D1.3

Concept for a fully automated control system and operating manual

THEGREEFA

Thermochemical fluids in greenhouse farming

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 101000801.

Document references

Project Acronym	**TheGreefa**
Project Title	**Thermochemical fluids in greenhouse farming**
Project Coordinator	**Serena Danesi (ZHAW)**
Project Duration	**October 2020 – May 2024 (44 months)**

Deliverable No./Title	**D1.3** Concept **for a fully automated control system and operating manual**
Dissemination level [1]	**PU**
Work Package	**WP1**
Task	**Task 1.3: Demonstrator 1: Development and demonstration of a fully automated process control**
Lead beneficiary	**ZHAW (Serena Danesi)**
Contributing beneficiary(ies)	**Hanspeter Meyer (MEYER)**
Due date of deliverable	**31/07/2022**
Actual submission date	**15/07/2022**

[1] PU = Public

PP = Restricted to other programme participants (including the Commission Services)

RE = Restricted to a group specified by the consortium (including the Commission Services)

CO = Confidential, only for members of the consortium (including the Commission Services)

Document history

V	Date	Beneficiary	Short description of contents and/or changes
0	15/07/2022	Serena Danesi (ZHAW)	First release

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 101000801.

Table of Contents

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 101000801.

Executive Public Summary

The scope of this deliverable is the presentation of the demonstrator installed in the greenhouse of Meyer Orchideen AG for the operator of the greenhouse. It will be useful for the operators of the greenhouse to understand the plant, what they have to look for during the operation and give also instructions to start and switch the plant. It is a sort of operating manual.

A brief introduction is given to the absorption processes based on the contact between humid air and salt solutions (hereafter referred to as thermochemical fluids or TCF) and how the absorption processes can be used to control air temperature and humidity.

In addition, the main components of the installed sorptive air conditioning system are presented.

With the support of the Piping and Instrumentation Diagram (P&ID), the demonstrator installed in the Meyer's greenhouse is described: the process, the control concept, the control system and the independent safety system.

The instructions to operate the plant are given at the end of this document.

Please note, this document incorporates parts of the deliverable D1.1 "Concept for a partial automation for greenhouse air conditioning in temperate, warm summer climate zone", which is confidential. They are fundamental parts of the operating manual, without which it would be incomplete and the operators / readers could not find important information to follow the procedure and instructions.

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 101000801.

1 Sorptive air-conditioning in greenhouses

The overall concept underpinning the project is based on an innovative use of absorption processes in the greenhouse air-conditioning (also referred as sortive air conditioning). This concept is achieved using the hygroscopic properties of fluid salt solution, here called thermo-chemical fluid (TCF), which has the ability to provide multiple functions and services such as heating, cooling and de-/humidification within a single device, here called the absorber. An aqueous magnesium chloride solution ($MgCl_2$) has been resulted the more appropriate TCF (performance/cost) for the air control in the greenhouses (see the H2020 project H-Disnet, GA 695780).

When the TCF with a high concentration of hygroscopic medium gets in contact with the humid air produced in a greenhouse, by the transpiration of the plants, it absorbs part of the air humidity releasing the latent heat of the humidity in form of sensible heat: 1 ton of air humidity absorbed by the TCF releases appr. 680 kWh of heat (right part of Figure 1). This is a condensation process: the water passes from the gas state (vapour, humitidy in the air) to a liquid state (water in the TCF). The uptake of water dilutes the TCF.

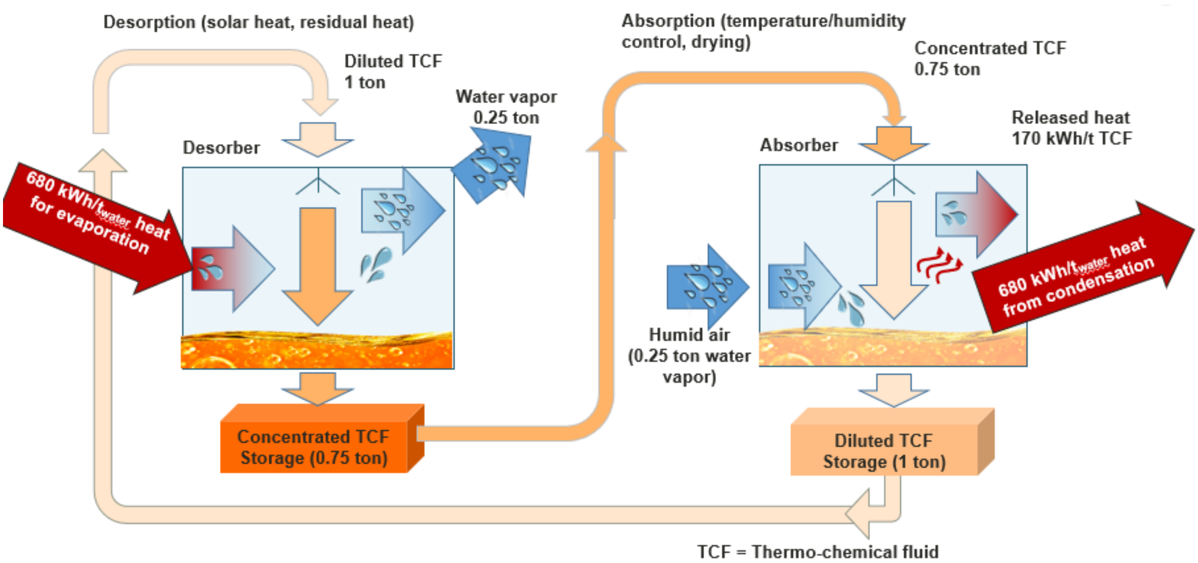


Figure 1: TCF-cycle for control of air humidity and temperature

When the TCF is diluted to a certain degree, the process cannot be continued and the TCF must be regenerated. The absorbed water must be driven out again. To do that, the same amount of energy as released by the absorption process shall be reintroduced in the system, again appr. 680 kWh/ ton of evaporated water. The water is released in form of water vapour taken up by dry air (left part Figure 1). Heat sources with temperatures below 60°C of are largely enough for the regeneration process, the exact temperature depends on the phase equilibrium of pressure vapour between the TCF and ambient air.

The air conditioning in greenhouses is appropriate for this kind of applications because plants release a large amount of humidity through transpiration, which requires to be removed. The TCF has the function to remove this excess of humidity production and at the same time useful heat is released (transformation of latent heat in sensible heat). A further advantage of the sorptive air condition in the greenhouse, is that it is not any more necessary to exchange fresh air with the extern to control the humidity, that means that the thermal energy losses can strongly be reduced (Figure 2).

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 101000801.

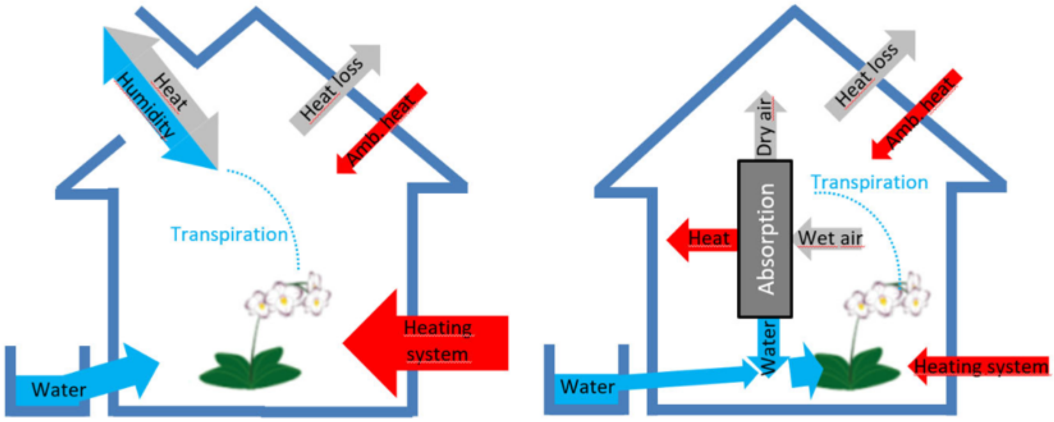
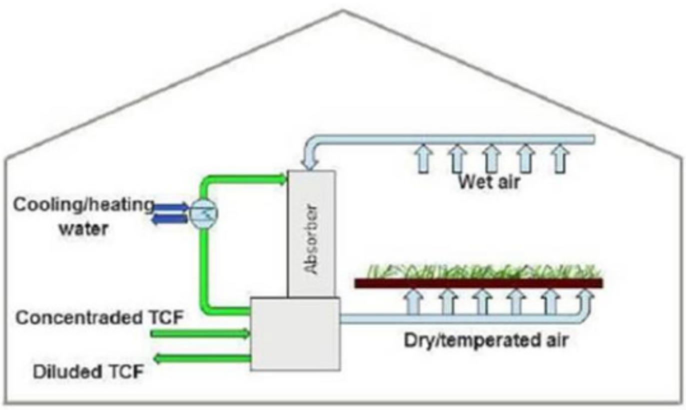


Figure 2: Energy and mass flow in a greenhouse without an active humidity control (left) and a greenhouse with TCF air conditioning as in the TheGreefa (right)

The ZHAW analysed and tested the capacity and the performances of the absorber for the air conditioning in the greenhouses during the H2020 project H-Disnet and in other national and academic projects. During these projects a new air distribution system has been developed and installed at the Meyer's greenhouse: the conditioned air is injected directly below the crops (Figure 4). This configuration allows to save additional energy because it is not necessary anymore to treat the air of the entire greenhouse to reach the required conditions but only the air above the crops. Another advantage is the possibility to create different climate conditions inside the same room associating an absorber for each table which required different air conditions (because of different crops).



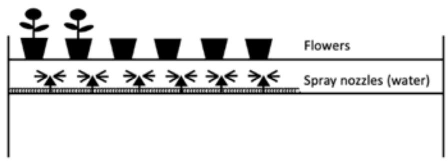


Figure 4: Schema of the conditioning system for greenhouses

Figure 3: evaporating cooling installed below the tables

The system is also used for dehumidification and cooling. In this case, the combination with the evaporation cooling could be necessary: excess humidity is removed in the absorber, here the air temperature is cooled by the cooling water. In case a lower air temperature is required, water is sprayed under the flowers and the evaporation of the water drops down the temperature of the dry air coming from the absorber (Figure 3).

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 101000801.

