Low valued energy sources UPgrading for buildings and industry uses

LowUP Commissioning and Startup Relevant environment 2

Deliverable D4.13

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About LowUP

LowUp – Low valued energy sources UPgrading for buildings and industry uses – is developing efficient alternatives to supply heating and cooling for building and industries, based on the use of renewable free energy and heat recovery from non-valuated residual energy sources that are currently wasted. As a result, these technologies will contribute at reducing significantly CO_2 emissions and primary energy consumption, and increase the energy efficiency in buildings.

Led by the Spanish firm ACCIONA, the LowUp project gathers 13 partners (3 large companies, 3 research and technology organisations and 7 SMEs) from 7 European countries. During 48 months, the consortium will develop efficient alternatives to supply heating and cooling for buildings and industries based on renewable free energy as well as non-valuated wasted thermal sources:

- 3 technologies will be developed and demonstrated: one heating and one cooling system for buildings, and one heat recovery system for industrial processes.
- The three systems will be demonstrated at four demo sites: a pilot office building in Seville (Spain, ACCIONA Construction); a water treatment plant in Madrid (Canal de Isabel II & ACCIONA Water); a Pulp and Paper mill in Setubal (Portugal, The Navigator Company); and a student hall in Badajoz (Spain, University of Extremadura).

For more information visit: www.lowup-h2020.eu

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Executive Summary

This report (D4.13 "LowUP Commissioning and Startup Relevant environment 2") has been elaborated within the LowUP Project (GA #723930) and provides the description of rules and procedures for a successful design, integration and installation of all the devices, systems, subsystems, including primary equipment and auxiliary devices that have to be designed for the Madrid, Setubal and Tecnalia demo site according to Spanish and Portuguese regulations.

As a **result**, here is presented a start-up of the components that composes different installations at component level and finally, at system level, describing how equipment and units were integrated in order to achieved expected performances of operation.

Keywords

Industrial heat recovery, monitoring, control of energy systems, high-temperature heat pump, rotary heat exchanger

List of acronyms and abbreviations

API	Application Programming Interface
BAS	Building Automation System
BACN	Building Automation and Control Network
BAU	Business-as-usual
BEMS	Building Energy Management System
BMS	Building Management System
HVAC	Heating, Ventilating and Air Conditioning
HX	Heat exchanger
JDBC	Java DataBase Connectivity
ODBC	Open DataBase Connectivity
PCM	Phase Change Material
PLC	Programmable Logic Controller
REST	REpresentational State Transfer
SOA	Service-Oriented Architectures
SWHR	Sewage Water Heat Recovery
WC	Water-Cooled
WWTP	Waste Water Treatment Plant

1   Introduction

The procedures stated in this Commissioning and Start up procedure cover the activities in preliminary tests and inspections, functional performance tests and the commissioning of newly completed installations and existing ones after major alteration.

The idea of this report is giving information about all activities undertaken from the placement of technology up to delivery in operation conditions, in order to have a base for future implementations.

This report will describe how HReX technology, integrated in a multifunctional plug & play skid and installed in two different environments, has been tested, fixed and started up in all its components.

On other hand, all activities undertaken for the HP units, which cover the most difficult part of HP LowUP solution, will also be described.

2   Rotating heat recovery system

In this section, it´s going to be explained how was the commissioning and start-up of the Heat recovery system installed in EDAR Arroyo Culebro Cuenca Baja, located in Getafe (Madrid) in Pulp & Paper factory of Navigator company in Setubal.

The demo at WWTP in Madrid has been used as real environment test bench to validate the operation of RHeX with a fluid with high density and viscosity, so with high potential of causing fouling problems in traditional heat exchangers.

The demo of P& factory in Setubal is more oriented to show reliability of the system when installed in aggressive and corrosive environment which require expensive technologies for contention or continuous maintenance for preventing damages.

RHeX pretends to be a more efficient and operation cheaper solution for these fluids which require tailor made technologies for these plants which have to deal with fluids with a lot of suspended particles and potentially corrosive chemical components.

2.1   WWTP – Madrid

First at all, is shown the P&ID of the system to identify each component and its position, it must be underlined how the commissioning was made for the skid, which includes control & monitoring, heat rejection, heat exchange and fluid circulators, as shown in picture below.
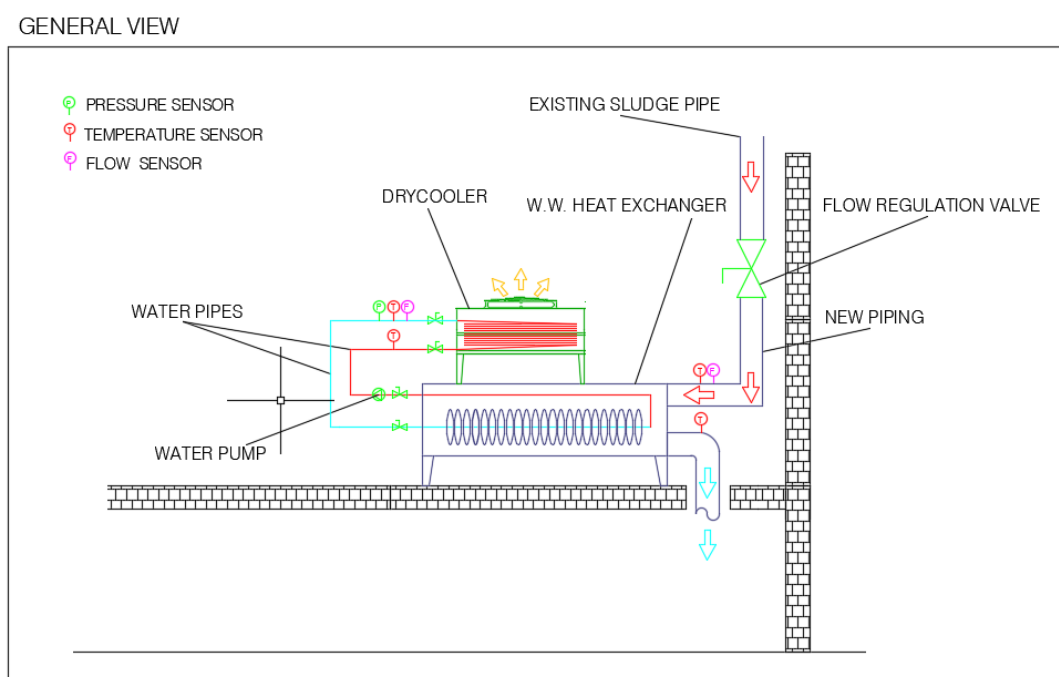
Figure 1. PI&D of the installation

2.1.1   *Commissioning at component level*

Once all equipment was installed in the skid, at factory before shipping, the first thing to do was integrating in the facilities, as described in previous deliverables. It was necessary install the skid over the line between the anaerobic digester and decanting pool in the outlet of effluent stream.

In order to increase the validity of tests, fluid the fluid has been taken directly from the digester, instead from the outlet, in order to operate the heat exchange from water-sludge to clean water and so adding high component of suspended material (sludge).

Next figure shows the skid installed in its final position in this environment.

Figure 2. System installed

2.1.1.1   *Rotating Heater exchanger*

The RHeX is placed in the lower part of the skid and is fed in primary loop by water-sludge directly coming from the biodigestor, without any pumping system because using the static head by the height of the biodigestor itself.

Figure 3. Heater exchanger integrated in the skid

RHeX works with primary fluid by gravity, so extremely attention was paid in validating that the installation of the skid was perfectly horizontally, which allows the correct flowing of sludge from inlet to outlet.

Before starting with the sludge, the primary loop of RHeX was filled with water, to test the integrity of the metal pool, of lenticular discs, of the rotor and the absence of obstructing elements along the direction of the flow.

Mechanic physical elements for draining the pool from excess of filling were checked as well as the level sensors; on other hand, visual inspection of rotor shaft and bearing was taken prior to activation of the rotating system of RHeX.

Figure 4. rotating shaft

For controlling the rotation of the shaft, an electric motor is powered by VSD driver for frequency variation; first verification was the correct sequence of electric phases inlet and outlet of the VSD, then the correct voltage of power supply and the correct operation of overcurrent and short circuit protections.

Then rotation of the shaft was forced with manual control of the VSD driver, checking correct way of rotation, starting with low frequency until reaching nominal speed in time frame of 30 minutes, always with water as primary fluid, instead of effluent.

Once verified the operation with water, the sludge is progressively introduced in the RHeX with water, through the same pipe, reducing proportionally water during time, until having 100% effluent as inlet primary fluid in the pool, keeping the shaft rotating. It was verified that flowing of effluent was correct and without obstruction, as expected.

2.1.1.2   Dry cooler

The drycooler is used for rejecting heat in the environment via passage of air through water coil, so most important things are 1) the operation of the fans, with bottom-up air flow, at different speeds, and 2) the sealing of the coil water loop, for avoiding leakages and allowing proper water flowing.

For controlling the rotation of the fans, individual electric motors are powered by VSD driver for frequency variation; first verification was the correct sequence of electric phases inlet and outlet of the VSD, then the correct voltage of power supply and the correct operation of overcurrent and short circuit protections. Then a visual inspection of the fans and of the coil to check absence of obstruction elements.

The rotation of the fans was forced with the manual control of the VSD driver, checking correct way of rotation, starting with low frequency until reaching nominal speed in a time frame of 5 minutes; then

acceleration and deceleration ramps were implemented with a total cycle time of 5 sec, from 0 to 100% (and viceversa).

Differently from the shaft, fans can achieve high rpm, so at maximum speed it was checked that the skid was not suffering vibration for any unbalance of rotating elements.

Figure 5. Dry cooler at Madrid WWTP

It was checked that air flow would move proportionally to fan speed, without affecting the operation of other elements of the speed.

In next section, filling of the primary water loop is described including commissioning of water pump.

