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Design Manual

GAHP-WS

water/water gas absorption heat pump

Platform PRO

Revision: A

Code: D-MNL045

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1 OVERVIEW AND TECHNICAL CHARACTERISTICS

The GAHP-WS is a highly efficient water-water absorption heat pump, with a water-ammoniac thermodynamic cycle (NH_3 - H_2O), equipped with fumes condensation heat recovery, designed for producing both cold water and hot water for process systems where the production of both heating and cooling power are required at the same time, and in all systems in which heating power is required for an auxiliary service (post-heating for air handlers, heating swimming pool water, pre-heating domestic hot water, etc.) as well as cooling power for a conditioning system.
The electromechanical components of all GAHP-WS absorption heat pump equipment can be reduced to the burner, fan and solution pump. This characteristic of absorption systems reduces power consumption as well as service requirements.
The water-ammoniac thermodynamic employed by the GAHP-WS, is implemented in a hermetically-sealed (welded) circuit which does not require coolant top-ups.
The maximum delivery temperature for these units is 65°C (in heating mode) and the maximum return temperature is 55°C. The minimum/maximum external air temperatures are -30°C / +45°C.
The minimum evaporator output temperature (delivery to aquifer) for the GAHP-WS unit is 3°C, while the maximum return temperature is 45°C.
The GAHP-WS heat pump can be installed both indoors and outdoors.
The GAHP-WS unit employs polypropylene flue pipes; The high available head (up to 80 Pa) enables considerable versatility in installation.

Principal benefits

Efficiency: the GAHP-WS is capable, in nominal conditions, of reaching efficiencies of 230% in the case of simultaneous use of its available heating and cooling power, and 165% when using renewable energy sources to produce only heating power (tested by VDE and DVGW-Forschungsstelle).
It does not require external sources: when using the full heating and cooling power, it is not necessary to use renewable energy sources such as aquifer bores and heat exchangers.
Reduced energy consumption: since it consumes only 0.47 kWe per 41.6 kW of heating power and 16.6 kW of cooling power, thanks to the use of methane gas or LPG.
No increase in installed electrical power: given the limited electrical draw of each unit (470 W), this enables the implementation of heat pump systems without significantly increasing the overall electrical consumption of the plant. This enables the construction of more simple electrical circuits and also means that the power supply contract need not be changed. It also means that UPS systems can be installed using smaller emergency generators.
Stable operation in extreme external temperatures: even at an external temperature of -30°C, the GAHP-WS unit guarantees efficiencies which depend exclusively on the plant's operating conditions, and can thus be used to advantage even in especially cold locations without the need for backup systems based on boilers or electrical heaters.

Specification of supply

GAHP-WS HT WATER-WATER ABSORPTION HEAT PUMP
Gas powered water-ammonia absorption water-water condensation heat pump unit for simultaneous production of hot water up to a delivery temperature of 65°C and chilled water for geothermal applications, suited for indoors and outdoors installation, with water condensation and evaporation, methane/LPG powered, composed of a hermetically sealed heating/cooling circuit in carbon steel, titanium steel coil evaporator heat

exchanger, titanium steel coil condenser/absorber heat exchanger, fumes side condensation heat recovery circuit, equipped with limit thermostat - overpressure safety valve - fumes pressure switch and thermostat - stainless steel multigas mixture burner - microprocessor controller for all functions - flow meter - water flow meter - flame controller - gas valve - enamelled galvanised steel sheeting panelling - polypropylene fumes evacuation and condensation drain pipes.
Nominal thermal capacity (at burner) 25.70 kW.
Nominal heating power (W10/W50) 41.60 kW.
Nominal cooling power (W10/W50) 16.60 kW
Power supply 230 V 1N - 50 Hz.
Electrical power absorption 0.47 kW.
Operating weight 300 kg.
Water fittings (out/in) 1 ¼" F.
Gas fitting ¾" F.
Overall dimensions: width/depth (848 mm x 690 mm), height 1278 mm.

