# TEMPERATURE CONTROL, CHILLER UNITS.

**By Application Manager Michael Laustsen, Grundfos, Denmark**

## Introduction:

Pump operations often play an important role in being able to have an optimum running process with the highest output at the lowest production costs. This is both when it comes to energy used per produced component, prolonging the lifetime of tools if the pump is used in a moulding machine or similar, and when it comes to ensuring a fast production.

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## Purpose:

The purpose of this White Paper is to present some of the ways you can operate a pump in a simple heat exchanger unit but with a huge difference in energy consumption, use of components, etc. Furthermore, the benefits of using pumps with integrated frequency converters (MGE motors) will be explained.

## Background:

Chiller units comprise just one example of the many applications within temperature control where correct system design and construction are important to ensure the correct temperature at your process. The pumps used for this operation are often compact pumps because they are built into cabinets or mounted on skids, where space is always limited.

These demands require an advanced pump setup that can adjust quickly and precisely to changing demands, while doing so in an energy-efficient manner. It is important, therefore, to look beyond the pump and consider the whole system/unit early on in the design process.

## Total Efficiency

When it comes to efficiency, it is important to look at “total efficiency” because buying the perfect pump and motor will be of no use to you if you operate against a half-closed valve, or if there are fundamental design flaws in the system. It is important from the outset to look at what possibilities are available: is it possible to use the cheapest method of regulation and still get the precision we need? The correct control strategy is also important, especially when we take the load profile from the system into consideration.

## System Regulation

The diagram below shows three examples, all with the same system requirement: a specific temperature out of a heat exchanger. However, the way the goal is accomplished is very different. The difference in philosophy lies in what we call the development from S to E to I. (Standard product approach to Extended product approach to Intelligent system approach)

**S**: This system operates at constant speed (fig.1) – i.e., the pump is rotating at constant speed. We have temperature measurement at the discharge of the heat exchanger, which is fed into a regulating valve, and this regulates the temperature by reducing the flow through the heat exchanger. The result for the pump will be that it slides up and down the pump curve. (The red pump curve at fig 4)

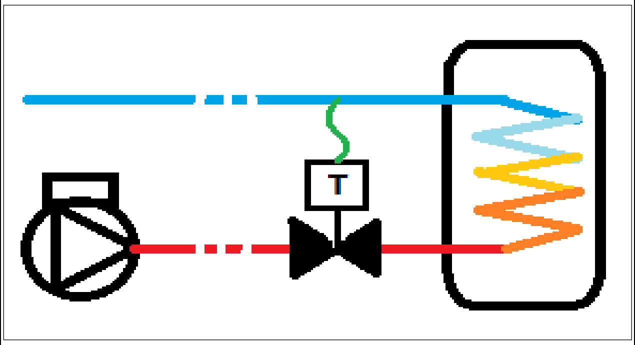



Figure 1: Regulating valve, Full speed

**E**: The second system (fig. 2) is commonly used in many systems. Here we have a pump which is regulating at a constant differential pressure, meaning it keeps a constant differential pressure between the discharge of the pump and the return from the heat exchanger. But once again, the temperature out of the heat exchanger is controlled the same way as in setup 1, where we have a temperature-controlled regulating valve, limiting flow so we have constant temperature. The result for the pump will be that it keeps a constant pressure, a horizontal curve in the Q/h chart. (The yellow pump curve in fig 4)