2.1.1.3   *Water loop and circulation Pumps*

Circulation pump is installed in line with primal loop piping; it includes in the motor a VSD regulator, which is embedded in the electric motor over the pump body. Most of problems come if the rotor works in dry conditions for absence of water or for excess of air in the loop; so, before starting the pump, a preliminary filling and purging was mandatory.

Electrical connection was revised according to sequence of the electric phases, in voltage and in circuit breakers; once filled the loop, first start was achieved at minimum speed, checking the sense of rotation and the direction of the fluid. No leakages were detected along the loop.

Figure 6. In line Water pump

Clean water loop, or secondary loop of RHeX, is also used as primary loop from the dry cooler and is a closed loop for transmission of heat from sludge to air. It is composed by plumbing elements like valves, piping, expansion tank, safety system, etc… and it's integrated with sensors and actuators necessary for the operation of the skid.

Filling the water loops is achievable through a pressure reduction valve installed between the expansion tank and the piping, while air purge can be achieved only with a valve installed over dry cooler manifolds.

The first thing made, was to fill the water circuit 1.5 times the maximum operating pressure and leave it for around 30 minutes, then it was verified that the pressure did not drop more than 0.6 bar and that no cracks appeared.

Purging the loop was the most complex activity, because a lot of air is trapped in the upper part of lenticular discs, which are in the lower part of the skid; so purging must be achieved through a long period, which includes operation of the pump of the shaft at different speeds. The entire operation has required more than a week of recirculation and had to be repeated each time the loop requires a refill.

2.1.1.4   Control and automation components

The system is composed by a plc to which are connected all sensors and actuators; the plc is connected to an embedded pc where is host the SCADA for the control. All the monitoring components were connected to the PLC, and once all the connections had been checked, they were first tested manually and then through the PLC / SCADA.

The flowmeters could be tested manually through the built-in screen and with the start-up of the water pump. Once verified manually, the equipment was checked by means of the readings in the PLC. It was

verified that the connection of the flowmeter with the PLC was not correct due to a failure in the equipment power supply. This problem was fixed and the reading was verified to be correct.
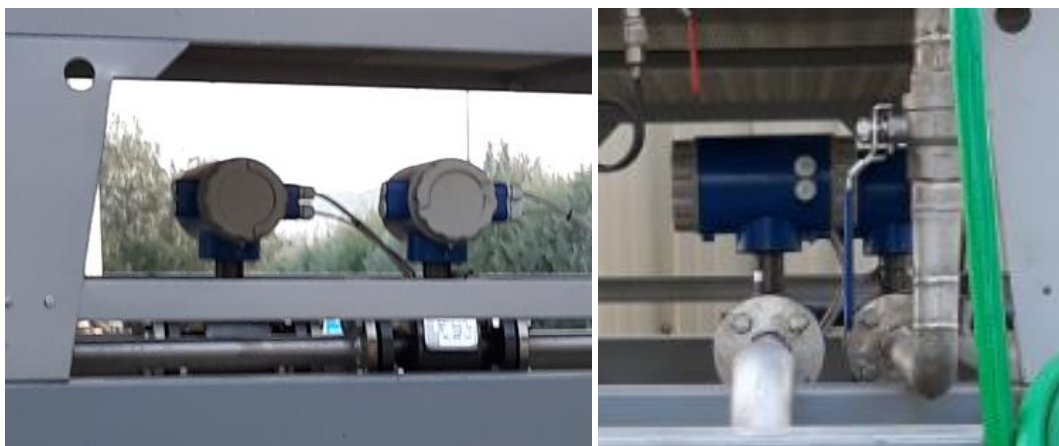

Figure 7. Flow meter installed

To verify the temperature sensors, it was necessary to do it from the PLC / SCADA; therefore, after connecting the temperature sensors, from the SCADA temperature changes were verified at the different points where the temperature sensors were distributed.

The following image, it shows temperature sensors distributes in the installation.
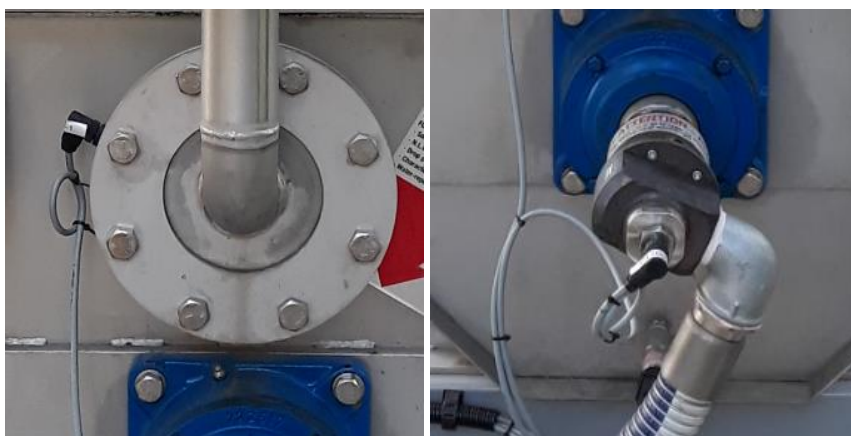
Figure 8. Temperature sensor

The PC is the bridge between the plc and the 3G router used for remote connection with Seville supervisor and database; so automatic restore of the system in case of power failure had to be configured on all devices, maintaining the skid in safety conditions during rebooting activities.

Communication with the remote LowUP supervisor was also configured with slave-master hierarchy over internet for data transfer; for safety reasons, a remote access to pc and so to SCADA was also configured, in order to have real time connection for remote recommissioning.

All this equipment are shown below:

Figure 9. Inputs/Outputs PLC (Left), PC (Center) and 3G router (right)

Due to the nature of the demo, characterization test had to be done automatically, for operating when environment conditions would make air heat rejection possible; a specifically developed java software was used to communicate different setpoints for pump, drycooler and shaft according to planned tests. The software was tested in communication with SCADA and in proper right interpretation of environmental conditions, before at lab level and then at skid level.

With this equipment, it was possible to start up the installation at the system level, which will be explained in the next section.

2.1.2 Commissioning at system level

Once hardware side was commissioned (switching on/off, direction of rotation, speed variation, sensors measurement and communication), next step was the software that control the skid. This section explains software and each part to manage the system.

The software used for these tests were SCADA, for making test in real time locally, and java software, for making test remotely automatically. SCADA was the first to be checked, in order to see if at supposed working conditions the skid was able to match required performances.
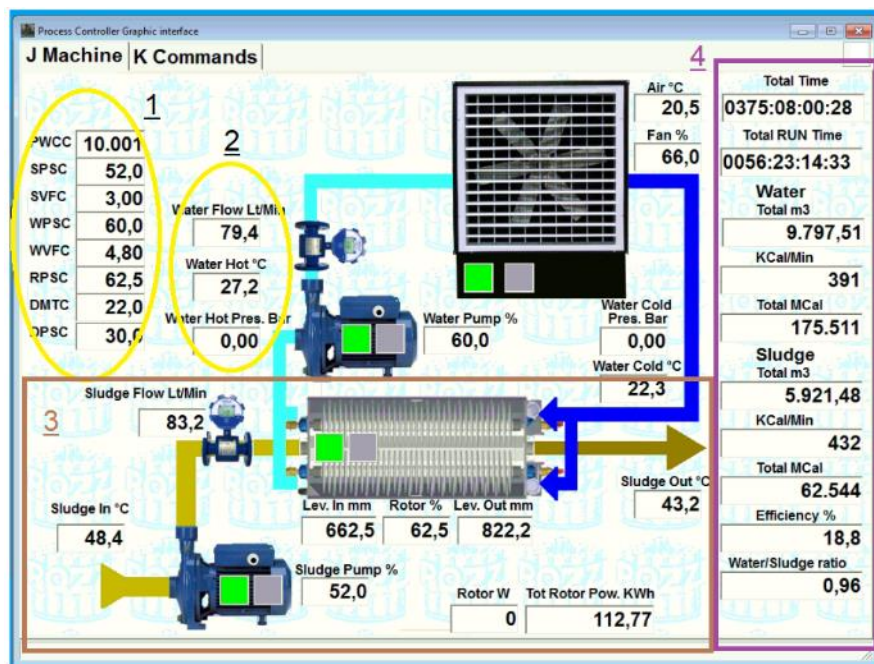

Figure 10. SCADA software

In the last figure, software window is divided in different parts, see below:

1. Parameter to manage the system: Rotor speed, Water Cold temperature, Sludge and water pump flow.
2. Information parameter of water circuit
3. Sludge information: Sludge pump, Heater exchanger rotor speed, temperature sensors.
4. General information: water circuit energy, sludge circuit energy, efficiency of the system.

With this interface, the user is able to modify setpoint by setpoint, until achieving desired operation; the installation was started manually, but it was necessary to test all the commands to control the system remotely and checking how single devices and the system as a whole would behave.

The first thing was to check the sensors readings distributed throughout the system, which were checked with the analogic sensors installed as described above (temperature and flow). It was confirmed that reading of the sensor corresponded to correct magnitude and to correct position.

After the checks on the readings, the write variables were checked, specifically, sludge pump speed, water pump, HReX rotor and dry cooler speed. It was confirmed that writing of the actuators corresponded to correct magnitude and to correct device.

This verification was preliminary to automatic implementation of pre-designed strategies; to each strategy correspond a specific way of operation of each device, which in most of the cases is associated to a PID for regulation of the actuator. The following table shows the different operating modes of the system that were used for the tests; working mode corresponds to PWCC of the SCADA.

Table 1. Heat recovery system working mode.

