ENGINEERING
TOMORROW

Technical Article - hydronic balancing

New ways of **balancing** two-pipe systems

How to achieve superior hydronic balance in heating systems by utilising the Danfoss *Dynamic Valve*™ type RA-DV and the Grundfos MAGNA3 speed controlled pump

Introduction

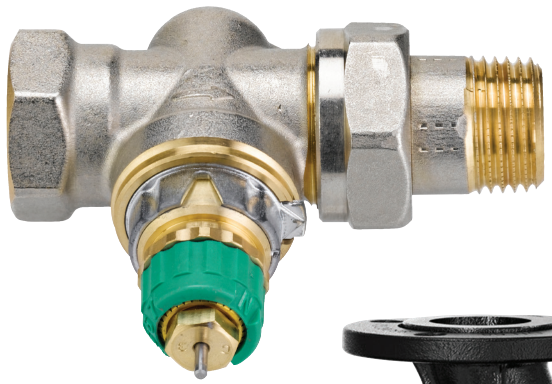
Low energy consumption in buildings is not something which comes easy. Ensuring that the components in a heating system work together is a pre-requisite when we want low heating bills. A means of ensuring low energy consumption is to balance the heating system correctly, and this article will explain how the new Danfoss *Dynamic Valve™* type RA-DV and the new Grundfos MAGNA3 speed controlled pump work together superbly to achieve this.

We will first look at how we compensate for the variations in partial, and how the requirement to balance the heating system means we need to control flow; and to obtain this, we need to control the differential pressure across valves as well.

We will show how this can be done by utilising the Danfoss *Dynamic Valve*™ type RA-DV in combination with the Grundfos MAGNA3 variable speed controlled pump, looking at an installation in Fredericia, Denmark, where 60 apartments in a 10 storey building has heating supplied from a system consisting of two Grundfos MAGNA3 pumps serving two mixing loops, each supplying 10 raisers, each of which has manual balancing valves of Danfoss type MSV mounted. This installation showed that utilising the speed controlled Grundfos MAGNA3 pump and Danfoss *Dynamic Valve*™ type RA-DV in combination ensures problem free operation of a heating system.

Heating systems need to be commissioned properly to ensure high comfort and lowest possible cost of operation. In earlier days commissioning was a complicated matter where lots of different valves and measuring tools needed to be utilised for proper commissioning.

The difference today is that designated flow can now easily be set on each radiator and pump set point by means of the new Danfoss dP tool™ (for measuring differential pressure) in combination with Grundfos GO (offering mobile access to Grundfos online tools). Not only does this ensure pump optimisation and lowest energy use, it also reduces time for commissioning substantially.

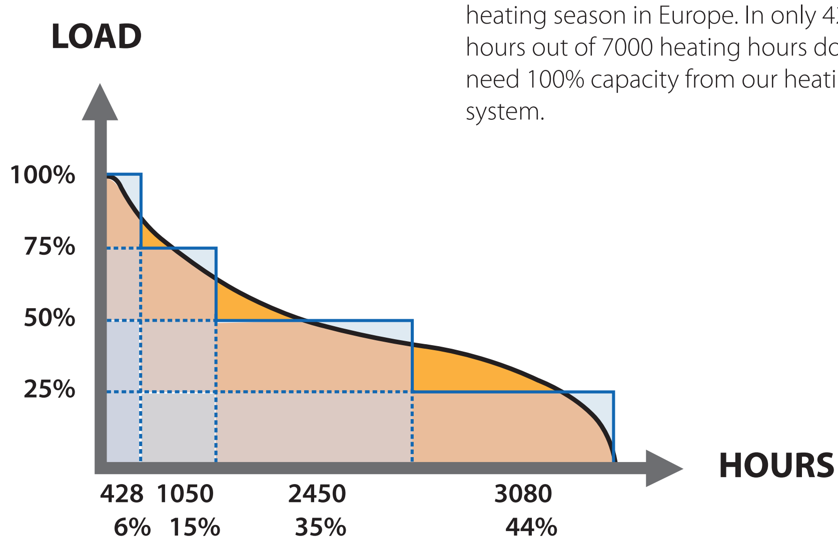


The challenge: balancing two-pipe systems

The uneven distribution of heat between units – single radiators or apartments – in a heating system is what we refer to as a balancing problem. A heating system is balanced when an even distribution of hot water is ensured thereby ensuring maximum comfort at minimum running cost.

