Content

1. Introduction 3

1.1 General description 3

1.2 History of hydronic balance 3

2. Technical description 4

2.1 Hydronic regulation at the radiator 4

2.2 Hydronic balance of the pipework 4

2.3 Methods of calculation 5

3. VOB 7

4. Potential of energy saving 8

4.1 General information 8

4.2 Calculation of the potential of energy saving 8

4.3 Energy saving in exemplary projects 9

5. How to carry out hydronic balance 10

6. Conclusion 10

Explanation

This professional information explains that the hydronic balance of heating and cooling systems is necessary and that it comes up to the great demands on the techniques for energy saving.

This brochure describes the hydronic balance and shows the potentials for energy saving. It is addressed to the specialised trade and shall be of help for the exploitation of this field of the market at the end user.

This professional information was written in cooperation with:

Consulting engineer Dr.-Ing. Hans-Joachim Koch, Bielefeld, Germany

Oventrop GmbH & Co. KG, D-Olsberg, Germany

Imprint

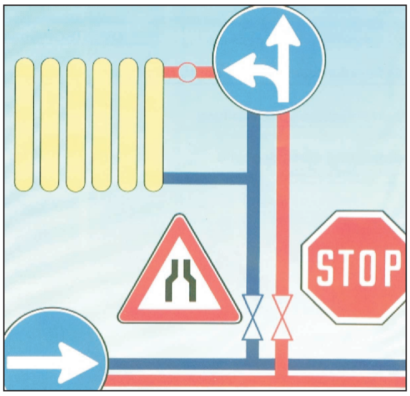
Published by: Zentralverband Sanitär Heizung Klima
Rathausallee 6, D-53757 St. Augustin
Telephone (0 22 41) 2 90 56 - 58
Telefax (0 22 41) 2 13 51 oder 2 11 31
E-Mail Zentralverband-SHK@t-online.de
Internet http://www.wasserwaermeluft.de

1. Introduction

1.1 General description

The hydronic balance of the pipework in buildings is not only an economic and ecological necessity but it is also required according to the DIN standards and decrees (e.g. VOB/C – DIN 18380).

Hydronic balance is the limitation of the volumes of flow to values corresponding to the heat demand of the installation (see illustr. 1).



***Illustr. 1:** Regulation of the volume of flow within the pipework*

Each heating system with separate heat production and transfer of the heat to the heating zone is confronted with the problem of the correct distribution of heat covering the required demand. The same applies to cooling systems.

The tiled stove of bygone times elucidates the problems of an uneven heat distribution. At the oven it is too warm and the area of the outer walls is too cold.

The pumped hot water system which is nowadays usual, distributes the heat evenly according to the required demand in all rooms which shall be heated. This distribution of heat calls for a volume of flow which is distributed within the pipework according to the required heat demand.

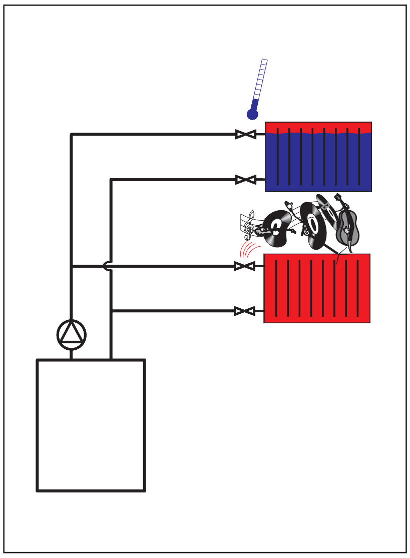
Unfortunately, this is not given in most cases. Following the principle of lowest resistance, the heating water flows back to the heating core on the shortest way. Normally this way leads through the radiators situated closest to the circulation pump so that an insufficient quantity of heating water reaches the radiators situated at a more distant and unfavourable point within the pipework. This results in insufficiently heated rooms and overheated rooms near the heating core (see illustr. 2).

Practice shows that this problem is often misjudged. Very often, too small pumps, too low flow temperatures or a too small heat producer are thought to be the reason for the insufficient distribution of heat. As a consequence, too large pumps are installed, the flow temperature is exceeded or the setting of the heating system is misadjusted.

This results in flow noises within the heating system, overheated rooms and rooms with insufficient heat supply (see illustr. 2).

Moreover, this is coupled with an increased energy consumption for heat production and distribution.

With an optimum use of energy this problem can only be solved by a **hydronic balance** producing the same resistance for all radiators within the network of heat distribution. By doing this demanding job, the skilled plumber may offer a comfortable and economic heating system to his customers.



***Illustr. 2:** Problems caused by an insufficient distribution of heating water within the pipework*

Advantages of hydronic balance:

- Saving of energy
- Environmental care
- Comfort (no over- or undersupply, no noises)
- Fulfilment of the corresponding rules and their control by means of a documentation (e.g. records or energy passport)

1.2 History of hydronic balance

In the heating systems with gravity circulation of bygone decades, a sufficient quantity of heating water was led to the radiators by means of the thermal buoyancy via the cross sections of the pipes. The next step towards an adaptation of the water quantity was the realisation of fixed resistances in the form of valves within the pipework and at the radiator.

