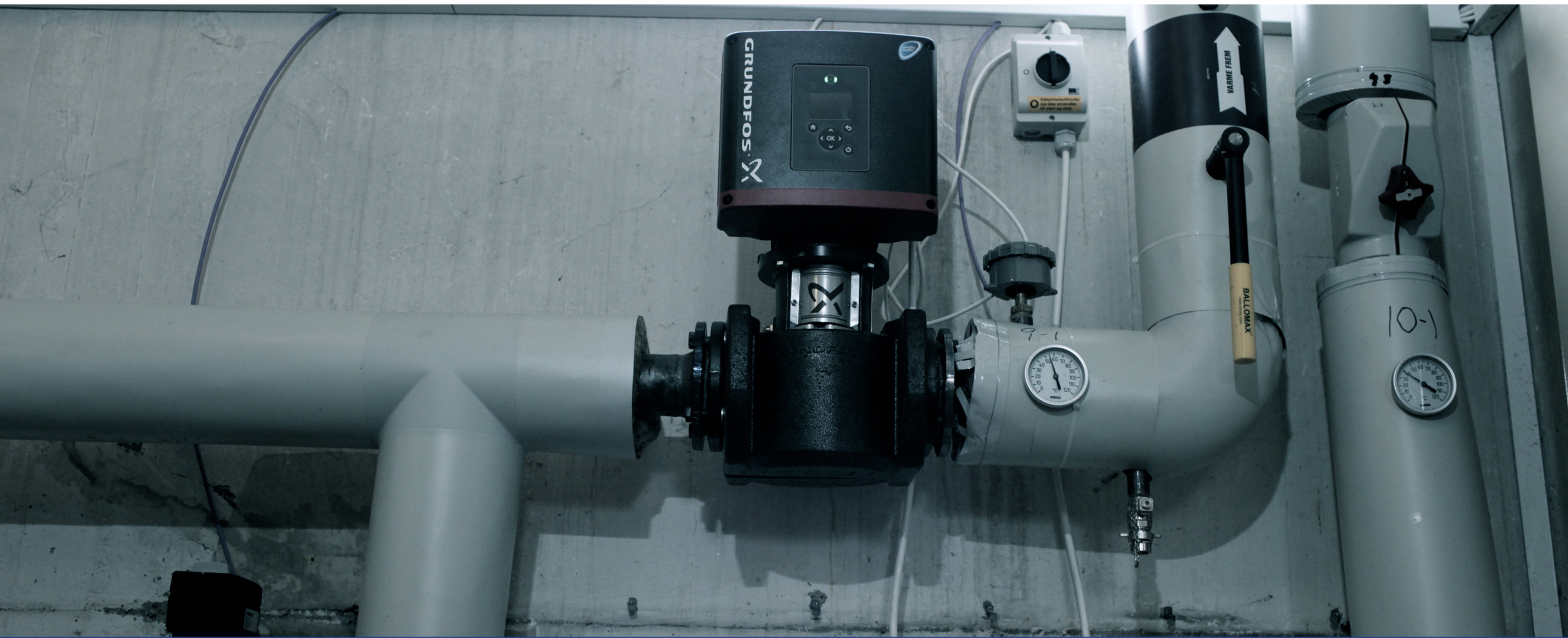


Triple win in HVAC

How to increase system efficiency in a one pipe heating application

INTRODUCTION

High efficiency in district heating systems starts at one place; at the customer's installations. Plant managers at district heating systems are therefore constantly searching for ways to reduce losses in their networks.

Of course, one obvious way to reduce losses is to reduce output flow temperatures from the production plant. This would reduce the losses from the pipes to the surrounding soil. This has been done for years and has drastically reduced the loss of temperature between production and final use at the consumers.

However, there are limitations to how low temperatures can get and still fulfil the aim of providing sufficient heat to the connected customers. This is a challenge - especially in old networks - and typically, the flow temperature is kept at no lower than 65° - 70°C. But energy loss in flow pipes is not the only source of inefficiency. The fact that customers are not able to cool down the delivered hot water is to some extent an even bigger challenge. The connected customers should deliver at least the minimum required average Delta T. Otherwise, they may be subject to penalties from the district heating company. This creates major challenges specifically in one-pipe heating systems.