1.1 Meyer Orchid greenhouse

The sorptive greenhouse air-conditioning system is used to air-condition the greenhouse No. 12 of Meyer Orchideen AG in Wangen near Dübendorf (Figure 5). The greenhouse has a surface of 600m^2 and there are 28 planting tables. The orchids in this greenhouse are in the flowering stage, which requires a constant indoor climate with a temperature of 18 to 22°C and a relative humidity between 50% and 70%.

Figure 5: Greenhouse No. 12 of Meyer Orchideen AG. One of the 9 absorbers in market in green (right). The orange pipes on the top are the air suction pipe system. The new structure of table is visible (white wall with blue edge around the crops)

The sorptive greenhouse air-conditioning system consists of nine absorbers, one desorber, four buffer storage tanks plus the balance of plant. The absorbers are installed inside the greenhouse, each of them supplies conditioned air to a minimum of 2 up to a maximum of 4 tables. The air is conveyed to the absorbers through a bored piping system installed at a height of about 3 meters above the tables. The tables are enveloped in a wall to maintain the conditioned air directly on the crops. The desorber and the four storages are located outside the greenhouse in a wood container (Figure 6).

The system is connected to water circuit of the heating and cooling system.

Figure 6: Desorber (left) and TCF storage tanks (right) in the container outside the greenhouse.

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 101000801.

1.2 Main components of the sorptive greenhouse

The section describes the main components of a sorptive air conditioning for a greenhouse. The tag-numbers are referred to the P&ID in Figure 12.

Absorber (*LW1 - LW9*):

Air conditioning takes place in absorption scrubbers (absorbers).

The humidity and temperature required by the crop are maintained at the requested level adjusting the air humidity and temperature of the air leaving the absorber as follows (Figure 7):

- The inlet TCF temperature (Tx.1) determinates the outlet air temperature (Tx.3), the TCF temperature is controlled in the heat exchanger Wx.1. The control loop is described in section 2.2.
- The outlet air humidity (Mx.1) is given by the TCF concentration. The control loop is described in section 2.3

The air enters the absorber from lateral ducts located on the top and then flows in a lateral duct to the lower part of the absorber. Here the air changes the direction: the air flows from the bottom to the top through plastic random packings, the TCF from the top to the bottom. The absorption process takes place in the active part of the absorber, e.g. coloured part of the Figure 7. At outlet of the active part, the air passes through a demister before leaving the absorber.

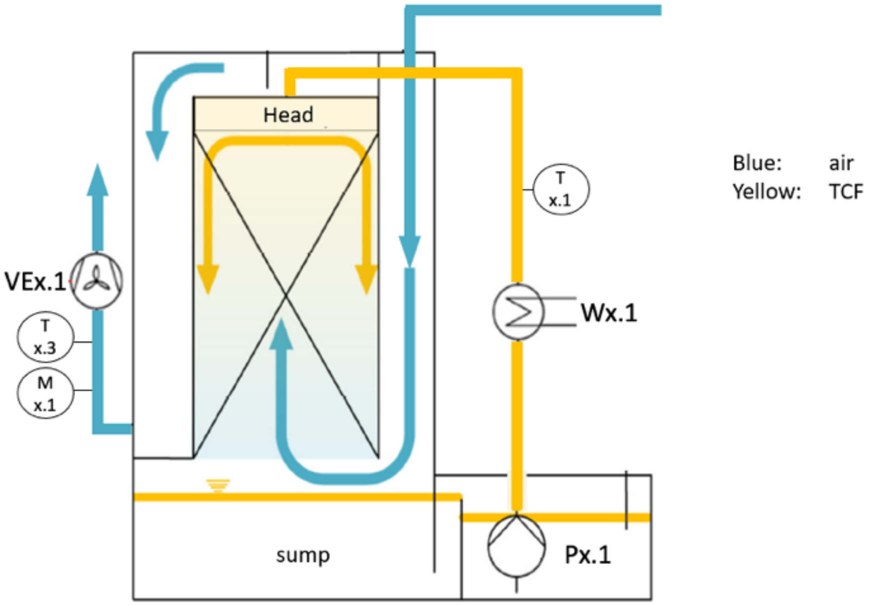


Figure 7: flow diagram of the absorber

The air is sucked into the absorber through a fan. The fan (VEx.1) is located at the outlet of the absorber, the absorber operates under the ambient pression. The under pressure avoids leakage of untreated air from the absorber.

On the TCF side, the TCF is extracted from the sump by the recirculation pump (submersible centrifugal pump-Px.1) and pumped via the plate heat exchanger (Wx.1) into the absorber head, where it is evenly distributed over the packing (Figure 8) by a liquid distributor (in yellow, (Figure 8). The TCF leaving the active part (blue, (Figure 8) is collected in a sump (viola, (Figure 8) by floating packings (red, Figure 8) and flows through them into the sump.

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 101000801.

The floating packing (Figure 9) prevents aerosol formation in the scrubber. The scrubber stands completely in the sump and has outlet openings for the salt solution at the bottom. This siphon separates the air in the scrubber from the atmosphere in the receiver tank so that it can be operated atmospherically open to the greenhouse environment. Between the scrubber and the solution circulation pump, there is a partition wall, which ensures a uniform flow and thus prevents the occurrence of a heterogeneous TCF concentration distribution. Part of the lower part of the partition wall is open to equalise the liquid levels between the two parts.

All parts of the absorber in contact with the TCF are made of polypropylene or polyvinyl chloride. The heat exchanger has a coating of Parylene on the TCF side.

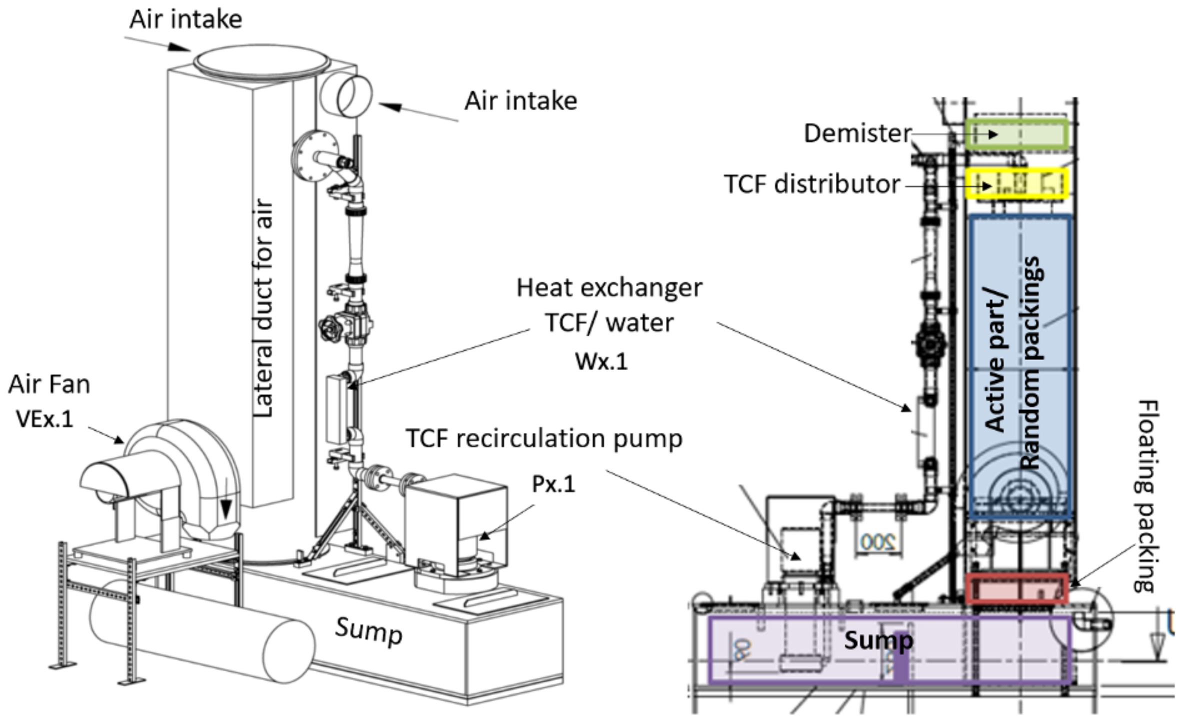


Figure 8: technical drawings of the absorber installed at the Meyer Orchids greenhouse

Main design features and operating data:

- Absorber diameter: 0.5 m
- TCF inside the absober/sump: 0.4 m^3
- Packing: Pall-Ring 15, 1.3 m fill height
- TCF distributor: Perforated floor distributor
- Demister: Wire knitted demister
- Gas velocity (empty absorber): 1 m/s
- TCF flow density: 12 $m^3/(h\ m^2)$

The air for the crop's tables 26 and 27 is treated in the absorber LW9 of the TU-Berlin, which differs considerably from the absorbers. This device is a special construction in which the TCF runs off a tissue surface in countercurrent to the air. The construction is more complex than the other absorbers and has a lower air loading capacity (empty tube speed) but has a the very TCF flow density.

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 101000801.

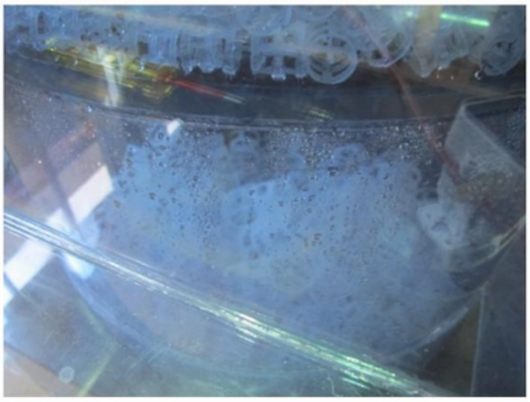
 Pall-rings of different dimensions	 Pall-rings inside the absorber. In the upper part of the picture, pall-rings 15 mm to increase the contact surface between the air and the TCF; in the bottom part, pall-rings 50 mm below the air injection duct to avoid dripping of the TCF and formation of droplets which bounce up in the air to be treated.

Figure 9: random packing

Crop's table (*table 1 - 28*)**:**

The conditioned air is supplied via performed pipes located under the crop's table (Figure 10). The tables are enclosed airtight all around with tarpaulins so that the air flows upwards over the table surface into the area of the crops. The lateral escape of the air is prevented by an approx. 20 cm high border around the entire table. A layer of gravel on the table surface ensures that the air flowing upwards is homogeneously distributed. A temperature change of the conditioned air on the way between the absorber outlet and the area of the plants caused by heat loss to the environment can be compensated by the bottom-heating, which is a part of the conventional heating system of the greenhouse.

