Low valued energy sources UPgrading for buildings and industry uses

LowUP installation and integration handbook for relevant environment 1 (heating and cooling solutions)

Deliverable D4.6

Lead Beneficiary: ACCIONA
October/2019

Silvio Vitali-Nari[1] / Carlos Ramos Rodríguez[1]

[1]*ACCIONA Construcción*

www.lowup-h2020.eu

The LowUP project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement n°723930.

Document Information

Grant Agreement: 723930

Project Title: Low valued energy sources UPgrading for buildings and industry uses

Project Acronym: LowUP

Project Start Date: 1 November 2016

Related work package: WP 4: Installation, operation and validation in a relevant environment

Related task(s): Task 4.2: LowUP solutions integration and manufacturing

Lead Organisation: ACCIONA

Submission date: September 2020

Dissemination Level: Public

History

Date	Submitted by	Reviewed by	Version (Notes)
03/09/2018	Silvio Vitali-Nari	Silvio Vitali-Nari	v0.1: Document layout and Table of Contents
10/06/2019	Silvio Vitali-Nari	Silvio Vitali-Nari	v0.2: First draft on contents
18/06/2020	Carlos Ramos	Silvio Vitali-Nari	v1_Revised version of contents
08/09/2020	Carlos Ramos	Silvio Vitali-Nari	v2_Final version

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 to reducing significantly CO_2 emissions and primary energy consumption, and increasing 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 systems will be demonstrated at 4 demo sites: A Pilot Office building in Seville (Acciona Construccion, Spain), a Waste 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

Coordinator contact
Rafael C. Socorro Hernández
Acciona Construcción S.A.
Avda. Europa, 18, 28108 Alcobendas (Madrid, Spain)
email: rafaelclaret.socorro.hernandez@acciona.com

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Executive Summary

This report (D4.6 "Integration and installation handbook Env 1") has been elaborated within the LowUP Project (GA #723930) and provides the description of rules and procedures learned during design, integration and installation of all devices composing the systems of Seville demo site, according to Spanish regulations.

As a result, a consistent record of calculations and good practices related to equipment installation is here presented.

Keywords

Installation procedures, monitoring, control of energy systems, operation, maintenance, systems and subsystems.

List of acronyms and abbreviations

AHU	Air handling unit
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
WC	Water-Cooled

1 Introduction

During this phase of the project, the goal was an adaptation, installation and integration of LowUP concepts. This deliverable is focused on Heat-LowUP and Cool-LowUP concepts.

Process of adaptation to the relevant environment is the main task in this deliverable according to integration necessities as defined in preliminary lay-outs.

According to results from previous tasks (mainly within WP2), Heat-LowUP and Cool-LowUP prototypes, previously individually fully tested by the manufacturer, have been implemented at their final sites; all of them have been integrated with existing settings of ACCIONA pilot plant at Seville.

Every unit/component of the Cool and Heat system is here presented, completed with schemes of systems, technical characteristics, performance, security components in the system, etc. The integration rules of every component have been shown to explain how they work and how to match every system between them.

According to recommendations of the manufacturer, space of Sevilla demo site has been adapted to ensure that every system complies with manufacturer requirements and with security measures.

The procedure of legalization of the thermal system is hence described according to local regulation and public administration notifications that are necessary to legalize components of cool and heat Lowup.

Finally, operation and maintenance task of every unit/component is presented with the purpose of preventing malfunction in each unit, always considering restrictions and requirements of Spanish regulation.

2 Presentation of the system

2.1 HEAT SYSTEM

Different elements are integrated as a complete system:

- Electricity and heat solar collectors.
- Stratified water storage.
- Waste water heat recovery system (Wasenco) emulator.
- Hydronic Heat pump.
- Radiant floor.

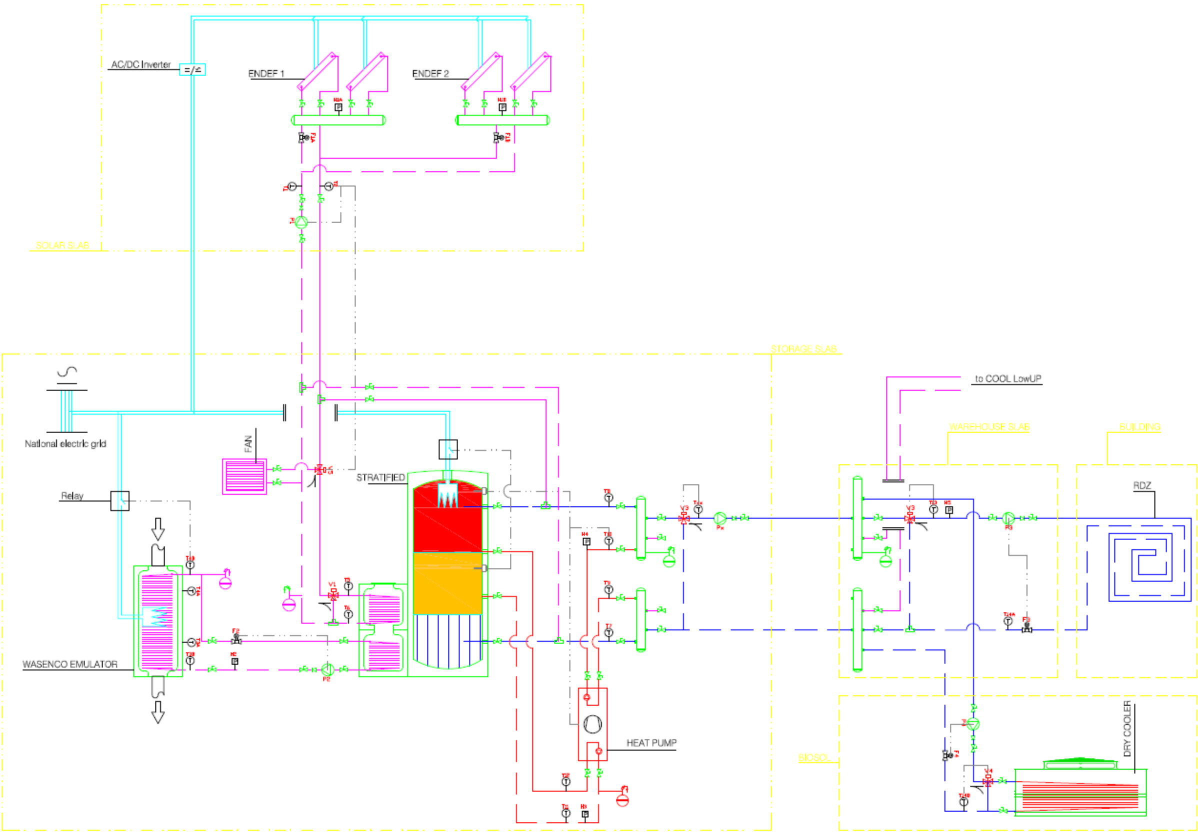


Figure 1: Heating system – Connection of components

The concept was designed to provide stable heat to Acciona lab office building during winter season through solar radiation, achieved from hybrid solar thermal PV panels connected to the radiant floor via storage tank. A back-up heat system is connected with the tank and is based on water to the water heat pump.

The Heat LowUP is connected to an existent dry cooler, which is used to emulate thermal loads rejecting heat in the environment; it proceeds from previous R&D projects of Seville demo site.

2.1.1 Solar field

Figure 2: Heating system – Solar field with the pumping station

Table 1. Solar field characteristics

Cell	156x156mm
Nº de cells	60
Glass	3.2mm glass
Weight	45.8 kg
Dimensions	1645 x 978 x 93(+25)mm
Connection box	IP65 / IP67
Longitude de cable	1000mm
Section de cable	4mm²
Nº de diodes	3
Connectors	MC4 compatible
Marco	Aluminium

Electrical specifications:

Nominal power (Pmax)	255 Wp
Nominal Voltage (Vmp)	31.65 V
Nominal Current (Imp)	8.06 A
Voltage de Open Circuit (Voc)	38.58 V
Short-circuit Current (Isc)	9.06 A
Tolerance power	0 + 4.99 Wp
Efficiency	15.98%
Coefficient temp. voltage	-0.37%/K
Coefficient temp. current	+0.06%/K
Coefficient temp. power	-0.47%/K
Voltage max of system	DC 1000V (TUV)

Operation temperature	-40ºC / +85ºC
Max Inverse current	15A
IP protection	IP65
Security	II

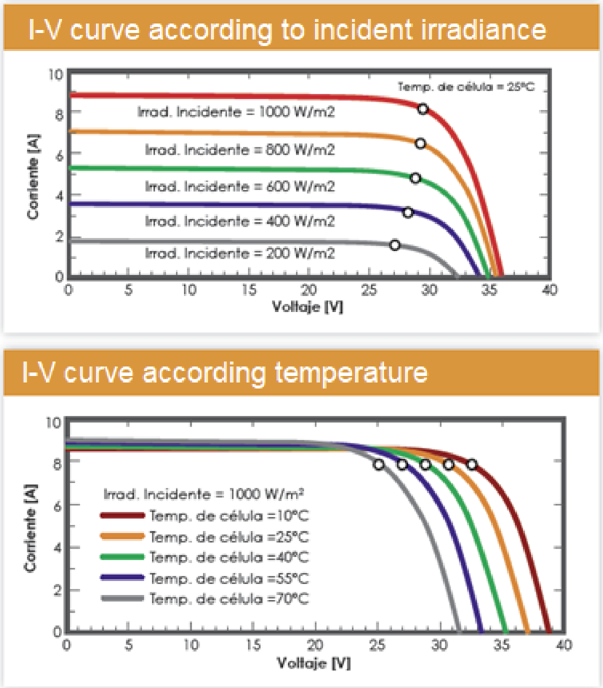


Figure 3. Current-Voltage graphic of solar panel

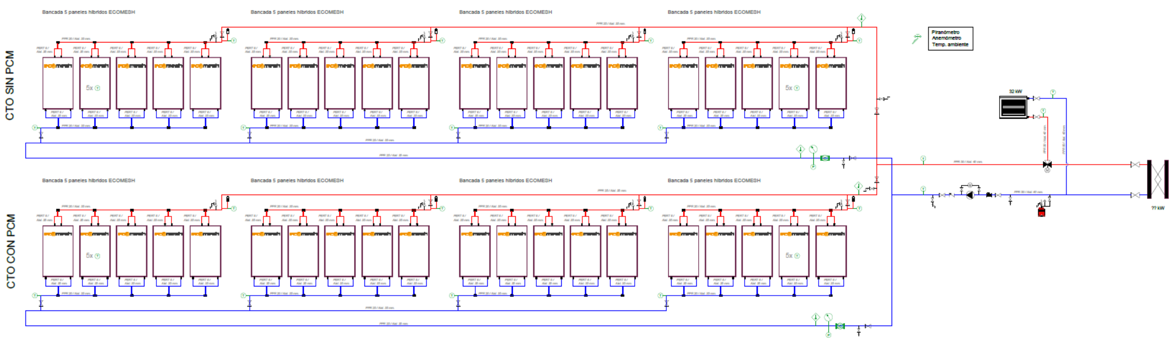


Figure 4. Hydraulic schema of the solar field

Two solar fields (with and without PCM) have been installed in parallel for testing purposes and hydraulic balance; each field is composed by 20 panels in parallel, divided into rows of 5 units, as indicated by temperature lift calculated during the engineering phase.

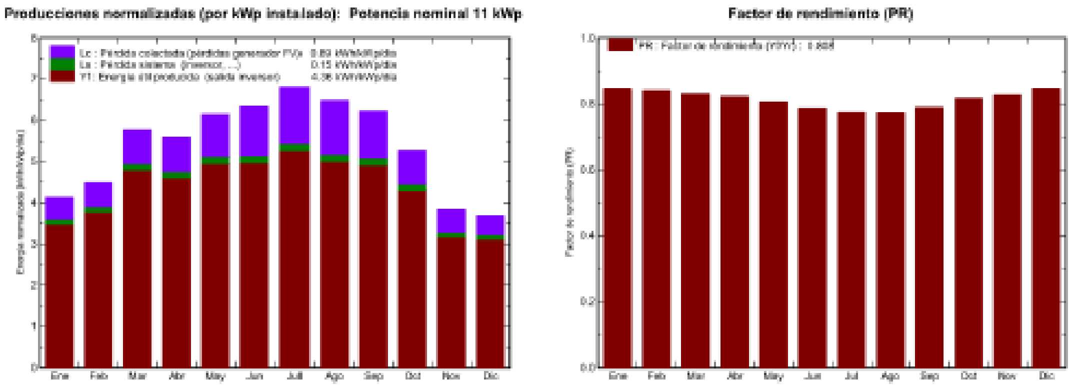
The variable speed pump allows the regulation of water as a function of outlet temperature.

According to electrical technical characteristics, production simulation was made to validate the best option to install according to demonstration purposes; finally, below showed simulation presents the selected size of the solar field for this project.

Resultados principales de la simulación

Producción del Sistema — **Energía producida** 17.19 MWh/año — Produc. específico 1591 kWh/kWp/año

Factor de rendimiento (PR) 80.8 %



Balances y resultados principales

	GlobHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray kWh	E_Grid kWh	EffArrR %	EffSysR %
Enero	78.0	11.20	128.0	124.6	1207	1166	12.15	11.74
Febrero	91.0	12.30	125.6	122.5	1181	1142	12.11	11.71
Marzo	146.0	14.50	178.8	173.8	1655	1600	11.93	11.53
Abril	161.0	16.20	167.7	162.6	1538	1487	11.82	11.43
Mayo	205.0	19.50	190.3	184.2	1712	1654	11.59	11.20
Junio	216.0	24.00	189.8	183.2	1665	1609	11.30	10.92
Julio	235.0	27.30	210.8	203.8	1821	1760	11.13	10.75
Agosto	202.0	27.30	200.7	194.4	1732	1673	11.12	10.74
Septiembre	161.0	25.10	186.7	181.4	1642	1588	11.33	10.96
Octubre	120.0	19.50	163.5	159.4	1491	1441	11.75	11.36
Noviembre	75.0	15.10	114.8	111.8	1061	1025	11.90	11.50
Diciembre	67.0	11.80	114.1	111.1	1077	1041	12.16	11.75
Año	1757.0	18.69	1970.7	1912.8	17781	17186	11.63	11.24

Leyendas:

- GlobHor: Irradiación global horizontal
- T Amb: Temperatura Ambiente
- GlobInc: Global incidente en plano receptor
- GlobEff: Global efectivo, corr. para IAM y sombreados
- EArray: Energía efectiva en la salida del generador
- E_Grid: Energía reinyectada en la red
- EffArrR: Eficiencia Esal campo/superficie bruta
- EffSysR: Eficiencia Esal sistema/superficie bruta

Figure 5. Simulation result for solar field

Next table shows the thermal specification of hybrid solar panel:

Table 2. Thermal specifications

Max pressure	10 bar
Heat recovery	Cu
Capacity	1,2 L
Optical efficiency (ηo)	0.51
Coef. Thermal loss, a1	4.93 W/m2k
Coef. Thermal loss, a2	0.021 W/m2k2
Pressure loss	0.04 bar

Next section shows a schema of hydraulic circuit distributed in the solar field and its connections

2.1.2 Stratified tank

Figure 6. Stratified tank installed in Seville demo

- Size: DN 1600mm x H 3550mm
- Working pressure 3 bar
- Stratified loading port for solar thermal energy of 1 "IG
  - Maximum flow 4,000l / h
  - Maximum temperature 90ºC
- Stratified cargo port for greywater recovery of 1 "IG
  - Maximum flow 2,000l / h
  - Maximum temperature 90ºC
- Stratified loading port for the 1 "IG heat pump
  - Maximum flow 2,000l / h
  - Maximum temperature 90ºC
- 1 "IG laminated radiant floor return port
  - Maximum flow 7.000l / h
  - Maximum temperature 90ºC
- Laminated resistance of 3 * 2,5kW
- 14 sensor sockets
- Top purge of 1 "IG
- Lower 1 "1 / 2IG drain
- Insulation 120mm for heat - Hub 6,500 litres

Now, hydraulic schema with its connections is presented:

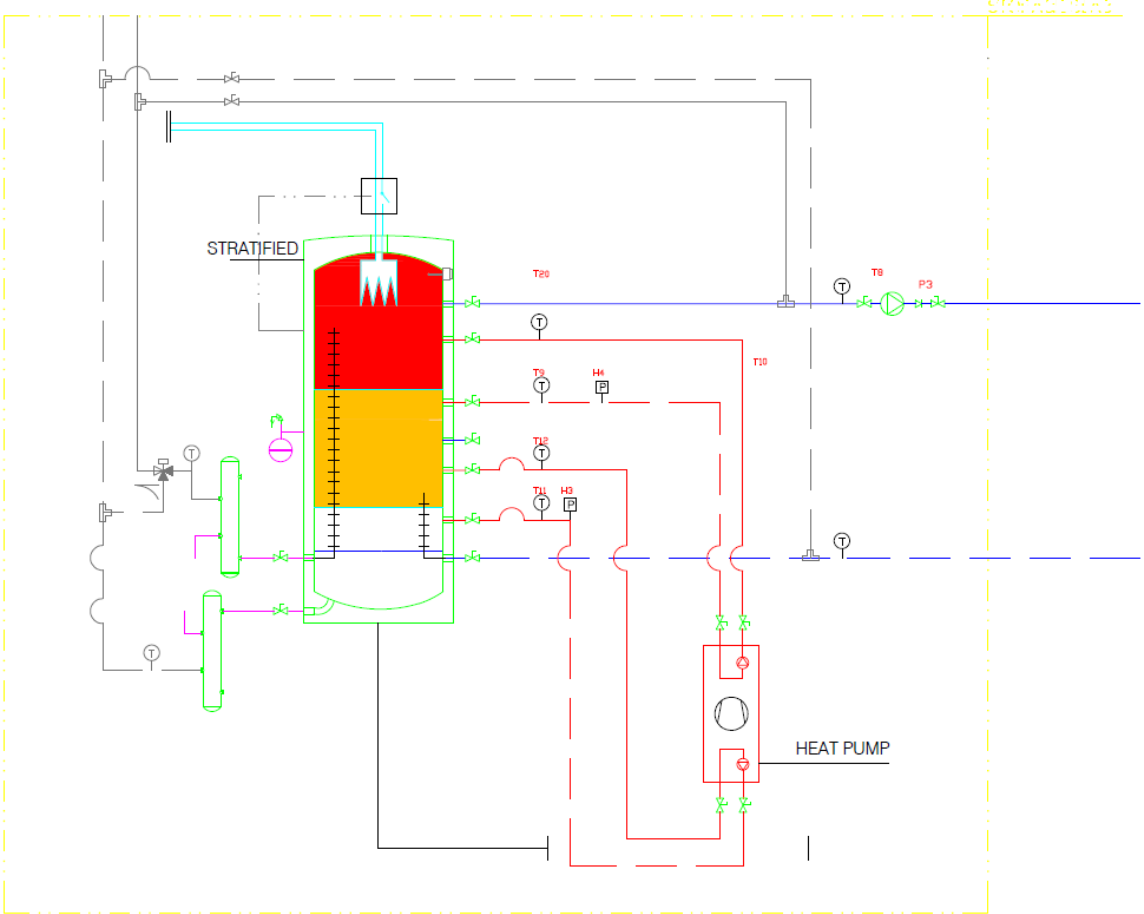


Figure 7. Hydraulic connections of the tank with resto of Heat LowUP

The tank is fed in the lower part by solar field and heat recovery emulator; the energy flows along the stratification column to its respective temperature layer; the radiant flow is connected with the top of the tank in order to exploit the higher stored temperature.

The w-t-w heat pump is connected in the cold sink with the lower part of the tank while the hot sink with the upper part of the tank. On the top 3 controlled electric resistance work as a backup system.

2.1.3 Wasenco tank (at Rucab)

The waste water heat recovery tank was installed at Rucab student residence with the purpose to recover heat from dishwashers and kitchen cooking pots and return it to clean water incoming in the same dishwashers, reducing the heating necessary for the cleaning cycle.

As follow, technical specification of this equipment:

Figure 8. Waste water heat recovery tank

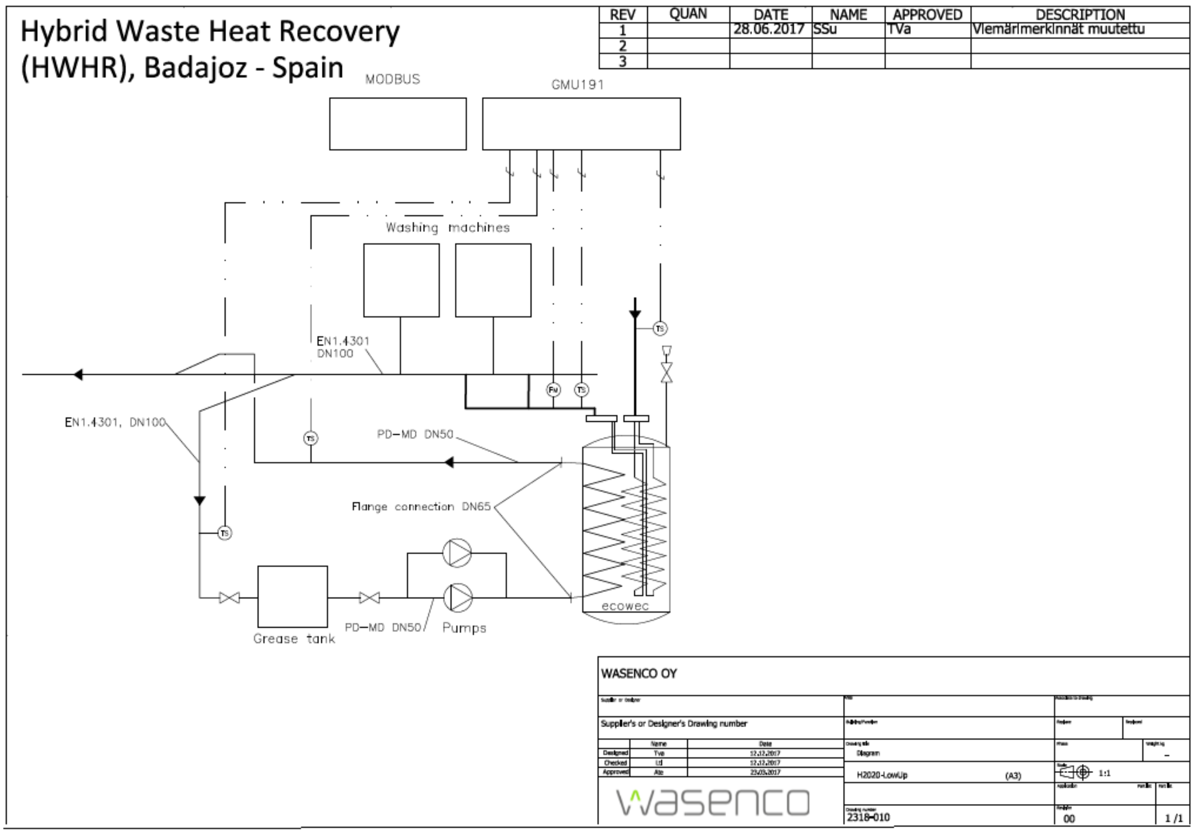


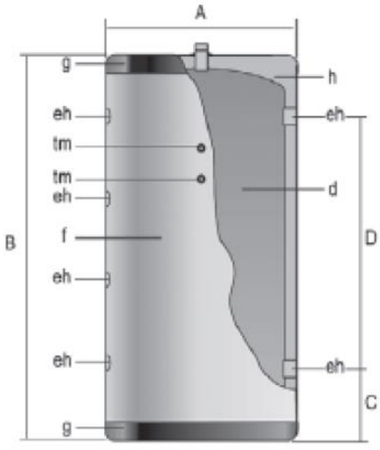
Figure 9. Waste water recovery schema at Rucab (Badajoz)

2.1.4 Emulation tank

The emulation tank is a normal storage tank with the same dimensions of Wasenco tank but integrated with an electric resistance able to replicate (through the control system) the operation of the tank at

Rucab and so operating as an emulator. This means that the demo of Seville is virtually integrated with Rucab demo, in terms of energy.