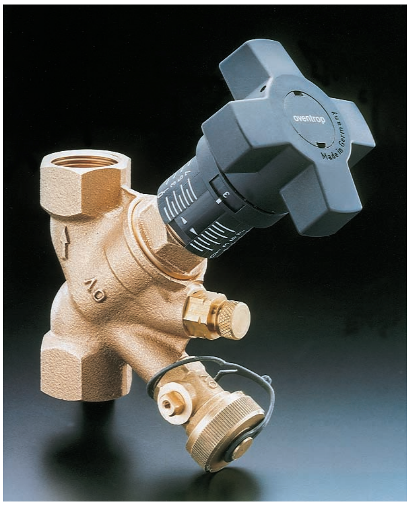
In Germany, the shortage and the involved rise in costs of heating energy (oil crisis) at the beginning of the seventies, led to the first "Decree for energy saving demands to heating- and domestic water installations" of 1978.

This decree and the following Decree for Heating Installations (HeizAnlV) as well as the resulting heating cost accounting based on the effective consumption lead to the demand for a more economic and comfortable hydronic balance.

The result were new valves, controls and regulators distributing the volume of flow within the heating system according to the demands.

§ 7 of the Decree for Heating Installations (HeizAnlV) called for an automatic individual room temperature control of these heating systems and this demand is fulfilled by the installation of thermostatic radiator valves.

The progressive computer technique accompanied this development with even better, more comfortable and useful software programmes for the calculation of the pipework.



***Illustr. 4:** Double regulating and commissioning valve "Hydrocontrol"*

2. Technical description

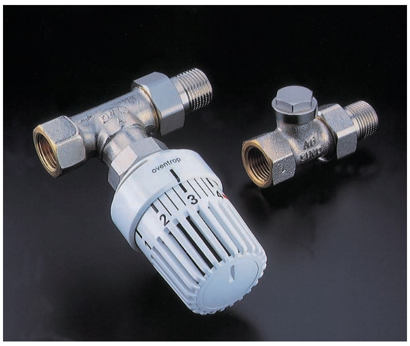
2.1 Hydronic regulation at the radiator

The hydronic balance of a water distribution system depends on a number of facts which may not be calculated easily. This is why an exact balance of the system may only be carried out by means of a calculation of the heat demand and of the pipework.

The following steps of calculation are necessary for the hydronic balance:

- calculation of the heat demand for each individual room
- calculation of the heating surfaces and their volume of flow taking the resulting, effective return temperatures into consideration
- calculation of the pipework with the calculated volumes of flow of the radiators

An important step is the regulation when bringing the installation into operation. Here, the adaptation of the volume of flow and the presetting at the thermostatic radiator valve prove to be of advantage and the industry offers fully developed systems of valves and controls for radiators. Especially presettable thermostatic radiator valves and radiator lockshield valves allow the adaptation of the volume of flow by means of the presetting at the radiator (see illustr. 3).



***Illustr. 3:** Thermostatic radiator valve and radiator lockshield valve*

The scale at the valve body allows a quick setting of the calculated value of presetting. That's how the adapted radiator output according to the calculation of heat demand is guaranteed.

A high valve authority has to be considered when choosing the thermostatic radiator valves. That's how the regulation of the room temperature via the thermostatic radiator valve (e.g. valves with fine presetting) is improved.

2.2 Hydronic balance of the pipework

Volumes of flow and differential pressures exceeding the permissible design range may perhaps cause noises at the radiator. This is why they have to be throttled within the pipework by means of suitable double regulating and commissioning valves or differential pressure regulators.

Here, the industry also offers fully developed balancing systems. The specialist will have to decide for each individual case which valve or regulator has to be installed from the economical point of view.

➢ Double regulating and commissioning valves

Double regulating and commissioning valves are installed in hot water central heating systems and cooling systems and permit an adaptation of the volumes of flow between the various circuits of the system (see illustr. 4).

The regulation of the double regulating and commissioning valves may be carried out with the system in operation which guarantees realistic flow values during full demand

***Illustr. 5:** Regulation by means of the flow meter "OV-DMC 2"*

periods or within the design range (see illustr. 5).

➢ Differential pressure regulators

Differential pressure regulators are proportional regulators working without auxiliary energy. They are required for a constant regulation of the necessary nominal value.

Differential pressure regulators are designed for use in heating or cooling systems to maintain a constant differential pressure within a necessary proportional band (see illustr. 6).

***Illustr. 6:** Differential pressure regulator "Hydromat DP"*

➢ Flow regulators

Flow regulators are installed as proportional regulators without auxiliary energy for a constant regulation of the set flow rate. They are designed for use in heating or cooling systems to maintain a constant flow within a necessary proportional band (see illustr. 7).

2.3 Methods of calucation

According to the VOB/C-DIN 18380 standard, the heat demand has to be taken into consideration when calculating the heating water circulating within the pipework. Corresponding software programmes make this job easier. Pipe dimensions and presetting values are automatically assigned to the valves and controls within the pipework and at the radiators.

Moreover, the software programmes with CAD-support also allow the illustration of the pipework and all other components of the installation. All valves and controls as well as presetting values are assigned correspondingly and are defined in a general drawing.