New ways of operating these once so challenging one-pipe systems can provide:

1. Increased yearly average Delta T.
2. Improve district heating network's total efficiency.
3. Avoidance of customer penalty.

In this white paper, we will examine a specific case where these challenges all have been dealt with.

TABLE OF CONTENT

Anders Nielsen

Application Manager
Grundfos Commercial
Building Services

FACTS ABOUT LANGENÆS

Areal: 200m x 40m

Floors: 17

Residents: 942

Number of apartments: 350

Water consumption in 2015: 967,000 m^3

The seven-storey building at Langenæs was built in 1957. The building now has 942 residents and each flat is approximately 90 m2. For a long time the building has been struggling with an excessively high Delta T. The building has undergone different improvements such as new windows and façade insulation. These improvements have all reduced the building's heat loss. Let's take a closer look at the challenges there were with the system at Langenæs, and how these challenges were dealt with.

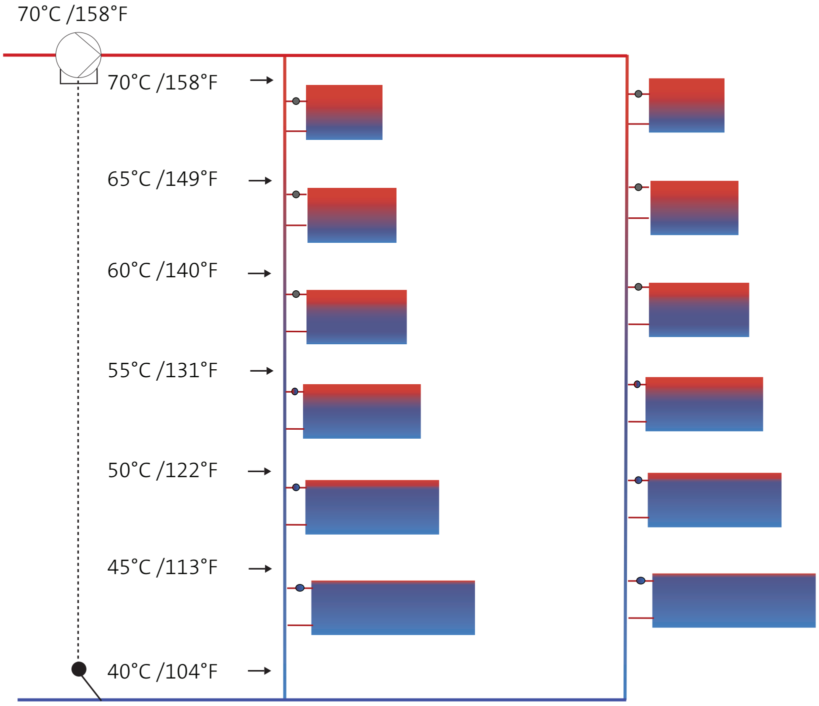
The specific layout of the Langenæs HVAC system can be seen in the diagram on the right. The main pipes are placed in the basement and vertical risers deliver flow to three down pipes. As it can be seen, each of these has a number of radiators connected. The radiators are connected as a one-pipe system, where both flow and return are connected to the same pipe. This is the difference between a one-pipe and a two-pipe system, where flow and return pipes are connected separately to each radiator.

The original/new* criteria for the heating system:

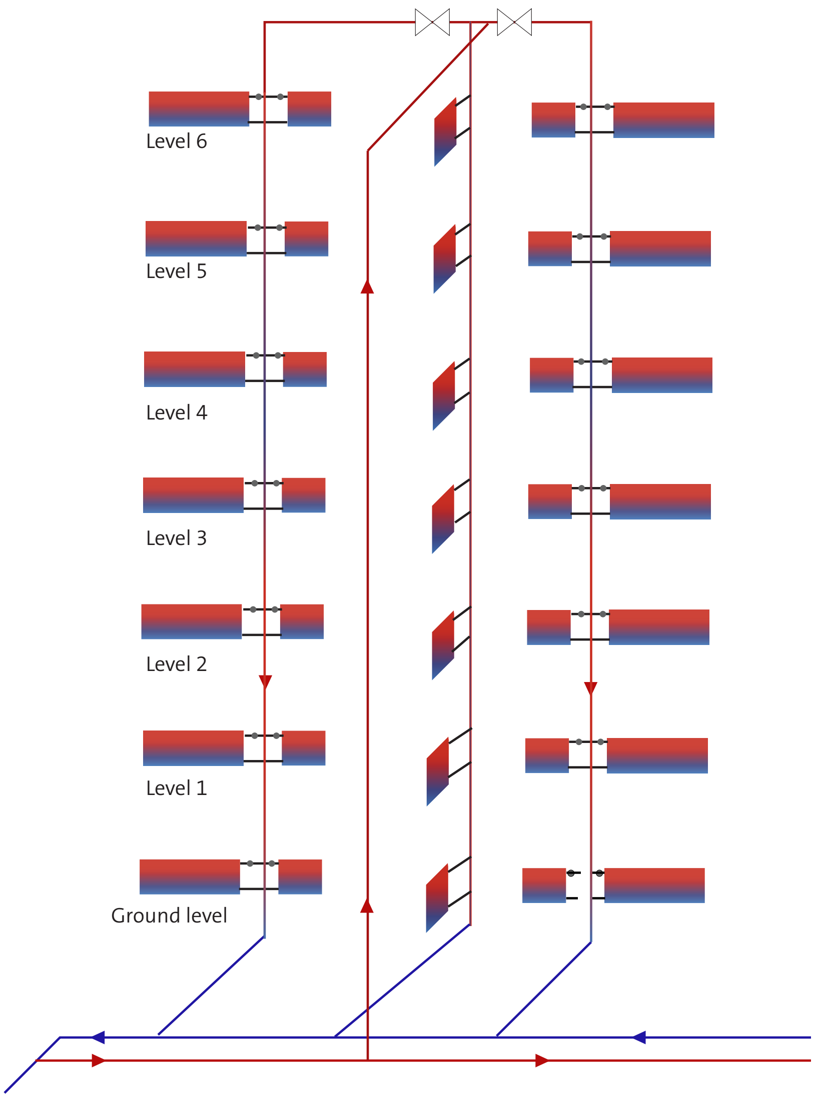
Installed capacity originally:	300 kW / 1023642 BTU
Needed installed capacity today:	150 kW / 512000 BTU
Flow temperature.	70°C / 158°F
Return temperature:	40°C / 86°F

***Due to new windows and improved facade insulation.*

Even though the required installed capacity has been reduced, the radiators stayed the same and so have the design temperatures. On the right you see an overview of the radiator system.



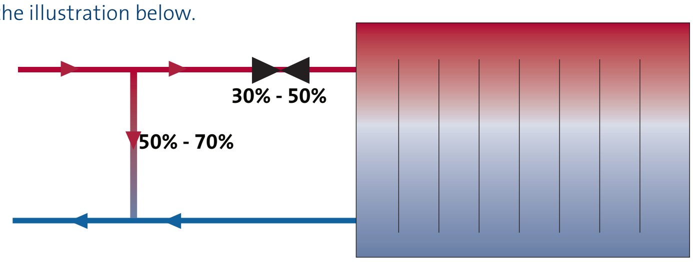
The principle of the one pipe heating system.

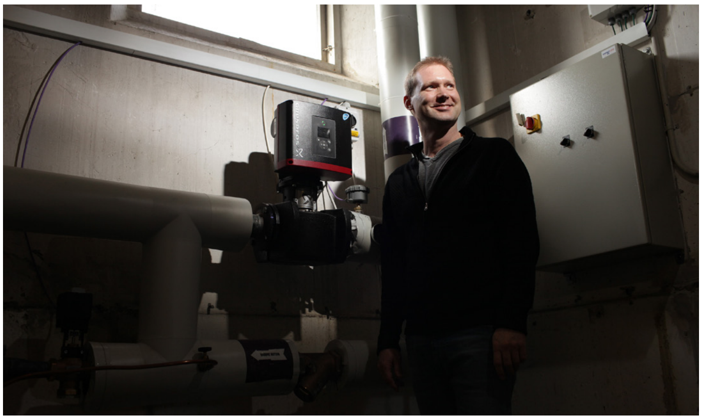


A zoomed drawing from the actual piping in the heating system at Langenæs

THE CHALLENGE

Each radiator flow and return is connected to the same main pipe. This means that the circulated water will flow through the radiator or the by-pass pipe in the middle. At the design stage, 30-50% of the flow is flowing into the radiator and the rest is passing through the pipe, just before the radiator. See the illustration below.