As follow, technical specification of this equipment:



Model	G140	G200	G260	G370	G600
Peso en vacío (Kg)	35	44	52	66	95
p ("gas/H)	1"	1"	1"	1"	1"
s ("gas/H)	-	-	-	-	-
k ("gas/H)	-	-	-	-	-
eh ("gas/H)	1-1/4"	1-1/2"	1-1/2	2"	3"
tm ("gas/H)	1/2"	1/2"	1/2"	1/2"	1/2"
Cota A (mm)	480	620	620	620	770
Cota B (mm)	1155	985	1240	1725	1730
Cota C (mm)	160	170	170	175	200
Cota D (mm)	840	625	875	1350	1291

Figure 10. Technical characteristics of emulation tank

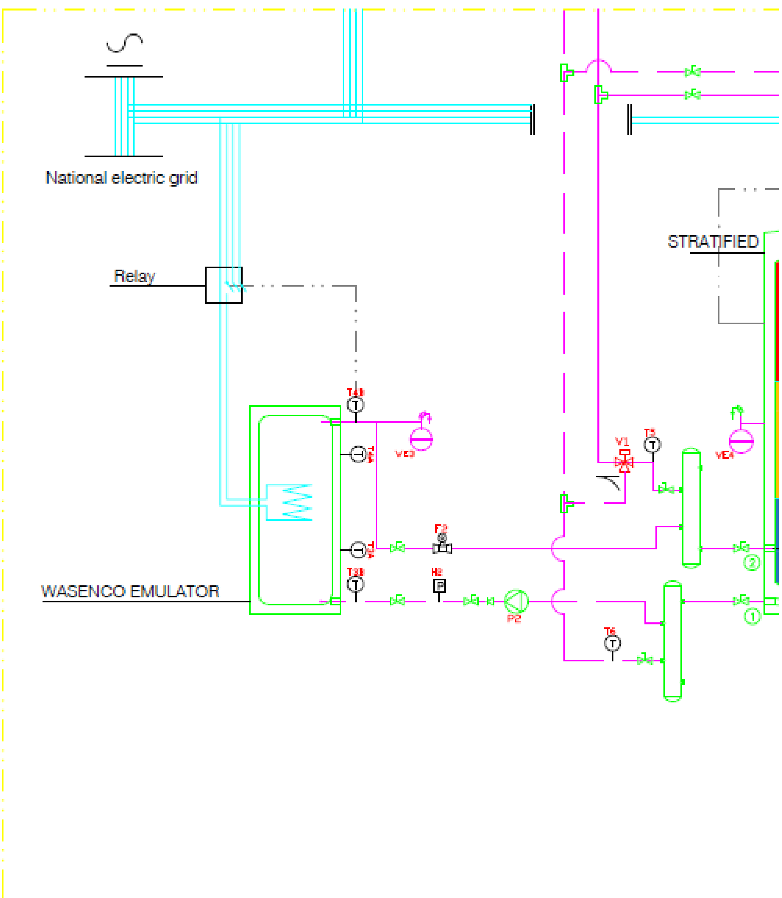


Figure 11. Emulation tank connections in Seville demo site

The tank is connected with the lower part of stratification tank through a fixed speed circulation pump, which is operated according to the quantity of heat stored in the tank and in the function of the temperature achieved inside. The tank works in parallel to the solar field according to the same principle of providing energy to storage tank when conditions are suitable and favourable.

2.1.5 Heat pump

Water to water reversible heat pump working with refrigerant fluid and used for indoor installation.

The HP is used to boost residual energy, from the bottom of the tank, into the upper part thank to temperature lift from compression cycle; the thermocline allows a net separation between cold and hot temperature water.

As follow, technical specification of this equipment:

Figure 12. Heat pump installed in Seville demo

APLICACIÓN: UNIDAD PARA PANELES RADIANTES

TAMAÑOS			17	21	31	41	51	61	71	81	91	101	121
Refrigeración													
Potencia frigorífica	1	kW	8,07	8,83	10,5	13,8	17,7	21,9	26,2	29,6	33,6	37,5	42,3
Poten. ass. Compresores	1	kW	1,42	1,53	1,94	2,33	3,04	3,88	4,81	5,17	5,94	6,87	7,82
Potencia absorbida total	2	kW	1,43	1,54	1,95	2,34	3,05	3,89	4,82	5,18	5,95	6,88	7,83
EER		kW	5,64	5,73	5,38	5,9	5,80	5,63	5,44	5,71	5,65	5,45	5,4
Calefacción													
Potencia térmica	3	kW	6,95	7,5	9,36	12	16,1	19,7	24,7	26,5	31	36,7	41,6
Poten. ass. Compresores	3	kW	1,28	1,4	1,77	2,27	2,88	3,53	4,47	4,89	5,62	6,41	7,28
Potencia absorbida total	2	kW	1,29	1,41	1,78	2,28	2,89	3,54	4,48	4,9	5,63	6,42	7,29
COP		kW	5,39	5,32	5,26	5,26	5,57	5,56	5,51	5,41	5,51	5,72	5,71
Compresor													
Tipo compresor			SCROLL										
N° compresores			1										
Etapas de capacidad Estándar			1										
Carga refrigerante (C1)		kg	0,9	0,9	1,1	1,1	1,4	1,6	1,9	2,5	3,2	3,1	3,3
Circuito refrigerante			1										
Intercambiador interior													
Tipo evaporador interior	4		PHE										
Cantidad			1										
Caudal del agua	1	l/s	0,39	0,42	0,5	0,66	0,85	1,05	1,25	1,41	1,61	1,79	2,02
Caudal maxi. del agua		l/s	0,64	0,7	0,84	1,1	1,41	1,74	2,09	2,36	2,68	2,99	3,37
Preponderancia útil bomba		kPa	46.9	43.1	43.4	28.3	20.4	41.0	33.3	24.3	17.8	83.5	41.8
Contenido de agua		l	0,6	0,6	0,8	0,8	0,9	1,1	2,2	2,5	2,9	2,9	3,2
Intercambiador exterior													
tipo cambiador exterior	4		PHE										
Cantidad			1										
Caudal del agua		l/s	0,45	0,49	0,59	0,77	0,99	1,23	1,48	1,66	1,89	2,12	2,39
Caudal maxi. del agua		l/s	0,76	0,82	0,99	1,28	1,65	2,05	2,47	2,77	3,15	3,53	3,99
Pérdidas de carga		kPa	28	31	31	43	49	51	59	52	53	75	80
Conexiones													
Conexiones agua	5		1"GAS F										
Vaso de expansión													
Capac. vaso expansión		l	1				2						
N° vasos de expansión			1										
Circuito hidráulico													
Máx.pres.lado agua		kPa	550										
Ajuste válvula seguridad		kPa	600										
Alimentación													
Alimentación estándar			230/1/50				400/3/50+N						
Dimensiones													
Longitud		mm	402	402	402	402	402	573	573	573	573	573	573
Profundidad		mm	602	602	602	602	602	604	604	604	604	604	604
Altura		mm	785	785	785	785	785	858	858	858	858	858	858
Peso de la unidad estándar													
Peso del envío		kg	79	81	84	88	96	112	126	143	159	160	166
Peso en funcionamiento		kg	81	83	86	90	98	115	129	147	163	164	170

(1) Datos referidos a la siguiente condición :
agua intercambiador interior = 23/18 °C
agua intercambiador exterior = 30/35 °C

Figure 13. Technical characteristics of the heat pump installed in Seville demo

The basic schema for properly connection is the following:

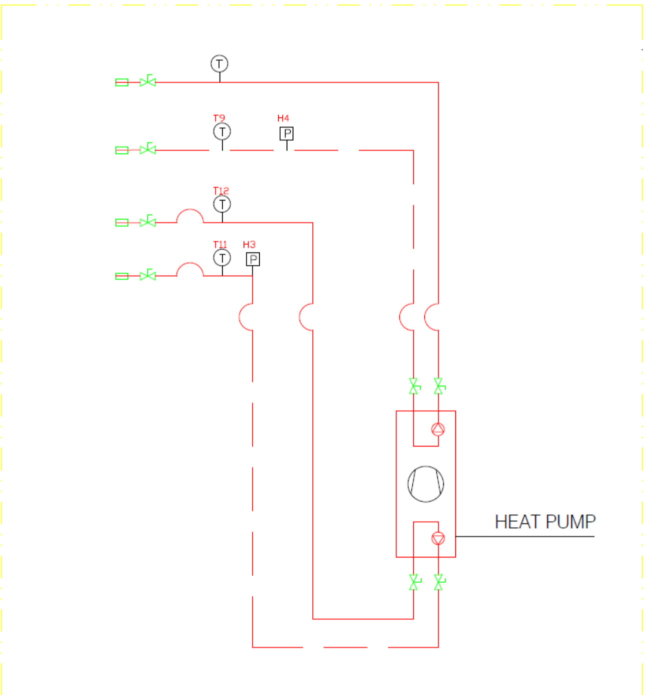


Figure 14. The basic schema of Heat pump installation

The purpose of the HP is to work as back up when solar radiation is not enough to achieve requested temperature by radiant floor. Energy achieved by solar field is boosted in temperature and directly moved to higher temperature layers of the tank.

2.1.6 Radiant floor

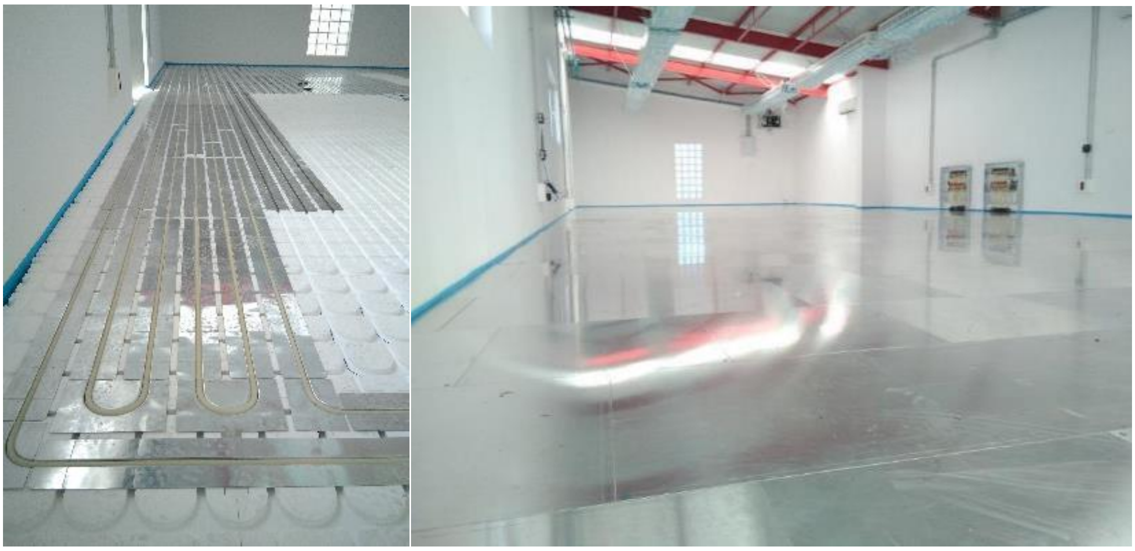


Figure 15. Pipes inside the radiant floor (left) and last layer (metallic) of the radiant floor (right)

The radiant floor is based on dry installation concept, by which the tubes are not embedded in the concrete, but are placed over an insulation layer with a specific shape for installation of curves.

The system is directly fed by stratification tank, so with variable temperature depending on availability of the sink during the different hours of the day along the season.

Radiant floor system has the following characteristics:

Table 3. Design characteristics of radiant floor

TM theoretical [°C]	DT theoretical [°C]
38,4	5,0

Collector	att.	TM [°C]	Power [W] High	Power [W] Low	Power [W] Total	Caudal [l/h]	PDC [mmH2O]	Fabb. pipe [m]	H2O tub [l]	Sup. covered [m²]
Coll 1	8	31,0	3465	778	4243	1200	3927	484	38	
Coll 2	8	31,0	3445	770	4215	1200	3904	481	38	
Totals	16		6910	1547	8457	2400	3927	965	76	116

This unit shows a 72,90 W/m² power deployment and 20,70 L/h·m².

Components of the radiant floor are listed below:

- Collectors.
- Thermal energy meters.
- Regulation accessories.
- Water circuit connection accessories.

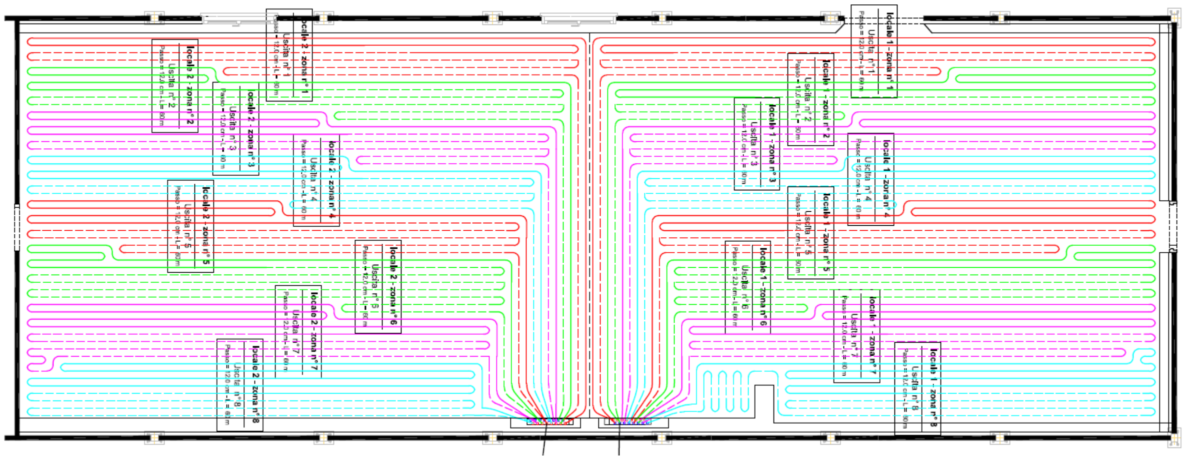


Figure 16. Schema of water pipes on the radiant floor system

Thermostat devices are used to regulate indoor temperature through the ON/OFF actuation comparing the indoor temperature measure with a predefined value. The control strategy actuates on the energy production unit and also on the secondary circuit pumps and valves.

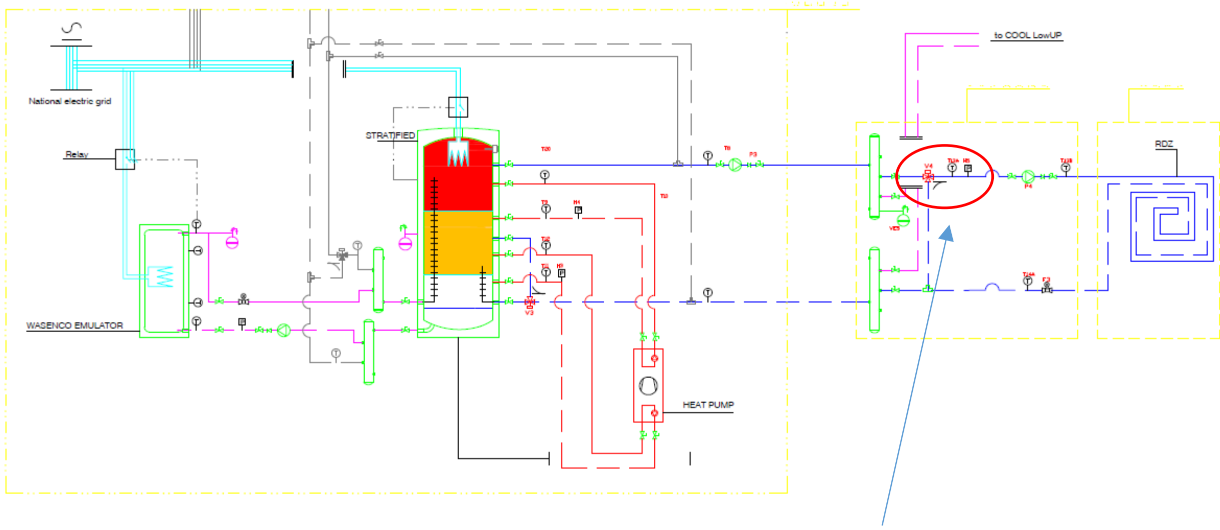


Figure 17. Schema with thermostat acting in 3-way valve

The regulation to fixed point sends an always established temperature for the most unfavourable winter conditions. With flow temperature set regardless of conditions outdoor. Equipment prepared to regulate up to 150 m².

Table 4. Combination of radiant floor controlling with other systems

Regulation	Radiant system	Air conditioning	External conditions adaptation	Occupation adaptation	Regulation efficiency level

Fixed point	YES	NO	NO	NO	1
Climatic	YES	NO	YES	NO	2
Climatic (advanced)	YES	YES	YES	YES	3

2.1.7 Dry cooler

Figure 18. Dry cooler installed in Seville demo

The system is used to simulate thermal loads out of winter season and to increase the load of the building during the winter season, in order to test operation of the radiant floor along with its entire working range. Its presence is purely for testing purposes.

Dry cooler system has the following characteristics:

AEROENFRIADORES SIMPLES (Baja Velocidad - Low Speed)		IDR-75		IDR-90		IDR-115		IDR-140		IDR-165		IDR-230		IDR-290	
		Δ	Y	Δ	Y	Δ	Y	Δ	Y	Δ	Y	Δ	Y	Δ	Y
Potencia / Capacity (Dt=15K) Glycol 34%	Kw	73,65	61,42	88,00	71,54	112,50	90,40	138,90	114,40	167,20	136,75	230,00	180,50	290,91	233,52
	Kcal / h	63.339	52.821	75.680	61.524	96.750	77.744	119.454	98.384	143.792	117.605	197.800	155.230	250.183	200.827
Caudal de Glicol / Glycol Flow	m³/h	14,1	11,7	16,7	13,7	21,5	17,2	26,5	21,8	31,9	26,1	42,8	34,4	55,5	44,56
Pérdida de Carga / Pressure Drop	K Pa	36,00	26,13	46,16	32,51	39,81	27,10	20,2	14,4	25,26	17,72	37,42	25,47	72,37	49,16
Caudal de aire / Air Flow	m³/h	28.500	22.000	26.400	20.400	34.500	26.000	55.500	42.000	54.800	42.000	69.000	52.000	86.250	65.000
Ventiladores / Fan Motors	Nº	2 x 630	2 x 630	3 x 560	3 x 560	2 x 800	2 x 800	3 x 800	3 x 800	4 X 630	4 X 630	4 x 800	4 x 800	5 x 800	5 x 800
Velocidad Std / Std speed	RPM	1340	1070	1320	1000	880	660	880	660	1340	1070	880	660	880	660
Consumo total / Consumption 380V-std	Kw / A	3,8 / 6,4	2,7 / 4,4	3,75 / 4,35	2,4 / 4,35	4 / 8	2,5 / 4,6	6 / 12	3,75 / 6,9	7,6 / 12,8	5,4 / 8,8	8 / 16	5 / 9,2	10 / 20	6,25 / 11,5
Nivel Sonoro / Noise Level	dB (A)	57	52	57	51	50	44	52	46	60	55	54	48	54	48
DATOS COMUNES - *GENERAL DATA*															
Dimensiones / Dimensions	A mm	2.020	2.020	2.570	2.570	2.420	2.420	3.620	3.620	4.020	4.020	4.820	4.820	6.020	6.020
	B mm	-	-	-	-	-	-	2.395	2.395	1.995	1.995	2.395	2.395	2.395	2.395
	C mm	-	-	-	-	-	-	1.225	1.225	2.005	2.005	2.425	2.425	2.425	2.425
	D mm	2.120	2.120	2.670	2.670	2.520	2.520	3.720	3.720	4.120	4.120	4.920	4.920	6.120	6.120
	E mm	1.240	1.240	995	995	1.360	1.360	1.360	1.360	1.240	1.240	1.360	1.360	1.360	1.360
	F mm	1.070	1.070	945	945	1.260	1.260	1.260	1.260	1.070	1.070	1.260	1.260	1.260	1.260
	G mm	990	990	865	865	1.180	1.180	1.180	1.180	990	990	1.180	1.180	1.180	1.180
	H mm	640	640	595	595	760	760	760	760	640	640	760	760	760	760
	I mm	600	600	600	600	860	860	860	860	600	600	860	860	860	860
	J mm	540	540	540	540	800	800	800	800	540	540	800	800	800	800
Conexiones / Connections	Diam. Gas	2"	2"	2 1/2"	2 1/2"	3"	3"	4"	4"	4"	4"	4"	4"	4"	4"
Superficie / Surface	m²	144,15	144,15	214,43	214,43	273,9	273,9	308,13	308,13	384,41	384,41	547,78	547,78	684,25	684,25
Volumen Interno / Tube Volumen	dm³	21,7	21,7	32,3	32,3	41,3	41,3	46,4	46,4	57,9	57,9	82,5	82,5	101,8	101,8
Peso Neto / Net Weight	kg	192	192	250	250	331	331	438	438	515	515	610	610	762	762

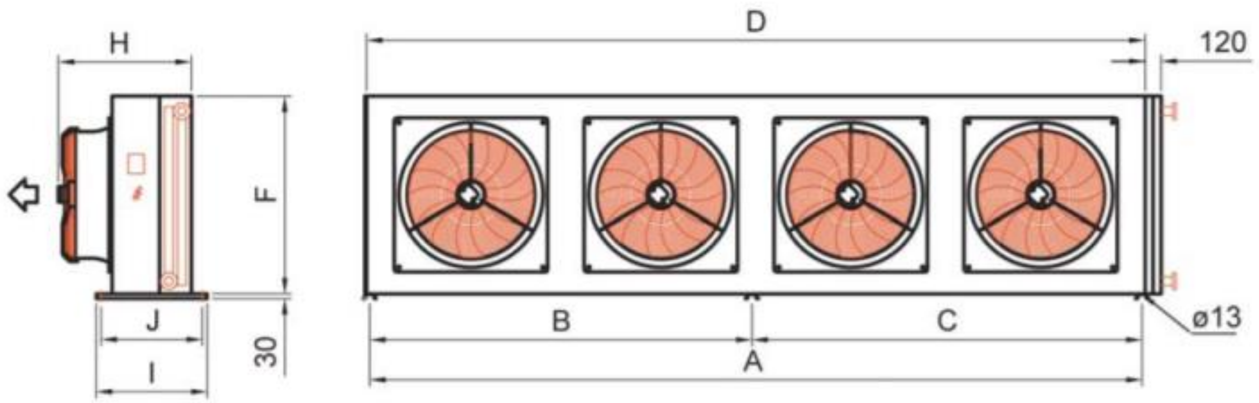


Figure 19. Technical characteristics from the dry cooler

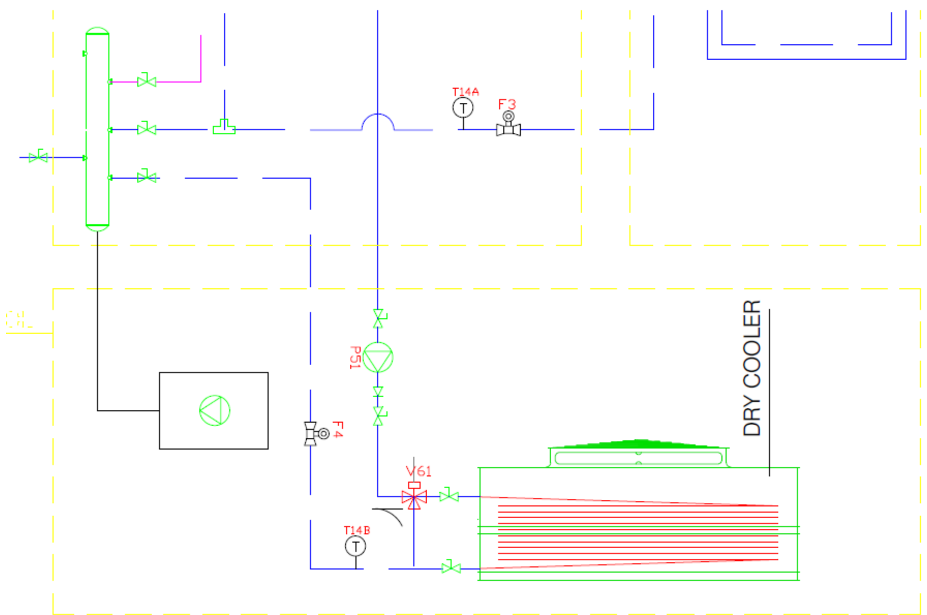


Figure 20. Connection schema of the dry cooler in the installation

The dry cooler is installed in parallel with respect to the radiant floor, with three-way valve for regulation of temperature and variable speed pump for the regulation of flow. By the combination of these devices, any thermal load can be emulated.