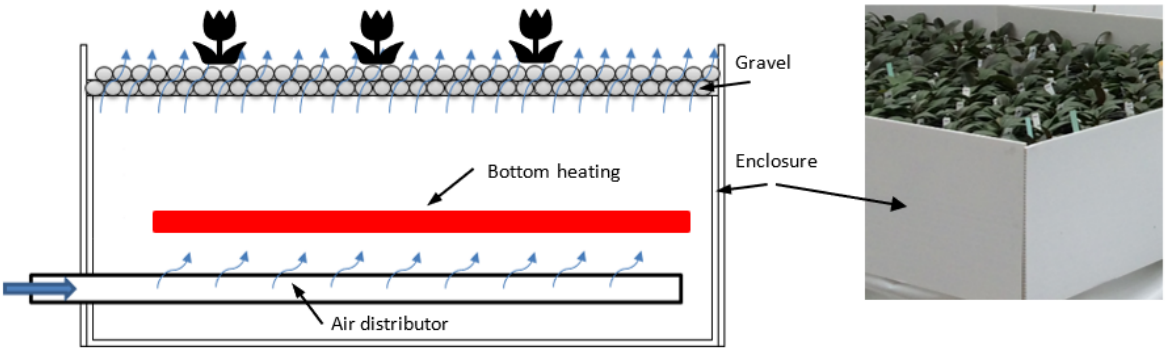


Figure 10: Structure of the direct climate-controlled planting tables

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 101000801.

Desorber (*LW10*):

The desorber is used to regenerate (referred also as concentrate) the diluted TCF.

The desorber has a similar design to the absorber (Figure 11), but it is operated under positive pressure (fan at the air inlet) and has no lateral ducts. The air enters the desorber directly from the bottom and leaves it at the top. The energy input required for desorption process is given heating the to TCF in the heat exchanger W10.1.

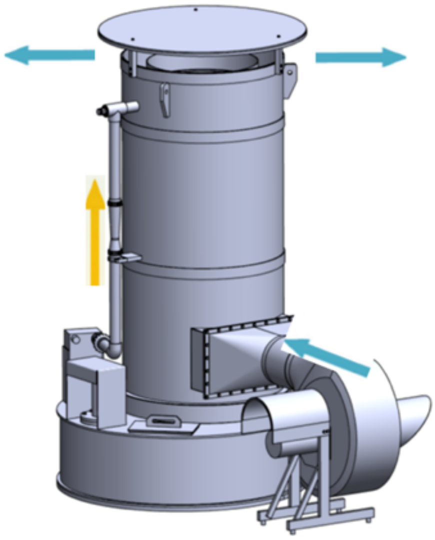


Figure 11: Drawing of the desorber (TCF direction in yellow, air direction in blue)

Main design features and operating data:

- Desorber diameter: 1.2 m
- TCF inside the desober/sump: 1 m^3
- Packing: Pall-Ring 25, 1 m fill height
- Liquid distributor: Channel distributor
- Demister: not installed
- Gas velocity (empty desorber): 1 m/s
- TCF flow density: 12 $m^3/(h\ m^2)$

Buffer storage tank for the concentrated TCF (S1) and diluted TCF (S2)

Two set of two hydraulically connected IBC tanks are installed near the desorber. They serve as buffer storage for the diluted and the concentrated TCF. The storage tank sets, each with a capacity of approx. 2 m^3 can hold the total amount of concentrated TCF required for the sorption air-conditioning system installed in the demonstrator. During normal operation, there is up to 0.2 m^3 in each the absorber's sump and approx. 1 m^3 TCF in the desorber sump.

1.3 System description

The structure of the entire system is shown in the P&I diagram (Figure 12).

Dotted lines indicate parallel pipeline with the same functions, for example 9 parallel lines of diluted TCF enter to storage S2.

In the nine **absorption scrubbers** (also called **absorbers)** (**LW1 - LW9**), the air, which is taken from the greenhouse ceiling via a piping system evenly distributed, is treated by a tempered TCF in order to maintain the optimum humidity and temperature for the plants in the greenhouse. **Fans** (**VE1.1- VE1.9**) then transport the conditioned air via pipes to the tables. One absorber can treat the air necessary for two up to four tables.

The temperature of the TCF is adjusted in **heat exchangers** (**W1.1 - W9.1**); the heat exchanger is a part of the absorber circuit. All the absorbers are connected to this circuit. Water flows in the absorber circuit. The water is heated via **heat exchanger W20.2** by a heating circuit of the entire greenhouse using wood pellets and groundwater heat pump or is cooled down via **heat exchanger W20.3** connected to the cooling water circuit of the entire greenhouse.

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 101000801.

The relative humidity of the conditioned air, which is almost in phase of equilibrium with the TCF in the absorber head, can be directly adjusted via the concentration of the TCF in the absorbers. Since the TCF is constantly enriched with absorbed humidity, it is necessary to replace periodically the diluted TCF with a concentrated TCF. The diluted TCF is pumped by the **pumps P1.2 - P9.2** from the absorber scrubbers into the storage **tank S2** and the concentrated TCF stored in the storage **tank S1** is pumped to the absorbers by the **pumps P30.1 – P30.9.** The installed pumps are diaphragm pumps.

The regeneration (concentration) of the TCF is carried out by the **desorber LW10**, which operates in batch mode (see section 1.4). The diluted TCF stored in tank S2 flows to the sump of the desorber through a natural gradient and recirculated to the head of the desorber by the **pump P10.1**. When the desired TCF concentration is reached, the concentrated TCF is redirected to the storage tank S1.

The temperature in the desorber for the regeneration process (e.g. evaporation process of the water in the TCF to the air) influences the velocity need to reach the required concentration of the TCF. The TCF is heated in the **heat exchanger W10** by glycol-water solution of an intermediate heating circuit (desorber circuit). The glycol-water solution (frost-proof) is necessary because the desorber is housed outside.

1.4 Strategy for TCF

The concentration of TCF inside the absorber shall be maintained at a certain percentage to allow the absorption process, only in this way it is possible to control the air humidity in the greenhouse. A too diluted TCF cannot any more control the air humidity.

The control strategy to maintain the correct concentration inside the absorbers can be implemented as continuous process or as a batch process. In previous projects carried out in a greenhouse-lab at the ZHAW, the approach of continuous concentration control was followed: a concentrated TCF is continuously filled into the absorber sump, so the resulting mixing concentration in the sump can be kept constant. Such a process involves large mixing losses. Working with $MgCl_2$, as in TheGreefa greenhouse, the maximum TCF concentration is 33%, corresponding to the solubility limit at storage temperature. That means, for example, approx. 60% of the initial volume of concentrated TCF (33%) is required to increase the concentration in the sump from 24% to 28%.

TheGreefa is operated in batch mode: the TCF is recirculated in the absorber and its concentration decreases constantly. As soon as the concentration of the TCF becomes too low, the required humidity in the greenhouse cannot be maintained at the required level and increased over the maximum admissible value. The TCF is changed, the absorber sump is then emptied and filled with concentrated TCF.

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 101000801.

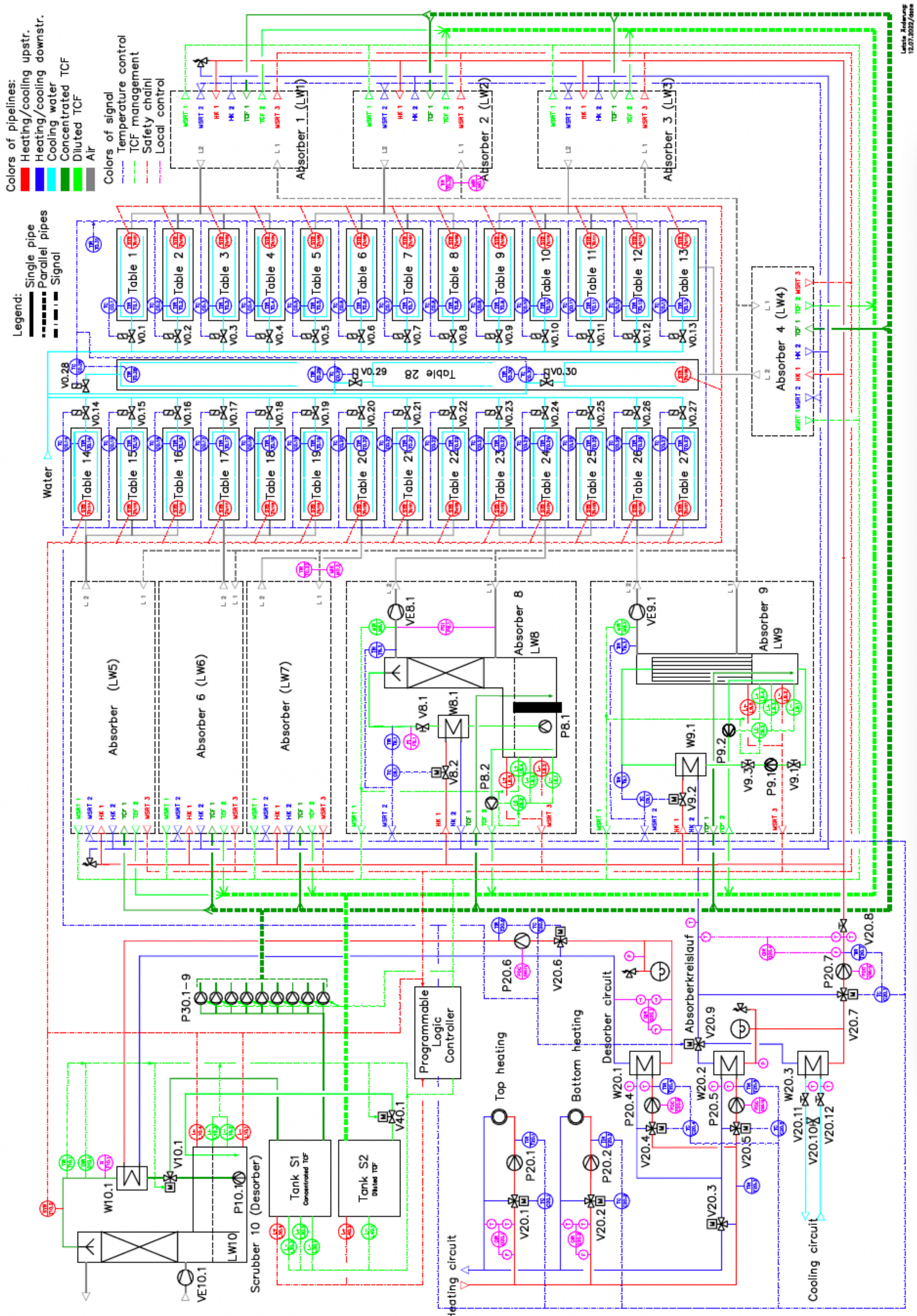


Figure 12: P&ID of the sorptive greenhouse air-conditioning in the demonstrator in Wangen bei Dübendorf.