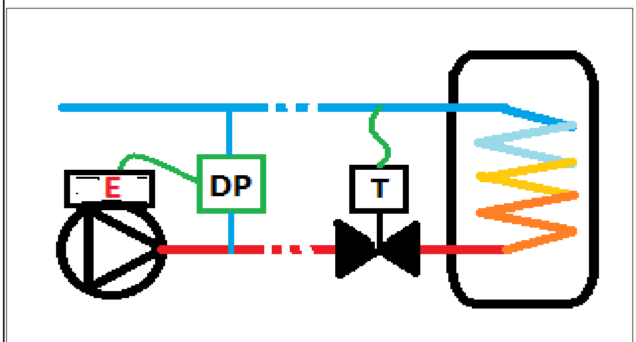
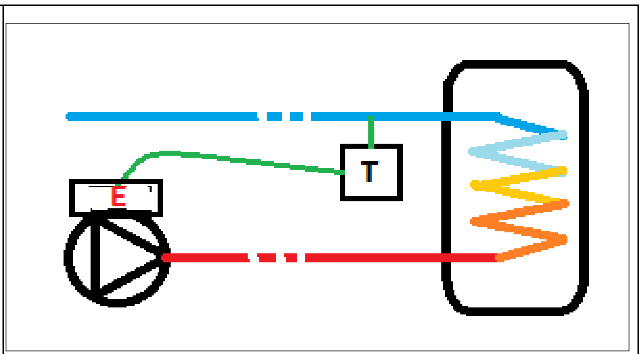



Figure 2 Constant differential pressure

| | |
|---|---|
| **I**: The last example is the 'I' system -the 'Intelligent' way of doing things (fig.3). We take the temperature measurement and feed it directly to the E motor (a motor with built-in frequency converter). In addition, we use the PI regulator in the E-motor to keep a flow, which corresponds to the desired temperature from the heat exchanger. We now have no need for the regulation valve and thus eliminate the continuous pressure loss over it.<br><br>The result for the pump will be that it follows a curve which is very similar to proportional pressure. (The green pump curve in fig 4) | <br>Figure 3 Temperature controlled feedback to MGE |

A comparison of the three system types can be seen on the curve chart in fig 4, showing different load curves.

N.B. The reason the **I** system –direct temperature control- shows a constant flat flow at low loads is because we want to keep a small flow in the system in order to provide information feedback to the temperature transmitter. When you have a heating and cooling system, you cannot turn off the pumps completely; you must have a minimum flow in order to have something to measure.

These three different curves relate to each system. Remember, all three systems are doing the same job: providing constant temperature out of the heat exchanger.

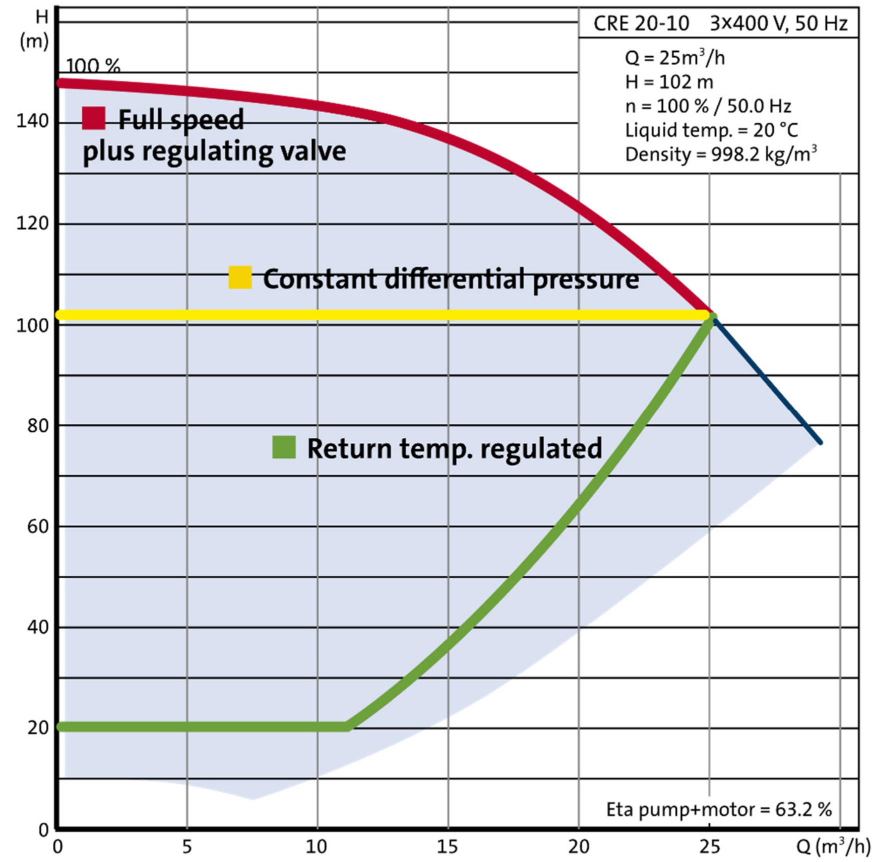
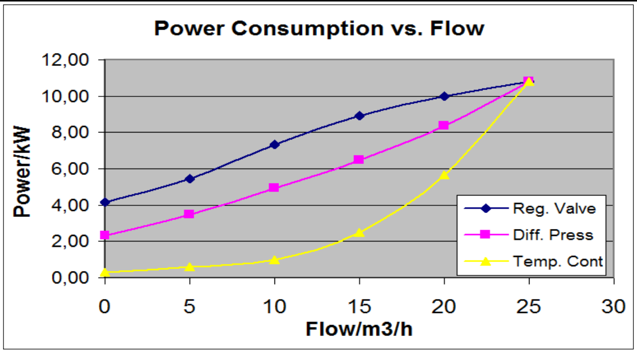