2.2 COOL SYSTEM

Different elements are integrated as a complete system:

- BOREALIS compact air handling unit.
- FAFCO Icebat.
- HALTON chilled beams.

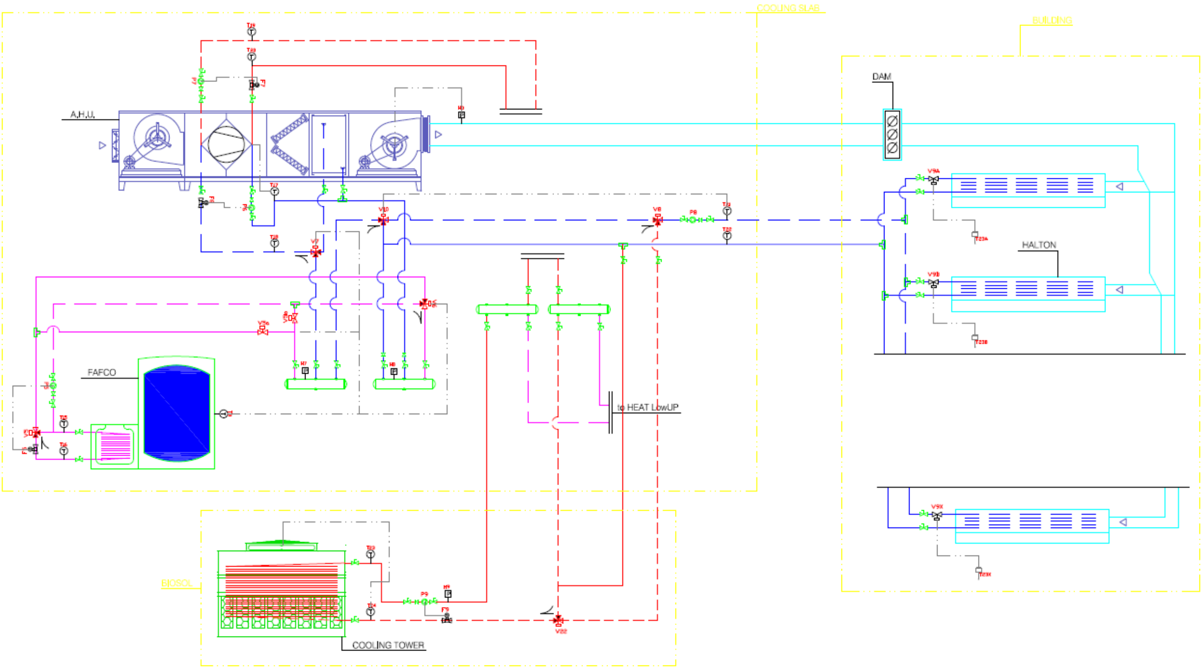


Figure 21. Cooling system – Connection of components

The system is designed in order to provide primary air for ventilation + cooling for thermal load: the cool can proceed in real-time from the chiller to the beams or in shifted time from the tank to the beams; this last way of operation supposes a previous cool loading from the chiller to tank during no thermal load moments (for example night).

2.2.1 AHU & chiller

Figure 22. AHU & CHILLER installed in Seville demo

This air handling unit is a piece of autonomous equipment with condensation by Water, designed and manufactured ad-hoc for the purposes of the project. In this case, GAX-015-05 model has been selected for being a compact, self-contained unit consisting of a reversible geothermal heat pump with the hydronic group, plus a unit of air treatment for 100% outside air with the possibility of partial recirculation.

Table 5. BOREALIS GAX-015-05 Air handling unit technical data

Compressors	1 unit, SCROLL type
Cooling power	32,20 kW 13->10 °C ; 30->35 °C
Heating power	41,40 kW 30->35 °C ; 16 °C
Electrical power in cooling mode	5,90 kW EER 5,46
Electrical power in heating mode	6,10 kW COP 6,79
Production water flow	9.800 L/h
Cooling tower water flow	5.500 L/h
Available pressure in production circuit	50 kPa
Available pressure in tower circuit	42 kPa
Airflow	1.500 m³/h
Fan electrical power	0,52 kW

The next figure represents the basic scheme for AHU&CHILLER integration. As it can be seen, cooling production serves to the different elements (AHU and Chilled beams). The necessary vessel must be installed in order to avoid unnecessary stress in the hydraulic circuit. Furthermore, heat removed from the building must be managed. In this case, an hybrid (semi-wet) cooling tower has been connected to the condenser.

The integration must be necessary complemented with the circulation pumps and control elements, in order to increase the possible ways of operation of this machine with different strategies.

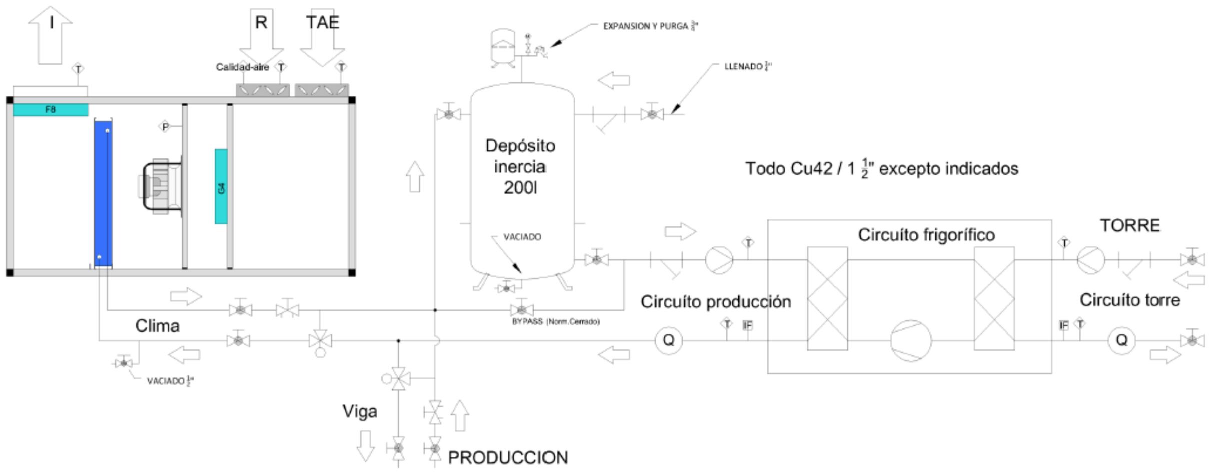


Figure 23. The hydraulic and frigorific circuit inside the unit

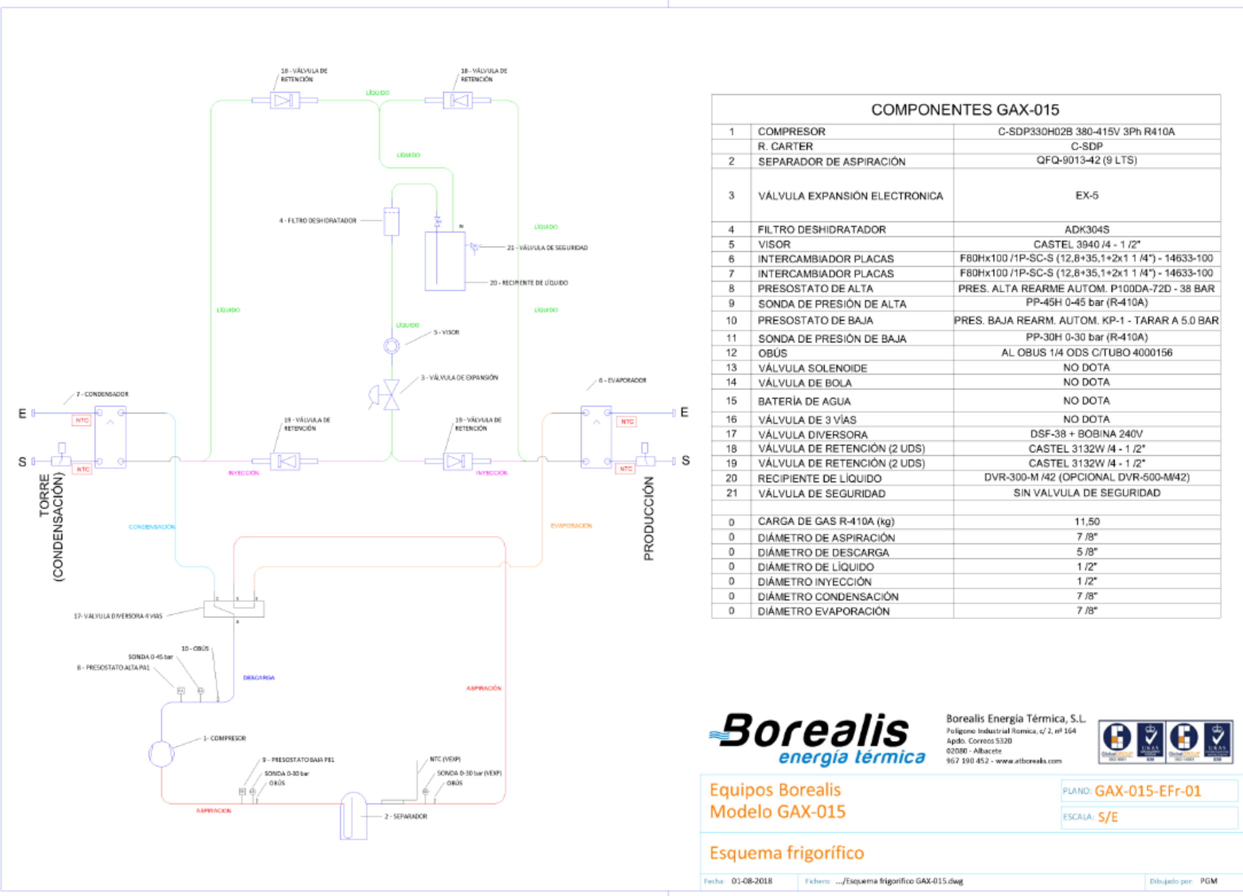


Figure 24. Frigorific circuit

2.2.2 PCM tank

Figure 25. PCM tank installed in Seville Demo

The tank is designed to store cool with PMC instead of water; a specific heat exchanger is submerged in the PCM, operating for both charging and discharging through the same water loop. The pump station is installed in order to invert flow direction according to required operation strategy, while the block of 2 and 3 ways valves has been designed in order to facilitate the shifting of flow direction and regulating the operating temperature of PCM.

The technical data of the 96 kWh FAFCO icebat tank is the following:

Dimensions	
L1 (mm)	1 870
L2 (mm) Header axis	1 600
B (mm)	1 595
H1 (mm)	1 960
H2 (mm)	2 060
H3 (mm)	2 200
D (mm)	100

Figure 26. Dimensions of PCM Tank

Latent storage capacity	96	kWh
Max. operating temperature	40	ºC
Max. operating pressure	3	bar
Total PCM content	2 218	l
Solid PCM volume usual charge	1 550	l
Solid volume of additional PCM	668	l
Exchangers content	130	l
Approximate shipping weight	820	kg
Approximate operating weight	3 187	kg
Floor area	3	m²

Figure 27. Characteristic of PCM Tank

Now, connections scheme of PCM tank installation with its sensors and valves is presented.

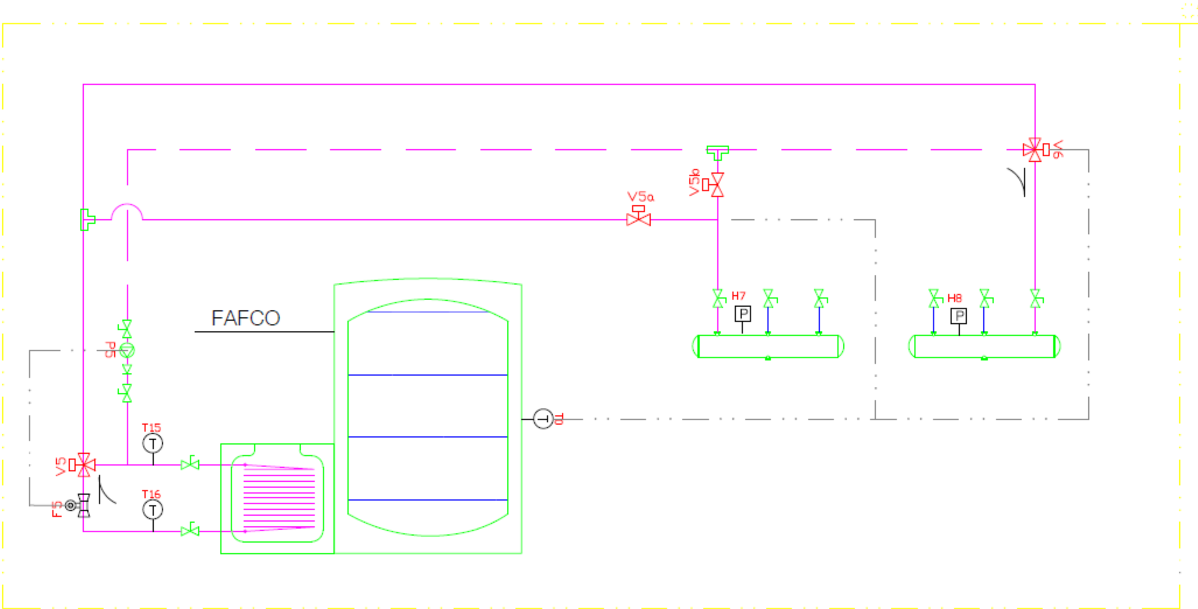


Figure 28. P&ID details of specific connections at Seville plant

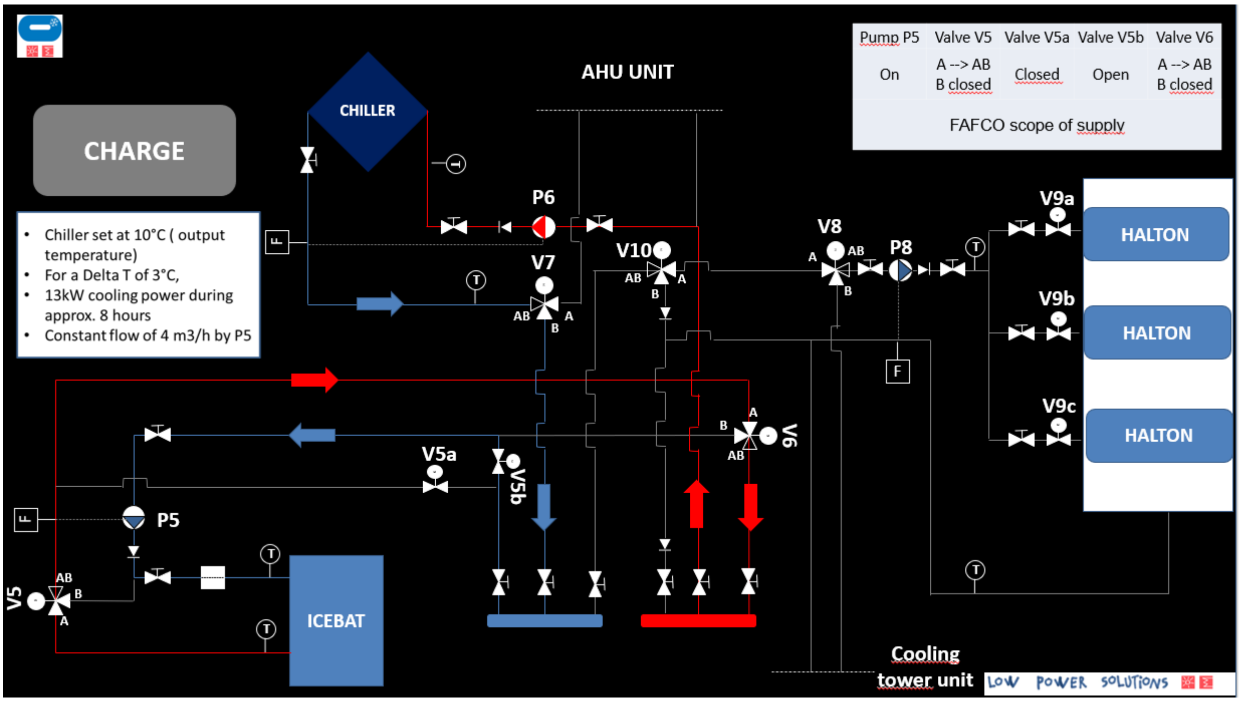


Figure 29. P&ID of charging operation

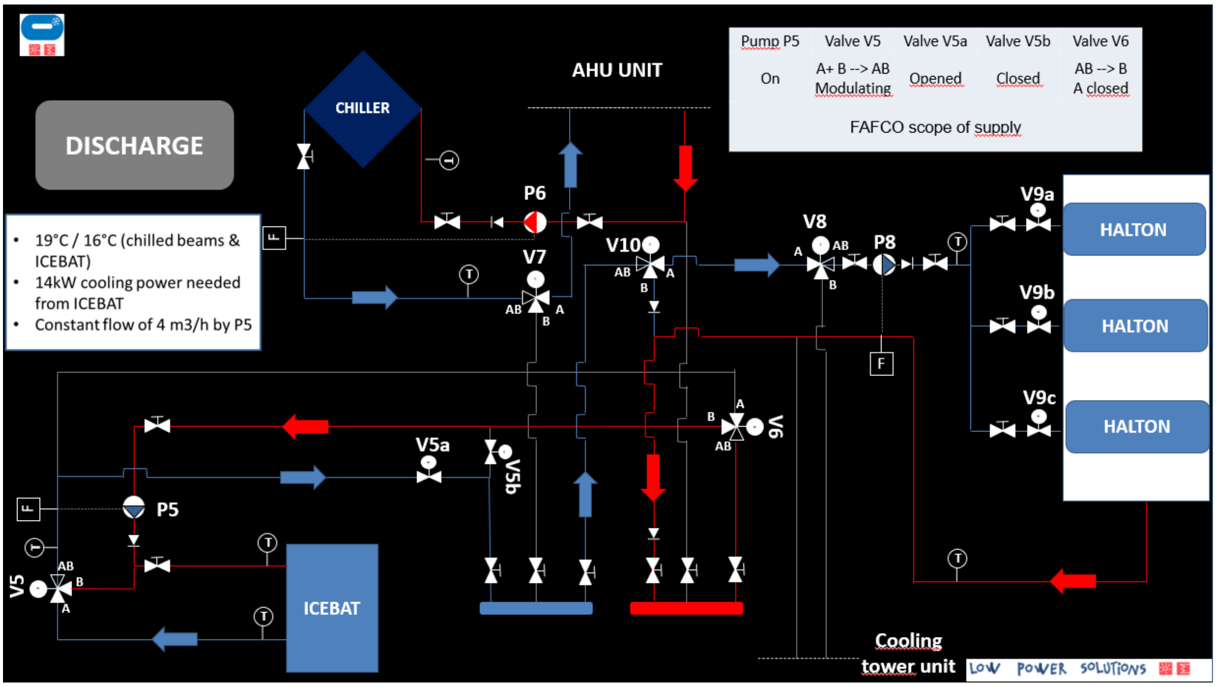


Figure 30. P&ID of discharging operation

2.2.3 Chilled beams

Figure 31. Chilled beams installed inside the office

Chilled beams are used as terminals for ventilation and cooling within the office building + warehouse; they are integrated with adaptive lighting and temperature regulation system for the comfort of end-users. Beams are feed with air from AHU and with cold water from tank/chiller.

Beams worked with fixed water temperature and fixed air pressure incoming in the coils; the two ways valves embedded in the case regulate the flow according to office cool requirements (temperature) while embedded dampers regulate airflow in the function of the thermal load of the building. Halton control manages the opening of both in the function of the setpoint defined by user, activity and number of persons present in the building.

REE and REO HALTON chilled beams are included in the REX series and are adaptable active chilled beams for exposed installation.

Factor de climatización			Clase		
		Unidad	A	B	C
Temperatura de funcionamiento	Invierno	°C	22+-1	22+-2	22+-3
Temperatura de funcionamiento	Verano	°C	24,5+-1	24,5+-1,5	24,5+-2,5
Vertical temperature gradient	0,1 m / 1,1 m	°C	2	3	4
Velocidad media	Invierno	m/s	0,15	0,18	0,21
Velocidad media	Verano	m/s	0,18	0,22	0,25
Nivel de presión acústica	Oficinas	dB(A)	30	35	40
Nivel de presión acústica	Oficinas paisajísticas	dB(A)	35	40	45
Tasa de ventilación	Oficinas	l/s m²	2	1,4	0,8
Tasa de ventilación	Oficinas paisajísticas	l/s m²	1,7	1,2	0,7
Hipótesis de diseño	Tasa de ocupación:	Capacidad de refrigeración: para las oficinas, 0,1 persona/m², para las oficinas paisajísticas, 0,07 persona/m²			
	Capacidad de refrigeración:	50W/m²			

Valores objetivo de climatización según el informe 1752 del CEN, sobre los valores máximo para las condiciones térmicas.

Figure 32. Chilled beams technical characteristics

Now, technical information for the installation is presented:

Office room + Warehouse		
SUPPLY AIR		
Chilled beams Office room	**8**	
Chilled beams Warehouse room	**3**	
distance between beams in Warehouse	3660	mm
Static pressure beams	104	Pa
Supply air flow, boost	399	l/s
Office room each beam	42	l/s
Warehouse each beam	21	l/s
Supply duct size round diameter	400	mm
Supply duct velocity	3.2	m/s
Supply air flow, normal	255	l/s
Office room each beam	24	l/s
Warehouse each beam	21	l/s
Supply duct size round diameter	400	mm
Supply duct velocity	2.0	m/s
Supply air flow, min	103	l/s
Office room each beam	5	l/s
Warehouse each beam	21	
Supply duct size round diameter	400	mm
Supply duct velocity	0.8	m/s

Figure 33. Calculation for chilled beams system

2.2.4 Cooling tower

Figure 34. Cooling tower installed in Seville demo

Cooling tower Ecodry 3DK is a centralized closed-circuit adiabatic (semi-wet) cooling system designed to replace the old cooling tower technology (totally wet). Installed outside the building, it rejects the heat extracted from the cooling process, achieving:

- Better cooling performance with increased heat transfer efficiency
- Outstanding operating costs savings, resulting in a low Total Cost of Ownership
- New standards in terms of Environmental Impact, from both water footprint and total emissions
- Avoiding legionella problems related to the warm water basin

The cooling tower is also directly connected with returns from chilled beams, in order to be used as a cold sink in specific moments of the year, reducing compressor consumption during the production of cooling.