Working Mode	Description	Water Pump	HX Rotor	Dry Cooler
00000	Plant OFF	OFF	OFF	OFF
10111	PLANT ON	ON	ON	ON
11011	PLANT ON	**Fixed Speed**	ON	ON
11101	PLANT ON	ON	**Fixed Speed**	ON
11110	PLANT ON	ON	ON	**Fixed Speed**

To be able to set speed values in the different devices, it was necessary to set different working modes and then write the speed variables and check through the flow meters, the flow rates in the pumps and speeds in the HEeX rotor and the dry cooler.
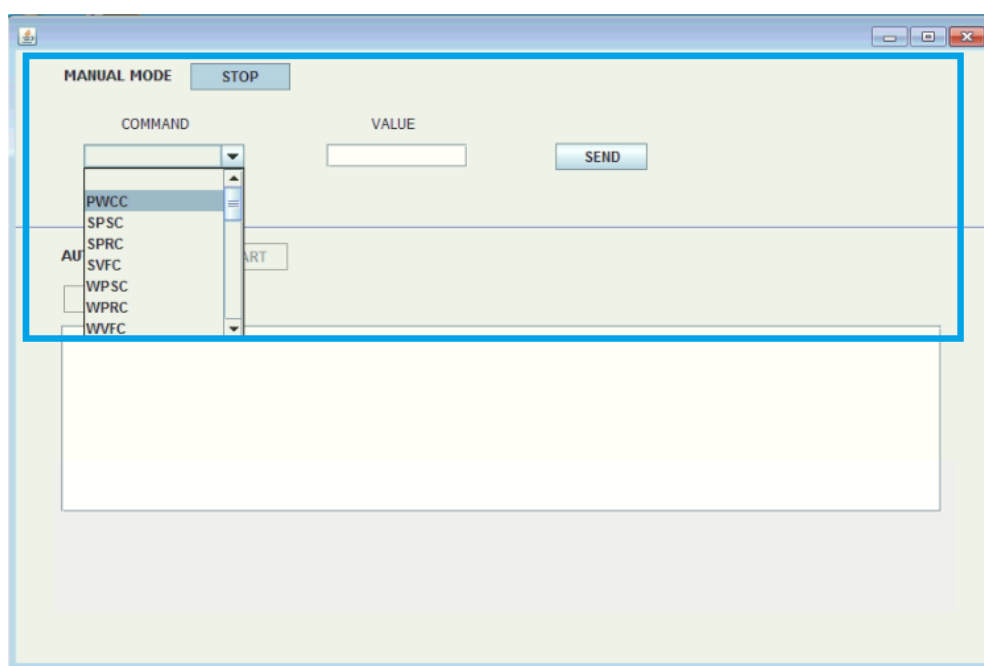

Figure 11. User interface for manual mode in java software

Manual mode means defining which actuators work and at which setpoint; semi automatic means to select the operation and define the setpoint; automatic mode means that all strategies of operations are pre-programmed and automatically executed by the java software.

In Automatic mode it is enough switching on, and that Java app is going to launch many various tests. The automatic mode changes the different values of the installation to be able to do all the possible tests and cover all the use cases.
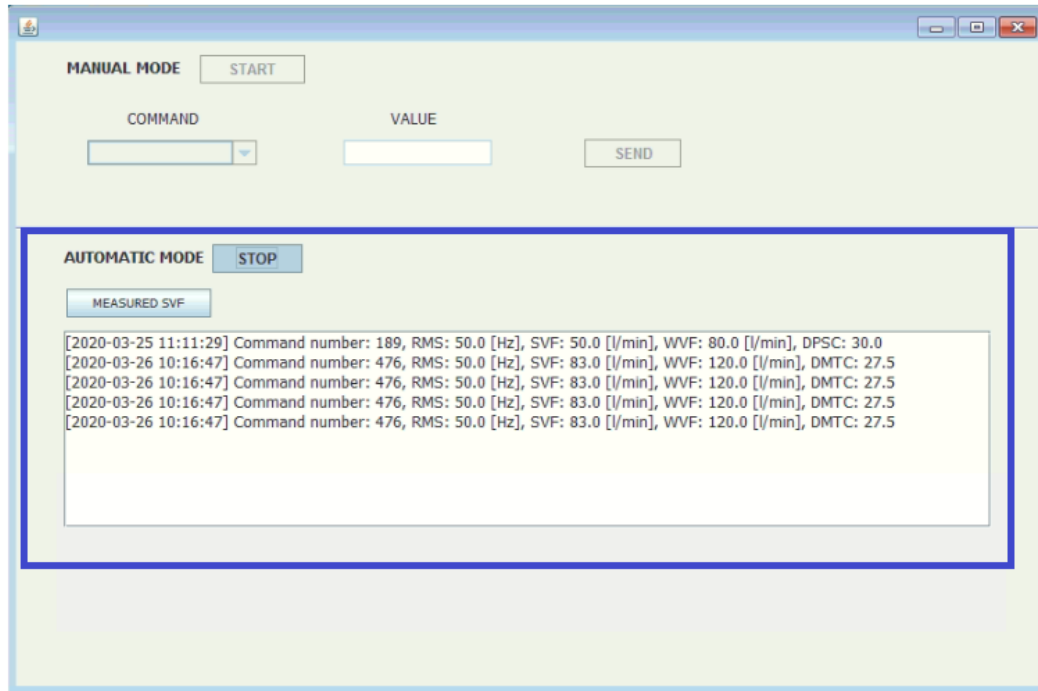
Figure 12. Automatic mode

Testing was based on validating all modes of operation and the reliability of the java software in sending correct writings to the SCADA. Once SCADA as well is verified, what is missing is the calibration of the PID regulating fan, shaft and pump.

2.2 Pump & Paper Factory - Setubal

First at all, is shown the P&ID of the system to identify each component and its position, it must be underlined how the commissioning was made for the skid, which includes control & monitoring, heat rejection, heat exchange and fluid circulators, as shown in picture below.

Figure 13. PI&D of the installation

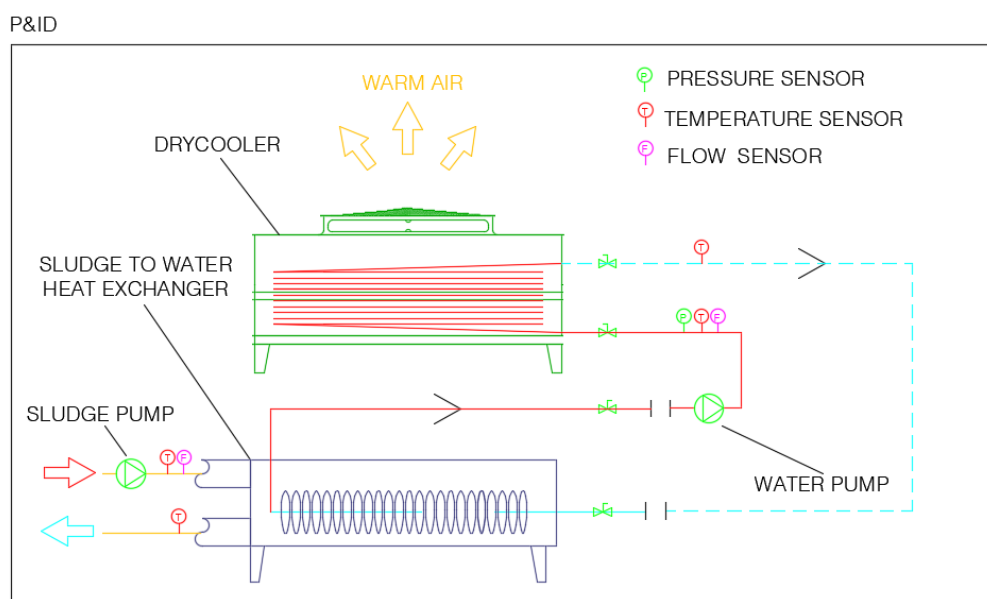Setubal and Madrid skids are technological twins, exception for the effluent way of feeding; so, all activities undertaken for common elements will not be repeated in this section. Focus will be on differences encountered during commissioning.

2.2.1   Commissioning at component level

Once all equipment was installed in the skid, at factory before shipping, the first thing to do was integrating in the facilities, as described in previous deliverables. It was necessary install the skid at the end of gathering pipeline for the residual effluent outcoming from the factory, which corresponds to the beginning of local WWTP, in the decanting pool.

In order to increase the validity of tests, fluid the fluid has been taken directly from one specific point of the pool, where concentration of pollutant is the highest, in order to test the resistance of the RHeX to such corrosive and aggressive environment.

The pool is divided in 2 part: the principal where the effluent arrives directly from the factory for being stabilized and for decanting most of suspended particles, and a secondary which is not accessible from particles for effect of decantation in the primary zone. The RHeX pumps the effluent from primary zone and returns it just before secondary zone.

Next figure shows the skid installed in its final position in this environment.

Figure 14. The skid placed and the two different zones of the pool

2.2.1.1 Rotating Heater exchanger

As it can be seen, the RHeX is placed for both skids in the same position and the activities undertaken for this demo was totally similar that ones already described for Madrid demo, so please refer to previous sections.

Figure 15. Heat exchanger installed

2.2.1.2 Dry Cooler

All procedures for drycooler of Madrid can be applied to Setubal skid, so please refer to previous sections.

Figure 16. Dry cooler installed

2.2.1.3   Loops and circulation Pumps

There are two options for filling up the clean water loop: the first one was from a pressurized tank, while the second one was by fireman truck (no close network to the skid). In order to overcome this situation, the most suitable solution was to make use of the private fire brigade of the Navigator Company.

Next figures show process of filling.

Figure 17. Filled from fireman truck

Filling and purging activities had to be run at the same time, because of evident impossibility to have an automatic re-filling in case of loss of pressure; before filling all other components of the skid have been previously deeply tested, in order to save time and avoid possible problems with pressurized water.

This activity with the truck have been repeated 3 more times in different weeks, in order to maintain the right operation pressure. All activities of commissioning related with water loop and water pump have already been described in previous section. The pipe is connected to the skid via steel reinforced flexible plastic pipe.

Effluent loop is fed by submerged pump suspended in the pool though a steel cable hanged from a metallic post, which was specifically installed for achieving the installation of the pump on the most relevant part of the pool. This post allowed also the proper positioning of the plastic pipe avoiding obstructions and consequent overpressure.