*Figure 4 In systems where the duty point is constant, each of the three strategies perform equally well, but when the load is reduced, direct temperature control offers optimum efficiency and energy savings.*

If we look at the power consumption for each system, we can see the power consumption for full speed load curve, the constant pressure differential load curve and the direct temperature load curve. Looking at each system operating at one-third load, we can see there is a huge difference in power consumption, which can be directly associated with energy savings. On the other hand, there is little difference between the systems when operating at full flow capacity, since the chosen method of regulation no longer plays a role. However, it is of course necessary to ensure that the pump is correctly dimensioned for the task.




## The influence of load profiles on energy use

Clearly, therefore, it is vital to consider the load profile when choosing a set-up. The three sample load profiles in Figure 5 show significant savings with the constant differential set-up compared to the regulated valve system. However, direct temperature control is by far the most energy-efficient option.

Since it is a fact that most cooling pumps are oversized, and load profile C is the most common, the temperature control solution has a massive advantage. Figure 5 shows how the temperature control set-up brings a 72% energy savings in this scenario in this example.

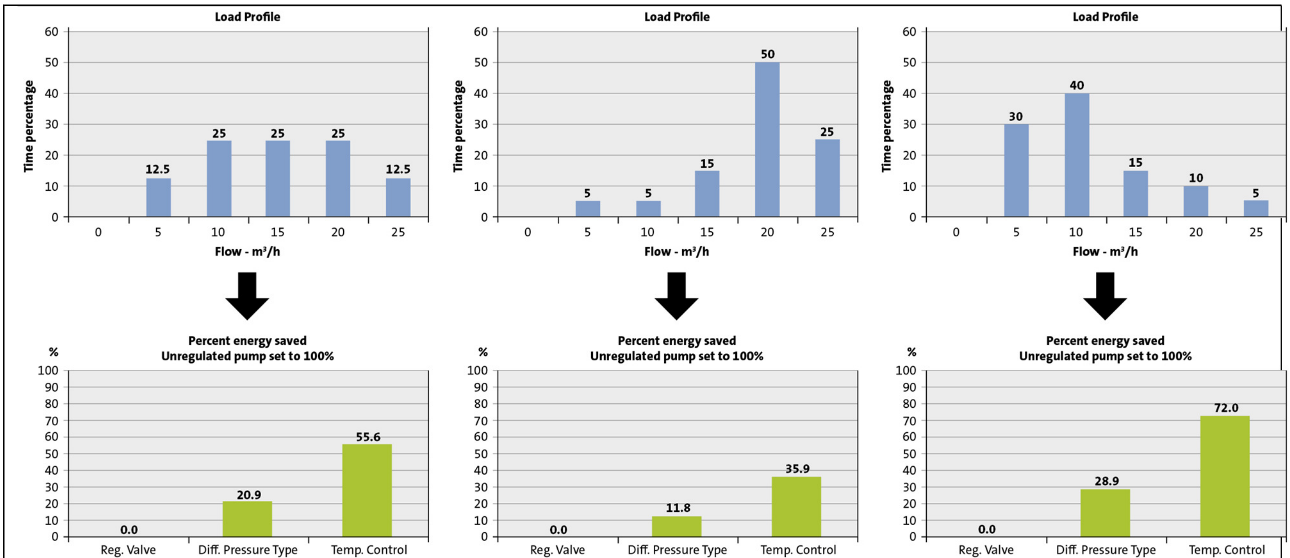



*Figure 5) Three sample load profiles – A, B and C – and the percentage energy savings using alternative constant differential pressure and temperature control options. Load profile A has a random flow request from the system, so the pump supplies flows from all over the pump curve. Load B is a stable process with the same flow requirement most of the time; the pump can be sized so it operates in its best efficiency point most of the time. Load C is often the most common situation, the pump is oversized and it is operating at a much lower flow than it is actually designed to do. This results in a low efficiency on the motor and pump most of the operation time.”*

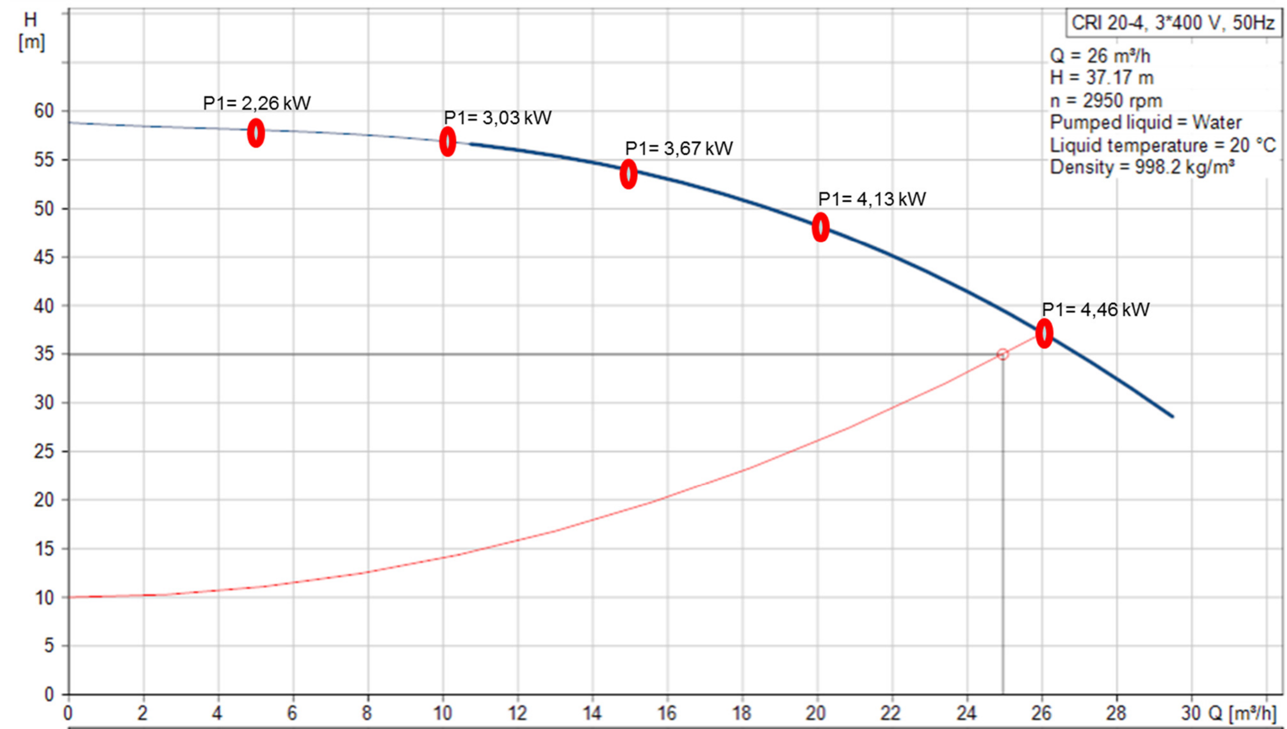
**Practical example.**

With this in mind, here is a practical example of how many kWh per year you can actually save by selecting the correct method of control.