Now, technicals characteristics of this unit are presented:

MECHANICAL[1]															
Model	Rows	Fans Per Row	Total Fans	Dimensions[2] mm						Victaulic™ Connections[4] mm (in)	Internal Volume liter	Approximate Weights		Sound Level dB(A) @ 10 m	
				L	W	H[3]	H[3] (+40)	H[3] (+84)	H[3] (+188)			Shipping[5] kg	Operating[6] kg	Fan Type[7]	
														EC	EZ
3DK11P	1	1	1	2,523	1,127	2,923	3,323	-	-	DN100 (4)	70	365	500	51	49
3DK21P	1	2	2	3,643	1,127	2,923	3,323	-	-	DN100 (4)	120	565	700	54	52
3DK31P	1	3	3	4,743	1,127	2,923	3,323	-	-	DN100 (4)	140	725	900	56	54
3DK41P	1	4	4	5,902	1,127	2,929	3,329	-	-	DN150 (6)	160	940	1,200	57	55
3DK51P	1	5	5	7,020	1,127	2,929	3,329	3,769	-	DN150 (6)	180	1,145	1,400	58	56
3DK71P	1	7	7	9,225	1,127	2,987	3,387	3,827	-	DN200 (8)	255	1,630	1,900	60	58
3DK101P	1	10	10	12,525	1,127	2,987	3,387	3,827	-	DN200 (8)	350	2.275	2,700	61	59

Figure 35. Technical characteristics of the cooling tower installed in Seville demo

Connections schema of the cooling tower installed in Seville demo is presented below:

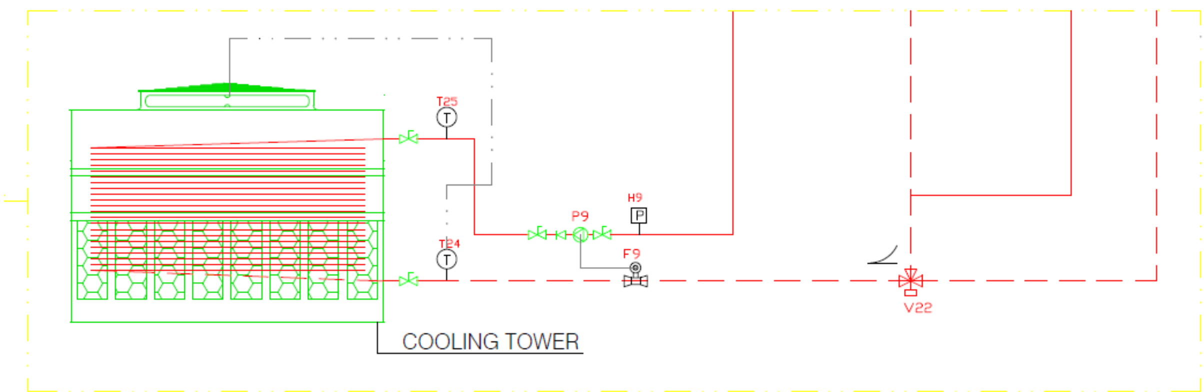


Figure 36. Connection schema of cooling tower

This cooling tower is connected directly to chiller dissipation loop, on one side, but also connected to the line from chilled beams to chiller through 3-way-valve. The tower pre-cools the inlet water to the chiller, reducing the temperature lift for the compressor, and so reducing electrical consumption.

The cooling tower water circuit is connected to chilled beams through the heat exchanger. Water return from chilled beams exchanges heats with water circuit from the cooling tower to reduce the temperature and to reduce electrical consumption.

Next figure, shows heat exchanger installed in Seville demo site:

Figure 37. Heat exchanger between cooling tower and return from chilled beams

2.3 MONITORING COMPONENTS

Different types of sensors complete the installation, necessary to integrate the control system with reliable information about the ongoing performance of different pieces of equipment and status of all components.

Some of the most important and relevant are described below.

2.3.1 Three-phase electrical energy meter

Figure 38. One of the electrical energy meters installed in Seville demo

The energy meter is used to measure and log consumption of electric devices fed by main electric cabinets. By this way, it's possible understanding the real efficiency of the entire system.

Table 6. Energy meter technical data

Technical features		
Power circuit	Rated voltage	230 Vac / 127 Vac, depending on the model
	Tolerance	± 20%
	Frequency	50...60 Hz
	Consumption	< 2 W / 10 VA
Voltage measurement circuit	Connection	Three-phase
	Reference voltage	3 x 127/220...3 x 230/400 Vac
	Frequency	50 / 60 Hz
	Self-consumption	< 2 W / 10 VA
Current measurement circuit	Nominal current *In*	5 A
	Maximum current	65 A
	Self-consumption	< 0.1% of *In*
Accuracy	Active Energy	Class B (EN 50470) Class 1 (IEC 62053-21)
	Reactive Energy	Class 2.0 (IEC 62053-23)
Impulse output	Type	Optocoupled
	Electrical features	max. 24 Vdc 50 mA
Environmental features	Operating temperature	-25 ºC...+70 ºC
	Relative humidity	5%...95% without condensation
Mechanical features	Protection degree	IP 51 installation / IP 40 terminals
	Dimensions	70 x 90 x 64 mm
	Weight	340 g
	Material	ABS + V0 self-extinguishing polycarbonate
Standards	EN 50470-1, EN 50470-3, IEC 62052-11, IEC 62053-21, IEC 62053-23	

2.3.2 Flow meter

Figure 39. One of the flow meters installed at Seville demo

The flow energy meter is used to measure and log consumption of thermal devices fed by thermal units; it is also used for the regulation of the flow of different pumps with variable speed driver. By this way, it's possible understanding the real efficiency of the entire system.

It is composed of a flow meter integrated with two temperature sensors installed on hot and cold pipes.

The MULTICAL® 403 calculates the energy using the formula indicated in the EN 1434-1 standard, where the international temperature scale of 1990 (ITS-90) and the definition of the pressure of 16 are used bar.

Simplifying, the calculation of energy can be expressed as follows:

- Energy = V x ΔΘ x k.
- V is the volume of water supplied
- ΔΘ is the measured temperature difference
- k is the thermal coefficient of water

The integrator calculates the energy in [Wh], which is subsequently converted into the unit of measurement selected.

2.3.3 Static pressure sensor

The PL-528 range of static pressure transmitters is suitable for use with liquids and non-aggressive gases compatible with the FPM. The pressure transmitter is based on proven ceramic technology for exceptional performance speed and reliability.

Figure 40. One of the pressure sensors installed in the Seville demo

Output:		
	PL-528-x	4-20mA (2-wire loop powered)
	PL-528-x-V	0-10Vdc
Supply voltage:		
	4-20mA	7 to 33Vdc
	0-10Vdc	12 to 33Vdc or 24Vac ±15%
Load:		
	4-20mA	$\leq \frac{\text{Supply voltage} - 7V}{0.02A}$ (Ohm)
	0-10Vdc	>10Kohm
Current consumption:		
	4-20mA	<23mA
	0-10vdc	<7mA
Electrical connections		DIN EN175301-803-A
Accuracy @ 25°C, 45% RH 24Vdc supply:		
	Characteristic line	±0.3 % fs
	Resolution	0.1% fs
	Thermal characteristic	±0.2 % fs/10K max.
Response time		<2ms, 1ms typical
Load cycle		<100Hz
Overload/rupture:		
	0 to 4bar version	3 x measuring range fs
	6 to 40 bar versions	2.5 x measuring range fs
Materials in contact with the medium		Stainless steel 1.4305/AISI 303 FPM (Viton) & Ceramic A12O3 (96%)
Temperature:		
	Media	-15 to 125°C
	Ambient	-30 to 85°C
Dimensions		104 x 65mm
Pressure connection		½" BSP male manometer combi
Protection		IP65
Conformity		EN 61326-2-3, CE Marked, EMC
Country of origin		Switzerland

Figure 41. Specification of the pressure sensor

2.3.4 Temperature sensor

Weatherproof IP65 Housing, a wide range of sensing element types, and stainless-steel probe. Immersion sensors are for direct mounting into the PDCSY-TT-PO range of stainless-steel pockets.

Figure 42. Few of the temperature sensors installed in Seville demo

Output types:		
	Passive	Resistive
	Active (selectable)	Current4-20mA *or* Voltage 0-10Vdc
Accuracy:		
	Thermistor	±0.2°C 0 to 70°C (32 to 158°F)
	PT100a	±0.2°C @ 25°C (77°F)
	PT1000a	±0.2°C @ 25°C (77°F)
	NI1000	±0.4°C @ 0°C (32°F)
	-CVO	±0.4°C @ 25°C (77°F)
Probe (PDCSY-TT-322 & PDCSY-TT-341):		
	Material	Stainless steel
	Dimensions	65, 150, 250mm x 6mm dia. (2.56, 5.91, 9.84" x 0.24" dia.)
Probe (TT-342):		
	Material	Stainless steel
	Dimensions	150, 250mm x 6mm dia. (5.91, 9.84" x 0.24" dia.)
	Cable length	1 Meter (3.28ft)
	Terminal head	53 x 49mm dia. (2.09 x 1.93" dia.)
Housing:		
	Material	ABS (flame retardant type VO)
	Dimensions	75 x 70 x 50mm (2.91 x 2.76 x 1.97")
Protection		IP65
Ambient range		-10 to +90°C (14 to 194°F)

Figure 43. Specification of the temperature sensor

3 Contents of systems and subsystems

LowUP solution implemented at Seville demo site is represented by two different systems, integrated into the same building, serving for Heating and Cooling services for an office use environment. The heating solution is described in D4.3, and Cooling solution is covered in D4.4.

3.1 Integration rules

For temperature-based purposes, low enthalpy ratios can be, in a simple way, characterized trough the following way:

Table 7. Enthalpy ratios

Thermal resource		Range of temperatures	Technology	Uses
Conventional	Very low enthalpy	5-25 ºC	Heat pump	HVAC direct use
	Low enthalpy	25-50 ºC	Heat pump (in case)	Direct use
		50-100 ºC		Direct use
	Medium enthalpy	100-150 ºC	Binary cycles	Electricity production Industrial processes
	High enthalpy	> 150 ºC		Electricity production
Non-conventional	EGS – HDR (i.e.)	> 150 ºC	Binary cycles	Electricity production
	Super-critic cycles	> 300 ºC		Hydrogen production

Focusing on the Very low to Low enthalpy resources (from 5 to 100 ºC), applications are mainly limited to residential and services sectors. If the energy comes from renewable energy sources, other non-renewable (mainly based on carbon cycle) can be avoided in use.

The basic uses of low-enthalpy energy uses are the following:

- Domestic hot water production (isolated and district distribution).
- Heating (isolated and district distribution).

Another interesting point to be considered in relation to the integration and application of these solutions is the potential cascade-based integration of systems (or technologies). In this sense, different units and services can be "connected" taking profit of the residual energy content, the ones that are "below" in the energy flow direction. This is the application base for energy waste energy use from industrial facilities.

There are several restrictions that have to be included in the scheme for design. Apart of the obvious and related to the security of systems and people (non-radiation sources, materials compatibility, etc.), operation parameters must be considered since de beginning, in order to avoid bad designs or extra cost solutions. Low enthalpy uses means, in general, extra "surface" (flows, effort, etc.) that is directly related to investment and operation cost.

The following table includes a classification-based list of units/solutions/technologies according to the "position" and role in the system:

Table 8. Classification of units

Solution	Temperature range operation	Other data
Energy sources		
Thermal solar panel		W_{peak}/m^2
Intermediate unit (storage)		
Water storage		
End unit		
Improved classical design emitters	45-55 ºC	Possible energy savings close to 50% in comparison to classic temperatures.
Chilled beam	35 to 50 °C winter 16 to 19 °C summer	150-1.100 W/m
Radiant floor	40 ºC winter 16 ºC summer	50-100 W/m² dT = 5 K Q = 20-35 L/h·m²

4 Installation procedures

4.1 Installation assistance

This section explains how it was installed all the components according to the local regulations.

4.1.1 Solar field

This system was designed to provide 1,5 times the necessary energy for the office building; the number of panels determined the way of installation on the ground, with the purpose of reducing space but achieving the best radiation along the year.

In this kind of system, it is very important not having shadows and strings were installed with 2.5 m of space between them. Another important thing is the inclination of the panels, and this system between 15º-20º in Spain, while orientation is 180º (south) in order to maximize production of solar radiation.

Next figure shows rows of the panel with required space around them and necessary inclination with aluminium structure.

Figure 44. Free space between strings of panels.

Figure 45. Panel bearing structure.

The solar field is composed by hybrid panels, which is the combination of PV panels and thermal heat recovery system installed on the back shield; so, in order to prevent electroshocking and classical problems related with air and water, mechanical safety systems like bleeders or isolated electrical connections were integrated.

Next figures show that kind of security components on the side of the panel.

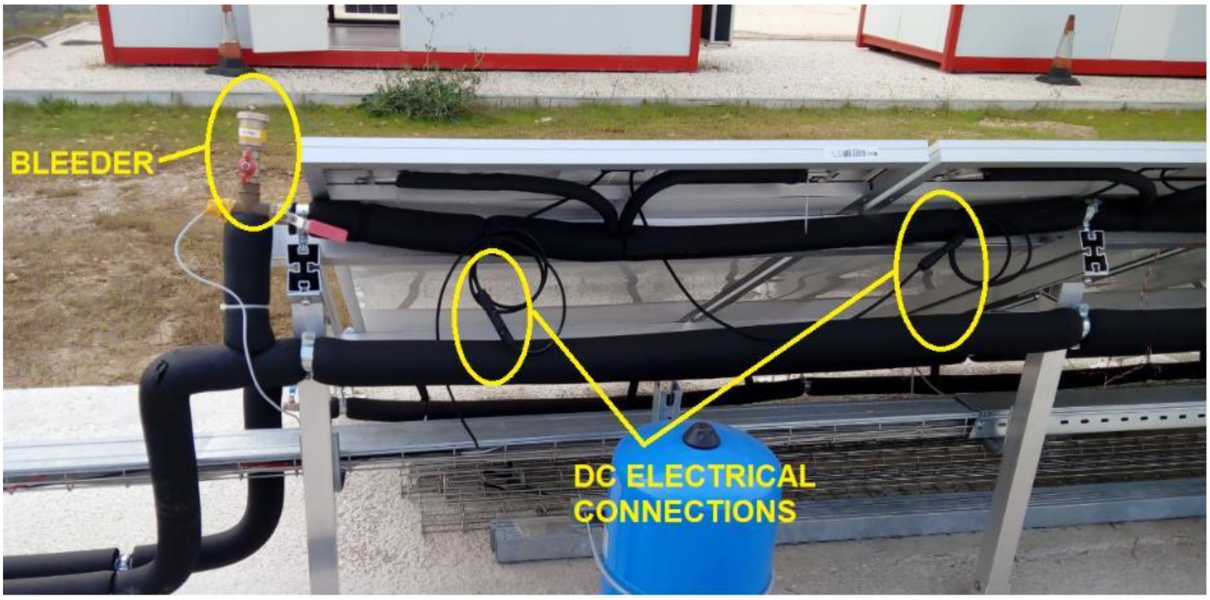


Figure 46. Bleeder and electrical connections in the solar field.

Another security element on solar field installation is dry cooler, to prevent heat problems in the primary circuit and cool it during the period when the heat is not required from the building, but solar radiation is high. In this case, intrinsically safety is replaced by the plc control system for temperature regulation; circulation pump avoids stagnation, deviation valves close the water loop over itself and connection with a storage tank is cut off, so all heat is directed to air rejection system.

Next figure shows the installation of the dry cooler, with its temperature sensor.

Figure 47. Dry cooler (left) and temperature sensor for the dry cooling system.

Control side of solar field is composed of pressure and temperature sensors, a VSD pump, flow meters and an electrical cabinet with plc. Power and control wiring proceeds from the local electrical cabinet and connects to all the components of the solar system.

That cabinet needed to be installed over the floor but spaced below both for ventilation and facilitating electrical connections.

Next figure shows connections in the cabinet and electrical components of security.

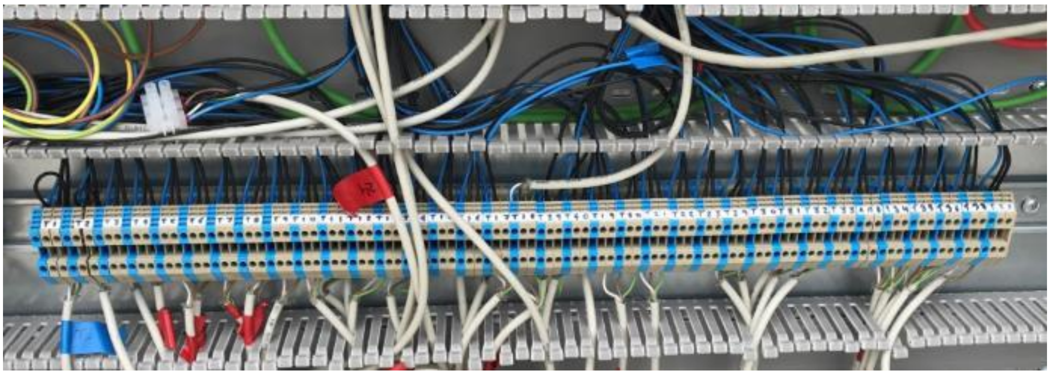


Figure 48. Electrical connections in the solar field cabinet.

Figure 49. Control connections of local plc.

About hydronic, the system has sensors and pump distributed over the installation; in order to install the pump in a secure way, it was necessary some components like a filter, isolating valves, pressure sensors, 2-way valves and correct hold-down systems for each one.

Next figures show the mounting system of some elements of the circuit.

Figure 50. Detail of solar field pump.

Next figures show components installed on the primary circuit of the thermal solar field.

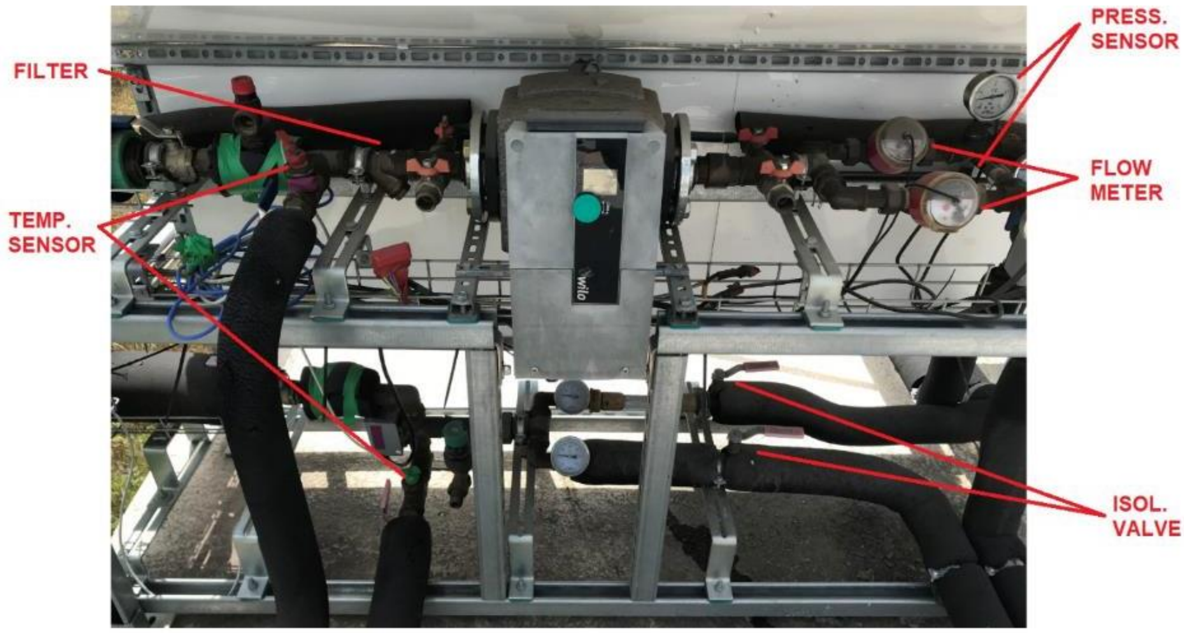


Figure 51. Solar pump station with regulating devices.

To distribute energy along the installation was necessary to install insulated pipes, isolation (cutting off) valves and other components to ensure the correct way to work. To ensure the minimum exposure to the sun energy of some components, it was installed a shielded structure to protect most delicate components.

Hydraulic side of solar field is controlled by both Endef PLC and LowUP PLC. Endef controls and regulates the operation of the pump (P1 in the diagram) with respect to outcoming temperature in function of required setpoint. LowUP plc regulates the access of the solar loop to the stratified tank through V1 3ways valve, in order to feed it only with required temperature and not lower.

Therefore, during warm-up, the valve excludes the solar loop from the tank, while the pump circulates the water at fixed flow until achieving the desired temperature from the panels; once the temperature is achieved, the valve opens, and pumps regulate speed according to intensity of the radiation (and so setpoint temperature).

