ENGINEERING TOMORROW

Application Guide

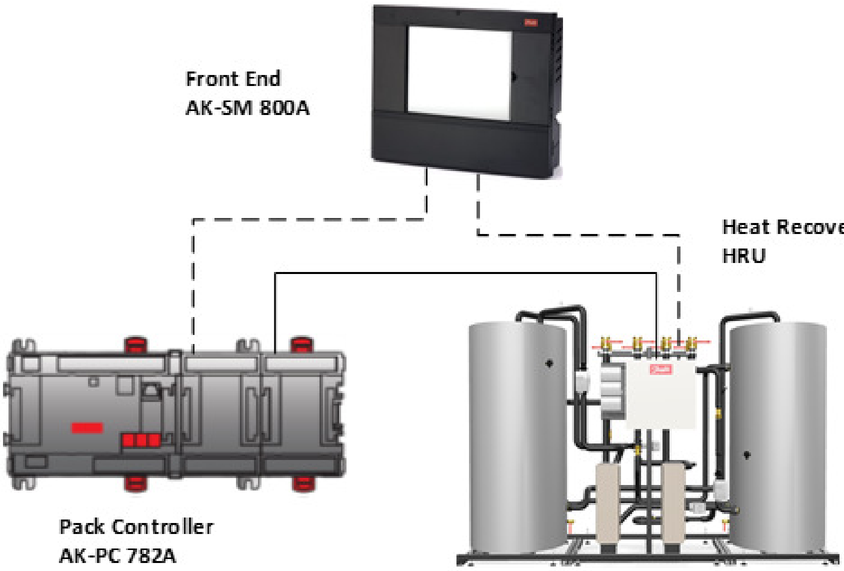
Heat Recovery Unit

Contents

1. Introduction

Refrigeration systems with transcritical CO_2 have been taking market shares in recent years. Transcritical systems are now everyday business and the technology is mature.

The application guideline contains a short background on the theory behind heat reclaim in transcritical systems and how to correctly select the Danfoss Heat Recovery Unit to get the highest overall system efficiency. It also covers setup procedures for the Danfoss Heat Recovery Unit (HRU), dedicated configuration settings related to interactions with the Danfoss Pack Controller AK-PC 782A and integration with the Danfoss Front End system AKSM 800A as well.



1.1 Properties of carbon dioxide

Carbon dioxide CO_2 is a natural substance that plays an important role in many natural and industrial processes. In nature, carbon dioxide plays a role in photosynthesis in plants and is one of the most important contributors to the global warming effect. In industry, carbon dioxide is used as dry ice for transport cooling, to generate the sparkling effect in some beverages, and as a protection.

It is odorless, non-flammable, and non-toxic, but if the concentration of carbon dioxide rises above the natural level in atmospheric air, it will cause the human breathing rate to increase. It is heavier than air, so if large quantities escape in a closed room the highest concentrations will typically be found close to the floor.

When carbon dioxide is used as a refrigerant it is often referred to by its refrigerant number R744.

Figure 1. shows a phase diagram of R744. The three well-known phases: solid, liquid and vapor are shown as colored areas. A phase change occurs when a process crosses a boundary between areas like evaporation or condensation for a process crossing the boundary between liquid and vapor phases. At the boundaries, the two phases exist in equilibrium, and properties, such as temperature and pressure, become dependent. The boundary line between liquid and vapor are often referred to as the vapor pressure curve.

Two important state points are marked in the figure: the triple point and the critical point. The triple point represents the condition where all three phases can co-exist in equilibrium. At temperatures below the triple point temperature, liquid cannot exist - in other words the triple point temperature sets the lower temperature limit for any heat transfer process based on evaporation or condensation. At the other end of the vapor pressure curve, the critical point marks the upper limit for heat transfer processes based on evaporation or condensation.

At temperatures and pressures higher than those at the critical point, no clear distinction can be drawn between what is called liquid and what is called vapor. Thus, there is a region extending indefinitely upward from, and indefinitely to the right of, the critical point - and this region is called the fluid region. The fluid region is bounded by lines that do not represent phase changes, but which conform to arbitrary definitions of what is considered a liquid and what is considered vapor. A condition in the fluid region is referred to as a supercritical condition - or very often also as a gas condition.

All substances have a triple point and a critical point, but for most of the substances used as refrigerants, the triple point and critical point are found for conditions that lie outside the region where they are normally used.

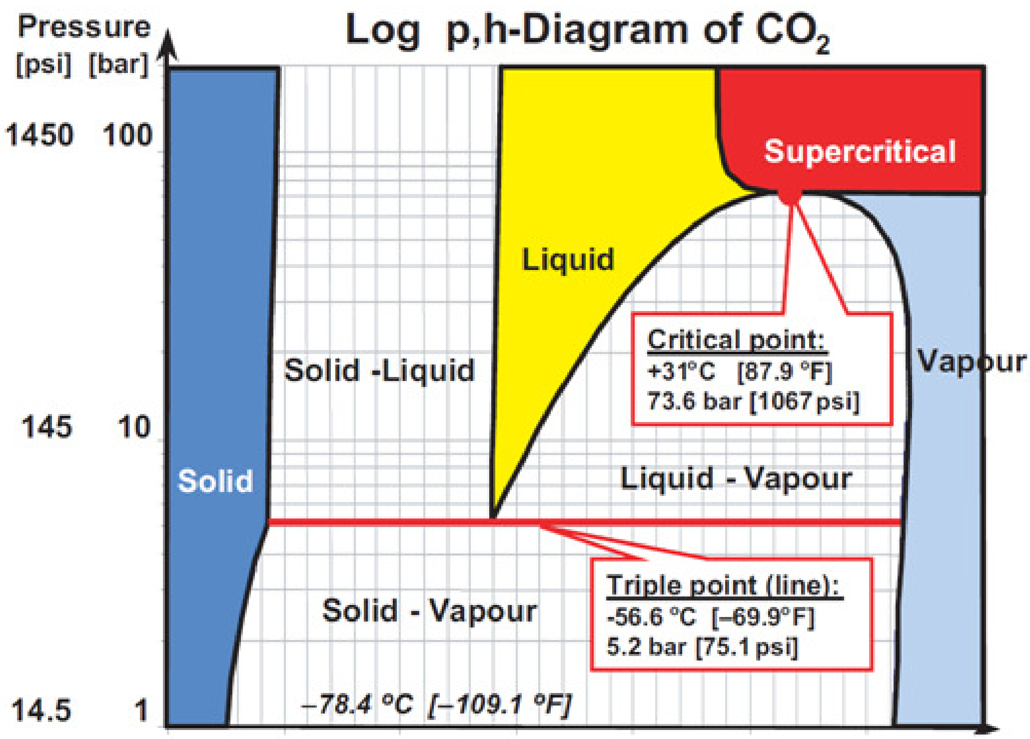


Figure 1.: Phase diagram for R-744
source DKRCI.PZ.000.F1.02 / 520H3002

1.2 Heat recovery in CO_2 transcritical systems

In normal systems with condensing refrigerants, pressure and temperature are tied together, but in transcritical systems pressure and temperature can be controlled individually. This gives some possibilities regarding heat reclaim.

During normal operation without heat reclaim, the high pressure is kept at a level where the optimum COP is obtained. Please observe the red line in Figure 2.

The pressure in the gas cooler is controlled by the Vhp valve. Regulation must have inputs from both a pressure transmitter Pgc and a temperature sensor out of gas cooler Sgc. Both must be fitted in the outlet and it is very important to install sensor Sgc immediately after the gas cooler.

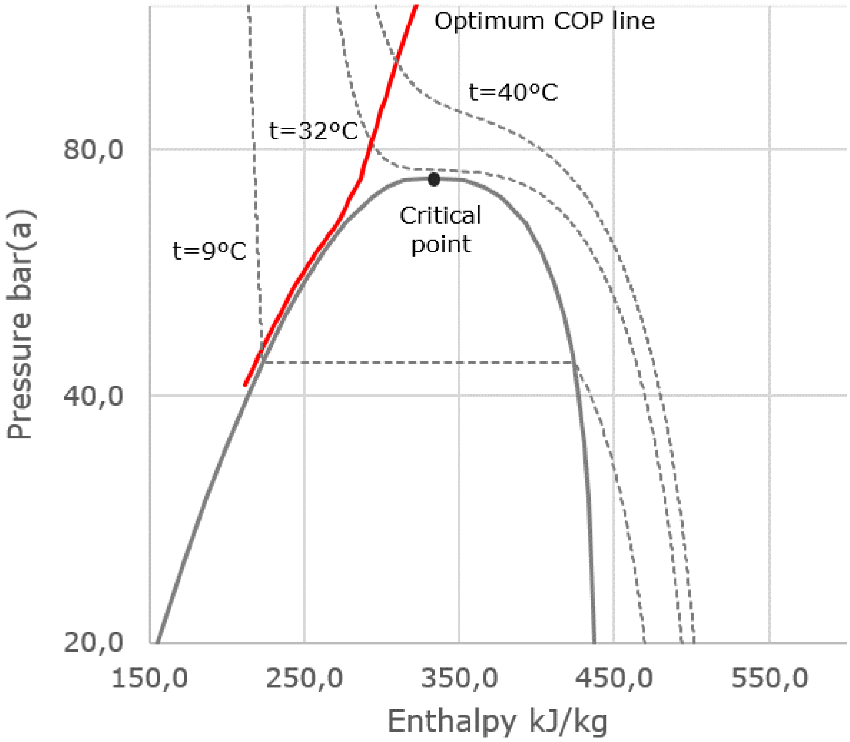
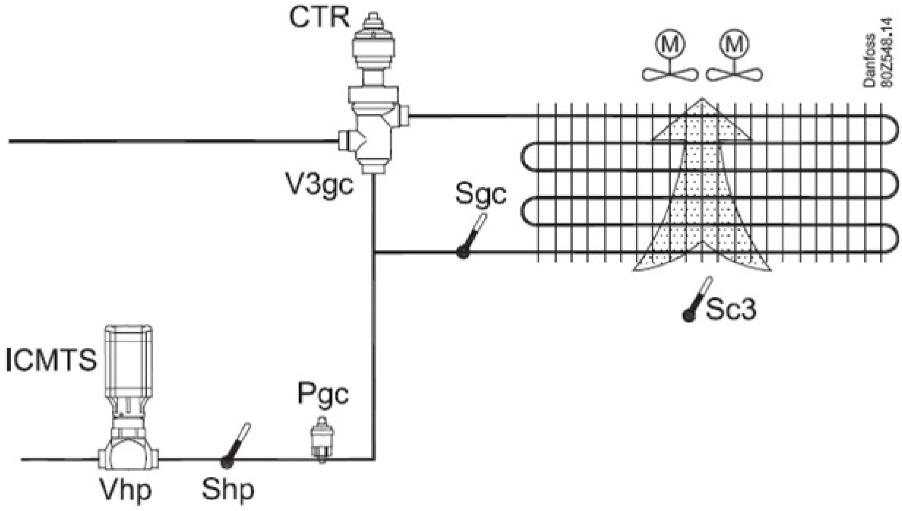
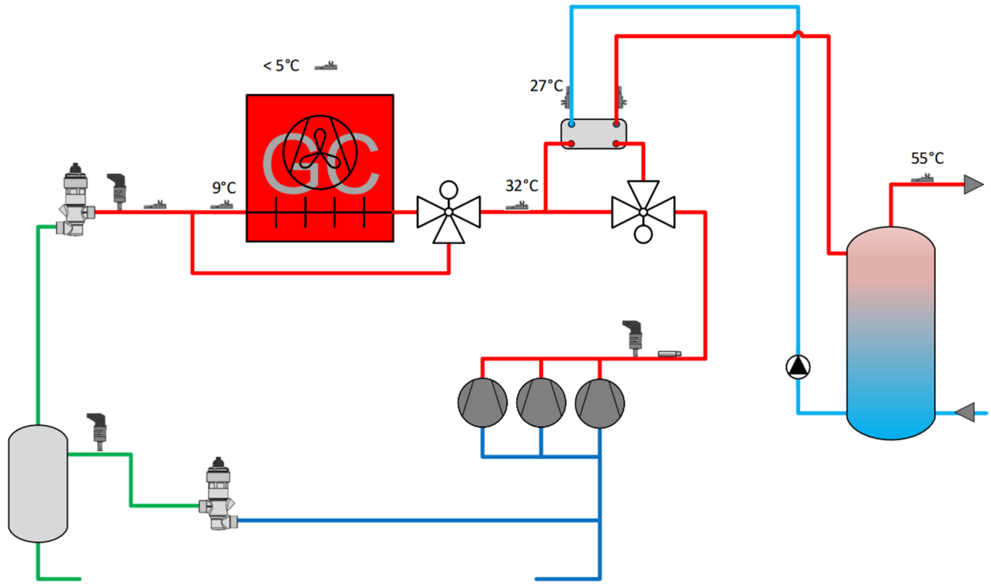


Figure 2.: Optimum COP line with dependency upon temperature out of gas cooler



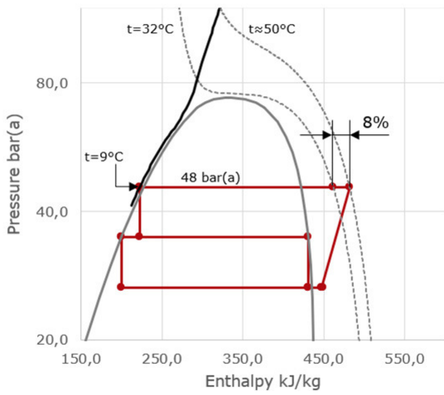
If the gas can be routed outside of the gas cooler by V3gc valve, a Shp sensor must be installed. If the Shp sensor measures too high a temperature, the gases will be routed through the gas cooler again. This is done automatically by a pack controller AK-PC 782A. During cold periods, if ambient temperatures allow, the pressure is typically kept at minimum 48 bar ~ 9 °C or higher. At this pressure there is very limited potential for heat reclaim. If the pressure is raised, the amount of heat that can be reclaimed and the achieved water temperature increase.

Example: In a heating system, there is a request to heat recirculating water from return temperature 27°C to supply temperature 55°C. The ambient temperature is below 5°C, enabling a low temperature out of the gas cooler. Heat load on the system needs to be reclaimed with the lowest possible energy consumption. The temperature difference of the heat reclaim HX is set to 5 K at the outlet. The temperature out of the gas cooler is kept at 9°C in all modes where the gas cooler is active. By getting more heat recovery request, the temperature out of the gas cooler will be increased up to the optimum COP line, reaching Maximum Heat Recovery operation mode.

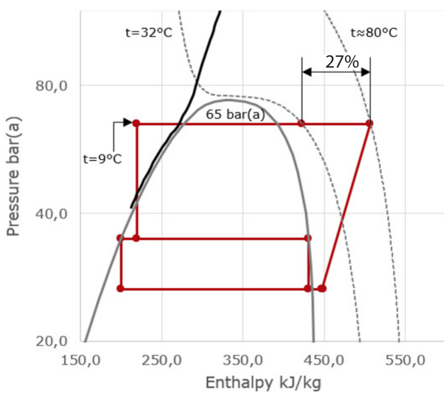


Under these conditions, the discharge temperature from the compressors is approx. 50°C and therefore it is not possible to produce 55°C hot water. To make the system able to deliver 55°C, the discharge pressure needs to be higher and therefore the pressure needs to be raised.

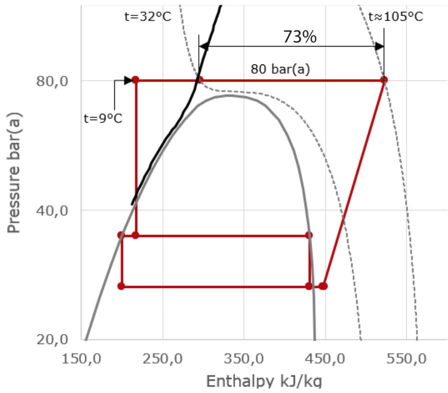
At 50 bar high pressure, the discharge temperature is around 55°C and therefore it is possible to start reclaiming heat from the system, but there is not enough temperature difference on the heat exchanger. By increasing the pressure further, the amount of heat taken out of the system increases.



Further increasing pressure in the gas cooler, the heat reclaim ratio and discharge temperature increase.

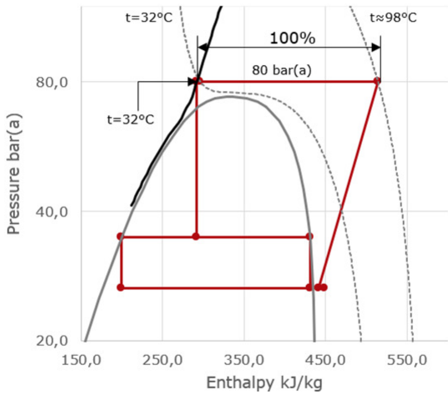


Keeping the same temperature out of the gas cooler and 80 bar in the gas cooler, approximately 73% of the heat is reclaimed at a cooling COP of 3.3.



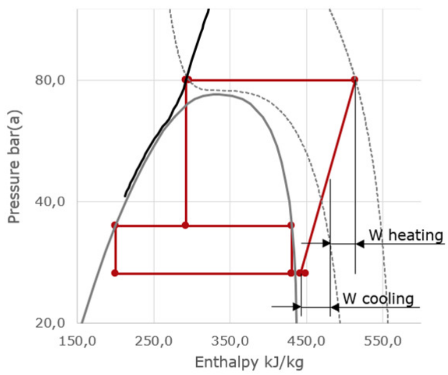
To increase the heat reclaim ratio, the temperature out of the gas cooler can be increased by slowing down the fan speed. As the last stage, the gas cooler can be completely bypassed. By doing this, the ratio will go to 100% because there is no heat loss to the ambient, and all heat is reclaimed.

This process will engage more compressors in operation to compensate lower refrigeration efficiency as a result of a higher gas fraction in the receiver. By performing this mode, more heat can be transferred to the water system.



Since the heat output from the system varies with the pressure, it is interesting to look at how heating COP changes.

In normal operation, the system operates with highest efficiency following an optimal COP pressure curve (in this example: 48 bar). This means that no matter how much heat we pull out of the system, it will consume energy for keeping cooling demand. Therefore, the heating COP of the system is calculated taking heat recovery capacity divided with the extra energy consumed by the compressors. This is done because then it is possible to compare the heating COP with alternative heating sources.



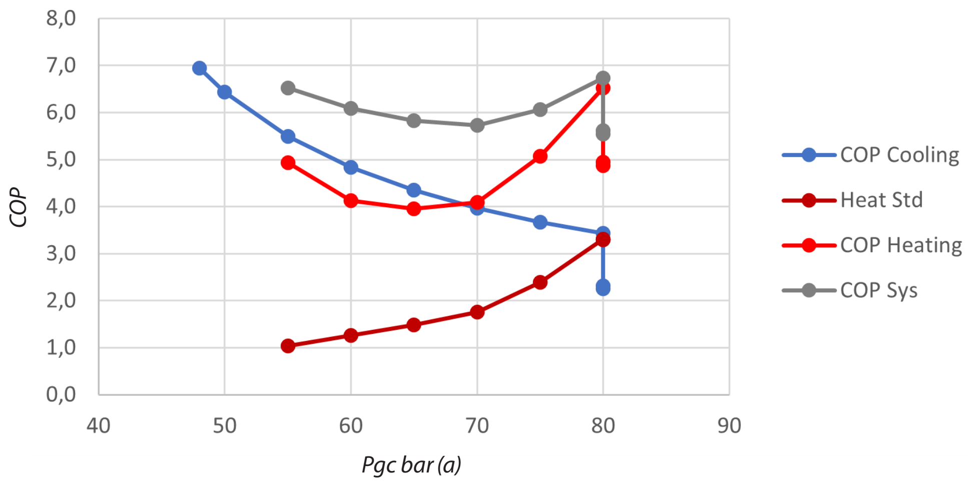
The heat recovery ratio is the ratio between the maximum heat available and the heat used.

The heating COP varies with the ambient temperature. At high ambient temperatures, the compressor work used for refrigeration is higher and therefore the compressor work for heating is less. At lower ambient temperatures, the pressure cannot be decreased, and therefore this will not affect the heating COP.

This analysis was done with ambient temperatures below approximately 5°C. In normal operation, temperature out of the gas cooler is 9°C and pressure in the gas cooler 48 bar(a).

Sgc [1] °C	Shr2 [2] °C	Pgc [3] bar(a)	COP [4] Cooling	COP [5] Heating Standard	COP [6] Heating	COP [7] System	HR ratio %
9	32	48	6,9				8
9	32	50	6,4				10
9	32	55	5,5	1,0	4,9	6,5	16
9	32	60	4,8	1,3	4,1	6,1	21
9	32	65	4,3	1,5	4,0	5,8	27
9	32	70	4,0	1,8	4,1	5,8	35
9	32	75	3,7	2,4	5,1	6,1	50
9	32	80	3,4	3,3	6,5	6,7	73
31,4	32	80	2,3	3,3	4,9	5,6	98
32	32	80	2,2	3,3	4,9	5,5	100

1) Sgc – temperature out of gas cooler
2) Shr2 – temperature out of heat recovery exchanger
3) Pgc – pressure in the gas cooler
4) COP Cooling – cooling capacity divided by total electrical energy for compressors
5) COP Heating Standard – heating capacity divided by total electrical energy for compressors
6) COP Heating – heating capacity divided by additional electrical energy for compressors because of heat recovery operation mode
7) COP system = COP Cooling + COP Heating Standard



2. Precondition for installing HRU

Installation of the HRU requires fulfilment of different preconditions in cooling and heating systems.

2.1 Mandatory preconditions for installation

To install HRU, some conditions must be met:

- The CO_2/water heat recovery heat exchanger must be installed on refrigeration rack
- Motorized 3-way valve must be installed on refrigeration system to bypass CO_2 heat exchanger when there is no need for heat recovery.
- A 0-10 VDC circuit must be established between the HRU and the refrigeration controller.
- Safety valve must be installed on heat recovery circuit – as close as possible to CO_2 heat exchanger.
- 4 sensors on the CO_2 heat exchanger must be mounted.
- Main heating pump P1 size must be determined in relation to the system's peak effect/power and must be able to supply entire installation, and the HRU. If P1 is an existing pump, it must be checked if it can deliver the flow when the HRU's pressure loss is added to the system.
- In central heating systems, the volume of the expansion tank must include HRU. A 2-tank solution requires approx. 40 l extra volume. In an existing installation, it is important to check whether the expansion tank volume is sufficient. A manometer and safety valve must also be fitted.
- Cooling pack must be set to heat recovery.

2.2 Important preconditions for optimal operation

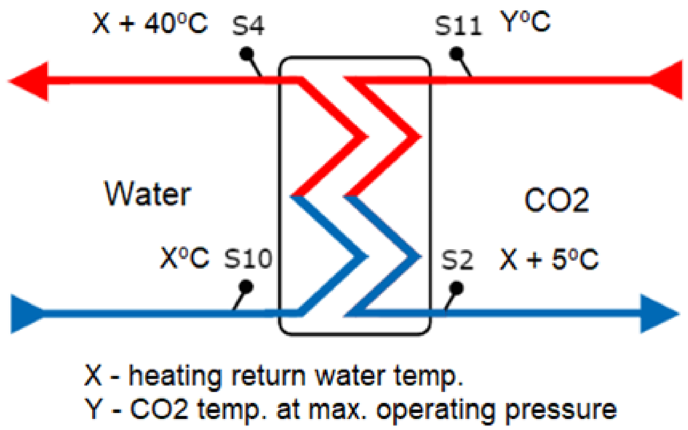
To ensure stable and efficient operation of HRU and refrigeration system, the below conditions should be fulfilled:

- The CO_2 heat exchanger should be sized for nominal operating parameters of the heat recovery circuit
- The CO_2 heat exchanger and high-pressure piping from the compressor must be insulated
- Vibration dampers should be fitted between the CO_2 heat exchanger and the fixed plumbing installation
- Balancing valve on heat reclaim circuit should be mounted
- Heating, ventilation, and domestic hot water systems must be configured to ensure lowest possible return temperature.
- It should be ensured that operation of the cooling system is optimized to avoid excessive starting and stopping of the cooling compressors.

2.3 CO_2 heat exchanger sizing

Sizing of a CO_2 heat exchanger is crucial for an efficient heat recovery process. If too small, a heat exchanger will not recover all the available energy during peak load condition for a refrigeration system.

Danfoss recommendation is to use in calculation max. pressure and temperature of the CO2 in transcritical operation mode. CO2 mass flow should be equal to max. winter condition for stores without heat resale and maximum compressors capacity for stores with heat resale. For the water side, the inlet temperature should be equal to the design return temperature from the heating system. To store more energy in buffer tanks, the water outlet temperature should be at least 40°C higher than the inlet temperature, but not higher than 85°C. For the highest efficiency, the temperature difference between water inlet and CO_2 outlet should not be higher than 5°C.



2.4 Recommended dimensioning temperatures in heating system

To ensure the highest possible heat recovery, the return temperature from the heating system should be as low as possible. This can be achieved by sizing heat consumers' circuits with recommended temperatures (based on heat consumer type) or by using return temp. limitation valves (enough heat needs to be ensured in peak load conditions).

2.4.1 Recommended dimensioning temperatures

In new heating installations, recommended design parameters should be max:

Heat consumer circuit:	Flow temperature:	Return temperature:
Radiators	60	30
Floor heating	45	25
Ventilation	60	30
Domestic hot water	65	25

Lowering the heating return temperature increases efficiency, but will require more heating surfaces.

In existing buildings, it is important to optimize heating systems with regard to water flow, and settings in electronic controllers for heating, ventilation, and domestic hot water systems. The return temperature should be lowered as much as possible, while ensuring that enough heat will be delivered to consumers in peak load condition.

2.4.2 Return temperature limitation valve

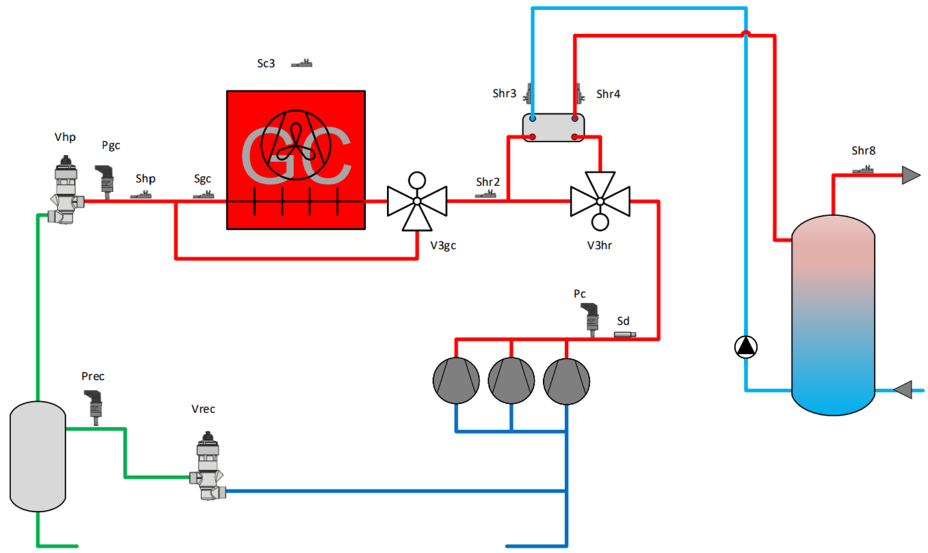
Installation of the return temperature limitation valve, like Danfoss NovoCon®/ AB-QM, can increase heating system efficiency. By extending the delta T of the heat consumer, less flow is required to deliver the same amount of energy.

Larger temperature span requires more heating surface, so before installation of a return temperature limitation valve, the heating system must be checked to ensure that enough energy will be available in peak load condition if new operating parameters apply.

3. How to control the heat recovery process in CO_2 transcritical systems?

In CO_2 systems, the higher pressure and temperature makes it possible to recover heat for tap water and heating. Regulation is carried out during transcritical and subcritical states and the controller will control the gas pressure/condensing pressure so that the system achieves the optimum COP when the recovered heat is taken into account.

The Heat Recovery circuit will take the energy it needs. If there is then any excess energy, this is removed via the gas cooler. There must be a cooling requirement in order to supply for heat recovery.



There are safety functions for the individual regulation functions, for example:

- Boiling at Shr3, Shr4 and Shr8
- An Shr3 temperature must be lower than the gas temperature that can be sent into the heat exchanger. If the Shr3 temperature is higher, the heat recovery circuit is not enabled.

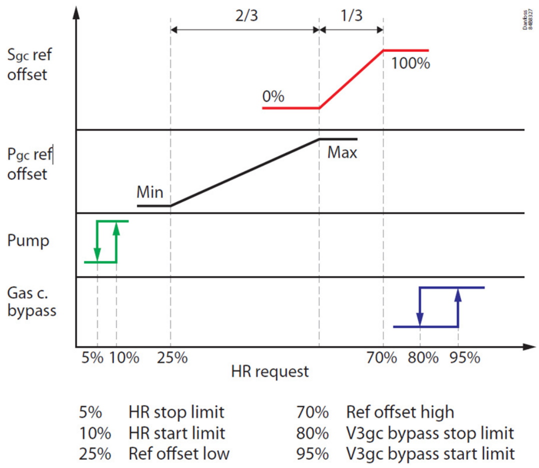
Shr2: CO_2 temperature after the heat recovery exchanger
Shr3: Heat exchanger cold water access temperature
Shr4: Heat exchanger hot water outlet temperature
Shr8: Hot water temperature in the tank or after the tank
Sd: Compressor CO_2 discharge temperature
Sc3: Ambient temperature
Sgc: CO_2 temperature after the gas cooler
Shp: CO_2 temperature after gas cooler bypass connection
Pc: CO_2 compressor discharge pressure
Pgc: Pressure in the gas cooler
Prec: Pressure in CO_2 receiver
V3hr: Heat recovery 3-way valve
V3gc: Gas cooler 3-way bypass valve
Vhp: High pressure expansion valve
Vrec: Gas bypass expansion valve

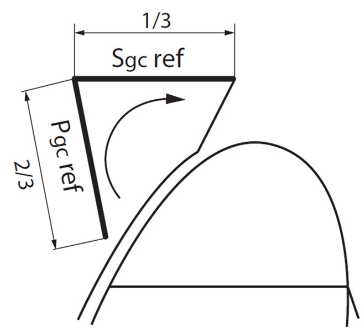
Regulation in the pack controller AK-PC 782A/B
can be carried out using one of the following three principles when the circuit calls for heat:

1. Basic control (no HP offset).
2. Heat reclaim mode: Hp offset and temperature reference
3. Heat reclaim mode: Max. heat reclaim

In systems where a Danfoss Heat Recovery Unit (HRU) will be installed, it is mandatory to select 3rd option Maximum Heat Recovery, because the regulation is solely based on the external heat request (consumer request) on an analogue input and a start signal on a digital input. Note, there is no active thermostat control for the heat recovery mode. To prevent any boiling in the system, the heat recovery will be stopped as soon as any of the Shr3, Shr4 or Shr8 temperatures are above 95 °C.
An external ECL heat controller installed on the HRU will send a heat request signal between 0 and 10 V in relation to heating demand 0 to 100%, which will be used to start the following functions in order to achieve maximum heat recovery:

1. Signal on DI input for heat recovery is received (mandatory, to enable the function) and the reference for the pressure Pgc is increased to “Pgc HR min.”
2. The external voltage signal is registered (the higher the value, the greater the need for heat). The signal is converted by the controller to 0-100% capacity and will have the following impact:





a. ON/OFF control of pump and by-pass valve V3hr The pump is released to start, when the request signal reaches the “HR start limit” and the by-pass valve V3hr opens for the heat recovery. The valve V3hr goes into "bypass" when the "HR stop limit" is reached, and the pump is stopped after 180 sec.

b. Pressure and temperature increase The pressure is measured with the pressure transmitter Pgc and controlled with the High pressure valve Vhp. Depending on the Heat request, the pressure reference “Pgc HR ref” will be raised from “Pgc HR min” to “Pgc HR Max”. After reaching the "Pgc HR max", then “Sgc ref” is raised from “Sgc min” to “Sgc max”. The consequence of the increased gas cooler reference is a decrease in the fan speed. (Min. Sgc is calculated by the controller based on the receiver pressure reference that has been set).

c1. V3gc is modulating: The controller controls the fans and the valve, to maintain energy optimized control (bypassing of the gas cooler will only be allowed when the fans are at 0% and vice versa). Shp is the control sensor when the gascooler is bypassed.

c2. V3gc is set to an on/off valve (see illustration): the fans will be stopped and the valve V3gc routes the gas outside the gas cooler. If the HR request is between V3gc bypass stop limit & V3gc bypass start limit, the V3gc won't bypass unless Shr2 & Sgc are lower than "TC max HR".

The “Heat recovery status” picture shows the current regulation status.

Relay output (additional heat output)

A relay can be reserved that will pull in if the received signal exceeds 9.5 V (4.75 V) for more than 10 minutes. The relay will be cut out when the signal is lower than 9.3 V (4.65 V). The relay is defined in the function: “Additional heat output”, and can be used to start e.g., a heat pump evaporator.

Start conditions
The following conditions must be fulfilled in order to start the heat reclaim function:

1. External heat request via the digital input
2. Pump Control mode is set to "Auto"
3. At least one MT compressor must have been running for at least 2 minutes
4. "Sd MT" must be higher than Shr3 brine temp.
   If "Control signal" = "S8" or "S4", then "Sd must be higher than (Shr3 +1K)
   If "Control signal" = "Shr4 – Shr3", then "Sd must be higher than (Shr3 + Delta T)
5. Shr2 is higher than "TC HR max" (default 27 °C)
6. All sensors are OK
7. The "Anti boiling" is not active

When all conditions are fulfilled, the following start sequence will be carried out:

1. The pump will be started when the heat request is higher than "HR start limit" (if not already running)
2. The flow switch will report "Flow OK", if mounted
3. The bypass valve will switch position and the discharge gas will be looped through the heat exchanger

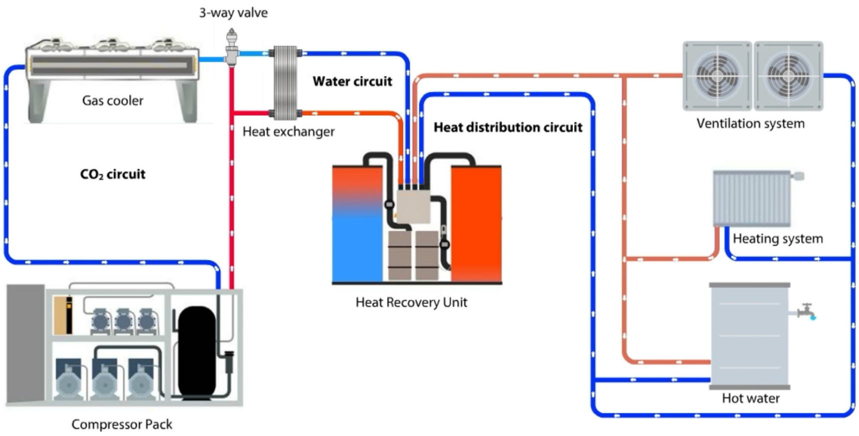
Stop conditions
The heat recovery will be stopped at one of the following conditions:
1. The external heat request signal on the DI is stopped
2. The analogue heat request signal goes below "HR stop limit"
3. The "Pump control mode" is set to OFF
4. Last MT compressor stops
5. The "Sd MT" discharge temperature is below the "Shr3" temperature
6. The "Shr2" is lower than the set saturated temperatures of the set
   minimum gas cooler pressure limit "TC HR min" (default 27 °C)
7. Anti-boiling safety is active
8. One or more of the relevant sensors are defective

When one of the stop conditions is active, the following stop sequence will be initiated:
1. The three-way valve V3hr will switch position and bypass the gas
2. The pump will continue to run 240 sec. in order to remove the excessive heat in the heat exchanger.
   If a new heat request arises within the 240 sec., the pump will keep running.