Figure 18. Effluent piping

Sludge pump was submerged in the sludge once electrical connections were tested about voltage current and circuit breakers, and then it was started up and it was running for relevant period. Different speed test have been checked until finding out minimum necessary speed for winning piping head and the maximum for feeding the HReX within correct operation range.

When others verifications were being made, pump was submerged in the pool through the help of the post and handling the flexible pipe manually for facilitating the operation. Once verified that no obstacles were affecting the placement of the pump, the pump vas hanged few centimetres from the basement of the pool, in order to be exposed to decanted suspended particles, but not totally submerged.

During test for identify the proper position in the pool, the security cable what keeps sludge pump in suspension broke, and it had to be fixed.

Figure 19. Security cable broken

Pump was squeezed out of sludge and suspension system was fixed by Navigator staff, then, pump was submerged again and started up.

Following normal start-up after some problems, different components were set in manual mode to check its parameters and its performance. Frequency variable drive from the sludge pump was tested in manual mode changing its parameters by hand in the cabinet. Sludge flow increase and decrease was observed in flowmeter and sludge pipe and that verification was checked ok.

Next figure shows the device returning sludge to the pool of sludge after passing it through the heat exchanger.

Figure 20. Heat exchanger returning sludge to the pool

All procedures for water pumps of Madrid can be applied to Setubal skid, so please refer to previous sections.

2.2.1.4   *Monitoring components*

Flowmeters distributed in the installation allow us to see the circulating flow through each of the circuits (primary and secondary), and they were checked before installation.

Figure 21. Flow meter of the installation

Firstly, this equipment were visually verified through their screen and later, once the connection to the PLC was made, their operation was verified.

The installed temperature sensors were directly connected to the PLC and their operation was verified once the hydraulic circuits were operating normally.
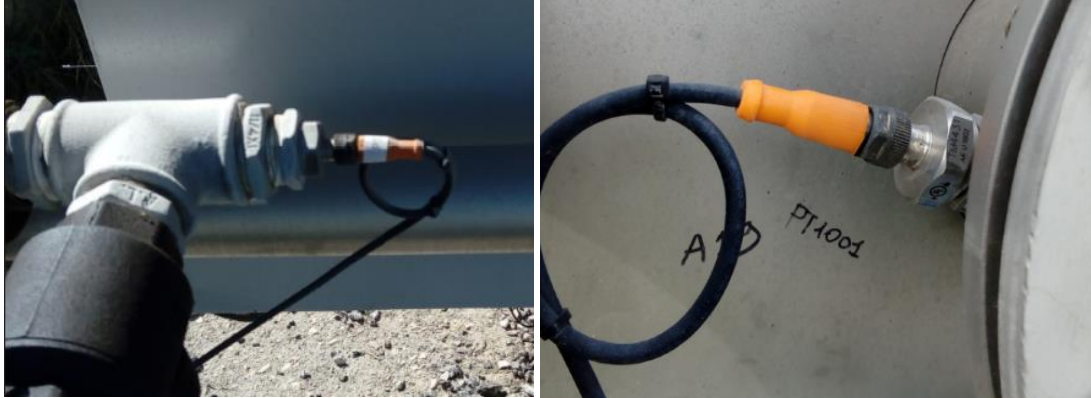

Figure 22. Temperature sensor

After few days, aggressive environment, wet and dusty atmosphere damaged some components of the system. Next figures show the aggressive environment inside the plant.

Figure 23. Aggressive environment

That situation produced some damages in Master PLC mainly. Master module of the PLC burned and had to be replaced for new one, and also in/out modules had to be replaced.
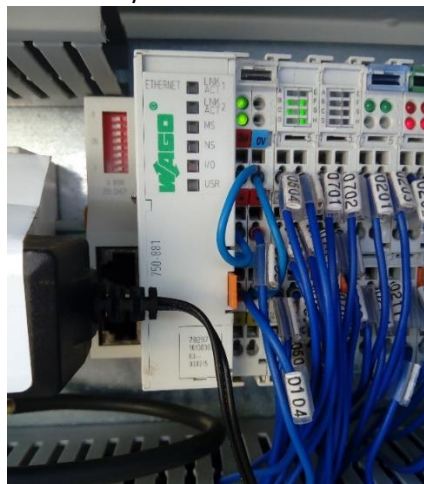

Figure 24. PLC module replaced

Almost together in time, embedded computer suffered some problem and had to be replaced for a new one as well. Next figure shows the embedded computer replaced.

Figure 25. Embedded computer replaced

So, with these important problems occurred in few days, it was important to make the electric cabinet vapour tight even if maintaining a minimum degree of ventilation for heat removal; so most of holes in the electrical cabinet was covered.

Figure 26. Electrical cabinet´s holes covered

A protection against aggressive environment was taken in the electrical cabinet, and it was installed a plastic screen to protect it.

Figure 27. Protection installed in electrical cabinet

Other important problem found in the system was bad reading of temperature sensor after few days, and this situation believes was provoked by aggressive environment. The first step taken is, removing,

cleaning with antioxidant products and overprotected from corrosion with a heat-shrink tubing, as it is can be observed in the following figures:

Figure 28. Sensors removed and cleaned

However, this action does not give the expected results, and the probes are replaced by probes with an integrated 4-20 mA transmitter.

2.2.2 Commissioning at system level

Once installation side was started up, next step was stated up software what control the system developed by Pozzi. Activities experimented in Madrid were replied totally in Setubal, with the introduction of the waste water pump instead of manual valve.

Table 2. Heat recovery system working mode.

Working Mode	Description	Sludge Pump	Water Pump	HX Rotor	Dry Cooler
00000	Plant OFF	OFF	OFF	OFF	OFF
10111	PLANT ON	**Fixed Speed**	ON	ON	ON
11011	PLANT ON	ON	**Fixed Speed**	ON	ON
11101	PLANT ON	ON	ON	**Fixed Speed**	ON
11110	PLANT ON	ON	ON	ON	**Fixed Speed**

The integration between java software and local SCADA was efficiently achieved in Madrid and procedure was totally replicated; the pump was already verified so the automatic operation started easily. For all procedures, please refer to previous sections.

3 High performance Heat Pump

3.1 Tecnalia demo

The demonstrator of Tecnalia is a thermal lab used for characterization of HVAC equipment, so it highly technological in terms of hardware (piping and electricity) and already provided with distributed control system for centralized supervision.

Here below is presented the P&ID of the installation of the HP with respect to heat and cold sink, as described in previous deliverables.
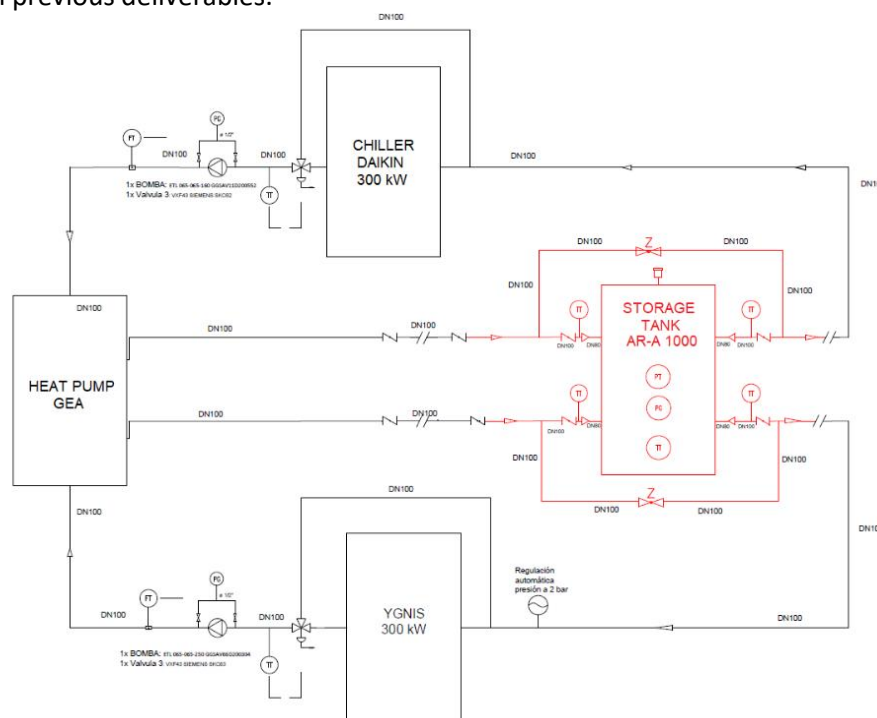

Figure 29. P&ID of heat pump installation

3.1.1 Commissioning at component level

The heat pump represents the highest level of technology developed within the project, not only for the mechanical components for such size of compressor, but also for the control system designed for the optimization of performance according to project conditions.

Furthermore, the heat pump defers from the HReX skid for the simple fact that the containerized solution is integrant part of the development of the project, while the skid is part of the integration but not part of the development. So, hosting container must be commissioned as well as integrating part of HP solution.

Even more, HP was not tested at factory, when HReX was; this previous test of the manufacturer saved a lot of time during start-up at relevant environment.

3.1.1.1 Preliminary checking

Skids container located on level bench, with water pipes (condensation and evaporation) connected in the absence of opening valves. It is necessary to carry out an electrical connection, (general panel and leak box), mounting the leak box, motor-compressor alignment, oil charge, pressure test with technical nitrogen, NH_3 charge and initial start-up of the unit.

The container was not anchored to the ground, so it was painted around the supports to check in some way that the container does not move due to the vibration emitted by the compressor.

3.1.1.2 *Electrical checking*

Assembly of a leakage box making the electrical connections and electrical supply. Wiring is installed for voltage disconnection in the event of a leak. As there is no circuit breaker in the connection supplied by panel, this operation will be done manually with this wired alarm.