1.1 TECHNICAL DATA

Table 1.1 – TECHNICAL DATA

			GAHP WS
RENEWABLE SOURCE OPERATING CONDITIONS			
Renewable source water flow rate	nominal (W10W50)	l/h	2850
	maximum	l/h	4700
	minimum	l/h	2300
Renewable source pressure drop	at nominal flow rate	bar	0,33
Renewable source water return temperature	maximum	°C	45
Renewable source delivery water temperature	minimum	°C	3
Nominal thermal differential		°C	5
OPERATION WHEN HEATING			
OPERATING POINT W10W50	G.U.E. gas usage efficiency	%	166 (1)
	Thermal power delivered	kW	41,6 (1)
	Power recovered from renewable source	kW	16,6
OPERATING POINT W10W65	G.U.E. gas usage efficiency	kW	143 (1)
	Thermal power delivered	kW	35,8 (1)
	Power recovered from renewable source	kW	11,5
Thermal capacity	Nominal (1013 mbar - 15°C)	kW	25,7
	true peak	kW	25,2
NOx emission class			5
NOx emission		ppm	25
CO emission		ppm	36
Hot water delivery temperature	maximum for heating	°C	65
	maximum for ACS	°C	70
Hot water return temperature	maximum heating	°C	55
	minimum	°C	2
Hot water flow rate	nominal	l/h	3570
	maximum	l/h	4000
	minimum	l/h	1000
Hot water pressure drop	for nominal water flow rate(W10W50)	bar	0,54
Ambient air temperature (dry bulb)	maximum	°C	45
	minimum	°C	0
Thermal differential	nominal	°C	10
gas consumption	methane G20 (nominal)	m3/h	2,72
	methane (MIN)	m3/h	1,34
	G30 (nominal)	kg/h	2,03
	G30 (MIN)	kg/h	0,99
	G31 (nominal)	kg/h	2,00
	G31 (MIN)	kg/h	0,98
ELECTRICAL SPECIFICATIONS			

			GAHP WS
Power supply	Voltage	V	230
	TYPE		SINGLE PHASE
	Frequency	50 Hz supply	50
Electrical power absorption	nominal	kW	0,47
Degree of protection	IP		X5D
INSTALLATION DATA			
Level of acoustic power		dB(A)	67
Minimum storage temperature		°C	-15
Maximum operating pressure		bar	4
Water content inside the apparatus	HOT SIDE	l	4
	COLD SIDE	l	3
Water fitting	TYPE		F
	thread	" G	1 1/4
Gas fitting	TYPE		F
	thread	" G	3/4
Safety valve outlet channel fitting		" G	1 1/4
Fume outlet	Size	mm	80
	Residual head	Pa	80
	Product configuration		C63
Maximum condensation water flow rate		l/h	4,0
Size	width	mm	848
	height	mm	1278
	depth	mm	691
Weight	In operation	kg	300
GENERAL INFORMATION			
INSTALLATION MODE			C13, C33, C43, C53, C63, C83
COOLING FLUID	AMMONIA R717	kg	7,7
	WATER H2O	kg	10
MAXIMUM PRESSURE OF THE COOLING CIRCUIT		bar	35
METHANE GAS FEED PRESSURE (G20)		mbar	17-25
PED data			
COMPONENTS UNDER PRESSURE	Generator	l	18,6
	Leveling chamber	l	11,5
	Evaporator	l	3,7
	Cooling volume transformer	l	4,5
	Absorber/condenser	l	3,7
	Cooling absorber solution	l	6,3
	Solution pump	l	3,3
TEST PRESSURE (IN AIR)		bar g	55
SAFETY VALVE PRESSURE CALIBRATION		bar g	35
FILLING RATIO		kg of NH3/l	0,159
"SEALED SYSTEM" TARE		kg	165
FLUID GROUP			GROUP 1°

Notes
(1) As per EN12309-2 evaluated over the actual thermal capacity. For operating conditions other than nominal, refer to Section 2 SIZING AND CHECKING GAHP-A SYSTEMS → 13.
(2) For capacities other than nominal, refer to the values given in Table 1.2 Pressure drop of single GAHP-WS unit: condenser side → 7 (heating mode) or Table 1.3 Pressure drop of a single GAHP-WS evaporator side → 8 (conditioning mode).

Table 1.2 – Pressure drop of single GAHP-WS unit: condenser side

Pressure drop of single GAHP-WS unit: condenser side								
Water flow rate	VECTOR FLUID TEMPERATURE AT OUTLET (T_{hm}) OF GAHP-WS							
	30°C	35°C	40°C	45°C	50°C	55°C	60°C	65°C
l/h	Pressure drop (bar)							
1000	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06
1100	0.09	0.08	0.08	0.08	0.08	0.07	0.07	0.07
1200	0.10	0.10	0.09	0.09	0.09	0.09	0.08	0.08