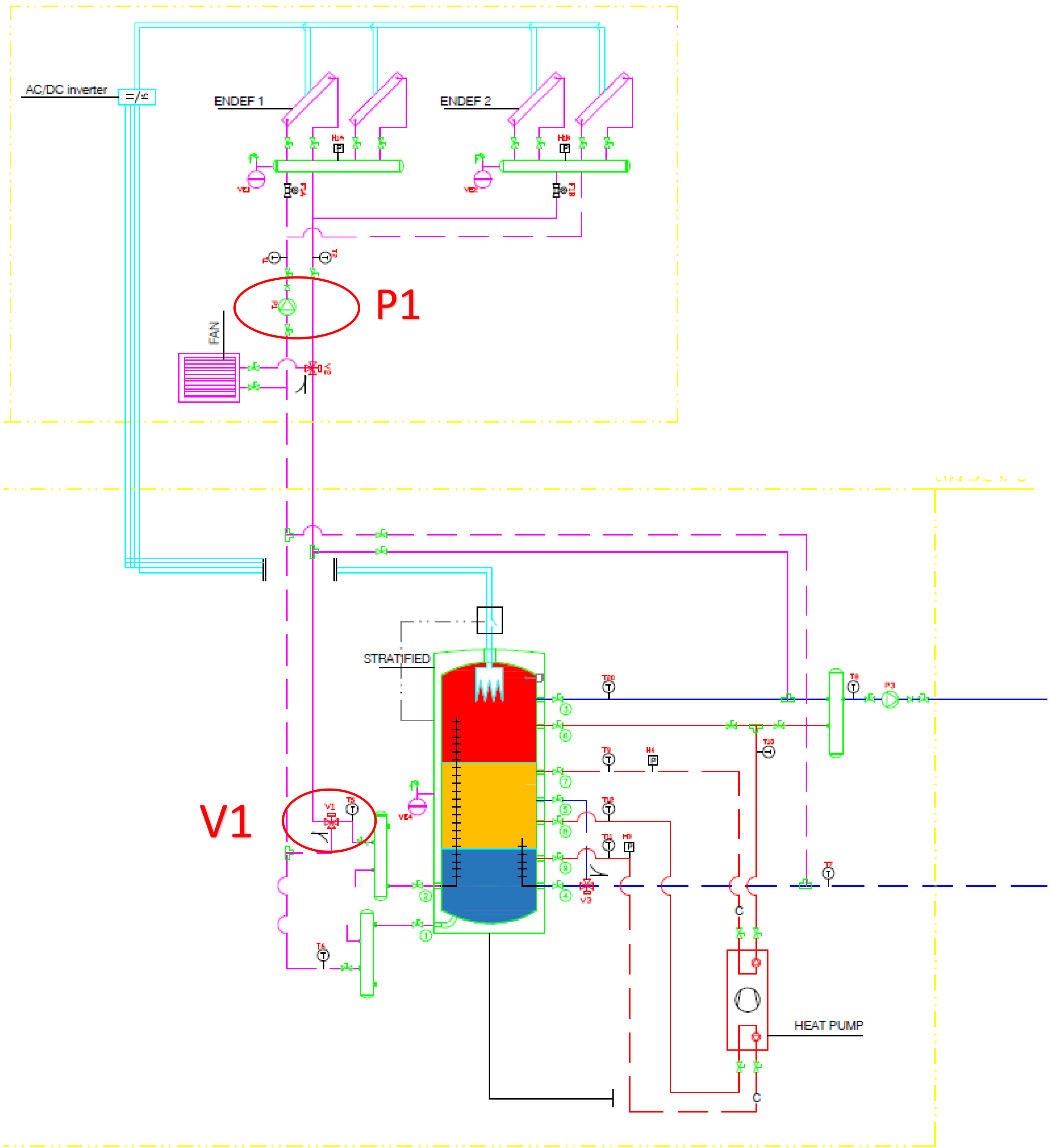


Figure 52. Solar field diagram

Figure 53. Structure to avoid sun radiation (left) and anchorages of solar field pipes.

Preliminary checks in the solar field side

- Pressure tests in the circuit with air and water.
- Verify the subjections of the pipes and distances of separation with other pipes are correct.
- The joints of the pipes with other components had to be correct as well.
- Sensors were tested with analogic sensors distributed by the installation.
- Pumps were checked with analogic flow meter.

AC/DC Inverter was installed in the backside of the electrical cabinet, the closer as possible to DC source, in a dry zone and protected from the sun of the afternoon. Minimum distance on the back was respected to ensure natural ventilation through the passive heat rejecter.

Next figure shows the mounting of the inverter.

Figure 54. Structure for DC/AC Inverter.

Before start-up, some task has to be prepared.

Preliminary checks

- Do not mount the inverter on a pillar
- A solid support surface must be available for mounting
- The mounting location must not be exposed to direct solar irradiation
- The mounting location should be freely and safely accessible at all times
- AC and DC disconnectors need to remain in the “OFF” position
- Fuses are not connected

4.1.2 Stratified storage tank

Stratified tank storage is a mid-point in the workflow of the HEAT LowUP. It´s an element that stores a large quantity of energy in both temperature and volume.

That water is cumulated at low temperature (max 50ºC) and that why it´s necessary to have good insulation and a correct sealing for maintaining the losses.

Storage tank does not need to be fixed on the ground due to its weight; it is simply installed in a vertical position, and pipes were connected to the tank.

Next figure shows the tank placed in its final position and some of the connections.

Figure 55. Joints and pipes connections on the storage tank.

Keeping water at the correct temperature is an important thing for fulfilling the objectives of the project, so insulation of the tank became up to 12 cm of thickness.

Next figure shows a part of this tank insulation.

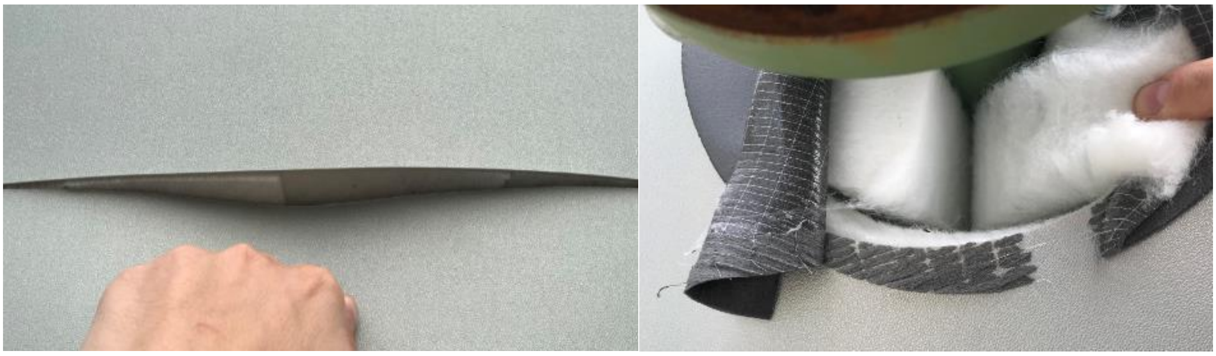


Figure 56. Insulation of tank.

To test the efficiency of heat stratification, the tank was provided with specific temperature monitoring system based on the vertical distribution of temperature probes immersed in the water.

Next figure shows how temperature sensor was installed.

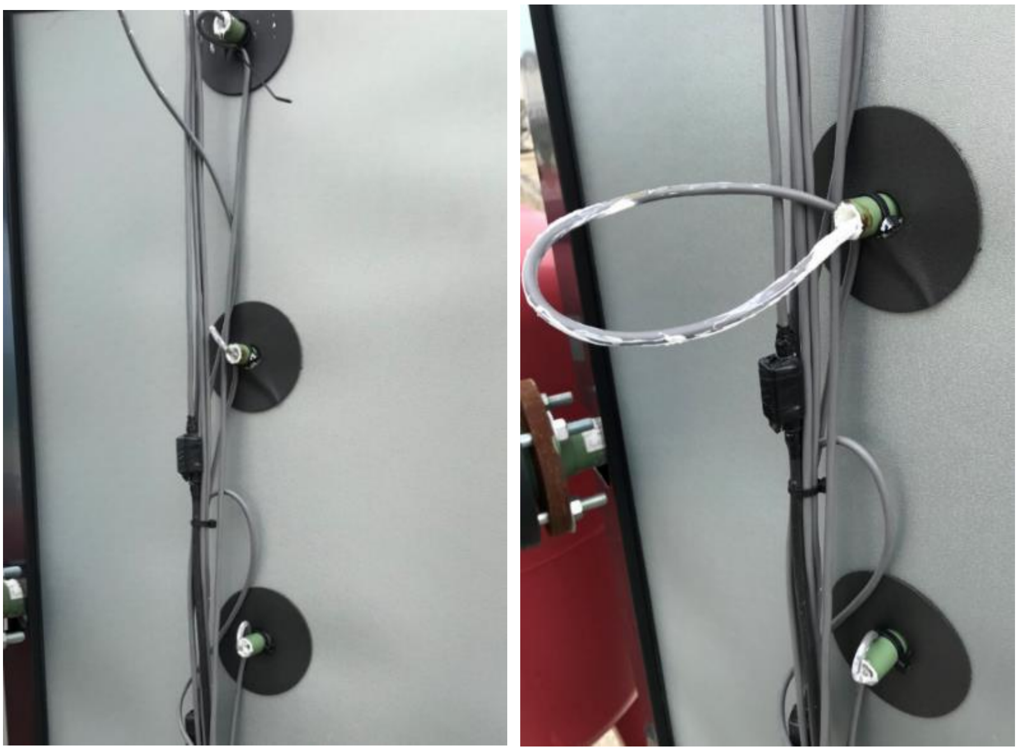


Figure 57. Temperature sensor in the storage tank.

Before start-up, some task has to be prepared.

Preliminary checks

- Good anchoring to the floor.
- Correct distance between the tank and the elements around.
- All the security components installed and tested.
- Drains and overflows are connected and free from blockage.

4.1.3 Heat pump

The heat pump was one of the most fragile elements in the installation; that is why some tasks require to be was made before starting up. First thing was the correct situation leaving security space around it as it presented in the next figure.

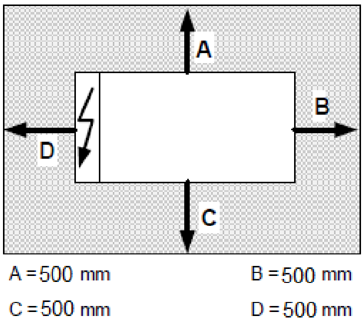


Figure 58. Recommendation of free space around the heat pump.

This unit needed to be installed raised from the ground and avoiding installations in places subject to flooding. Fixing/supporting points was necessary as well due to the weight of the unit. Next figure supporting point to the ground.

Figure 59. Supporting recommended of the heat pump.

Another important point in this section was flexible joints on all hydraulic connections for excluding transmission of vibrations from the compressor to pipes. Isolating valves, filters and flow meter are necessary for this kind of the installation. Next figure shows all the components installed at the inlet/outlet connection.

Figure 60. Heat pump connections and security components.

In order to start-up, the unit needed flow switch, pressure and temperature sensor. Next figure shows that's components connected around the unit.

Figure 61. Control and security components installed in the heat pump.

Before the starting-up, some task has to be prepared.

Preliminary checks

- Ensuring all security components are installed.
- Correct anchoring in the floor

4.1.4 Radiant floor

The radiant floor is the end of a flow that begins in the solar field and passes through the storage tank. So, to supply water from the stratified tank, it was necessary to install two pumps operating in series in order to overcome higher pressure losses due to long distance between tank and office (a passage for truck is present in the demo, as shown in latter picture.

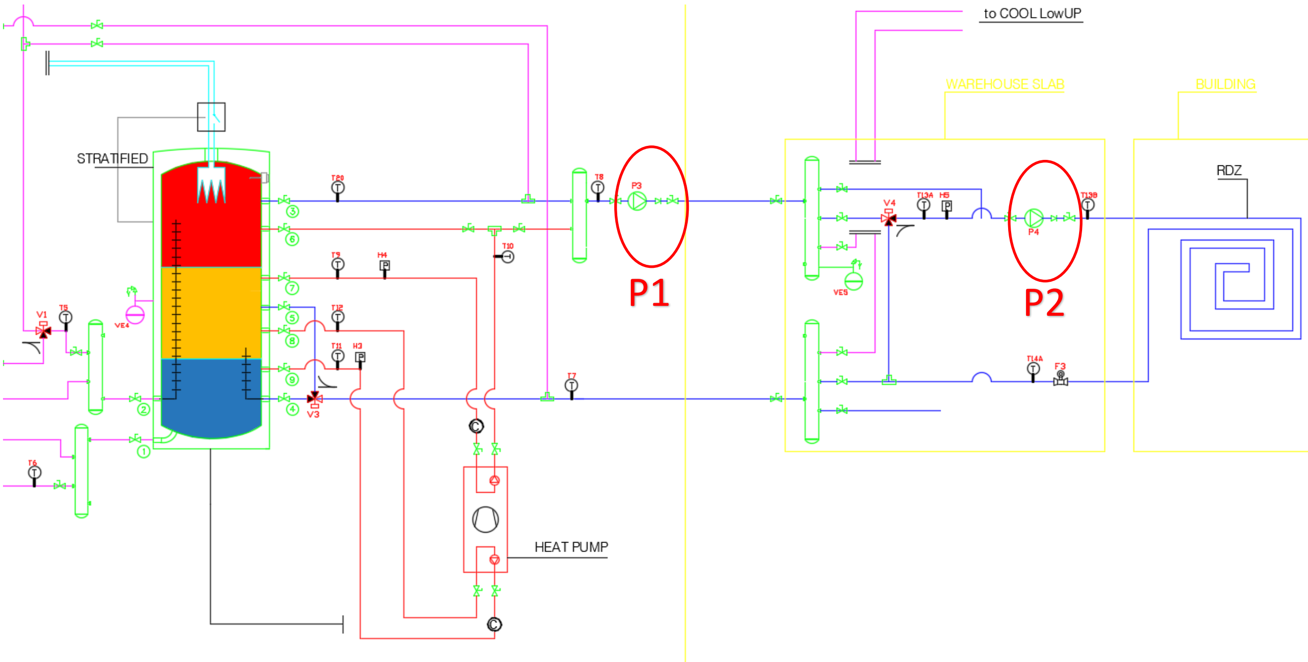


Figure 62. Schema of radiant floor circuit.

Figure 63. Pumps of radiant floor circuit. Pump 1 (left) and Pump 2 (right)

The way from the tank to the radiant floor manifold had to be isolated to ensure there were no thermal losses. Next figure shows pipes insulation and mounting in its way to the radiant floor.

Figure 64. Insulation in water pipes from the storage tank to the radiant floor through the truck passage.

Before going inside the office, water mix in the manifold that was firmly anchored to the outside wall, then, pipes go in through the wall to connect with the radiant floor manifold installed inside the office. Next figure shows outside manifold and radiant floor manifold.

Figure 65. Supply and return manifold (left), supply and return pipes through the wall to the radiant floor.

Inside the office was installed the radiant floor manifold and all the pipes on the floor. Distribution of the water in each circuit is managed from the radiant floor manifold which it was installed inside the office and has an isolating valve and balancing valves to ensure all circuit work correctly. Next figure shows the supply and returns manifold inside the office.

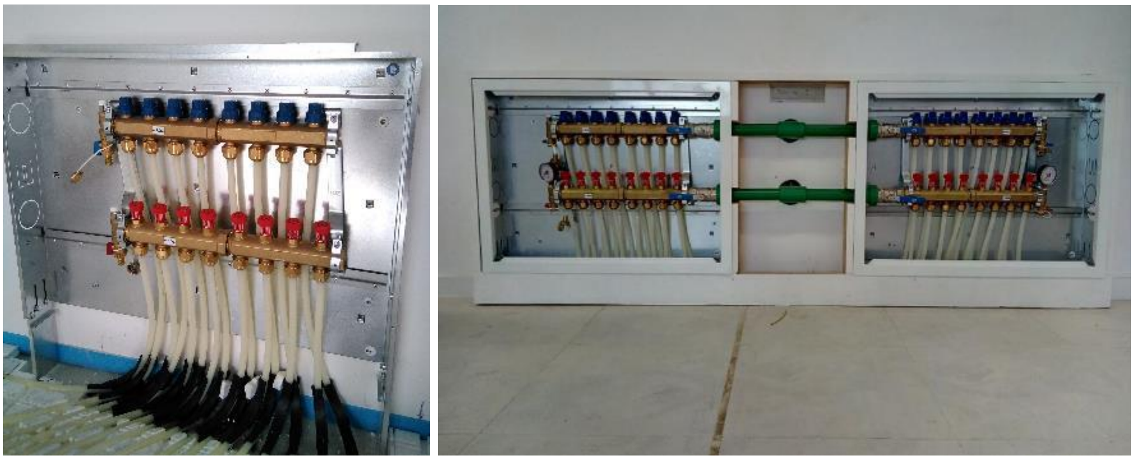


Figure 66. Manifold with pipes connections (left). The final status of radiant floor manifold (right).

Radiant floor layer consists of an insulation layer bellow the pipes to ensure heat is not going down, pipes layer, and metal layer over pipes in order to distribute the forces on the floor. Finally, a ceramic tile was installed to finish the floor. Next figure shows different layers installed at the office to make sure radiant floor work correctly.

Figure 67. Pipes inside the radiant floor (left) and last layer (metallic) of the radiant floor (right)

Preliminary checks

- Pressure tests in the circuit with air and water.
- Verify the subjections of the pipes and distances of separation with other pipes are correct.
- The joints of the pipes with other components had to be correct as well.

4.1.5 Wasenco tank (at Rucab)

Wasenco tank was installed in parallel to existing wastewater line coming from the kitchen to the main collector, on one side; on another side in parallel to the existing clean water line that is coming from the ground to the kitchen. The necessity of installing it in parallel was determined by the requirement of connecting to the lines with always the possibility to revert the installation in case of failure and so no primary affecting service of the residence.

In the picture below are represented the interceptions for the connections from the kitchen to tank for wastewater:

Figure 68. waste water bypasses

Connections for waste water have all been made in plastic, in order to maintain reduced cost and facilitate the passage of wastewater within the pipes; sectioning valves have been installed in order to control the by-pass manually in case of problems with the line.

The waste water passes through a grease separator before being pumped to the tank, where the heat is recovered, stored and delivered to the clean water passing through it.

Figure 69. Grease separator-pumping station-recovery tank.

The clean water side has been realized in copper, in order to maintain the original pipes of the building, always using the same principle of the bypass in case of failure; the system has been completed with sensors of flow and temperature, in order to monitor the performance of the system and expansion system due to variation of temperature.

Most of the components have been mounted on the ground, using a rubber layer to avoid possible vibrations and to recollect possible leakages; on the other hand, hydraulics have been fixed on the top of the tank, using the same structure: control panels and electric cabinets directly on the wall.

Figure 70. Grease separator-pumping station-recovery tank.

Preliminary checks

- Ensuring all security components are installed
- Joints are correctly installed and do not drain
- Electrical protections are correctly installed and control system work
- No leakages from wastewater

4.1.6 Thermal emulator

Thermal emulator simulates work of the RUCAB installation and consists of a storage tank, electrical resistance and water pump. In order to control the performance of this system, pressure and temperature sensor ware installed inside the tank and the next figure show it. The emulator thermally and hydraulically replicates the operation of Wasenco tank.

Figure 71. Temperature sensor inside Wasenco emulator.

To ensure pipes were installed correctly and do not support the weight in joints, some metallic beams were installed to hold pipes and the components around.

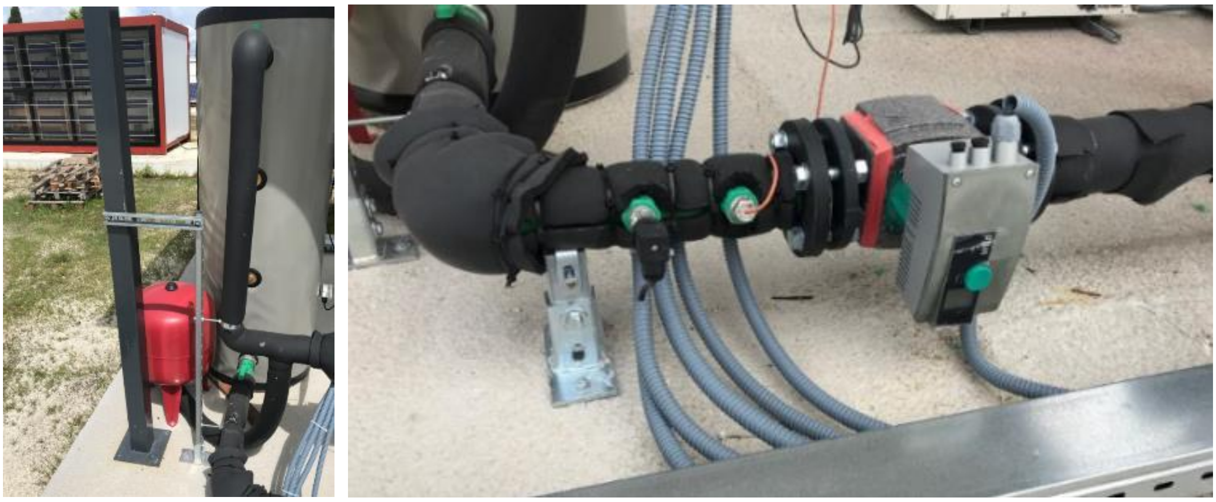


Figure 72. Fixing structure to hold pipes, pump and tank in Wasenco emulator.

A security element as bleeder was installed on the top of the tank to ensure the correct start-up and periodic maintenance of the system.

Figure 73. Bleeder on Wasenco Tank.

Preliminary checks

- Ensuring all security components are installed
- Joints are correctly installed and do not drain
- Electrical protections are correctly installed and control system work

4.1.7 Dry cooler

The unit had to be installed outdoors, in an area protected from flooding, ensuring that all conditions (negative outdoor temperatures, corrosive atmosphere, altitude, etc.) were taken into account.

In order to correctly operate the system, a large free space bellow and on top of the unit is needed. Next figure shows free space bellow.

Figure 74. Free recommended space around the dry cooler.

The electrical connection had to be protected, and that connection was covered with the case of the unit. Next figure shows where electricals connection is.

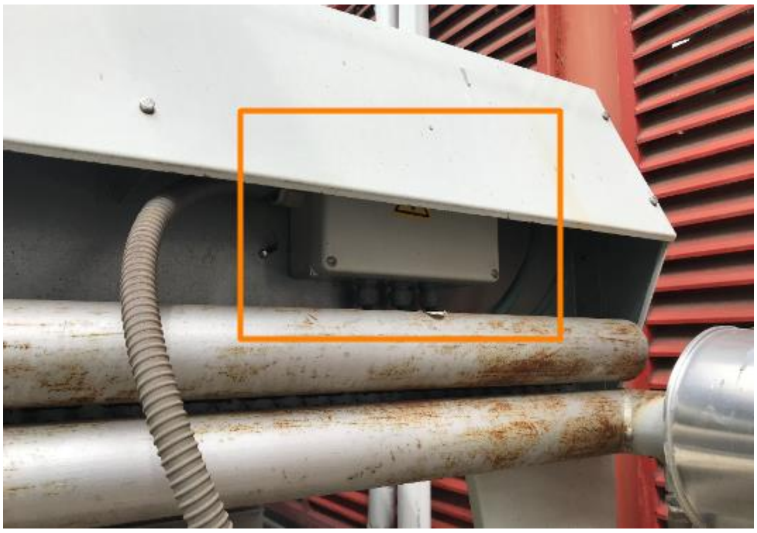


Figure 75. The electrical connection in a dry cooler.

Joints and pipes had to be isolated to avoid energy loses, and the next figure shows how this operation was made (the dry cooler was already existing when LowUP was installed).

Figure 76. Insulation pipes and joints in a dry cooler.

Preliminary checks

- Ensuring the hydraulic circuit is full of water
- Joints are correctly installed and checked
- Electrical protection is correctly installed

4.1.8 AHU, chiller and PCM tank

The most important thing, in this case, is that unit are suitable for outdoor use only, so that why this equipment was installed outside of the warehouse.

The unit had to be installed on a robust and perfectly levelled foundation and furthermore had to be able to support the weight of the equipment. That why it was installed in a compact sand foundation and over rubber sheets to reduced noise and vibrations.

Figure 77. Rubber sheets in PCM Tank and Chiller.

Manufacturer requested a free area of obstacles around the equipment, in order to ensure optimum ventilation to the condenser, avoiding any warm air recirculation and insufficient air supply to the air-cooled condenser.

On the other hand, tank and chiller require minimum space for maintenance from all sides. Additional rain protection was installed for the chiller, in order to protect electronic components from humidity. Most of the protection panels are dismountable while piping connections are connected to equipment through flanges, in order to speed up connection works.

Next figure shows free space around the units.

Figure 78. Free space around PCM Tank and Chiller.

Isolating valves was necessary to install between chiller and water circuit, in order to limit water losses in case of leakages and speeding up water filling operations. Isolating valves are flanged, which gives more security and speed up installation works.

Next figure shows isolating valves and sensor installed for this unit.

Figure 79. Flange isolation valve and sensors.