We will use the following specifications for the example:

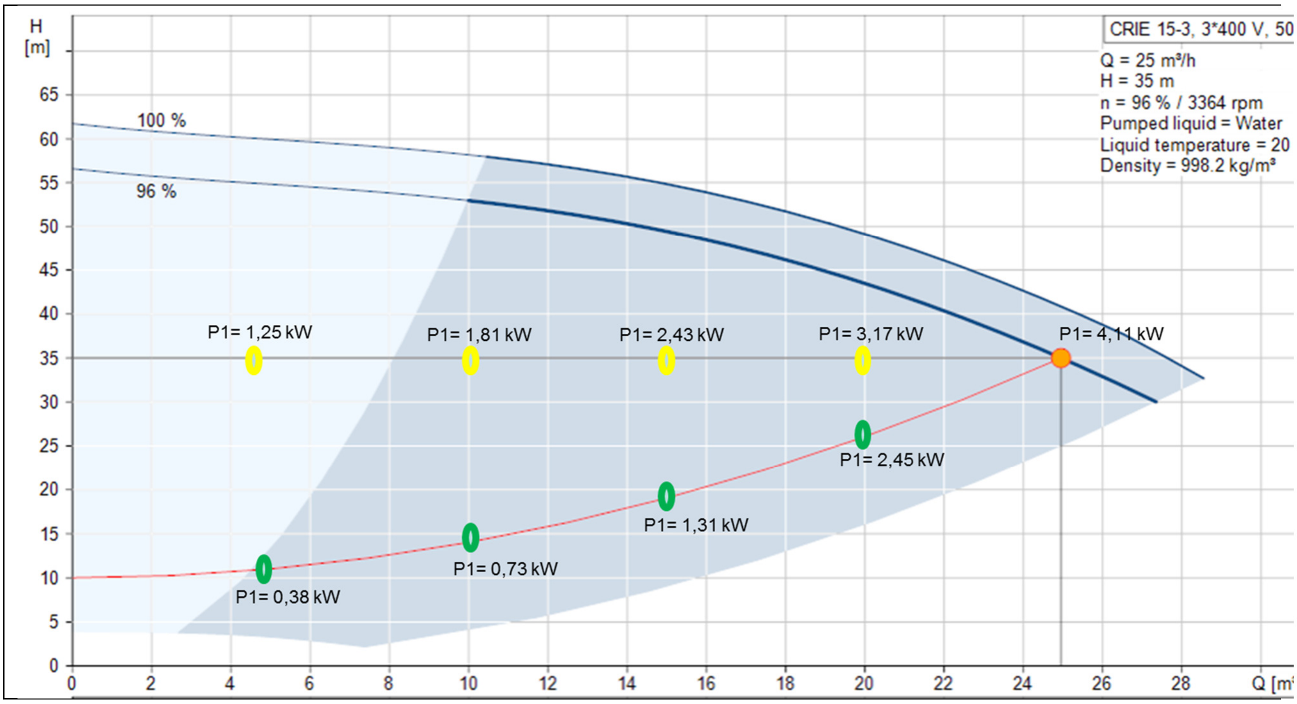
Flow: 25 $m^3$/h
Head: 35 meters
Days a year: 300
Hours a day: 24
Load profile: As in example A in Figure 5 above.

The pump chosen for the Standard product approach would be a CRI20-4, (see the curve and duty points below.)




This pump will have a 5.5 kW motor. The reason it cannot operate directly in the duty point of 25 $m^3$/h at 35 meters is that the pump is a little bit too big for the chosen duty point, but without a frequency converter, it is impossible to do better.