1300	0.11	0.11	0.11	0.10	0.10	0.10	0.09	0.09
1400	0.13	0.12	0.12	0.12	0.11	0.11	0.11	0.10
1500	0.14	0.14	0.13	0.13	0.13	0.12	0.12	0.11
1600	0.16	0.15	0.15	0.15	0.14	0.14	0.13	0.13
1700	0.18	0.17	0.17	0.16	0.16	0.15	0.15	0.14
1800	0.20	0.19	0.18	0.18	0.17	0.17	0.16	0.16
1900	0.21	0.21	0.20	0.20	0.19	0.18	0.18	0.17
2000	0.23	0.23	0.22	0.21	0.21	0.20	0.19	0.19
2100	0.25	0.25	0.24	0.23	0.23	0.22	0.21	0.20
2200	0.28	0.27	0.26	0.25	0.25	0.24	0.23	0.22
2300	0.30	0.29	0.28	0.27	0.27	0.26	0.25	0.24
2400	0.32	0.31	0.30	0.29	0.29	0.28	0.27	0.26
2500	0.35	0.33	0.32	0.32	0.31	0.30	0.29	0.27
2600	0.37	0.36	0.35	0.34	0.33	0.32	0.31	0.29
2700	0.40	0.38	0.37	0.36	0.35	0.34	0.33	0.31
2800	0.42	0.41	0.40	0.39	0.38	0.36	0.35	0.34
2900	0.45	0.44	0.42	0.41	0.40	0.39	0.37	0.36
3000	0.48	0.46	0.45	0.44	0.43	0.41	0.40	0.38
3100	0.51	0.49	0.48	0.46	0.45	0.44	0.42	0.40
3200	0.54	0.52	0.50	0.49	0.48	0.46	0.45	0.43
3300	0.57	0.55	0.53	0.52	0.51	0.49	0.47	0.45
3400	0.60	0.58	0.56	0.55	0.54	0.52	0.50	0.48
3500	0.63	0.61	0.59	0.58	0.57	0.54	0.52	0.50
3600	0.67	0.65	0.62	0.61	0.60	0.57	0.55	0.53
3700	0.70	0.68	0.66	0.64	0.63	0.60	0.58	0.56
3800	0.74	0.71	0.69	0.67	0.66	0.63	0.61	0.58
3900	0.77	0.75	0.72	0.71	0.69	0.66	0.64	0.61
4000	0.81	0.78	0.76	0.74	0.72	0.70	0.67	0.64

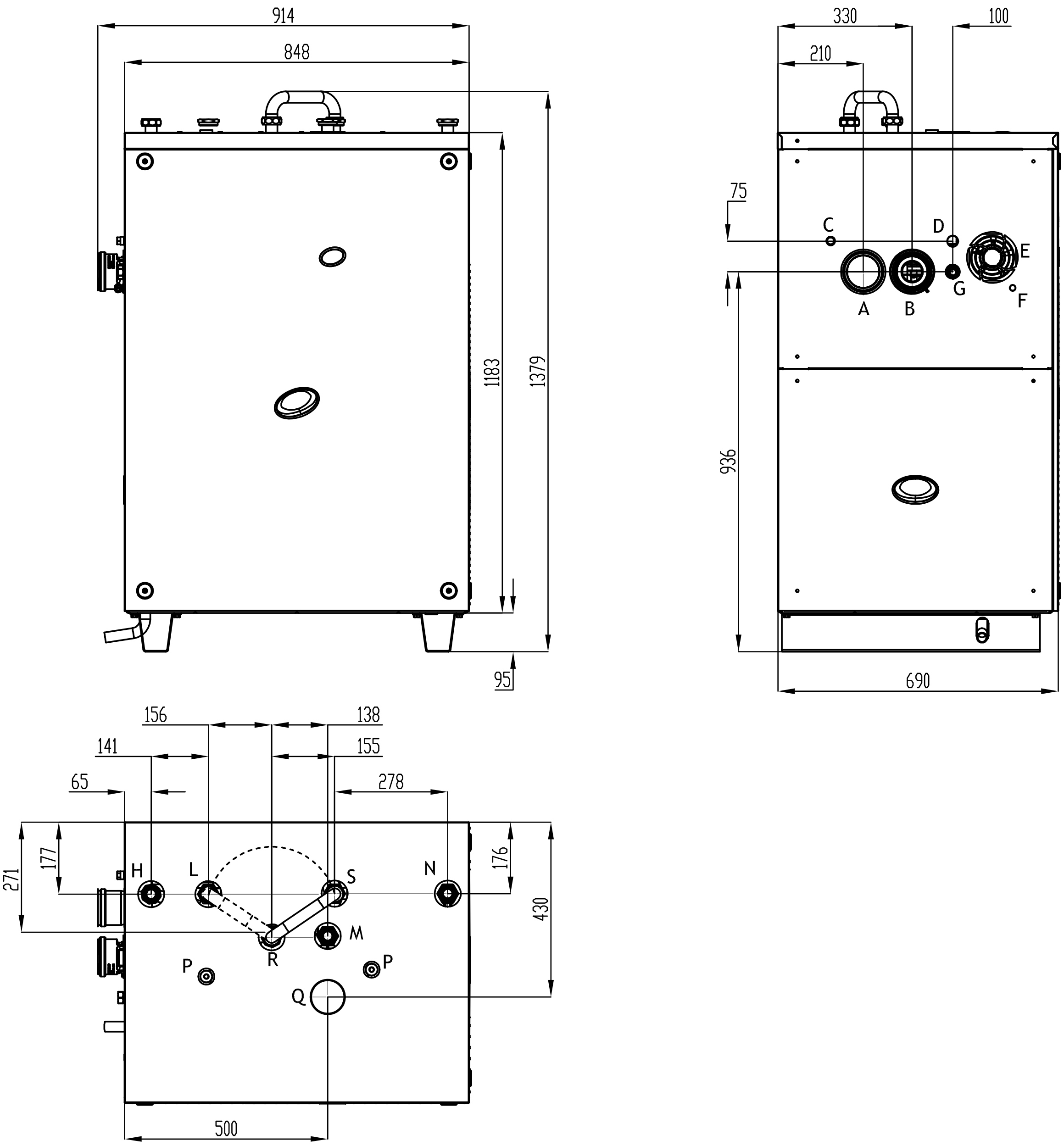
Table 1.3 – Pressure drop of a single GAHP-WS evaporator side