Should a pipework calculation be impossible, e.g. in case of refurbishment, the calculation may be based on approximate values.

With an estimated differential pressure of 200 mbar at the valve, "acceptable" set values are obtained in small installations with a pump head of about 200 mbar and in large installations with a decentralised regulation of differential pressure to approximately 100 mbar per pipe.

With a **known heat demand** and a fixed temperature difference, the volume of flow of the individual radiator and the presetting at the valve are obtained.

***Illustr. 7:** Flow regulator "Hydromat Q"*

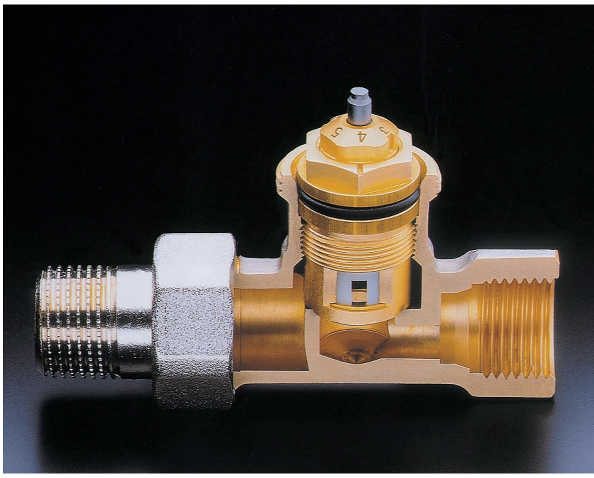
Example 1:

Q	=	1200 W
$\Delta\vartheta$	=	20 K
c	=	1.163 W*h/(l*K)

$$\dot{V} = \frac{Q}{c * \Delta\vartheta} = \frac{1200}{1.163 * 20} = 52\, {}^{l}\!/_{h}$$

1) Formula signs and units see below

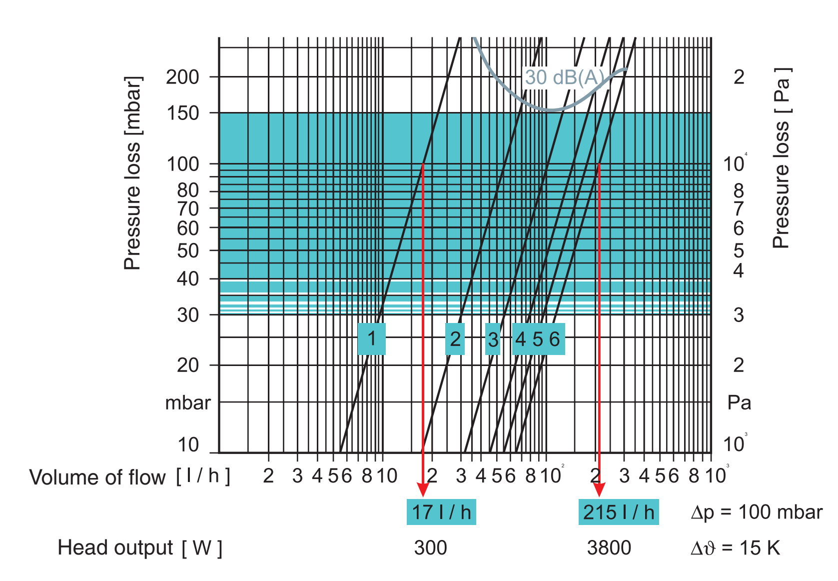
With the volume of flow of 52 l/h and the differential pressure of 100 mbar, a presetting value of 2 can be taken from the design chart (see illustr. 8 and 9).



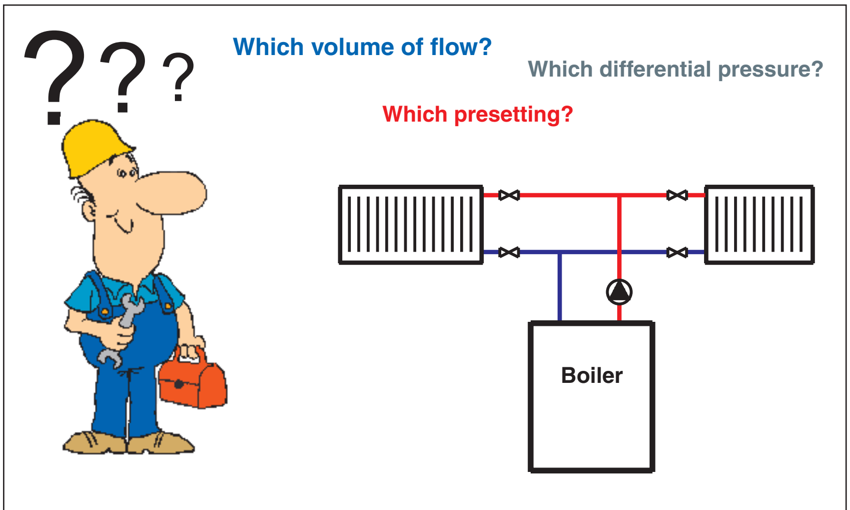
***Illustr. 8:** Thermostatic radiator valve "Series AV 6"*

If the heat demand of the room is unknown, it is possible to calculate the heat demand following § 4, paragraph 2 of the Decree for Heating Installations (HeizAnlV) under the given fringe conditions.