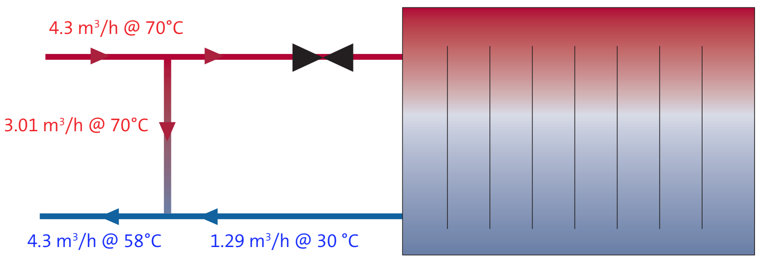


The Energy Inspector Mads Kjær Birk in front of his new system.

HOW THE SYSTEM IS SIZED AND OPERATES

The total heat needed for the building is 150 kW which gives a total flow of: $\frac{150 \times 0.86}{30} = 4.3\ m^3/h$

If we assume 50% of the water runs through the radiators, it gives us 4.3/2 = 2.15 m3/h for the radiators and the same amount through the main pipe.
If this situation changes and only 30% of the water runs through the radiator, it gives a flow of 4.3 x 0.3 = 1.29 m^3/h.
This leaves us with 4.3 – 1.29 = 3.01 m^3/h in the main pipe.



Clearly, when the amount of water circulating in the main pipe increases, this will lead to reduced Delta T, as the water which is not flowing into the radiators will not be cooled. In above theoretical example, the new return temperature will then be:
$\frac{1.29 \times 30 + (4.3-1.29) \times 70}{4.3}$ = **58°C** equal to a decrease of **48%** in Delta.

In the chart below you can see how return water temperature (Tr), is affected by reduced demand/load, when we have constant flow in the system (which is what we will have in all one-pipe systems which have not been re-commissioned).

As it can be seen, the return temperature gradually increases as the load

Outdoor temp.	Load %	kW Φ	Tf	Tr	Q
- 12°C / 10.4°F	100	150	70	30	3.2
4.8°C / 23.4°F	75	112.5	67	31.9	3.2
2.6°C / 36,7°F	50	75.0	63	39.5	3.2
9.9°C / 49.8°F	25	37.5	59	47.3	3.2
17.2°C / 63.0°F	15	22.5	55	48.0	3.2

The development of return water temperature Tr, according to heat requirement, (Load). Traditional control of the system with constant flow.

requirement for the building decreases. Why this is happening can be seen below.
The delta T for the system is calculated based on the formula: $\Phi = Q \times \Delta T$

Φ: Heat Load kW
Q: Flow m3/h
ΔT: Delta T (flow Temperature – Return temperature) **Ex**: kW requirement by heat load of 15 % = 22.5 kW
Delta T will be 22.5/3.2* = **7.0°C**

***As the flow is constant, this value is given to be 3.2 m^3/h*

THE PENALTIES FOR NOT MEETING THE YEARLY REQUIRED DELTA T

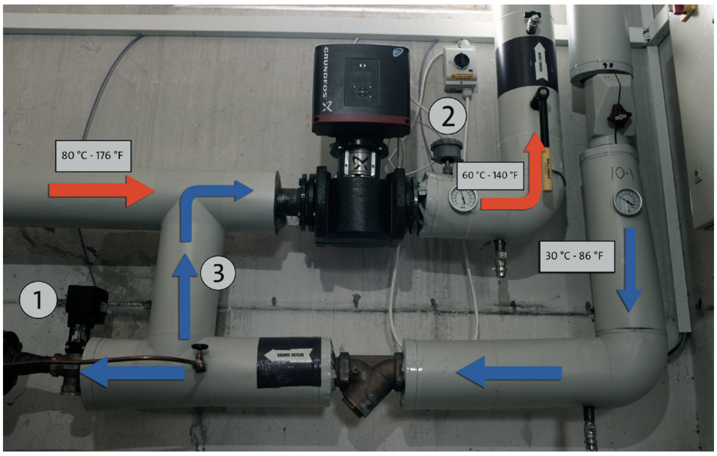
In this case the specific district heating plant required a minimum of 30°C in average Delta T in customers' heating applications. If this cannot be met, a fine will be issued at the end of year. The fine is currently 0.9 EURO/°C/MWh. Below you can see the situation in 2013 at Langenæs. There were clear economic incentives to deal with the low Delta T problems at Langenæs.

