1. The design flow must be available at all terminals

Common Problems

Problems, typical indicating that condition number one is not met:
- Too hot in some parts of the building, too cold in other parts.
- Installed power is not deliverable at intermediate and/or high load.
- Long delay before the desired room temperatures are obtained at start-up after each setback.
- Higher than expected energy costs

Obtaining the correct flows.

The power transmitted by a terminal unit depends on the supply water temperature and the water flow. These parameters are controlled to obtain the required room temperatures. Control is only possible if the required water flows are available and to obtain the required flows, they must be measured and adjusted. This is why hydronic balancing is essential.
The discussion is limited to the question: How do you do it? Is it, for instance, possible to obtain a correct flow distribution by sizing the plant carefully? The answer, in theory, is yes. But in practice, it’s just a dream. Production units, pipes, pumps and terminals are designed to cover the maximum need. If a link of the chain is not properly sized, the others will not perform optimally. As a result, the desired indoor climate will not be obtained and the comfort will be compromised. One might think that designing the plant with some security factors would prevent most problems. However, even if some problems are solved that way, others are created, particularly on the control side. Some over sizing cannot be avoided because components must be selected from existing commercial ranges. These generally do not fit the calculations made. Moreover, at the design stage, the characteristics of some components are not known since they will be selected by the contractor at a later stage. It is then necessary to modify the original plant design to take into account the installation as built, which frequently differs from the initial design. Hydronic balancing enables the required flows to be obtained in the actual installation, compensates for over sizing and justifies the investments made.

Distribution system with constant flow

In a distribution system with constant flow (Figure 1a), the three-way valve is calculated to create a pressure drop at least equal to the design pressure drop in the coil C. This means a control valve authority of at least 0.5, which is essential for good control. If the pressure drop in the coil plus the pressure drop of the control valve is 20 kPa and the available differential pressure (ΔH) is 80 kPa, then the difference of 60 kPa must be taken away by the balancing valve STAD1. If not, this circuit will experience a flow of 200%, making control difficult and disturbing the rest of the plant.
In Figure 1b, the balancing valve STAD2 is essential. Without it, the bypass AB will be a short circuit with an extreme overflow, creating underflows elsewhere in the plant. With STAD2, the primary flow qp is measured and adjusted to be a somewhat higher than the secondary design flow qs, measured and adjusted with STAD3.
Balancing ensures correct flow distribution, prevents operational problems and lets controllers really control.

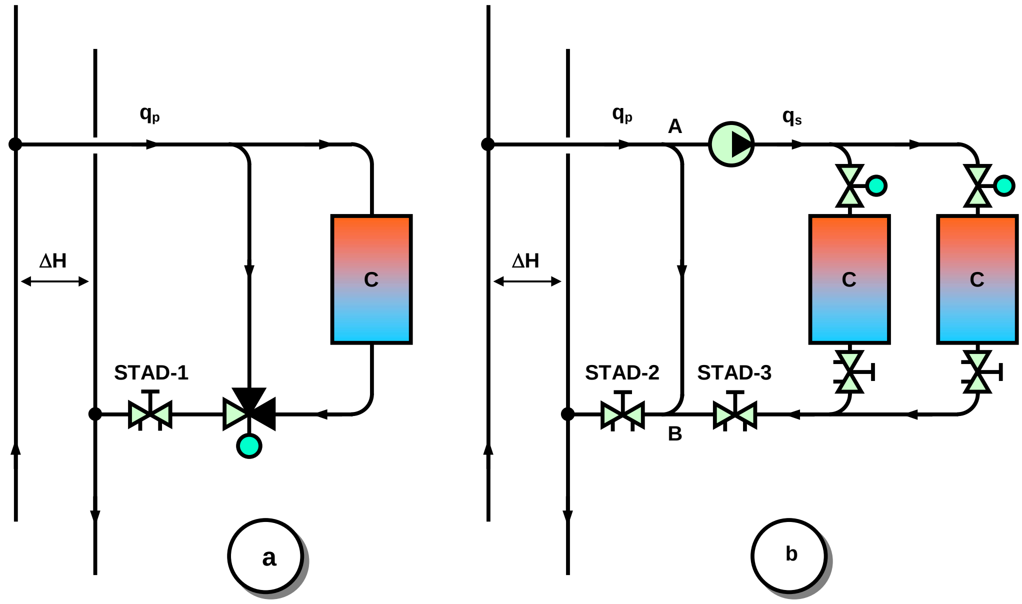

Figure 1. Examples of constant flow distribution systems.