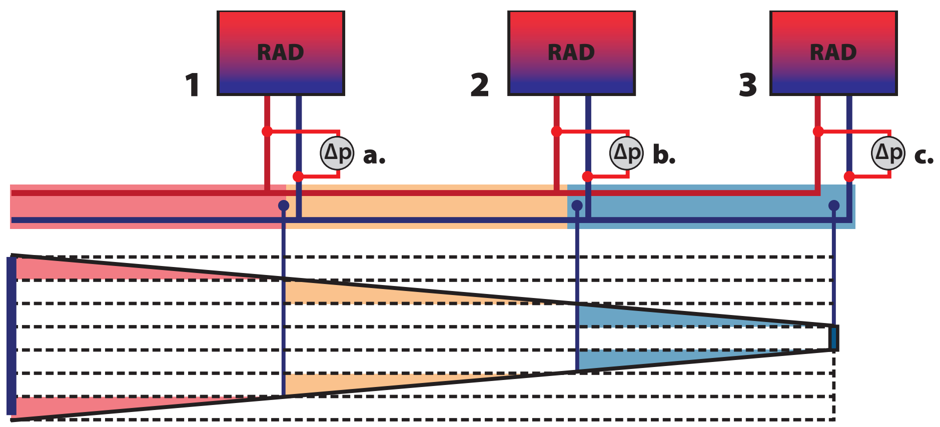
Or to put it in another way, a heating system is in balance when the flow in the whole system corresponds to the flow rates that were specified for the design of the system. This is a key challenge for many two-pipe systems.

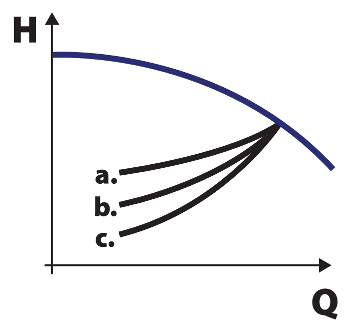
Let us first look at the general challenge in operating two-pipe heating systems. The load profile below shows how load is changing during a heating season in Europe. In only 420 hours out of 7000 heating hours do we need 100% capacity from our heating system.