For the Extended product approach and Intelligent product approach, a CRIE15-3 is chosen, and only fitted with a 4 kW motor. The reason we can go lower in pump size here is that with the integrated frequency converter on the motor we do not just spin the pump at 2900 rpm as standard but can speed it up to around 3500 rpm. In this way, a smaller pump can do more work. The CRIE15-3 has the following curve and duty points for the two setups.




| | **CRI 20-4**<br>**Standard product approach** | **CRIE15-3**<br>**Extended product approach** | **CRIE 15-3**<br>**Intelligent system approach** |
|---|---|---|---|
| 5 m³/h for 12.5% of the time: 900 hours/year | 2034 kWh | 1125 kWh | 342 kWh |
| 10 m³/h for 25% of the time: 1800 hours/year | 5454 kWh | 3258 kWh | 1314 kWh |
| 15 m³/h for 25% of the time: 1800 hours/year | 6606 kWh | 4374 kWh | 2358 kWh |
| 20 m³/h for 25% of the time: 1800 hours/year | 7434 kWh | 5706 kWh | 4410 kWh |
| 25 m³/h for 12.5% of time: 900 hours/year | 4014 kWh | 3699 kWh | 3699 kWh |
| **Total** | 25542 kWh | 18162 kWh | 12123 kWh |

Therefore, for a standard pump size used in a heat exchanger with an average load profile, you will be able to save around 13419 kWh a year by regulating the pump correctly. On top of this saving, you also have the following potential benefits.

- You can save a regulation valve
- The pressure loss over the regulation valve is not calculated into above example, which means that the energy saving actually would be bigger.
- In this case, you will be able to use a smaller pump do to the pumping: with a frequency converter it will be running faster.
- In some cases, you could choose an even smaller pump, as you do not have to compensate for the pressure loss in the valve but only the pipe and heat exchanger losses.

Of course, the pump plus frequency converter would be more expensive than a standard pump and for the example and sizes chosen it would be as follows:
CRI20-4, 5.5 kW motor PN 96500348, Price index 100
CRIE15-3, 4 kW motor PN 96514518, Price index 140

With an average price of 0.2 euro/kWh you would save €2,684 a year in energy costs.

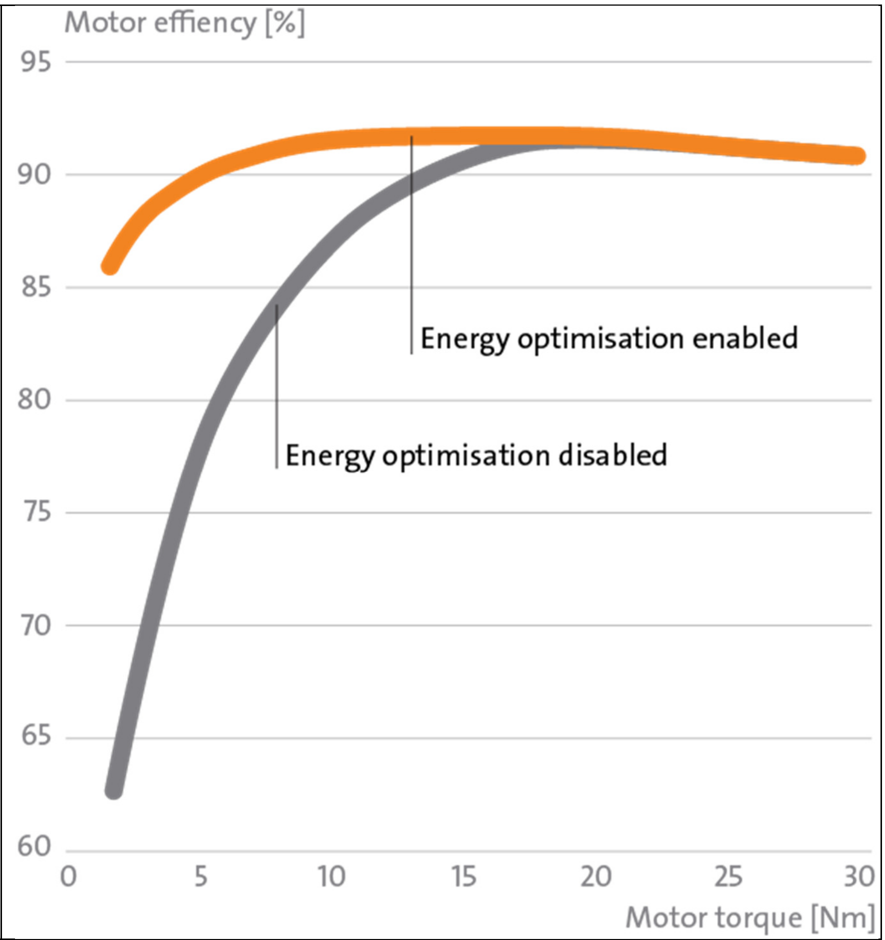
**This means that the extra cost for CRIE15-3 will have a payback time of 2-3 months**.