Distribution system with variable flow

In a distribution system with variable flow, underflow problems occur essentially at high loads.

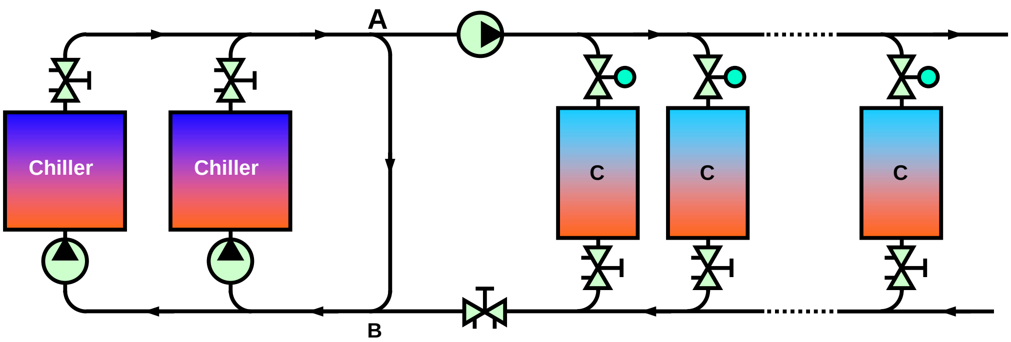

Figure 2. Example of a variable-flow distribution system

At first glance, there appears to be no reason to balance a system with two-way control valves on the terminals, since the control valves are designed to modulate the flow to the required level. Hydronic balancing should therefore be obtained automatically. However, even after careful calculations, you find that control valves with exactly the required kvs are not available on the market. Consequently, most control valves are oversized. Fully open control valves cannot be avoided in many situations, such as during start up, when big disturbances occur, when some thermostats are set at minimum or maximum value or when some coils have been undersized. In these cases and when balancing valves are not in place, overflows will result in some circuits. These will create underflow in other circuits.

Using a variable speed pump will not solve this problem since all the flows will change proportionally when the pump head is modified. Attempting to avoid overflows this way will simply make the underflows more significant.

The entire plant is designed to provide its maximum power at maximum load. It is then essential that this maximum power is available when required. Hydronic balancing, made in design conditions, guarantees that all terminals can receive their required flow, thus justifying the investments made. At partial loads, when some control valves close, the available differential pressures on the circuits can only increase. If underflows are avoided in design conditions, they will not occur in other conditions.

Start up

In distribution systems with variable flow, start-up after each setback is a serious consideration since most control valves are driven fully open. This creates overflows which produce excessive pressure drops in some of the piping network, starving the terminals in the less favoured sections of the system. The unfavoured circuits will not receive adequate flow until the favoured spaces have reached thermostat set point (provide these set points have been reasonably chosen), allowing their control valves to begin to throttle. Start up is therefore difficult and takes a longer time than expected. This is costly in terms of energy consumption. A non uniform start-up makes management by a central controller and any form of optimisation practically impossible.

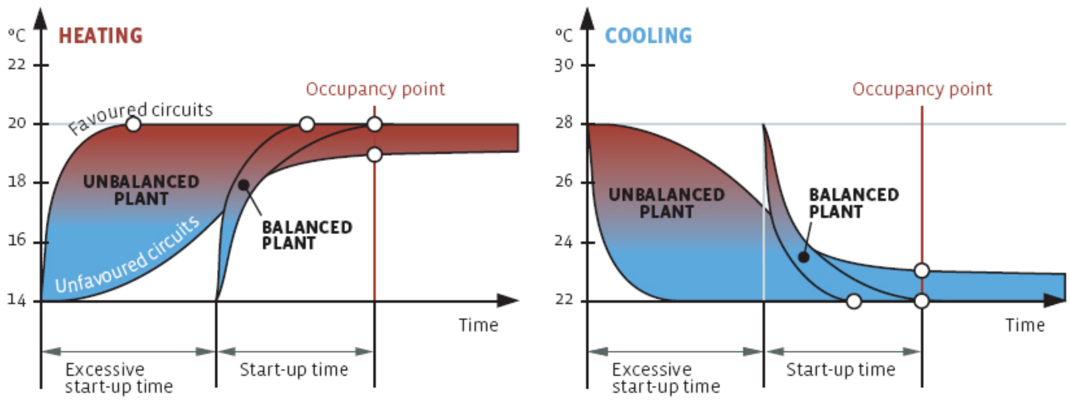

Figure 3. An unbalanced plant has to start up earlier, increasing the energy consumption.