Formula sign	Designation	Unit
Q	Heat demand	W
Q_{spez}	Specific heat demand	W/m²
$\dot{V}$	Volume of flow	l/h
$\Delta\vartheta$	Differenz	K
c	Converted spec. heat capacity	W*h/(l*K)



Illustr. 9: *Design chart of thermonstatic radiator valve „Series AV 6"*



Illustr. 10: *Hydronic – The unknown character in our heating installation*

Example 3:

House with several flats with:
Q_{spez} = 70 W/m^2
$\Delta\vartheta$ = 15 K

$$\dot{V}_{spez} = \frac{Q_{spez}}{c * \Delta\vartheta} = \frac{70}{1.163 * 15} = 4 l/(h * m^2)$$

Room surface A_R = 24m^2

$$V = V_{spez} * A_R = 4 * 24 = 96 l/h$$

Design 1 Presetting value = 3 (see illustr. 12) with a thermostatic radiator valve of the "Series AV 6"

Design 2 Presetting value = 5.7 (see illustr. 13) with a thermostatic radiator valve of the "Series F"

The more a correct calculation is replaced by estimated values, the larger are the tolerances. However, results which are achieved on the basis of realistic estimated values, allow a control of the hydronic balance of the installation. This is how the circulating water quantities can be reduced by more than 50%.

The important thing is that volumes of flow e.g. of 300% or only 20% (over- and undersupply) do not occur in the installation. Volumes of flow between 90 and 120% are absolutely tolerable (see illustr. 14).

§ 4, paragraph 2 of the Decree for Heating Installations (HeizAnlV) of 1994 says that in houses with 1 or 2 flats a specific heat output of 100 W/m^2 and of 70 W/m^2 in houses with more flats may not be exceeded. (see illustr. 10 and 11).

Example 2:

House with several flats with:
Q_{spez} = 70 W/m^2
Room surface A_R = 24m^2
is Q = 1680 W
$\Delta\vartheta$ = 15 K

$$\dot{V} = \frac{Q}{c * \Delta\vartheta} = \frac{1680}{1.163 * 15} = 96 l/h$$

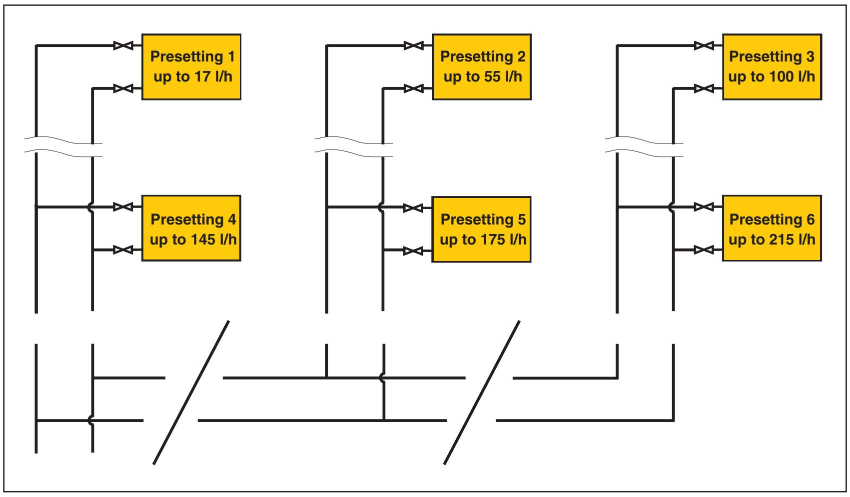
The Decree for Heating Installations limits the max. specific heat demand to:

- House with one/two flats max. 100 W/m^2
- House with several flats max. 70 W/m^2

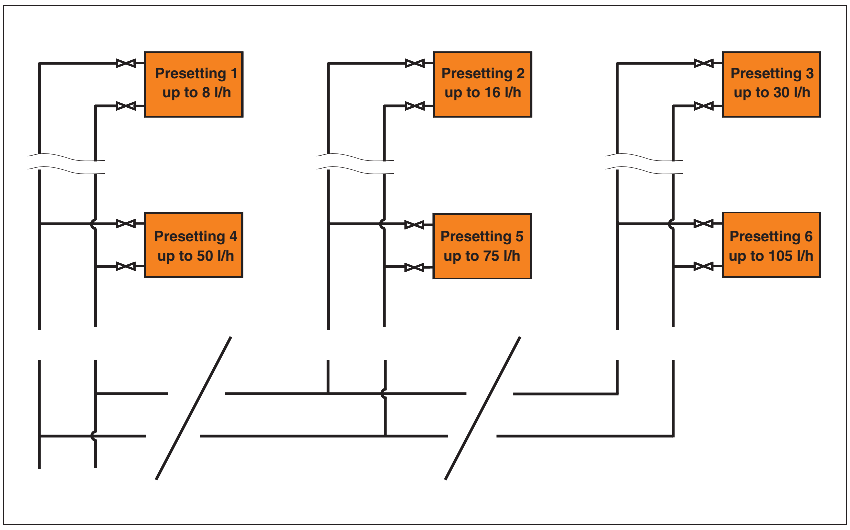
This means a volume of flow of: $\dot{V} = \frac{\dot{Q}}{1,163 \times \Delta\vartheta}$