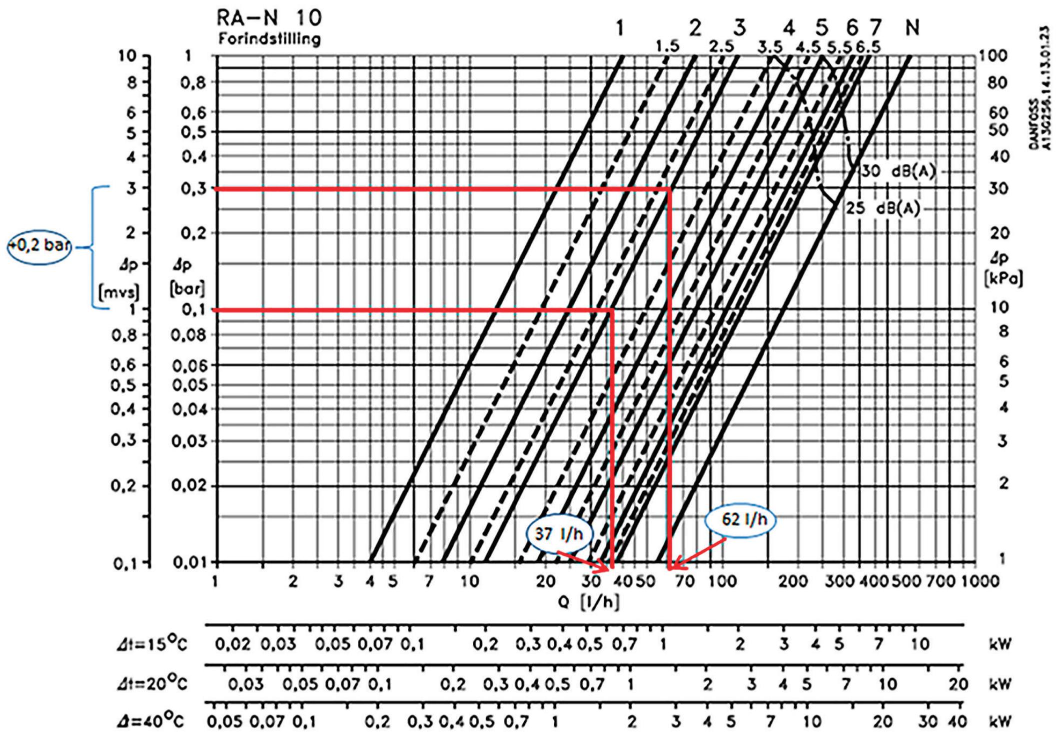
In order to compensate for the variations in load, we equip our systems with thermostatic valves on each radiator. The thermostat will reduce the flow through the individual radiator and ensure the required room temperature is maintained.

As pressure loss increases by the square of flow, the differential pressure across the first radiator valves is substantially higher than it is at the last consumer, as shown in the illustration below.

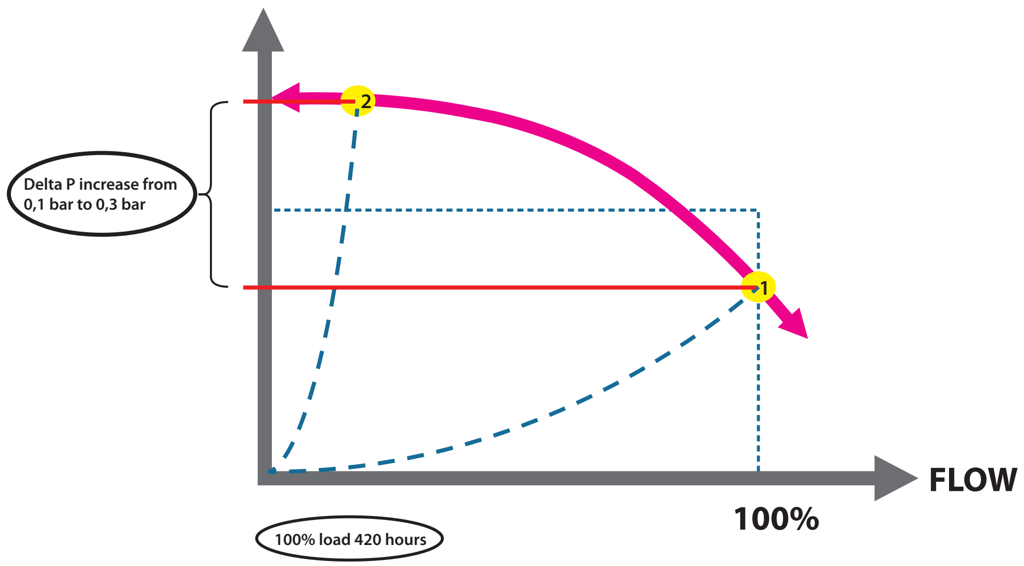




As different radiators need different flows in order to heat up the room in question, it is possible to pre-set the maximum flow on each radiator valve. The pre-setting can be seen in the graph below for a typical radiator valve. The pre-setting can be adjusted from 1-7 and finally in "N position" which indicates a fully-open valve.