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 101000801.

2 Control concept for a full automated control system

The full automated control system is designed to maintain the temperature and humidity in the greenhouse inside the required range of value and to manage the substitution and the regeneration of the TCF without the intervention of the operators.

The scope of this demonstrator is to test the technology of the TheGreefa, which has been installed for the first time in a commercial greenhouse; the control system of the demonstrator TheGreefa is integrated to the standard existing control system in order to guarantee the correct set-up of temperature and humidity also in the remote case of outage of the TheGreefa.

Standard operation without TheGreefa

The greenhouse of Meyer Orchideen AG is controlled by a climate control system from RAM GmbH (here named RAM climate computer). The existing standard heating system uses warm water flowing in pipes located under the crop's table (bottom heating) and in pipes suspended 3 m above the tables as well as along the outer façade (top heating). The bottom heating is used to heat the air around the crops, while the top-heating heats the entire greenhouse. The heating systems controlled the average greenhouse temperature. During solar radiation, depending on the intensity of the solar radiation, the radiation input is reduced by extending shading screens. In case of intensive solar radiation and extended shading screens, the air in the greenhouse can heat up very strongly. In this case, the ventilation flaps are opened. The flap opening is controlled by the air temperature in the greenhouse above the shading screens (T0.31) and the wind conditions. To reduce heat losses via the greenhouse roof, an energy screen is extended at night. This can also be used in addition to the shading screen to reduce radiant energy input in the event of very extreme solar radiation.

Integration of TheGreefa

The concept of the new programmable logic controller (PLC) for TheGreefa demonstrator and its interface to the existing control system (RAM climate computer) is reported in the Figure 13.

The new PLC consists of a Master Control System, nine absorber controllers, a desorber controller and a safety chain. The Master Control of TheGreefa has the control of the new installation and take over the control of the top and bottom heating of the conventional heating system, as soon as the "TheGreefa" is put on ON.

The master controller communicates with the substations of the "absorber control" and "desorber control", and regulates the supply to the bottom and top heating during sorption operation, the temperature of the heating and cooling circuit as well as the TCF management of the regeneration. The absorber controllers regulate the emptying and filling of the TCF from and into the absorbers, the heating and cooling of the absorbers via the absorber circuit and the evaporating cooling. The desorber control regulates the regeneration of the salt solution.

The Master Control of TheGreefa cannot influence the ventilation, the shading screens and energy screens. The set-point of the ventilation has an inertia and to avoid that the flaps are continuously opened and closed during the operation of TheGreefa, new setpoints of temperature and humidity shall be entered manually into the RAM Climate computer to deactivate the ventilation to the extern within a defined range. All other sensors and actuators of the climate computer are not affected. The recirculation fans are manually deactivated, they are not connected to the RAM climate computer. The set-up of the alarm values of the conventional greenhouse control are not changed.

A signal redirection via an additional relay is installed in the control cabinet of the RAM Climate Computer. In case of a cable break, power failure or activation of the safety chain, the relay drops out and control is transferred from the Master Control of TheGreefa to the RAM Climate Computer. The safety chain is described in section 2.4.

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 101000801.

The actual configuration of the Master Control does not allow to change parameters. All values (Table 1), included the temperature and humidity for the tables, are contained in the software of the PLC. They can be changed only by ZHAW. This to prevent that an operator inadvertently changes the setpoints during the demonstration.

Table 1: list of target values for PLC and absorber cabinet, with the names used in the software and the reference measurement points

T_PT_max	*Maximum admissible temperature for tables, evaporation cooling [°C]*	*T0.yy*
TAmin	*Setpoint temperature for absorber circuit, switching on heating [°C]*	*T20.7*
TAmax	*Setpoint temperature for absorber circuit, switching on cooling [°C]*	*T20.7*
TL	*Target temperature for tables [°C]*	*T0.yy*
THD	*Target temperature desorber circuit heat exchanger [°C]*	*T20.4*
TD	*Target temperature desorber heat exchanger [°C]*	*T20.6*
THA	*Target temperature absorber circuit heat exchanger [°C]*	*T20.5*
TAH	*Target temperature absorber circuit in heating mode [°C]*	*T20.7*
TAK	*Target temperature absorber circuit in cooling mode [°C]*	*T20.7*
dT_PT_UE	*Overtemperature limit value (deviation from setpoint #TL) of the air temperature above the planting tables, switching on bottom heating [K]*	*T0.yy-Tx.3*
dT_PT_UA	*Overtemperature limit value (deviation from setpoint #TL) of the air temperature above the planting tables, switching off bottom heating [K]*	*T0.yy-Tx.3*
TUH	*Target temperature bottom heating circuit [°C]*	*T20.2*
TG_OE	*Target value for greenhouse temperature for switching on top heating [K]*	*T0.31*
TG_OA	*Target value for greenhouse temperature for switching off top heating [K]*	*T0.31*
TOH	*Target temperature top heating circuit [°C]*	*T20.1*
LK	*Max TCF concentration [Ma%]*	*f(D10.1, T10.1)*
Mmax	*Max admissible relative humidity [%]*	*Mx.1*
TSh	*Target for TCF temperature, heating mode [°C]*	*f(Tx.3–T0.yy)*
TSk	*Target for TCF temperature, cooling mode [°C]*	*f(Tx.3–T0.yy)*
τ1	*Time interval between two temperature controls in evaporating cooling mode [sec]*	
τ2	*Duration of water spraying in evaporating cooling mode [sec]*	
AL1	*Time interval between switching OFF and ON Px.2, TCF change in the absorber [sec]*	
nAL	*Number of switching OFF Px.2, TCF change in the absorber*	

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 101000801.

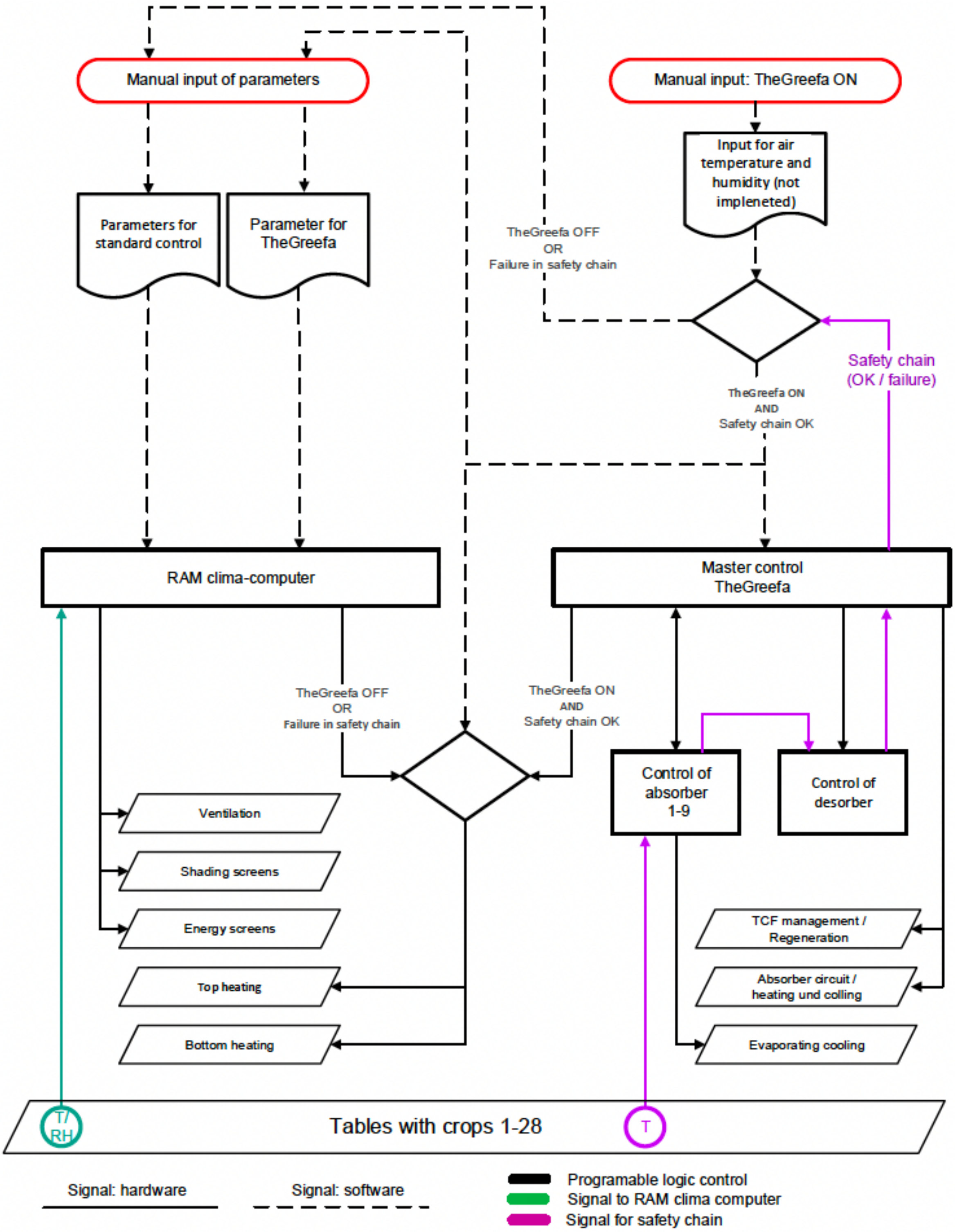


Figure 13: concept schema of the new PLC (Master Control) and its interface to the existing control system (RAM climate-computer)

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 101000801.

2.1 Absorbers and air system

The air for the greenhouse is treated inside nine absorbers.

The TCF recirculation pump Px.1 pumps the TCF from the sump to the top of the absorber via heat exchanger Wx.1. The pump operates in continuous without regulation. The position of the valve Vx.1 must not be changed, it corresponds to the design flowrate and to the installed pump. The flowrate of the TCF is locally indicated by Fx.1

The air is fed below the crops table by the ventilator VEx.1 installed at the absorber outlet. The ventilator operates in continuous without regulation. The air flow rate can be determined by a manual differential pressure measurement with a U-tube manometer (PDIx.1).

The temperature of the air leaving the absorber Tx.3 is controlled setting the TCF temperature entering the absorber Tx.1, while the humidity of the air leaving the absorber Mx.1 depends on the TCF concentration inside the absorber. The temperature and relative humidity of the conditioned air are continuously monitored. In addition, the temperature and relative humidity of the air drawn from the greenhouse is also measured on both halves of the air intake system (T0.32, T0.33, M0.1 and M0.2).

