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Hydronic Balancing a Necessity for Good Control and Improved HVAC Performance

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In theory, modern HVAC systems can satisfy the most demanding requirements for indoor climate and operating costs. In practice, however, not even the most sophisticated systems always perform as promised. As a result, comfort is compromised and operational costs are higher than expected.

This is often because the mechanical design of the HVAC plant does not meet some conditions necessary for stable and accurate control. Three important conditions are:

1. The design flow must be available at all terminals.
2. The differential pressure across the control valves must not vary too much.
3. Flows must be compatible at system interfaces.

This article discusses in brief the first of these conditions- problems resulting from violation of the condition, why the problems occur and how to prevent them at the design stage.

Common Problems

These problems are typical indications that condition number one (i.e. that the design flow is available at each terminal) is not met:

-Higher than expected energy costs

-Installed power is not deliverable at intermediate and/or high load.

-Too hot in some parts of the building too cold in other parts.

-Long delay before the desired room temperatures are obtained when starting up after night setback.

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.

Some people, however, seem to think that it is sufficient to indicate design flows on the drawings in order to obtain them in the pipes. But to obtain the required flows, they must be measured and adjusted. This is why specialists are convinced that 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 (unless the plant is calculated with a diversity factor). If a link of the chain is not properly sized, the other 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 oversizing 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 them necessary to modify the original plant design to take into account the installation as built, which frequently differs somewhat from the initial design.

Hydronic balancing enables the required flows to be obtained in the actual installation, compensates for oversizing and justifies the investments made.

Distribution systems with constant flow

In a distribution system with constant flow (**Figure 1 a**), 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 STAD-1. If not, this circuit will experience an overflow of 200% making control difficult and disturbing the rest of the plant.

In Figure 1b, the balancing valve STAD-2 is essential. Without it, the bypass AB will be a short circuit with an extreme overflow creating underflows elsewhere in plant. With STAD-2, the primary flow **qp** is measured and adjusted to be a somewhat higher than the secondary design flow **qs** measured and adjusted with STAD-3.

Balancing ensures correct flow distribution prevents operational problems and lets controllers really control.

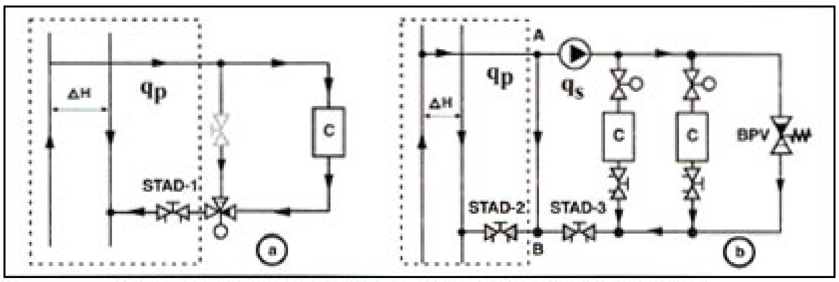

Figure 1 : Examples of circuits in constant-flow distribution systems

Distribution system with variable flow

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

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. Total opening of the 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 (with or without a diversity factor). It is them 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.

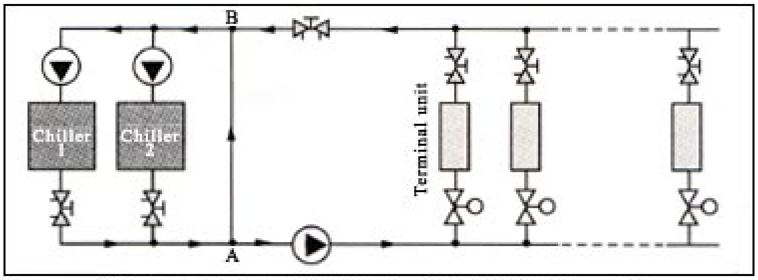

Figure 2 : Example of a variable-flow distribution system

Morning start up

In distribution systems with variable flow, morning start up after each night setback is a serious consideration since most control valves are driven fully open. This creates overflows which produce unpredictable 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 haves reached thermostat set point (if these set points have been reasonably chosen), allowing their control valves to begin to throttle. Start up is therefore difficult and takes a long 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.

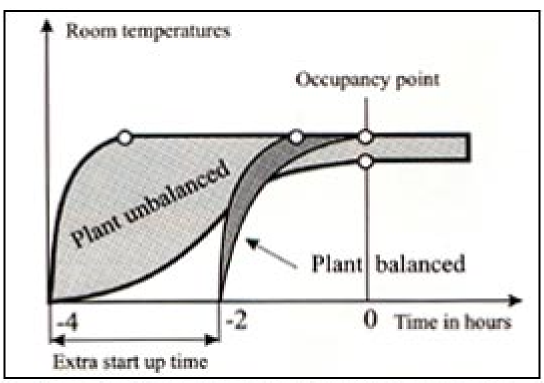

Figure 3 : An unbalanced plant has to start up earlier, increasing the energy consumption

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

The tools required for balancing

To balance a plant, the required tools must meet these conditions:

- The flow must be measurable with an accuracy of about ± 5%. The balancing procedure makes it possible to check if the plant works a designed, to detect faults and to decide upon measures to correct them.
- The flow must be easy to adjust, thus making the plant flexible.
- The balancing device must guarantee long-term reliability. It must be resistant to aggressive water.
- During flushing, the balancing devices should not have to be removed and should not require the use of special filters.
- The setting position must be easy to read and be protected by a hidden memory. Full-throttling range should require at least four full turns of the hand-wheel to enable sufficient resolution of the setting.
- A balanced cone should be available for big sizes to reduce the torque required to set the valve against high differential pressures.
- A shut-off function must be included in the balancing valve.
- A measuring instrument must be available, so that flows can be measured easily, without having to use diagrams. The instrument should incorporate a simple balancing procedure report. The instrument should also enable the evolution of flows, differential pressures and temperatures to be registered for diagnostic purposes.

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, filters, 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. TA Balance is incorporated into the balancing instrument 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 must 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**)

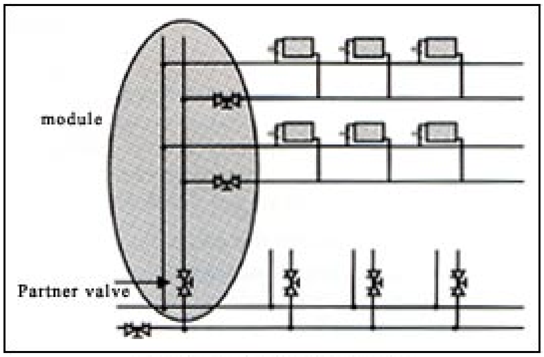

Figure 4 : Balancing module

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 required 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. All overpressure is taken, and measured, in this valve. This overpressure is sometimes so high that a smaller pump can be installed to reduce pumping costs.

When this operation is completed, design flows are available at all terminals. A computer printout provides a list of settings, differential pressure and water flows for each balancing valve.

Conclusion

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

In theory, modern control technology makes this objective obtainable. In practice, however, not even the most sophisticated controllers always 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 is available at all terminals. Hydronic balancing is necessary to ensure that this condition is met. Hydronic balancing prevents overflow in some circuits from causing underflow in others, detects the degree of pump oversizing and generally verifies that the plant works as its designer intended.

Reference: R. Petitjean, Total hydronic balancing.

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