Figure 30. Electrical box in the container

A piece of wood is removed from the ventilation grilles and extraction fan. It is observed that if it´s raining, the water falls into the container. . A defense grille to the extraction fan was installed on the outside and a small canopy to prevent rainwater from entering the container was mounted.

Figure 31. Rainwater inside the container before works

There is a large entrance of outside air through the grille, not being able to heat the room with the existing heater, one more is added. Half of the grille is covered, thereby reaching the minimum room temperature.

Electrical wiring supply of the extraction fan hadn´t correct characteristic and it was necessary changed because this electrical cable runs inside the container.

Figure 32. Electrical cable before works

It is observed by testing the operating performance that the relay of 970KA4A does not give a trip output; this is due to the switched contact of relays 970KA2 (11-12-14) and 970KA4A (11-12-14) do not

act, requiring the use of another free contact in 970KA2 (21-22-24). Changing of relay 970KA4 (41-42-44) electrical connection from 970KA4A relay because of it does not have free contacts. Both relays are in parallel. Changes in electrical scheme are corrected.
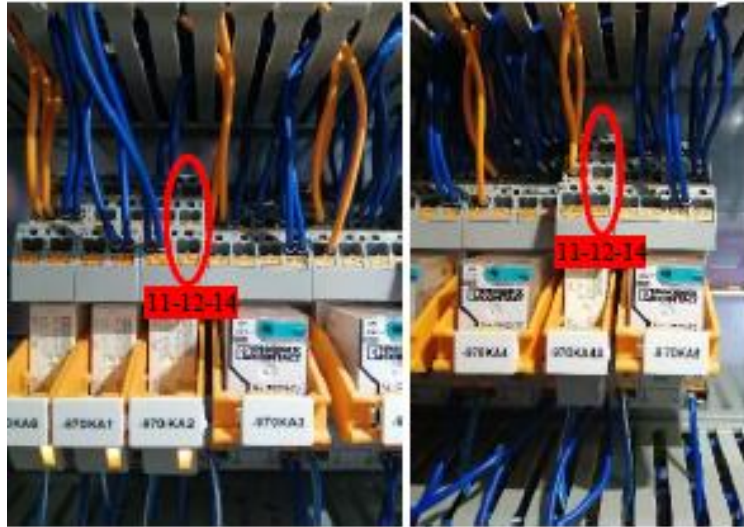

Figure 33. Relays with fails

Mounting of pH electrodes, leaving these with mineral water and shut-off valves closed. Parameters are calibrated and configured in JUMO AQUIS 500 and PT100 sensor are installed in both devices.

After filling the hot and cold water lines and after a few hours with the recirculation pumps running, the JUMO valves open at a water temperature of 35ºC. The Ph rises from 6.98 to 8.30. The pre-alarm value is configured in OMNI at 9.50 and alarm at 10.00.

Correct performance of the ammonia detection and extraction system was checked.

Figure 34. PT100 installed (left) and JUNO AQUIS 500 installed (right)

GV sensor calibration and alarm with pre-alarm adjustment as established by manufacturer. Calibration adjustment is performed in a clean and ventilated environment. After calibrating the detector, an alarm is triggered with NH_3 operating the system correctly.

Different calibrations are listed below:
- 1. Voltage test 5V (1) .
- 2. GV sensor value 5V (2).
- 3. Prealarm level 500 ppm – 1,75V.
- 4. Alarm level 3000 ppm – 2,6V.
- 5. Detector working correctly.
- 6. NH3 leaking alarm checked. Fan running.

Figure 35. Different calibration listed above

Figure 36. Different calibration listed above, (5) and (6)

3.1.1.3 Mechanical checking

Then, other important thing was made as motor-compressor coupling and alignment leaving it below tolerance limits.

Figure 37. Radial and axial alignment

Next step was a leaking test with dry nitrogen at 18 bar. During this process it was found a small leak in safety valve of the evaporator. It was fixed immediately and tested again.

Figure 38. Pression at the beginning (left), pression at the end 1 day after (center and right)

After checking the tightness for almost 24h, vacuum is carried out by conditioning the container at 25ºC. For this action, it is necessary to cover the ventilation grille again and heat the container with electric heaters. And then, 25 liters of Kübler Summit RHT 100 oil are loaded.
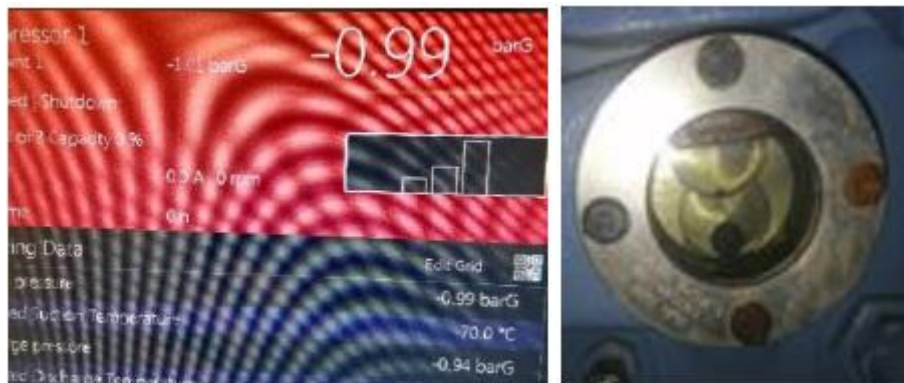

Figure 39. Vacuum at -1 bar (left) and oil level 80% (right)

Electrical performance, electrical and control signals and direction of rotation are checked, detecting faults in the program version. A new version of the program needs to be updated. The oil separator does not exist so this must also disappear with the new version.

After vacuuming for several hours, 48 kg of NH_3 were loaded. For this, it is necessary to heat the bottles with an electric mesh provided by Tecnalia and cool the container to an ambient temperature of 12ºC, starting it manually with a fan and opening the sides of the container.

HB level sensor was configured and calibrated from HB tool. During the calibration this didn´t respond as expected and it was necessary to regulate with the manual calibration to leave this in real values. It was necessary several drained of the level column to actually adjust the level reading.

Figure 40. HB Tool (left) and level column (right)

Once latest version of software was updated, motor-compressor protection is mounted as indicated by GRASSO. The nuts provided do not allow the screws to be tightened due to the machining carried out on them, so these are replaced by M6 nuts.

Figure 41. Protection of the motor-compressor

When it was checked the direction of rotation of the motor, abnormal noise was heard in the variable frequency drive. The cover is removed and a loose connector was seen rubbing against one of the cooling fans, it was fixed at the moment with no delays.

Figure 42. Loose connector inside variable frequency drive

Once the operation of the unit had been checked, the heat pump was started, checking operation with the water temperature at the evaporator inlet 35ºC and the condenser outlet 52ºC. After a few hours of operation, the pump stopped due to an alarm at the HB level sensor. It`s observed that this was at 100% with the level around 30%.

When hitting the lower part of the level pipe, the counterbalance tilts quite a bit from side to side, leaving it very heeled touching the pipe, by hitting it´s possible to leave a reading, but after starting it, it fails again.

The level sensor is disassembled to provisionally mount support blades, centering it as far as possible. It is reconfigured since the reading indicate didn´t correspond to reality and, as the first time, this adjustment is very difficult, without knowing the reason.

Figure 43. Mounting pieces on counterbalance

Again after a few hours of operation, this gave an alarm with the counterbalance centered again, it was observed that this controller was damaged because it had a reading again after small bumps. As the level control is carried out by subcooling, this control is cancelled, leaving in place a fixed level signal (7.5mA) to continue with the functional tests.
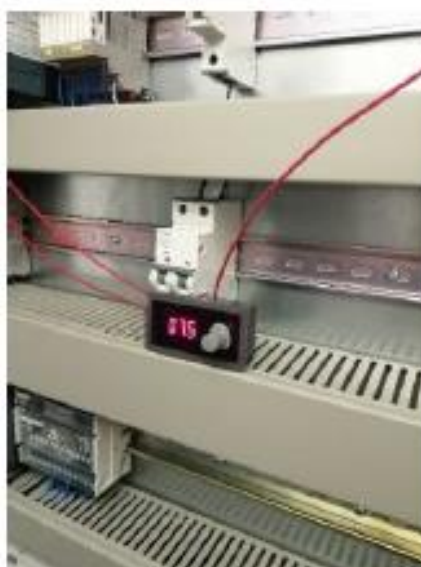

Figure 44. Fixed level signal to supply the sensor

By varying the temperature of the inlets to the evaporator and condenser according to tests, the liquid accumulates in the condenser, protection triggered due to high discharge pressure.

Injection valve didn´t open due to very high subcooling. It was necessary to manually drain this liquid and it was considered that at the moment the inlet temperature to the evaporator didn´t vary since it had been very close to the condenser outlet temperature. (44 and 48.5ºC)

It was started again with a fixed evaporator inlet temperature of 35ºC and only the water inlet to the condenser was varied as we increase the working temperature setpoint keeping 8-10 K of DT. In this way the heat pump works in a very stable way maintaining a subcooling between 0.5 and 3ºC. As the compression ratio increases, it was necessary to raise the water inlet to the evaporator, but this must always be done very gently.

The maximum temperature reached at the moment is 62ºC, it was left in the hands of Tecnalia staff to continue raising the temperature and taking operating data.

The condensation water flow switch was left bypassed because it didn´t work properly, the flow maintained by Tecnalia is in principle good and this is read as such, even with the ultrasonic meter, so it was necessary to replace it.

Then, every pipe and every wire were labelled according regulations, and the result can be showed below.
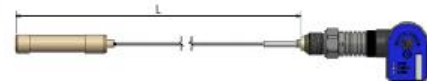

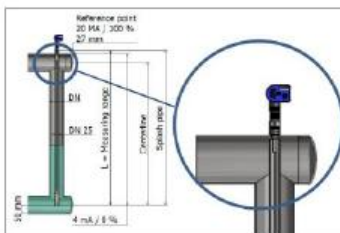**Figure 45. Labels in the wire and the pipes**

The reason why the level sensor fails was unknown, the total length of this is 580mm and the datasheet specifies that the minimum must be 600mm. It was recommended that the replacement of this sensor be for the HBLT-A2 coaxial version. In expert opinion, the operation was more suitable.

