Economics of Balancing

TA Hydronic College
Map of U.S. energy need

Heating Degree Days by Census Region

Cooling Degree Days by Census Region

Source: Energy Information Administration, *Annual Energy Review*, Table 8.9. (June 2008)

Source: Energy Information Administration, *Annual Energy Review 2008*, Table 1.10
All HVAC installations should reach 2 fundamental objectives:

1. To deliver the specified comfort level

2. To reach the first objective, while using a minimum quantity of energy
In theory, current technology involving state-of-the-art BMS systems makes it possible to achieve these 2 objectives.

In practice, even the most sophisticated control systems lead often to reduced comfort at increased operation costs.

In many cases, problems and therefore solutions are to be found on the hydronic side.
Symptoms related to typical hydronic problems

- Too hot in some parts, too cold in other parts

- Start-up after a set-back is difficult in some rooms

- Installed power is not deliverable

- Room temperatures fluctuate

- Higher energy consumption than expected
TA Hydronic’s 3 Key Conditions for Perfect Hydronic Control

Why and how to satisfy them in the simplest way
Overflows and underflows

Without hydronic balancing, the first circuits are in overflow creating underflows in other circuits. Control valves cannot solve this problem.

- **Underflow** = too cold
- **Overflow** = too warm

**62°F**

**74°F**

- Low differential pressure
- High differential pressure
To avoid complaints from building tenants

1st action:
Pumps are pushed to the maximum

- overflows increase
- underflows are reduced:

\[ q \sim \sqrt{\Delta p} \]  (turbulent flow)

But to compensate an underflow of 20% in a circuit (raising the flow by 25% from 0.80 \( q_c \) to \( q_c \))

The local available \( Dp \) must be increased by 56%!
Unbalanced plant usually means too high total flow

Increasing Dp circuit by 56%

Requires a brute-force increase of the pump head H by 56%

Leading to a total flow increase of 25%

20% underflow

q_{tot} \times 1.25

H \times 1.56

Dp circuit \times 1.56

Produced by TA Hydronic College
Pumping costs

Increasing the pump head to reduce underflows is very energy consuming.

\[ \text{Pumping costs} \approx C_0 + \frac{\text{Pump head} \times \text{Flow}}{\text{Pump efficiency}} \times 1.95 \times 1.56 \times 1.25 \]

With pumping costs representing up to:
(in annual energy consumption)

- Heating: 2-6%
- Cooling: 15-20%
To avoid complaints from building tenants

2nd action:
Supply water temperature is: increased in heating (decreased in cooling)

- unfavoured rooms start to be comfortable
- tenants from favoured rooms will react

Energy waste!
Increased CO₂ emission!
The cost of discomfort

Heating
The cost of 1°F too high room temperature over a year
4 to 7% *

Cooling
The cost of 1°F too low room temperature over a year
6 to 10% *

(*) of the plant annual energy consumption
Material life-time

Overflows means that **water velocity is higher than expected** per design

\[ \nu = \frac{1273q}{d_i^2} \]

with \( q \) in l/s, \( d_i \) in mm

Too high water velocity leads to erosion in pipe elbows and heat exchangers.

Control valves of circuits in overflows work with very short open/close cycles. This limits dramatically their actuator life-time.
In unbalanced buildings, tenants claim for bad comfort conditions.

Maintenance technicians waste their time repetitively visiting these buildings trying to fight symptoms.

**Case study Sep. 2004.**
Start-up after set-back

When a plant is unbalanced, the startup time is longer for the last circuits in underflow. Overflows do not result in higher power output of the terminal units.

When a plant is balanced, start-up is achieved simultaneously in all circuits.
Control valves not under control

In frequent cases, control valves do not control the flow in terminal units any longer. They are set fully open by the control system:

- At start-up after a set-back
- Because of sudden load variation
- Because of weird set-point at the thermostat
FONCTIONNEMENT DU SYSTEME DE CLIMATISATION
HOW TO USE THE AIR CONDITIONER

Durant l’hiver
Only in Winter

Durant l’été
Only in Summer

Positionner les boutons
Switch the buttons

1 : Sur position I
1 : On the position I

2 : Sur le motif « Neige »
2 : On the design « Snow »

3 : Thermostat vers le maximum
3 : Thermostat to the maximum

Hotel in Paris
Dear passengers:
Due to Central Airconditioning, we are unable to control the Lounge temperature.
Please bear with us.