Preliminary checks

- Ensuring hydraulic circuit is filled and air purge
- Joints are correctly installed
- Dampers have free space to open/close
- Electrical protections are correctly installed
- Anti-vibration systems are installed on pipes connected with chiller

4.1.9 Chilled beams

This system was installed suspended of structural beams with steel cable, with steel chain as "back-up" in case of failure. This kind of installation was necessary in order to preserve the requirement of the beams, which have the outlet of air in the upper part of the case, so installation embedded in the ceiling would reduce effectivity.

Next figure shows how beams were hanged.

Figure 80. Hanging system of chilled beams.

Pipes of the system needed to be isolated, and the next figure shows insulation for the building´s interior. The ventilation duct was isolated as well, but for aesthetic issues, cladding is inside the duct.

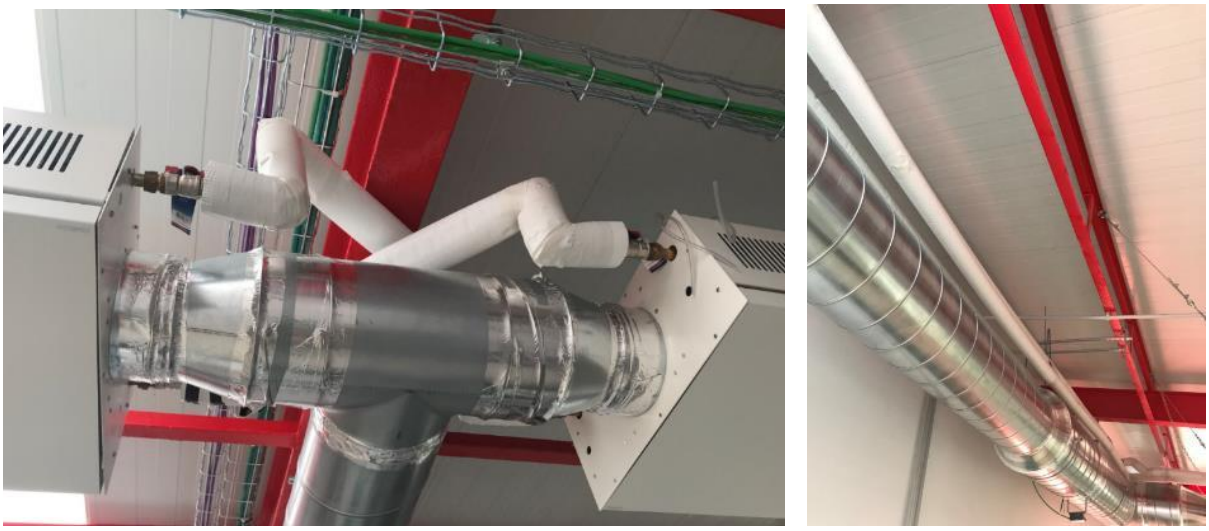


Figure 81. Insulated pipes and aerial connections for chilled beams

Each beam is completed my own control system for water, air and light; a temperature sensor and a luminosity sensor are used to regulate the intensity of temperature and light, according to setpoints coming from remote plc manager.

Next figure shows a detail of beam plc.

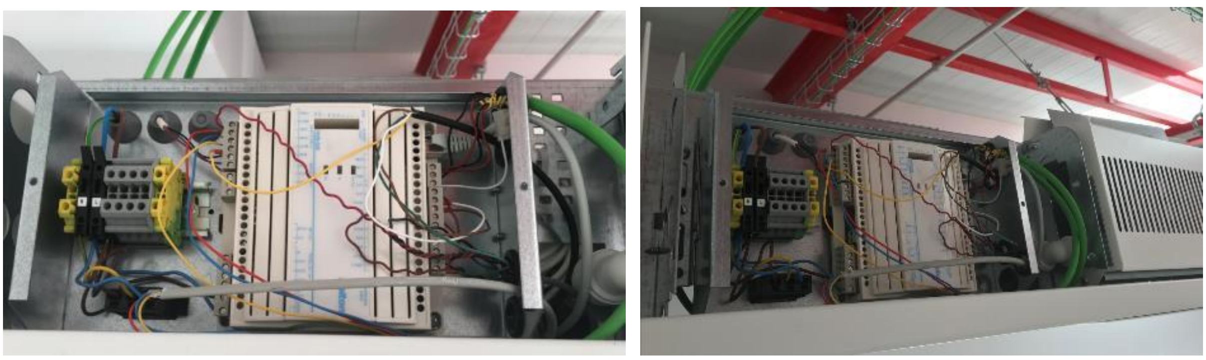


Figure 82. Control panel in the chilled beam.

Preliminary checks

- Ensuring that fixing is correct
- Ensuring all hydraulics joints are correctly installed
- Ensuring air circuit is correctly sealed, and it has no air loses

4.2 Integrated control system

One of the most important tasks made in LowUP the integration of all individual and proprietary control systems from different equipment, organized like a distributed control system, with only one master able to coordinate all of them according to a unique, efficient and real-time control strategy.

The master plc is then supervised by end-user through a SCADA, which is connected in parallel with an intelligent and predictive calculation engine, able to define operation strategies and setpoints.

A schema of Heat/Cool LowUP could be as the following diagram:

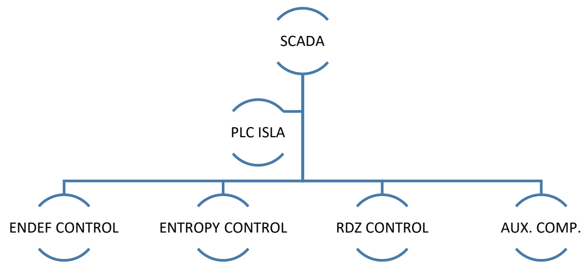


Figure 83. Distributed control for HEAT LOWUP

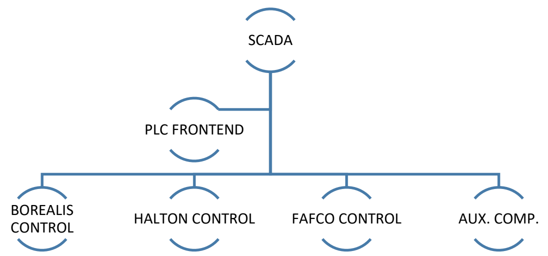


Figure 84. Distributed control for COOL LOWUP

Each system has its own communication protocol like Mod Bus RTU, Mod Bus TCP/IP and BacNet; through gateways, all of them are translated to Modbus TCP/IP for master plc, which then translate for the SCADA the values coming from different analogic sensors.

4.3 Legalisation and public administration notifications

According to the specific legalization rules of each country or region, engineering project, construction data (providers, execution company, etc.) and other relevant information must be submitted for approval before to start using the utility.

Different statements are involved. Initially, the main collector is the local government, that will be in charge of the whole activity validation (including non-related to utilities). Utilities notifications and validations are usually sent to a specific part of the regional or general government, more specialized on this kind of supervisions.

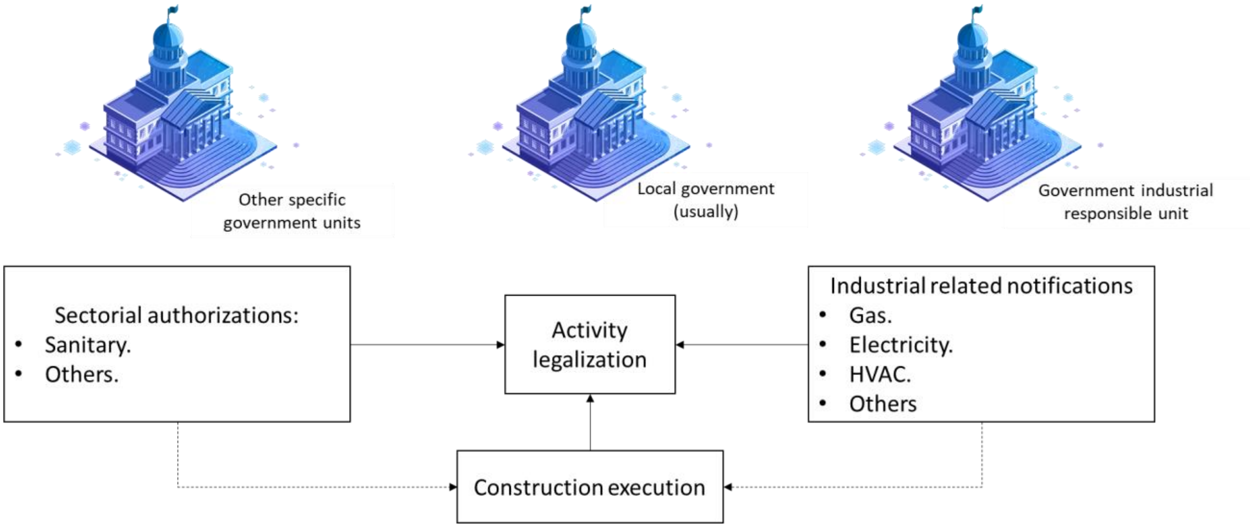


Figure 85. Notification tree

As seen in the figure below, the notification won't be done until the last steps of the procedure, usually until the utility is finished and ready to work in normal operation service.

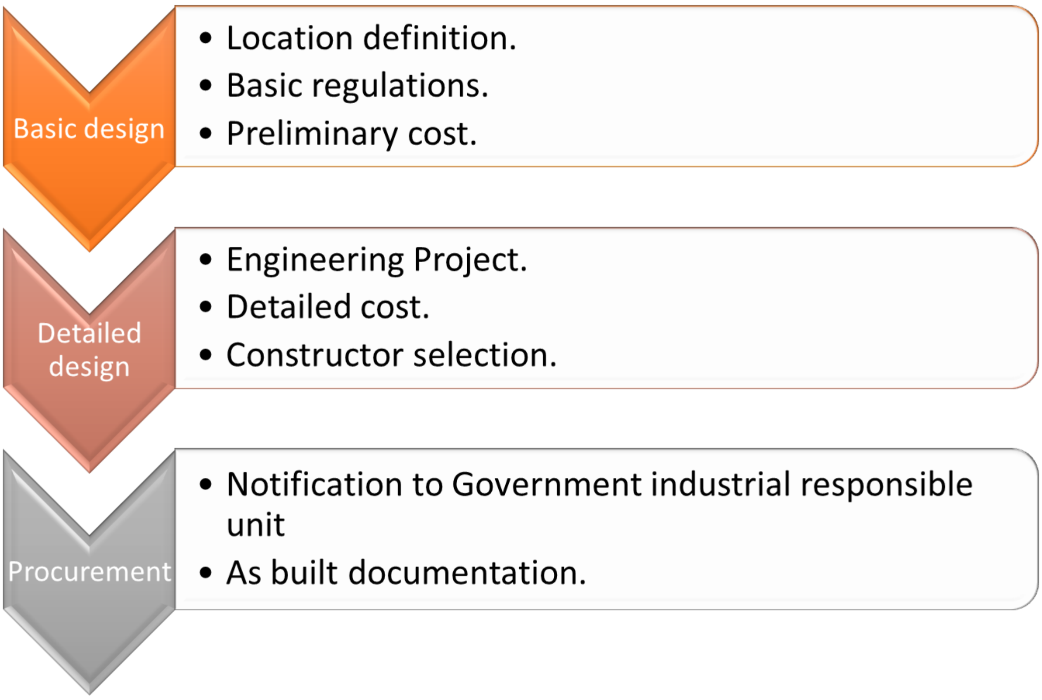


Figure 86. Engineering and legalization process

5 Operation and Maintenance

This chapter pretends to report required activities for the correct operation of all devices and equipment during the lifetime, with the purpose of reducing unexpected damages and fulfilling with local normative in terms of HVAC installations.

As explained before, the legionella risk is excluded in this installation because of the technology used for heat rejection. On the other hand, a conventional electro-mechanic maintenance plan is going to be described in order to prevent failures and provide the operation in the higher levels of efficiency.

5.1 Electro-mechanic management plan

Guide to Best Practice Maintenance & Operation of HVAC Systems for Energy Efficiency

The basic objectives for the electromechanical maintenance plan are:

- Improving the energy and water performance ratings
- Maintaining the performance and efficiencies of buildings that are currently delivering target ratings and require regular monitoring, fine-tuning and re-balancing of the HVAC Systems.

For buildings to deliver efficiencies and to achieve target performance ratings, it is essential that Stakeholders work in collaboration as a team, making changes necessary to realise the common goal of achieving sustainability.

The responsibilities for each stakeholder are outlined as follows:

The **Building Owner** has responsibility for maintaining and operating the Base Building Services. In a Gross Lease, the Building Owner also pays for energy costs for the Base Building Services, which is recovered from the Tenants as outgoings.

The Building Owner has the most influence for ensuring that buildings operate sustainably and has the potential to motivate and empower all Stakeholders to deliver efficiencies through best practice operation and maintenance.

Tenants pay the utility bills for energy supplied to the tenancy and consumed by tenants lighting and power (TLP). Tenants also have responsibility for the installation, maintenance and operation – including energy costs, associated with supplementary HVAC Systems.

The Facilities Manager (FM) is usually tasked with the responsibility for Building Maintenance. The FM has to implement the maintenance and environmental policies and strategies set by the Building Owner in accordance with the allocated resources.

The **Maintenance Contractor** (or Service Provider) is ideally placed to identify energy and water-saving opportunities in HVAC Systems and to implement these measures in partnership with the FM.

Design Engineers are engaged by the Building Owner and have responsibility for evaluating HVAC System requirements in accordance with the design brief, performing design calculations and issuing drawings and specifications to be used for installation, commissioning and maintenance during the defects liability period.

It is important to monitor the efficiency of a building and the performance of the maintenance contract with regards to delivering the necessary outcomes. This monitoring function may be performed by in-house staff or external ‘auditors’, or a combination of both.

5.1.1 Maintenance plan implementation

The figure below shows the important steps for implementing high-efficiency maintenance and the key Stakeholders who must participate in the process.

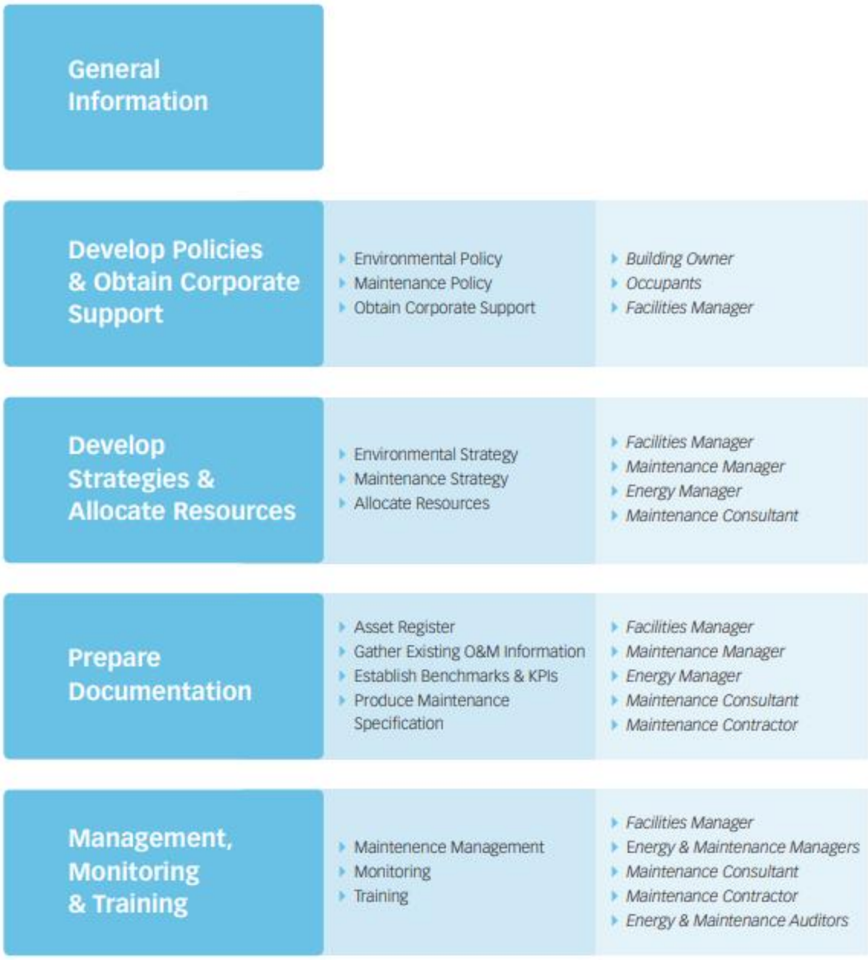


Figure 87. Maintenance steps

The maintenance management plan must be structured according to predefined systems families and adapted to the reality of the equipment finally installed.

The following tables show a complete set of operations for each component of the facility:

Table 9. Maintenance operations and frequencies for solar collectors

Operation nº	Work	Frequency
1	Verification of the state of cleanliness of the translucent protection of the collector panels	6 month
2	Verification of non-condensation and dirt under the protection of the collector panels	6 month
3	Verification of non-existence of corrosion and water leaks in the collector panels	6 month
4	Inspection of the collector's joints: verification of the absence of cracks and deformations	6 month
5	Verification of the condition of the absorber surface of the collectors: nonexistent corrosion, deformation and leakage	6 month
6	Checking the condition of the housings and breathing windows	6 month
7	Inspection of hydraulic connections: location and correction of leaks, tightening connections, checking water levels in circuits	monthly
8	Inspection of the support structure: state of degradation, signs of corrosion, screw tightening	6 month
9	Cleaning and descaling inside the hot water tank. Elimination of oxidations	2 years

Operation nº	Work	Frequency
10	Verification of wear status of sacrificial and replacement anodes, if applicable	yearly
11	Inspection of the thermal insulation of the hot water tank and correction, if applicable	year
12	Cleaning and verification of the operation of the primary coil or exchanger	month
13	Verification of efficiency (CF) and performance of primary/secondary exchanger	month
14	Verification of the density and pH of the primary heat transfer fluid and correction, if applicable	year
15	Verification of the condition of the primary circuit pipes: correction of leaks and oxidations	6 month
16	Verification of the tightness of the complete primary circuit and restitution, if applicable	2 years
17	Verification of the thermal insulation of the primary circuit pipes and correction, if applicable	6 month
18	Verification of the absence of humidity inside the insulation and replacement of these, if any	year
19	Verification of status and functionality of automatic drains. Hole cleaning	year
20	Verification of status and functionality of manual traps. Emptying bottles	6 month
21	Verification of status and operation of recirculation pumps. Clean and watertight	year
22	Verification of status and functionality of expansion vessels. Pressure check	6 month
23	Status verification and level adjustment in open expansion vessels	6 month
24	Verification of status and operation of the automatic filling system of the primary circuit	month
25	Status check and functionality of shut-off valves, non-existence check of seizures	2 years
26	Verification of status and functionality of safety valves and performance check	month
27	Verification of the state of electrical panels: interior cleaning, verification of door seals	year
28	Verification of electrical equipment, actuation of switches and tightening of connections	year
29	Verification of regulation thermostats, performance check and adjustment, if applicable	year
30	Verification of the status and functionality of the support system. See ranges of heat generators	year
31	Verification and adjustment of measuring instruments: thermometers, temperature probes and gauges of the installation	Year

Table 10. Maintenance operations and frequencies for autonomous air handling unit

Operation nº	Work	Frequency
1	External inspection of the equipment. Corrosion correction, paint deterioration and oil stains.	year
2	Inspection of protection grilles for fans, batteries and air intakes.	year
3	Verification of the state of the equipment support: rigid, anti-vibration mounts, shock absorbers, etc.	year
4	Verification of the condition of the gaskets in the equipment installed outdoors and substitution, if applicable	2 years
5	Verification of the condition of the gaskets in the equipment installed inside and substitution, if applicable	year
6	Verification of the state of the elastic conduit connection unions. Verification sealing and replacement, if applicable	2 years

Operation nº	Work	Frequency
7	Inspection of the state of removable panels and their closures and joints. Correction anomalies	2 years
8	Air leak inspection and correction if applicable	yearly
9	Inspection of the thermal and acoustic insulation of the panels and repair, if applicable	monthly
10	Air filter inspection and replacement, if applicable	
11	Checking the condition of the fins and the level of fouling of the interior battery. Fin combing and battery cleaning on both sides, if applicable	2 years
12	Inspection of water batteries. Tightness check and correction, if applicable	2 years
13	Checking the condition of the fins and the level of contamination of the external battery. Fin combing and battery cleaning on both sides, if applicable	2 years
14	Verification of the absence of tubes deformed by freezing	2 years
15	Inspection of condensers by water: cleaning of tubes or plates and heads, elimination scale and obstructions	yearly
16	Circuit tightness check. Equipment leak test	2 years
17	Verification of non-existence of internal water leaks in condensers	2 years
18	Verification of non-existence of internal leaks of refrigerant to the water circuit in condensers	2 years
19	Inspection of the condenser water circuit: correction of leaks and corrosion in the connections	2 years
20	Verification of the state and operation of pressure-reducing condensation control valves	2 years
21	Verification of the status and operation of safety valves. Status check of fuse plugs	2 years
22	Status check and cleanliness of the condensation collection tray and its drains	2 years
23	Correction of leaks and elimination of corrosion in the condensation collection tray. Bactericidal treatment of the tray	2 years
24	Inspection and cleaning of the siphon of the drainpipe of the condensate collection tray	2 years
25	Inspection of external axial fans, anchors, supports and free rotation. Nonexistence of vibrations	2 years
26	Inspection of exterior or interior centrifugal fans, anchors, supports and free rotation. No noise or abnormal vibrations	2 years
27	Inspection of transmissions by pulleys and fan belts: Verification of alignment, belt tension and condition and replacement, if applicable	2 years
28	Cleaning of fan blades and blades	yearly
29	Fan bearing and bearing inspection: check for clearance and greasing if applicable	2 years
30	Verification of the tightness of the unions and joints of refrigeration lines in equipment split system	monthly
31	Condition inspection and tightening of plugs and caps of refrigeration connections and valves of service	monthly
32	Verification of the absence of humidity in the refrigeration circuit, by means of an indicator liquid sight glass	monthly
33	Inspecting the coolant filter drier and replacing the filter or its cartridges, if applicable	2 years
34	External general inspection of compressors, elastic suspension, anchors, etc.	2 years
35	Oil level inspection in compressor crankcase sight glasses	month
36	Checking the status, operation and consumption of the crankcase heaters	2 years
37	Checking the condition of the refrigerating oil. Acidity test	2 years
38	Verification of the operation of compressor capacity control devices	2 years
39	Status verification and cleaning of electrical control, command and force panels, and moisture protection	2 years

Operation nº	Work	Frequency
40	Inspection of the contactor, switch and relay contacts, and replacement, if applicable	2 years
41	Inspection of signalling lights and replacement of lamps or cast LEDs	2 years
42	Inspection of frequency converters and variable speed control devices of motors	2 years
43	Status check and actuation of flow, air or water switches, and adjustment, if applicable	2 years
44	Functional verification of external safety series and external interlocks of the equipment	monthly
45	Status check and actuation of command pressure switches. Setpoint adjustment, if applicable	2 years
46	Verification of status and performance of safety pressure switches. Setpoint adjustment if applicable	monthly
47	Verification of status and performance of control thermostats. Set point adjustment, if applicable	2 years
48	Status verification and performance of safety thermostats. Set point adjustment, if applicable	month
49	Status check and actuation of thermostatic expansion valves and adjustment, if applicable	2 years
50	Checking the status and operation of check valves in the refrigeration circuit	2 years
51	Verification of status and performance of automatic equipment cycle inversion valves reversible	2 years
52	Status check and actuation of solenoid valves and service valves of the refrigeration circuit	2 years
53	Checking the condition and tightness of howitzer valves (Schraeder) for loading and circuit service	monthly
54	Inspection of electronic regulation and control programmers. Setting parameters, if applicable	2 years
55	Checking the tightness of the electrical connections in the controller box and in the control circuits	2 years
56	Inspection of electrical insulation of power supply lines to motors	2 years
57	Inspection of connections and grounding lines. Tightening connections	2 years
58	Tightening check of connections in compressor and motor terminal boxes	2 years
59	Checking the tightness of the compressor terminal joints and tightening or substitution, as appropriate	2 years
60	Verification and contrast of thermometers and manometers and other measuring instruments	yearly
61	Equipment operation check-in all cycles or modes for which It is designed	2 years
62	Verification of the absence of noise and abnormal vibrations during operation	2 years
63	Collection of operating data according to the control sheet. Performance determination refrigerator and comparison with design data	2 years