In the level displays you can see how ammonia boils due to evaporation.

Figure 46. Technical data from the sensor

Heat pump working correctly without alarms, Tecnalia is in charge of its operation in the absence of GEA and carried out the temperature rise gradually according to specifications. After start-up, HB level sensor and flow switch in the condenser were replaced.

3.1.2 Commissioning at system level

3.1.2.1   User interface

The software that controls the entire heat pump system is managed through an interface that is provided directly by GEA and that can be integrated as distributed system in a slave-master network.

To validate the installation, the control software had to be checked and configured in all its components; for this here below the description of how it must behave and appear. In case of mismatching, modification are mandatory to adapt the software to the hardware of the unit.

For each of the different windows, readings of sensors, alarms, indicators and scale of displayed valued where tested and validated.

This screen displays the most important operating data for the compressor. The gauges shown in the upper portion of the screen display the suction, oil differential and discharge readings; the indicator shown in the bottom left corner displays the current capacity slide valve reading, and the values displayed in the bottom right show the run time, current and rpm of the motor. The rpm reading corresponds to speed of the motor because of VSD.

Figure 47. Classic tab display

The screen shown below will appear when the GEA Omni™ panel is powered on. The central portion of the screen will change depending on the current display of the panel.

The menu bar on the left displays options used for navigation between displays or interfaces. The status bar at the bottom displays important information regarding the status of the panel and its devices. Both the menu bar and the status bar will remain visible at all times.
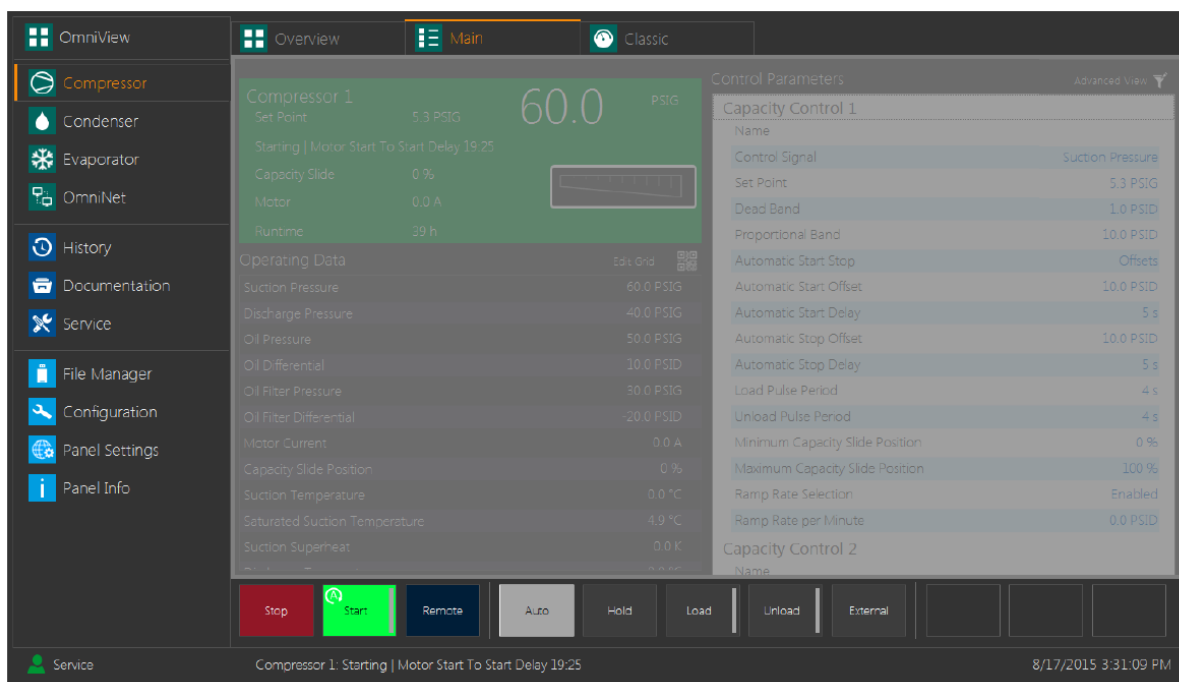
Figure 48. Initial screen

The main OmniView screen will display tiles corresponding to each device controlled by the panel. Each tile displays the name and pertinent information for the associated device.

Compressor

Tiles corresponding to compressors display the name, set point, status and current values associated with the compressor. While the capacity of the compressor is being increased, an upward facing arrow will be displayed in the lower right hand corner of the tile. Similarly, a downward facing arrow will be displayed in the bottom left hand corner of the tile if the compressor capacity is being decrease.

The icon in the upper right hand corner of the tile indicates the type of compressor. The icons are displayed below. The icon on the left is used to indicate a screw compressor, and the icon to the right indicates a reciprocating compressor.
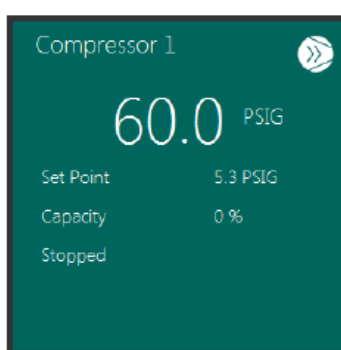

Figure 49. Compressor tile

The Compressor menu is used to control each compressor from the panel. There are multiple tabs which are detailed below. The bottom of the screen contains the eight standard buttons used to control the compressor. Active buttons are illuminated with black text and a white outline while inactive buttons are darkened with white text.
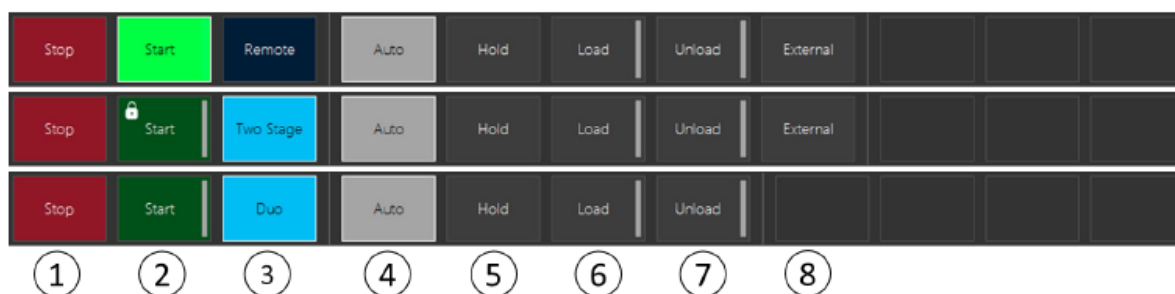
Figure 50. Compressor buttons

This table contains the current values associated with the compressor. The information in the table is divided into three columns. The left column contains the slice location of the value, if applicable. If the row in question does not correspond to a slice location, this column will be blank. The middle column contains the name of the variable. The right column contains the current value and units of the variable, if applicable. The Edit Grid button in the upper right corner of the table will display a fourth column containing check boxes which allows the user to toggle which rows are displayed.

Evaporator

These tiles each correspond to an evaporator zone. Each tile displays the name of the evaporator, the current zone temperature. Depending on the current status of the zone, the tile will also display either the time remaining on the defrost cycle or the temperature set point the zone is in the process of cooling to.
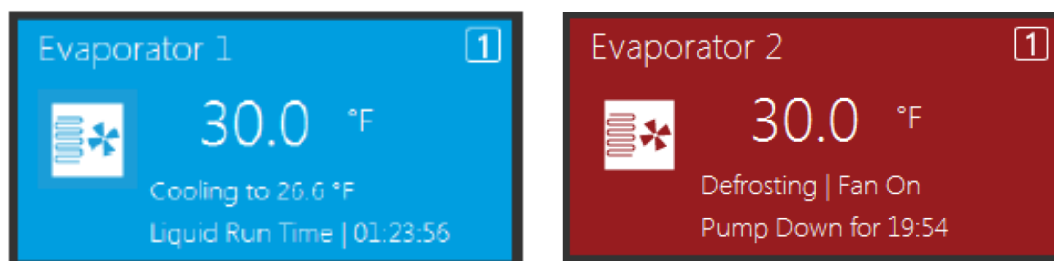

Figure 51. Evaporator tiles

The tile corresponding to the condenser sequencer displays important information relating to the control of condenser devices. The information displayed, from top to bottom, includes:
• Control value
• Set point
• Status
• Current step
• Fans running
• Pumps running

Figure 52. Condenser sequencer tile

Refrigerant Sensors

These tiles each correspond to a refrigerant sensor. Each tile will display the sensor name, the current reading and the range. The colour of the tile indicates the status of the sensor. The colours are:

- Light Green: No Annunciations,
- Yellow: High or High-High Refrigerant Warning,
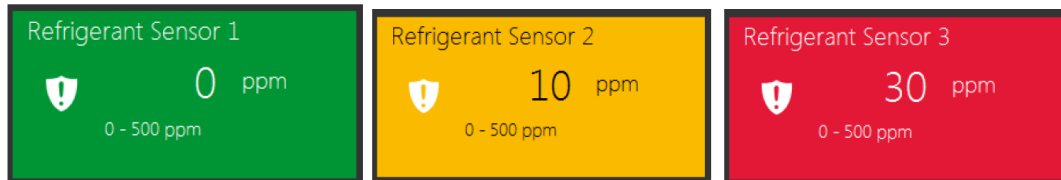- Red: High-High Refrigerant Shutdown.