4. HRU in detail

4.1 Description

The Heat Recovery Unit is designed to utilise excess heat from CO_2 refrigeration plants in supermarkets. It prioritises heating of own plant before sales of excess energy, e.g. to a district heating network.



To balance different usage patterns (temperatures and heating requirements) on the heating side and the production of excess heat on the cooling side, the unit has been designed as a buffer charging circuit. This results in very stable and uniform charging, also ensuring a long service life for the CO_2 heat exchanger.

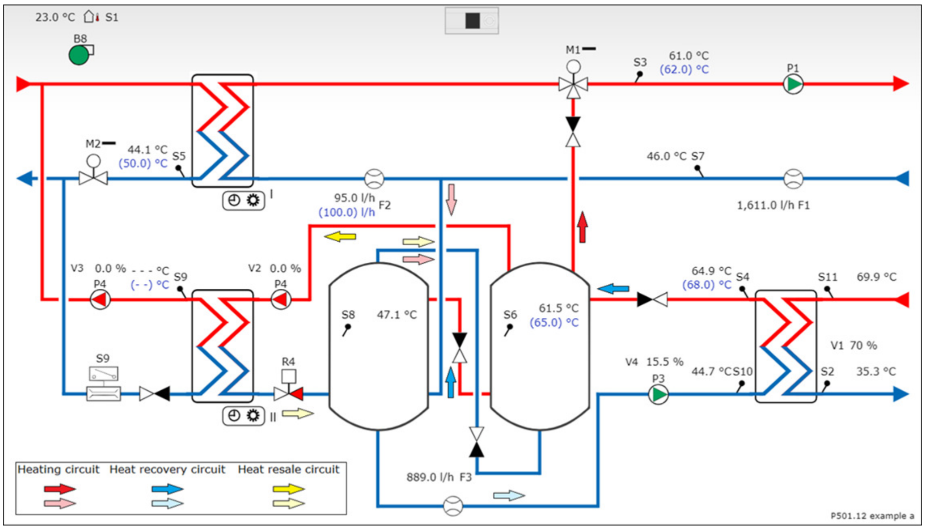
The flow temperature from the HRU unit is controlled by the building requirements (heating, domestic hot water, or ventilation), either by external temperature, via signals from other ECLs or via Modbus from an existing SCADA system.

In the event of possible sale of excess heat to the district heating network or other buyers, this can be managed in such a way that a constant temperature is supplied to those buyers.

The HRU unit can send a reference signal to the cooling plant indicating how much heat can be accumulated.

4.2 Control strategy

Unit can be split into 2 main circuits: heating circuit (on top) and heat recovery circuit (on bottom).



If the temperature in the tank (S6) is lower than the set point (which is visible in the bracket), ECL Controller sends 2 Volt signal to the pack controller. This is information that HRU can collect heat and 3-way valve on cooling pack needs to direct CO_2 flow through the heat exchanger. At the same time, pump P3 is started. It adjusts the flow through the HEX to achieve the right charging temperature. If on the lowest possible flow, charging temp. cannot be reached, ECL raises signal to the cooling pack to 10 V. It is information for pack controller to increase the pressure in the CO_2 circuit to boost the CO_2 temp. If both tanks will be filled with hot water, ECL will send 0V signal to pack controller. It means that 3-way valve needs to bypass the CO_2 HEX and pump P3 will be also stopped.

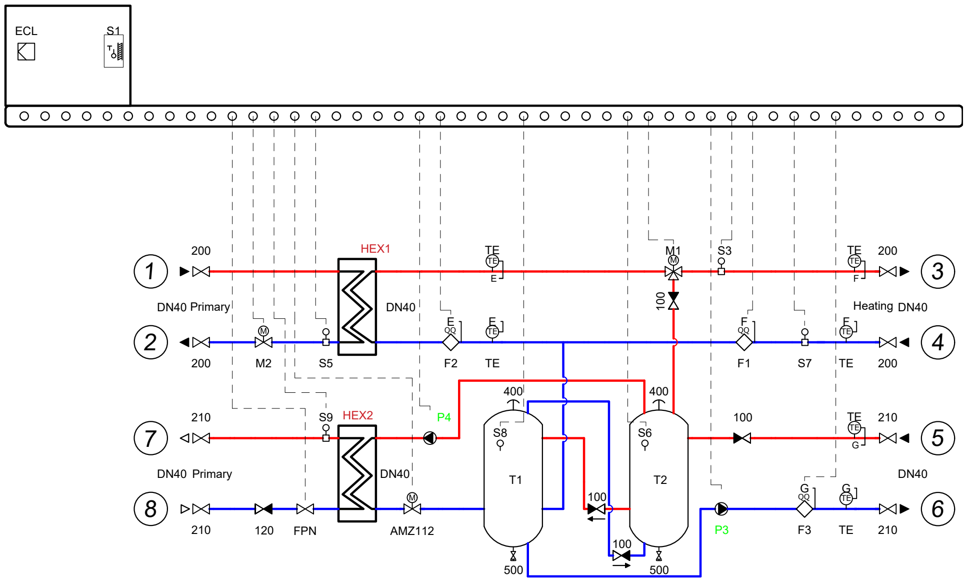
When hot water is stored in the tank, it can be used in heating consumers' circuits. The mixing valve M1 will adjust flow temperature to required level by mixing hot water from tanks with cold return water from heating circuits. If there is not enough heat in the tanks, HRU will add energy from auxiliary heat source. Flow temperature is then controlled by M2 valve on the primary return line. If we have more energy than needed, then M2 valve will be closed.

If more heat than is currently used for internal purposes is available, excess heat can be sold to the district heating network or local consumers. First the pump P4 on the primary side is started to overcome the pressure in the district heating network. When the flow in this circuit occurs (indicated by signal from flow switch), then pump P4 on the tank side will be started. It will adjust the right flow temperature through the heat resell heat exchanger. During export, the M2 valve must be closed (heat cannot be bought and sold at the same time).

4.3 HRU applications

4.3.1 Application A1

A1 is an indirect heating application with two tanks and heat resale option:



In this application, heat transfer from an auxiliary heat source (connections 1 and 2) to a secondary installation is realised via a plate heat exchanger. This solution ensures hydraulic system separation.

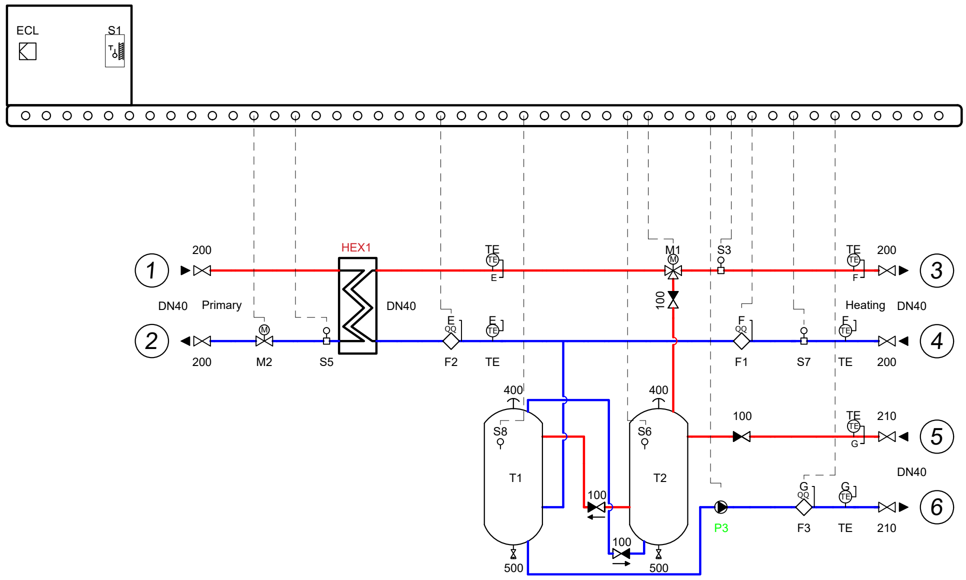
Heat consumer circuit (connections 3 and 4) is controlled by an M1 3-way valve. It mixes hot water from the storage tank with cold water from the heat return piping. In case of higher demand, additional heat can be added from the auxiliary heat source. In such cases, an M2 valve controls S3 flow temperature.

Surplus heat from a CO_2 refrigeration system is reclaimed through CO_2/water heat exchanger (part of refrigeration pack). The heat recovery process is controlled by variable speed of a P3 PWM pump, mounted on the water side of the circuit. Heat reclaimed from the CO_2 refrigeration system is stored in two 500L tanks. Usage of a buffer tank ensures continuous surplus heat reclaim independent of current heating needs. It also provides stable working conditions for the CO_2 heat exchanger.

If internal heat consumption is lower than heat reclaim, surplus heat can be exported to a district heating network through sale heat exchanger (connections 7 and 8). Sale temperature is controlled by variable speed of P4 PWM pump.

4.3.2 Application A2

A2 is an indirect heating application with 2 tanks and without heat resale option:



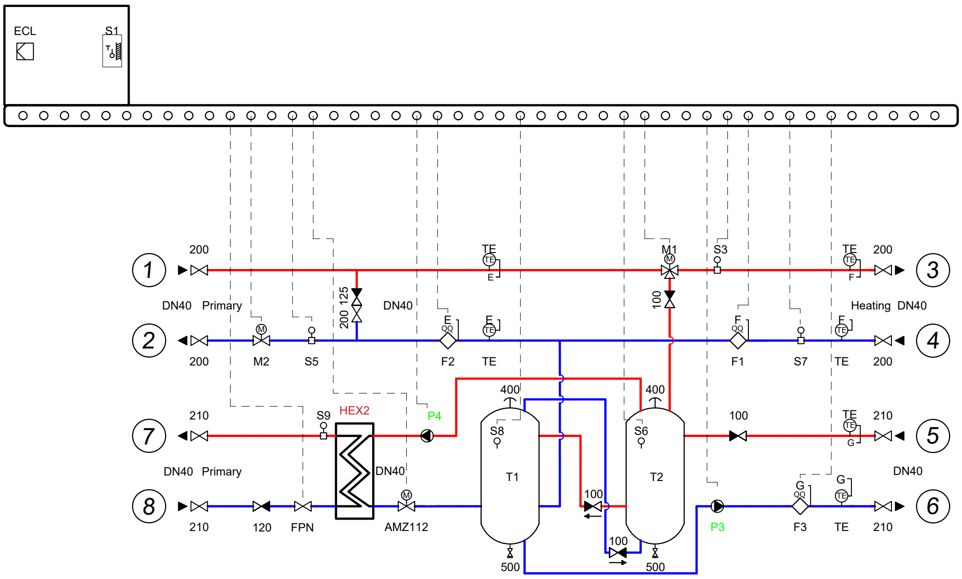
In this application, heat transfer from an auxiliary heat source (connections 1 and 2) to a secondary installation is realised via a plate heat exchanger. This solution ensures hydraulic system separation.

The heat consumer circuit (connections 3 and 4) is controlled by an M1 3-way valve. It mixes hot water from the storage tank with cold water from the heat return piping. In case of higher demand, additional heat can be added from an auxiliary heat source. In such cases, an M2 valve controls S3 flow temperature.

Surplus heat from a CO_2 refrigeration system is reclaimed through a CO_2 / water heat exchanger (part of refrigeration pack). The heat recovery process is controlled by variable speed of a P3 PWM pump, mounted on the water side of the circuit. Heat reclaimed from the CO_2 refrigeration system is stored in two 500L tanks. Usage of a buffer tank ensures continuous surplus heat reclaim independent of current heating needs. It also provides stable working conditions for the CO_2 heat exchanger.

4.3.3 Application A3

A3 is a direct heating application with 2 tanks and heat resale option:



In this application, heat transfer from an auxiliary heat source (connections 1 and 2) to a secondary installation is realised via direct piping with bypass. This solution ensures the lowest operating condition for the auxiliary heat source.

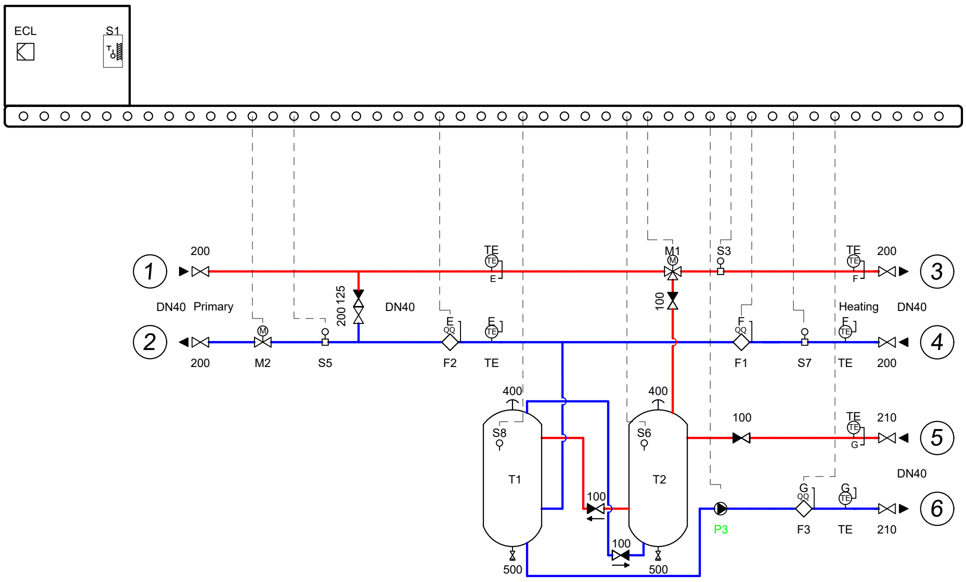
The heat consumer circuit (connections 3 and 4) is controlled by an M1 3-way valve. It mixes hot water from the storage tank with cold water from the heat return piping. In case of higher demand, additional heat can be added from the auxiliary heat source. In such cases, the M2 valve controls S3 flow temperature.

Surplus heat from the CO_2 refrigeration system is reclaimed through a CO_2 / water heat exchanger (part of refrigeration pack). The heat recovery process is controlled by variable speed of a P3 PWM pump, mounted on the water side of the circuit. Heat reclaimed from a CO_2 refrigeration system is stored in two 500L tanks. Usage of a buffer tank ensures continuous surplus heat reclaim independent of current heating needs. It also provides stable working conditions for the CO_2 heat exchanger.

If internal heat consumption is lower than heat reclaim, surplus heat can be exported to a district heating network through sale heat exchanger (connections 7 and 8). Sale temperature is controlled by variable speed of the P4 PWM pump.

4.3.4 Application A4

A4 is an indirect heating application with 2 tanks and without heat resale option:



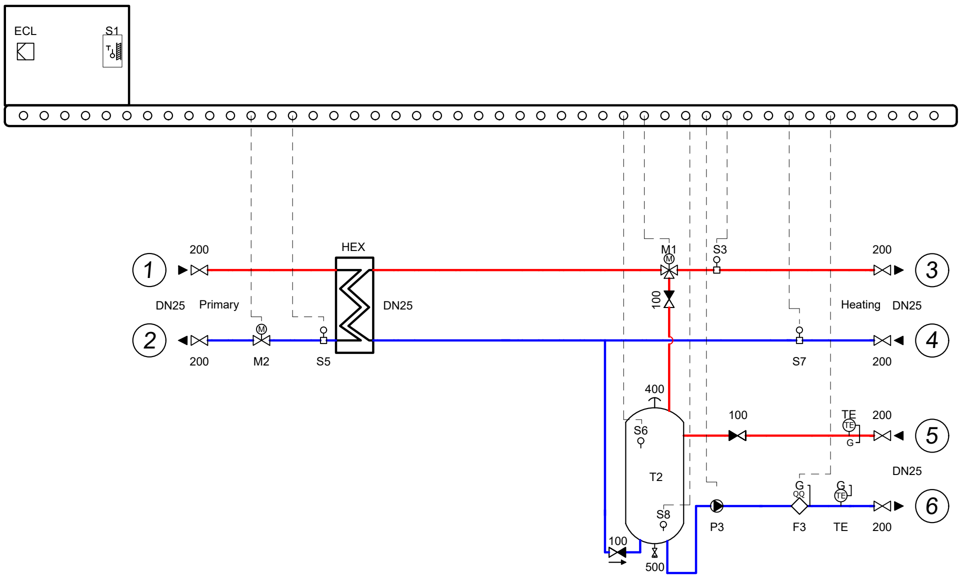
In this application, heat transfer from an auxiliary heat source (connections 1 and 2) to a secondary installation is realised via direct piping with bypass. This solution ensures the lowest operating condition for the auxiliary heat source.

The heat consumer circuit (connections 3 and 4) is controlled by an M1 3-way valve. It mixes hot water from the storage tank with cold water from the heat return piping. In case of higher demand, additional heat can be added from the auxiliary heat source. In such cases, the M2 valve controls the S3 flow temperature.

Surplus heat from the CO_2 refrigeration system is reclaimed through the CO_2/water heat exchanger (part of refrigeration pack). The heat recovery process is controlled by variable speed of the P3 PWM pump, mounted on the water side of the circuit. Heat reclaimed from the CO_2 refrigeration system is stored in two 500L tanks. Usage of a buffer tank ensures continuous surplus heat reclaim independent of current heating needs. It also provides stable working conditions for the CO_2 heat exchanger.

4.3.5 Application A6

A6 is an indirect heating application with 1 tank and without heat resale option:



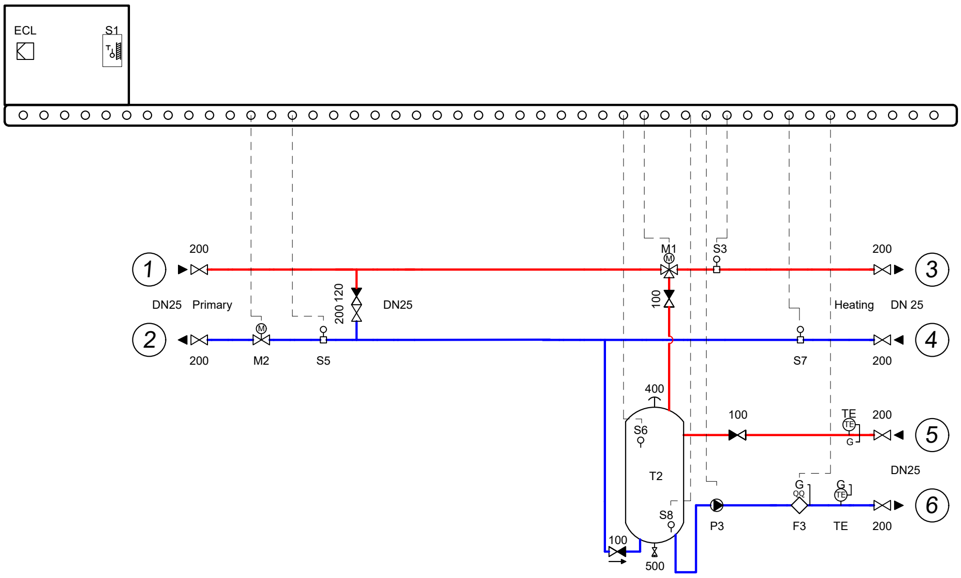
In this application, heat transfer from an auxiliary heat source (connections 1 and 2) to a secondary installation is realised via a plate heat exchanger. This solution ensures hydraulic system separation.

The heat consumer circuit (connections 3 and 4) is controlled by an M1 3-way valve. It mixes hot water from the storage tank with cold water from the heat return piping. In case of higher demand, heat can be provided by the auxiliary heat source. In such cases, the M2 valve controls S3 flow temperature.

Surplus heat from the CO_2 refrigeration system is reclaimed through the CO_2 / water heat exchanger (part of refrigeration pack). The heat recovery process is controlled by variable speed of the P3 PWM pump, mounted on the water side of the circuit. Heat reclaimed from the CO_2 refrigeration system is stored in a 500L tank. Usage of a buffer tank ensures continuous surplus heat reclaim independent of current heating needs. It also provides stable working conditions for the CO_2 heat exchanger.

4.3.6 Application A7

A7 is a direct heating application with 1 tank and without heat resale option:



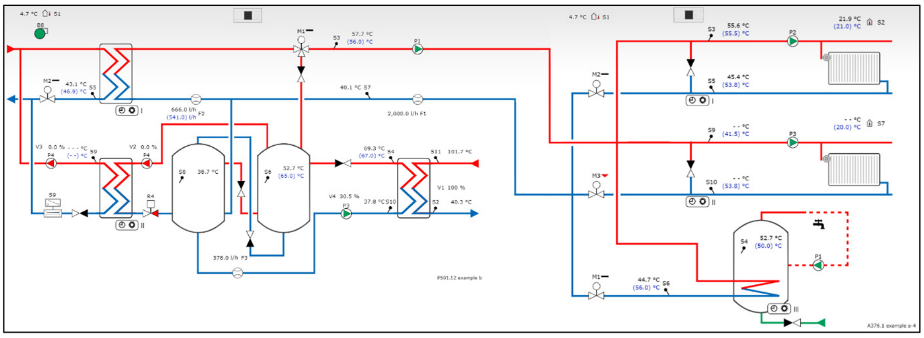
In this application, heat transfer from an auxiliary heat source (connections 1 and 2) to a secondary installation is realised via direct piping with bypass. This solution ensures the lowest operating condition for the auxiliary heat source.

The heat consumer circuit (connections 3 and 4) is controlled by an M1 3-way valve. It mixes hot water from the storage tank with cold water from heat return piping. In case of higher demand, heat can be provided by the auxiliary heat source. In such cases, the M2 valve controls S3 flow temperature.

Surplus heat from the CO_2 refrigeration system is reclaimed through the CO_2/water heat exchanger (part of refrigeration pack). The heat recovery process is controlled by variable speed of the P3 PWM pump, mounted on the water side of the circuit. Heat reclaimed from the CO_2 refrigeration system is stored in a 500L tank. Usage of a buffer tank ensures continuous surplus heat reclaim independent of current heating needs. It also provides stable working conditions for the CO_2 heat exchanger.

4.4 Heat consumers applications – examples

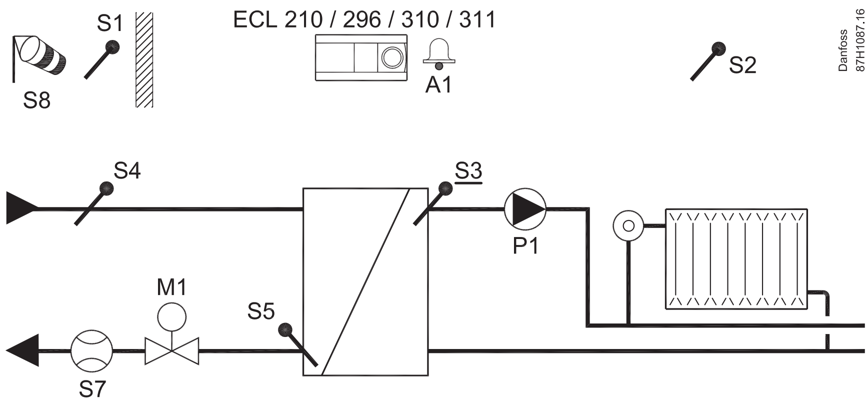
To control heat consumers' circuits, an additional ECL controller can be used in master-slave configuration. Those secondary side controllers can send the required flow temperature to the ECL mounted in the HRU. By doing so, optimal efficiency of the whole system can be achieved by precise flow temperature control and reducing the return temperature from the heat consumer circuit.

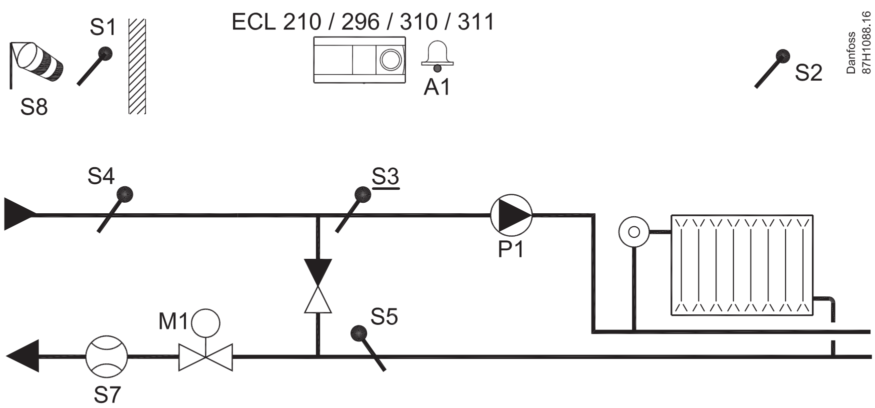


For more information regarding ECL controllers and applications, please visit the Danfoss web page: [ECL controllers | Danfoss]

4.4.1 Heating application - example

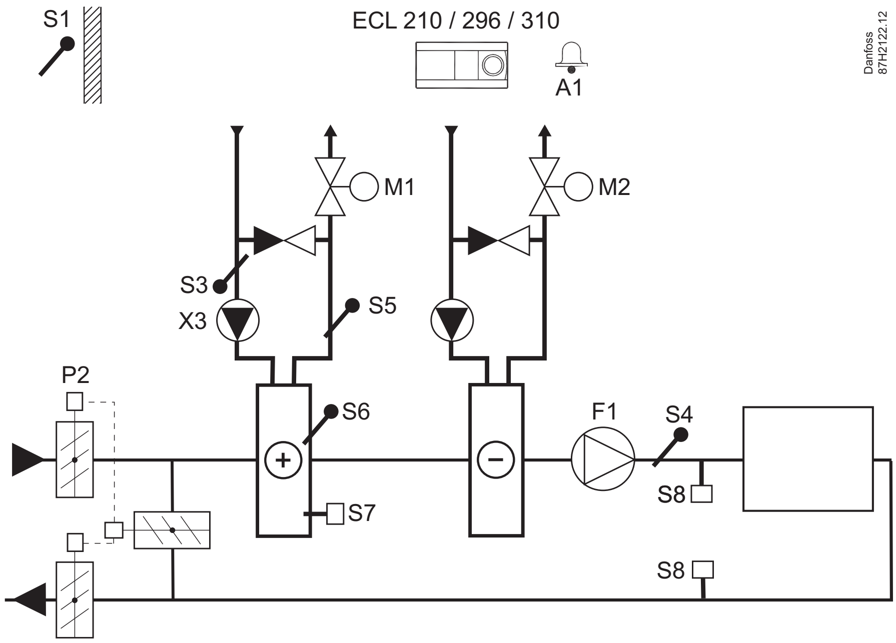
Application A230 is a weather-compensated control of flow temperature in a heating circuit. Room temperature and wind speed compensation is also available. Return temperature limitation can be set up. An alarm function in relation to flow temperature is available. It can be used for direct and indirect heating applications.





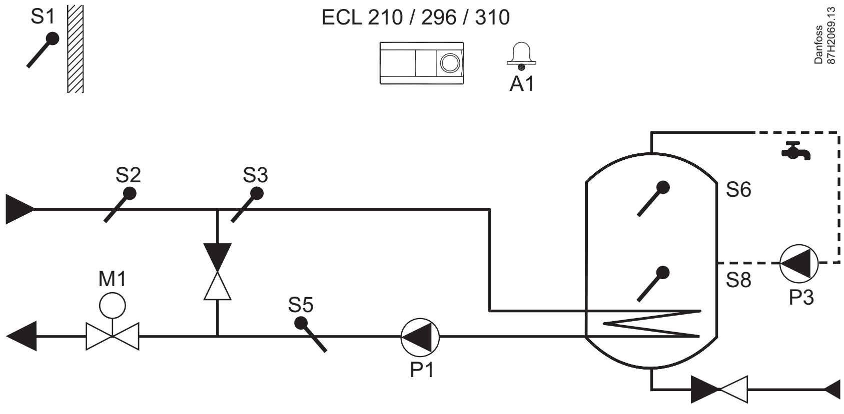
4.4.2 Ventilation application – example

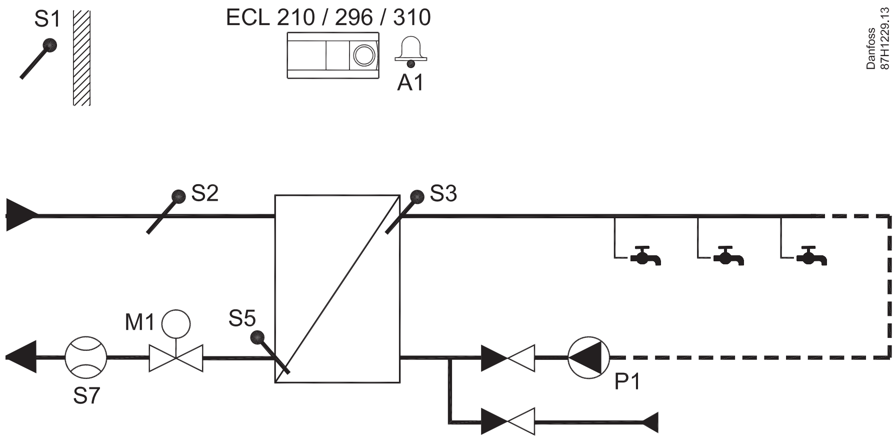
Application A314 can control temperature of ventilation systems with heating or cooling or a combination of these. Weather-based compensation, return temperature limitation, frost, and fire protection are available. Optional analogue control of crossflow or rotary heat exchanger. Alarm function can be related to duct / flow temperature, fire, and frost.

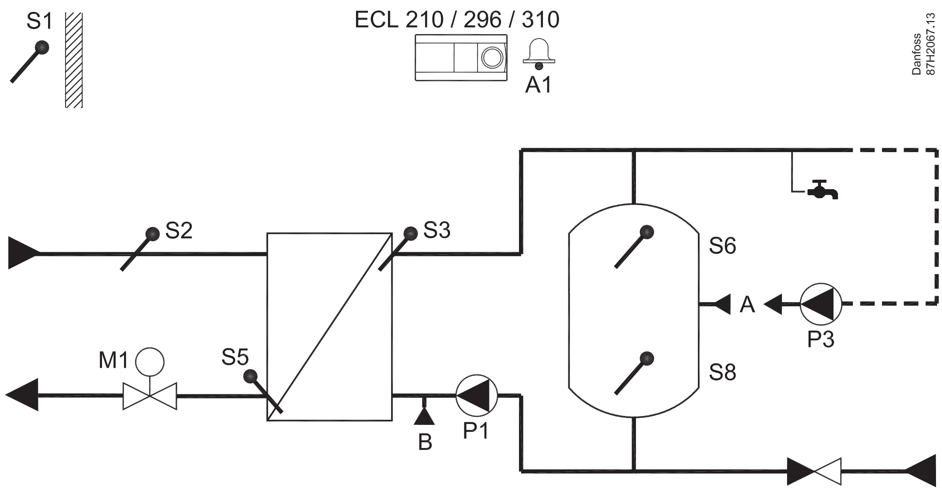


4.4.3 Domestic Hot Water application - example

Application A217 is advanced temperature control of a DHW circuit with storage tank, directly heated or with charging system. Return temperature limitation can be set up. An alarm function related to flow temperature is available.







5. Commissioning steps

Before system start-up, the mandatory steps listed below should be taken.

5.1 Connection tightening

After completion of installation, retighten all pipe unions in the HRU.

5.2 External sensor connection

Connect all required external sensors and ensure that they are mounted in the right location:

- The S4 sensor should be performed as a submersed sensor and sense completely into the heat exchanger.
- For parallel operation of 2 CO_2 heat exchangers, the S4 must be placed so that it measures the common outlet temperature and as close to the heat exchangers as possible.
- The submersed sensor must be in counterflow and in large pipe dimensions. Constriction (measuring blind) should be made for the S4 sensor. If the S4 is outside the heat exchanger, a min. flow must be ensured at the measuring point.
- The S10 is designed as a surface sensor and is placed close to the CO_2 heat exchanger and, as far as possible, on the upper side of a horizontal pipe.
- S11 & S2 are made with sensors that are heat-resistant (such as AKS 21 A 084N2007) with steel clamps/straps.
- S11 (Hot gas sensor): mount close to the CO_2 heat exchanger and preferably on the upper side of a horizontal pipe.
- S2 mounted outside of the CO_2 heat exchanger is to be mounted after the CO_2 3-way valve on the common outlet pipe to the gas cooler (thereby any bypass of the CO_2 exchanger can be registered via the ECL 310 Portal / log)

5.3 HRU boost signal connection

Check the 0-10 Vdc signal at the end of the galvanic separation via manual operation of ECL 310 V1 from 0 to 100%.

If the expected voltage is not measured, the DIP switch must be checked. If they are correct, but an incorrect value is still measured, it may be a wrong connection in the cooling control.

Check the output with disconnected connection to Pack.

5.4 Location of safety valve on water side

Safety valve must be placed close to the CO_2 heat exchanger and it must lead to a drain (risk of injuries from high temperature).

5.5 Location of balancing valves

If there is only one CO_2 heat exchanger, the balancing valve should be placed on the return circuit close to the HRU (possibly on the inlet from CO_2 heat exchanger).

If CO_2 heat exchangers are connected in parallel, a balancing valve must be fitted to the inlet of each of them separately, to have the right flow in both heat exchangers.

The balancing valve(s) on the heat recovery circuit are adjusted in relation to P3 min (15%) to ensure that we can regulate down by small effects on the CO_2 heat exchanger.

5.6 Water filling and ventilation

If possible, establish a fixed water connection so that it can be refilled without the need to establish a connection every time.

The system should be equipped with automatic air dischargers at the highest point of the system, places where there are natural air pockets (installations with inverted u piping) and on the accumulation tanks to release trapped air in the system in connection with water filling (remember that motor valves must be open fully).

5.7 Connection to ECL portal

The HRU should be connected to the ECL portal. After connection is established, all M-Bus energy meters and sensors S11 and S12 should be registered for future logging.