The air temperature in the area of the plants is monitored on each plant table (T0.1 to T0.30). If one of these temperature measuring points registers that the temperature falls below a predefined minimum temperature (STBmin, corresponding to T0.1xx, local controller) or exceeds a predefined maximum temperature (STBmax, corresponding to T0.1xx, local controller) the air conditioning of the greenhouse is automatically transferred to the conventional climate control system (RAM climate computer). The TheGreefa's system is switched off and a fault message is issued (see section 2.4). The management of the TCF for the humidity control is described in section 2.3.

2.2 Temperatur control

The air temperature (in PLC: TL) is primary controlled regulating the temperature of the TCF. In case it is not possible to reach the required air temperature only by controlling the TCF temperature, the bottom and top heating or the evaporating cooling are shechted on.

2.2.1 TCF temperature and heating / cooling system (absorber circuit)

The TCF is heated and cooled down by means of a secondary circuit, here called absorber circuit. The absorber circuit recirculation pump P20.7 is continuous operation and is controlled to maintain a constant pressure drop in the circuit (PDC10.12, local controller).

The water of the absorber circuit is heated or cooled respectively by the heat exchanger W20.2 or W20.3. The temperature (T20.7) is maintained at the set-point for heating or cooling mode by the valve V20.7 (in PLC: TAH or THK T20.7). The heating and cooling modes are controlled by valve V20.9, which acts as a changeover valve between heat exchangers W20.2 and W20.3. With the position closed (0%), heat is supplied to the absorber circuit via heat exchanger W20.2, the system is in heating mode. With the position open (100%), the absorber circuit is cooled via the heat exchanger W20.3, the system is in cooling mode.

The TCF inlet temperature to the absorber (Tx.1) is controlled by setting the valve Vx.2 via a cascade control (C20.7 and Cx.1) to a target (TSh if in heating mode and TSk in cooling mode), which is set as a function of the temperature drop between the air outlet temperature at the absorber and the air temperature on the plant table (Tx.3 – T0.y). In case an absorber serves more tables, the higher drop (Tx.3 – T0.y) is considered.

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 101000801.

The positions of all Vx.2 are recorded by the Master Control: when the valves Vx.2 of all absorbers are closed, the absorber circuit leaves the heating or cooling mode and switches in balancing mode.

In balancing mode, the absorber circuit is neither heated nor cooled, there is no control of the flow temperature (T20.7), valve V20.7 opens and the heat exchangers W20.2 and W20.3 are bypassed completely. The Master Control opens then all control valves (Vx.2) in fully open position. The circuit remains in balancing mode until the temperature of the circuit T20.7 exceeds the set-points for switching to cooling mode or falls below the set-point value for switching to heating mode (in PLC: TAmax or TAmin).

The pumps P20.5 is switched on when the circuit enters in heating mode and is switched off when the circuit enters in balancing mode. The frequency of the pumps in controlled by the PDC20.10 to maintain a constant pressure drop (local controller). The mixing valve V20.5 controlled by the T20.5 maintains the temperature at W20.2 inlet to a target value (in PLC: THA).

2.2.2 Evaporating cooling

The evaporating cooling is operated by the "Absorber Control". Please, refer to Figure 14. If the temperature on the tables T0.yy exceeds a set-point value Tmax (in PLC: T-PTmax), the valve V0.yy is opened and the gravel on the table is humidified. The temperature on the tables T0.yy is controlled at regular intervals. If T0.yy exceeds the set point Tmax, the valve V0.yy opens and stay open for a fixed duration $\tau 2$ (in Absorber cabinet: $\tau 2$) spraying water on the table. If the table temperature is still above the set point Tmax after the time interval $\tau 1$, (in Absorber cabinet: $\tau 1$) the V0.yy opens again. This continues until the temperature T0.yy is below the limit temperature Tmax.

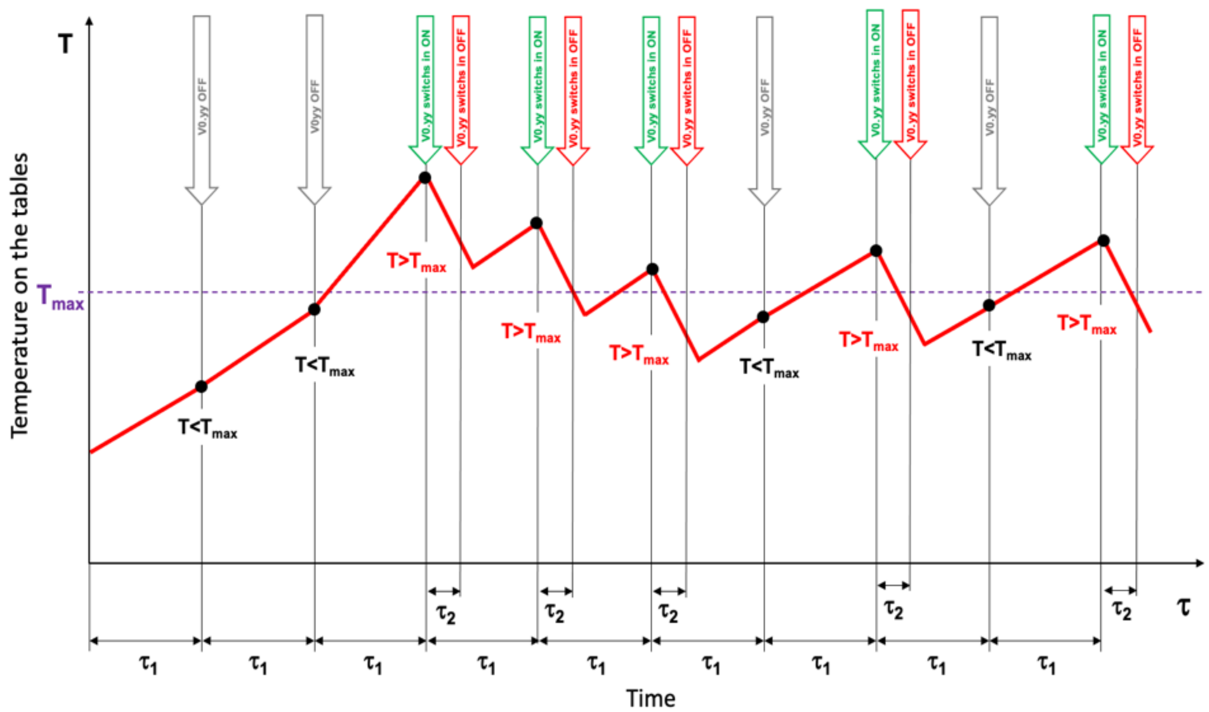


Figure 14: Procedure for evaporating cooling

2.2.3 Bottom heating

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 101000801.

The under-table heating or bottom heating is used to compensate the heat loss of the conditioned air between the absorber and the tables. If the temperature drop (T0.yy-Tx.3) at one of the crop tables exceeds a defined limit value (in PLC: dT_PT_UE), the Master Control switches on the pump P20.2 and opens the valve V20.2 in direction of the heating. If the temperature drop at all planting tables is less than another limit value (in PLC: dT_PT_UA), the pump is switched off and the V20.2 goes in bypass position. The valve V20.2 can only be 100% open or 100% closed to the heating, avoiding that the temperature T20.2 exceeds a set-point (in PLC: TUH).

2.2.4 Top heating

The top heater is used as a heat source to prevent condensation on the greenhouse envelope.

If the greenhouse temperature T0.31 falls below the specified limit value (in PLC: TG_OE), the Master Control switches on the pump P20.1 and opens the valve V20.1 in direction of the heating. If the temperature drops below another limit value (in PLC: TG_OA), the pump is switched off and the V20.2 goes in bypass position. The valve V20.2 can only be 100% open or 100% closed to the heating, avoiding that the temperature T20.2 exceeds a set-point (in PLC: TOH).

2.3 Humidity control

The concentration of TCF inside the absorber shall be maintained at a certain percentage to allow the absorption process, only in this way it is possible to control the air humidity in the greenhouse. A too diluted TCF cannot any more control the air humidity. In this case, the TCF shall be changed. The absorber is emptied till a minimum of 50 liters of diluted TCF (concentration 22.6%), then it is filled with 150 liters of TCF concentrated at 32%. The TCF concentration of the resulting 200 liters of TCF is 29.77% corresponding to a relative air humidity of 50%RH in phase equilibrium and at 20°C.

2.3.1 Procedure for TCF change in the absorber

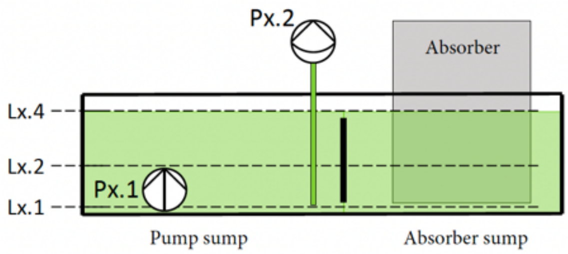
The air humidity is measured at the absorber outlet (*Mx.1)*. When the maximum permissible air relative humidity of 70% (in PLC: M_{MAX}), corresponding to a TCF of ξ=22.5% in phase equilibrium at 20°C, is measured, then the TCF shall be changed. The TCF change procedure can started only if the filling level of the storage S2 (diluted TCF) is below the level L40.1. In this case, the TCF change procedure can started only in case a maximum of one other absorber is in TCF change mode, when the level in S1 is above L30.2 In all other cases, the absorber is placed on hold. The TCF can be changed simultaneously from a maximum of two absorbers. This is determined by the filling level L30.2 in the storage S1. While the absorber is on hold, it operates as usual. An absorber has priority for the TCF change procedure as soon as the fill level Lx.4 is reached. If the TCF change procedure takes place at that moment in none or only in one absorber, the procedure of TCF change is started. If the level in S1 is below L30.1, the TCF change procedure cannot be started to preserve the P30.x from dried running.

This section describes the TCF change procedure, which is represented in a time sequence in Figure 15.

Time $\tau 0$:

Start of the TCF changing procedure as soon as the filling level Lx.4 is reached. Both pump and absorber sump are filled up to above the partition wall. The pump Px.2 is switched on.