Figure 53. Refrigerant sensor tiles

Pump Package

These tiles each correspond to a pump package device. Each tile displays the name of the pump package, the current reading of the control value, the current set point, the number of pumps and the type of differential pressure calculation used in the pump package.
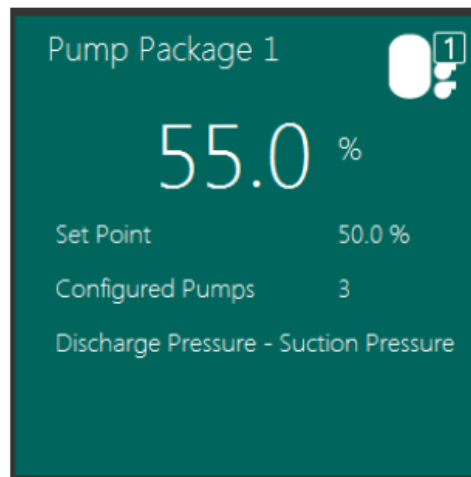

Figure 54. Pump Package Device Tile

One of the most important control in this system is the vibration control, that is showed below. This screen displays information pertaining to the VTrac vibration sensor. It will only be displayed if VTrac is enabled in the configuration of the panel. The data may be displayed in two different formats.

The format currently displayed can be switched by touching the button which is displayed to the left of the options button in the bottom right hand corner of the screen.
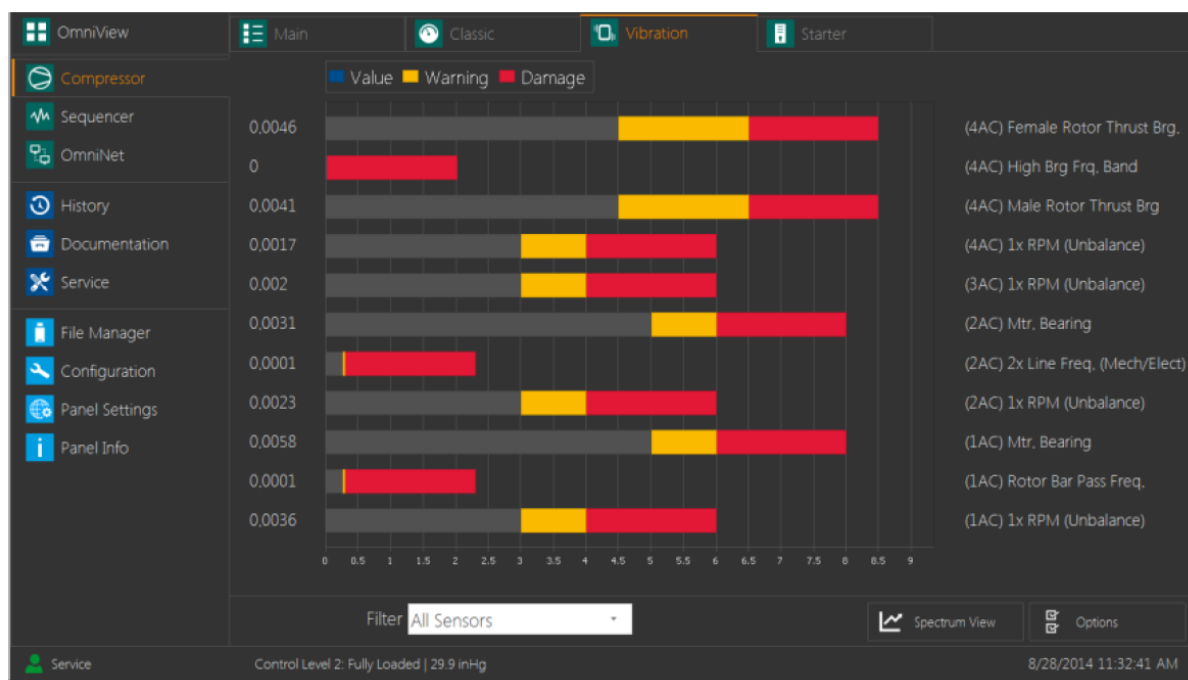
Figure 55. VTrac Damage View

By default, the measurements from all channels of the VTrac are viewed simultaneously. However, the drop down list displayed at the bottom of the screen may be used to limit the display to a single channel. When a channel is selected from the list, the graph will rescale to display only the measurement point or points associated with it.
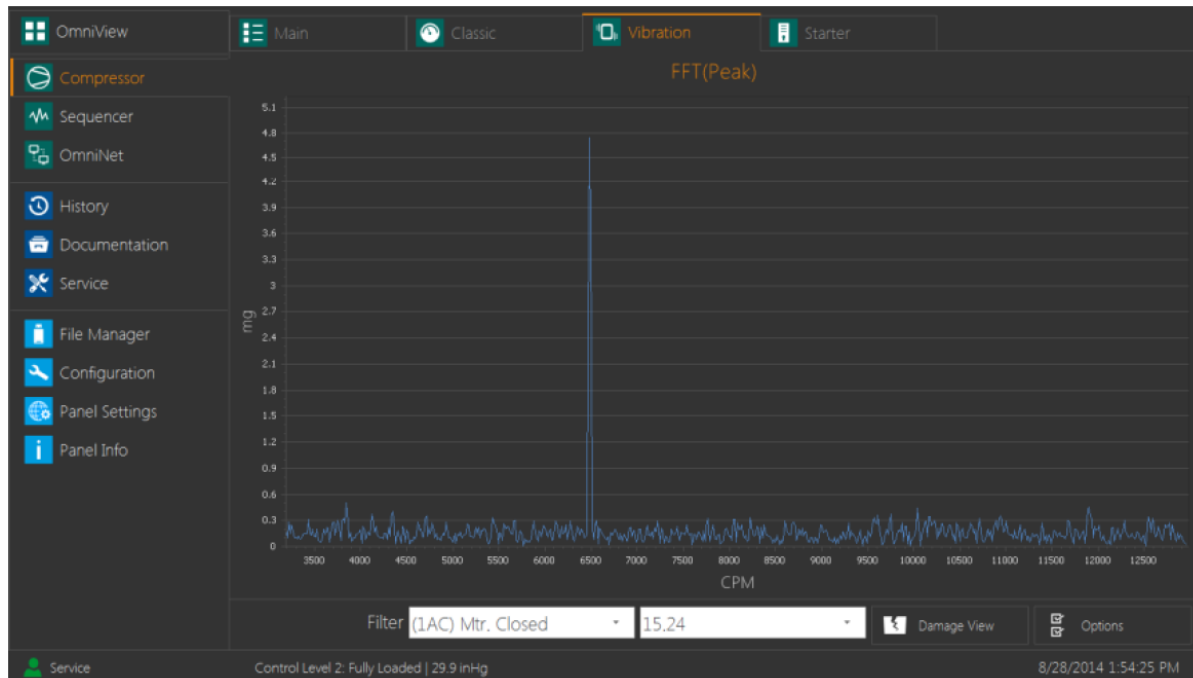

Figure 56. VTrac Spectrum View

The spectrum view, as shown above, displays the raw reading from the channel selected in the drop down list at the bottom of the screen. Multiple channels may not be displayed simultaneously in this view.

The vertical axis of the graph displays the vibration measurement and the horizontal axis displays the frequency. Both measurements are displayed in the current units as selected in the Options screen

described below. The second drop down list is used to select the scale of the measurements. The selected value indicates the distance between each tick on the vibration level axis.

3.1.2.2   Sensor calibration

Now, it´s explained how was the calibration of the system.

3.1.2.2.1   Sensors Tab

This tab is used to adjust the range of sensors monitored by the panel. The table is divided into nine columns. The leftmost column contains an icon that indicates whether the chosen point is an input or output. A green arrow pointing to the right indicates that the point is an input, and a blue arrow pointing to the left indicates that the point is an output.

Figure 57. Sensors Tab Display

The remaining columns are detailed below:
- Channel: The text in this column indicates the slice number and channel that the chosen point occupies in the I/O system.
- Description: This column contains the name of the chosen point.
- Measured: This column contains the calibrated value read from or transmitted to the chosen point.
- Raw Scaled: This column contains the raw signal received by associated sensor scaled between the selected minimum and maximum values.
- Offset: This column contains the value that is added to the reading displayed in the Raw Scaled column to obtain the measured value for the sensor.
- Raw Signal: This column contains the unscaled value received by the sensor.
- Min: This column contains the lowest allowable value for the chosen point during normal panel operation.
- Max: This column contains the highest allowable value for the chosen point during normal panel operation.

Touching a cell in the Min and Max columns will bring up a sub screen which will allow the user to change the range measured by the associated sensor. The Measured column is used during the

calibration process for the sensor. The calibration of the sensors may be reset using the Clear Calibration Data button displayed in the upper right hand corner of the display.

3.1.2.2.2 Pressure Transducer Calibration

1. Ensure that the control panel is in Service Mode and the compressor is Stopped.
2. Touch the cell associated with the Measured value of the sensor in question to bring up the calibration pad shown below.
3. Attach a calibrated gauge or digital multimeter attachment to the service valve of the transducer.
4. Remove the cover and open the service valve.
5. Record the actual pressure on the gauge or multimeter.
6. Use the keypad to enter the recorded value for the sensor. Maximum and minimum limits will be set automatically by taking the current reading and respectively adding and subtracting ten percent of the transducer's range.
   o Maximum and minimum values are displayed at the bottom of the keypad display. If the recorded value falls outside these bounds, it is an indication that the transducer may be damaged, incorrectly wired or of the wrong type.
7. Complete calibration for the sensor by touching the Enter button.
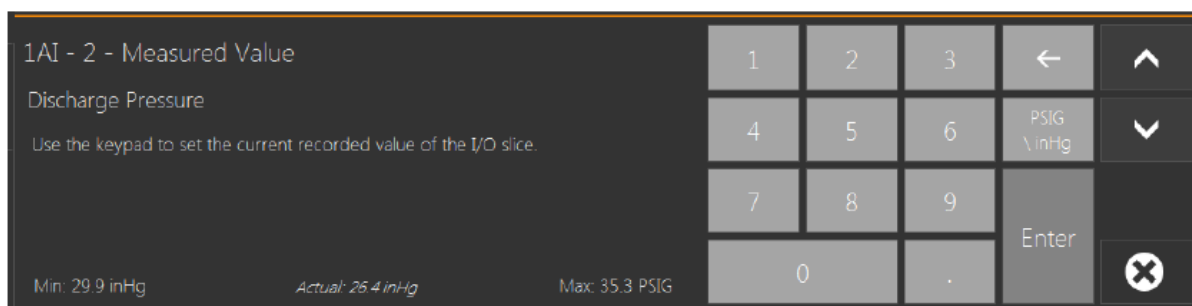

Figure 58. Pressure Sensor Calibration Pad

3.1.2.2.3 ICTD Temperature Transducer Calibration

Integrated Circuit Temperature Detectors (ICTD) temperature sensors should not be confused with other types of temperature measuring devices such as RTDs, thermocouples or thermistors.