On top of that, you can add the savings of a regulation valve and the pressure loss over it. Of course, this loss is small. However, whatever loss you have will be converted into heat in the liquid, which is certainly a disadvantage for any cooling application.

Besides the obvious savings shown above, Grundfos motors fitted with an integrated frequency converter actually have a function that will make the iSOLUTION even more environmentally friendly and save more energy. It is called Energy Optimization and with this function activated, the motor will keep its high efficiency even when the motor is partly loaded (see the curve below).

The motor control in the MGE is a “Field oriented Control” type, which makes it possible to control the motor torque and flux independently.
This possibility to control the flux is utilised to optimise the efficiency continuously.

The Energy optimisation function is a great advantage when the motor is partly loaded. This is often the case when the motor is driving a pump.




To set up an MGE motor to operate to a constant temperature is actually quite easy; you just do it with your smart phone (Android or iPhone) and the Grundfos GO app. You will need to set up the following things:

- Sensor signal and range
- Set the sensor to ‘feedback sensor’, meaning it is the one that you use to regulate the pump.
- Set the minimum speed. This has to be set, so there is always a flow through the heat exchanger.
- Choose ‘closed loop’, which means you want to use the MGE motor’s own PI regulator.
- Choose the set-point, which is the temperature you want to have.
- Finally, you have to set PI parameters so you have a good regulation.

This last point is often the one people struggle with, but with Grundfos products it is easy, because when you choose temperature regulation it automatically sets the PI parameters to recommended values. In that way you have a system that works immediately and you get the temperature you need. If you want to fine-tune it even more to your specific system, you can of course do that. On the next page you can see a number of screen shots showing how these parameters and setup dialogues appear in the Grundfos GO app.