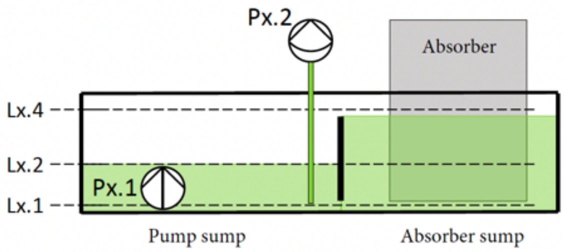
There is 120 liters of solution in the absorber sump and 140 liters of solution in the pump sump.



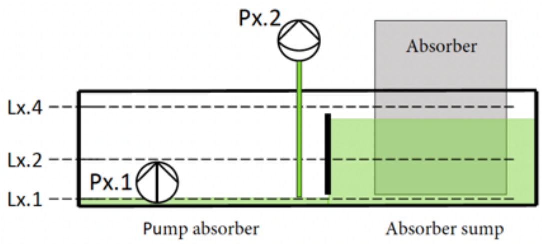
This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 101000801.

The Master Control deactivates the pump protection (Lx.2) in the safety chain as soon as the Px.2 is switched on. The pump protection (Lx.2) is bypassed during the entire TCF changing procedure.

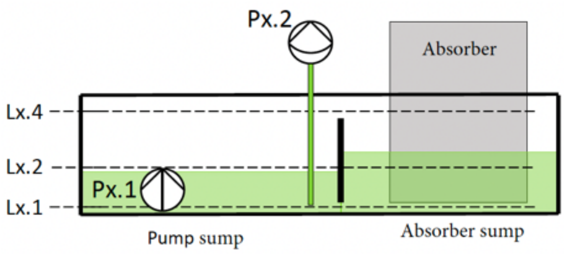
The TCF circulation pump (Px.1) remains in operation until the level Lx.2 is reached (pump dry run). After the solution circulation pump (Px.1) has been switched off, there is still about 155 liters of TCF: 120 liters up to the edge of the partition wall in the absorber sump and 35 liters up to the filling level Lx.2 in pump sump.

Time τ1: Switching off the circulation pump Px.1 when the filling level Lx.2 is reached. The absorber sump is filled up to the partition wall and the pump sump is filled up to the fill level Lx.2. There are 120 liters of TCF in the absorber sump and 35 liters in the pump sump.	

The entire pump sump is emptied into the storage S2 (diluted solution) by means of pumps Px.2 until the filling level Lx.1 is reached, then the pump Px.2 is switched off.

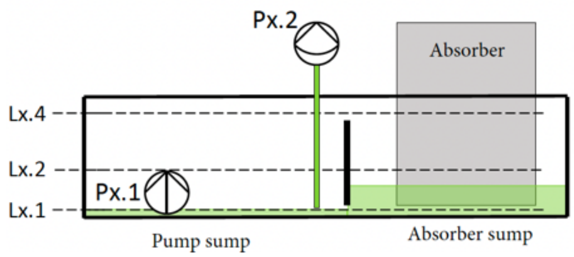
Time τ2: Switching off the pump Px.2 when the fill level Lx.1 is reached. There are 105 liters in the absorber sump and 5 liters in the pump sump.	

The volume flowrate of the pump Px.2 is higher that the flowrate flows through the equalisation holes in the lower part of the partition wall. For this reason, the emptying process takes place in time intervals with switching off and on the Px.2. After the switching off the Px.2, the TCF flows from the absorber sump to the pump sump through the holes of the partition wall: the TCF level in the pump sump increases and the Px.2 is switched on again after at time τ3 ((in absorber cabinet: AL1 after 3 minutes from the switching off of Px.2). The emptying process starts again.

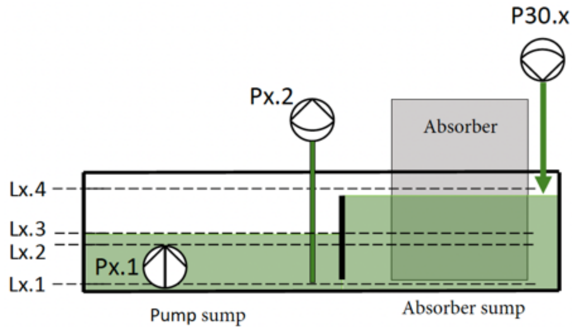
Time τ3: Switching on the pump Px.2. There are 80 liters in the absorber sump and 30 liters in the pump sump.	

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 101000801.

The pump Px.2 pumps the TCF into the storage S2 and is switched off as soon as the level Lx.1 is reached. The process is repeated three times (nAL in absorber cabinet) so that a residual volume of approx. 50 liters remains in the sumps.

Time τ4 The emptying process is completed and starts the filling process. Switching off pump Px.2, switching on pump 30.x. There are a total of 50 liters in the absorber system with a concentration of 22.5%.	

After the emptying process is completed, the absorber sump is filled with concentrated solution from the storage S1 by the pump (P30.x) until the filling level Lx.3. When the TCF changing procedure is completed and Lx.3 is reached, the P30.x pump is deactivated, the Px.1 pump is activated and the Lx.2 pump protection bypass is deactivated.

Time τ5 Switch off pump P30.x, switch on pump Px.1, reactivation of Lx.2 in the safety chain. There are 200 liters in the absorber system.	

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 101000801.

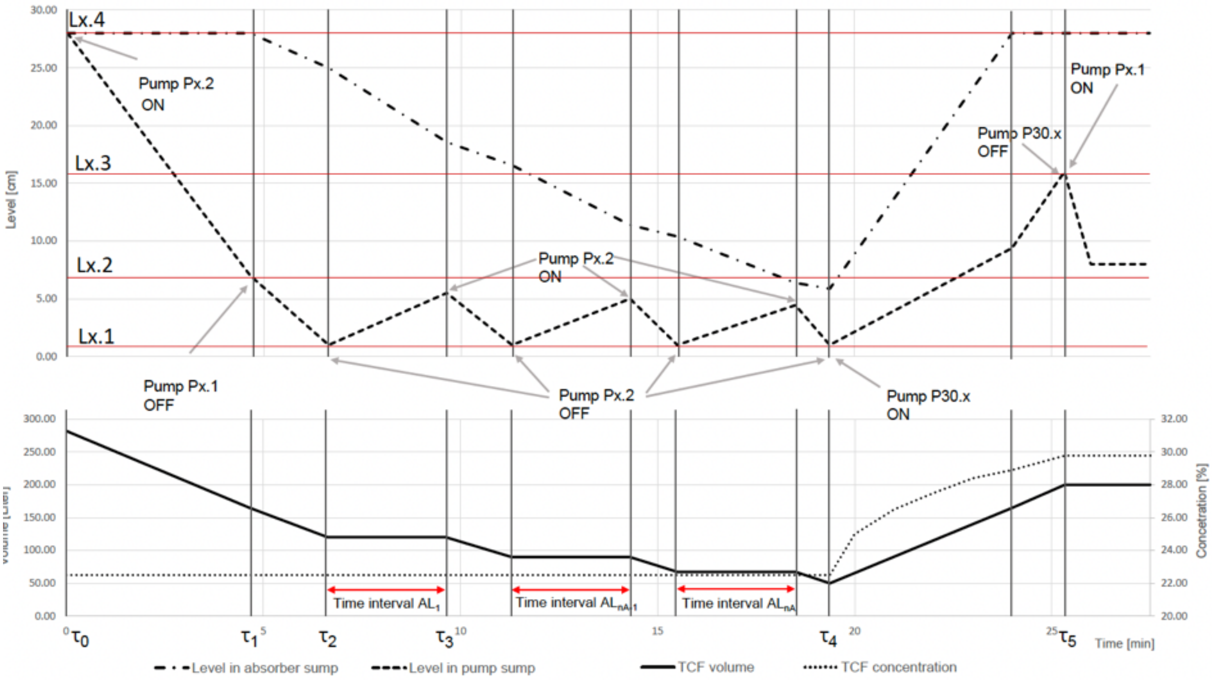


Figure 15: TCF changing procedure as time sequence

2.3.2 Desorber and TCF regeneration

The TCF needs to be regenerated when the concentration is too low and cannot absorb anymore the humidity from the air. The desorber LW10.1 enters in operation, the fan VE10 is switched on and blows the air from outside the greenhouse into the bottom part of the W10., as well as the TCF recirculation pump P10.1 is switched on and pumps the TCF from the desorber sump to the top of the desorber via the heat exchanger W10.1. The TCF flowrate is shown in a local flowmeter (FI10.1).

The desorber is filled with diluted TCF from storage S2 through a natural gradient via valve V40.1, which is normally in open position. When the level in the desorber reaches L10.3, valve V40.1 is closed, and desorption operation starts: the pump P10.1, the fan VE10.1, the valve V10.1 and the desorber heating circuit (V20.4, P20.4, V20.6, P20.6) are put into operation. The valve V10.1 is in circulation position, the TCF flows from the desorber sump to the top of the desorber. The P10.1 and VE10.1 operate at fixed frequency, the P20.6 and P20.4 are controlled by PDC20.11 (local controller) and PDC20.9 (local controller) to maintain a constant pressure drop in the circuit. The temperature of the water in the desorber circuit is maintained to target value (in PLC: TD) mixing the upstream and downstream in the V20.6 controlled by the T20.6. In the same way the temperature at the inlet of W20.1 is maintained (in PLC: THD) through the mixing valve V20.4 controlled by the T20.4.

Based on the density measurement D10.1 and the solution temperature T10.1, the concentration of the TCF is determined. If a TCF concentration of 32% is reached (in PLC: LK) the desorption process is terminated: P10.1, VE10.1 and P20.4 are switched off.

If the level in the storage S1 is below the level L30.3, the desorber can be emptied into the S1 (when the desorber tank is full till L10.3, the TCF volume in the desorber sump is less the volume capacity between the level L30.3 and L30.4 in S1): the valve V10.1 is brought into the emptying position, the P10.1 is switched on and feeds the TCF from the desorber sump to the S1 until the filling level L10.2 in the desorber sump is reached. After the

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 101000801.

desorber has been emptied, pump P10.1 is switched off, valve V10.1 is reset to the circulation position and valve V40.1 is opened.

Thermal energy flows

One of the objectives of TheGreefa project is the demonstration of its energy saving. For this scope, all the thermal heat entering the system is recorded:

- Q20.1 for the top heating
- Q20.2 for the bottom heating
- Q20.3 for the TCF regeneration
- Q20.4 for TCF temperature control in the absorbers. The Q20.4 distinguishes the energy used for heating and that for cooling.
- The energy supply by the evaporating cooling is not yet a recorded, but it can be calculated using the number of time the valves V0.yy opens (which is recorded), the water flowrate is known (which is fixed) and the duration of the spraying.