5.8 Functional test of components

All components listed below must be checked in manual overdrive in the ECL 310 controller:

- Pumps P1, P3 and P4 (if installed)
- Control valves M1 and M2
- Sensors reading
- M-bus energy meters readings
- Boost signal to pack controller to check if 3-way bypass valve on CO_2 heat exchanger is opening and closing

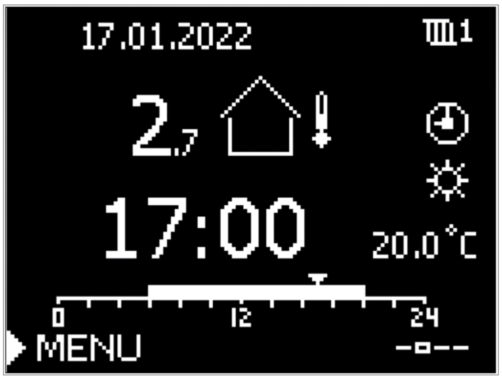
6. ECL configuration

6.1 Settings in controller

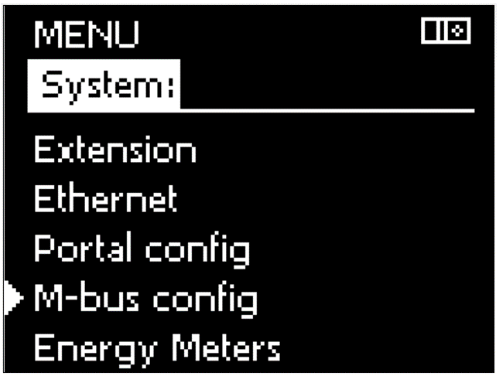
Danfoss recommends adjusting parameters using the ECL Portal. Before doing so, flow meters and connection to the ECL portal must be established manually in the controller.

6.1.1 Flow meter F1, F2 and F3 configuration

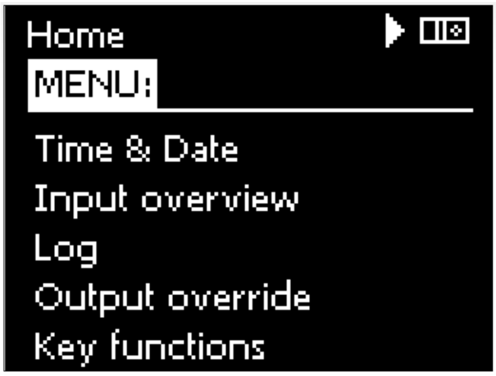
Controller menu:



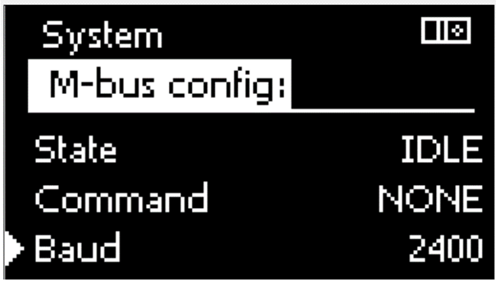
M-bus config:



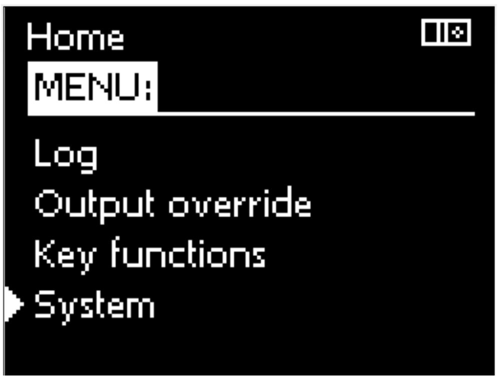
Common controller settings:



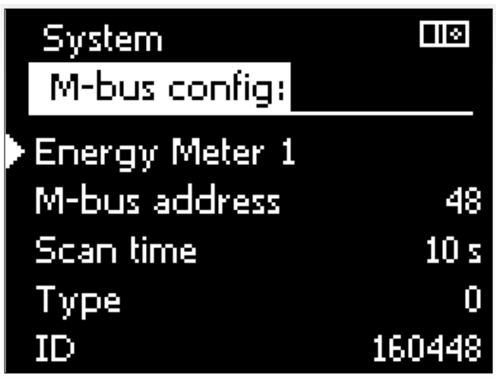
Set the Baud rate to 2400 for all connected meters.



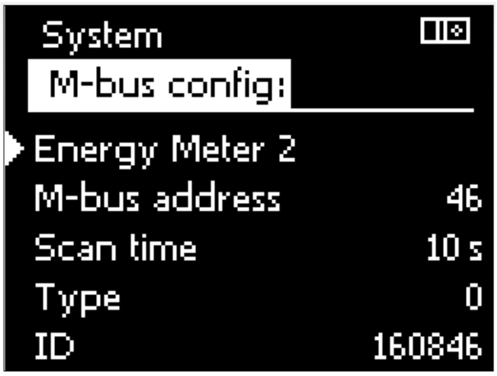
System:



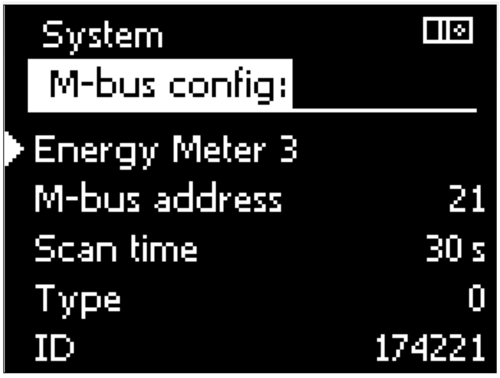
All flow meters must be configured in settings. M-bus address is last 2 digits from heat meter serial number. Flow meter F1 must be configured as Energy meter 1:



Flow meter F2 must be configured as Energy meter 2:



Flow meter F3 must be configured as Energy meter 3:

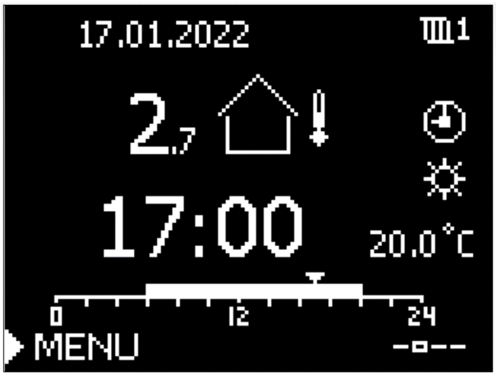


6.2 Connection to the ECL Portal

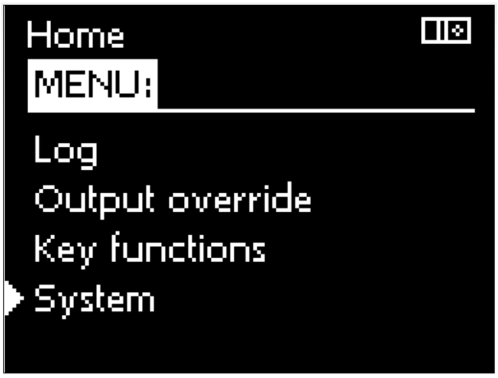
6.2.1 Settings in ECL Controller

Connect the network cable with the Internet connection to HRU controller. ECL Comfort 310 listens for communication on TCP port 502. For more information regarding communication with ECL controller, please check:
https://assets.danfoss.com/documents/198690/AQ074886472234en-010601.pdf

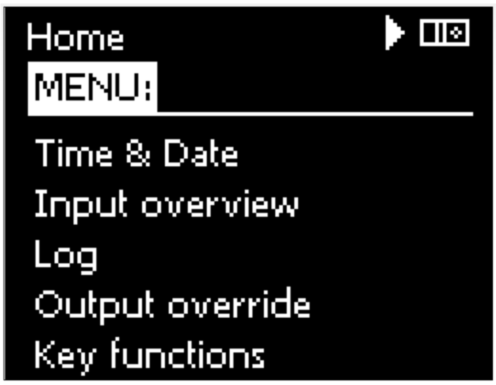
Controller menu:



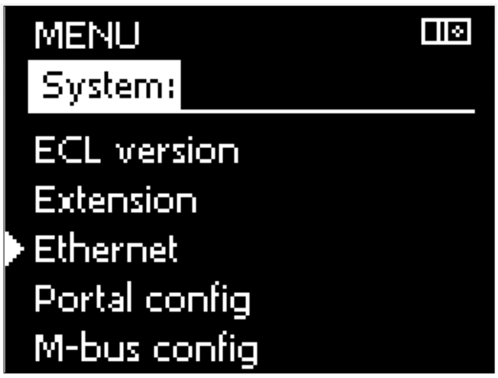
System:



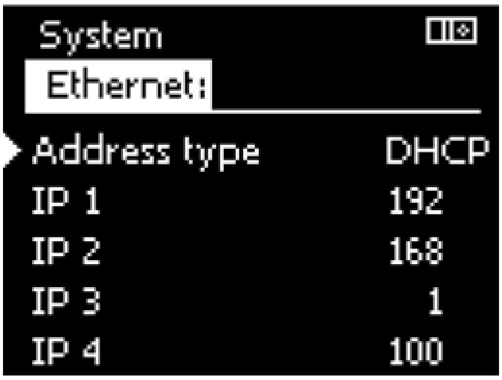
Common controller settings:



Ethernet:

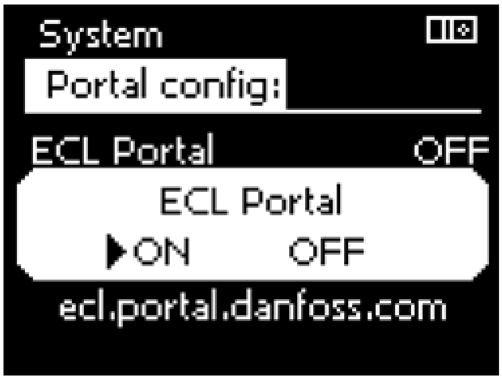


Activate automatic network addressing:

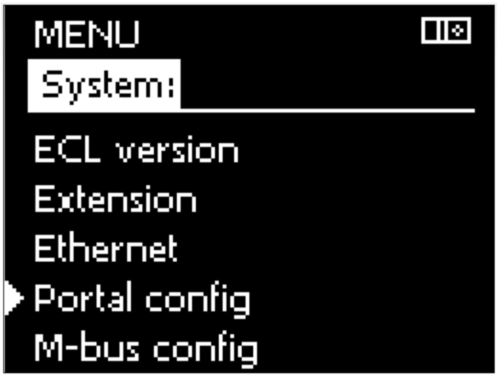


Or set up correct static IP address according to your network settings.

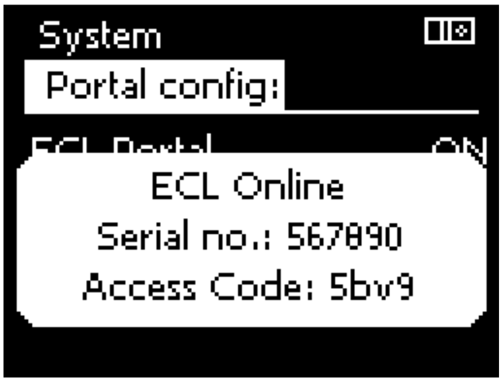
Set "ECL Portal" to "ON"



Portal config:



Check serial number and access code visible in Portal info:



6.2.2 Settings in portal

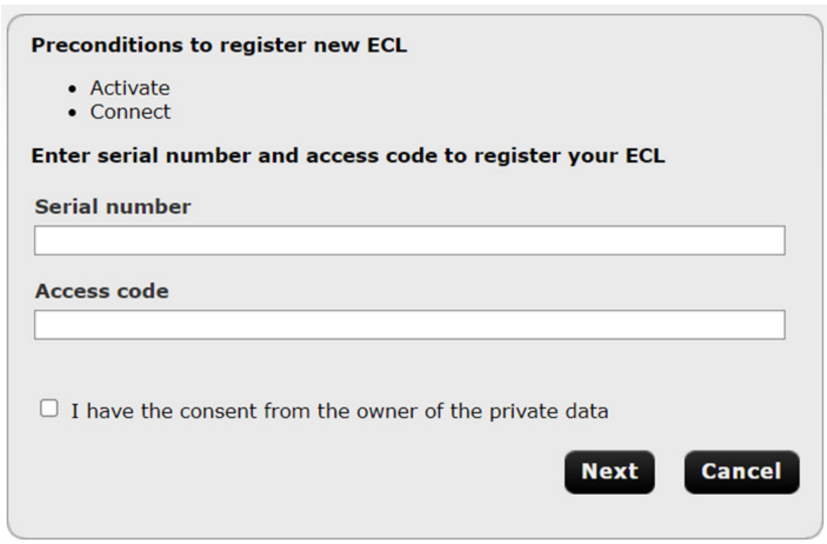
Go to ecl.portal.danfoss.com, create a user account by pressing on the 'new user' link and follow the instructions on screen.

You only need to do this the first time you register a controller to the ECL Portal.

6.2.3 Adding controller to a portal

ECL -> Register new ECL:

Register new ECL using the serial number and access code:



Insert ECL master data

6.2.4 Sensor S11 configuration

ECL -> Configurable input -> Configure new sensor input:

Set name of the sensor. Choose:
- Sensor ID to S11
- Type to Pt 1000
- Sensor Option to None

Click next. Check mark Data logging. Click create.

6.2.5 Heat meters configuration

Meters -> Register new meter:
Set meter name and M-bus address

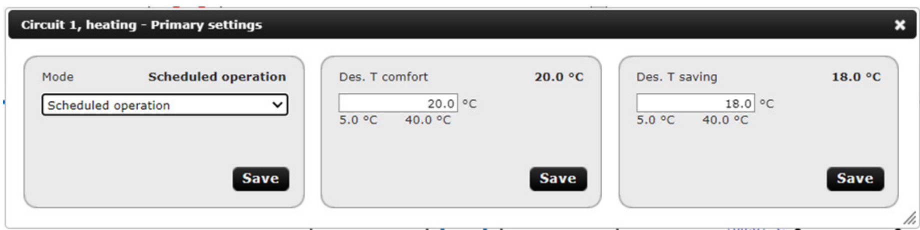
Click next. Check mark Data logging. Click create.

6.2.6 Circuit 1

Here all heating circuit parameters should be set.

6.2.6.1 Primary settings:

Settings -> Circuit 1 -> Primary settings

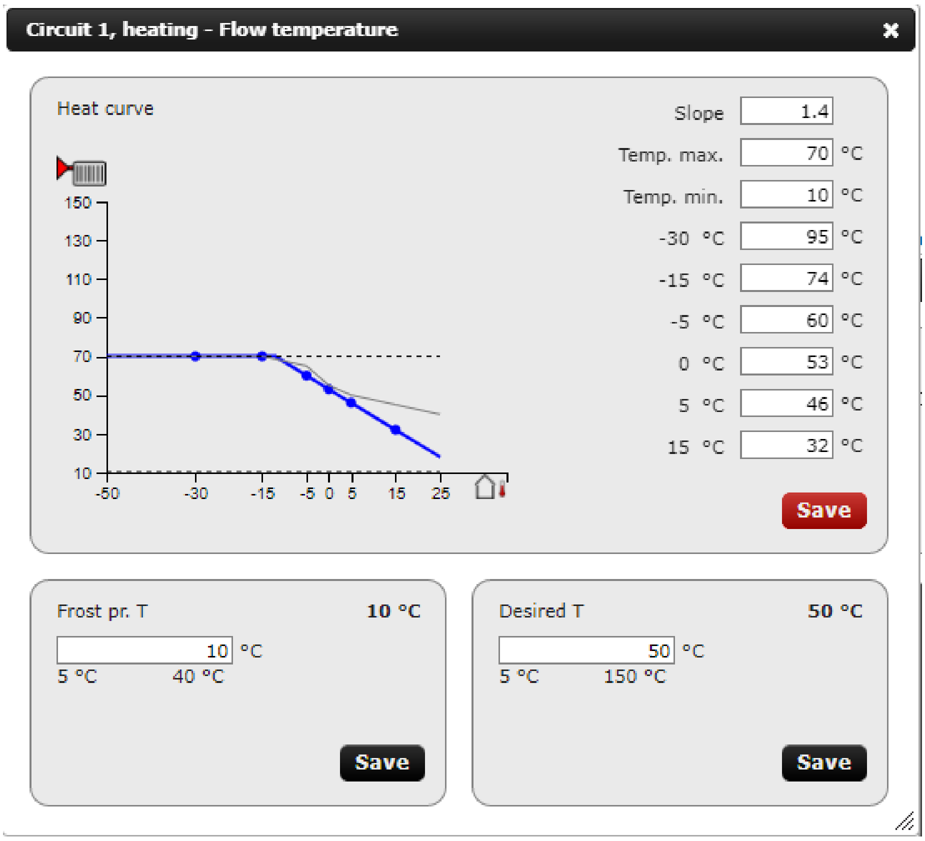


Choose Scheduled operation.

Set T comfort and T saving according to need.

6.2.6.2 Flow temperature

Settings -> Circuit 1 -> Flow temperature



The weather-compensated flow temperature can be configured here. Temperature should be adjusted according to heat consumer type.

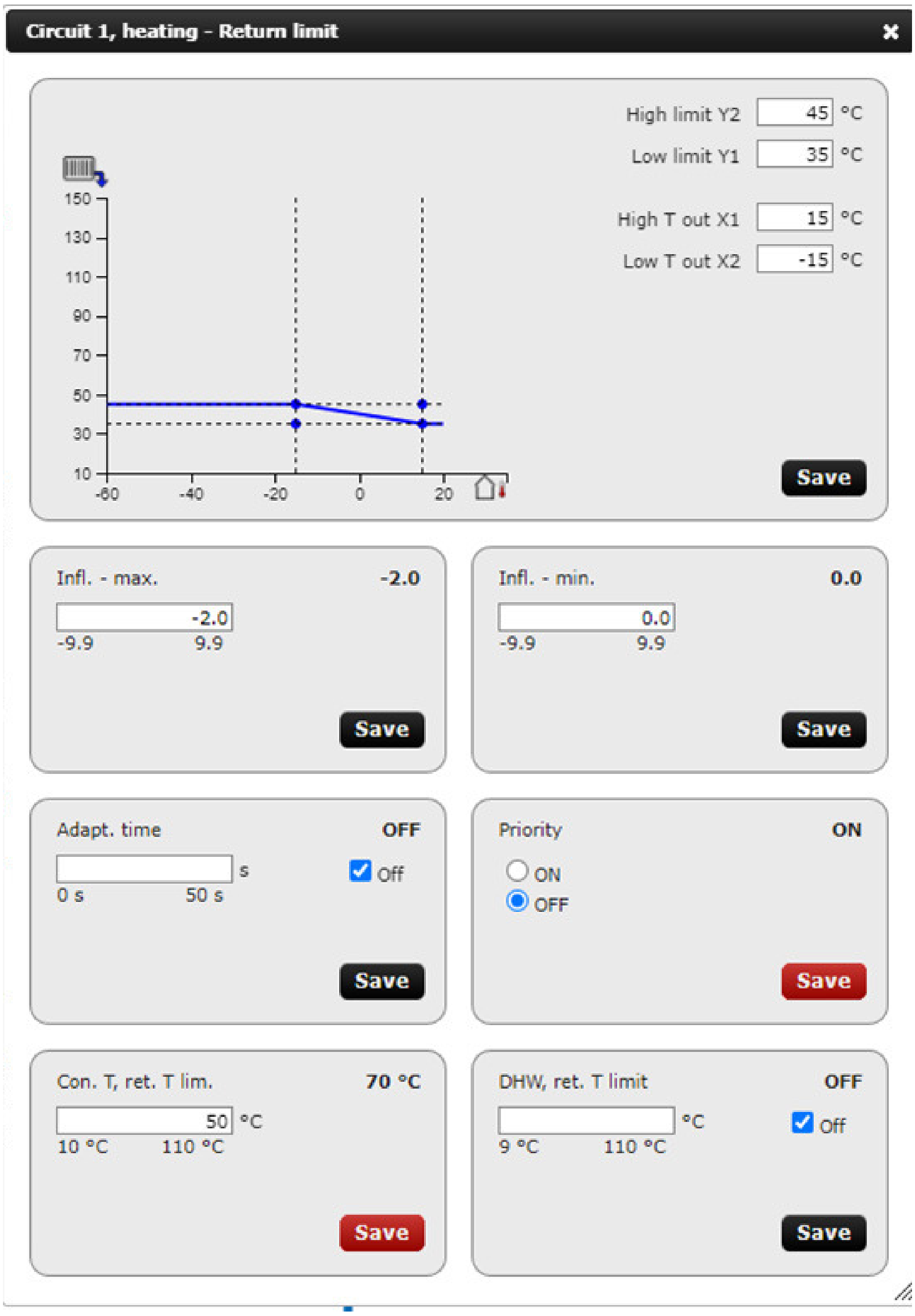
"Frost protection T" is the minimum temperature for S3.

"Desired T": if external override has been created for an available input, the desired fixed flow temperature (R3) from the HRU unit can be configured here.

The minimum and maximum flow temperature (R3) can be configured here.

6.2.6.3 Return Limit

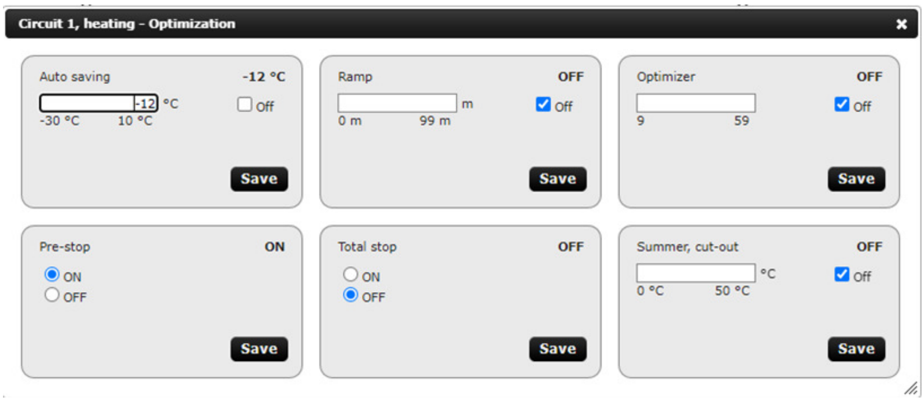
Settings -> Circuit 1 -> Settings -> Return temp. limit



Here you configure the highest permitted temperature desired at S5.
When this limit is exceeded, the "Infl. - max." setting can be adjusted to determine the impact on R3.

6.2.6.4 Optimization

Settings -> Circuit 1 -> Settings -> Optimization



If an external signal indicating the desired flow temperature (R3) is not received, these settings will apply together with the "Flow temperature" settings.

If a schedule has been configured for comfort/saving mode:

"Auto-save" will gradually reduce flow temperature

”Ramp” change from saving to comfort mode can take place slowly over the configured time.

6.2.6.5 Control par. 1

Settings -> Circuit 1 -> Control par. 1

*Parameters apply to the M1 flow temperature (S3).

“Xp” (proportional band) - A higher value will result in a stable but slow control of the flow temperature.

“Tn” (integration time constant) - Set a high integration time constant (in seconds) to obtain a slow but stable reaction to deviations. A low integration time constant will make the controller react fast but with less stability.

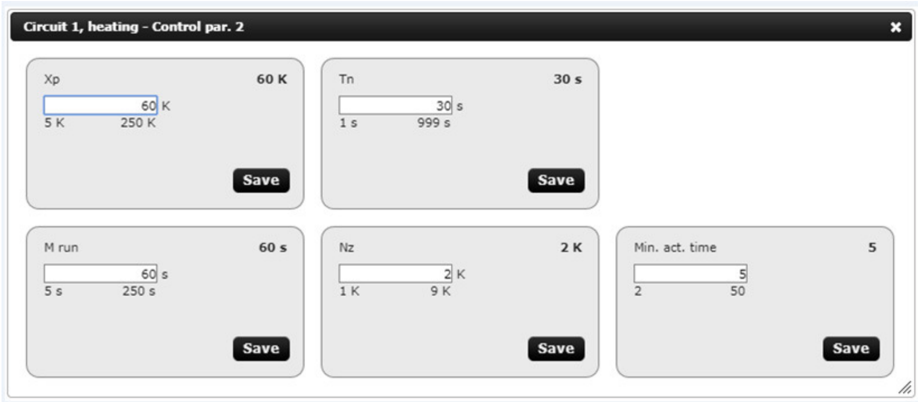
“M run” (running time of the motorized control valve) - 75 sec for HRU≤216 kW heating and 113 sec for HRU>216 kW heating

**Parameters apply to the mixing phase, i.e. when mixing of recovered heat and purchased heat takes place. Flow is associated with flow meter F2. Temperature controls (S3) are controlled by M2.

***Here, the anticipated flow temperature from auxiliary heat (district heating, boiler or other) is configured.

6.2.6.6 Control par. 2

Settings -> Circuit 1 -> Control par. 2



Here, control parameters (M2) are configured for the desired flow temperature R3.

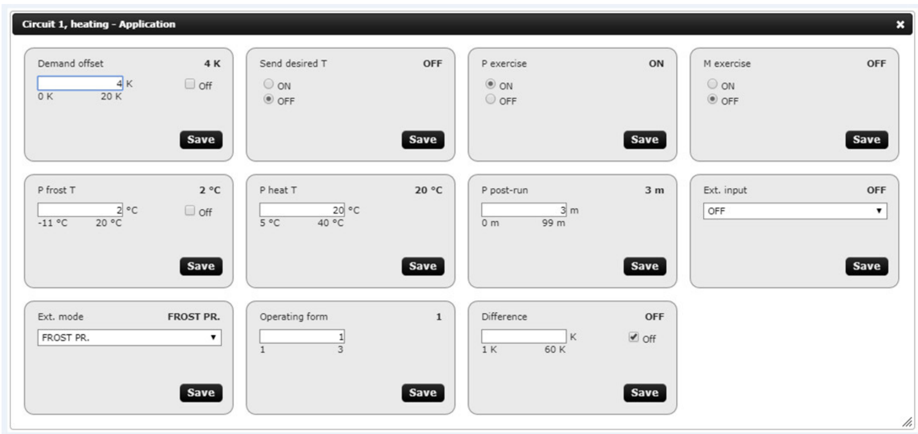
“Xp” (proportional band) - A higher value will result in a stable but slow control of the flow temperature.

“Tn” (integration time constant) - Set a high integration time constant (in seconds) to obtain a slow but stable reaction to deviations. A low integration time constant will make the controller react fast but with less stability.

“M run” (running time of the motorized control valve):
- 120 sec for HRU≤85 kW heating
- 75 sec for HRU>85 kW and ≤ 216 kW heating
- 113 sec for HRU>216 kW heating

6.2.6.7 Application

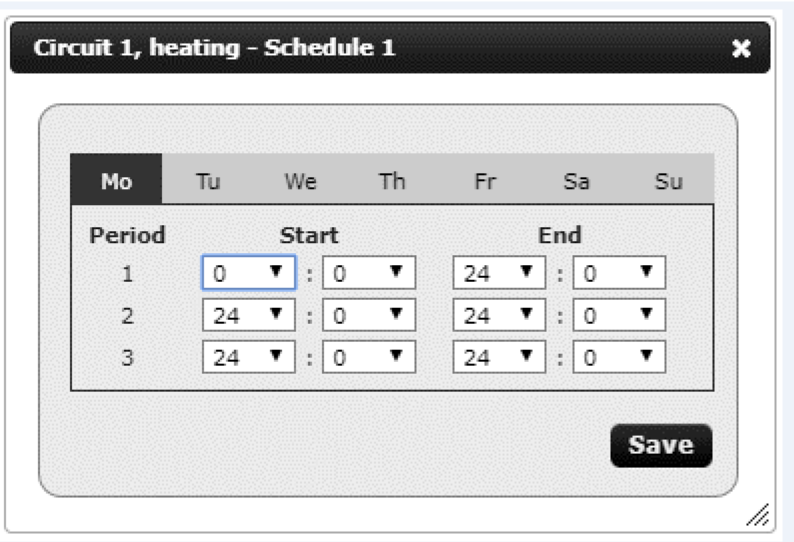
Settings -> Circuit 1 -> Application



"Demand offset" is the temperature that is added to the highest temperature requirement that may be received from one or more ECL 310 slave regulators.
"Operating form" – Here you select the mode of operation in which the HRU unit will run
1: All three phases: recovered / mix / auxiliary heat
2: Phases: recovered / auxiliary heat
3: 100% use of recovered heat

6.2.6.8 Schedule 1

Settings -> Circuit 1 -> Schedule 1



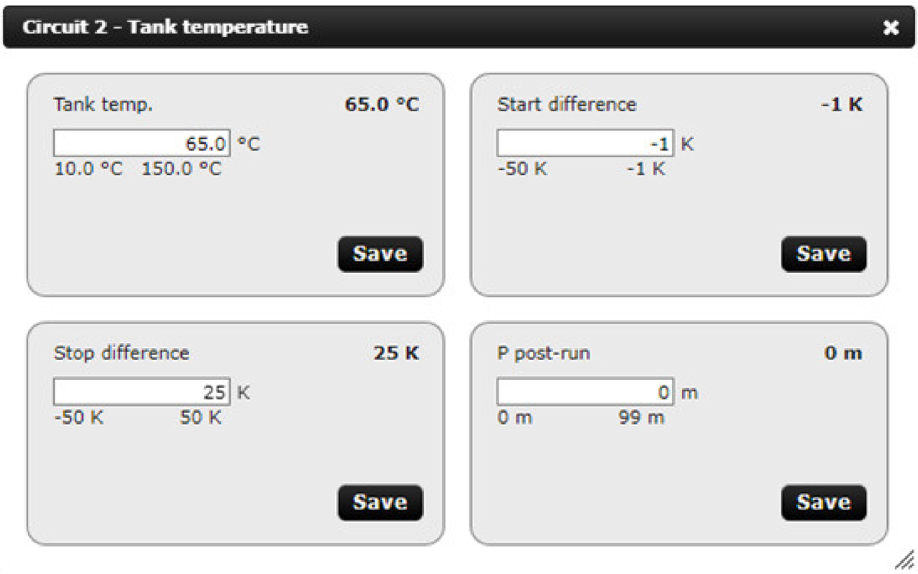
If an external signal indicating the desired flow temperature (R3) is not received, this schedule will apply to the configured comfort and saving mode temperatures.

6.2.7 Circuit 2

Here all heat recovery and heat resale parameters can be set.

6.2.7.1 Tank temperature

Settings -> Circuit 2 -> Tank temperature

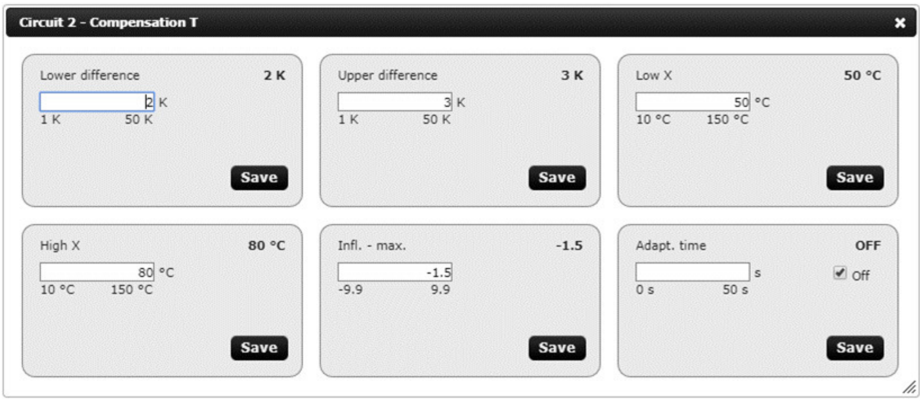


Here, you configure the desired temperature in the buffer/charger tanks and when charging should start and stop.

"Tank temp." – required tank temperature is base for calculation of the charging temp.

6.2.7.2 Compensation T

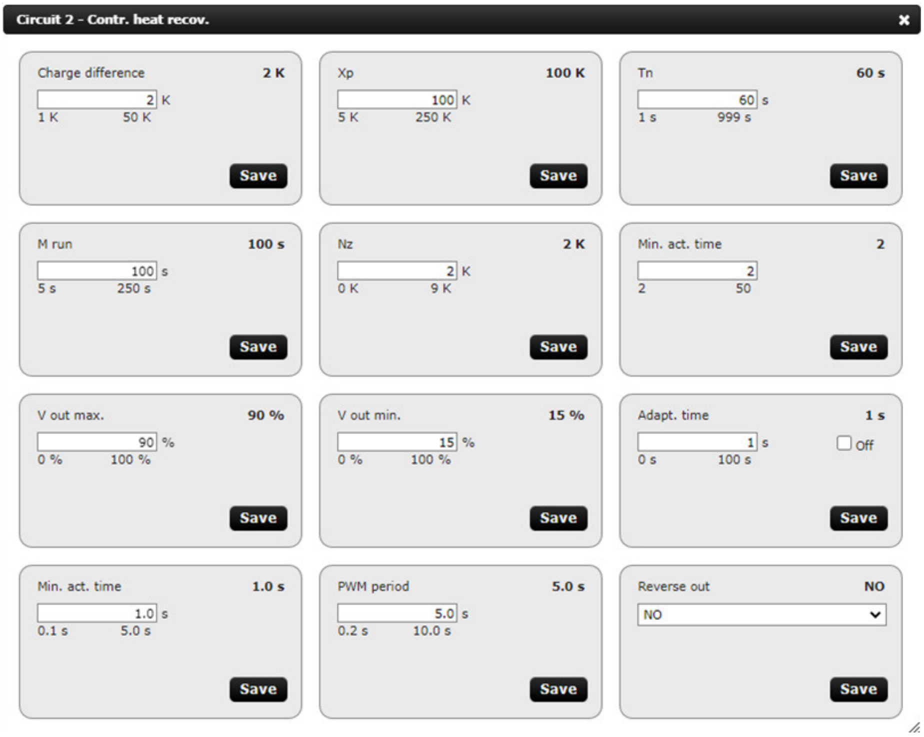
Settings -> Circuit 2 -> Compensation T



The permitted difference between temperatures S10 and S2 at high and low charging temperature respectively ("High X" and "Low X") can adjust the desired charging temperature (R4) with a desired amplification factor "Max. amplification".

6.2.7.3 Control heat recovery

Settings -> Circuit 2 -> Contr. heat recov.



"Charging difference" – desired charging temperature in relation to the tank temperature.

"V out. min." – you can configure the desired minimum charging flow given by P3.

"Adapt. time" – controls how fast the actual charging temp. adapts to the desired charging temp.

"Min. act. time" – min. PWM duty cycle. If "Adapt. time" setting is other than 0.

"PWM period" – PWM signal period length. Settings can be configured with "Min. act. Time" to specify how often pump will stop and start to achieve less flow.

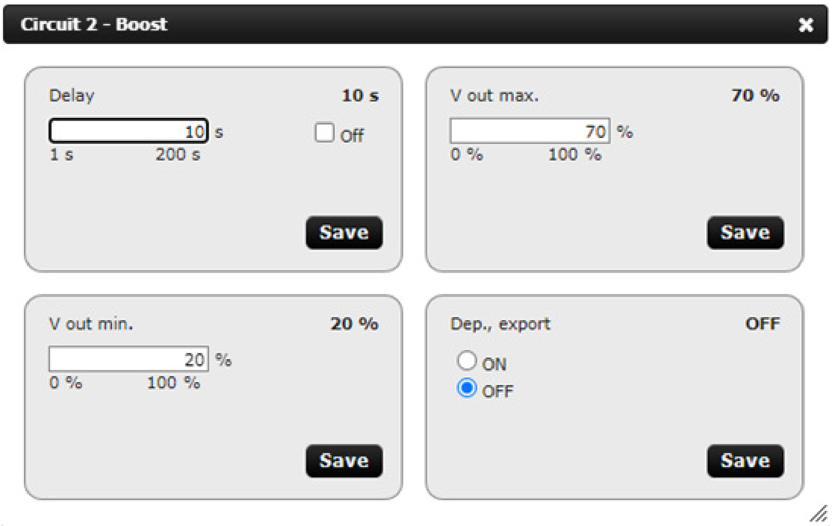
6.2.7.4 Control par., export

Settings -> Circuit 2 -> Control par., export

"Desired T" – The desired sale/export temperature.
"Start T" – Required tank top temperature (S6) before export can be started.
"Start difference" – Required tank bottom temperature (S8) before export can start.
"Stop difference" – Required tank top temperature (S6) to end export.
Example:
Export starts when both requirements have been met:
S6 > "Start T" > 80 °C
S8 > "Start T" + "Start difference" > 80-0 = 80 °C
Export stops when:
S6 < "Start T"+ "Stop difference" < 80-5 = 75 °C
Or if domestic hot water requirements are received from another ECL 310 if the setting "DHV priority" is ON.