An ICTD temperature probe consists of an electronic device that is imbedded in the probe which allows a very small current to pass that is proportional to the temperature of the device. The probe can be calibrated using a single point calibration method because the rate of change of the current passed through the ICTD vs. the temperature is linear.

1. Ensure that the control panel is in Service Mode and the compressor is Stopped.
2. Touch the cell associated with the Measured value of the sensor in question to bring up the calibration pad shown below.
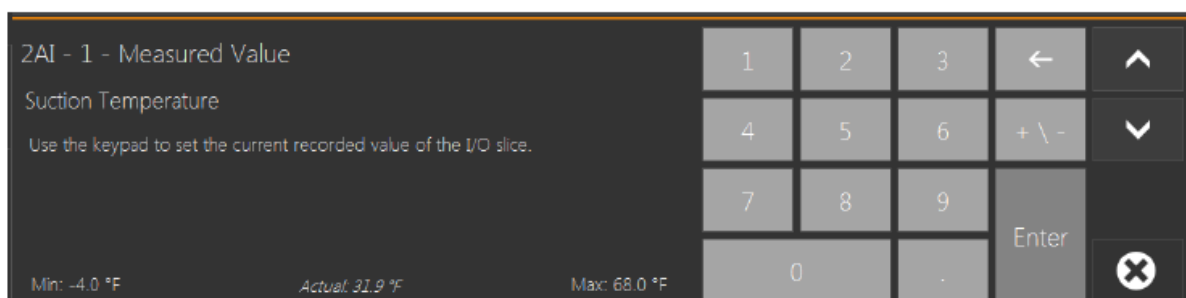

Figure 59. Temperature Probe Calibration Pad

3. Open the electrical box of the sensor.
4. Loosen the screw that retains the hold down tab and rotate the tab out of the way.
5. Remove the temperature probe from the well and immerse it in an ice water bath with a calibrated thermometer or digital multimeter attachment.
   - The ice water should be predominantly ice with just enough water to cover the Ice. The temperature of the ice and water mixture will approach the triple point of the water (~32.02 °F/ 0.01 °C).
6. Allow both devices to stabilize for approximately three minutes in the ice water bath.
7. Record the actual temperature on the thermometer or multimeter.
   - If a calibrated measurement device is not available, the channel should be calibrated to 32.0 °F/ 0.0 °C once the reading has stabilized.
8. Use the keypad to enter the recorded value for the sensor. Maximum and minimum limits will be set automatically by taking the current reading and respectively adding and subtracting ten percent of the sensor´s range.
   - Maximum and minimum values are displayed at the bottom of the keypad display. If the recorded value falls outside these bounds, it is an indication that the transducer may be damaged, incorrectly wired or of the wrong type.
9. Complete calibration for the sensor by touching the Enter button.

3.1.2.2.4   Capacity Slide Position Calibration

Touching the cell associated with the Measured value of the Capacity Slide Position will bring up the calibration pad shown below.
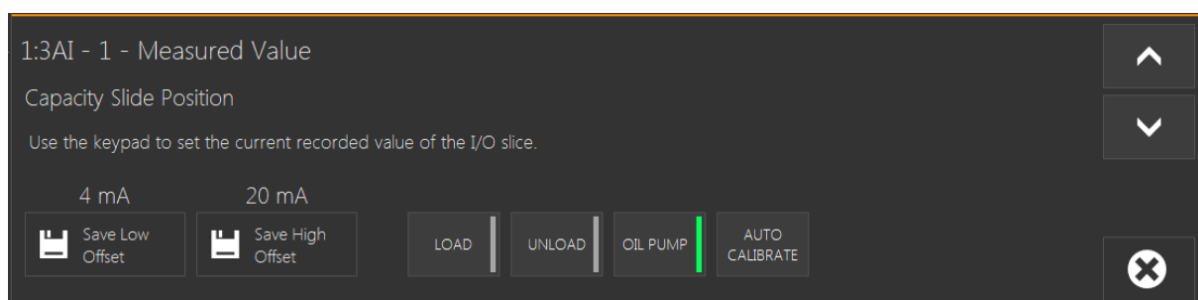

Figure 60. Capacity Slide Calibration Pad

The buttons displayed along the bottom row of the sub screen are used to calibrate these sensors. The functions of the buttons are:

1. LOAD

Touching this button will energize the solenoids to load the sensor to 100 %. Touching it a second time will de-energize the solenoids. While the solenoids are energized the indicator displayed on the right edge of the button will be illuminated green.

2. UNLOAD

Touching this button will energize the solenoids to unload the sensor to 0 %. Touching it a second time will de-energize the solenoids. While the solenoids are energized the indicator displayed on the right edge of the button will be illuminated green.

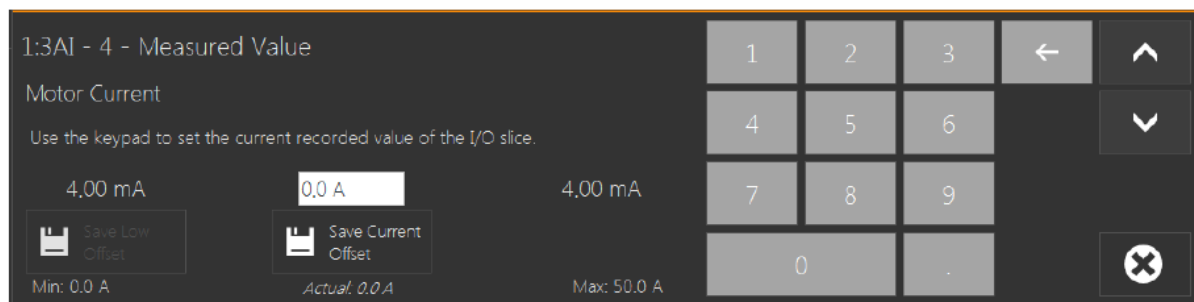### 3.1.2.2.5   Compressor Motor Current Calibration

Figure 61. Motor Current Calibration Pad

1. In the Main Tab of the Compressor Control Screen. Ensure that the compressor motor is stopped and the motor current reading is stable.
2. Start the compressor.
3. Load the compressor to 100 % if possible. The compressor must load to at least 50 % to complete the calibration process.
4. Touch the Hold button to maintain a constant capacity slide position.
5. Put the hand-held clamp of an amp probe around one of the compressor's motor leads or refer to the motor amp display on the starter if applicable.
6. In the Sensors Tab of the Configuration Screen. Touch the value in the measured column of the Motor Current row in the table to bring up the calibration pad and enter the measured motor current in the
10. text box located above the Save Current Offset button.
7. Touch the Save Current Offset button.
8. In the Main Tab of the Compressor Control Screen Unload the compressor to 0 %.
9. Stop the compressor.
10. In the Sensors Tab of the Configuration Screen. Touch the value in the measured column of the Motor Current row in the table to bring up the calibration pad and touch the Save Low Offset button.

4   Conclusions

Main result achieved, during the experience of installation and commissioning in external demos, is the importance of having fulfilled previously Factory Acceptance Tests, in order to reduce the risks and times with possible customers during the start-up of the equipments.

In case of SME like Pozzi, which cannot have global service like a big enterprise, but pretends to offer quality products reliable over time, the previous work of design, manufacturing and testing at Pozzi factory (before shipping) increase the degree of reliability and limit activities undertaken at site.

Of fact, the commissioning of both units at Madrid and Setubal was very similar, with minor modifications due to the experience acquired with activities of first skid. Main issue was detected with the purging of the skid clean water loop, because of the disposition of the elements, but in a real installation (where only RHeX would be provided) this risk would be highly mitigated. Purging was the biggest team consumer.

Other issue was related with the automation of the tests and so the integration of java software with SCADA/plc of the system; automatic reboot of all hardware and automatic connection between software allows remote operation without supervision but again in real operation in areal environment will not be the case.

In case of so aggressive environment like P&P factories, where corrosion can be detected in really few time, special attention must be paid to protect the controller and the sensors of the system, possibly with specific ventilated cabinets or placement in safer positions.

On other hand, a big manufacturer like GEA, which is able to move specialized technicians around the world, is able to produce technologies that are then tailored over customer application, so most of the times factory activities are less relevant with respect to field calibrations. This strategy is extremely efficient with high level technologies and allows really high performances and support during time, but requests more time of commissioning and can be subjective to higher number of faults.

Main issue with the containerized equipment was testing all individual components, both hardware and automation, and finalization of mechanic activities like coupling of compressor with motor and NH_3 filling. Individual components have been tested but the system as a whole (as a heat pump) hasn't, so activation of the technology part by part (pumping, sensing, compressor, power supply, etc..) was larger than expected.

Of fact, wrong installation of some components delayed the achievement of correct operation of heat pump, as evidenced by: test of refrigerant pressure, automatic switching off by the unit, incorrect movement of refrigerant in the loop, no achievement of desired setpoints. Nevertheless the technical ability of specialized personnel achieved the scope as expected.

Special mention must be given to proprietary control systems, which showed reliability and quick capability of configuration.

5 Bibliography

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[IV] Operation manual of every system.

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