Pressure drop of a single GAHP-WS evaporator side														
Water flow rate	VECTOR FLUID TEMPERATURE AT OUTLET (T_{cm}) OF GAHP-WS													
	2°C	3°C	4°C	5°C	6°C	7°C	8°C	9°C	10°C	11°C	12°C	13°C	14°C	15°C
l/h	Pressure drop (bar)													
1000	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.09	0.09	0.09	0.09	0.09
1100	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.10	0.10	0.10
1200	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.11
1300	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13
1400	0.16	0.16	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14	0.14	0.14
1500	0.17	0.17	0.17	0.17	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.15	0.15
1600	0.19	0.19	0.19	0.19	0.18	0.18	0.18	0.18	0.18	0.17	0.17	0.17	0.17	0.17
1700	0.21	0.21	0.21	0.20	0.20	0.20	0.20	0.19	0.19	0.19	0.19	0.19	0.18	0.18
1800	0.23	0.23	0.23	0.22	0.22	0.22	0.22	0.21	0.21	0.21	0.21	0.21	0.20	0.20
1900	0.25	0.25	0.25	0.24	0.24	0.24	0.24	0.23	0.23	0.23	0.23	0.22	0.22	0.22
2000	0.27	0.27	0.27	0.26	0.26	0.26	0.26	0.25	0.25	0.25	0.25	0.24	0.24	0.24
2100	0.29	0.29	0.29	0.29	0.28	0.28	0.28	0.27	0.27	0.27	0.27	0.26	0.26	0.26
2200	0.32	0.32	0.31	0.31	0.31	0.30	0.30	0.30	0.29	0.29	0.29	0.28	0.28	0.28
2300	0.34	0.34	0.34	0.33	0.33	0.33	0.32	0.32	0.32	0.31	0.31	0.31	0.30	0.30
2400	0.37	0.36	0.36	0.36	0.35	0.35	0.35	0.34	0.34	0.34	0.33	0.33	0.32	0.32
2500	0.39	0.39	0.39	0.38	0.38	0.38	0.37	0.37	0.36	0.36	0.36	0.35	0.35	0.34
2600	0.42	0.42	0.41	0.41	0.41	0.40	0.40	0.39	0.39	0.38	0.38	0.38	0.37	0.37
2700	0.45	0.45	0.44	0.44	0.43	0.43	0.42	0.42	0.42	0.41	0.41	0.40	0.40	0.39
2800	0.48	0.48	0.47	0.47	0.46	0.46	0.45	0.45	0.44	0.44	0.43	0.43	0.42	0.42
2900	0.51	0.50	0.50	0.49	0.49	0.48	0.48	0.47	0.47	0.46	0.46	0.45	0.45	0.44
3000	0.53	0.53	0.52	0.52	0.51	0.51	0.50	0.50	0.49	0.49	0.48	0.48	0.47	0.47
3100	0.56	0.56	0.55	0.55	0.54	0.54	0.53	0.53	0.52	0.51	0.51	0.50	0.50	0.49
3200	0.59	0.59	0.58	0.58	0.57	0.57	0.56	0.55	0.55	0.54	0.54	0.53	0.52	0.52
3300	0.63	0.62	0.61	0.61	0.60	0.59	0.59	0.58	0.58	0.57	0.56	0.56	0.55	0.55
3400	0.66	0.65	0.64	0.64	0.63	0.62	0.62	0.61	0.61	0.60	0.59	0.59	0.58	0.57
3500	0.69	0.68	0.68	0.67	0.66	0.66	0.65	0.64	0.64	0.63	0.62	0.62	0.61	0.60

3600	0.72	0.72	0.71	0.70	0.69	0.69	0.68	0.67	0.67	0.66	0.65	0.64	0.64	0.63
3700	0.76	0.75	0.74	0.73	0.73	0.72	0.71	0.70	0.70	0.69	0.68	0.68	0.67	0.66
3800	0.79	0.78	0.78	0.77	0.76	0.75	0.74	0.74	0.73	0.72	0.71	0.71	0.70	0.69
3900	0.83	0.82	0.81	0.80	0.79	0.79	0.78	0.77	0.76	0.75	0.75	0.74	0.73	0.72
4000	0.86	0.85	0.85	0.84	0.83	0.82	0.81	0.80	0.80	0.79	0.78	0.77	0.76	0.75