6.2.7.5 Boost

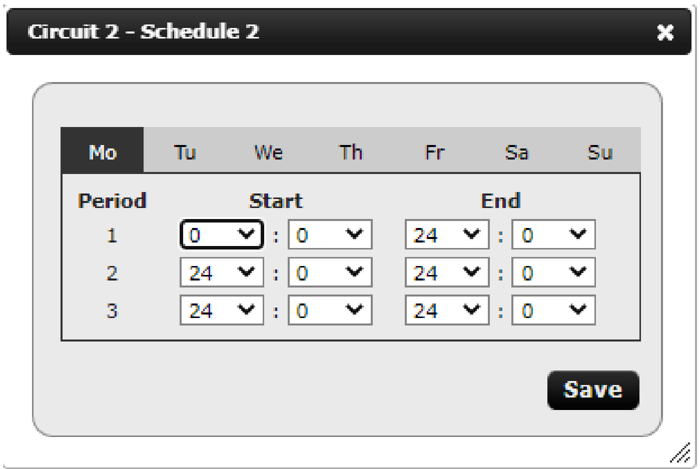
Settings -> Circuit 2 -> Boost



Boost is an expression of how much energy the HRU can reclaim. This signal (0-10VDC) ECL 310 sends to the cooling plant.
“Delay” – Time needed to change boost signal by 1%
“V out. min.” – Min signal during operation
“V out max.” – Max level of signal transmitted to the pack controller.
"Depended on export ON" – This setting can increase the "Boost" signal to the cooler in the event of export/sale of recovered heat. This happens if the tank temperature (S6) is lower than the desired start temperature for export "Start T," or if the current charging temperature (S4) is lower than the desired tank temperature (R6).
"Depended on export OFF" – This setting can increase the "Boost" signal to the cooler. This happens only if the current charging temperature (S4) is lower than the desired tank temperature (R6).

6.2.7.6 Schedule 2

Settings -> Circuit 2 -> Schedule 2



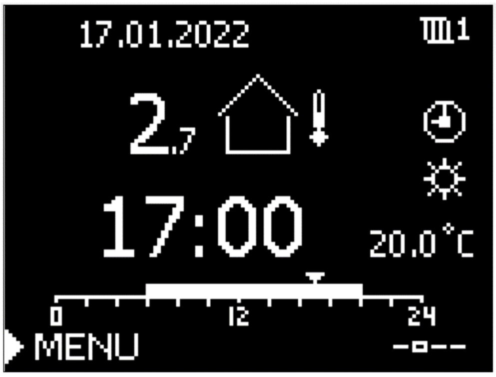
Here, you can configure a Schedule for when you want to export excess energy.

6.3 Connection to Leanheat monitor portal

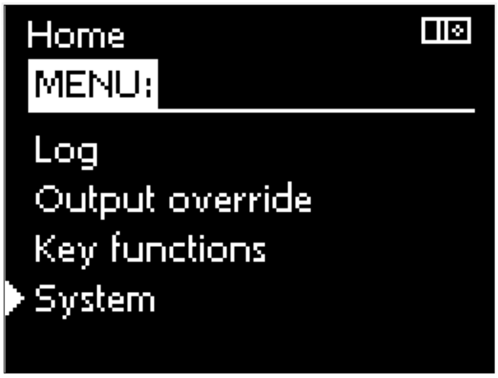
6.3.1 Settings in ECL Controller

Connect the network cable with the Internet connection to your ECL Comfort 310. Next follow below steps:

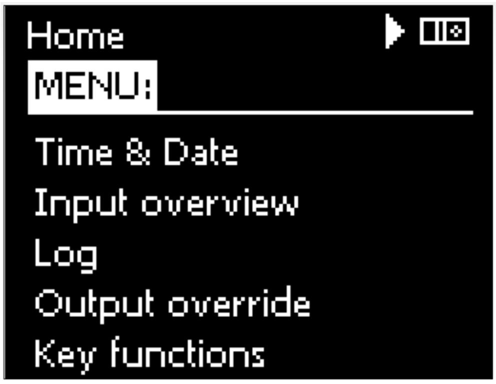
Controller menu:



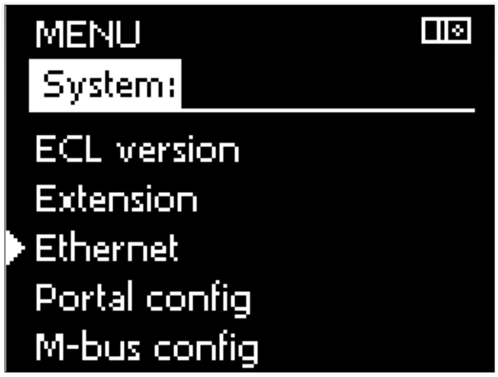
System:



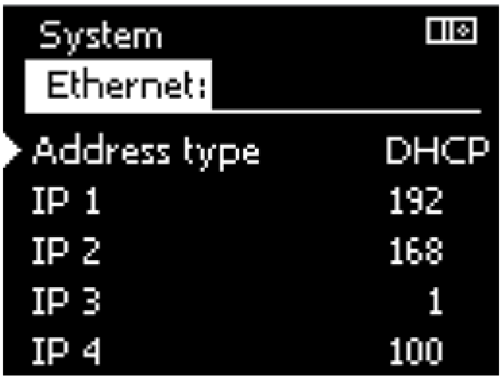
Common controller settings:



Ethernet:

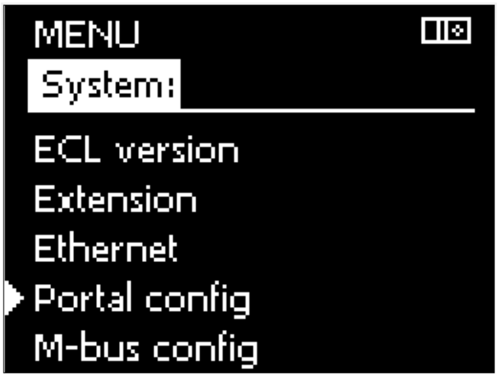


Activate automatic network addressing:



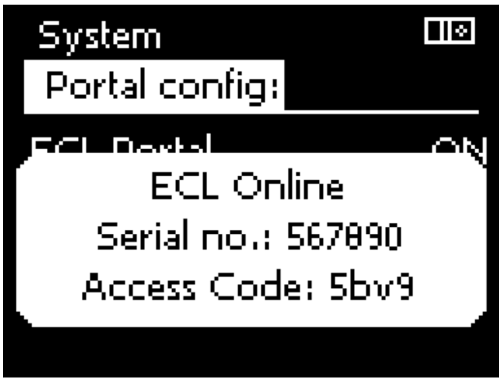
Or set up correct static IP address according to your network settings.

Portal config:



Make sure that URL is “lcl.portal.danfoss.com”, then Set "ECL Portal" to "ON"

Check serial number and access code visible in Portal info:

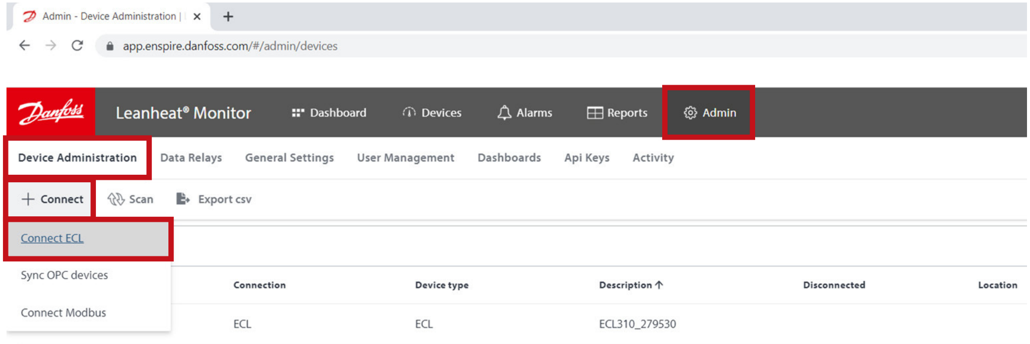


6.3.2 Settings in portal

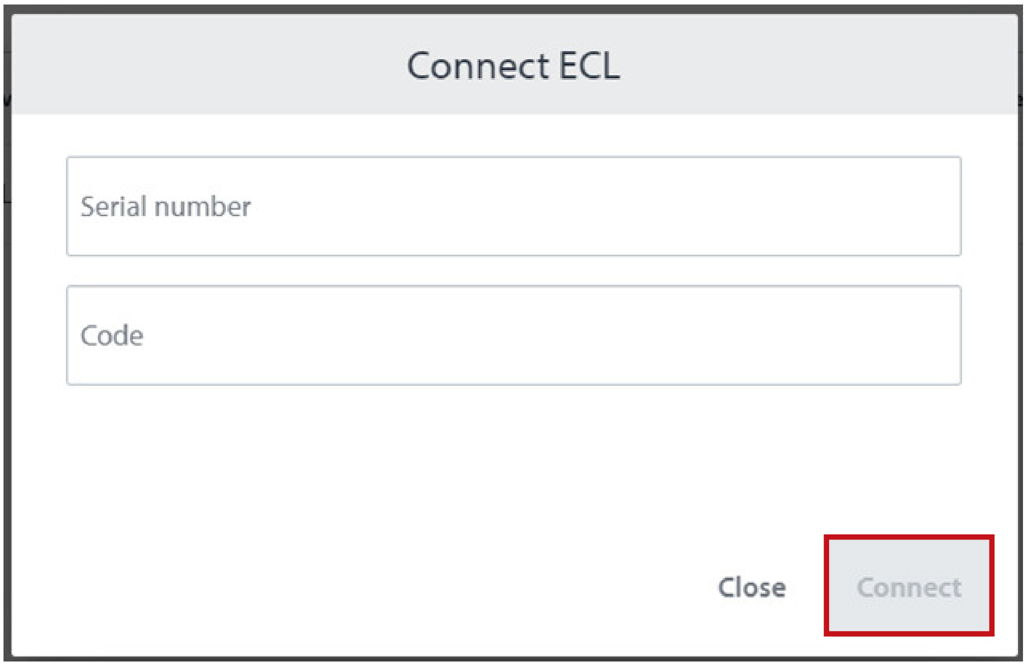
Go to app.enspire.danfoss.com and login to your account.

6.3.3 Adding controller to a portal

Admin -> Device Administration -> Connect -> Connect ECL:

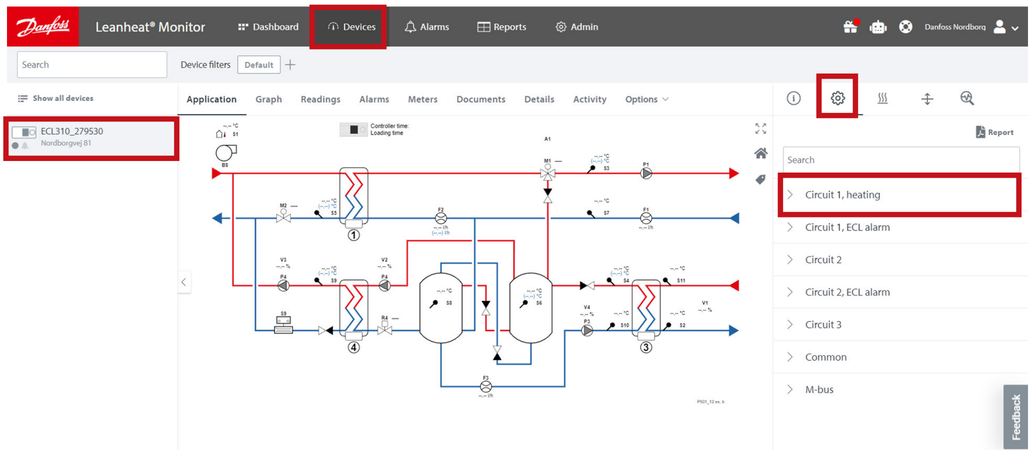


Input the serial number and access code
which you got from your device and click "connect":

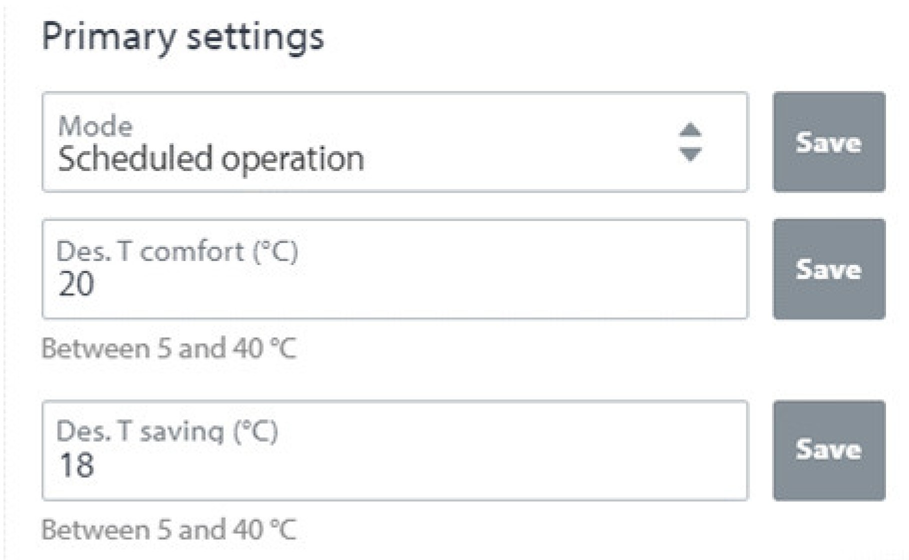


6.3.4 Circuit 1

Devices -> ECL310 (HRU) -> Settings -> Circuit 1, heating
Here all parameters regarding Heating circuit should be set.

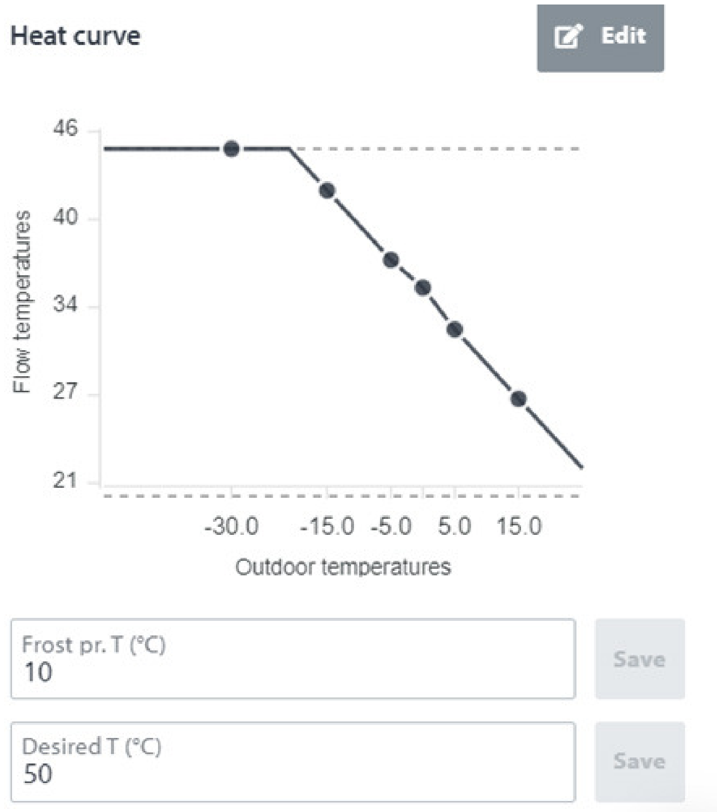


6.3.4.1 Primary settings:



Choose Scheduled operation.
Set T comfort and T saving according to need.

6.3.4.2 Flow temperature



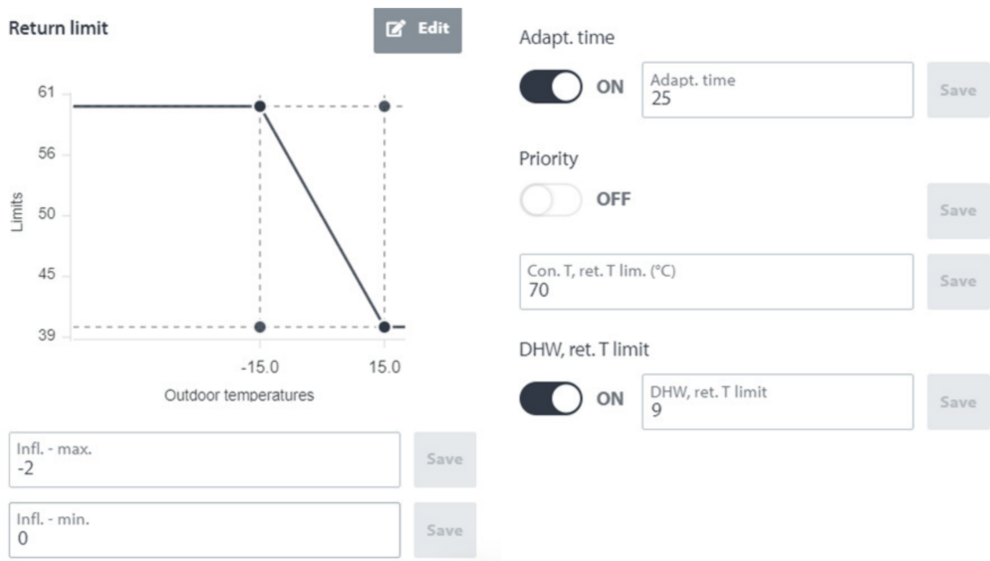
The weather compensated flow temperature can be configured here. Temperature should be adjusted according to heat consumer type.

"Frost protection T" is the minimum temperature for S3.

"Desired T" if external override has been created for an available input, the desired fixed flow temperature (R3) from the HRU unit can be configured here.

The minimum and maximum flow temperature (R3) can be configured here.

6.3.4.3 Return limit



Here you configure the highest permitted temperature desired at S5.

When this limit is exceeded, the “Infl. - max.” setting can be adjusted to determine the impact on R3.

6.3.4.4 Optimization

If an external signal indicating the desired flow temperature (R3) is not received, these settings will apply together with the "Flow temperature" settings.

If a schedule has been configured for comfort/saving mode:

"Auto-save" will gradually reduce flow temperature

”Ramp” change from saving to comfort mode can take place slowly over the configured time.

6.3.4.5 Control par. 1

*Parameters apply to the M1 flow temperature (S3).

“Xp” (proportional band) - A higher value will result in a stable but slow control of the flow temperature.

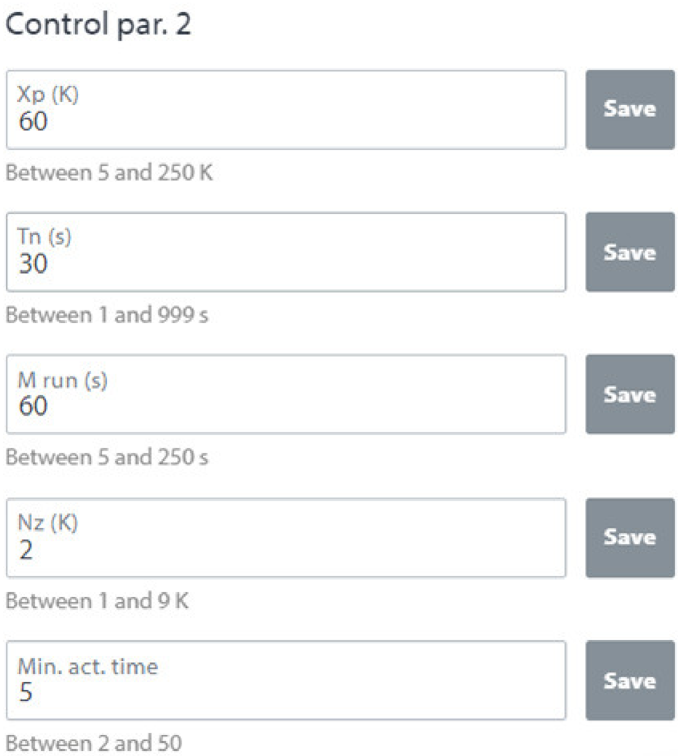
“Tn” (integration time constant) - Set a high integration time constant (in seconds) to obtain a slow but stable reaction to deviations. A low integration time constant will make the controller react fast but with less stability.

“M run” (running time of the motorized control valve) - 75 sec for HRU≤216 kW heating and 113 sec for HRU>216 kW heating

**Parameters apply to the mixing phase, i.e. when mixing of recovered heat and purchased heat takes place. Flow is associated with flow meter F2. Temperature controls (S3) are controlled by M2.

***Here, the anticipated flow temperature from auxiliary heat (district heating, boiler or other) is configured.

6.3.4.6 Control par. 2



Here, control parameters (M2) are configured for the desired flow temperature R3.

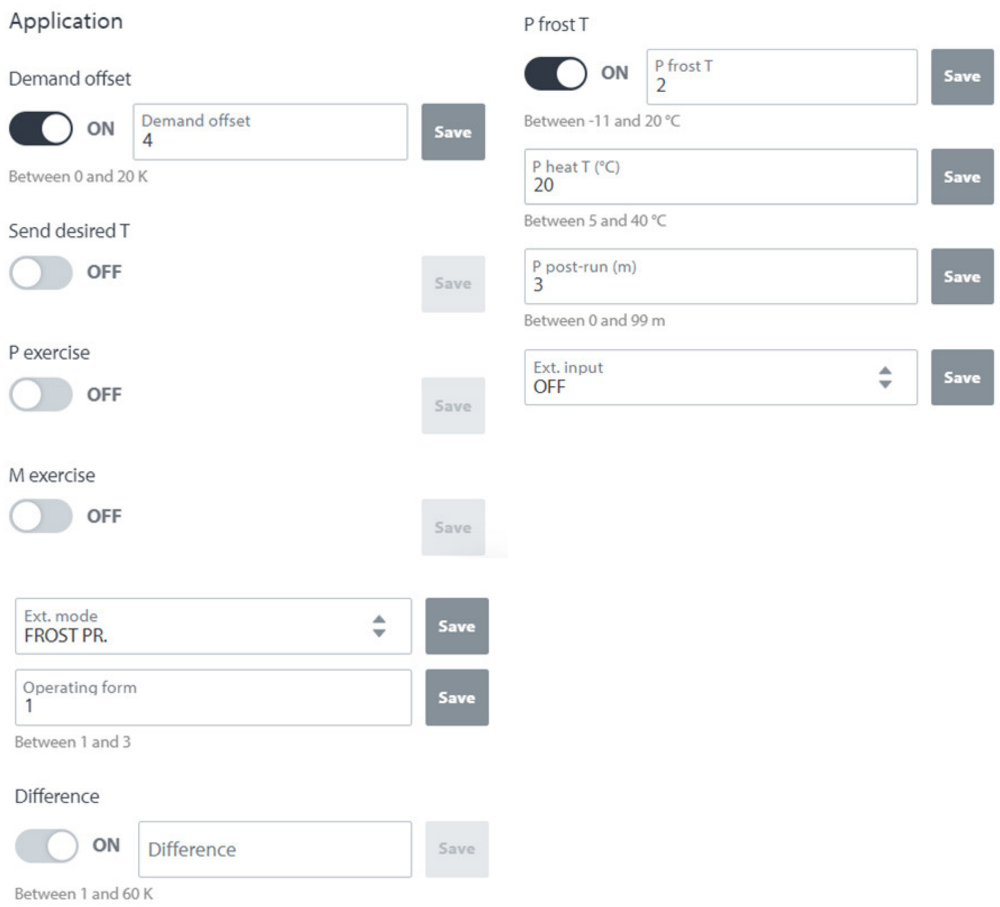
“Xp” (proportional band) - A higher value will result in a stable but slow control of the flow temperature.

“Tn” (integration time constant) - Set a high integration time constant (in seconds) to obtain a slow but stable reaction to deviations. A low integration time constant will make the controller react fast but with less stability.

“M run” (running time of the motorized control valve):

- 120 sec for HRU≤85 kW heating
- 75 sec for HRU>85 kW and ≤ 216 kW heating
- 113 sec for HRU>216 kW heating

6.3.4.7 Application



"Demand offset" is the temperature that is added to the highest temperature requirement that may be received from one or more ECL 310 slave regulators.

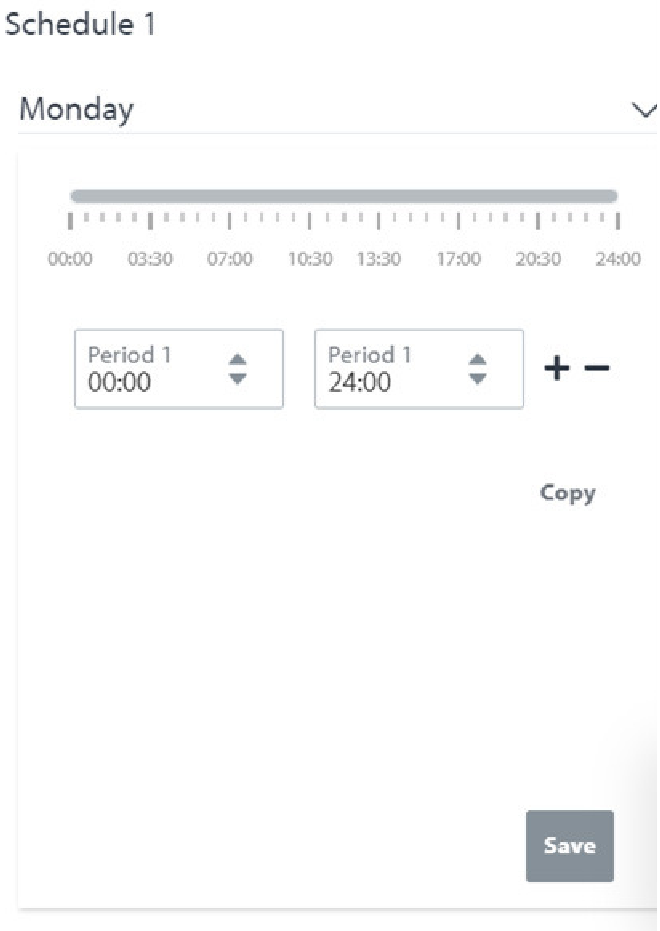
"Operating form" – Here you select the mode of operation in which the HRU unit will run

1: All three phases: recovered / mix / auxiliary heat

2: Phases: recovered / auxiliary heat

3: 100% use of recovered heat

6.3.4.8 Schedule 1

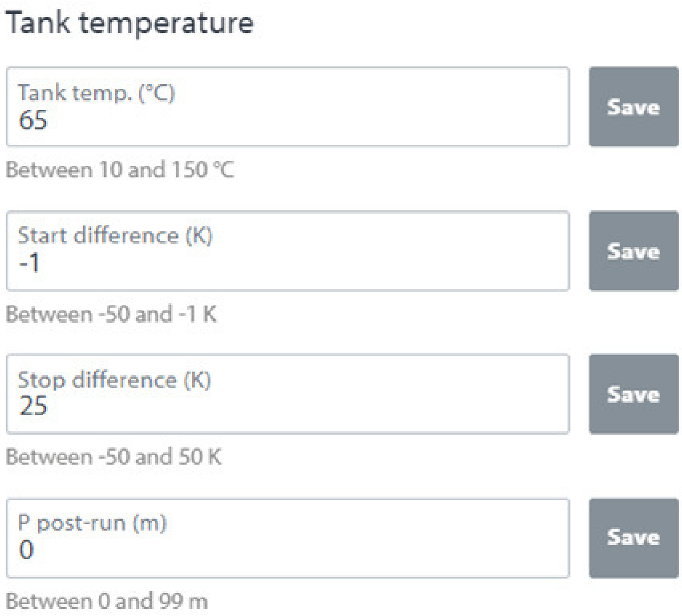


If an external signal indicating the desired flow temperature (R3) is not received, this schedule will apply to the configured comfort and saving mode temperatures.

6.3.5 Circuit 2

Devices -> ECL310 (HRU) -> Settings -> Circuit 2
Here all parameters regarding Heat recovery and Heat resale can be set

6.3.5.1 Tank temperature

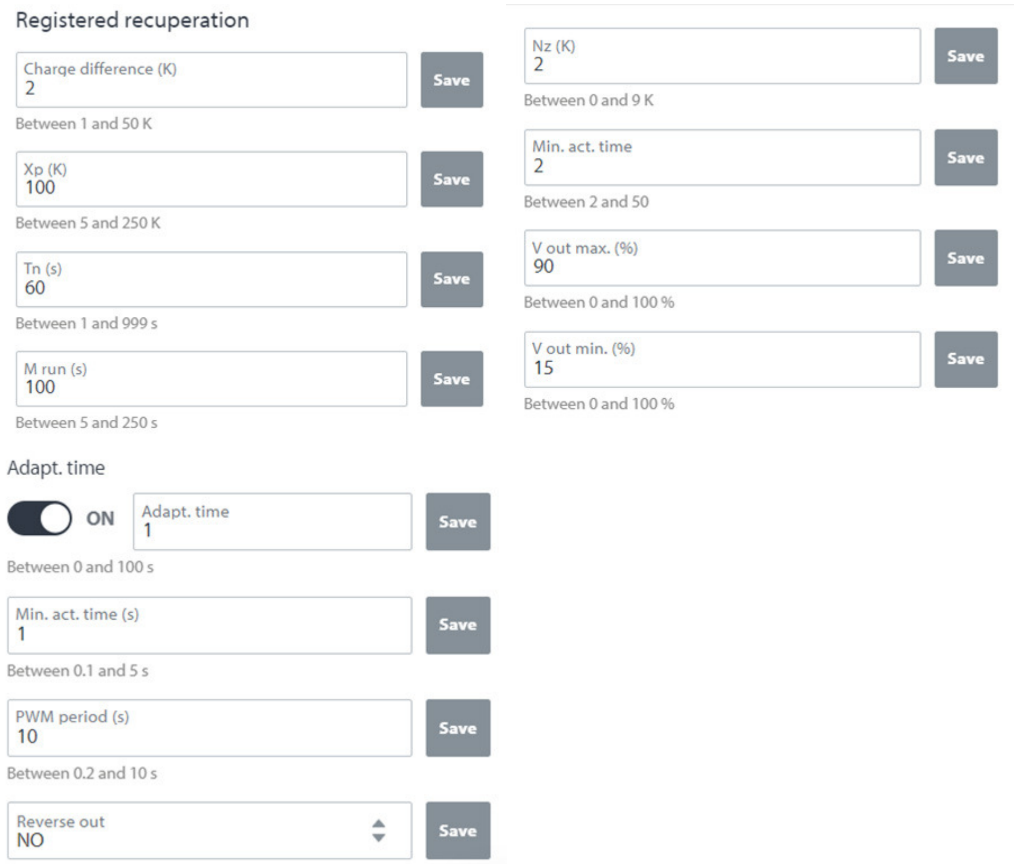


Here, you configure the desired temperature in the buffer/charger tanks and when charging should start and stop.
"Tank temp." – required tank temperature is base for calculation of the charging temp.

6.3.5.2 Compensation T

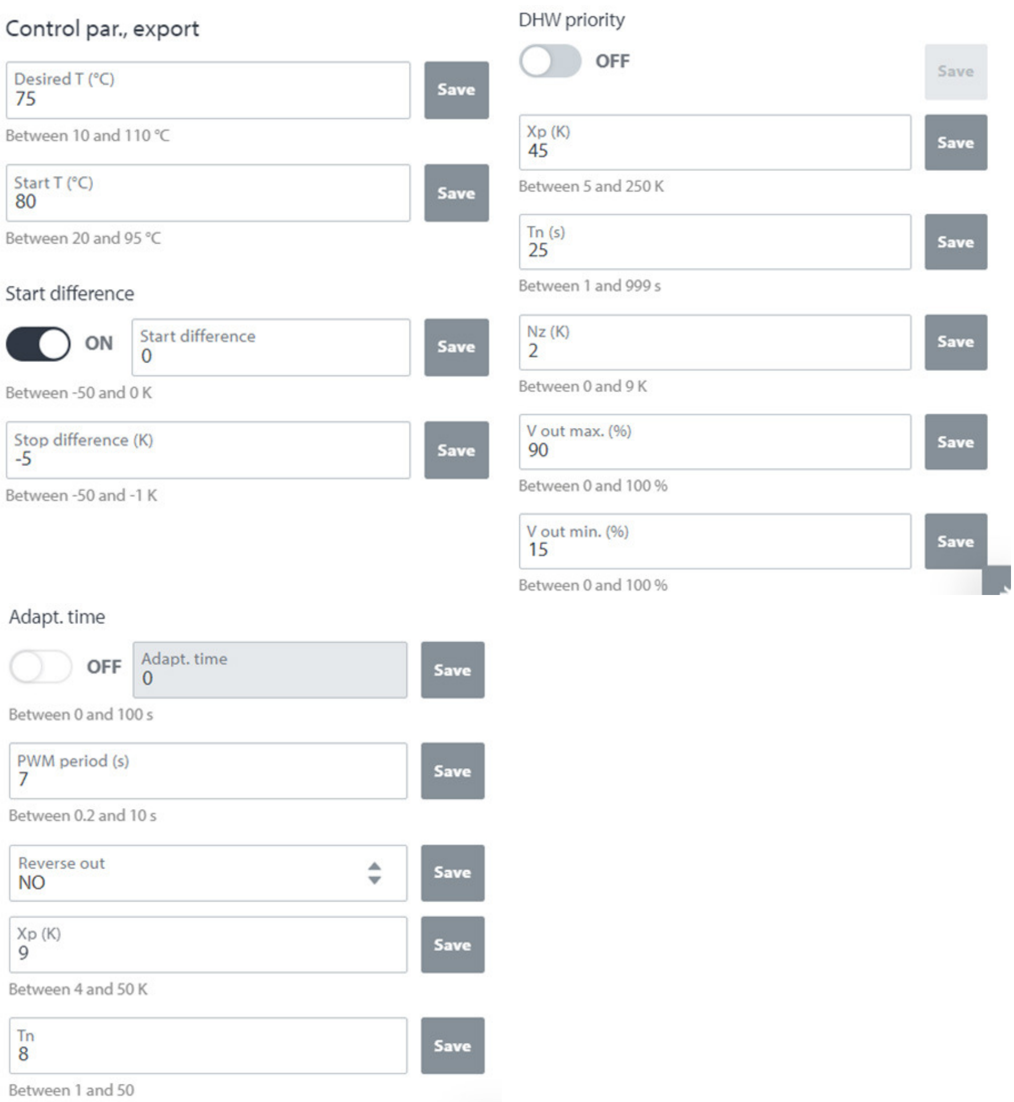
The permitted difference between temperatures S10 and S2 at high and low charging temperature respectively ("High X" and "Low X") can adjust the desired charging temperature (R4) with a desired amplification factor "Max. amplification".