Residential buildings	Specific heat demand	Specific volume of flow per m^2, Effective surface with a temperature difference of		
	q_{spez}	20 K	15 K	10 K
up to 2 flats more than 2 flats	100 W/m² 70 W/m²	~4,3 l/h ~3,0 l/h	~6,5 l/h ~4,5 l/h	~8,6 l/h ~6,0 l/h

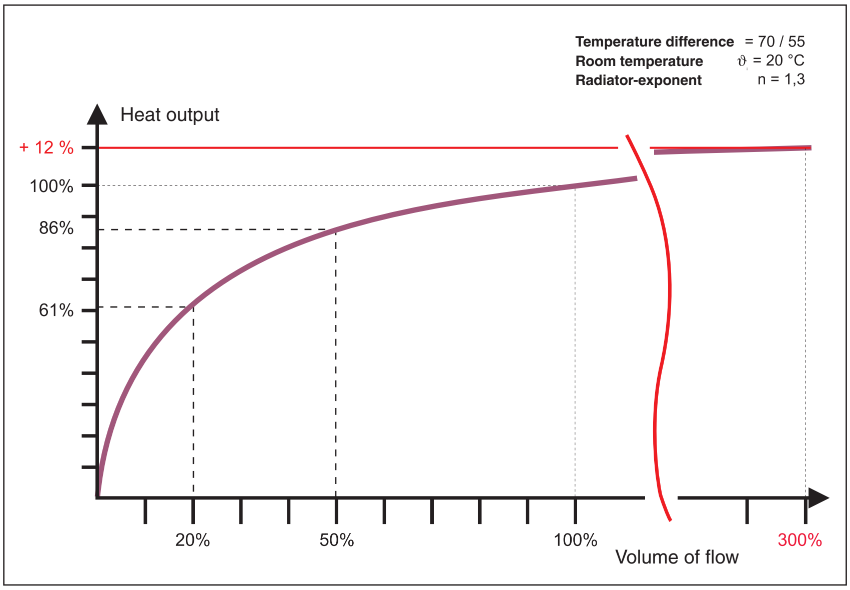
Illustr. 11: *Estimated designation of the volumes of flow of the radiators related to the room surface*



***Illustr. 12:** Presetting of the Oventrop thermostatic radiator valves "Series AV 6" based on a pressure loss of 100 mbar over the valve*



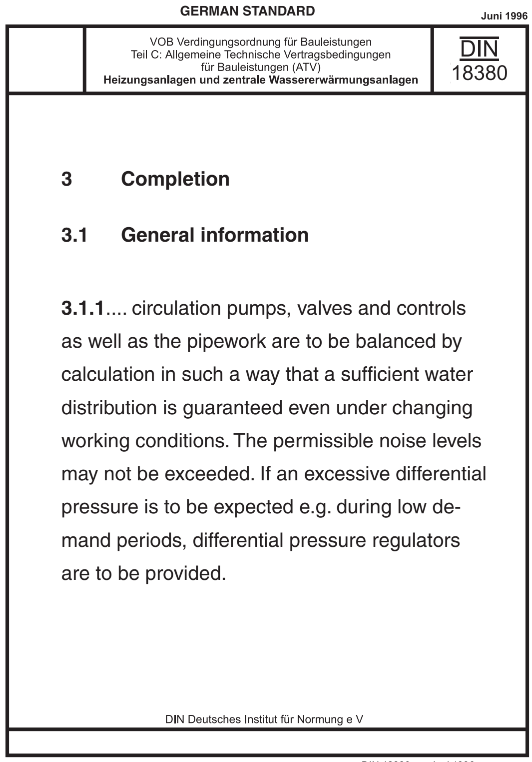
***Illustr. 13:** Presetting of the Oventrop thermostatic radiator valves "Series F" based on a pressure loss of 100 mbar over the valve*



***Illustr. 14:** Heat output depending on the volume of flow*

3. VOB

According to the VOB/C – DIN 18380 standard, a hydronic balance has to be carried out in each heating installation (see illustr. 15).



GERMAN STANDARD | Juni 1996

VOB Verdingungsordnung für Bauleistungen
Teil C: Allgemeine Technische Vertragsbedingungen
für Bauleistungen (ATV)
Heizungsanlagen und zentrale Wassererwärmungsanlagen

DIN 18380

3 Completion

3.1 General information

3.1.1.... circulation pumps, valves and controls as well as the pipework are to be balanced by calculation in such a way that a sufficient water distribution is guaranteed even under changing working conditions. The permissible noise levels may not be exceeded. If an excessive differential pressure is to be expected e.g. during low demand periods, differential pressure regulators are to be provided.

DIN Deutsches Institut für Normung e V

***Illustr. 15:** Extract from the VOB/C – DIN 18380 standard*

Moreover, the VOB/C – DIN 18380 standard, paragraph 3.5.1 says that the hydronic balance has to be carried out in such a way that a sufficient quantity of heating water according to their heat demand is supplied to all heat consumers. This is also valid after a room temperature setback or when the operation of the heating system was interrupted.