1.2 DIMENSIONS

Figure 1.1 – Size



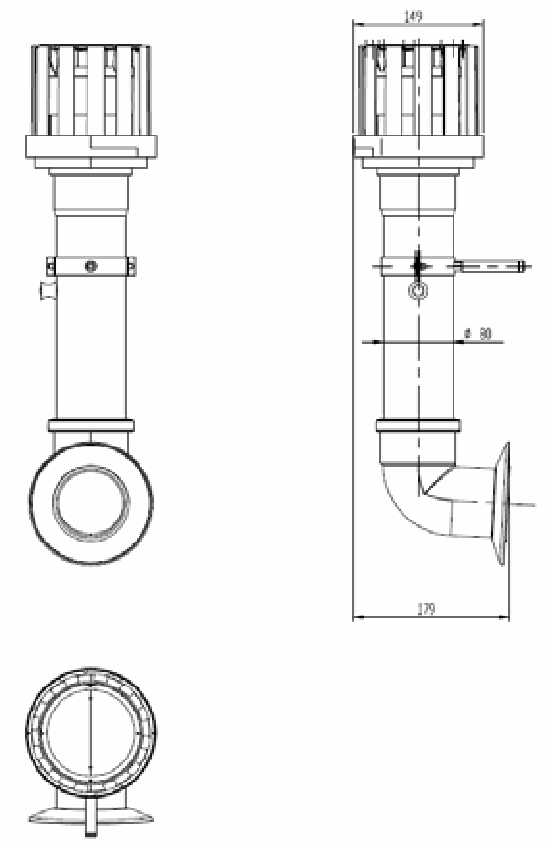
LEGEND

A Fumes outlet
B Combustion air intake
C Manual reset fumes thermostat
D Power cable input
E Cooling fan
F Appliance on indicator
G Gas fitting dia. ¾"
P Appliance lifting hooks
Q Safety valve outlet ducting

R-S HYDRONIC SWITCH IN CONDENSER POSITION
H Hot water return dia. 1"¼
L Renewable source water return dia. 1"¼
M Renewable source water delivery dia. 1"¼
N Hot water delivery dia. 1"¼

R-L HYDRONIC SWITCH IN EVAPORATOR POSITION
H Renewable source water return dia. 1"¼
M Renewable source water delivery dia. 1"¼
N Hot water delivery dia. 1"¼
S Hot water return dia. 1"¼

Figure 1.2 – Drain outlet



Detail of provided drain outlet.

2 SIZING AND CHECKING GAHP-A SYSTEMS

2.1 DESIGN PARAMETERS

The principal design parameters are the heating and cooling power and G.U.E. (Gas Utilisation Efficiency) evaluated under the design conditions.
The G.U.E. is the ratio between the useful heating (or cooling) power and the actual thermal capacity.
The G.U.E. and the heating and cooling power are direct functions of the condenser inlet water temperature T_{hr} and the evaporator inlet temperature T_{cr}.
The selection of these two temperatures depends on the exchange equipment external to the heat pump, such as heating system terminals, ground heat exchangers or process plant heat exchangers.
These parameters are assumed as design parameters along with the thermal differential ΔT of the vector fluid.
The latter is normally assumed to be 10°C in heating mode and 5°C in conditioning mode; the minimum and maximum values in heating mode are equal respectively to 7.5°C (corresponding to a maximum flow rate of 4000 l/h at the nominal thermal power) and 30°C (corresponding to a minimum flow rate of 1000 l/h at the nominal thermal power). In conditioning mode, the minimum and maximum values are equal respectively to 3°C (corresponding to a maximum flow rate of 4700 l/h at the nominal thermal power) and 6°C (corresponding to a minimum flow rate of 2300 l/h at the nominal thermal power).
Given the value of ΔT, the values of T_{hr} and T_{cr} are determined automatically by the temperature of the desired plant water delivery temperature T_{hm} and T_{cm}. Once these values have been determined, simply use the heating and cooling efficiency tables in Paragraph 2.2 DESIGN PARAMETER TABLES → 13.
These tables express, for each return temperature "T_{hr}" and "T_{cr}", the value of the heating power q_h and cooling power q_c of the GAHP-WS units.
Another parameter which should be borne in mind in designing H_2O - NH_3 absorption systems is the maximum condenser return temperature "T_{hr} max", set to the value of 55°C.