When a heating system is equipped with a constant speed pump, the delivered differential pressure will vary greatly, as shown in the illustration below. When flow is reduced the delta P across the individual valve will increase. In the above example the needed flow at max load is 37 l/h. But when the differential pressure increases (+0.2 bar), the flow will increase, as shown to 62 l/h = 67 %.



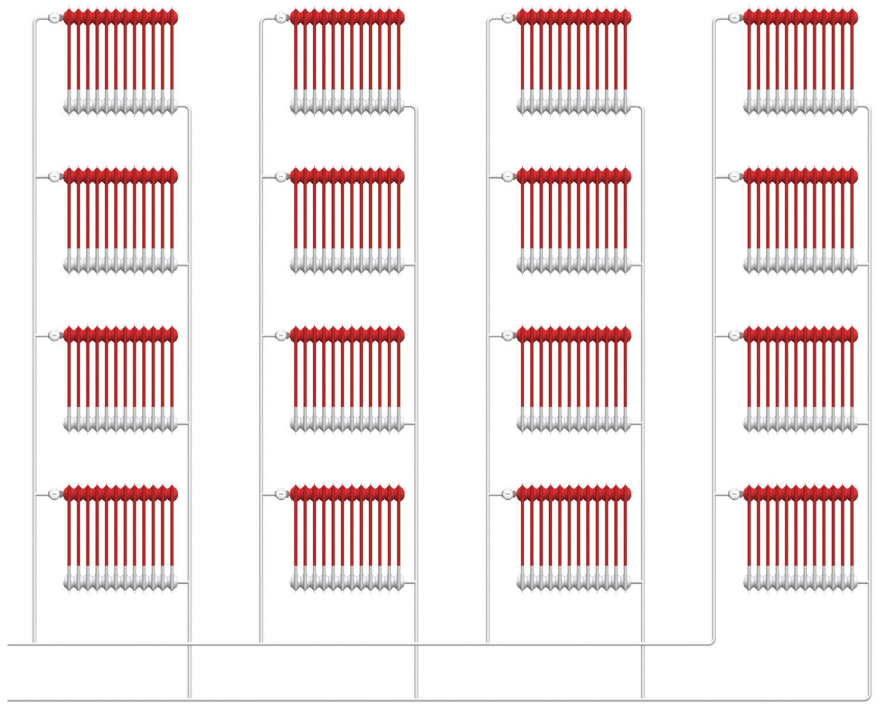
As flow decreases, the differential pressure increases in a fixed speed pump.

The conclusion is that, in order to meet the designated flow, we need to control the differential pressure across valves as well. We will now see how this was done.

Static vs dynamic commissioning of heating 2-pipe systems

A major challenge is that heating systems are often constructed and designed to meet the heating requirements in the worst case scenario, such as when outdoor temperatures are extremely low. But as this occurs only a few times every year (if at all) the system will be oversized in the remaining period. This typically results in overspending on energy.

The following example of static commissioning of a heating system with dynamic requirements is from an installation in Fredericia, Denmark, where 60 apartments in a 10 storey building has heating supplied from a system consisting of two Grundfos MAGNA3 variable speed controlled pumps serving two mixing loops, each supplying 10 raisers, with a total 273 RA-N DN 10 radiator valves and and static balancing valves of Danfoss type MSV mounted. The building is from 1972 and was renovated in 1985, including new windows and façade.



The two mixing loops each supply 10 raisers at the 10 storey apartment building in Fredericia, Denmark.