2.4 Safety chain

To prevent damage to the crop and to the components/structure of the greenhouse, the following critical parameters are monitored and connected to a safety chain:

- Protection of crops from damage.
  - Monitor temperature in the entire area on all plant tables (T0.101 - T0.128), safety temperature limiter
  - Temperature must be in the range 15 - 26°C.
- Avoid leakage of the TCF
  - Overflow protection in the absorption scrubbers (LW1-9, level monitor Lx.5) and the desorber (LW10, level monitor L10.4)
  - Overflow protection at thestorage S1 (L30.4) and S2 (L40.2)
- Avoid damage to centrifugal pumps due to dry running
  - Dry-running protection in the absorption scrubbers (LW1-9, level monitor Lx.2) and the desorber (LW10, level monitor L10.1)
- Avoid too high a temperature in the desorber LW10 (ϑmax = 60°C).
  - Solution inlet temperature (T10.2), safety temperature limiter

The sensors with alarm listed above are integrated into a safety circuit. In case of an alarm cannot be solved, the control is transferred to the RAM climate computer via a hardware controller. The functions of the safety chain operate also in the event of a cable break, power failure or software error.

All components of the safety chain are connected in series by hardware. A switch is installed in the control cabinets of each absorber, it activates the bypass of the safety chain for the respective absorber. This will be used to deactivate one or more absorbers, so that the system can continue to operate with the remaining absorbers. In this way, individual absorbers can be deactivated for inspection, maintenance and intervention without interrupting the safety chain and without switching off the entire system. The bypass of the safety chain at the absorbers is communicated to the Master Control (Figure 13).

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 101000801.

3 Operating manual

The control cabinet of the Master Control is located next to the entrance of the greenhouse and functions as the central control unit. There are two switches on the control cabinet of the master control for switching on and off the sorption mode. The control cabinet of Master Control serves as the main distribution for the electrical connections to the substations and scrubbers.

A control cabinet with its own PLC is installed for each absorber and desorber. These cabinets control the associated absorber /desorber and its functions as a substation of the Master Control (Figure 16 and Figure 17).

The instructions for operate the plant and switching on/off are reported in the following sections.

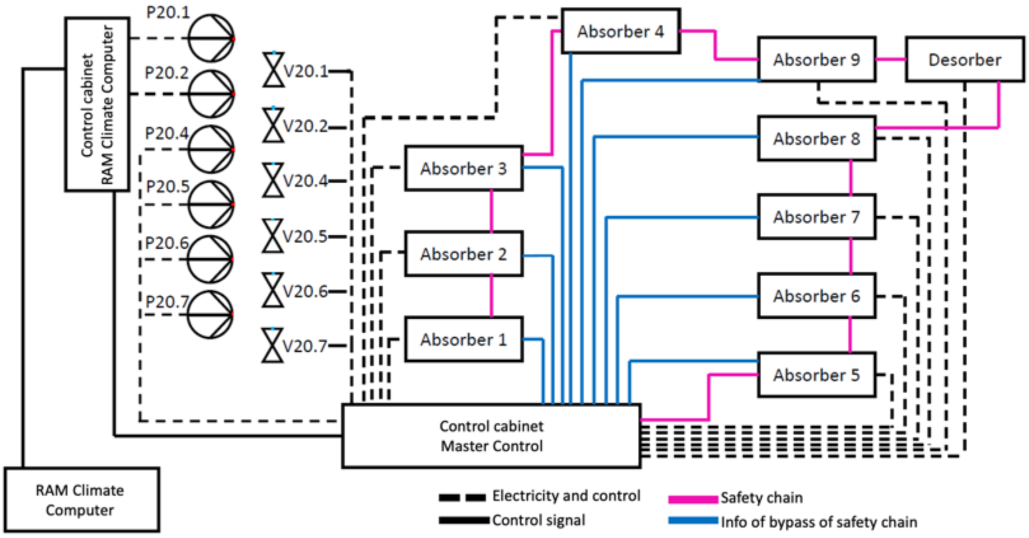


Figure 16: connection between the different cabinets and electricity supply

Figure 17: Master Control Cabinet (left, middle) and Absorber Control Cabinet (right)

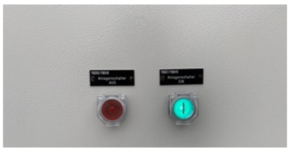
This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 101000801.

3.1 Switching ON/OFF of TheGreefa

Switching ON

The Master Control of TheGreefa takes over the control of the top and bottom heating of the conventional greenhouse control (RAM Climate Computer), but cannot influence the ventilation, shading and energy screen.

The following operations are necessary to allow the Master Control of TheGreefa to operate:

<table>
<tr><td>Switching OFF the ventilation of the greenhouse, first switcher on the top in the Cabinet of the Ram Climate Computer (1 ON, 0 FF)</td><td></td></tr>
<tr><td>Set-up in the RAM Climate Computer of new parameters necessary in order not to hinder the operation of the Master Control</td><td>
<table>
<tr><th></th><th colspan="2">TheGreefa ON</th></tr>
<tr><td></td><td>Lower limit</td><td>Upper limit</td></tr>
<tr><td>Ventilation, day</td><td>19°C</td><td>26°C</td></tr>
<tr><td>Ventilation, night</td><td>19°C</td><td>26°C</td></tr>
<tr><td>Relative humidity</td><td>35%RH</td><td>75%RH</td></tr>
<tr><td>Alarm for temperature</td><td>Min. 15.0°C</td><td>Max. 37.0°C</td></tr>
<tr><td>Alarm for humidity</td><td>Min. 20%RH</td><td>Max. 95%RH</td></tr>
</table>
</td></tr>
<tr><td>The TheGreefa can now be switched ON, green button (Anlagenschalter EIN) in the Cabinet of the Master Control</td><td></td></tr>
</table>

All measured values are shown in real time on the display of the Master Control (Figure 18).
The input parameters are shown the screen “Parametereingabe”, but they can be changed only by entering a code.

Default parameters:

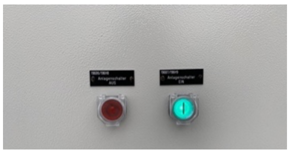
- Target temperature on tables: 20°C
- Max. relative humidity on table: 70%
- Max. TCF concentration at desorber: 32%

The other parameters (see Table 1) are here not reported because they will be optimised during the demonstration phase.

This project has received funding from the European Union’s Horizon 2020 research and innovation Programme under grant agreement 101000801.

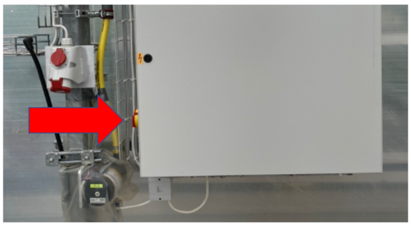
Switching OFF

The following operations are necessary to allow RAM Climate Computer to take over the control:

<table>
<tr><td>Switching ON the ventilation of the greenhouse, first switcher on the top in the Cabinet of the Ram Climate Computer (1 ON, 0 FF)</td><td></td></tr>
<tr><td>Set-up in the RAM Climate Computer of new parameters necessary for the RAM Climate Computer to take over the control of the standard air controlling system</td><td>
<table>
<tr><th></th><th colspan="2">TheGreefa OFF</th></tr>
<tr><td></td><td>Lower limit</td><td>Upper limit</td></tr>
<tr><td>Ventilation, day</td><td>19°C</td><td>21°C</td></tr>
<tr><td>Ventilation, night</td><td>19°C</td><td>22°C</td></tr>
<tr><td>Relative humidity</td><td>35%RH</td><td>70%RH</td></tr>
<tr><td>Alarm for temperature</td><td>Min. 15.0°C</td><td>Max. 37.0°C</td></tr>
<tr><td>Alarm for humidity</td><td>Min. 20%RH</td><td>Max. 95%RH</td></tr>
</table>
</td></tr>
<tr><td>The TheGreefa can now be switched OFF, red button (Anlagenschalter AUS) in the Cabinet of the Master Control (Photo is on ON)</td><td></td></tr>
</table>

3.2 Switching ON / OFF single absorber

Each single absorber can be switched off in case of inspection, maintenance, intervention or others without switching off the entire system. In this case the safety chain of the single absorber is bypassed. It is reactivated automatically by switching on the absorber.

<table>
<tr><td>Switching ON / OFF the red button on the side of the cabinet.</td><td></td></tr>
</table>

3.3 Switching ON / OFF desorber

The desorber can be switched on/off only with the entire system (section 3.1).

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 101000801.

Figure 18: Screenshot of the Master Control Computer, overview of the system

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 101000801.