2.2 DESIGN PARAMETER TABLES

Table 2.1 – Unitary heating power GAHP-WS

UNITARY HEATING POWER GAHP-WS							
EVAPORATOR RETURN TEMPERATURE (T_{cr})	WATER DELIVERY TEMPERATURE (T_{hm})						
	35°C	40°C	45°C	50°C	55°C	60°C	65°C
	WATER RETURN TEMPERATURE (T_{hr})						
	25°C	30°C	35°C	40°C	45°C	50°C	55°C
	q_h [kW]	q_h [kW]	q_h [kW]	q_h [kW]	q_h [kW]	q_h [kW]	q_h [kW]
6°C	43,7	42,8	41,1	39,4	37,2	35,2	33,4
7°C	43,8	42.9	41,4	39,9	37,8	35,9	34,0
8°C	43,8	43,0	41,8	40,5	38,4	36,5	34,6
9°C	43,9	43,1	42,1	41,0	39,0	37,1	35,2
10°C	43,9	43,2	42,4	41,6	39,6	37,7	35,8
11°C	43,9	43,3	42,6	41,8	39,8	37,9	36,0
12°C	43,9	43,4	42,7	42,0	40.0	38,1	36,2
13°C	43,9	43,5	42,8	42,2	40,2	38,3	36,5
14°C	43,9	43,5	43,0	42,4	40,4	38,6	36,7
15°C	43,9	43,6	43,1	42,6	40,6	38,8	36,9
16°C	43,9	43,6	43,2	42,8	40,8	39,0	37,1
17°C	43,9	43,6	43,3	43,0	41,1	39,2	37,4
18°C	43,9	43,6	43,4	43,2	41,3	39,4	37,6
19°C	43,9	43,6	43,5	43,4	41,5	39,7	37,8
20°C	43,9	43,6	43,6	43,6	41,7	39,9	38,1

21°C	43,9	43,6	43,6	43,6	41,9	40,1	38,3
22°C	43,9	43,6	43,6	43,6	42,1	40,3	38,5
23°C	43,9	43,6	43,6	43,6	42,4	40,6	38,8
24°C	43,9	43,6	43,6	43,6	42,6	40,8	39,0
25°C	43,9	43,6	43,6	43,6	42,8	41,0	39,2
26°C	43,9	43,6	43,6	43,6	42,8	41,1	39,4
27°C	43,9	43,6	43,6	43,6	42,8	41,2	39,7
28°C	43,9	43,6	43,6	43,6	42,8	41,3	39,9
29°C	43,9	43,6	43,6	43,6	42,8	41,5	40,1
30°C	43,9	43,6	43,6	43,6	42,8	41,6	40,4

Table 2.2 – G.U.E. GAHP-WS unit in heating mode

G.U.E. GAHP-WS IN HEATING MODE							
EVAPORATOR RETURN TEMPERATURE (T_{cr})	WATER DELIVERY TEMPERATURE (T_{hm})						
	35°C	40°C	45°C	50°C	55°C	60°C	65°C
	WATER RETURN TEMPERATURE (T_{hr})						
	25°C	30°C	35°C	40°C	45°C	50°C	55°C
6°C	1,734	1,697	1,630	1,563	1,478	1,401	1,324
7°C	1,736	1,702	1,644	1,585	1,501	1,424	1,348
8°C	1,738	1,707	1,657	1,607	1,524	1,448	1,372
9°C	1,740	1,711	1,670	1,629	1,547	1,471	1,396
10°C	1,743	1,716	1,683	1,651	1,570	1,495	1,419
11°C	1,743	1,719	1,689	1,659	1,578	1,503	1,428
12°C	1,743	1,722	1,694	1,667	1,587	1,512	1,438
13°C	1,743	1,724	1,699	1,675	1,595	1,521	1,447
14°C	1,743	1,727	1,705	1,683	1,604	1,530	1,456
15°C	1,743	1,728	1,709	1,690	1,612	1,539	1,465
16°C	1,743	1,728	1,713	1,698	1,621	1,548	1,474
17°C	1,743	1,728	1,717	1,706	1,630	1,556	1,483
18°C	1,743	1,728	1,721	1,714	1,638	1,565	1,492
19°C	1,743	1,728	1,725	1,722	1,647	1,574	1,502
20°C	1,743	1,728	1,729	1,730	1,655	1,583	1,511
21°C	1,743	1,728	1,729	1,730	1,664	1,592	1,520
22°C	1,743	1,728	1,729	1,730	1,672	1,601	1,529
23°C	1,743	1,728	1,729	1,730	1,681	1,609	1,538
24°C	1,743	1,728	1,729	1,730	1,689	1,618	1,547
25°C	1,743	1,728	1,729	1,730	1,698	1,627	1,556
26°C	1,743	1,728	1,729	1,730	1,698	1,632	1,565
27°C	1,743	1,728	1,729	1,730	1,698	1,636	1,575
28°C	1,743	1,728	1,729	1,730	1,698	1,641	1,584
29°C	1,743	1,728	1,729	1,730	1,698	1,645	1,593
30°C	1,743	1,728	1,729	1,730	1,698	1,650	1,602

Table 2.3 – Unitary cooling power GAHP-WS

UNITARY COOLING POWER GAHP-WS							
EVAPORATOR RETURN TEMPERATURE (T_{cr})	WATER DELIVERY TEMPERATURE (T_{hm})						
	35°C	40°C	45°C	50°C	55°C	60°C	65°C
	WATER RETURN TEMPERATURE (T_{hr})						
	25°C	30°C	35°C	40°C	45°C	50°C	55°C
	q_c [kW]	q_c [kW]	q_c [kW]	q_c [kW]	q_c [kW]	q_c [kW]	q_c [kW]
6°C	17,6	17,6	15,9	14,2	12.0	10,1	8,2
7°C	17,6	17,7	16,2	14,7	12,6	10,7	8,8
8°C	17,6	17,8	16,6	15,3	13,2	11,3	9.4
9°C	17,6	17,9	16,7	15,8	13,8	11,9	10,0
10°C	17,6	18,0	16,8	16,6	14,5	12,7	10,8
11°C	18,7	18,1	17,4	16,6	14.6	12,7	10,8
12°C	18,7	18,2	17,5	16,8	14,8	12,9	11,0
13°C	18,7	18,3	17,6	17,0	15,0	13,1	11,3
14°C	18,7	18,3	17,8	17,2	15,2	13,4	11,5