6.3.5.3 Control heat recovery



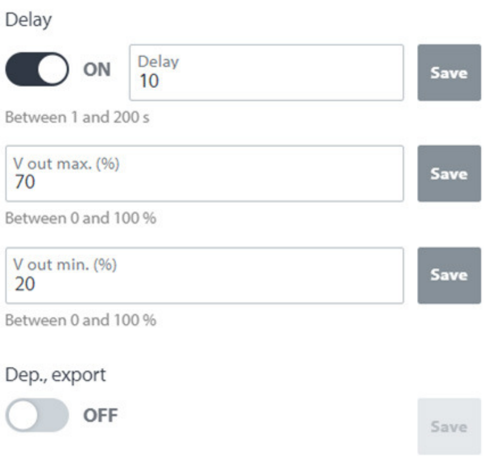
"Charging difference" - desired charging temperature in relation to the tank temperature.
"V out. min." - you can configure the desired minimum charging flow given by P3.
"Adapt. time" – Controls how fast the actual charging temp. adapts to the desired charging temp.
"Min. act. time" – min. PWM duty cycle. If "Adapt. time" setting is other than 0
"PWM period" – PWM signal period length. Settings can be configured with "Min. act. Time" to specify how often pump will stop and start to achieve less flow.

6.3.5.4 Control par., export



"Desired T" - The desired sale/export temperature.
"Start T" - Required tank top temperature (S6) before export can be started.
"Start difference" - Required tank bottom temperature (S8) before export can start
"Stop difference" - Required tank top temperature (S6) to end export
Example:
Export starts when both requirements have been met:
S6 > "Start T" > 80 °C
S8 > "Start T" + "Start difference" > 80-0 = 80 °C
Export stops when:
S6 < "Start T"+ "Stop difference" < 80-5 = 75 °C
Or if domestic hot water requirements are received from another ECL 310 if the setting "DHV priority" is ON.

6.3.5.5 Boost



Boost is an expression of how much energy HRU can reclaim. This signal (0-10VDC) ECL 310 send to the cooling plant.

“Delay” – time needed to change Boost signal by 1%

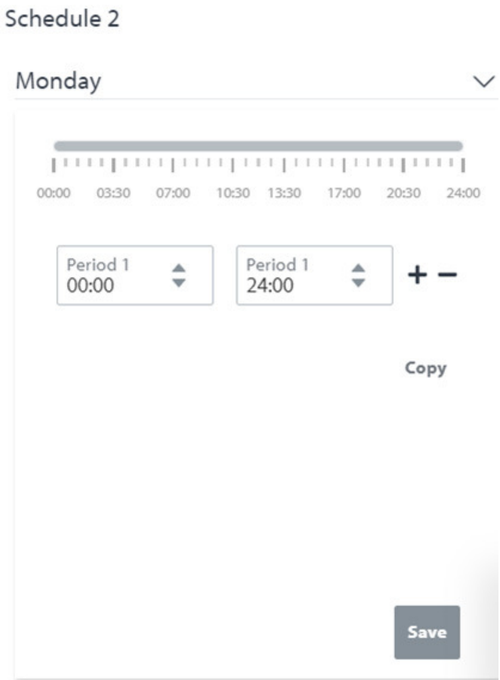
“V out. min.” – Min signal during operation

“V out max.” – Max level of signal transmitted to the pack controller.

"Depended on export ON" - This setting can increase the "Boost" signal to the cooler in the event of export/sale of recovered heat. This happens if the tank temperature (S6) is lower than the desired start temperature for export "Start T," or if the current charging temperature (S4) is lower than the desired tank temperature (R6).

"Depended on export OFF" - This setting can increase the "Boost" signal to the cooler. This happens only if the current charging temperature (S4) is lower than the desired tank temperature (R6).

6.3.5.6 Schedule 2



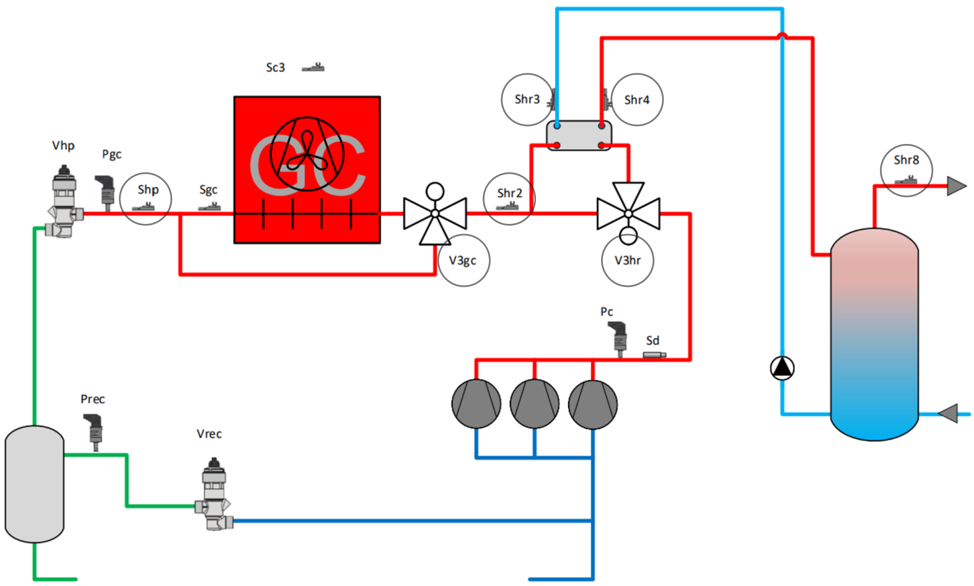
Here, you can configure a Schedule for when you want to export excess energy.

7. How to set up Pack Controller AK-PC 782A to operate with Danfoss Heat Recovery Unit (HRU)

To set up and configure Danfoss Pack Controller AK-PC 782A, you must use the Service Tool. You can download the latest version here:

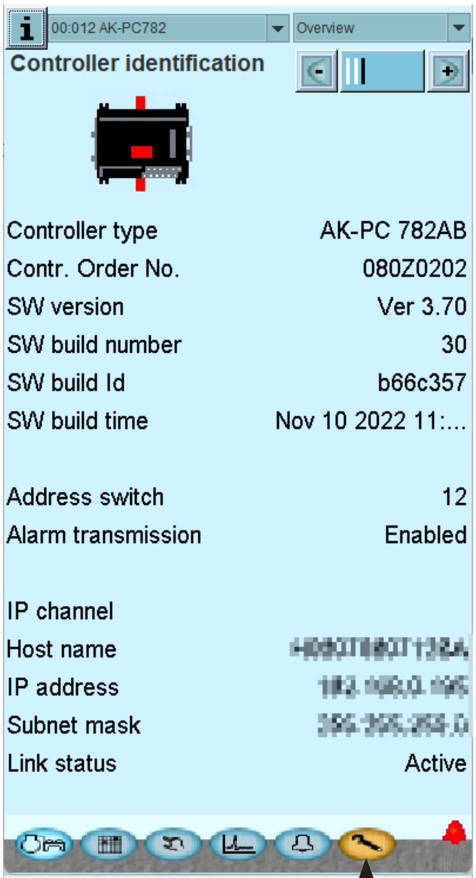
https://www.danfoss.com/en/service-and-support/downloads/dcs/adap-kool-software/ak-st-500/

Depending on selected heat recovery features, the following inputs and outputs must be configured.



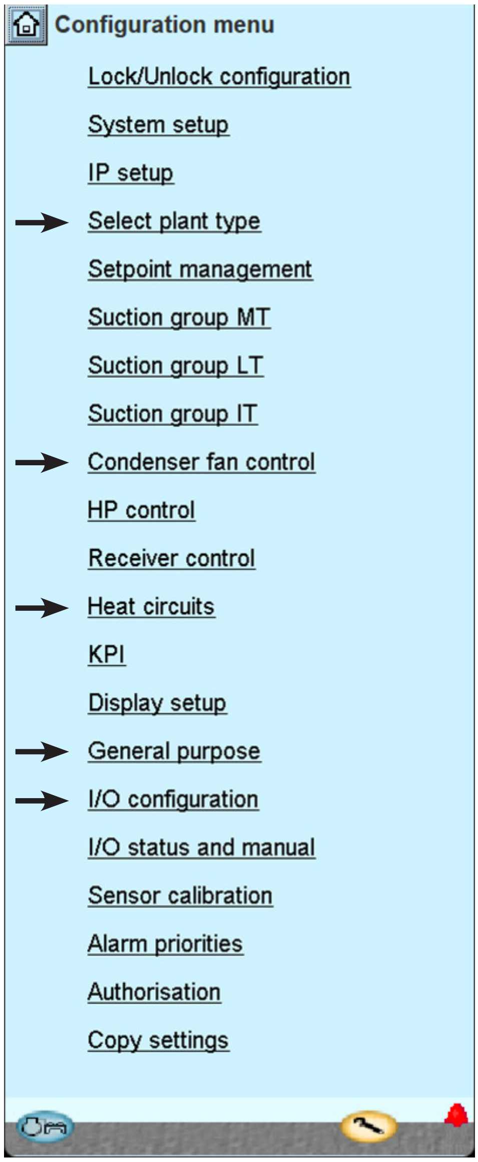
7.1 Heat recovery general settings

Setup and configuration based on AK-PC 782A software version 3.7

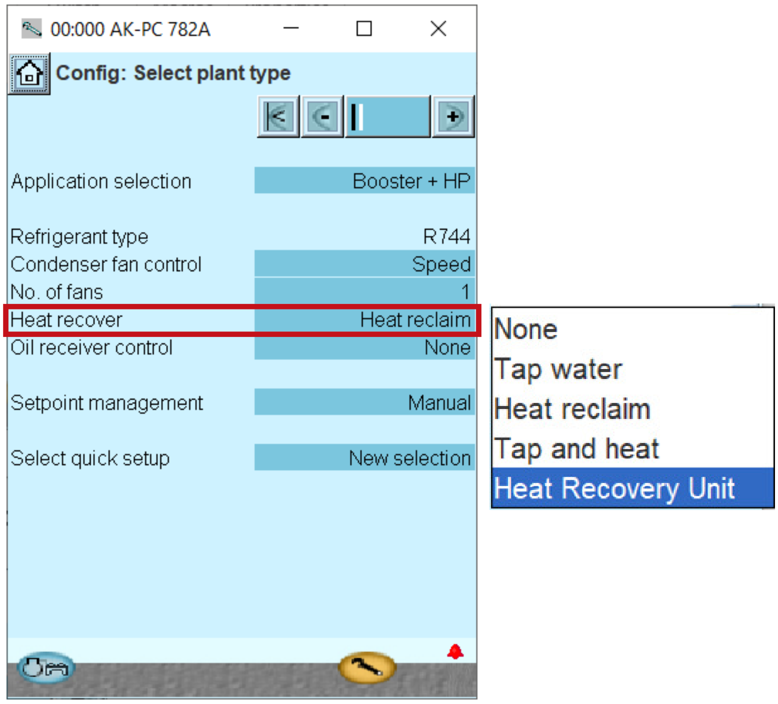


Configuration menu

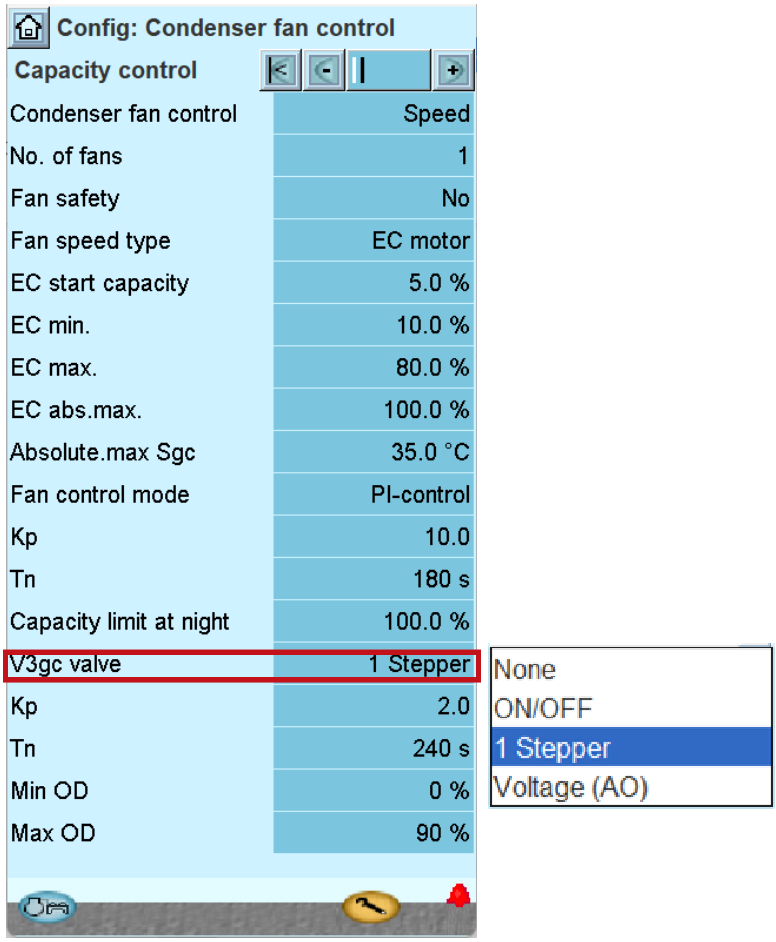
Configuration menu
menus necessary to set up



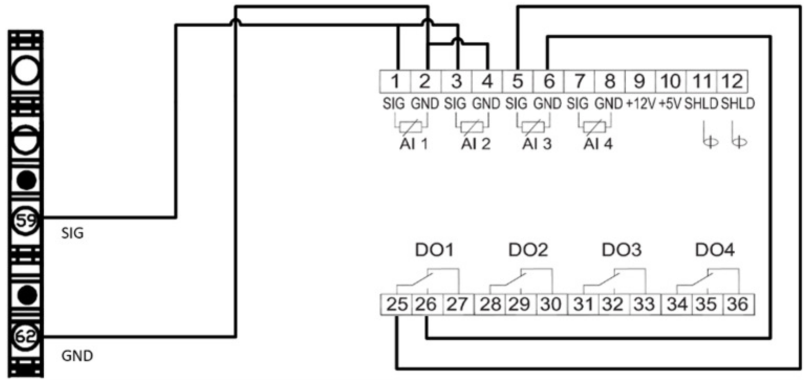
In menu **Select plant type** select an option for **Heat Recovery Unit** or **Heat recover**



If there is in the system Gas cooler bypass valve V3gc select menu **Condenser fan control** > **Capacity control** and V3gc valve type



Wiring diagram



HRU
(Heat Recovery Unit)

HC1 request 0 - 10V

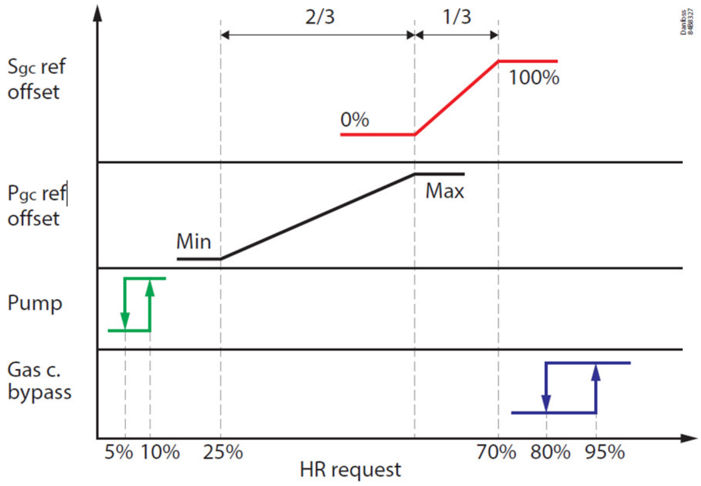
Signal is galvanic isolated within the HRU unit, so no need for additional isolation.

AK-PC 782A/B
AI1 - HC 1; signal 0 - 10V
General purpose HR enable function
AI2 - HC 1; Voltage signal used for voltage switch to enable HR
AI3=DI3; dry contact; "HR enable"
DO1 – Voltage switch

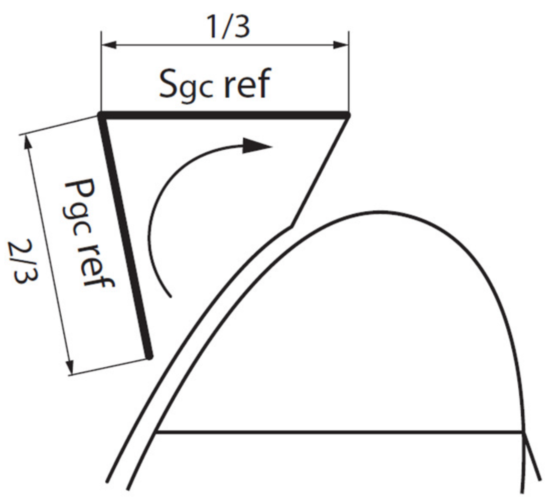
7.2 Setup with heat reclaim type = Heat Recovery Unit

The external voltage signal is registered (the higher the value, the greater the need for heat). The signal is converted by the HRU controller to 0 – 100% capacity and will have the following impact:

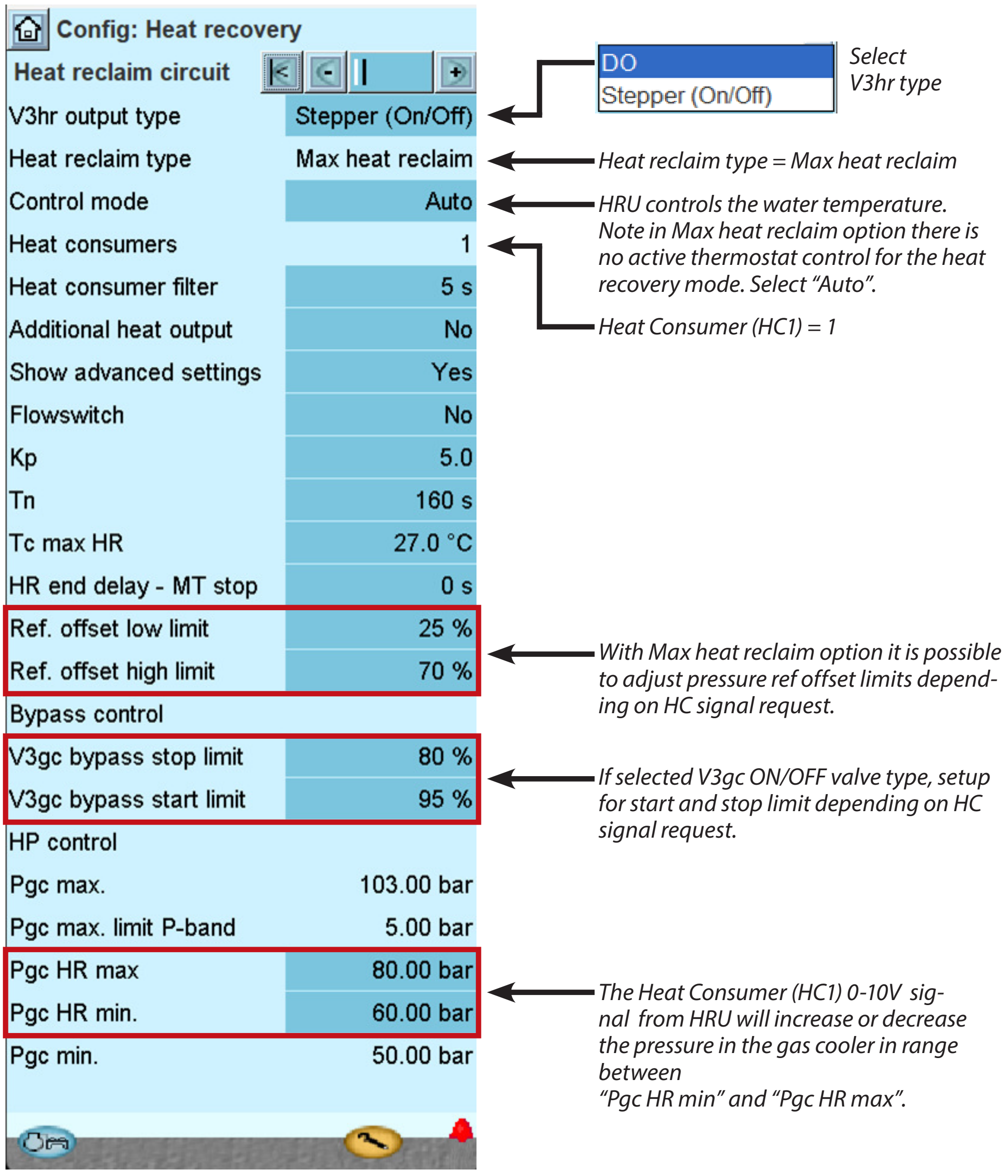
Here is example with on/off V3gc bypass valve but it is also possible, and preferable, to design system with V3gc modulating valve which provide very stable temperature control out of gas cooler.



5%	HR stop limit	70%	Ref offset high
10%	HR start limit	80%	V3gc bypass stop limit
25%	Ref offset low	95%	V3gc bypass start limit



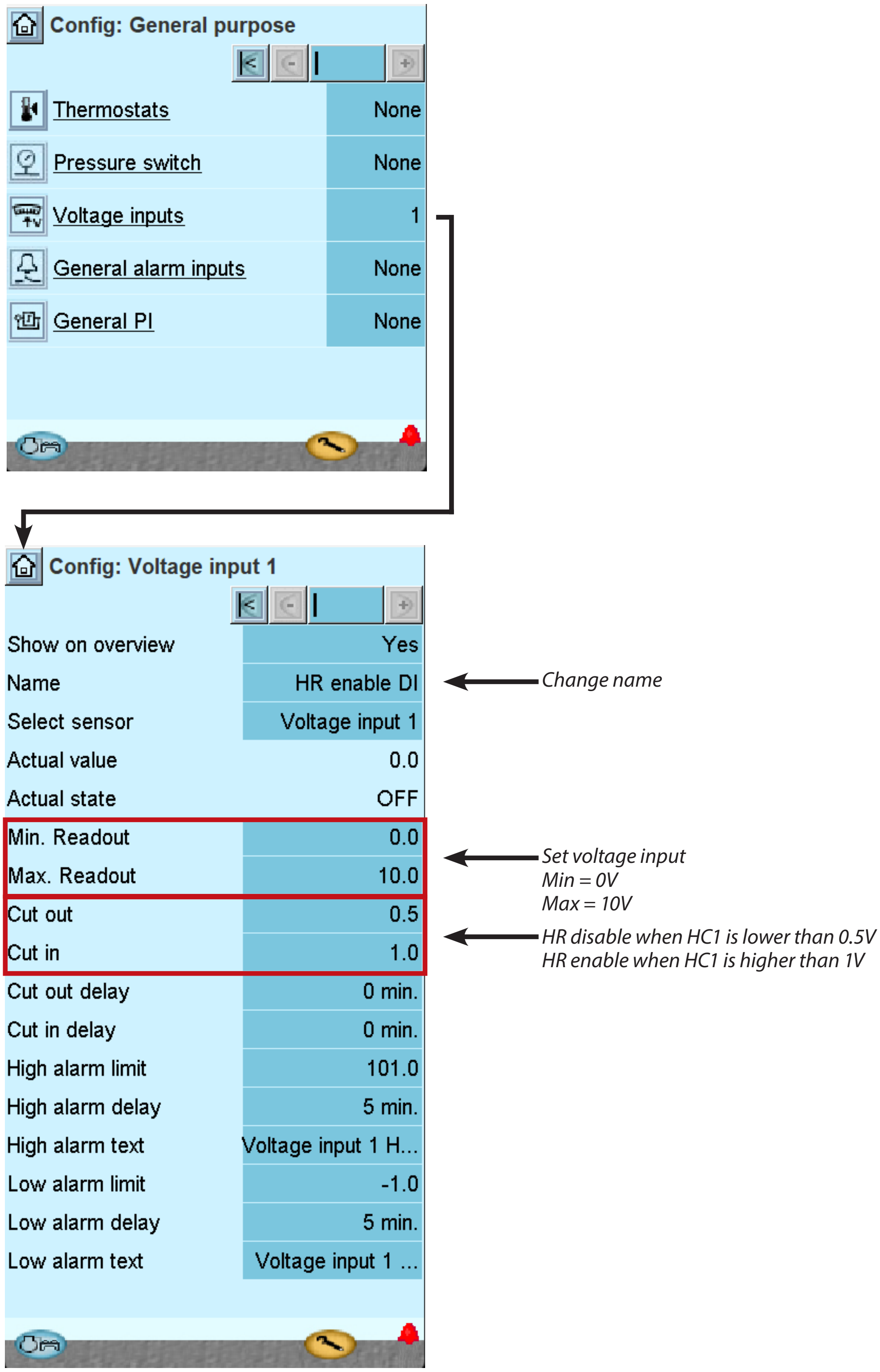
Under **Heat recovery** menu select
Heat reclaim circuit



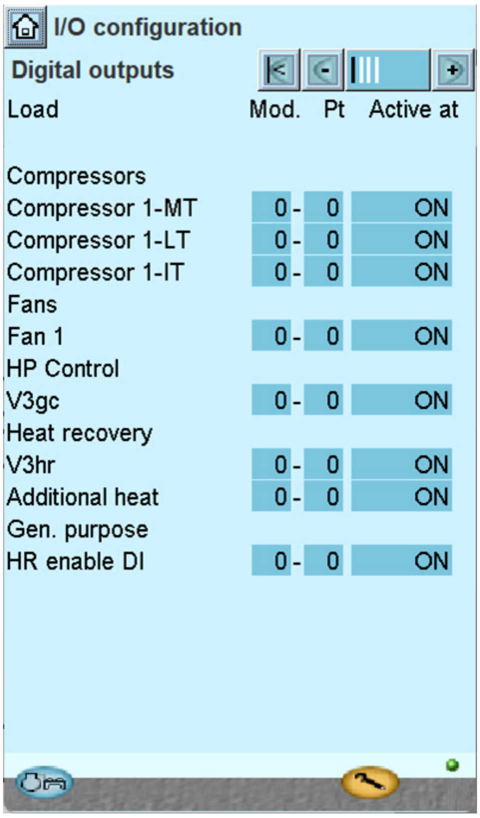
General purpose menu

HRU doesn't have digital output to enable Heat Recovery algorithm in AK-PC 782A/B so it is necessary to setup separately following action:

HR enable DO control based on HC1 signal and wire it to HR enable DI



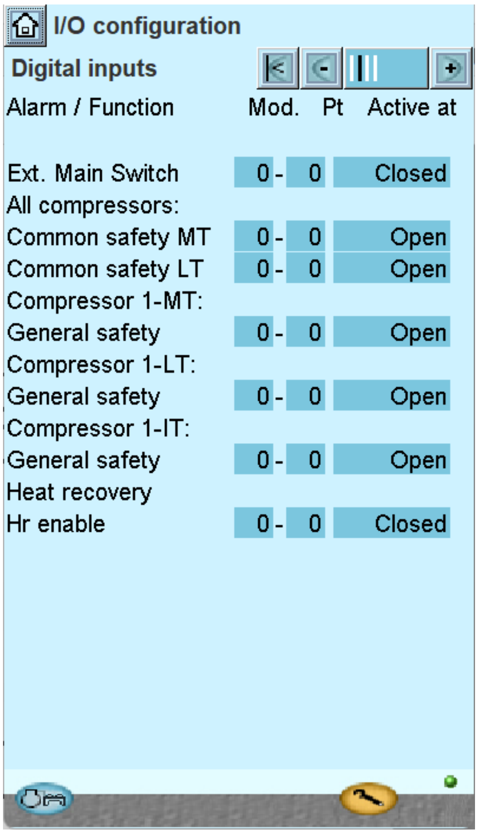
Under **Heat recovery** menu select
Heat reclaim circuit



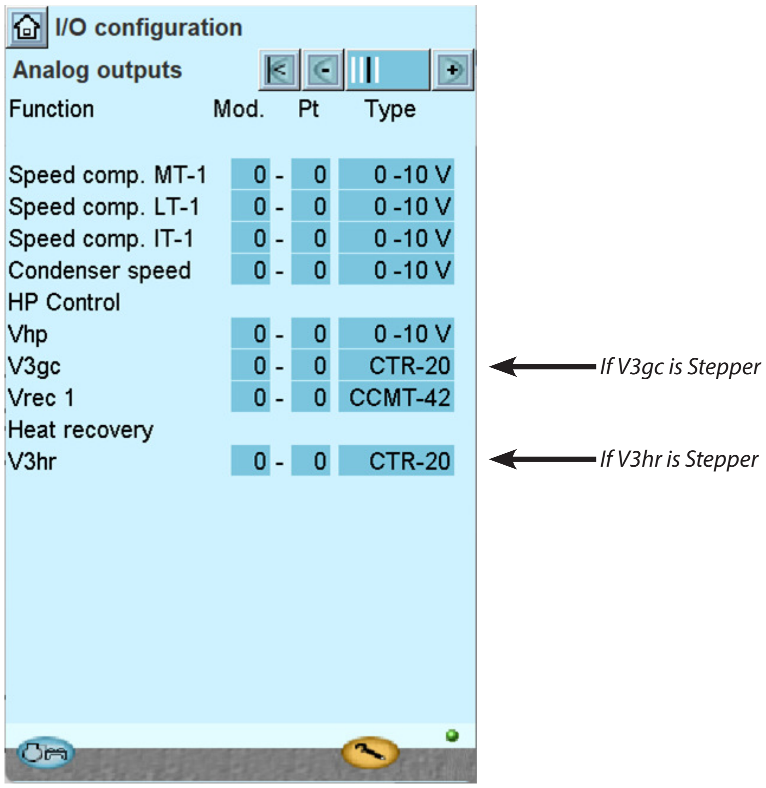
If V3gc is ON/OFF

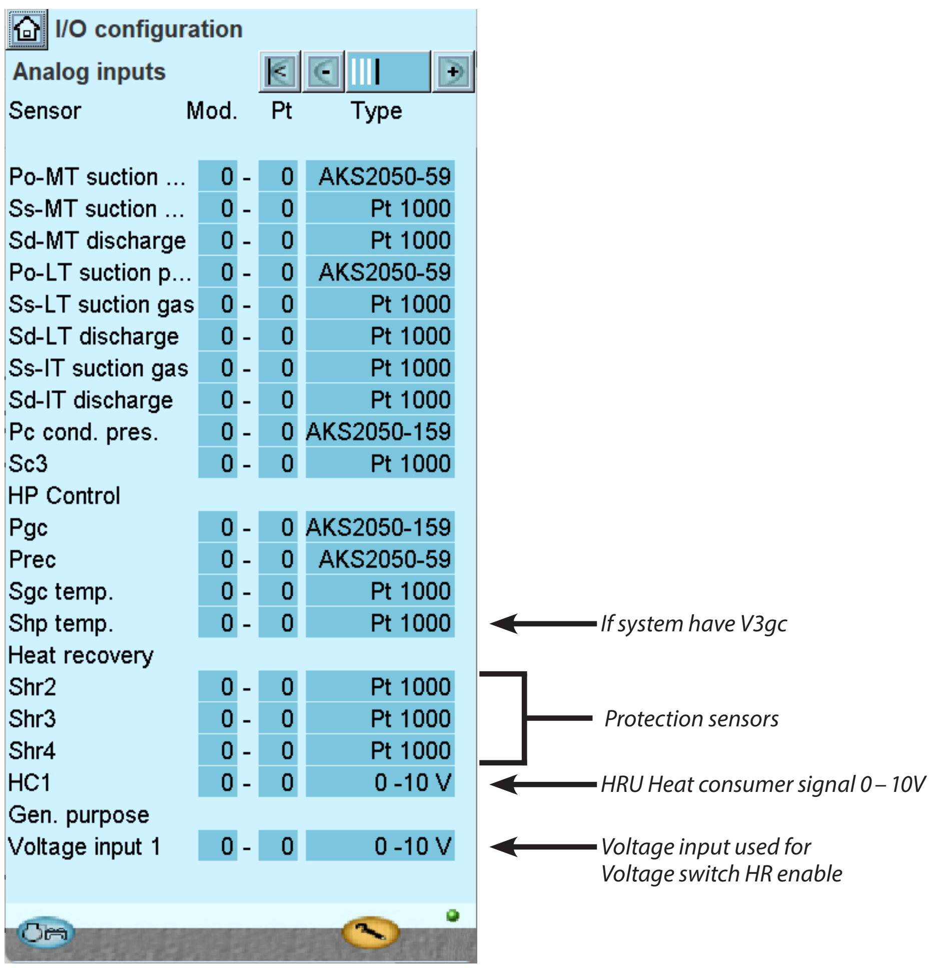
If V3hr is ON/OFF

HR enable
Gen. purpose DO



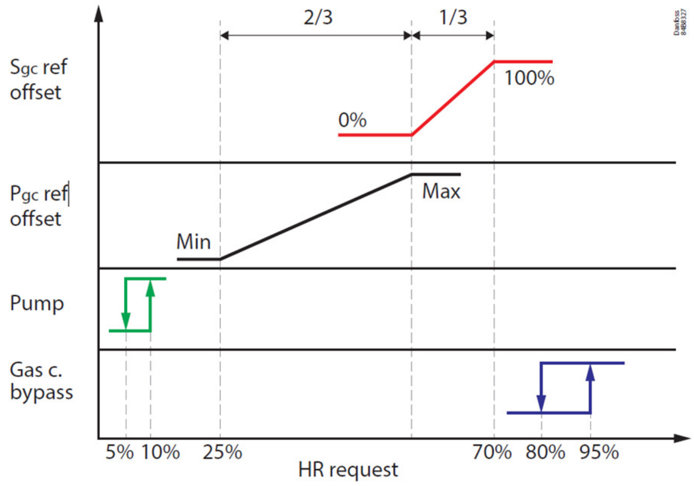
DDI to enable HR
wired from "HR enable DI"
Gen. purpose DO


I/O configuration
Analog outputs
Function Mod. Pt Type
Speed comp. MT-1 0 - 0 0 -10 V
Speed comp. LT-1 0 - 0 0 -10 V
Speed comp. IT-1 0 - 0 0 -10 V
Condenser speed 0 - 0 0 -10 V
HP Control
Vhp 0 - 0 0 -10 V
V3gc 0 - 0 CTR-20
Vrec 1 0 - 0 CCMT-42
Heat recovery
V3hr 0 - 0 CTR-20
If V3gc is Stepper
If V3hr is Stepper