Required average Delta T:	30.0°C
Realiset Delta T:	24.09°C
Deviation: 30 – 24.09 =	5.91°C
Penalty: 5.91 x 614.87 =	3634 Kr / 488 Euro

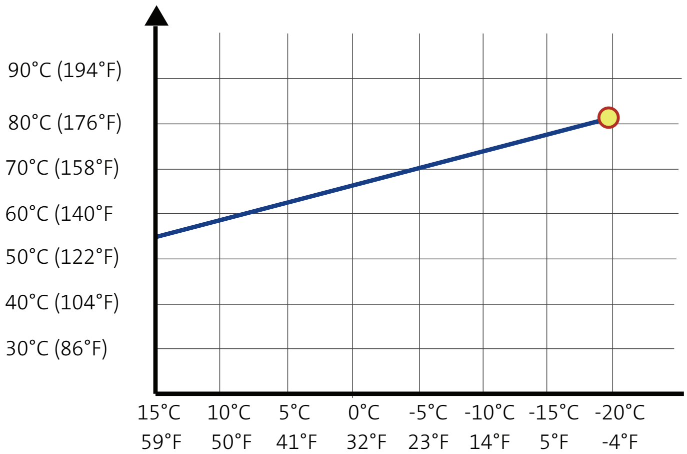
In 2011 - 2012 and 2013 the bulding at Langenæs was fined for having a low Delta T.

THE NEW APPLICATION

Let's take a closer look at how we fixed the problems at Langenæs and what the new application looks like. In order to control the heat flow into the system, the flow temperature is controlled by a central CTS system. This is done in a mixing loop, where the flow temperature is set by means of the actual outdoor temperature.



If the actual flow temperature needs to be 60°C, measured by the temperature sensor 2, the motorized valve no 1 is partly closed, allowing a certain amount of the return water from the system to be directed through bypass no 3 and into the flow pipe for the system. In this way the flow temperature from the district heating plant, being 80°C on the chart, is reduced to the desired 60°C.

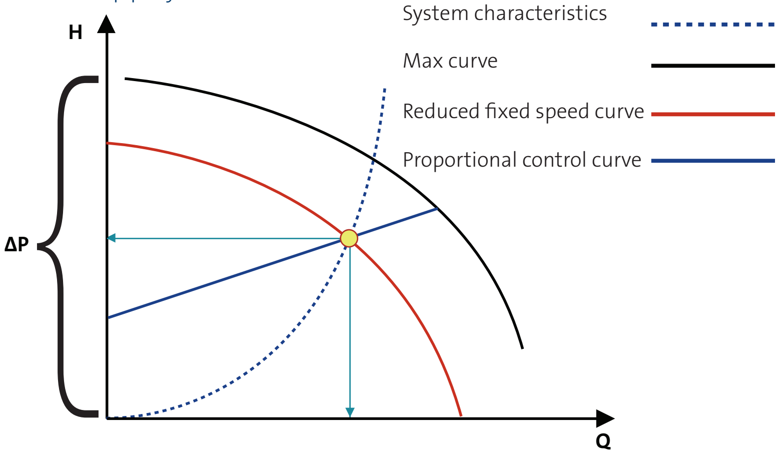


The example above is based on an outdoor temperature of approx 7°C.

A close up of the TPE3 pump installed at Langenæs.