Table 11. Air handling units

Operation nº	Work	Frequency
General		
1	Exterior surface condition inspection, cleaning and corrosion removal	Year
2	Paint Review of Exterior Surfaces	Year
3	Inspection of exterior protective roofs	Year
4	Verification of non-existence of air leaks due to the panel, door and register joints	

Operation nº	Work	Frequency
5	Inspection of door closings and registers. Weatherstrip repair and replacement, if applicable	Year
6	Inspection of the module connection screws. Replacement of rusty screws	Year
7	Verification of the state of waterproofing, joints and asphalt fabrics. Repair, if applicable	Year
8	Verification of the state and functionality of the anti-vibration mounts	Year
9	Cleaning the interior surfaces of all sections and modules	Year
10	Verification of the condition and tightness of flexible joints in duct nipples and repair, if applicable	2 years
11	Inspection of the state of the interior thermoacoustic insulation and repair if necessary	year
12	Inspection of the interior lighting circuit. Replacement of blown lamps and defective components	year
Free cooling sections and gates in general		
13	Verification of the status and functionality of the airflow regulation gates	2 years
14	Cleaning the exterior surfaces of the slats and hatch frames	2 years
15	Checking the free rotation of the slats, with the servomotors in the manual actuation position	2 years
16	Cleaning of slat support hinges and subsequent lubrication	2 years
17	Verification of anchors and jaws of servo motors. Tightening of prisoners and replacement, if applicable	2 years
18	Interlocking of the servomotors and verification of the free movement of the slats in response to commands	2 years
19	Verification of automatic gate opening and closing routes and adjustment, if applicable. Verification of servo motor limit switches	2 years
20	Inspection of the condition of the conductors and protections of the control circuits and power supply of servo motors	2 years
21	Inspection of the condition of the conductors and protections of the connection circuits between control elements, sensors, regulators, etc. Replacement of faulty cables, cable glands and bushings	2 years
22	Checking the performance of loops and control loops based on command signals	2 years
23	Verification of actuation and operation conditions of regulation and control devices, adjustment of parameters, if applicable	2 years
24	Airflow measurement in free cooling mode and comparison with nominal design values	2 years
Filters		
25	Inspection of the cleanliness of the air filters. Cleaning or preferably replacement, when necessary	Month
26	Cleaning filter sections and support frames	Month
27	Functional check of the automatic control warning of dirty filters	2 years
28	Checking the tightness of the frame holders and filter support frames and repair if necessary	Year
29	Verification of status and operation of rotary filter drive devices, adjustment and lubrication, if applicable	2 years
Air treatment batteries		
	Inspection of battery heads and racks. Cleaning and elimination of oxidations	Year
	Verification of non-existence of air passages outside the batteries. Joint repair and step sealing	Year

Operation nº	Work	Frequency
1	Checking the condition of the fins and the level of battery fouling. Fin combing and battery cleaning on both sides, if applicable	Year
2	Inspection for damage to fin surfaces: bent, broken, corroded fins	Year
3	Verification of the correct contact between fins and battery tubes. Non-existence of galvanic corrosion	Year
4	Verification of the absence of tubes deformed by freezing	Year
5	Verification of the correct circulation of the water inside the tubes. Measurement of head losses water side and comparison with those of design. Internal cleaning of coils, if applicable	Year
6	Verification of the absence of signs of water, steam or refrigerant leaks in the batteries. Leak correction, if applicable	Quarter
7	Verification of status and functionality of air traps in water supply circuits to the batteries. Hole cleaning	Quarter
8	Verification of status and operation of automatic water flow control valves	2 years
9	Inspection of the cleanliness of the water filters before the control valves	2 years
10	Verification of the opening and closing of the automatic control valves, in manual mode, unlocking the servomotors	2 years
11	Verification of anchors and jaws of servo motors. Tightening of prisoners and replacement if applicable	Year
12	Interlocking of the servomotors and verification of the free movement of the valves in response to command signals	Quarter
13	Verification of opening and closing routes of automatic valves and adjustment, if applicable. Verification of servo motor limit switches	2 years
14	Verification of the status and operation of frost protection systems for water batteries	Year
15	Verification of status and tightness of trays for collecting water condensates. Tray cleaning, removal of scale, oxides and sludge, and tightness correction, if applicable	2 years
16	Inspection and cleaning of drain siphons for condensate collection trays	2 years
17	Checking the slopes of the condensate collection trays towards the drain points	Year
18	Verification of status and operation of electric heating batteries	Quarter
19	Functional verification of control thermostats and safety of batteries of electrical resistors	Month
20	Checking safety interlocks of batteries of electrical resistances, contacts of fan contactors, flow switches, etc.	Month
21	Cleaning the exterior surfaces of electric heater batteries	2 years
Fans and their motors		
22	Verification of the condition of the exterior surfaces of the fans. Elimination of oxidations in enclosures. Exterior cleaning of surfaces	Year
23	Verification of the condition of racks, supports and anti-vibration elements. Cleaning and elimination of oxidations. Replacement of anti-vibration mounts, if applicable	Year
24	Verification of the absence of accumulated and embedded dirt on the impeller blades. Cleaning and descaling of impellers and blades	Year
25	Inspection of bearings and bearings of motorized fans: verification of clearances and adjustment, if applicable	Year
26	Inspection of bearing and bearing lubricators, cleaning and lubrication, if applicable	Year

Operation nº	Work	Frequency
27	Checking the direction of rotation of the fans	Quarter
28	Verification of the absence of deformations and friction of the fan impellers with their casings	Year
29	Verification of the absence of abnormal noises and vibrations during normal operation	Quarter
30	Verification of keyways and keyways of shafts. Key adjustments and replacement, if applicable	Year
31	Verification of the absence of noise from the slip transmission belts	Quarter
32	Checking the wear condition of the transmission pulley channels. Pulley replacement, if applicable	Year
33	Inspection of the condition of the transmission belts. Tension adjustment or a belt replacement, as appropriate	Quarter
34	Verification of belt and pulley drive alignment and adjustment, if applicable	Quarter
35	Verification of the condition of the supports and support slides of the motors. Tightening anchor bolts	Year
36	Verification of the absence of noise and abnormal vibrations from the motors during operation	Quarter
37	Checking clearance in motor bearings and replacement, if applicable	Year
38	Inspection of electrical insulation of power lines to fan motors	Year
39	Control of currents and temperatures in the supply conductors to fan motors	Quarter
40	Checking the tightness of electrical connections in the motor terminal boxes	Year
41	Status verification and cleaning of electrical control, command and force panels, and application of anti-humidity protection	Year
42	Inspection of frequency converters and variable speed motor control devices. Verification and adjustment of operating conditions according to the needs, if applicable	Quarter
43	Inspection of contactor contacts, switches and relays, motor protection and replacement, if applicable	Quarter
44	Verification of the actuation of the external and internal magnetothermic and differential protections (Clixon), of motors and adjustment, if applicable	Quarter
45	Inspection of motor grounding connections and lines. Tightening connections	Year
46	Inspection of the condition of the heat sink of frequency converters or variable speed drives	Year
47	Functional verification of external safety series and external interlocks of fan motors	Month
48	Measurement of voltages and currents per phase of motor power supply and contrast with the nominal plate	Month
49	Adjustment check of set points and actuation of electrical regulation and safety elements	Quarter
50	Collection of operating data according to the control sheet. Determination of performance of the UTA as a whole and its specific sections in particular and comparison with design data	2 years

Table 12. Circulation pumps

Operation nº	Work	Frequency
1	Inspection of external corrosion and general condition of housings, axle, screws. Cleaning and deoxidized, if applicable	Year
2	Paint condition inspection and paint review, if applicable	Year

3	Verification of the condition of the connections with the pipes and collectors. Elimination of oxidations	Year
4	Verification of the state of the anti-vibration elastic couplings, check of hardening and replacement, where appropriate	Year
5	Verification of the state of thermal insulation and exterior protections and repair, if applicable	Year
6	Inspection of the general condition of benches and anti-vibration mounts. Bench cleaning and substitution of supports, if applicable	Year
7	Verification of the tightening of the bed anchor bolts	Year
8	Inspection of in-line pump support status and repair or entrenchment, if applicable	Year
9	Inspection of the oil level in the crankcase of the base pumps. Oil replacement if applicable	Quarter
10	Inspection of the motor-pump shaft coupling. Replacement of dowels or drag sheets, if applicable	Quarter
11	Verification of motor-pump shaft alignment and adjustment, if applicable	Year
12	Verification of nonexistence of water leaks and leaks in mechanical seals	Quarter
13	Checking and adjusting drip on packing seals. Changing the graphite bead when appropriate	Quarter
14	Inspection of the press cooling water collection bowl. Cleaning the cups and the drainage pipes	Quarter
15	Inspection of water leaks by seals and retightening or replacement of seals if any	Month
16	Verification of no noise or abnormal vibrations during operation	Month
17	Verification of noise caused by cavitation during operation. Checking working pressures	Month
18	Inspection of play and wear on shafts, bearings and bearings	Quarter
19	Keyway and keyway inspection. Gap verification. Tightening of studs and replacement of cotter pins, if applicable	Year
20	Inspection of abnormal heating in seals and bearings	
21	Inspection of bearing and seal cooling devices	Year
22	Checking the tightness of the electrical connections to the motor cladding	Year
23	Inspecting the condition of the engine cooling fan. Verification of the absence of contacts with the casing and replacement of the fan in case of observing eccentric rotation	Year
24	Inspection of connections and grounding conductors. Retighten connections	Quarter
25	Inspection of the motor starter: contactors, switching and protection relays and circuit breakers. Replacement of contactor contacts and adjustment of thermomagnetic relays, when necessary	Quarter
26	Verification of status and functionality of electrical interlocks between pumps and other equipment	2 years
27	Collection of voltage and consumption data on motor terminals and comparison with the nominal ones	Month
28	Data collection of operating conditions and comparison with nominal design	Month

Table 13. Air ducts, diffusion elements and accessories

Operation nº	Work	Frequency
Ducts		
1	Exterior condition inspection: oxidations, joints, detached adhesive tapes, cracks, loss of insulation, plaster, etc. Correction of observed defects	Year
2	Leakage inspection. Locating Air Leaks Through Joints or Joints - Sealing Joints	Year

3	Duct deformation inspection: deformation correction or reinforcement application	Year
4	Inspection for signs of humidity, water leaks on pipes. Defect correction	Year
5	Verification of non-existence of corrosion in metallic conduits. Cleaning and protection of rusty areas	Year
6	Union condition inspection. Correction of deformations and leaks	Year
7	Inspection of the condition of the external thermal insulation and vapor barrier and repair, if applicable	Year
8	Inspection of flexible or elastic couplings and joints with machines: correction of breaks and leaks	Year
9	Inspection of the supports: verification of spacing, anchors, fixings to the tie rods, anchor plugs, no vibrations	Year
10	Internal inspection: accumulated dirt, detachment of panels, baffles, insulation, etc. Internal cleaning if applicable	Year
11	Internal inspection of fiberglass ducts: verification of the absence of deterioration in the surfaces in contact with the air, erosions in the fiberglass. Repairs, if applicable	Year
12	Checking the status of weatherstripping and seals of access and replacement records, if applicable	Year
13	Closing check and adjustment of manual flow regulation gates	Year
Motorized regulation gates		
21	Inspection of the condition of the slats and support hinges. Cleaning of surfaces in contact with air and lubrication of hinges, if applicable	Year
22	Checking the positioning of the gates. Manual opening and closing	Year
23	Verification of the fixing of the slats. Verification of the absence of noise and vibrations caused by the air flow during normal operation. Adjustments, if applicable	Year
24	Inspection of mechanical drive systems: tightening of screws and wheelhouse and lubrication of ball joints, if applicable	Year
25	Verification of status and operation of servo motors. Tightening electrical connections. Checking response to command signals	Year
26	Verification of routes in motorized gates. End of career inspection. Adjustments, if applicable	Year
Air diffusion, return and extraction elements		
27	Inspection of exterior condition: cleaning of surfaces and areas of influence	Year
28	Verification of the fixing of slats, fins and nozzles. No noise check and vibrations caused by air flow during operation. Settings, if applicable	Year
29	Verification of status and functionality of flow regulation gates, manual or automatic. Free open and close check. Adjust, if applicable	Year
30	Inspection of baffles. Orientation correction, if applicable	Year
31	Measurement of air flow rates, by sampling, and comparison with design values	Year
32	Checking the condition and securing of frames and fasteners	Year
33	Inspection of the sealing of diffusion elements to ducts and walls. Correction, if applicable	Year
Overpressure damper		
34	Inspection of slat support. Verification that there are no abnormal noises or knocks during operation. Checking the closing of the air passages, at rest	Year

35	Cleaning exterior surfaces	Year

Table 14. Hydraulic networks, components and accessories

Operation nº	Work	Frequency
Pipes		
1	Inspection of corrosion and water leaks in all visible sections of the pipe networks of all systems	Month
2	Inspection of the condition of the protective paint. Paint review, if applicable	Year
3	Thermal insulation inspection: condition check, repair of missing surfaces insulation	Year
4	Inspection of the external termination of the insulation. Protection repair, if applicable	Year
5	Inspection of the anchors and supports of the pipes in general. Defect correction	Year
6	Inspection of the condition of the expansion compensators. Status check of elastic dilators	Year
7	Inspection of dilatation possibilities. Verification of mobile anchorages and non-existence of deformations. Deformation correction, if applicable	Year
8	Inspection of vibration dampers and anti-vibration mounts. Corrections, if applicable	Year
9	Inspection of signaling and identification of pipeline circuits. Replacement, if applicable	Year
10	Status verification, checking and contrast of manometers and thermometers	Year
11	Verification of the status and functionality of air bleed valves and automatic drains	Year
12	Verification of filling devices and checking of water levels in all circuits	Month
13	Verification of the state of the bushings. Damage correction, if applicable. Sealant Inspection	Year
Valves		
14	Inspection of valve shaft seals and gaskets - tightening and leak correction	Quarter
15	Verification of the performance and function of each valve: closing, regulation, retention	2 years
16	Checking the correct positioning of each valve in the normal operating condition	Quarter
17	Verification and greasing of screw-type valve gearboxes	Year
	Accumulator deposits	
18	Corrosion inspection on exterior surfaces. Elimination of oxidations and paint overhaul, if applicable	Year
19	Verification of non-leakage of water in tank: inspection of maintenance hole covers	Month
20	Internal corrosion inspection. Cleaning and elimination of oxidations, dirt and sludge	Year
21	Verification of the status and functionality of safety valves. Watertight closure verification	2 years
22	Verification of the status and functionality of emptying and independent valves	2 years
23	Verification of the status and functionality of air bleed valves and automatic traps	2 years
24	Status verification, checking and contrast of manometers and thermometers	Year
25	Thermal insulation inspection: condition check, repair of surfaces with lack of insulation	Year
26	Inspection of the external termination of the insulation. Protection repair, if applicable	Year
	Elastic couplings / Anti-vibration sleeves	
27	Inspection of the state of the elastic material. Hardening check. Absence of cracks or bulges	2 years
28	Deformation inspection. Correction of stresses produced by pipes	Year
29	Water leak inspection	Month
	Open expansion vessels	
31	Inspection of maximum and minimum water levels	Month

32	Inspection of the water make-up valve. Status and functionality check	2 years
33	Overflow inspection. Elimination of obstructions	Year
34	Interior and exterior cleaning and corrosion removal	2 years
Closed expansion vessels		
35	Membrane inspection, checking its integrity. Replacement of broken membranes	2 years
36	Verification of non-existence of external corrosion. Elimination of oxidations. Exterior cleaning	2 years
37	Leak inspection	Month
38	Checking the air pressure in the expansion chamber	Month
39	Expansion volume check	2 years
40	Verification and contrast of manometers	Year
41	Verification and contrast of safety valves	Month
42	Inspection of compressors and other air injection devices	Year
43	Solenoid valve inspection	2 years
44	Verification of status and functionality and contrast of pressure switches	2 years
Expansion compensators		
45	Deformation inspection. Tolerance check	Year
46	Leak inspection	Month
47	Verification of alignments of pipes connected to compensators. Alignment correction	Year
	Water filters	
48	Inspection of water leaks in closures, joints and covers	Month
49	Inspection of the condition and cleaning of the filter element: basket, sieve, etc.	2 years

Table 15. Water / Water Heat Exchangers

Operation nº	Work	Frequency
Plate exchangers		
1	External inspection: tightness, non-leakage of fluid to the outside	Month
2	Verification of absence of corrosion in edges of plates and heads. Elimination of oxidations	Quarter
3	Inspection of the state of thermal insulation. Repair or replacement, if applicable	Year
4	Checking the tightness between circuits, primary and secondary: inspection joint status	Quarter
5	Exchanger opening. Plate cleaning, removal of obstructions and encrustations. Replacement of damaged plates and gaskets Shell and tube bundle exchangers or forks	Year
6	External inspection: watertightness, non-leakage of fluid to the outside, state of joints and connections	Month
7	External inspection of housings: condition, paint, absence of corrosion. Cleaning and elimination of oxidations	Year
8	Inspection of the state of thermal insulation. Repair or replacement, if applicable	Year
9	Internal inspection of tubes. Mechanical cleaning. Verification of non-existence of deformations, widening, corrosion, erosion	Year
10	Leakage check between primary and secondary circuits	Quarter
11	Corrosion inspection on the tube plates, removal of oxide deposits. Cleaning and descaling of heads. Tube to tube exchangers (counter current)	Year
12	External inspection: tightness, non-leakage of fluid to the outside, condition of connections	Month
13	External inspection of the casing tube: state of paint, no corrosion	Year
14	Inspection of the state of thermal insulation. Repair or replacement, if applicable	Year

15	Checking the tightness between primary and secondary circuits	Quarter
16	Chemical cleaning of primary and secondary circuits	Quarter

Table 16. Air conditioning terminal units. Inductors and Cold Beams

Operation nº	Work	Frequency
Inductors and chilled beams		
1	External inspection: state of paint, non-existence of corrosion, water leaks and humidity	Year
2	Enclosure and grid inspection: deformation correction. Elimination of obstructions to the air passage	2 years
3	Inspection of the state of thermal insulation. Repair or replacement, if applicable	Year
4	Inspection of condensation collection trays: inclination towards drainage, non-existence of corrosion and leaks	2 years
5	Cleaning of condensation collection trays. Application of bactericidal products, if applicable	2 years
6	Inspection of condensate drainage pipes and pipes: siphon cleaning	2 years
7	Cleaning of air filters. Rack and Media Inspection	Quarter
8	Inspection of the water coil, condition of the fins, no leaks. Cleaning the battery	Quarter
9	Air bleeding in batteries	Quarter
10	Condition check and cleaning of induction nozzles: checking their fixings	Quarter
11	Verification of non-existence of abnormal noises caused by air flow. Primary air flow check and adjust if applicable	2 years
12	Inspection of connections to air ducts: tightness check. Leak correction	2 years
13	Inspection of the automatic water flow control valves. Functional verification and adjustment	2 years
14	Inspection of air flow regulation gates. Functional verification and adjustment, if applicable	2 years
15	Inspection of control thermostats, in the environment or on the air return to the equipment. Function check and adjustment	2 years

Table 17. Air conditioning terminal units. Radiant Floors and Ceilings

Operation nº	Work	Frequency
Radiant Floors and Ceilings		
1	Exterior inspection of radiant ceiling panels: state of paint, nonexistence of corrosion and humidity. Paint review, if applicable	Year
2	Inspection of the condition of supports for radiant ceiling panels and their strengthening, if applicable	2 years
3	Inspection of circuits and branch pipes in exposed sections, according to the range of pipes	2 years
4	Verification of non-existence of leaks and water leaks. Evidence inspection moisture in soils	Month
5	Verification of nonexistence of condensation symptoms	2 years
6	Verification of tightness of stopcocks and holders. Manual opening and closing. Drip inspection on stopcock presses	2 years
7	Verification and adjustment of circulating water flows through the different circuits and areas. Verification of temperature homogeneity throughout the radiant surface	2 years
8	Inspection of recirculation pumps, according to range of pumps	Month
9	Thermostatic valve inspection. Watertightness. Acting check	2 years

10	Inspection of air traps, manual and automatic. Air purge and removal. Verification of non-existence of air inside the circuits.	Month
11	Verification of circuit temperature sensors. Specifically the position and the state of condensation sensors on cold ceilings and floors	2 years
12	Inspection of regulation and control ties. Control unit and valves verification automatic water flow control. Function check and adjustment	2 years
13	Data collection of return and water temperatures and environment and comparison with design	2 years

Table 18. Regulation and control systems and equipment

Operation nº	Work	Frequency
Electromechanical control		
	Inspection of electrical power circuits: switches, protections and signaling	Quarter
	Inspection and tightening of electrical connections	Year
	Verification of status and operation of thermostats and temperature sensors. Adjust, if applicable	Quarter
	Verification of status and operation of regulators and switchboards. Adjust, if applicable	Quarter
	Verification of status and operation of analog regulation rheostats. Adjust, if applicable	2 years
	Verification of status and operation of pressure switches. Leak correction and adjustment, if applicable	2 years
	Checking the condition of capillary tubes of pressure switches and pressure sensors. Cleaning or replacement, if applicable	2 years
	Verification of status and operation of humidistats. Adjust, if applicable	2 years
	Verification of status and operation of cam programmers and stage controllers. Adjust, if applicable	2 years
	Verification of status and operation of regulating valves according with the command signal. Checking of routes and limit switches and adjustment, if applicable	2 years
	Verification of status and operation of regulating gates according with the command signal. Checking of routes and limit switches and adjustment, if applicable	2 years
	Verification of status and operation of valve and gate servo motors. Tightening of connections, securing of supports and anchors and adjustment, if applicable	Quarter
	Fluid Flow Switch Inspection, Status and Performance Verification, Oxidation Cleaning and Removal	Quarter
	Inspection of tank level switches. Status check, function check and adjustment, if applicable	Quarter
	Verification of status and operation of timers and programmers. Tighten electrical connections and tighten, if applicable	2 years
	Verification of the operation of the entire regulation and control system	2 years
Control by electronic automation		
	Inspection of electrical power circuits: stabilized voltage sources, switches, protections and signaling, and their connections	2 years
	Inspection of signal circuits and communication "buses". Verification of wiring and connections	2 years
	Verification of status and performance of modules and peripheral controllers. Wiring and connections	Quarter
	Status and actuation verification of sensors and temperature controls and thermostats	2 years

	Verification of status and performance of pressure controls, transducers and pressure switches	2 years
	Status check and performance of humidity controls, probes and humidistats	2 years
	Verification of status and performance of fluid flow controllers and switches	Quarter
	Verification of status and performance of sensors and level controllers	Quarter
	Checking analog and digital inputs on modules and switchboards. Connections and signals	2 years
	Checking analog and digital outputs on modules and switchboards. Connections and signals	2 years
	Checking signal inputs on actuators, servo motors, automatic valves and receivers	2 years
	Verification of data and configuration parameters on the main controller and adjustment, if applicable	2 years
	Inspection of the data accumulated in the main memory: active alarms and incident history	Quarter
	Verification of control logics and verification of system behavior based on established programming. Modifications and adjustments, if applicable	2 years

Table 19. Electrical panels and distribution lines for air conditioning

Operation nº	Work	Frequency
1	General cleaning of the frame and protection against humidity	Year
2	Inspection of the state and review of paint in all the elements that need it	Year
3	Inspection of signalling and identification of panel components and replacement, if required	Year
4	Functional check of switches, circuit breakers and contactors	Quarter
5	Inspection of the state of the contactor contacts. Cleaning and replacement if applicable	Quarter
6	Verification of the status and operation of thermal relays and general protection equipment	Quarter
7	Contrast and adjustment of measuring instruments: voltmeters, ammeters, fasimeters, etc.	Quarter
8	Verification, contrast and adjustment of measuring instruments: recorders and analyzers.	Quarter
9	Verification of circuits and grounding conductors. Earth resistance measurement	Quarter
10	Verification of electrical insulation of protections and lines of all circuits	Year
11	Verification of tightening and securing of contacts, readjustment of terminals and terminal blocks	Year
12	General inspection of the interior wiring of the panel and corrections, if applicable	Year
13	Thermographic or direct verification of temperatures in the equipment and in the conductors	Year
14	Checking the status of signaling and alarm fuses and pilot lights and resetting, if applicable	Month
15	Measurement of voltages and currents in the main connection to the panel and determination of imbalances	Quarter
16	Measurement of voltages and currents in the main circuits supplied from the panel and determination of imbalances	Quarter
17	Tightening Check of Grounding Circuit Connections	Month
18	Verification of set points of circuit breaker protection and differential switches	Month
19	Verification of the tightness of line connections of all circuits, at both ends	Year
20	Verification of the tightening of power line connections to motors, at both ends	Quarter
21	Verification of electrical insulation and temperature of conductors of power supply lines to motors	Year

6 Conclusions

In conclusion, this document pretended to be a guideline about one the possible way of integrating different pieces of equipment from different manufacturers into a unique installation originally prepared for traditional HAVC small units.