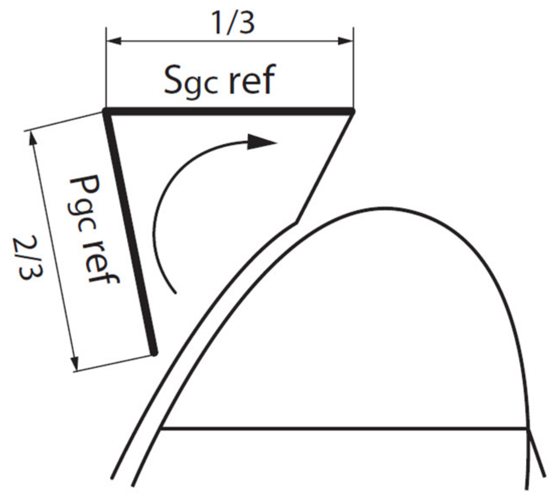

I/O configuration
Analog inputs
Sensor Mod. Pt Type
Po-MT suction ... 0 - 0 AKS2050-59
Ss-MT suction ... 0 - 0 Pt 1000
Sd-MT discharge 0 - 0 Pt 1000
Po-LT suction p... 0 - 0 AKS2050-59
Ss-LT suction gas 0 - 0 Pt 1000
Sd-LT discharge 0 - 0 Pt 1000
Ss-IT suction gas 0 - 0 Pt 1000
Sd-IT discharge 0 - 0 Pt 1000
Pc cond. pres. 0 - 0 AKS2050-159
Sc3 0 - 0 Pt 1000
HP Control
Pgc 0 - 0 AKS2050-159
Prec 0 - 0 AKS2050-59
Sgc temp. 0 - 0 Pt 1000
Shp temp. 0 - 0 Pt 1000
Heat recovery
Shr2 0 - 0 Pt 1000
Shr3 0 - 0 Pt 1000
Shr4 0 - 0 Pt 1000
HC1 0 - 0 0 -10 V
Gen. purpose
Voltage input 1 0 - 0 0 -10 V
If system have V3gc
Protection sensors
HRU Heat consumer signal 0 – 10V
Voltage input used for
Voltage switch HR enable

7.3 Setup with heat reclaim type = Max heat reclaim

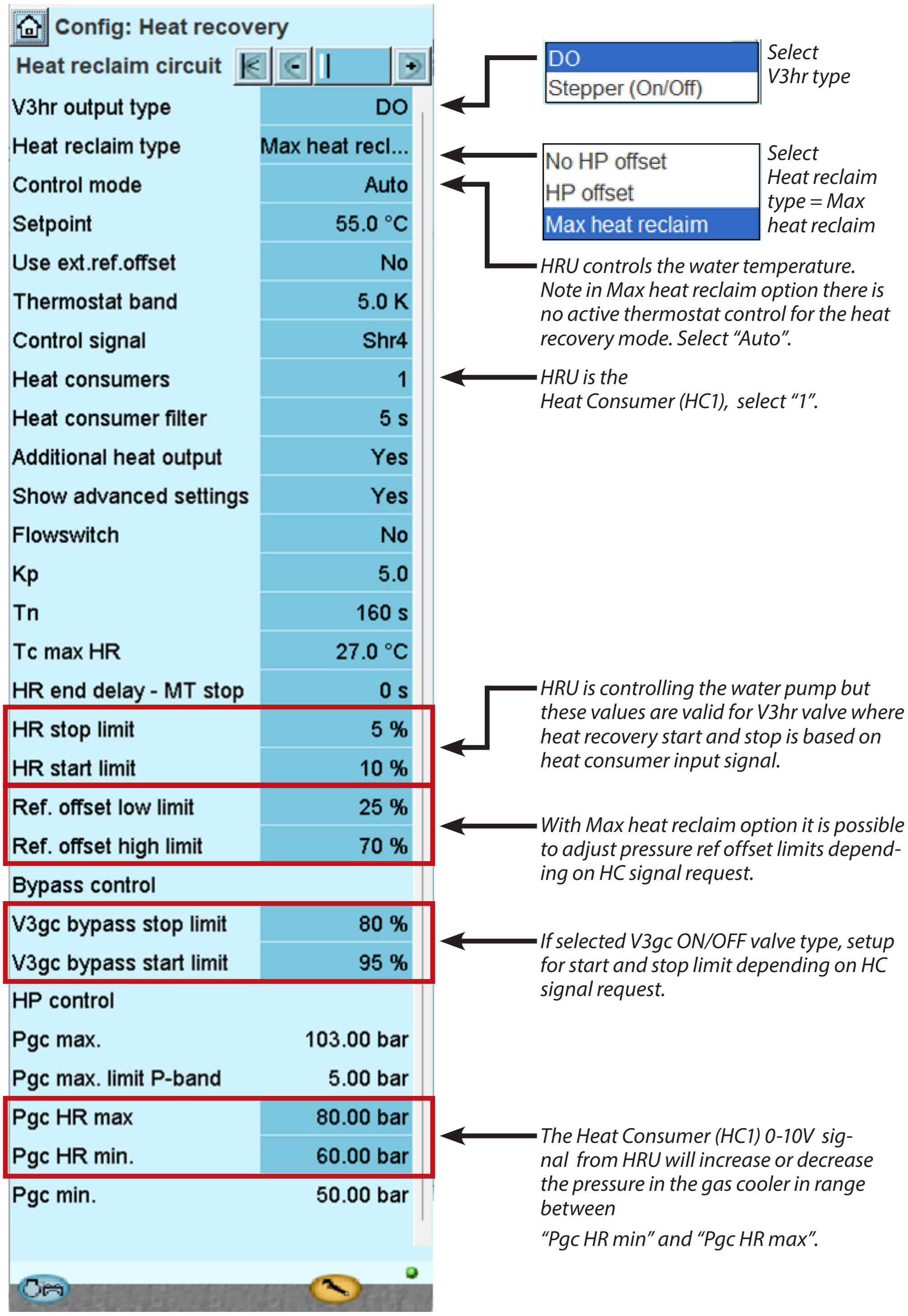
The external voltage signal is registered (the higher the value, the greater the need for heat). The signal is converted by the HRU controller to 0-100% capacity and will have the following impact:



5%	HR stop limit	70%	Ref offset high
10%	HR start limit	80%	V3gc bypass stop limit
25%	Ref offset low	95%	V3gc bypass start limit



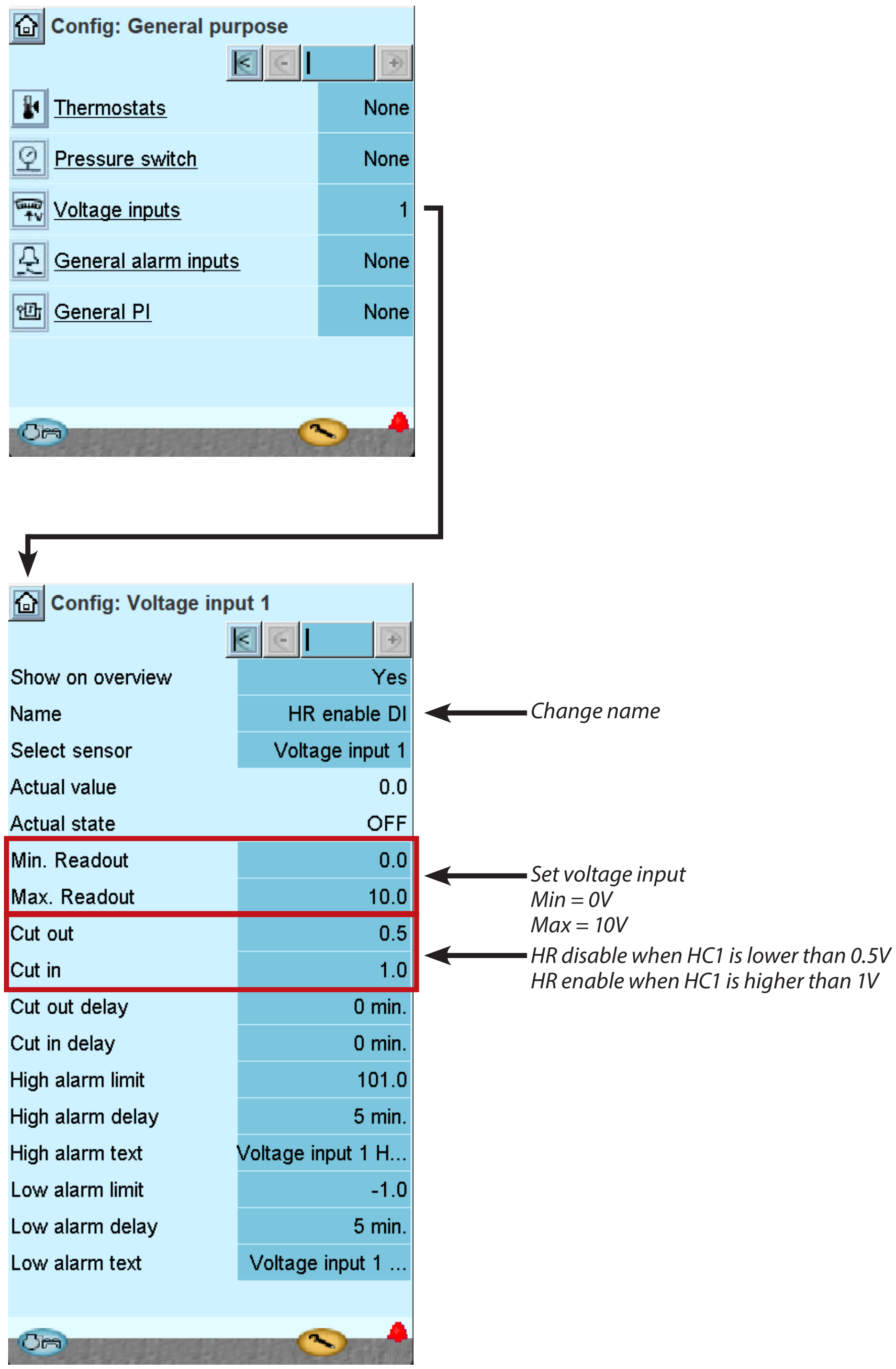
Under **Heat recovery** menu
select **Heat reclaim circuit**



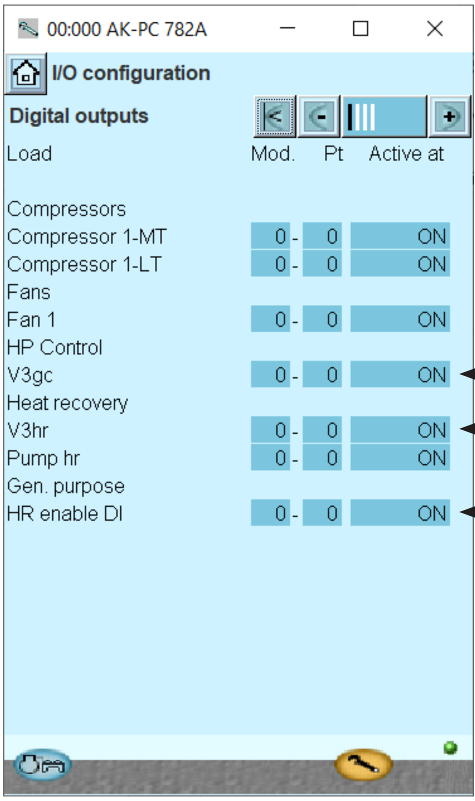
General purpose menu

HRU doesn't have digital output to enable Heat Recovery algorithm in AK-PC 782A/B so it is necessary to setup separately following action:

- HR enable DO control based on HC1 signal and wire it to HR enable DI



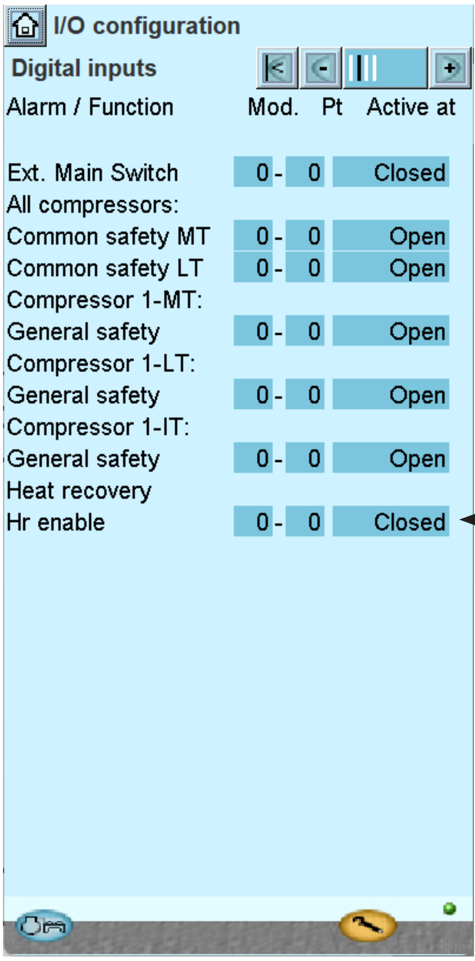
I/O Configuration menu setup



If V3gc is ON/OFF

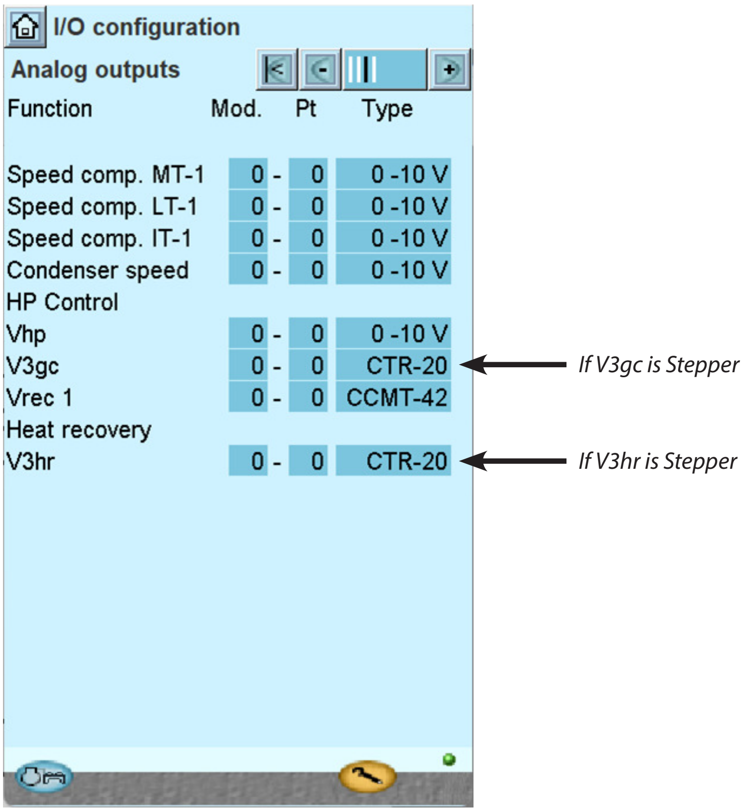
If V3hr is ON/OFF

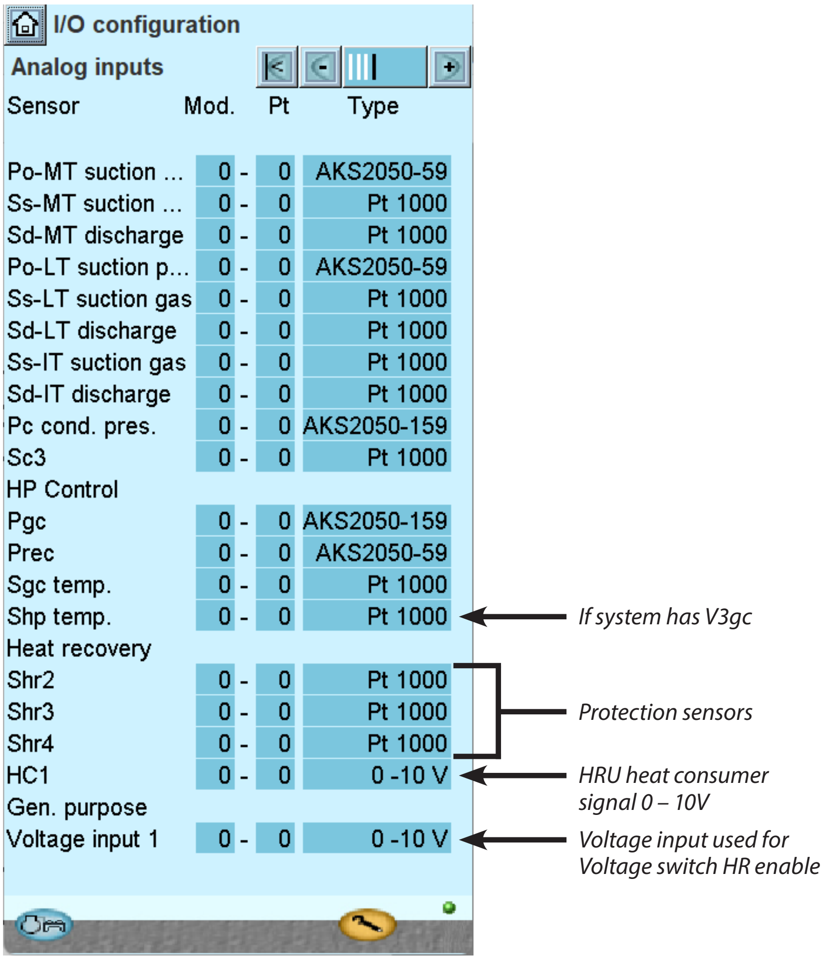
HR enable
Gen. purpose DO



DI to enable HR Wired from "HR enable DI"

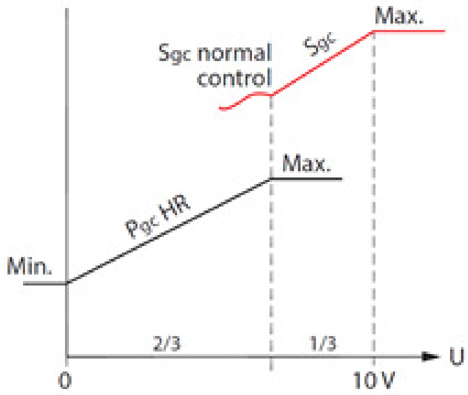
Gen. purpose DO

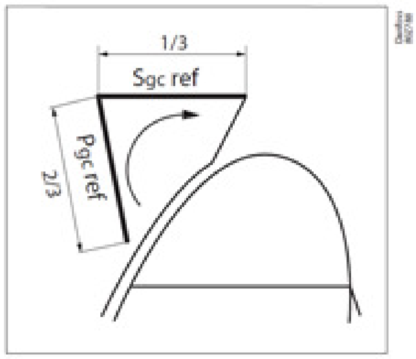

I/O configuration
Analog outputs
Function Mod. Pt Type
Speed comp. MT-1 0 - 0 0 -10 V
Speed comp. LT-1 0 - 0 0 -10 V
Speed comp. IT-1 0 - 0 0 -10 V
Condenser speed 0 - 0 0 -10 V
HP Control
Vhp 0 - 0 0 -10 V
V3gc 0 - 0 CTR-20
Vrec 1 0 - 0 CCMT-42
Heat recovery
V3hr 0 - 0 CTR-20
If V3gc is Stepper
If V3hr is Stepper

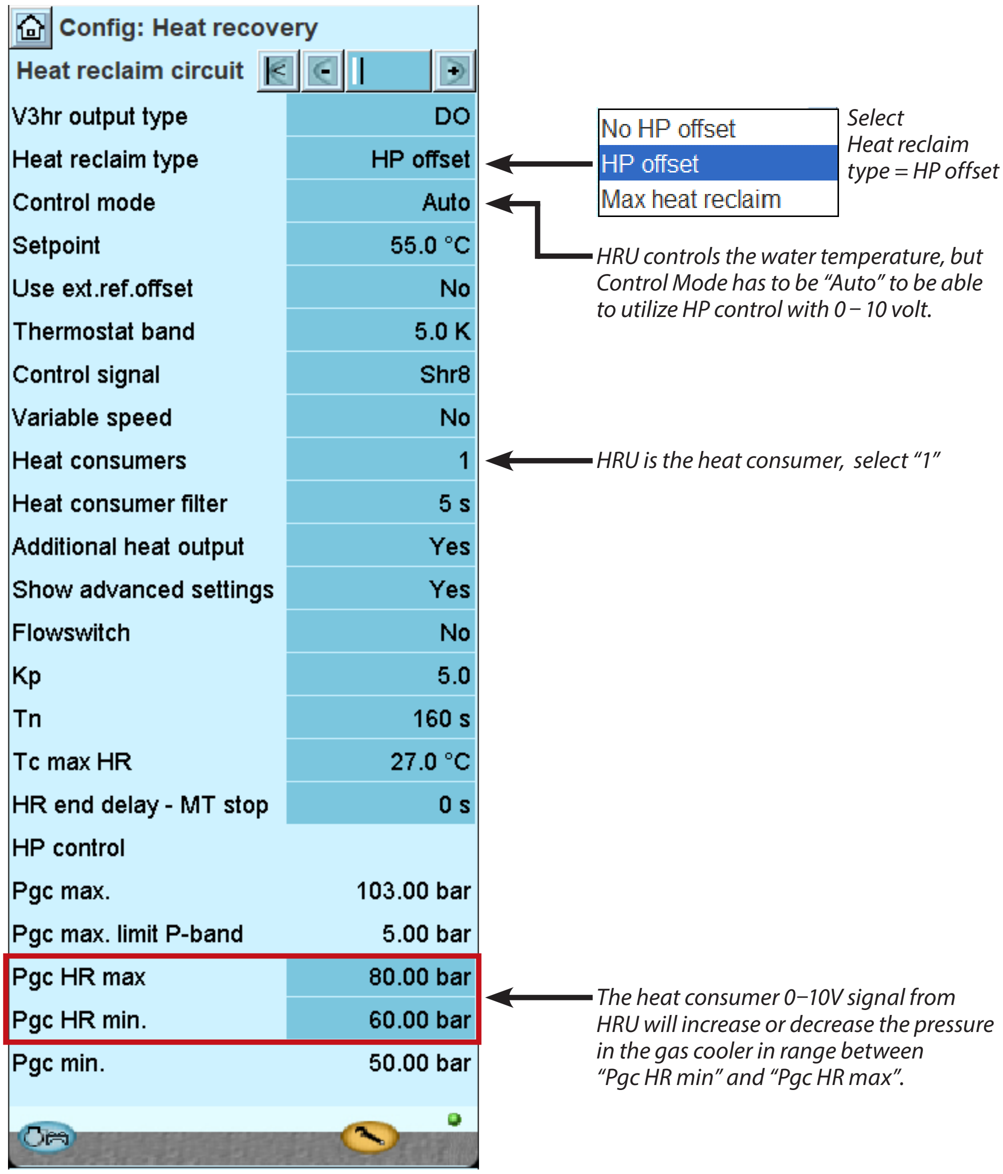

I/O configuration
Analog inputs
Sensor Mod. Pt Type
Po-MT suction ... 0 - 0 AKS2050-59
Ss-MT suction ... 0 - 0 Pt 1000
Sd-MT discharge 0 - 0 Pt 1000
Po-LT suction p... 0 - 0 AKS2050-59
Ss-LT suction gas 0 - 0 Pt 1000
Sd-LT discharge 0 - 0 Pt 1000
Ss-IT suction gas 0 - 0 Pt 1000
Sd-IT discharge 0 - 0 Pt 1000
Pc cond. pres. 0 - 0 AKS2050-159
Sc3 0 - 0 Pt 1000
HP Control
Pgc 0 - 0 AKS2050-159
Prec 0 - 0 AKS2050-59
Sgc temp. 0 - 0 Pt 1000
Shp temp. 0 - 0 Pt 1000
Heat recovery
Shr2 0 - 0 Pt 1000
Shr3 0 - 0 Pt 1000
Shr4 0 - 0 Pt 1000
HC1 0 - 0 0 -10 V
Gen. purpose
Voltage input 1 0 - 0 0 -10 V
If system has V3gc
Protection sensors
HRU heat consumer signal 0 – 10V
Voltage input used for Voltage switch HR enable

7.4 Setup with heat reclaim type = HP offset and temperature reference

The external voltage signal is registered (the higher the value, the greater the need for heat). The signal is converted by the HRU controller to 0-100% capacity and will have the following impact:



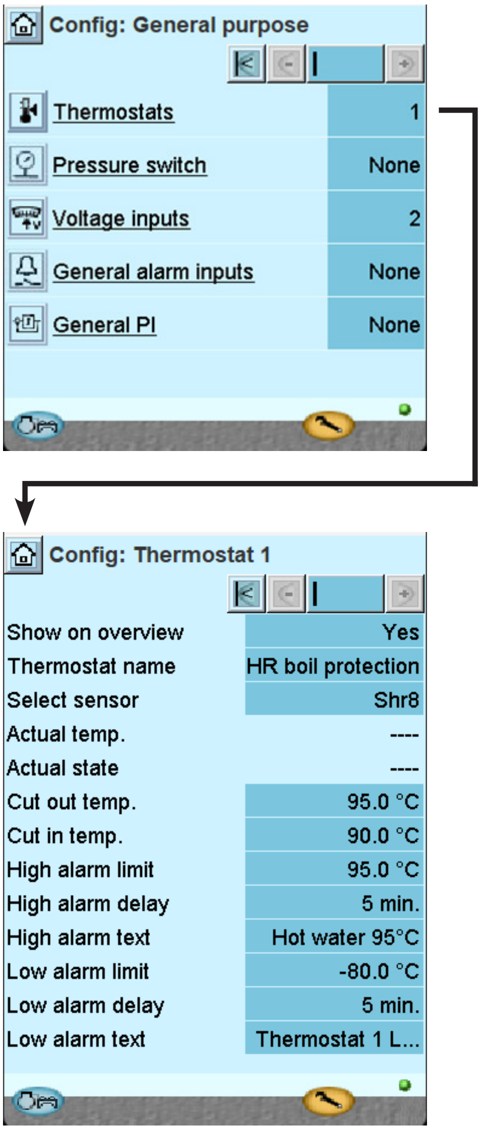



Config: Heat recovery
Heat reclaim circuit
V3hr output type DO
Heat reclaim type HP offset
Control mode Auto
Setpoint 55.0 °C
Use ext.ref.offset No
Thermostat band 5.0 K
Control signal Shr8
Variable speed No
Heat consumers 1
Heat consumer filter 5 s
Additional heat output Yes
Show advanced settings Yes
Flowswitch No
Kp 5.0
Tn 160 s
Tc max HR 27.0 °C
HR end delay - MT stop 0 s
HP control
Pgc max. 103.00 bar
Pgc max. limit P-band 5.00 bar
Pgc HR max 80.00 bar
Pgc HR min. 60.00 bar
Pgc min. 50.00 bar
No HP offset
HP offset
Max heat reclaim
Select Heat reclaim type = HP offset
HRU controls the water temperature, but Control Mode has to be "Auto" to be able to utilize HP control with 0 – 10 volt.
HRU is the heat consumer, select "1"
The heat consumer 0–10V signal from HRU will increase or decrease the pressure in the gas cooler in range between "Pgc HR min" and "Pgc HR max".

General purpose menu

With HP offset option it is necessary to setup separately following actions:

- Hot water protection based on Shr8 temperature sensor
- V3hr valve control based on HC1 signal
- HR enable DO control based on HC1 signal and wire it to HR enable DI

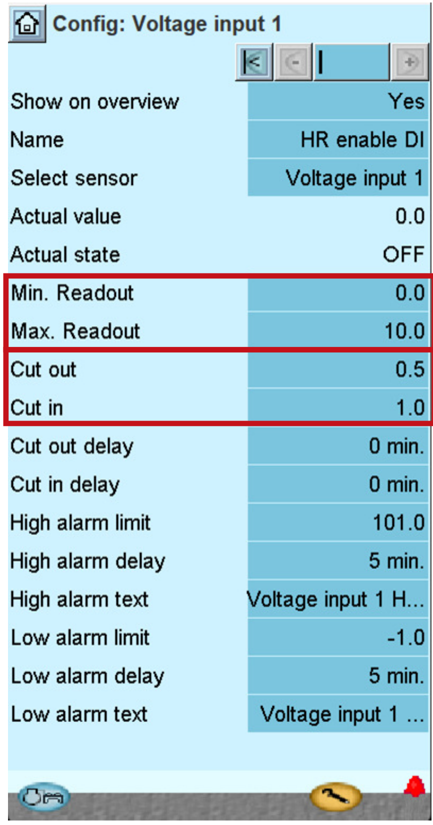


Boil protection is done with thermostat function by use of Shr8 temperature sensor.

Thermostat DO have to close externally V3hr valve.

Note:

ECL on HRU will automatically decrease HC1 0 – 10V signal if temperature is too high.

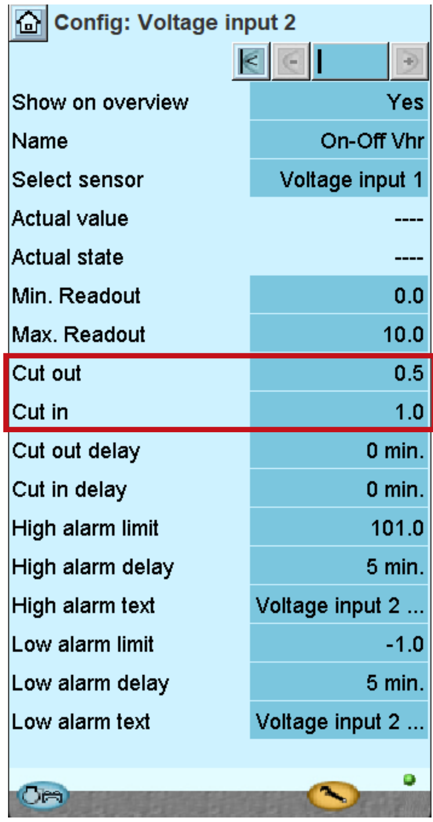


Change name

Set voltage input
Min = 0V; Max = 10V

HR disable when HC1 is lower than 0.5V

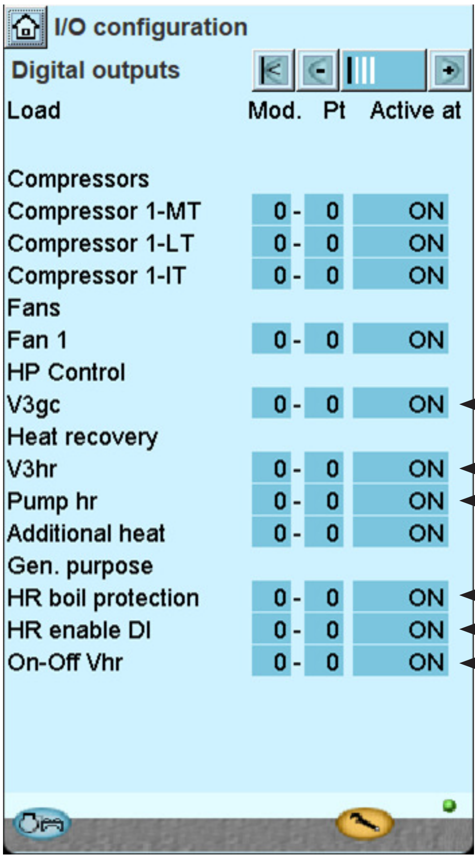
HR enable when HC1 is higher than 1V



Change name

Off - V3hr when HC1 is lower than 0.5V
On - V3hr when HC1 is higher than 1V

I/O Configuration menu setup



If V3gc is ON/OFF

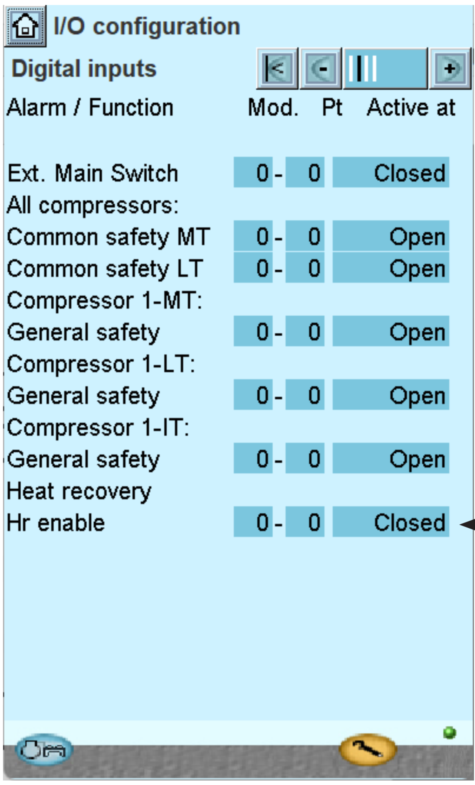
Not used; Set 0 - 0

Not used with HRU; Set 0 - 0

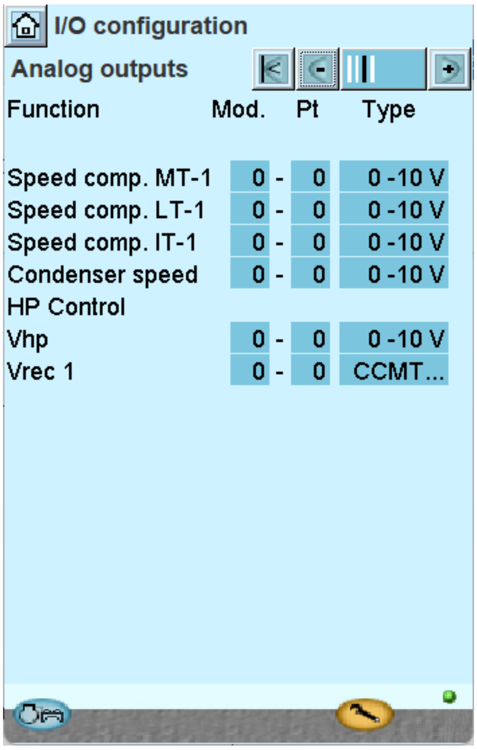
Boil protection

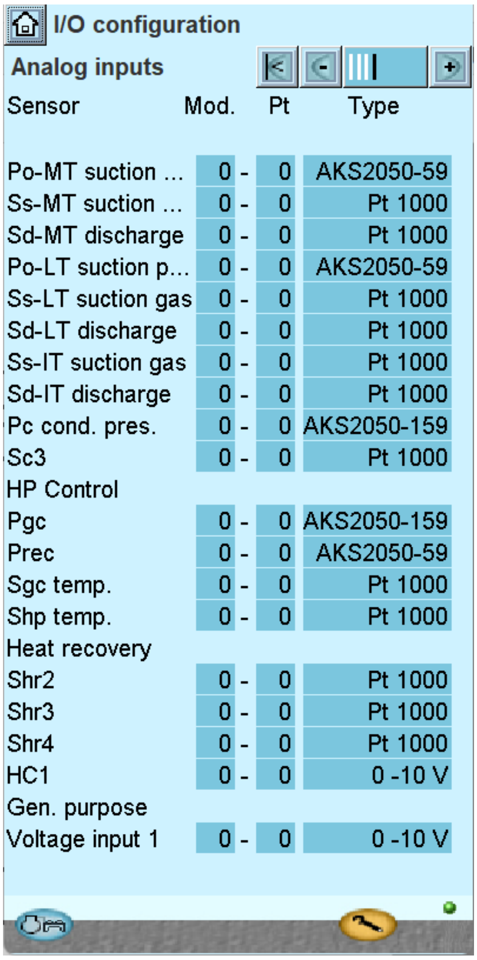
HR enable Gen. purpose DO

V3hr external control



DI to enable HR Wired from
“HR enable DI” Gen. purpose DO





If system have V3gc

Protection sensors

HRU Heat consumer signal 0 – 10V

Voltage input used for
Voltage switch HR enable and V3hr

8. Maintenance recommendations

To ensure stable and efficient operation of the HRU and Cooling Pack, Danfoss recommends connecting unit to ECL Portal for surveillance, regular maintenance, and service.