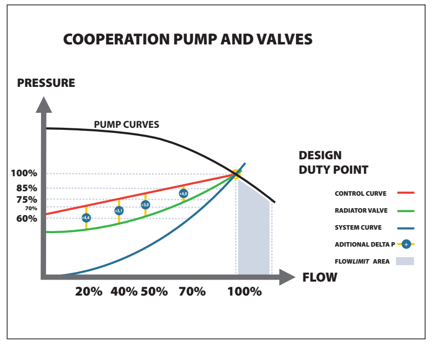
We will now look at how the system operates, with static balancing valves and static radiator valves, with pre-setting. Later, the same test is performed, but this time with dynamic valves. The test is done not only at full load but more importantly at partial load too.

At the same time, differential pressure has been measured at the furthest radiator to make sure that there is enough pressure to reach the designated flow for the radiator furthest away, in this case it is 10 kPa and the designated flow is 30 l/h, so the pre-setting will be 2.5 for the radiator valve.

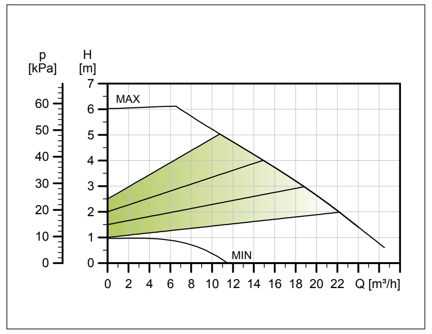
In the test we have set the control mode for the pump to be proportional pressure mode first and secondly constant pressure mode.

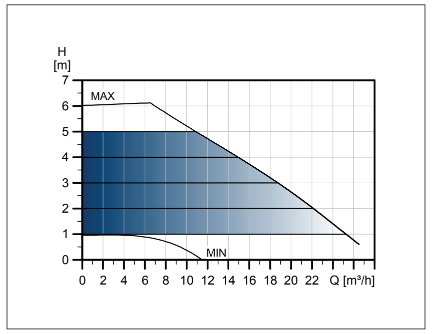
And then we have added the new Danfoss *Dynamic Valve*™ type RA-DV in combination with the new Grundfos MAGNA3 speed controlled pump.

The MAGNA3 pump can be set in proportional pressure mode, which will enable the pump to reduce delivered differential pressure, when flow is decreasing. See the chart, below left.



The red line shows the proportional control curve and the green line the minimum required differential pressure in the system. As can be seen from the blue circles, there will always be surplus differential pressure available. Therefore we need the pump and the dynamic radiator valve to work well together.





Even though the MAGNA3 pump reduces its delivered differential pressure, there will at partial load still be a delta P surplus across the radiator valves*, shown in the table below.

The key issue here is that although a speed controlled pump helps, it cannot keep differential pressure stable; this is an issue solved by pressure-independent dynamic valves.

Static radiator valve

Control mode, pump	System load 100 %	System load 50 %	Increased ΔP (by 50 % load)	Increased flow
Proportional	10.2 kPa	18.0 kPa	7.8 kPa	33 % increase
Constant	10.2 kPa	27.3 kPa	17.1 kPa	46 % increase