The integration required adaptation of the building in order to host the heating and cooling terminals, and allow the access of air and water from outside to the interior; if the passing through of pipes is something common during construction, the way of anchoring the terminals was the result of each specific technology, by which unusual structural adaptation was required during building refurbishment.

The nature of the beams required an installation which excluded embedding in the ceiling, so exposure to sight required special solutions for maintaining safety condition, functionality and aesthetic principles. The retrofitted radian floor, based on dry concepts and reduced thickness, required the correct levelling of the basement, which was achieved with a solution of liquid concrete.

On the other hand, generation and storage equipment were more similar to other traditional market solutions, so the complexity was reduced, considering the advantage of outdoor installation; apart from space around the devices, some requirements about vibration, ventilation or heat dissipation, no specific solution had to be engineered nor applied.

From the electromechanical point of view, hydraulic connections used part of the frames of the equipment for anchoring and so saving space around the installation, keeping all element at favourable height for maintenance and commissioning. The use of flanges speeded up the installation, reduce leakages and will reduce times during maintenance/substitution of damaged components.

The use of PPR piping simplified the installation process, reducing the total weight of the installation and so the number of workers involved during operation; this kind of solution also expanded the possibilities to place anchors for bearing pipes, like the own device structure, due to reduced weight. Welding process also resulted faster because of the simplification introduced by PPR joints for curves, unions and sensor placement. No galvanic effect is present on PPR.

The installation of different air purging points spread around the highest points of the installation will simplify commissioning and water filling; separation through valves will reduce water losses in case of maintenance. The installation of 3 ways valves and VSD pump will increase the operability of the system in achieving correct operation of designed strategies maintaining the system at the top of its functionality.

Finally, the solution based on distributed control system will facilitate the fault detection during commissioning and will allow excluding miss working devices without affecting the LowUP supervisor; even more, the processing load is distributed around the installation so, in case of fault of one system, the other will not be affected.

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8 ANNEX - ELECTRICAL AND CONTROL WIRING

This section shows the electrical or control wiring diagram of different systems installed in Seville demo.

8.1 Solar field

Electrical diagram of PVT solar field:

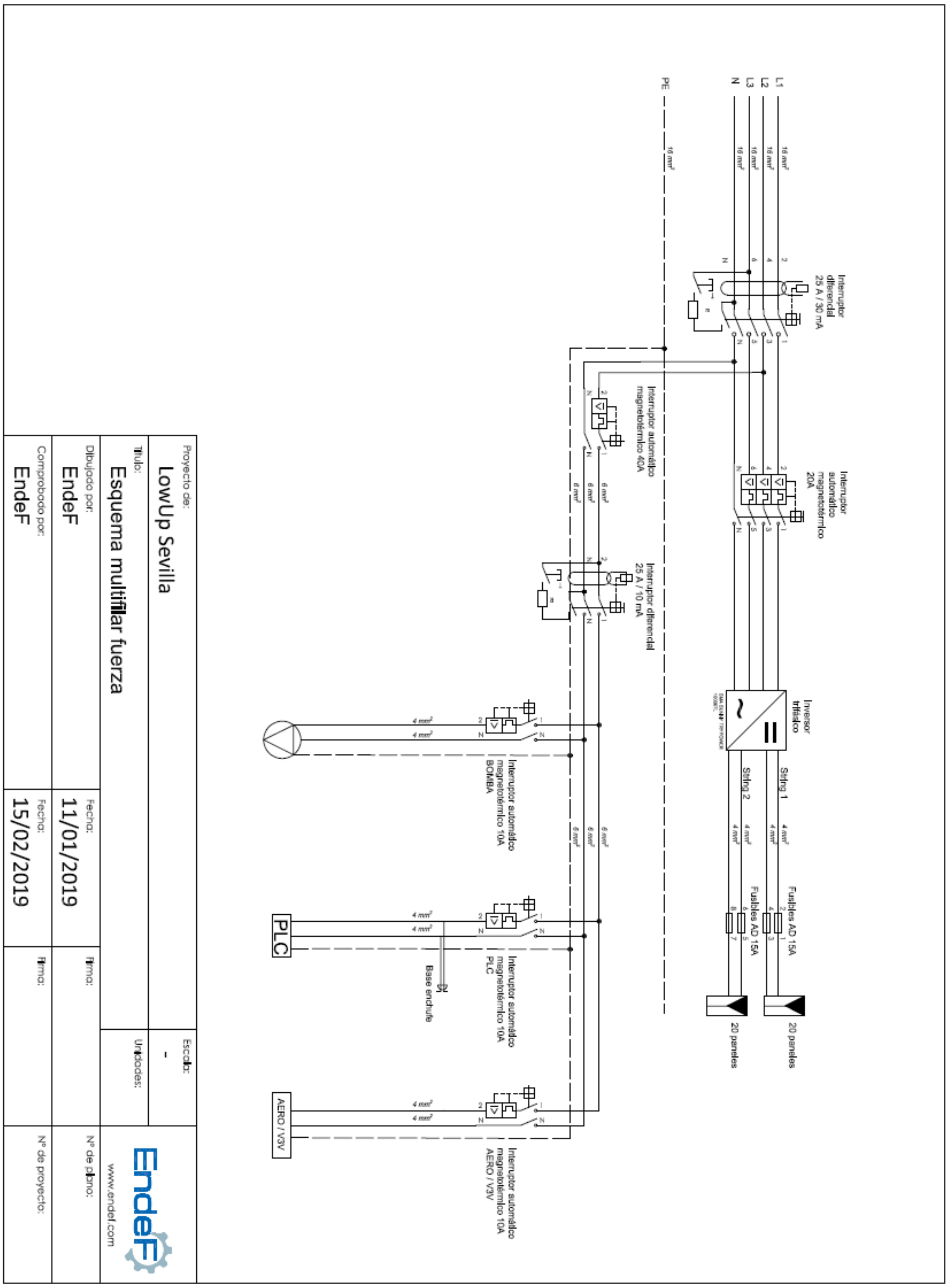

Figure 88. Electrical diagram

The control diagram of ENDEF installation:

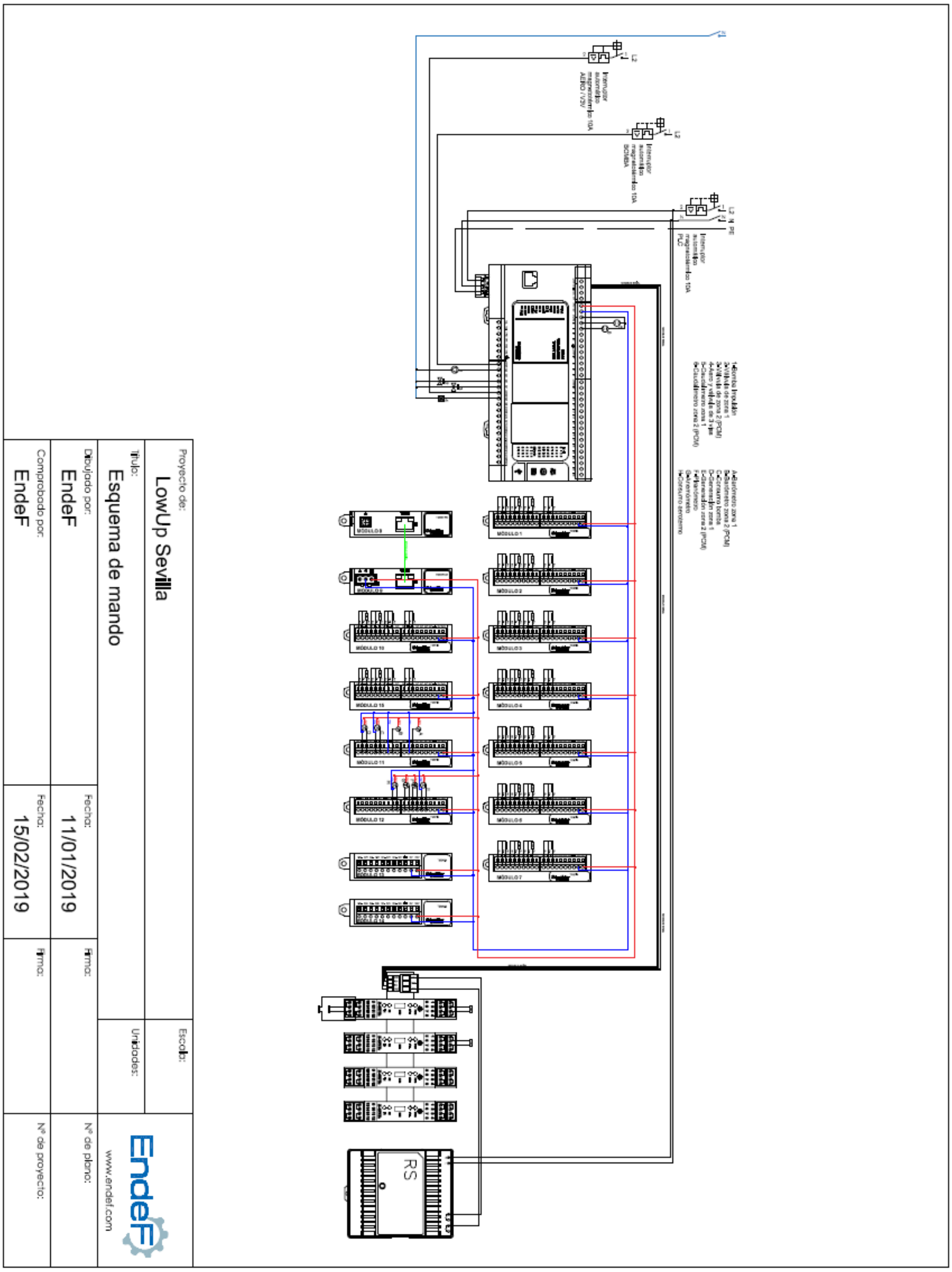

Figure 89. Control diagram

8.2 Radiant floor

About control system of RDZ, the controller is connected as the following picture:

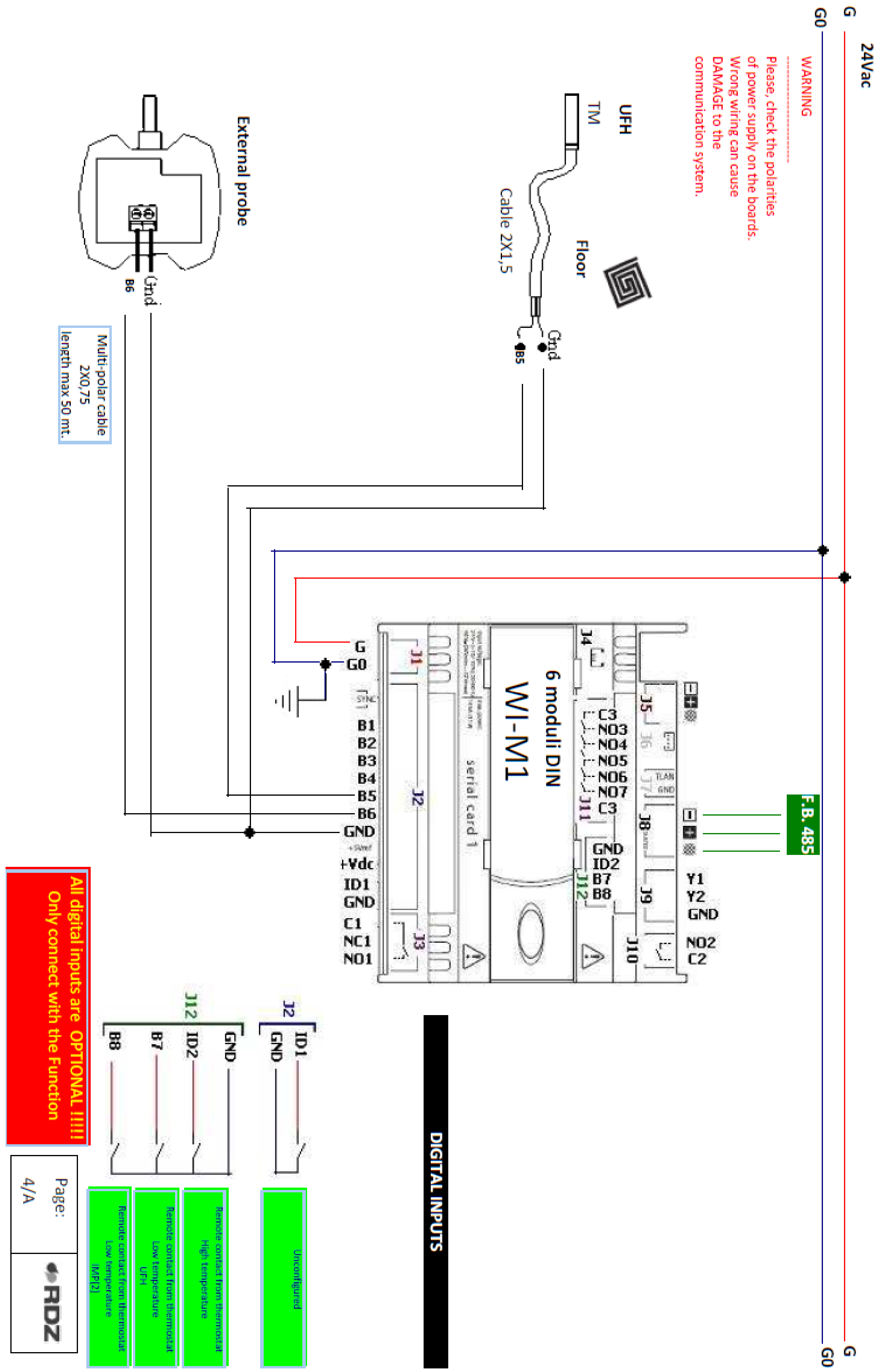

Figure 90. Wiring diagram of the control system

8.3 AHU, chiller and PCM tank

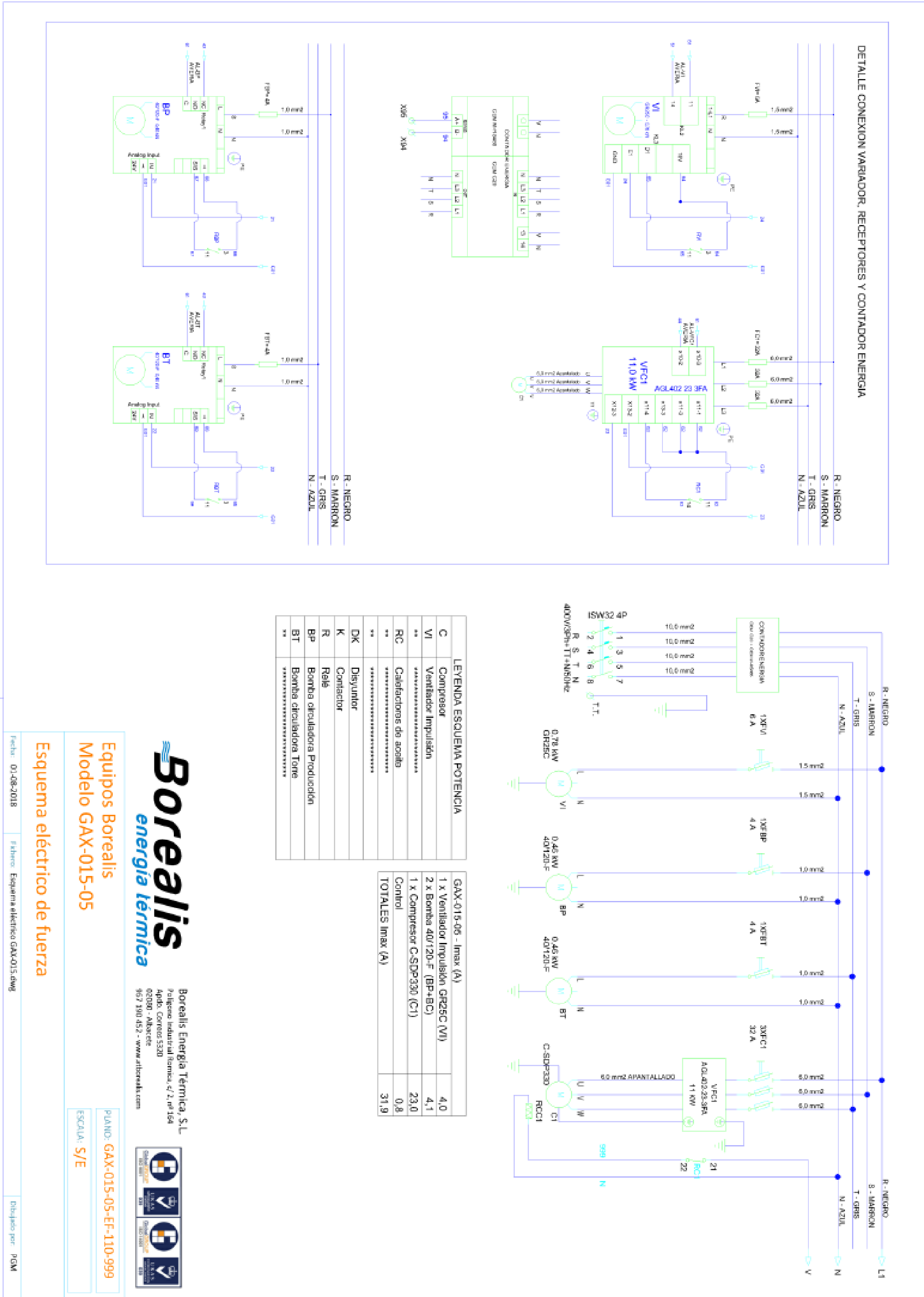

Figure 91. Power electric wiring

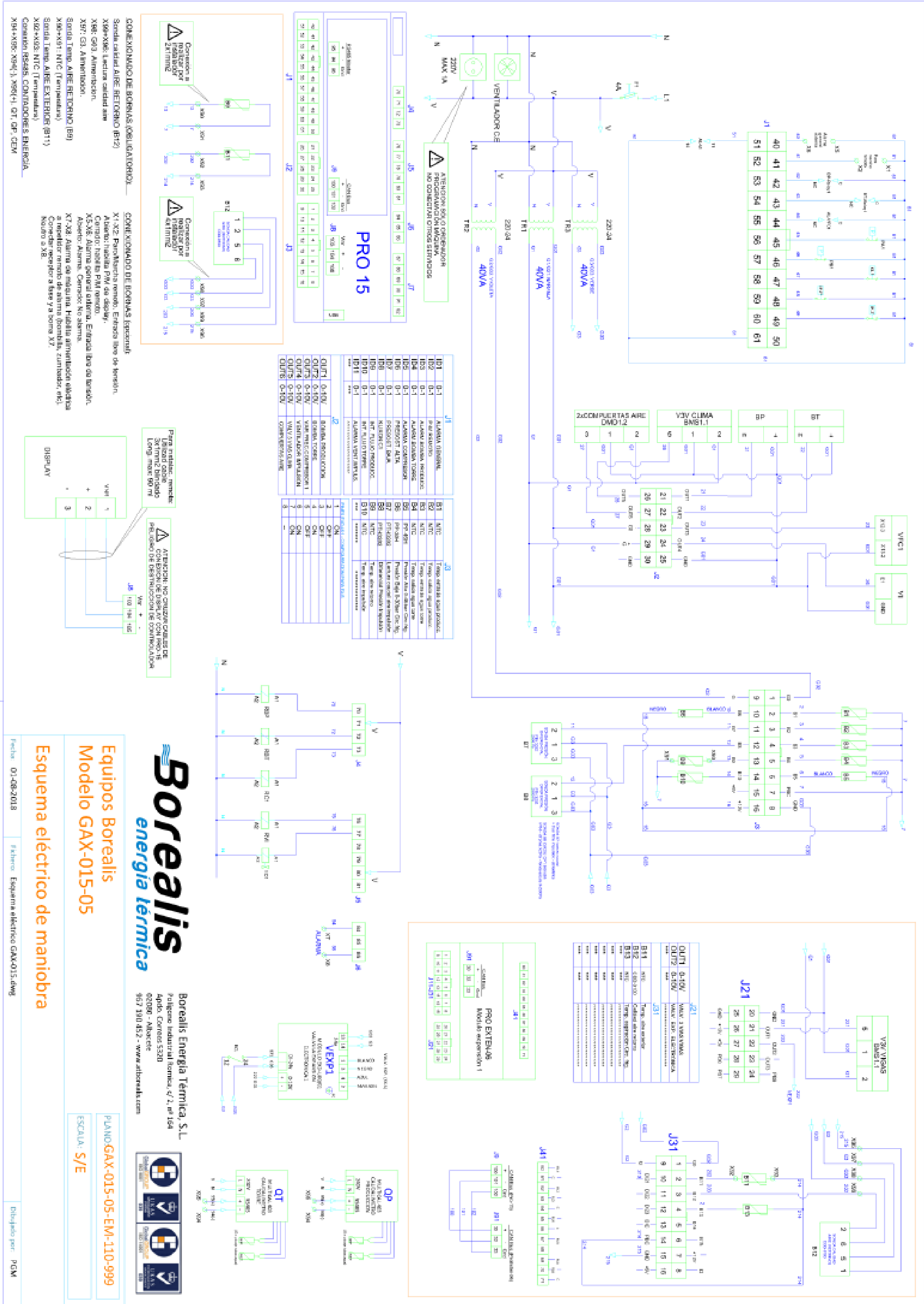

Figure 92. Control wiring