The challenge of the previous set-up

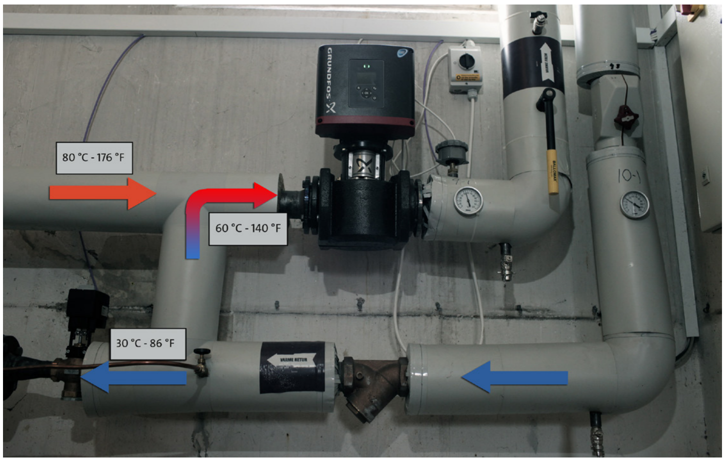
The original pump was a Grundfos MAGNA 50-120. This pump operates based on measured differential pressure across the pump. As the resistance is almost the same whether the flow goes through the radiator or through the main pipe, the pump will have limited ability to change its speed, and thereby, the delivered flow. This control strategy does not work in a one-pipe system.



Reduced Delta T in a one-pipe heating system is an inevitable result of having a system with constant flow when heat requirements are declining. So something had to be done. Let's take a look at the new approach.

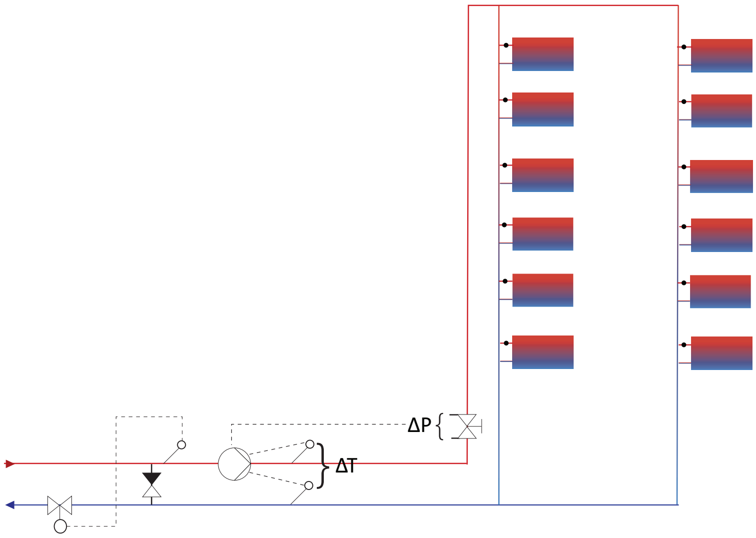
Change of control strategy

In order to control the flow into the system, the control of the pump is changed from Delta P control to Delta T control. When the return temperature starts to increase, it must be due to reduced heat demand. More flow is going through the main pipe, uncooled. So now we operate the pump by setting up a scheme where the pump maintains a desired Delta T across the secondary flow and return. As it can be seen in the chart below, we strive to maintain a constant return temperature of 30°C, which will give us a big increase in Delta T compared to the original control strategy.

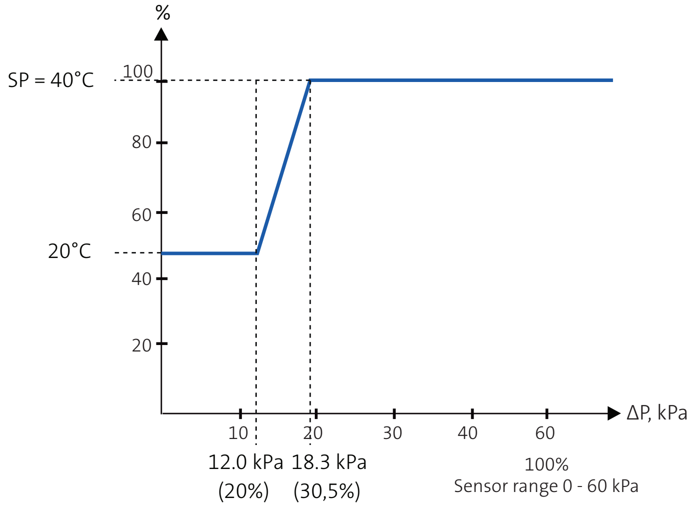


The TPE pump where control mode is changed to Delta T control.