The VOB is, however, very often not respected. This means that many heating systems do not fulfil the valid rules and do not correspond to the latest developments in technology.

4. Potential of energy-saving

4.1 General information

One heating system may not be compared with the other and for this reason, the potential of energy saving of a heating system may not be generalised. Acceptable statements are based on estimates and on experiences gained in the past. According to that, 80-85% of all the buildings in Germany are not balanced according to the VOB/C – DIN 18380 standard. This means that too high volumes of water flow uncontrolled within the pipework of individual systems resulting in a too high energy consumption and additional heat losses.

Based on the average figures of energy consumption according to the VDI 3808 within the buildings in the Federal Republic of Germany, the energy saving for residential buildings is 10–30 kWh/(m^2*a) and for administrative buildings 6 to 17 kWh/(m^2*a) assuming an estimated potential of energy saving of about 5-15%. For a residential building with a heated surface of 140 m^2 and an annual level of utilisation of 85% of the heat production, this already means a saving of 150 to 450 l of heating oil per year.

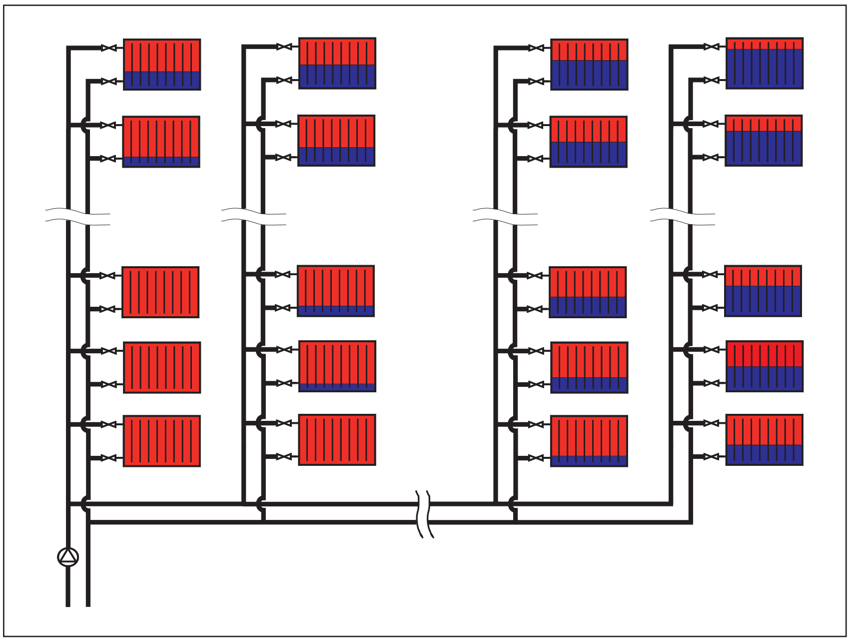
This corresponds to an annual reduction of the carbon dioxide emissions by 450 to 1300 kg.

4.2 Calculation of the potential of energy saving

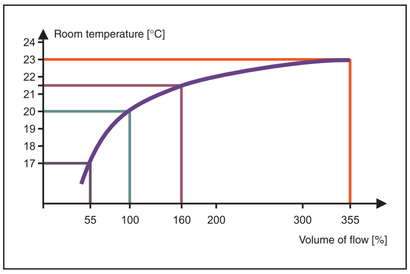
An exact estimation of the enery saving resulting from a hydronic balance is almost impossible. The faulty influences on the different systems of heat distribution are varying. Moreover, it is very difficult to generalise the behaviour of consumers.

A temperature control by means of the window (overheated rooms) as well as the degree of increase of the flow temperature or the pump capacity may not be calculated in advance.

Mainly, the potential of energy saving is attributed to the following effects:



Illustr. 16: *The missing hydronic balance within the heating system results in a wrong heat transport towards the radiators*



Illustr. 17: *Effect of the volume of flow on the room temperature with a constant heating surface*

➢ Excessive room temperature

An increased heat output is caused in the radiators with an excessive volume of flow. The thermostatic radiator valves tend to produce noises as they are not designed for the high volumes of flow. The consumer often opens the thermostatic radiator valves to reduce the noise production. The result is too high a room temperature (see illustr. 17). An increase of the room temperature by 1°C causes an energy loss being about 6% higher. A control of the room temperature by means of the window causes considerably higher losses.

➢ Higher flow temperatures

An increase of the flow temperature causes higher heat losses of the heat producer (losses of exhaust and heat emission). Moreover, the pressure loss within the pipework is increased which results in a room temperature increase in unheated areas, e.g. cellar rooms.

➢ Characteristic values according to VDI 3808:

Theoretically the following modifications in energy saving are caused by changing the parameters of the installation according to the design algorithms of the VDI 3808 as follows:

- Room temperature: with an increase of the room temperature by 1 Kelvin, the heat losses rises by about 6%

- Loss of exhaust:
  Increase of the exhaust temperature by 20 Kelvin = increase of the exhaust loss by 1.2%

- Loss of heat emission:
  Increase of loss of heat emission by 0.25% when increasing the boiler temperature by 10 Kelvin

- Loss in distribution:
  Increase of loss in distribution by 1.5% when increasing the average heating water temperature within the pipework by 10 Kelvin

- Window control:
  Heat loss depending on behaviour of consumer

With the described loss factors, an energy saving of about 5-15% related to the complete heat producing- and heat distributing installation can be achieved by carrying out the hydronic balance of the system.