Meassured values at the radiator furthest away

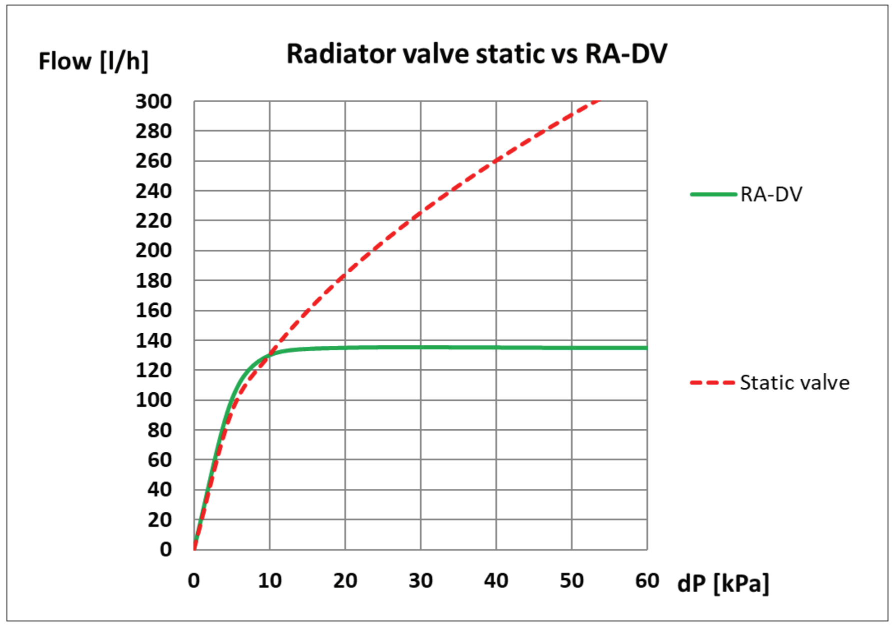
Dynamic radiator valve

Control mode, pump	System load 100 %	System load 50 %	Increased ΔP (by 50 % load)	Increased flow
Proportional	9.8 kPa	10.5 kPa	0.7 kPa	< 1 % increase
Constant	9.9 kPa	10.6 kPa	0.7 kPa	< 1 % increase

Meassured values at the radiator furthest away

*Assuming that the heating system is a traditional widespread system. If this is not the case and instead the system is equally divided in two parallel systems, the optimum control mode will be constant pressure.

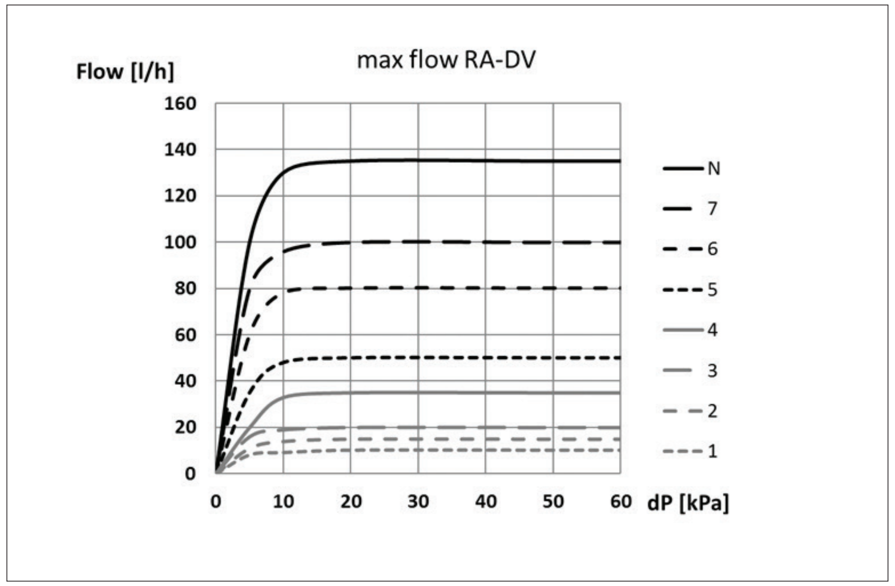
So what that this tell us is that, with static radiator valves at partial load of 50 %, the radiators will have (17.1- 7.8) = 9.3 kPa increased pressure. What this means in risk of overflow can be seen in the figure below.



Using the Danfoss dP tool™ to balance a radiator.

When differential pressure increases from 7.8 kPa to 17.1 kPa, the flow will increase from 80 to 132 l/h, whereas the dynamic valve will keep the flow constant.

The increased delta P at part load would create overflow and increase the heating bill, showing the need to control the delta P correctly. Using the Danfoss *Dynamic Valve*™ type RA-DV keeps the flow constant, even when delta P is changing. A differential pressure controller inside RA-DV keeps the pressure drop over the control valve on the constant level which means that a constant flow through the RA-DV valve is maintained. This is shown in the graph below.