In a distribution system with constant flow, underflows and overflows remain both during and after start-up, making the problem much more difficult.

Reverse return system

In order to obtain the correct flows, attempts have historically been made by using reverse return systems (also called Tiechelman after the inventor or 3-pipe systems). The principle is quite simple and the main idea is to get the same available differential pressure for all coils by carefully selecting the correct pipes and adding a third pipe.

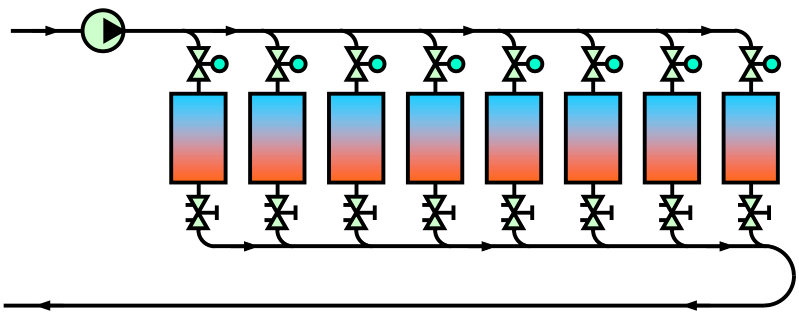

Figure 4. Reverse return system

Theoretically, this might work, but in practise there are many disadvantages with this kind of system.

A third pipe is necessary
In principle, a third pipe must be installed, designed for the total flow and this can considerably increase the cost of the plant. Furthermore, this third pipe creates non-negligible additional pressure loss as well as heat gains in cooling and heat losses in heating which will increase the energy need of the building.

The same pressure drops cannot be obtained in all pipe segments
Since pipe diameters are standardised, it is practically impossible to obtain equal pressure drops in all pipe segments. For instance, with a flow of 32 m^3/h (8, 9 l/s), the linear pressure drop will be 96 Pa/m and 346 Pa/m respectively when changing from a DN 100 pipe to a DN 80. If the required pressure drop is 200 Pa/m, it will be impossible to find the correct pipe for that flow. The result will be different available differential pressure for the different coils.

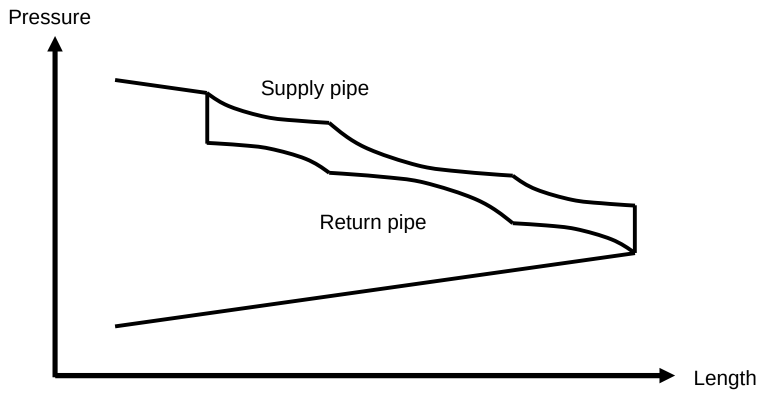

Figure 5. Available differential pressure

Do we really need the same dp for each coil?
An equal differential pressure only makes sense if the units concerned are identical, both for their hydraulic resistance and their design flow. What point is there in applying an identical differential pressure on coils requiring different differential pressures?

What if the plant is modified later on?
The reverse return system is rigid by design and any subsequent modification makes the installed pipe diameters irrelevant. It is thus quite difficult and costly to make appropriate corrections unless balancing valves are installed.