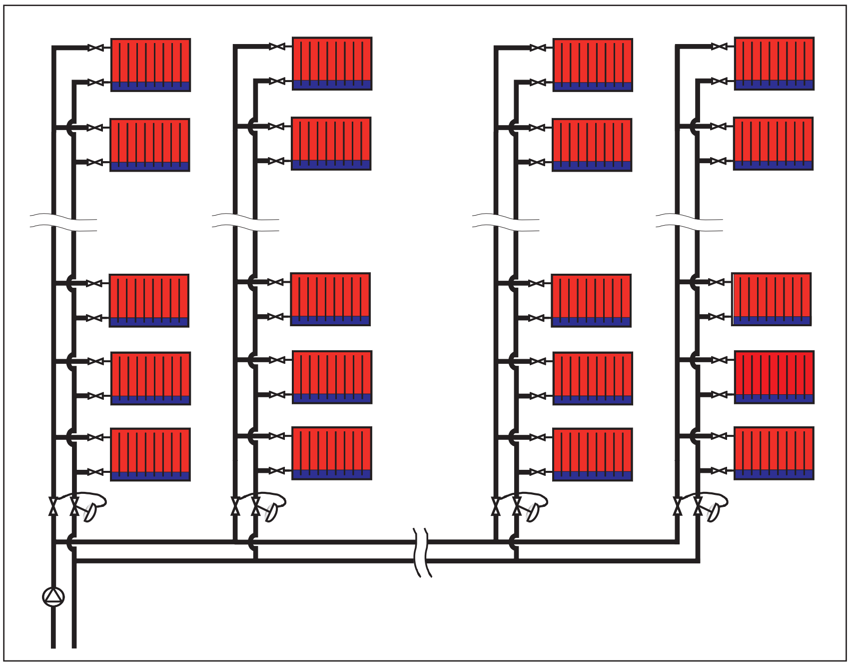
➢ Increased volume of flow of the circulation pump

An increased volume of flow of hot water (for the supposed elimination of the faults) within an unbalanced network of distribution leads to an increased energy consumption of the circulation pumps. With a calculated nominal pressure loss and a halving of the volume of flow, the consumption of driving energy can be reduced by 10 to 20%.

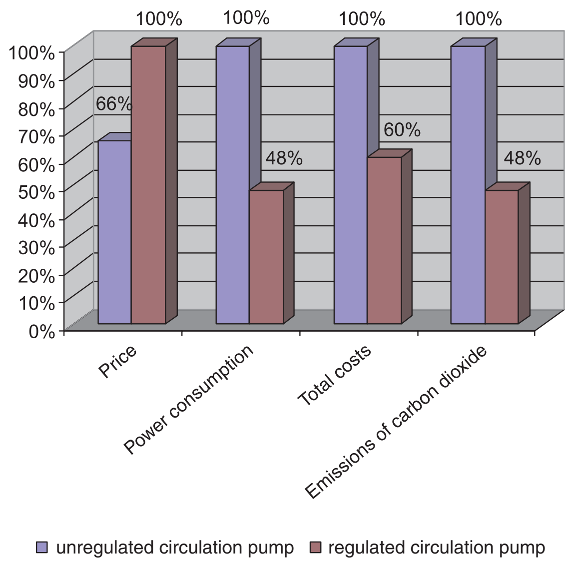
Note:

A hydronic balance is not always related to additional costs. As the running costs of the installation will be reduced by the hydronic balance, the necessary investments will soon amortise. Moreover, the carbon dioxide emission will be reduced.

An investigation (study: reduction of the carbon dioxide emission by refurbishing the pumps by Prof. Dr.-Ing. Bach, University of Stuttgart) revealed that the power consumption of circulation pumps in Germany is three times higher than necessary. Cautious predictions beyond the study even show that a hydronic balance of the heating system during refurbishment works in combination with an electronically regulated circulation pump will help to reduce the energy consumption of the pump by about 40% (see illustr. 19).



***Illustr. 18:** A correct heat transport towards the radiators due to a hydronic balance guarantees a troublefree operation of the system*



***Illustr. 19:** Possibility of energy saving by using electronically regulated circulation pumps; Source: Grundfos GmbH, Wahlstedt*

4.3 Energy savings in exemplary projects

Example: Potential of energy saving with a regulated pump

A pump capacity of about 50 Watt is required for the heat distribution in a house with 2 flats with a heat demand of 20 kW. If a 90 Watt pump is installed, the power consumption is 40 Watt too high. With 6000 working hours per year, this amounts to 240 kWh, which means additional costs of about 31,– € per year with a price of 0,13 €/kWh.

With the 20 million circulation pumps which are installed in Germany an potential of energy saving of

- Electric driving energy:
  2.2 billion kWh/a

- Emissions of carbon dioxide:
  1.32 million t/a

can be considered to be realistic. Two thirds fall to houses with 1 to 2 flats.