3.4 Component list (in German)

Messstelle	Nr.	Bezeichnung	Messbereich	Ausgangssignal	Messprinzip	Gerätebezeichnung	Hersteller	Datenblatt
Gewächshaus								
TIR	T0.29	Temperatur der Luft am Eintritt der Absorber 1-4	-20...+80°C	RTD	PT1000	TN:00630646	JUMO	
TIR	T0.30	Temperatur der Luft am Eintritt der Absorber 5-9	-20...+80°C	RTD	PT1000	TN:00630646	JUMO	
MIR	M0.1	Relative Feuchte der Luft am Eintritt der Absorber 1-4	0...100% rF	4...20mA	Hygrothermogeber	TN:00630646	JUMO	
MIR	M0.2	Relative Feuchte der Luft am Eintritt der Absorber 5-9	0...100% rF	4...20mA	Hygrothermogeber	TN:00630646	JUMO	
TIR	T0.31	Gewächshaustemperatur						
Tisch n (n=1-28)								
TIR	T0.n	Lufttemperatur auf Tisch für Tischbefeuchtung		RTD	PT1000		SAWI	
STB	T0.1n	Sicherheitstemperaturbegrenzer						
Absorber x (x=1-8)								
TIR	Tx.1	Lösungseintrittstemperatur		RTD	PT1000		SAWI	
TIR	Tx.3	Luftaustrittstemperatur	-20...+80°C	RTD	PT1000	TN:00630646	JUMO	
FI	Fx.1	Lösungsvolumenstrom	0-3000 l/h		Durchflussschwebekörper			
MIR	Mx.1	Luftaustrittsfeuchte	0...100%rF	4...20mA	Hygrothermogeber	TN:00630646	JUMO	
PDI	Px.1	Druckdifferenz						
L-	Lx.1	Füllstandssensor Lösungswechsel: Entleerung beenden	01 cm über Boden / 10L	RTD	Konduktiver Grenzschalter	Liquipoint T	Endress und Hauser	datenblatt
L-	Lx.2	Füllstandssensor Pumpenschutz Px.1	08 cm über Boden / 160L	RTD	Konduktiver Grenzschalter	Liquipoint T	Endress und Hauser	datenblatt
L+	Lx.3	Füllstandssensor Lösungswechsel: Befüllung beenden	X cm über Boden / min. 190L	RTD	Konduktiver Grenzschalter	Liquipoint T	Endress und Hauser	datenblatt
L+	Lx.4	Füllstandssensor Lösungswechsel: Priorität	30 cm über Boden / 280L	RTD	Konduktiver Grenzschalter	Liquipoint T	Endress und Hauser	datenblatt
L+	Lx.5	Füllstandssensor Überlaufschutz	33 cm über Boden / 308L	RTD	Konduktiver Grenzschalter	Liquipoint T	Endress und Hauser	datenblatt
Absorber 9								
TIR	T9.1	Lösungseintrittstemperatur	-20...+80°C	RTD	PT1000		SAWI	
TIR	T9.3	Luftaustrittstemperatur	-20...+80°C	4...20mA		TN:00630646	JUMO	
MIR	M9.3	Luftaustrittsfeuchte	0...100%rF	4...20mA	Hygrothermogeber	TN:00630646	JUMO	
L-	Lx.1	Füllstandssensor Lösungswechsel: Entleerung beenden		RTD	Konduktiver Grenzschalter	Liquipoint T	Endress und Hauser	datenblatt
L-	Lx.2	Füllstandssensor Pumpenschutz Px.1		RTD	Konduktiver Grenzschalter	Liquipoint T	Endress und Hauser	datenblatt
L+	Lx.3	Füllstandssensor Lösungswechsel: Befüllung beenden		RTD	Konduktiver Grenzschalter	Liquipoint T	Endress und Hauser	datenblatt
L+	Lx.4	Füllstandssensor Lösungswechsel: Priorität		RTD	Konduktiver Grenzschalter	Liquipoint T	Endress und Hauser	datenblatt
L+	Lx.5	Füllstandssensor Überlaufschutz		RTD	Konduktiver Grenzschalter	Liquipoint T	Endress und Hauser	datenblatt
Heiz/Kühlkreislauf								
T	T20.1	Temperatur Oberheizung Vorlauf		RTD	PT1000	Liquipoint T	Endress und Hauser	
T	T20.2	Temperatur Unterheizung Vorlauf		RTD	PT1000	Liquipoint T	Endress und Hauser	
TIR	T20.3	Temperatur Heizkreis Vorlauf		RTD	PT1000	Liquipoint T	Endress und Hauser	
T	T20.4	Temperatur vor W20.1		RTD	PT1000	Liquipoint T	Endress und Hauser	
T	T20.5	Temperatur vor W20.2		RTD	PT1000	Liquipoint T	Endress und Hauser	
T	T20.6	Temperatur Desorberkreislauf Vorlauf		RTD	PT1000		SAWI	
T	T20.7	Temperatur Absorberkreislauf Vorlauf		RTD	PT1000		SAWI	
QIR	Q20.1	Wärmezähler Oberheizung	5...130°C // qp: 10m3/h	visuell/bus	PT500	Amtron Sonic D	aqua metro	datenblatt
QIR	Q20.2	Wärmezähler Unterheizung	5...130°C // qp: 10m3/h	visuell/bus	PT500	Amtron Sonic D	aqua metro	datenblatt
QIR	Q20.3	Wärmezähler Desorberkreislauf						
QIR	Q20.4	Wärmezähler Absorberkreislauf	T=2...180°C // dT 2...120K	visuell/bus	PT500	UH50-C65-00	Siemens	
Speicher S1								
L-	L30.1	Füllstandssensor, Speicher ist leer	22 cm über Boden	RTD	Konduktiver Grenzschalter	Liquipoint T	Endress und Hauser	datenblatt
L+	L30.2	Füllstandssensor, Konzentrierte Lösung für den Lösungswechsel von #nA Absorbern vorhanden	55 cm über Boden	RTD	Konduktiver Grenzschalter	Liquipoint T	Endress und Hauser	datenblatt
L+	L30.3	Füllstandssensor, Desorber kann entleert werden	60 cm über Boden	RTD	Konduktiver Grenzschalter	Liquipoint T	Endress und Hauser	datenblatt
L+	L30.4	Füllstandssensor, Überlaufschutz	96 cm über Boden	RTD	Konduktiver Grenzschalter	Liquipoint T	Endress und Hauser	datenblatt
Speicher S2								
L+	L40.1	Füllstandssensor, Freies Volumen für den Lösungswechsel einer Anzahl von #nA Absorbern vorhanden	50 cm über Boden	RTD	Konduktiver Grenzschalter	Liquipoint T	Endress und Hauser	datenblatt
L+	L40.2	Füllstandssensor, Überlaufschutz	96 cm über Boden	RTD	Konduktiver Grenzschalter	Liquipoint T	Endress und Hauser	datenblatt
Desorber								
TIR	T10.1	Lösungstemperatur	-50...+100°C	4...20mA	PT100	TR10-ABA1CCSXG3000	Endress und Hauser	datenblatt
STB	T10.2	Sicherheitstemperaturbegrenzer			PT100		SAWI	
FI	F10.1	Lösungsvolumenstrom	0-3000 l/h		Durchflussschwebekörper			
DIR	D10.1	Dichtemessung	-50...+150 °C		Vibrationskörper	Liquiphant M FTL51C-AB8KDKDG4AA	Endress und Hauser	datenblatt
L-	L10.1	Füllstandssensor Pumpenschutz		RTD	Konduktiver Grenzschalter	Liquipoint T	Endress und Hauser	datenblatt
L-	L10.2	Füllstandssensor unterer Betriebspunkt		RTD	Konduktiver Grenzschalter	Liquipoint T	Endress und Hauser	datenblatt
L+	L10.3	Füllstandssensor oberer Betriebspunkt		RTD	Konduktiver Grenzschalter	Liquipoint T	Endress und Hauser	datenblatt
L+	L10.4	Füllstandssensor Havarieschutz		RTD	Konduktiver Grenzschalter	Liquipoint T	Endress und Hauser	datenblatt

This project has received funding from the European Union's Horizon 2020 research and innovation Programme under grant agreement 101000801.

Nr.	Bezeichnung	Hersteller	Gerätebezeichnung	Versorgung	Steuersignal	Stellung	Datenblatt
Tisch n (n=1-28)							
V0.n	Stellventil	RPE	Serie 3-360	24V	0… 24V	0…100%	
Wäscher x (x=1-8)							
LWx	Absorber x						
VEx.1	Ventilator	Funken Ventilatoren	HF R 180	230V		ein/aus	datenblatt
Px.1	Umwälzpumpe	Stübbe	ETLB-S 25-125S	230V		ein/aus	datenblatt
Px.2	Membranpumpe Lösung Rücklauf	Lilie	LP473M	24V		ein/aus	datenblatt
Vx.1	Handventil	Stübbe	MV310-	handbetrieb	handbetrieb		
Vx.2	Stellventil	Belimo	LR24A-SR	24V	2…10V DC	0…100%	datenblatt
Wx.1	Wärmetauscher	SWEP Wärmetauscher		keine			
Berlin Wäscher							
LW9	Wäscher 9						
VE9.1	Ventilator	Helios Rohrventilatoren				ein/aus	
P9.1	Umwälzpumpe	Kuenle	3-ph-Modell-Nr: 2718 510067 3	230/400V		ein/aus	
P9.2	Membranpumpe	Lilie	LP473M	24V		ein/aus	
V9.1	Handventil			handbetrieb	handbetrieb	0…100%	
V9.2	Handventil			handbetrieb	handbetrieb	0…100%	
W9.1	Wärmetauscher nach Pumpe			keine			
Heiz/Kühlkreislauf							
W20.1	Wärmetauscher Heizkreis-Desorberkreislauf	SWEP	B35TM2x60/1P-SC-S	keine			
W20.2	Wärmetauscher Heizkreislauf-Absorberkreislauf	hauser automatic	SL70-03-TM-30-CC_9	keine			
W20.3	Wärmetauscher Kühlkreislauf-Absorberkreislauf	Wegmann Wärmetauscher	WPL 28G-GG-60-1-1 / M	keine			
P20.4	Umwälzpumpe Zubringer Desorberkreislauf	Wilo Pumpen	Stratos MAXO 50/0.5-16 (DE)	230V		ein/aus	
P20.5	Umwälzpumpe Zubringer Absorberkreislauf	Wilo Pumpen	Stratos 50/1-8 (DE)	230V		ein/aus	datenblatt
P20.6	Umwälzpumpe	Wilo Pumpen	Stratos MAXO 50/0.5-16 (DE)	230V		ein/aus	datenblatt
P20.7	Umwälzpumpe Vorlauf Absorberkreislauf	Biral AG	ModulA 40-10-220 GREEN	230V		ein/aus	datenblatt
V20.3	Regelventil Beimischregelung	Siemens	SAS61.03	24V	2…10V DC	0…100%	datenblatt
V20.4	Regelventil Beimischregelung	Belimo	NV24A-SR-TPC	24V	2…10V DC	0…100%	
V20.5	Regelventil Beimischregelung	Belimo	NV24A-SR-TPC	24V	2…10V DC	0…100%	
V20.6	Regelventil Beimischregelung	Belimo	NV24A-SR-TPC	24V	2…10V DC	0…100%	
V20.7	Regelventil Beimischregelung	Belimo	NV24A-MP-TPC	24V	2…10V DC	0…100%	
V20.8	Handventil						
V20.9	Regelventil Heiz- Kühl und Ausgleichsbetrieb	Belimo	R3050-S4+SR24A	24V	2…10V DC	3-Weg, A oder B	
Desorber							
LW10	Desorber						
VE10.1	Ventilator	HF Ventilatoren	HF R 355 - 15D	230/400V		ein/aus	
P10.1	Umwälzpumpe	Stübbe	ETLB-S 32-125	400V		ein/aus	
V10.1	Regelventil Desorbieren ODER Befüllung Speicher 1	GF	Typ EA25	230 VAC 50/60 Hz		3-Weg, A oder B	
W10.1	Wärmetauscher	SWEP	B35TM2x60/1P-SC-S	keine			
Speicher S1							
P30.x	Membranpumpe Lösung Vorlauf	Lilie	LP1027	12V		ein/aus	datenblatt
Speicher S2							
V40.1	Regelventil Entleerung Speicher 2	GF	Typ EA15	230 VAC 50/60 Hz		0…100%	

This project has received funding from the European Union’s Horizon 2020 research and innovation Programme under grant agreement 101000801.