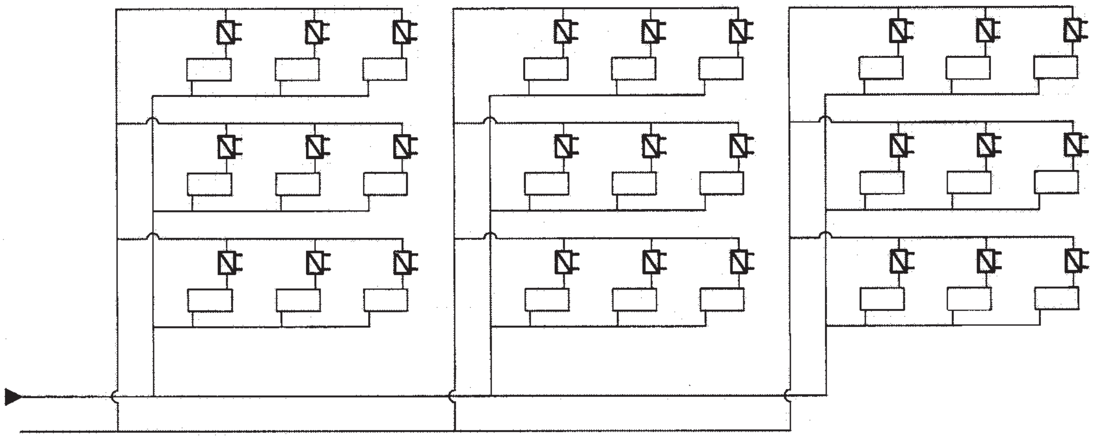

Figure 2.7 Water distribution system, dynamic balancing

In the static system each terminal has to be balanced in 9 groups of 3 terminals each. Hereafter the 9 terminal sections have to be balanced in 3 groups of 3 distributing lines each. After that the 3 main distributing lines have to be balanced. And finally the distributing line is adjusted to ensure the total design flow. This balancing procedure requires one balancing valve per terminal, one balancing valve per distributing line, one balancing valve per main distributing line and one balancing valve in the supply line.

In the dynamic system the individual terminals can be adjusted independently of each other. This simply requires one balancing valve per terminal.

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Why use Dynamic Balancing instead of Static Balancing?

The adjustment of a dynamic system is quick and easy. All that is needed is the right pre-adjustment/balancing valve specified for the rated flow. There is no need for measurements for making comparisons between the flows of the individual balancing valves.

When the features of an installation are to be calculated, the only uncertain factor will be any inaccuracy in the calculated flow rate. When a dynamic balancing valve is used the uncertainty regarding the distribution of pressure in the installation and consequently the calculated kv values of the balancing valves is eliminated.

Balancing valves are only needed for the individual terminals. There is no need for balancing valves in the distribution lines, main distribution lines and supply lines.

The individual terminals are 100 % safe from overflow without regard to the load distribution in the installation and independent of the dynamic load variation in the installation. In an properly balanced static system overflow (up to 300-400 %) may occur through some of the terminals.

The rated flow can be changed in one or more sections of the installation without upsetting the balance in the rest of the system. If the dimensional basis of the whole system turns out to be wrong after the installation, a static system can only be re-adjusted if the whole installation is re- adjusted.

The result of the adjustment is better when compared to static balancing, because the rated flow is controlled at an accuracy of +/- 5%.

After the installation the system can be changed/extended/restored without regard to the changes of the balance in the existing part of the system. In a corresponding static system this would often involve a change of the total design of the system.

From the foregoing, the following benefits of dynamic balancing can be stated:

- **Quick and easy adjustment**
- **Independent of errors/unreliabilities in the calculated distribution of pressure in the installation.**
- **Fewer balancing valves**
- **100 % safe from overflow**
- **Unproblematic re-adjustments**
- **More effective adjustment**
- **Great flexibility if the system is changed after the installation**

Due to these benefits the features of the system design will typically be as follows:

- **Cheaper installation**
- **Better comfort**
- **Greater flexibility**
- **More economical operation**

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