5. How to carry out hydronic balance

Illustr. 20 shows how to carry out hydronic balance. A distinction is made between new and existing installations (case of refurbishment).

According to the VOB/C – DIN 18380 standard, the person placing the order has to place the data required for the hydronic balance at the disposal of the person carrying out the job before starting the installation.

Important:

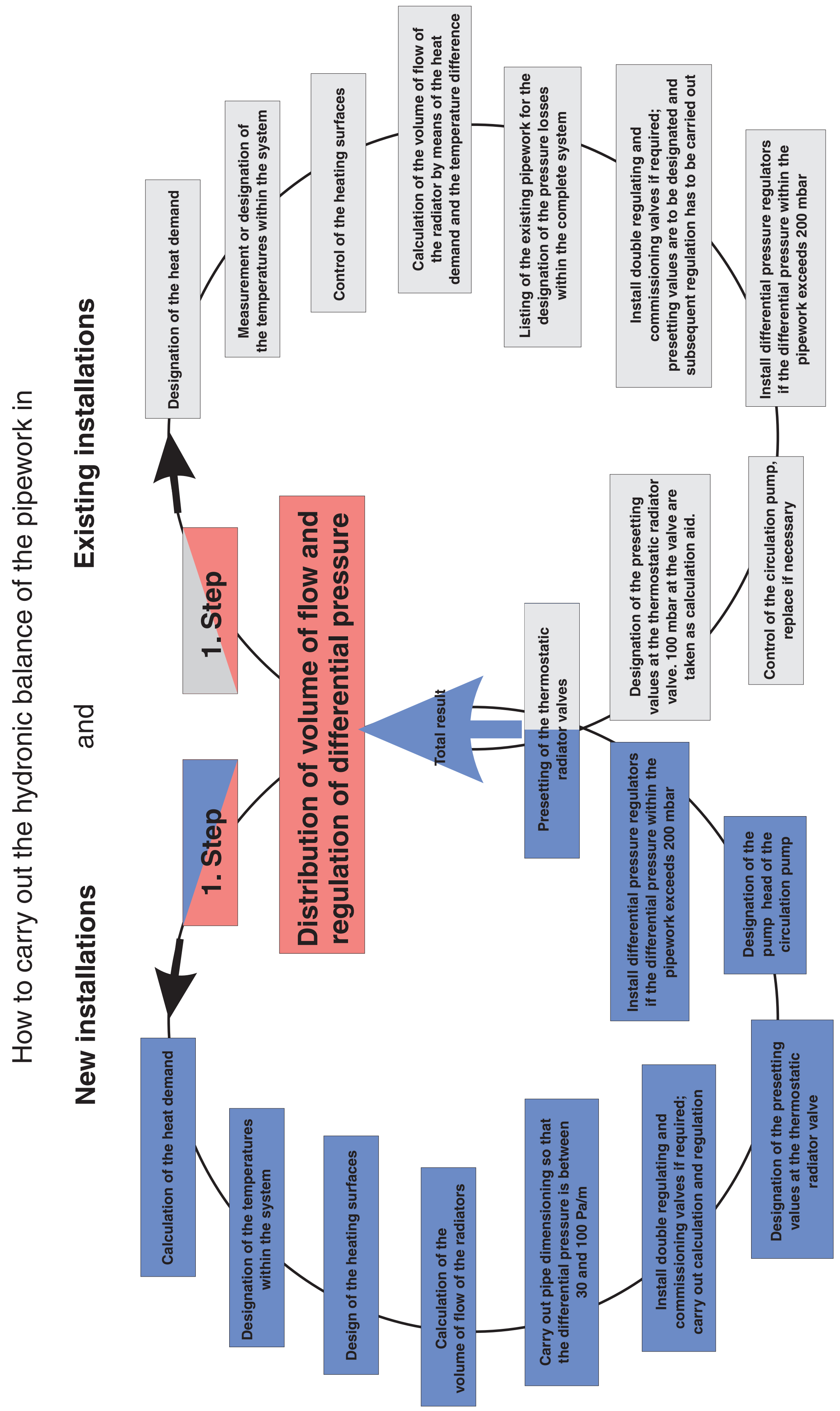
The calculation of the data required for the hydronic balance as well as the documentation is not to be considered as a minor job according to VOB, but as an additional job the person in charge has to be paid for separately.

6. Conclusion

A professional design and realisation of an installation including the hydronic balance according to the VOB/C – DIN 18380 standard reflects the competence of the plumber.

The documentation of the jobs which were carried out, the introduction to the dealing with the balanced system as well as the guarantees made by a master craftsman's company give the necessary security to the customer. Moreover, the documentation of the hydronic balance and a possible "energy passport" increase the market value of the real estate.

The reliable operation of the installation, a high degree of living comfort and a costcutting operation of the system justify the installation of high quality components which will amortise within a few years.



In new or existing installations, different procedures lead to a good balance, if the designation of the required values is carried out by means of a thorough calculation or in another way. The goal is an exact regulation of the volumes of flow at the radiator. The thermostatic radiator valve has to be protected against a too high differential pressure.

Illustr.: 20: *How to carry out hydronic balance*