So the answer to the challenge about additional delta P, is to utilise a speed controlled pump like the Grundfos MAGNA3 and use Danfoss *Dynamic Valve*™ type RA-DV, which in combination ensures problem free operation of a heating system, and this has been shown from the example from Fredericia discussed above. The installation has been running now for one year, and we can see that the cost for pump operation has been reduced by approximately 57 % or equal to 980 kWh/year.

Pump optimisation

If the pump runs optimally, the lowest possible energy use is ensured. Pump optimisation together with proportional pressure control is possible only with automatic balancing valves. Commissioning is made easy using the new Danfoss dP tool™ (for measuring differential pressure) in combination with Grundfos GO (offering mobile access to Grundfos online tools), and ensures pump optimisation and lowest energy use.

The Danfoss dP tool™ is an extremely useful, simple and unique tool used during commissioning that measures the available differential pressure. It is mounted on the critical valve where the differential pressure is lowest. In full load mode, the delta P needs to be 10 kPa. If the differentail pressure turns out to be either lower or higher than this, the set point, is adjusted on the MAGNA3 pump. The setpoint is related to the differential pressure delivered by the pump. Note that this value will always be higher than what messured across tha critical valve, as differentaial pressure decreases throughout the system.

Grundfos GO is the mobile tool box for professional users on the go. It is the most comprehensive platform for mobile pump control and pump selection including sizing, replacement and documentation and can be down-loaded to any iOs or Android device.

Having completed these steps you have ensured that the energy system is correctly commissioned, not only at design flow conditions, but also and most importantly at partial load conditions. Result will be lowest possible energy consumption for the entire heating system.

Conclusion

Superior heating systems need thorough commissioning, when lowest possible energy bills is the goal. By using the new and innovative Danfoss *Dynamic Valve*™ type RA-DV in combination with the new Grundfos MAGNA3 variable speed controlled pump, this is now highly achievable. In the specific case in Fredericia, Denmark, the achieved savings adds up to not less than 12 % of the heating bill. This is only possible utilising both the new Danfoss dynamic valve in combination with the new Grundfos MAGNA3 pump.

Heating systems need proper commissioning to ensure high comfort and the lowest possible cost of operation. In earlier days commissioning was a complicated matter where lots of different valves and measuring tools were needed for proper commissioning.

The difference today is that designated flow can now easily be set on each radiator and pump set point can be set by using both the Danfoss dP tool™ and Grundfos GO. Not only does this secure optimal function, it also reduces time for commissioning substantially.

This shows that there are plenty of reasons for you as a consulting engineer to chase down the potential energy savings that are out there in many housing associations.

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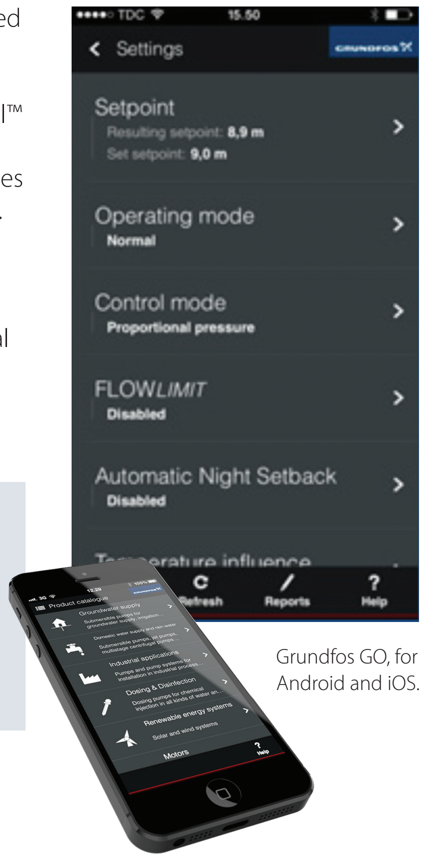

Grundfos GO, for Android and iOS.

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