Thank you!

Beijing International Airport
The design flow must be available at all terminal units in design conditions.
Achieving hydronic condition nr 1

Adjusting the **design flows** in all terminal units in **design conditions**

- Design conditions are the "worst" plant operating conditions, under which maximum flow is required: control valves are all fully open.
- If design flows are adjusted under design conditions, they can be obtained in all other conditions.

This should be achieved while creating the absolute minimum amount of additional pressure drops.
To enable **systematic balancing** with **optimal in pressure drop** result, hydronic distribution pipings must be decomposed into **hydronic modules**.
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Turning direction criterion for splitting into modules

For finding balancing valve locations resulting in the **lowest possible sizes**

![Diagram showing flow rates and directions]

At any bifurcation between many and many units **turn in the direction of the main flow** and place a balancing valve on the low flow side.
Balancing methods for hydronic modules

Proportional method
- adapted from air system balancing methodologies
- not optimal in pressure drops

Compensated method (Pr. Robert Petitjean, see CIBSE Code W)
- designed for application with balancing valves
- optimal in pressure drops
- by-product: all excess Dp is concentrated in the main valve

TA Balance method (Pr. Robert Petitjean)
- fully computerized: automatic determination of the index valve (on the worst unit)
- optimal in pressure drops
- by-product: all excess Dp is concentrated in the main valve
Order for balancing modules

The structure of hydronic modules can be seen as a hierarchical tree.

Before a module can be balanced, the whole descent of this module must be balanced.

Balancing order:
VSP set-point optimisation

A. System unbalanced
   Total flow higher than needed
   Pump power: 17.2 HP (100%)

B. System balanced
   Total flow adjusted – Excess Dp in main valve
   Pump power: 13.7 HP (80%)

C. System balanced
   Main valve re-opened; VSP set-point reduced
   Pump power: 9.8 HP (57%)

System curves

Pumping costs \( \approx C_0 + \frac{\text{Pumphead} \times \text{Flow}}{\text{Pump efficiency}} \)

- Pump head [ft]
- Flow [gpm]
- Design flow
- Overflow flow

Too high H
Optimum H
Savings are real

Pfizer pharmaceutical production unit

- Installed cooling capacity of 1535 ton (refrig.) 5.4 MW (3 chillers in cascade)
- Total design flow: 3400 gpm = 773 m³/h
- Problem: *production alarms*!
- 80 balancing valves from ½” to 8”

- Audit of plant with TA Select based on a first measurement campaign (presettings calculated, viscosity corrections checked)
- Full balancing performed using TA-Balance on one TA-CBI
Savings are real

**Before balancing**

Industrial plant
1535 ton (refrig.) cooling
3914 gpm
112 ft pump head

**After balancing**

3400 gpm (-13%)
90 ft pump head (-20%)
Pumping power reduction:
52 HP = 39 kW
Savings: 25,300 USD/year
17,200 €/year
"When you can measure what you are speaking about and express it in numbers you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind."

Lord Kelvin, 1883
Diagnostic is a key point

Through balancing, many hydronic problems may be detected
- Terminal units or exchangers wrongly mounted
- Pipe damaged or not connected as expected
- Shut-off valves partially shut
- Check valves or pumps installed back-to-front

Balancing exposes these flaws while they can still be cheaply repaired.

Diagnostic is one of the main use of balancing valves.
System Check

Measurement/Verification:
- Available head
- Filters or valves clogged
- Pipe damaged or not connected as expected
The Three Keys to Perfect Hydronic Control

1. The design flow must be available at all terminal units in design conditions.

2. The differential pressure across control valves must not vary too much.

3. The water flows must be compatible at system interfaces.
The Three Keys

Three simple conditions to satisfy in order to make hydronic systems work as expected from design
Thank you for your attention!

Questions?