The reverse return loop is only designed for constant flow system
When flows vary, differential pressures are no longer constant. Their relative variations are generally higher than those obtained in a direct return distribution, which will affect the control valve authorities at all locations.

Balancing valves are still necessary
In order to compensate for the earlier described matters, balancing valves should be installed to make the necessary corrections and adaptations. Furthermore, these balancing valves are important tools for diagnostics and trouble-shooting, which otherwise would be impossible. However, there exists no method for systematically balance a plant with reverse return design and it can only be carried out by calculation or iteration.

Balancing made simple

Hydronic balancing provides the opportunity to verify that the installation is correctly executed. It enables detection of and subsequent correction of most malfunctions (i.e., air, clogging, hydronic faults).

Using the TA Balance method is the easiest way to balance a plant. TA Balance is a computer programme based on the compensated method and incorporated into the balancing instrument TA-CBI. After some measurements in the plant, TA Balance calculates the correct settings for the balancing valves. The main advantage of this method is that one man can balance an entire plant using only one balancing instrument.

As in all other balancing procedures, the plant should be divided in modules. One module is formed by several circuits connected to the same supply and return pipes. Each circuit has its own balancing valve. Each module has a common balancing valve called the partner valve (Figure 4).

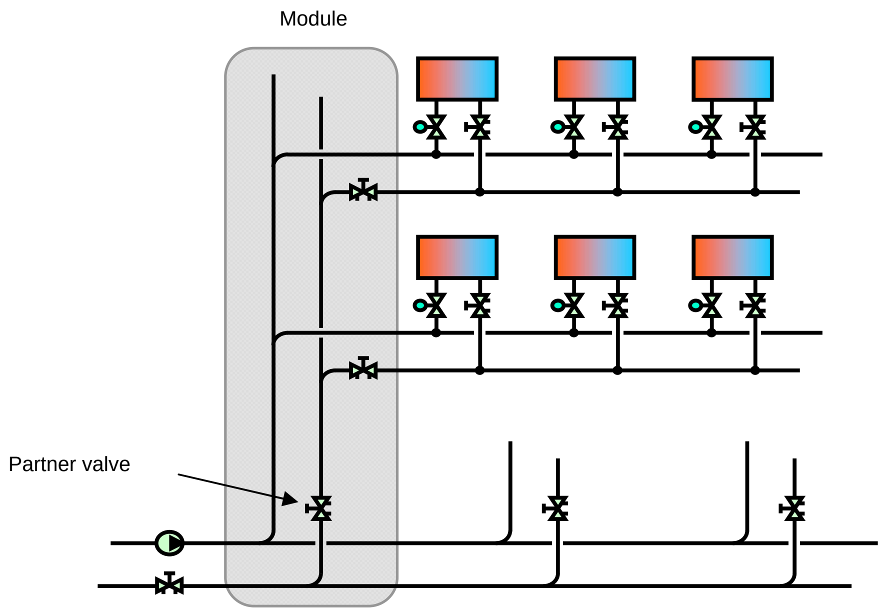

Figure 6. Balancing module.

The CBI detects the index circuit (the circuit that requires the highest differential pressure) and allocates a pressure drop of 3 kPa for the balancing valve of this circuit (the minimum pressure drop recommended for reliable flow measurements).

The settings of the other balancing valves are determined to obtain a relative balancing of the elements within the module. The settings do not depend on the actual available pump head or on the setting of other balancing valves in the plant. The determined values are set and locked.

When all modules have been individually balanced, the modules are then balanced in relation to one another using the same procedure. At this stage, the settings of the partner valves are determined.

Finally, the total design flow is adjusted with the main balancing valve when this operation is completed, design flows are available at all terminals.

All overpressure is taken and measured in this main balancing valve and the set point of the pump can be reduced with by the same value, decreasing the pump’s energy consumption.

Conclusion

The objective of any HVAC plant is to provide a comfortable indoor climate whilst minimising costs and operational problems.

In theory, modern control technologies make this objective possible. In practise, however, not even the most sophisticated controllers perform as promised. The reason is often that the conditions necessary for good control are not fulfilled.

One such condition is that the design flow must be available at all terminals. Hydronic balancing is necessary to ensure that this condition is met. Hydronic balancing prevents overflow in some circuits from causing underflows in others, detects the degree of pump over sizing and generally verifies that the plant works as intended.

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