In order to secure sufficient Delta P at the riser pipe furthest away from the pump, the actual Delta P is measured and kept within certain limits. Thus we ensure that the "critical" riser will always have sufficient Delta P to function. We use a combination of Delta T and Delta P control. Delta T control is the primary, as we always want to maintain a Delta T as high as possible, but we do not want to compromise comfort; therefore, we include the Delta P control as a "watch dog". The scheme, showing Delta P influence, can be seen in the chart below.

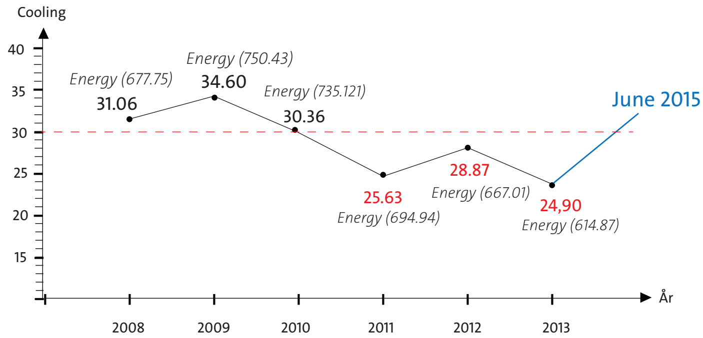


Setpoint influence



RESULTS SO FAR

The new Delta T controlled TPE pump was installed February 2015 and since that day and until end July, the average Delta T have increased by 7.44°C. This is an increase to 31.53°C from 24.1°C. This is as much as 30.7% increase.



The average Delta T has increased dramatically since the new control paradigm was introduced in 2010.

Consequences for tenants

As mentioned previously, the heating bill for tenants will be reduced as these do not any longer have to pay penalties due to poor yearly average Delta T levels.
Consequences for District Heating Plant:
Each year the district heating plant has to report xx mill kWh of energy savings to the state, for which they then get a bonus. In this particular case, the savings are calculated according to a specific formula:

Energy saving: 4.7kWh/°C/MWh x 7.44°C x 595 MWh = 20.805 kWh

7.44 is the actual delta T improvement.

595 MWh is the yearly energy consumption for the building.

7.44 is the actual delta T improvement.
595 MWh is the yearly energy consumption for the building.

The bonus is 0.40 DKK equal to 0.053 EURO per kWh calculated saving.
Total savings 0.053 X 20805 = **1103 EURO**.

Outdoor temp	Load %	kW Φ BTU	Tf_{pri}	Tf_{sec}	Tr Pri/Sec	Delta T Sec	Delta T Pri	Q m³/h
								Gal/min
-12°C 10.4°F	100	150.0 511821	80°C 176°F	70°C 158°F	30°C 68°F	40°C 104°F	50°C 122°F	3.2 14.1
4.7°C 23.5°F	75	112.5 383865	76,7°C 170°F	67°C 153°F	30°C 68°F	37°C 99°F	46.7°C 116°F	2.6 11.4
2.6°C 36.7°F	50	75.0 25591	73,5°C 164°F	63°C 145°F	30°C 68°F	33°C 91°F	43.5°C 110°F	2 8.8
9.9°C 49.8°F	25	37.5 127955	70,3°C 159°F	59°C 138°F	30°C 68°F	29°C 84°F	40.3°C 104°F	1.1 4.8
17.2°C 63.0°F	15	22.5 76773	67°C 154°F	55°C 131°F	30°C 68°F	25°C 77°D	37°C 99°F	0.8 3.5

Energy Inspector at Langenæs, Mads Kjær Birk.

"We have observed Delta T in our new system. Last year from January to October our Delta T was 20°C. With our new system fully functional, the Delta T this year in the same period is 29.9. I'm very happy that our new system now fulfil the building's needs and I'm looking forward to observing developments in the years to come"

CONCLUSION

The number of one-pipe heating systems in the world is tremendous. During the coming years, massive energy savings have to be harvested in the commercial building sector, as this is where roughly 40% of all energy is used. One place to start is to secure optimum control in all one-pipe heating systems, as these are far from energy efficient in the way they operate today.

Grundfos have proven a sure way to increase system efficiency in these systems. This is done by utilising Delta T control directly in the TPE pumps that are already well-known. If you want to know more about this innovative solution, please contact the author or your local Grundfos branch.

To learn more about the use of TPE3 in Langenæs check out our video via this QR code:

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