8.1 ECL portal surveillance

Automatic mail alarms can be set up in ECL Portal. By utilising them, failures or improper operation can be detected.

8.1.1 Examples of the monitored values

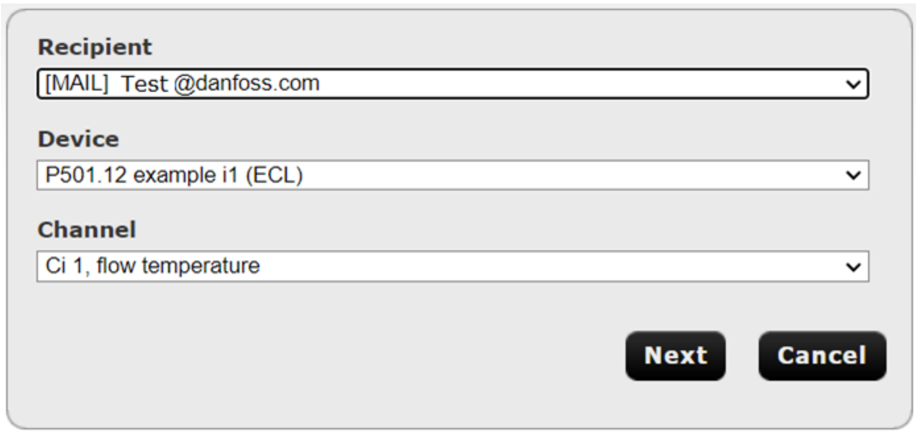
Alarms can be set on all sensors connected to the unit together with heat meter information. Internal controller alarms can be also sent by e-mail. Monitored values can be:

- Heat recovery circuit "Volume Flow" or "Energy forward" to monitor if heat reclaim is working (Portal alarm)
- CO_2 inlet temp. to monitor if cooling pack operates in heat reclaim mode (Portal alarm)
- Heating flow temp. to monitor if heating is supplied to the building (ECL Alarm)
- Heating return temp. to monitor if heating system operates in efficient way (Portal alarm)

8.1.2 ECL portal alarms setup

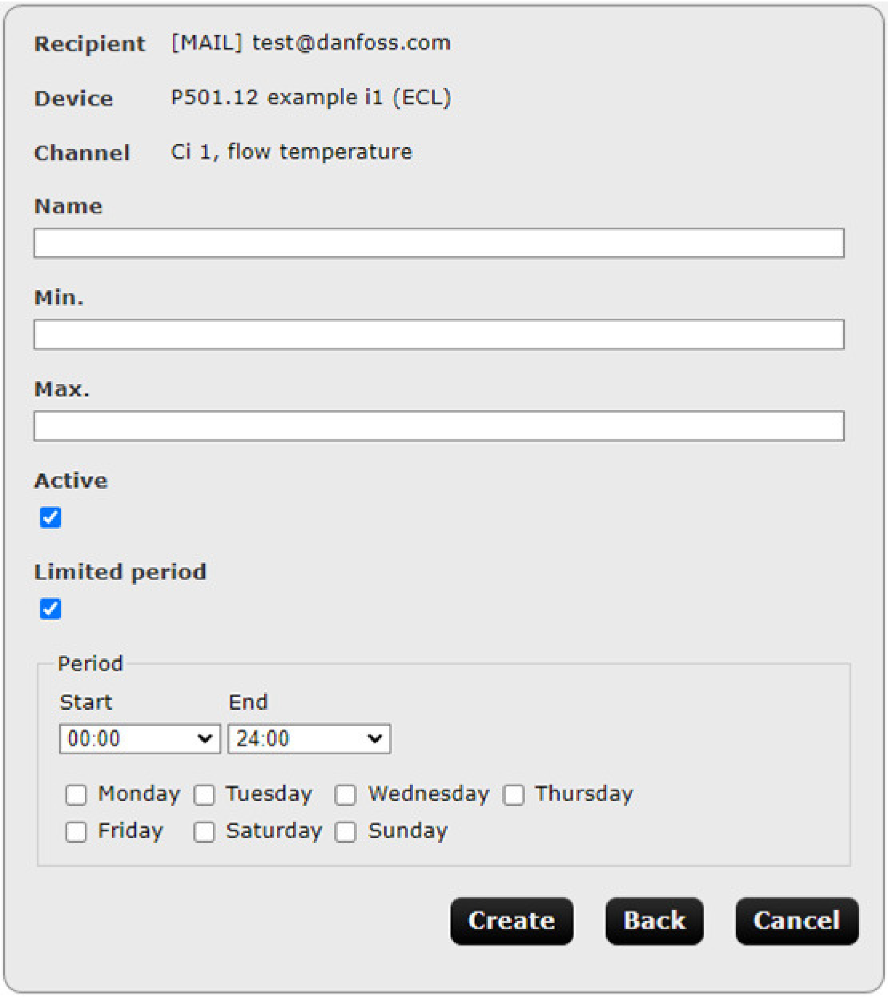
Alarms can be set on all sensors connected to the unit together with heat meter information. Internal controller alarms can be also sent by e-mail. Monitored values can be:

- Heat recovery circuit "Volume Flow" or "Energy forward" to monitor if heat reclaim is working (Portal alarm)
- CO_2 inlet temp. to monitor if cooling pack operates in heat reclaim mode (Portal alarm)
- Heating flow temp. to monitor if heating is supplied to the building (ECL Alarm)
- Heating return temp. to monitor if heating system operates in efficient way (Portal alarm)



In this menu, alarm can be configured.

Choose **Recipient** e-mail address, **Device** data source (application, heat meter or sensor) and monitored value in **Channel**. Click next.



In this menu, put Name, Min. and Max. value of the monitored parameter. You can also choose if monitoring should be continuous or only in required periods.

8.2 Maintenance plan (recommendation)

The most important actions for main components and assemblies are summarized in below table. Other instructions for components not specified in this application guide can be found separately in the component's instruction attached to unit documentation.

Interval	Maintenance	Comments
Every 2 months	Check all connections	If necessary, re-tighten and / or replace seals
	Check all parameters to nominal / actual values or admissibility	If excessive, restore proper parameters
	Clean strainers	If necessary
	General visual inspection of all components	In case of visible damage, perform a functional test and if necessary, replace the component
Every 6 months	Perform a functional test of the safety valve	Open the safety valve for a short period of time
	Perform a functional test of the electrical and electronic components	Manually switch the pump or open and close the actuator
	Perform an electrical test of the safety devices	Temperature monitor, sensors and / or limiters
	Clean strainers	If necessary
Every 12 months	Perform a functional and usability check of all components	For example, open and close the shut-off valves
	Perform a visual inspection of substation's appearance	Color (rust), insulation
	Check the heat exchanger	In case of contamination, clean / descale as needed
	Perform a visual inspection of the heat meter and water meter	Check legalization period
	Perform a visual inspection of the measuring devices	Manometer, thermometer
	Perform a visual inspection of the expansion vessels	Shape of vessels, tamper head, tightness of the membrane

8.3 Service recommendation

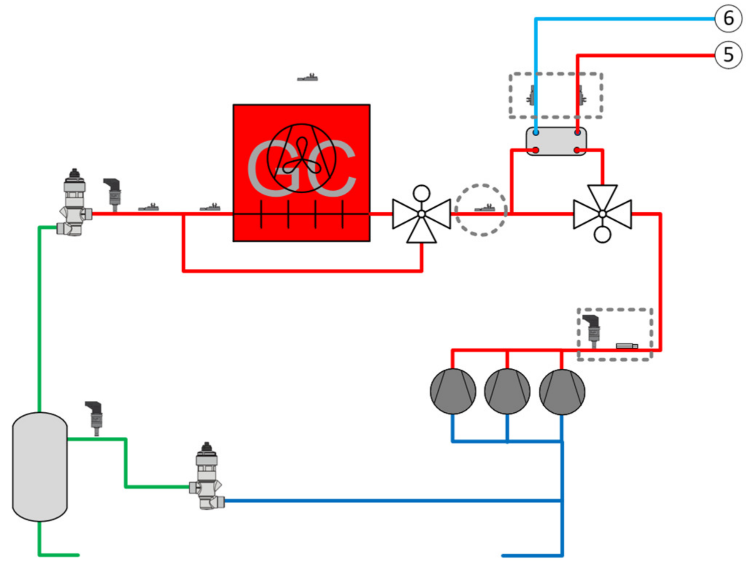
Because of seasonal changes in operation of heating and refrigeration system throughout the year, it is important to make adjustments in the system during the first heating season after commissioning. Danfoss recommend continuous monitoring of the unit in the ECL Portal (including alarms) and servicing the unit at least once per year.

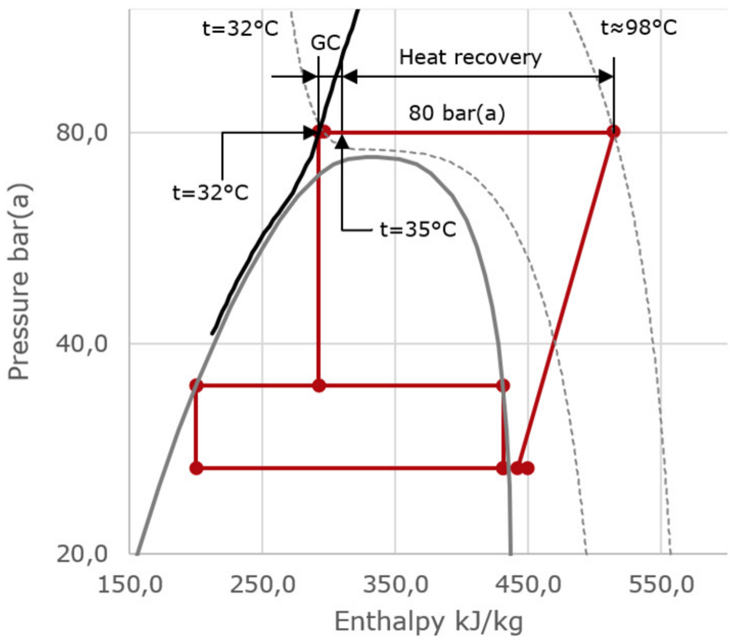
9. How to select the Heat Recovery Unit

For selecting HRU it is necessary to determine following conditions:

- Maximum CO2 temperature which will enter CO2/water heat exchanger in the heating season. This value depends on discharge pressure during heat recovery operation mode and system layout (are there only medium temperature compressors or there are also parallel compressors).
- Temperature difference between water return and CO2 exit temperature. Proposed value in between 2K to 5K.
- Water return (6) and supply (5) temperature on CO2/water heat exchanger.

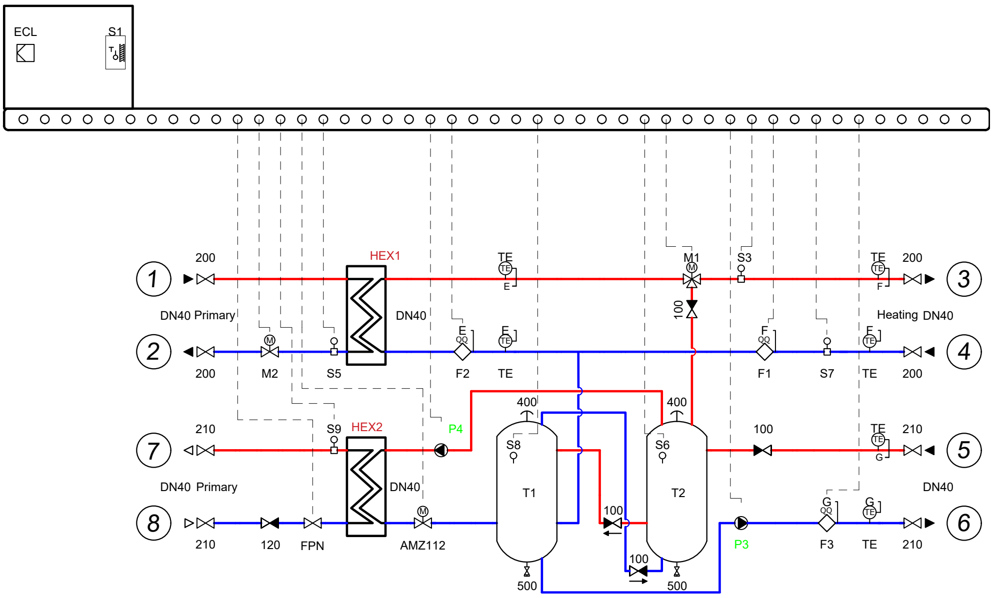
These values are required for selecting CO2/water heat exchanger (not part of HRU). How much heat can be recovered on selected heat exchanger you will get from the manufacturer heat exchanger selection software.





- Heating supply (3) and return (4) water temperature
- Requested heating capacity (or volume flow) demand
- HRU application A1, A2, A3, A4, A6 or A7

Application A1



1 DH supply
2 DH return
3 Heating supply
4 Heating return
5 Supply from cooling unit
6 Return to cooling unit
7 DH supply
8 DH return

Example:

During maximum heat recovery request mode, pressure in the CO_2 system is controlled on 80bar. When reaching maximum condition, temperature determined by optimum COP line is around 32°C. Water return temperature from the heating system and entering into the CO_2 heat exchanger is 30°C (best performance is if return temperature is between 26°C and 30°C). Temperature difference between water return and CO_2 exit temperature on the heat exchanger is 5K. This will result CO_2 temperature out of the heat exchanger is 35°C. Rest of the heat to 32°C will be released to the ambient via the Gas Cooler. Water supply temperature is 70°C. CO_2 heat recovery capacity is 140kW.

Heating demand capacity is 200 kW with supply temperature 60°C.

HRU Application A1

Heat recovery volume flow:
- Supply from cooling unit (5) = 70°C
- Return to cooling unit (6) = 30°C
- Heat recovery capacity =140 kW

$$v = \frac{Q}{\rho \times c \times \Delta T} \times 3600$$

$$v = \frac{140\ kW}{1000\ \frac{kg}{m^3} \times 4{,}181 \frac{kJ}{kgK} \times 40K} \times 3600 = 3{,}01 \frac{m^3}{h}$$

Heat supply volume flow:
- Supply temperature (3) = 60°C
- Return temperature (4) = 30°C
- Heating demand capacity = 200 kW.

$$v = \frac{Q}{\rho \times c \times \Delta T} \times 3600$$

$$v = \frac{200\ kW}{1000\ \frac{kg}{m^3} \times 4{,}181 \frac{kJ}{kgK} \times 30K} \times 3600 = 5{,}74 \frac{m^3}{h}$$

Match in selection list table max volume flow values higher than calculated.

				Heat reclaim capacity					
				up to 100	up to 150	up to 300	up to 400	**kW**	**Capacity ****
Heating demand	**Capacity***	**min. Flow**	**max. Flow**	0,03	0,04	0,06	0,10	**m3/h**	**min. Flow**
	kW	**m3/h**	**m3/h**	2,15	3,23	6,45	8,60	**m3/h**	**max. Flow**
	up to 22	0,20	0,62	146B9108	146B9109				
	up to 54	0,43	1,55	146B9120	146B9121	146B9122	146B9123		
	up to 85	0,65	2,44	146B9126	146B9127	146B9128	146B9129		
	up to 135	1,50	3,87	146B9132	146B9133	146B9134	146B9135		
	up to 216	2,50	6,20	146B9138	146B9139	146B9140	146B9141		
	up to 337	4,00	9,66	146B9144	146B9145	146B9146	146B9147		
	up to 540	4,00	15,49	146B9150	146B9151	146B9152	146B9153		

* Capacity based on 30K temperature difference
** Capacity based on 40K temperature difference

Selection list tables:

A1

				Heat reclaim capacity					
				up to 100	up to 150	up to 300	up to 400	kW	Capacity **
	Capacity*	min. Flow	max. Flow	0,03	0,04	0,06	0,10	m3/h	min. Flow
	kW	m3/h	m3/h	2,15	3,23	6,45	8,60	m3/h	max. Flow
Heating demand	up to 22	0,20	0,62	146B9108	146B9109				
	up to 54	0,43	1,55	146B9120	146B9121	146B9122	146B9123		
	up to 85	0,65	2,44	146B9126	146B9127	146B9128	146B9129		
	up to 135	1,50	3,87	146B9132	146B9133	146B9134	146B9135		
	up to 216	2,50	6,20	146B9138	146B9139	146B9140	146B9141		
	up to 337	4,00	9,66	146B9144	146B9145	146B9146	146B9147		
	up to 540	4,00	15,49	146B9150	146B9151	146B9152	146B9153		

* Capacity based on 30K temperature difference
** Capacity based on 40K temperature difference

A2

				Heat reclaim capacity					
				up to 100	up to 150	up to 300	up to 400	kW	Capacity**
	Capacity*	min. Flow	max. Flow	0,03	0,04	0,06	0,10	m3/h	min. Flow
	kW	m3/h	m3/h	2,15	3,23	6,45	8,60	m3/h	max. Flow
Heating demand	up to 135	1,50	3,87	146B9164	146B9165				
	up to 216	2,50	6,20	146B9168	146B9169	146B9170			
	up to 337	4,00	9,66	146B9173	146B9174	146B9175	146B9176		
	up to 540	4,00	15,49	146B9179	146B9180	146B9181	146B9182		

* Capacity based on 30K temperature difference
** Capacity based on 40K temperature difference

A3

				Heat reclaim capacity					
				up to 100	up to 150	up to 300	up to 400	kW	Capacity**
	Capacity*	min. Flow	max. Flow	0,03	0,04	0,06	0,10	m3/h	min. Flow
	kW	m3/h	m3/h	2,15	3,23	6,45	8,60	m3/h	max. Flow
Heating demand	up to 22	0,20	0,62	146B9191	146B9192				
	up to 54	0,43	1,55	146B9203	146B9204	146B9205	146B9206		
	up to 85	0,65	2,44	146B9209	146B9210	146B9211	146B9212		
	up to 135	1,50	3,87	146B9215	146B9216	146B9217	146B9218		
	up to 216	2,50	6,20	146B9221	146B9222	146B9223	146B9224		
	up to 337	4,00	9,66	146B9227	146B9228	146B9229	146B9230		
	up to 540	4,00	15,49	146B9233	146B9234	146B9235	146B9236		

* Capacity based on 30K temperature difference
** Capacity based on 40K temperature difference

A4

				Heat reclaim capacity					
				up to 100	up to 150	up to 300	up to 400	kW	Capacity**
	Capacity*	min. Flow	max. Flow	0,03	0,04	0,06	0,10	m3/h	min. Flow
	kW	m3/h	m3/h	2,15	3,23	6,45	8,60	m3/h	max. Flow
Heating demand	up to 135	1,50	3,87	146B9247	146B9248				
	up to 216	2,50	6,20	146B9251	146B9252	146B9253			
	up to 337	4,00	9,66	146B9256	146B9257	146B9258	146B9259		
	up to 540	4,00	15,49	146B9262	146B9263	146B9264	146B9265		

* Capacity based on 30K temperature difference
** Capacity based on 40K temperature difference

A6

				Heat reclaim capacity		
				up to 100	kW	Capacity**
	Capacity*	min. Flow	max. Flow	0,03	m3/h	min. Flow
	kW	m3/h	m3/h	2,15	m3/h	max. Flow
Heating demand	up to 22	0,20	0,62	146B9400		
	up to 54	0,43	1,55	146B9401		
	up to 85	0,65	2,44	146B9402		

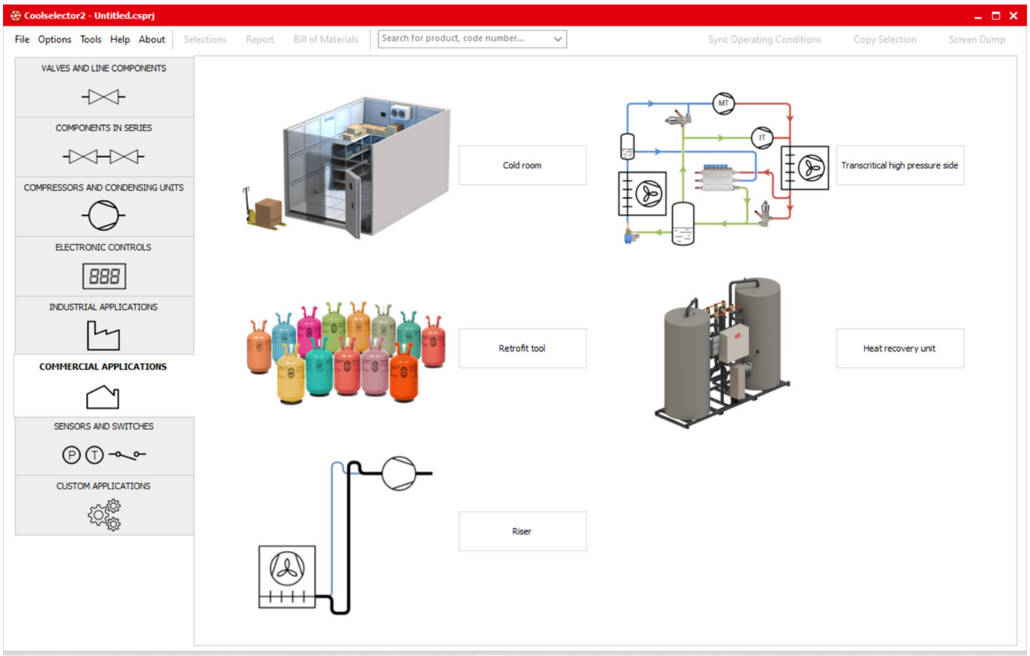
* Capacity based on 30K temperature difference
** Capacity based on 40K temperature difference

A7

				Heat reclaim capacity		
				up to 100	kW	Capacity**
	Capacity*	min. Flow	max. Flow	0,03	m3/h	min. Flow
	kW	m3/h	m3/h	2,15	m3/h	max. Flow
Heating demand	up to 22	0,20	0,62	146B9403		
	up to 54	0,43	1,55	146B9404		
	up to 85	0,65	2,44	146B9405		

* Capacity based on 30K temperature difference
** Capacity based on 40K temperature difference

Same HRU selection using Coolselector
Select within Commercial applications > Heat recovery unit



Heat recovery:

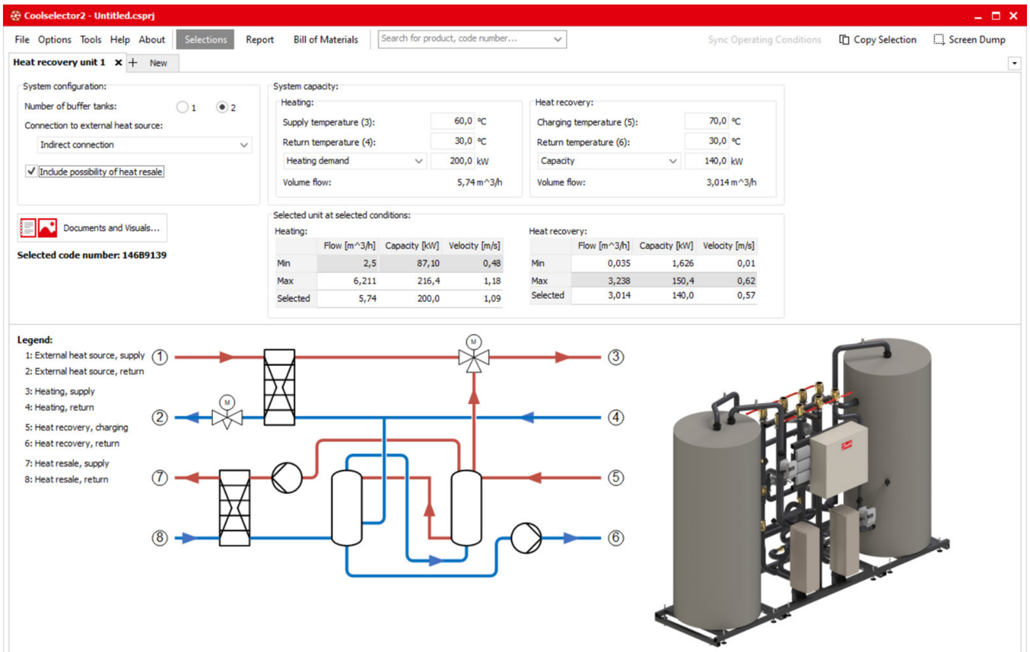
- Supply from cooling unit (5) = 70°C
- Return to cooling unit (6) = 30°C
- Heat recovery capacity =140 kW

Heat supply:

- Supply temperature (3) = 60°C
- Return temperature (4) = 30°C
- Heating demand capacity = 200 kW.

Indirect connection ; eg connection to the District Heating

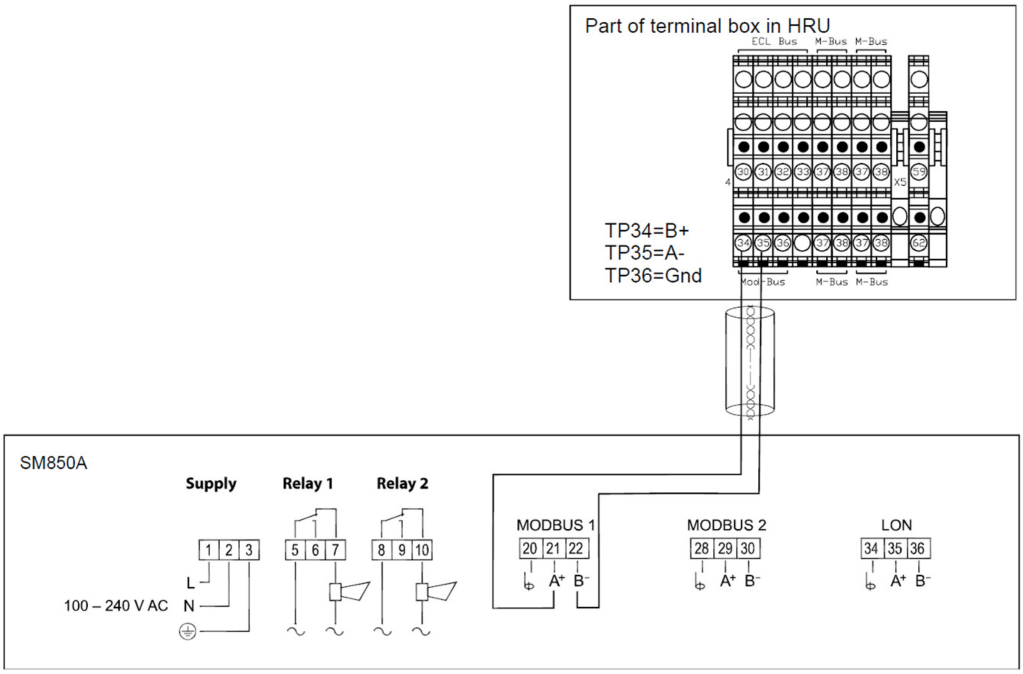
Heat resale option



10. How to set up system manager (800A) to operate with Danfoss Heat Recovery Unit (HRU)

10.1 Connect HRU to a system manager through Modbus

Wiring diagram ECL to the System Manager:



It is possible to use MODBUS 2 as a substitute for MODBUS 1

All devices in the network must used in the same communication settings, i.e. multiple communication are not allowed. The module can operate with

- 9600, 19200 or 38400 (default) baud rate
- 1 start bit
- 8 data bits
- even parity
- 1 stop bit

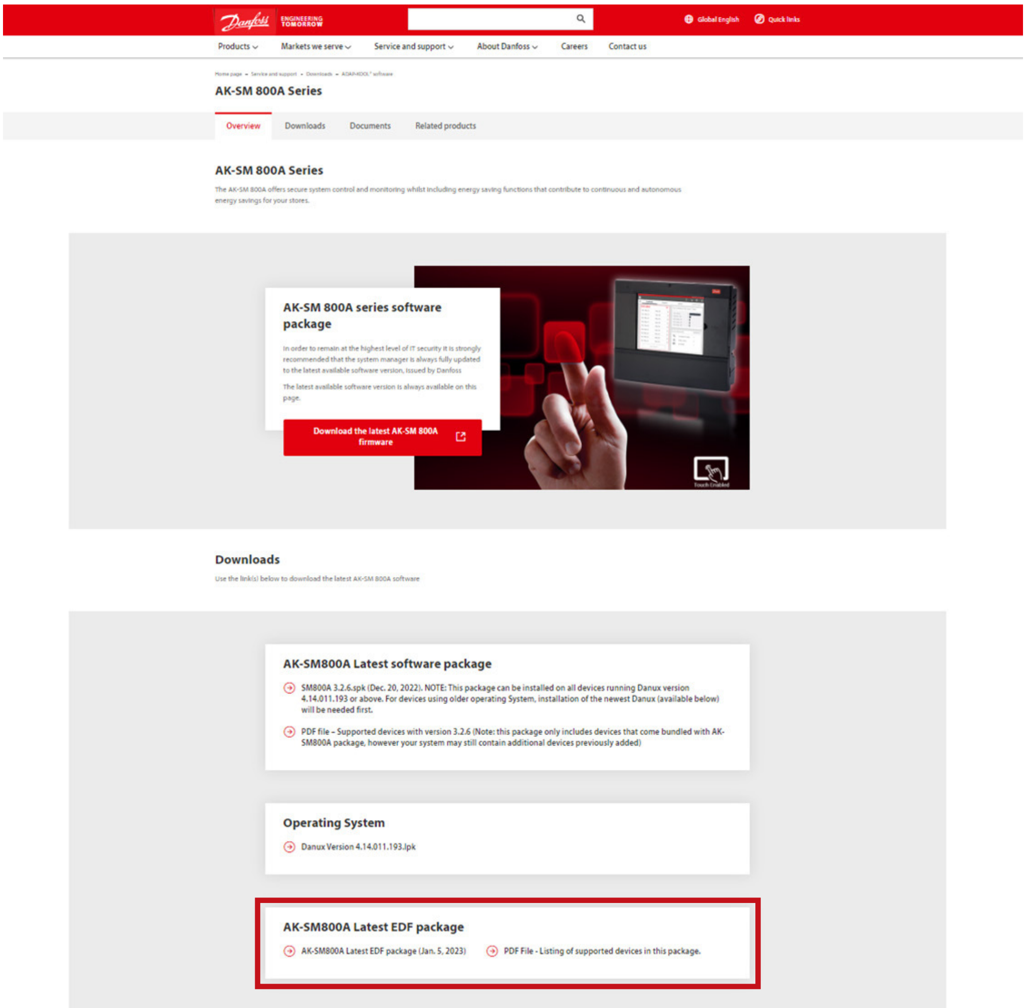
(in total 11 bits)

10.2 Download latest EDF package

Go to AK-SM 800A series webpage:

AK-SM 800A Series | Danfoss

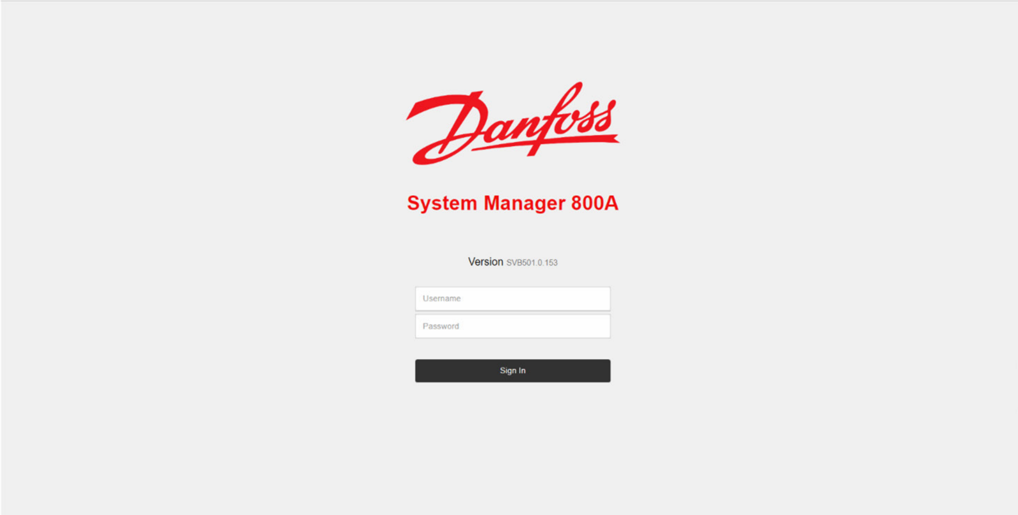
Locate the **Downloads** section and select **AK-SM800A Latest EDF package**.



Click on the "AK-SM800A Latest EDF package" to begin the download.

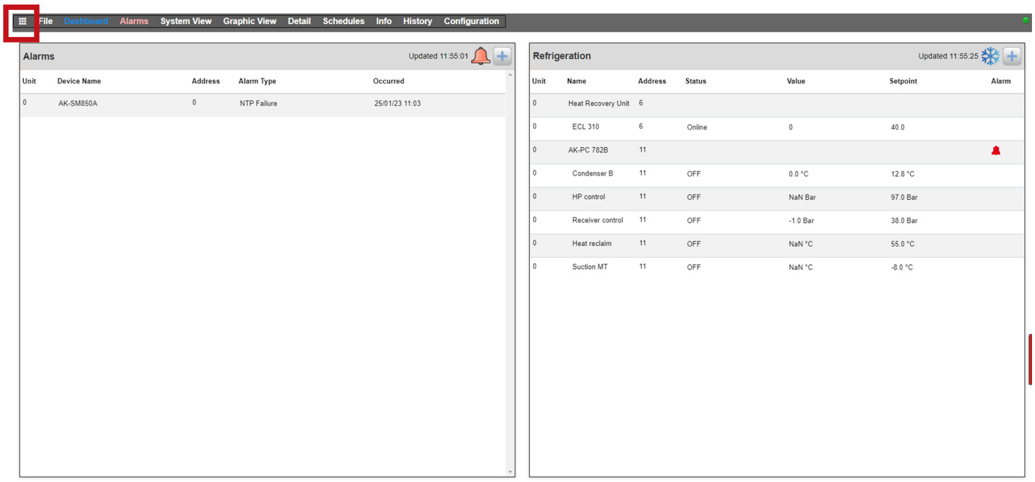
10.3 Add ECL Controller to System Manager Software

Login to the system using your username and password.