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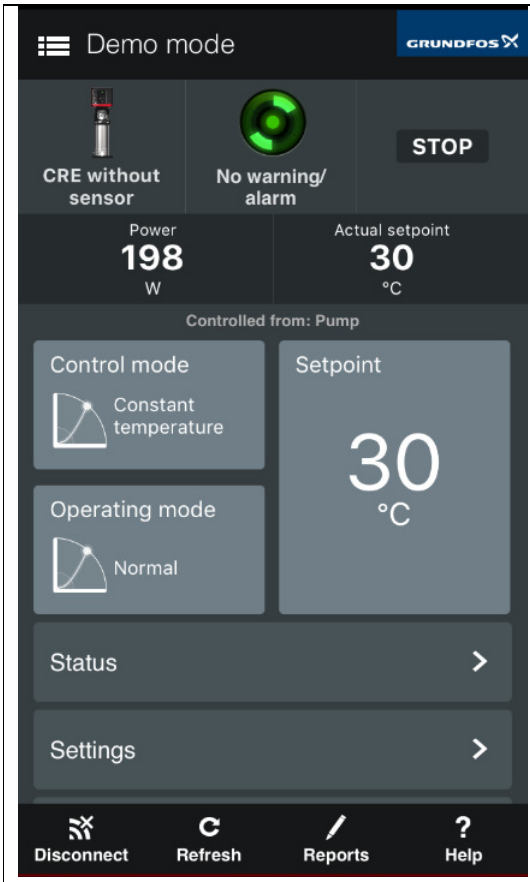
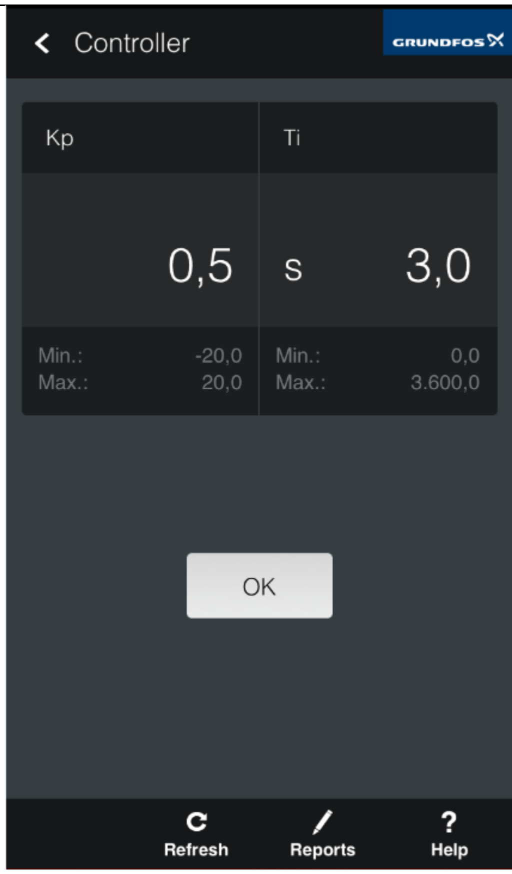
|   Overview in the Grundfos GO app when connected to a pump. You can see that constant temperature is chosen as the control mode and the Setpoint is 30 °C. |   These are the default PI parameters when you choose control mode, Constant temperature. Be aware that for a standard setup (shown here), it is straight regulation but in a cooling application you often need inverse regulation. To do that you must put a minus in front of the Kp value. |

## Conclusion

As described in this whitepaper there are different ways to get the requested temperature out of your heat exchanger. In summary, there are five things you have to consider:

- Pump and motor efficiency
- Regulating mode
- Sizing of system
- Load profile
- Losses in the system

This is where Grundfos iSOLUTIONS (intelligent solutions) comes into play. The approach goes beyond the pump to optimising the entire pumping system. Grundfos works to identify customers’ needs and help them avoid situations that would be uneconomical in the long term – for example, by setting up the most intelligent and efficient pump regulation mode in an industrial cooling application.

Besides this, there are several other advantages from using iSOLUTIONs. You have many more possibilities to monitor not only the pump performance but also the whole system performance, and you will be able react faster if, for example, the set point needs adjusting.

## Comparison sheet

### Benefits

| **Safety/Reliability** | No frequency converter | iSOLUTION |
|---|---|---|
| Motor protection included in pump drive. | ☹ | ☺ |
| Valves need maintenance. | ☹ | ☺ |
| Precise temperature | ☺ | ☺ |
| Lower risk of water hammers and cavitation. | ☹ | ☺ |
| Reduction of noise and vibrations: Fixed speed can cause resonance in pipes. | ☹ | ☺ |
| Valves can cause noise. | ☹ | ☺ |

| **Ease of use** | | |
|---|---|---|
| Range of possible start-up settings can be tailored to specific pump family (pre-configured) for simple commissioning. | 😐 | ☺ |
| Failure analysis with detailed log-files. The failure log can be evaluated with Grundfos GO. | ☹ | ☺ |
| Data transparency of energy consumption, speed, running hours etc. | ☹ | ☺ |
| All data can be sent to the main Scada or BMS system for monitoring and surveillance. | ☹ | ☺ |

| **Flexibility** | | |
|---|---|---|
| With an E-solution the temperature can be set within a range during commissioning. Higher system specs may also be covered. | ☹ | ☺ |

| **Integration** | | |
|---|---|---|
| Space saving: No need for extra control cabinets or space on a wall. | 😐 | ☺ |
| Easier system design. --> Fewer components and calculations needed. | 😐 | 😐 |

| **Maintenance** | | |
|---|---|---|
| No throttling valve needed. Valves also need maintenance. | ☹ | ☺ |