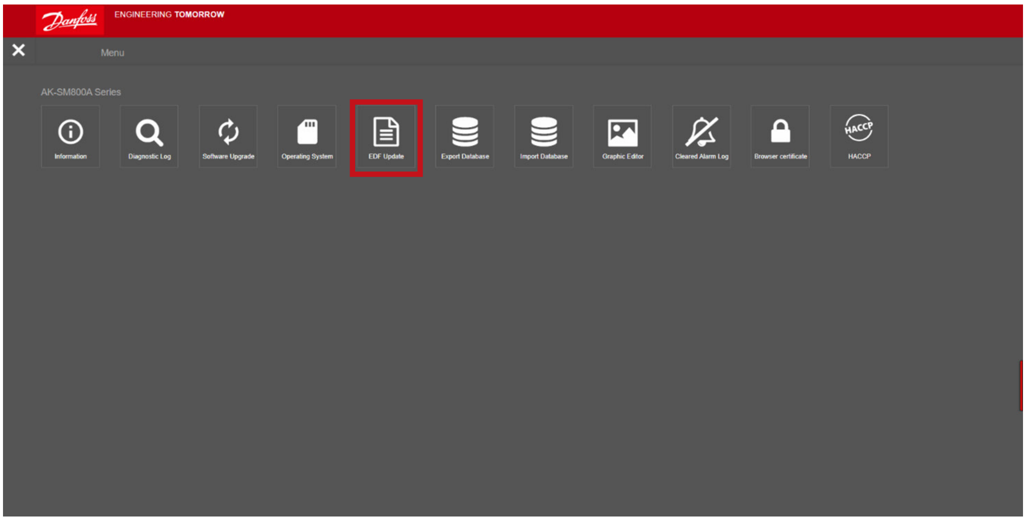


Once logged in, you will land on the **Dashboard** where you can view the overview of the System Manager and units connected to it.

Click **Menu** button.

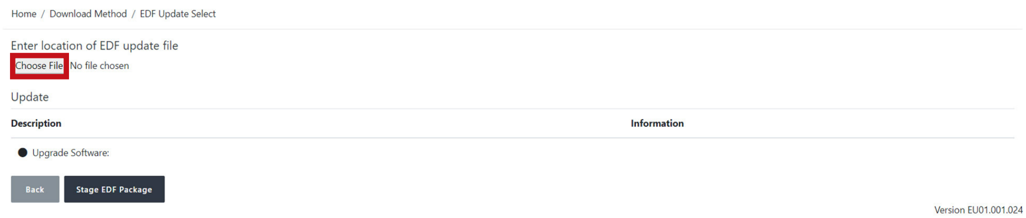


Select **EDF Update** from the menu options.

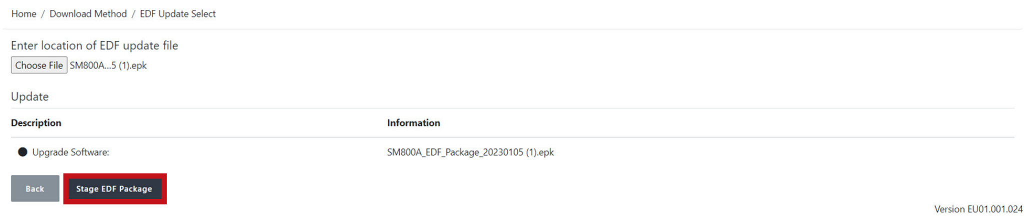


In the EDF Update section, select **Local Stored File** as the update method.

Click on **Choose File**. Select file downloaded in step 10.2 and press open.

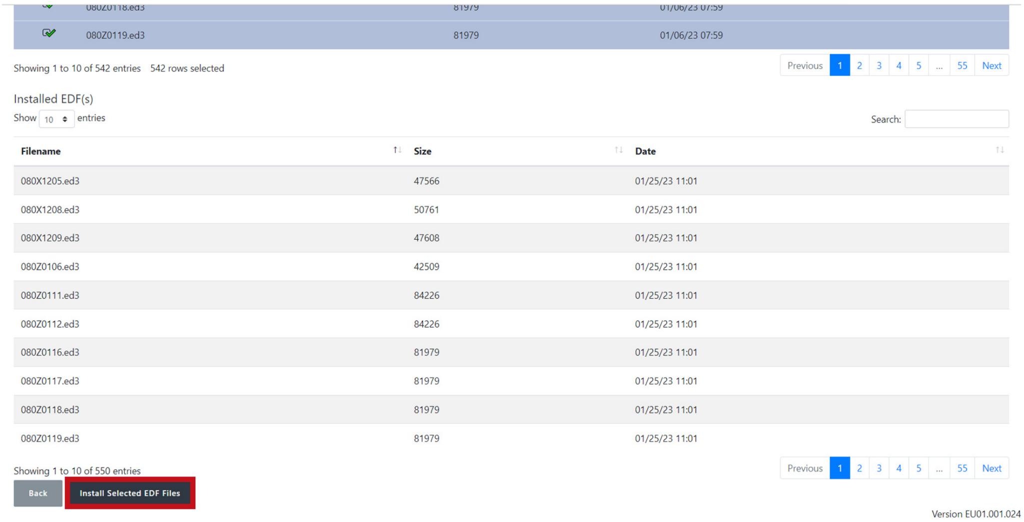


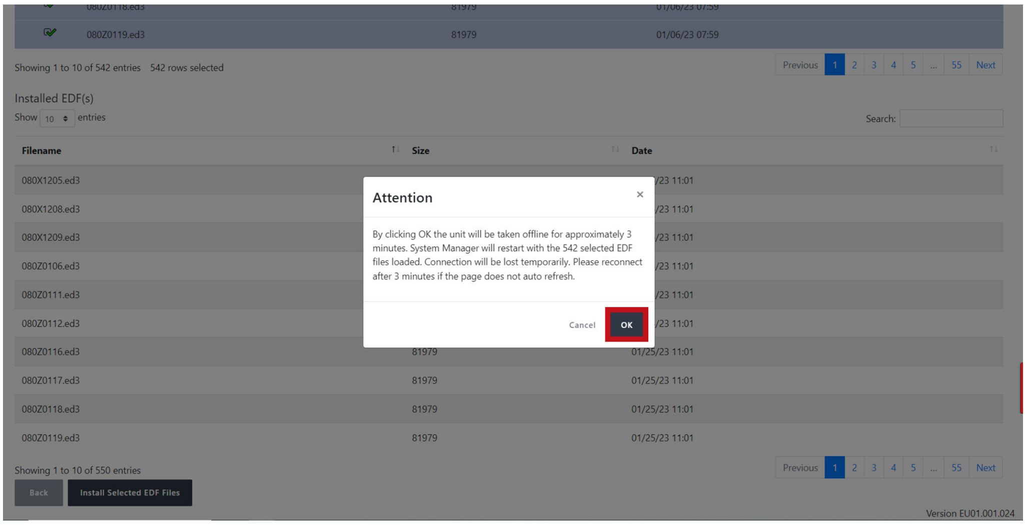
The file should now be visible in the **Upgrade Software** section.



Press **Stage EDF Package**.

Scroll down and under the **Installed EDF(s)** section, press **Install Selected EDF Files**. An Attention alert will pop up, press **OK**.

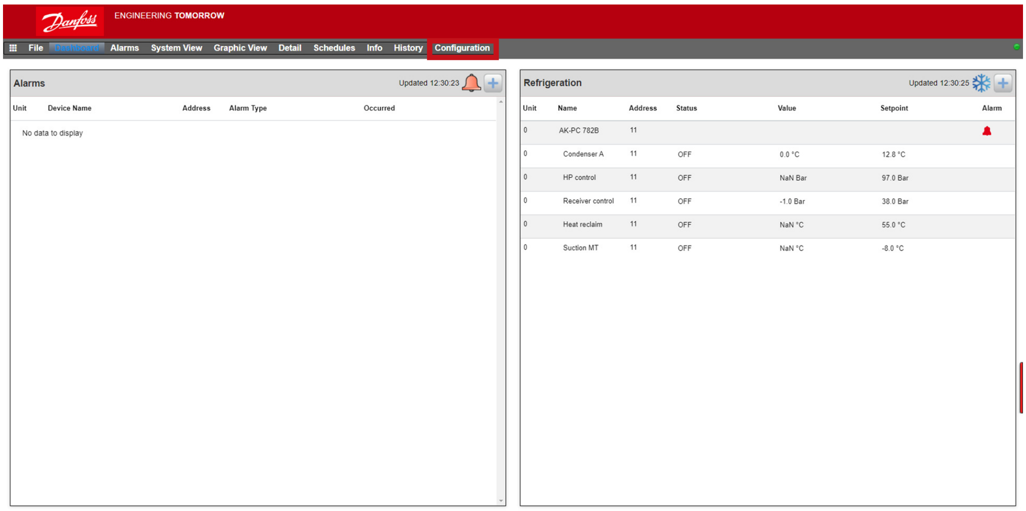




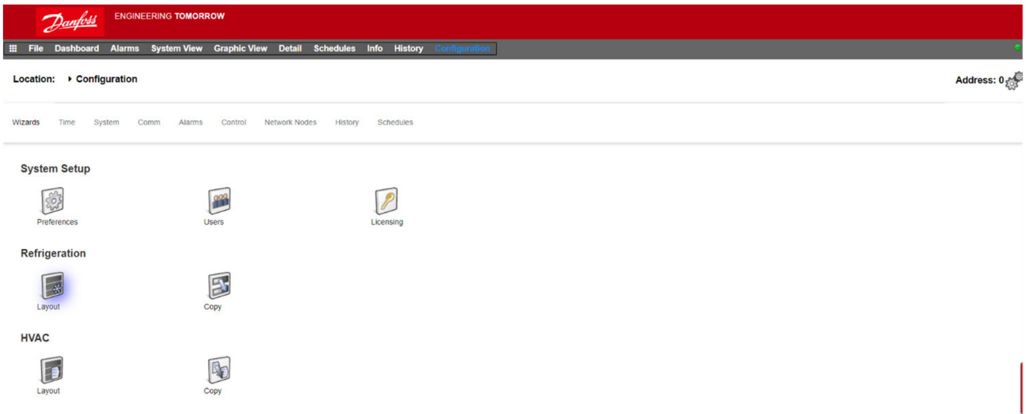
If the update is successful, a page will show up. Press **Home** and then close the **Menu** to get back to the Dashboard.

Note: HRU will be visible in the **Refrigeration section not in HVAC.*

In the top bar, click on **Configuration**.

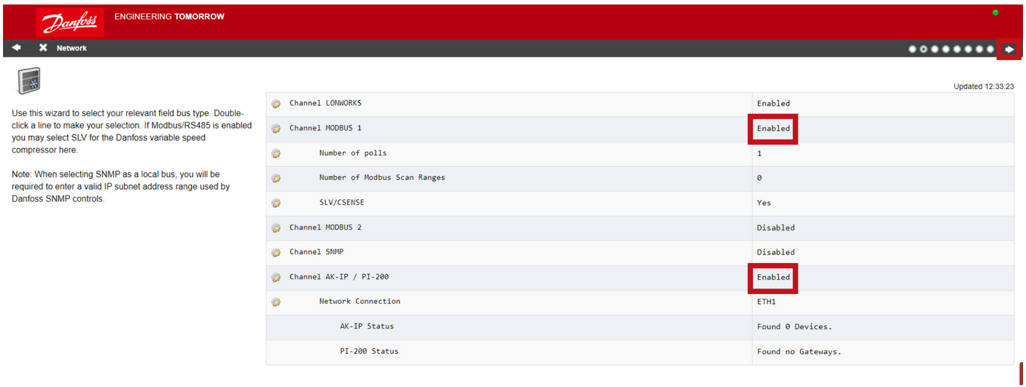


This page has three sections: System Setup, **Refrigeration**, HVAC. Select **Layout** in the **Refrigeration** section.

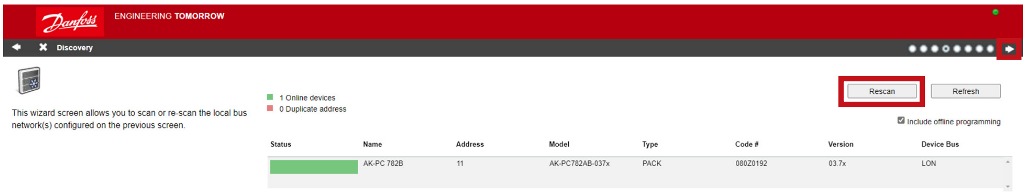


A briefing for the **Refrigeration** Configuration wizard will pop up. To move forward, click on the **arrow (Next)** in the right corner of the top bar.

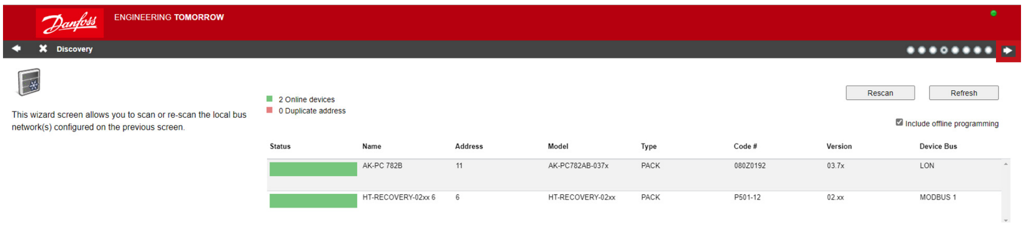
Network page opens. Make sure that needed buses are *Enabled*. Press the **Next** in the top bar again to access the **Discovery** site.



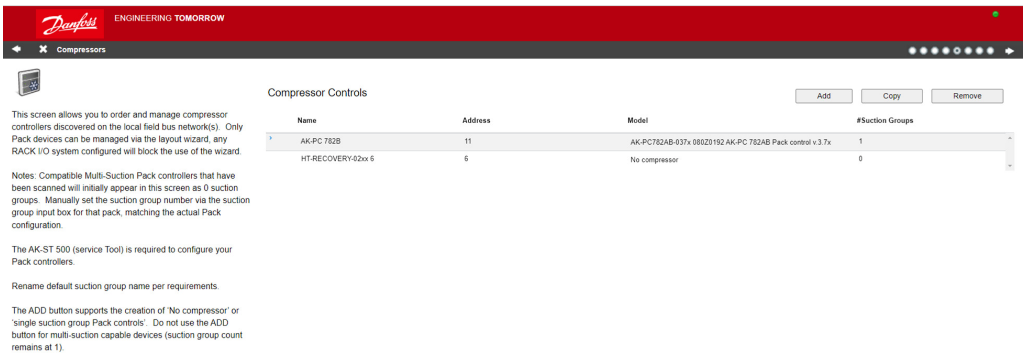
This will allow to access online devices, in this case the System Manager. Verify that its *status* is green. Press **Rescan** to scan and verify both the Heat Recovery Unit and System Manager.



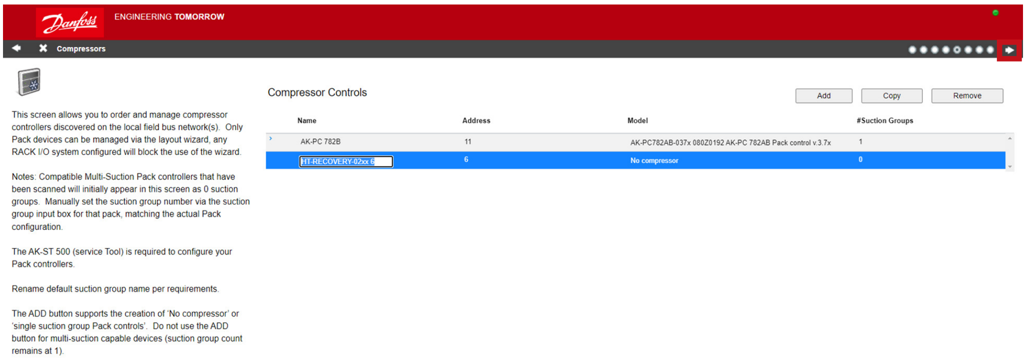
All relevant data should be uploaded. To continue, press **Next** again to get to the **Compressors page**.



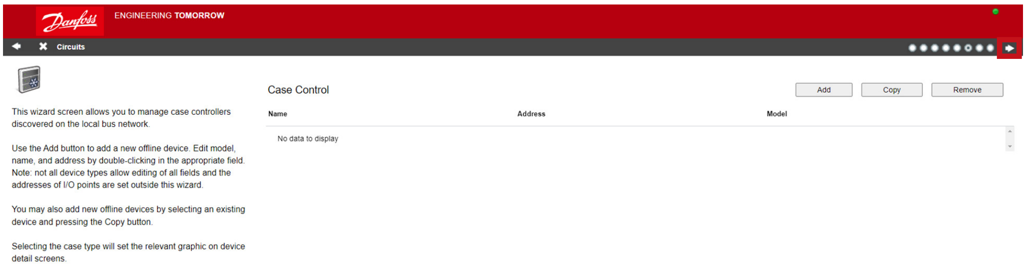
Compressors page gives overview of *Compressor Controls*.



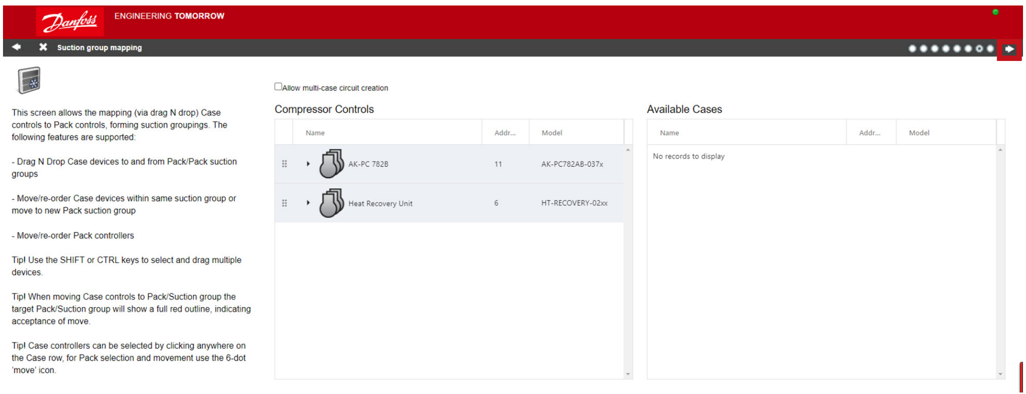
For a more concise view, there is an option to **rename** units by clicking twice on the current name. Then press **Next**.



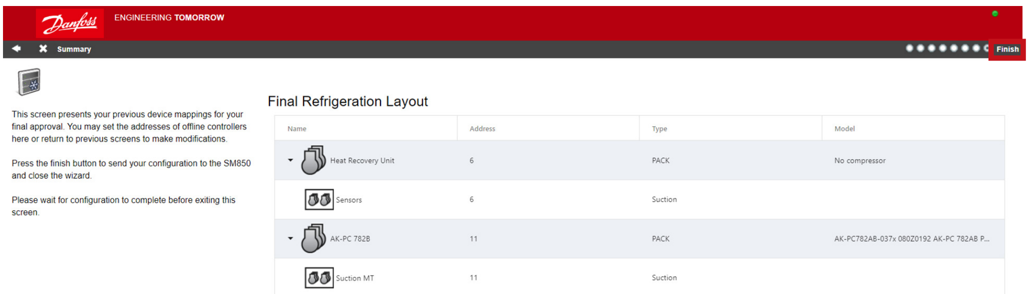
Press **Next** again to get to the **Circuits** site. Press **Next**.



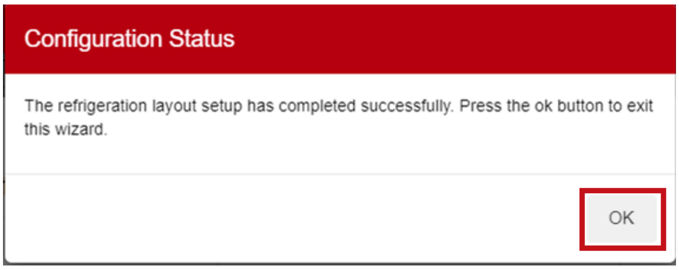
The next page, **Suction group mapping**, shows the mapping of Case Controls to Pack Controls, forming suction groupings. Press **Next**.



The **Summary** is a final approval step before sending the configuration to the System Manager. Press **Finish**.

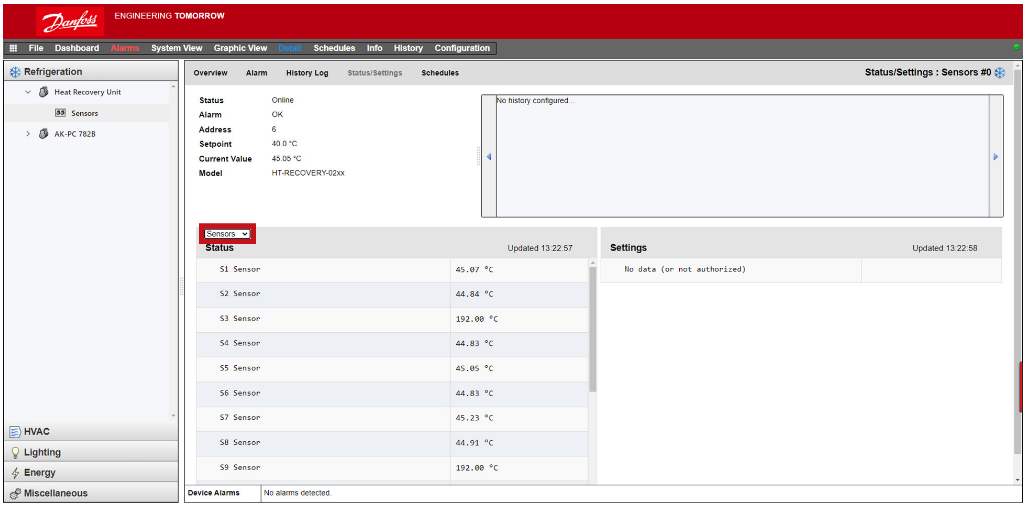


After configuring, the **Configuration Status** will pop up. Press **OK**.



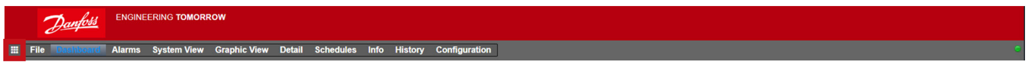
You will go back to the **Configuration** site again. In the top bar, choose **Detail**.

To view data for each sensor, choose **Sensors** in the section above **Status**.

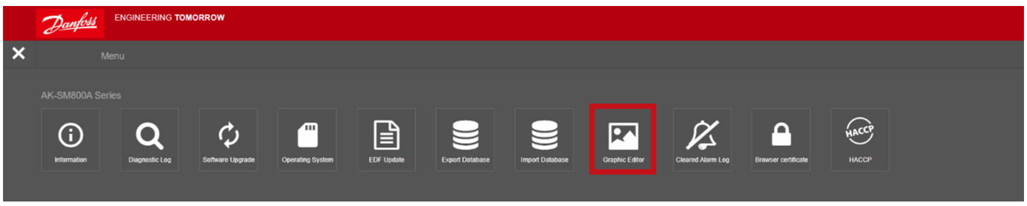


10.4 Present live readings from HRU

Click **Menu** button.



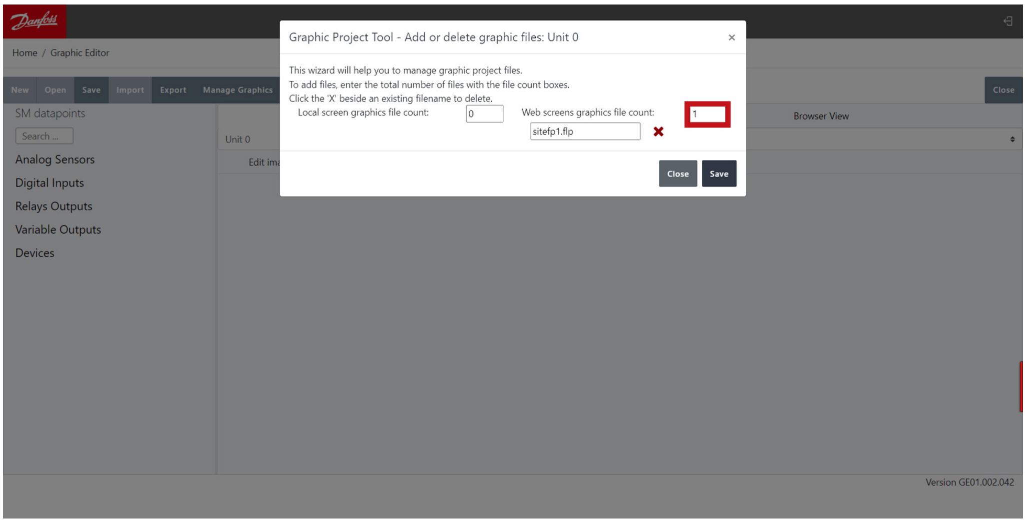
Choose **Graphic Editor**.



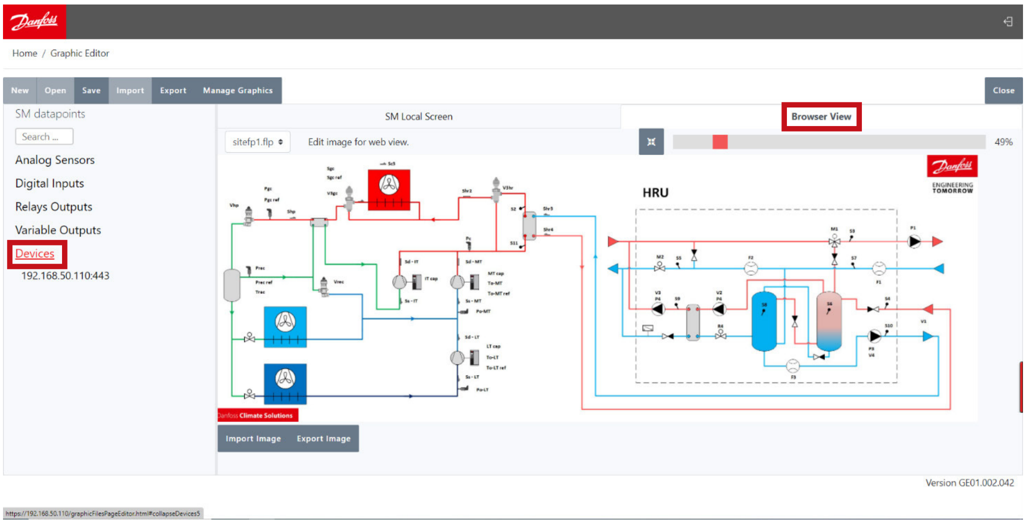
Press **Manage Graphics**.

In the **Graphic Project Tool**, choose the file in the **Web screens graphics file count**.
The file should be in the *jpeg*, *jpg*, or *flp* format.

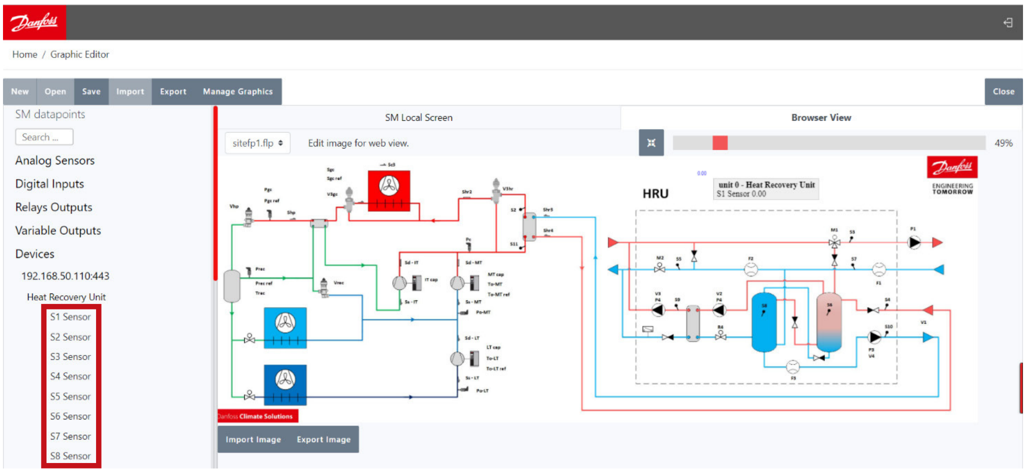
Change the **Local screen graphics file** Count *from 0 to 1*, and then **Save** it.
(Note: you can upload up to 5 files)



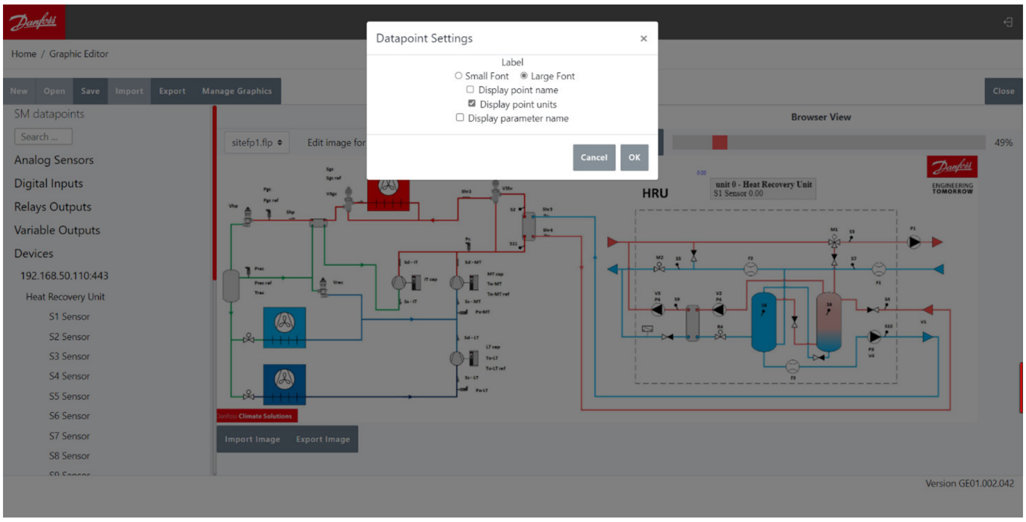
Click on **Browser View**.
Under **SM Datapoint** in the left section, click on **Device** and choose the **IP address**.



This will display an overview of the *sensors* in the system.
To place **Sensors** into the chart, grab them and place them in the desired location.
The same principle applies for **Controllers**.

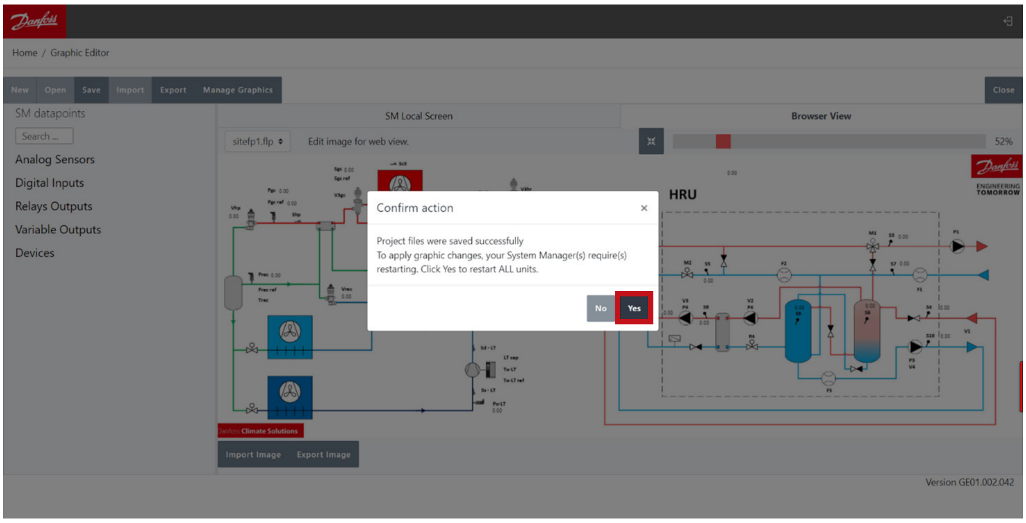


Each sensor has its **Datapoint** setting,which can be accesed by clicking on sesnor in the chart

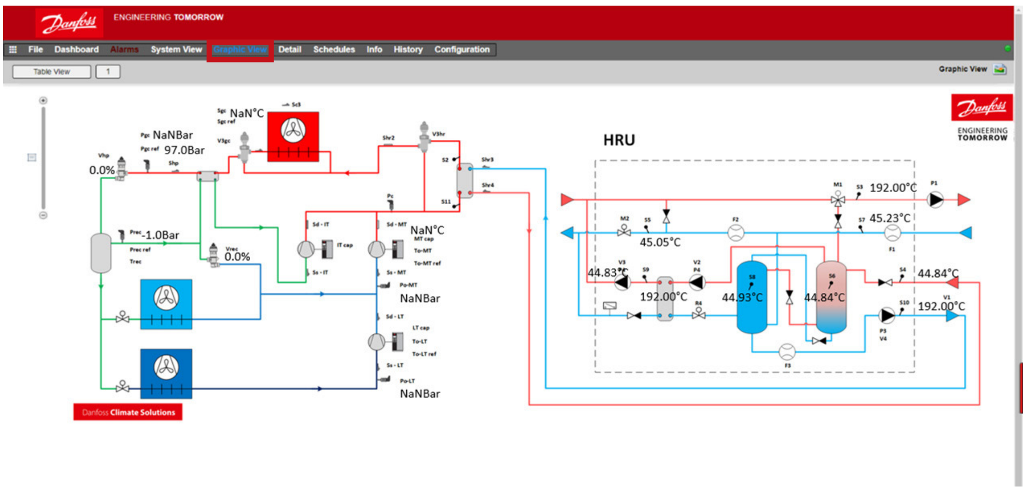


Once the sensors are placed, press **Save** in the left corner of the top bar.

A confirmation message will pop up, click **Yes**.



From this moment readings from HRU will be displayed in **Graphic View**.



ENGINEERING TOMORROW

HRU Application A1
Application A1 is indirect heating application with 2 buffer tanks and heat resale option. Waste heat from CO_2 can be used internally or sold back to district heating network.

HRU Application A2
Application A2 is indirect heating application with 2 buffer tanks and without heat resale option. Waste heat from CO_2 can be used only internally.

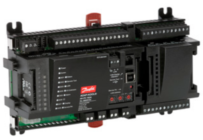
HRU Application A3
Application A3 is direct heating application with 2 buffer tanks and heat resale option. Waste heat from CO_2 can be used internally or sold back to district heating network.

HRU Application A4
Application A4 is indirect heating application with 2 buffer tanks and without heat resale option. Waste heat from CO_2 can be used only internally.

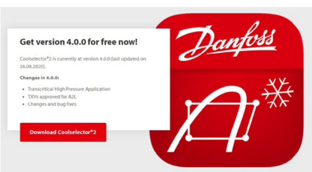
HRU Application A6
Application A6 is indirect heating application with 1 buffer tank and without heat resale option. Waste heat from CO_2 can be used only internally.

HRU Application A7
Application A7 is indirect heating application with 1 buffer tank and without heat resale option. Waste heat from CO_2 can be used only internally.

HRU controller – ECL 310
Danfoss electronic controllers (ECL) are intelligent temperature regulators for district heating and domestic hot water systems. By means of weather compensation and application keys, they can be adapted to a variety of district heating systems, ensuring a high level of comfort and optimum energy utilization.



Pack controller – AK-PC 782A/B
Danfoss offers a wide range of market-leading Pack Controllers.
Being the flagship and best-in-class controller for transcritical CO_2 pack controls, the AK-PC 782A/B offers the highest possible efficiency with the Multi Ejector.



Coolselector®2 – Transcritical High-Pressure Application
Helps you optimize energy consumption and increase efficiency in any system. Run unbiased calculations based on a set of operating conditions — such as cooling capacity, refrigerant, evaporation, and condensation temperature — and then select the best components for your design.
Check out the new Transcritical High Pressure Application area.

Danfoss A/S
Climate Solutions • danfoss.com • +45 7488 2222