15°C	18,7	18,4	17,9	17,4	15,4	13,6	11,7
16°C	18,7	18,4	18,0	17,6	15.6	13,8	11,9
17°C	18,7	18,4	18,1	17,8	15,9	14,0	12,2
18°C	18,7	18,4	18,2	18,0	16,1	14,2	12,4
19°C	18,7	18,4	18,3	18,2	16,3	14,5	12,6
20°C	18,7	18,4	18,4	18,4	16,5	14,7	12,9
21°C	18,7	18,4	18,4	18,4	16,7	14,9	13,1
22°C	18,7	18,4	18,4	18,4	16,9	15,1	13,3
23°C	18,7	18,4	18,4	18,4	17,2	15,4	13,6
24°C	18,7	18,4	18,4	18,4	17,4	15.6	13,8
25°C	18,7	18,4	18,4	18,4	17,6	15,8	14,0
26°C	18,7	18,4	18,4	18,4	17,6	15,9	14,2
27°C	18,7	18,4	18,4	18,4	17,6	16.0	14,5
28°C	18,7	18,4	18,4	18,4	17,6	16,1	14,7
29°C	18,7	18,4	18,4	18,4	17,6	16,3	14,9
30°C	18,7	18,4	18,4	18,4	17,6	16,4	15,2

Table 2.4 – G.U.E. GAHP-WS unit in conditioning mode

G.U.E. GAHP-WS IN CONDITIONING MODE							
EVAPORATOR RETURN TEMPERATURE (T_{cr})	WATER DELIVERY TEMPERATURE (T_{hm})						
	35°C	40°C	45°C	50°C	55°C	60°C	65°C
	WATER RETURN TEMPERATURE (T_{hr})						
	25°C	30°C	35°C	40°C	45°C	50°C	55°C
6°C	0,700	0,697	0,630	0,563	0,478	0,401	0,324
7°C	0,700	0,702	0,644	0,585	0,501	0,424	0,348
8°C	0,700	0,707	0,657	0,607	0,524	0,448	0,372
9°C	0,700	0,711	0,663	0,629	0,547	0,471	0,396
10°C	0,700	0,714	0,667	0,657	0,575	0,502	0,427
11°C	0,743	0,719	0,689	0,659	0,578	0,503	0,428
12°C	0,743	0,722	0,694	0,667	0,587	0,512	0,438
13°C	0,743	0,724	0,699	0,675	0,595	0,521	0,447
14°C	0,743	0,727	0,705	0,683	0,604	0,530	0,456
15°C	0,743	0,728	0,709	0,690	0,612	0,539	0,465
16°C	0,743	0,728	0,713	0,698	0,621	0,548	0,474
17°C	0,743	0,728	0,717	0,706	0,630	0,556	0,483
18°C	0,743	0,728	0,721	0,714	0,638	0,565	0,492
19°C	0,743	0,728	0,725	0,722	0,647	0,574	0,502
20°C	0,743	0,728	0,729	0,730	0,655	0,583	0,511
21°C	0,743	0,728	0,729	0,730	0,664	0,592	0,520
22°C	0,743	0,728	0,729	0,730	0,672	0,601	0,529
23°C	0,743	0,728	0,729	0,730	0,681	0,609	0,538
24°C	0,743	0,728	0,729	0,730	0,689	0,618	0,547
25°C	0,743	0,728	0,729	0,730	0,698	0,627	0,556
26°C	0,743	0,728	0,729	0,730	0,698	0,632	0,565
27°C	0,743	0,728	0,729	0,730	0,698	0,636	0,575
28°C	0,743	0,728	0,729	0,730	0,698	0,641	0,584
29°C	0,743	0,728	0,729	0,730	0,698	0,645	0,593
30°C	0,743	0,728	0,729	0,730	0,698	0,650	0,602

2.3 THEORETICAL BASES FOR THE CALCULATION OF GAHP-WS INSTALLATIONS

The design calculation of unit systems requires calculation of the heating power q_h for winter heating operation on the basis of the inlet temperatures for the condenser T_{hr} and evaporator T_{cr}.
The condenser inlet temperature can be set immediately by the conditions of operation of the system, while the evaporator return temperature is a function of the conditions of

exchange between the water chilled by the GAHP-WS and the aquifer water, surface water (lake, river, sea, etc.) or thermal waste of the industrial process being cooled.
Given these temperatures, it is possible to calculate the winter heating power q_{hi} using the efficiency tables. At the same time, we must also define the winter cooling power q_{ci} produced simultaneously with the heating power.
For the conditions of operation in the summer, we proceed in a similar manner, defining the machine's operating temperatures and then calculating the summer cooling q_{ce} and heating q_{he} powers.
Once the heating and cooling outputs of the individual GAHP-WS units have been determined in both seasons, it is possible to proceed in one of the following manners:

A. Select the maximum number of GAHP-WS units to ensure coverage of any operating requirement of the plant using the heat pumps.
B. Select the number of GAHP-WS units as a function of the maximum simultaneous exploitation of the heating and cooling powers offered by the heat pumps.

The first case is the more immediate and simple to calculate, since it requires the system to be sized on the basis of its heaviest projected duty, accepting a certain oversizing of the plant during one of the two seasons of use.
If we only need heating in the winter and conditioning in the summer, we can calculate the number of heat pumps required in the winter N_{Wi} directly as follows:

$$N_{Wi} = \frac{\dot{Q}_h}{\dot{q}_{hi}}$$

where Q_h is the heating power required by the winter heating plant.
In the same way we calculate the number N_{We} of GAHP-WS units required for summer conditioning services.

$$N_{We} = \frac{\dot{Q}_c}{\dot{q}_{ce}}$$

In the above formula, Q_c is the cooling power required for the conditioning service.
The number N_W of GAHP-WS units required by the plant in this case will be the larger of the two calculations.
In this case the plant uses a renewable source (underground or surface aquifer), or the use of any source of waste heat which is available in the summer and winter. To design the plant so as to exploit these sources of energy, we must determine the cooling and heating powers to be exchanged in the winter and summer respectively. The cooling power Q_{ci} to be exchanged in the winter with the renewable source is calculated as follows:

$$\dot{Q}_{ci} = \dot{q}_{ci} \cdot N_{Wi}$$

The heating power Q_{he} to be exchanged in the summer with the renewable source is calculated as follows:

$$\dot{Q}_{he} = \dot{q}_{he} \cdot N_{We}$$

The water temperatures are known at this point in the calculation, as well as the thermal differentials, since these have been estimated to obtain the values of T_{hr} and T_{cr}, so that the water flow rates required to exchange energy with the renewable source and to send to the GAHP-WS heat pump (the internal circuit and the external heat exchanger circuit, the latter not supplied with the GAHP-WS) will be automatically calculated once the above-mentioned powers are known.

Note at this point that, if the renewable source is discharged into the sewers or a ditch, or returned to the aquifer, we will have to account for heat differentials in the source which are within the local regulatory limits regarding the exploitation of the soil and aquifers.
The selection made on the basis of this criterion has the advantage of providing quick and simple estimates, but it may result in overspecifying the number of heat pump modules for one of the two seasons of operation. If the surplus of GAHP-WS modules occurs in the winter, so that $N_W = N_{We}$, this could result in pointless cost overruns for the system.
In the case of technological systems serving industrial processes, in which the GAHP-WS units are required to produce heating and cooling power at the same time, one must identify the power requirements of the application throughout the various seasons of operation of the plant, so as to use the hot and cold water circuits as far as possible at the same time, to obtain the greatest operating efficiency from the system. This evaluation will bear in mind the heating power Q_h* and cooling power Q_c* required simultaneously from the system and will calculate the number of GAHP-WS units on the basis of one or the other of them.
One therefore calculates the number of heat pump units on the basis of the simultaneous heating and cooling power requirements.

$$N_{Wh}^* = \frac{\dot{Q}_h^*}{\dot{q}_h}$$

$$N_{Wc}^* = \frac{\dot{Q}_c^*}{\dot{q}_c}$$

In order to maximise the efficiency of the system, one selects the greatest simultaneity of use of the heat pumps.

$$N_{Wh}^* \leq N_{Wc}^* \Rightarrow N_W = N_{Wh}^*$$

If this condition is satisfied, the entire partial heating power Q_h* and a part of the partial cooling power Q_c* will be provided by the GAHP-WS units, while the maximum heating power Q_h and maximum cooling power Q_c will be supplemented by boilers and refrigerators.
If, on the other hand, the following condition is satisfied, the entire partial cooling power Q_c* and a part of the partial heating power Q_h* will be provided by the GAHP-WS units, while the maximum heating power Q_h and maximum cooling power Q_c will be supplemented by boilers and refrigerators, the number of which, with heating powers q_{CA} (kW) and cooling powers q_{GA} (kW) are given by the previous relations.

$$N_{Wc}^* \leq N_{Wh}^* \Rightarrow N_W = N_{Wc}^*$$

If the number of heat pumps N_W defined as above is sufficient to handle the entirety of the two simultaneous loads, heating Q_h* and cooling Q_c*, it will not be necessary to design the renewable energy plant (aquifer wells). If further to the preceding condition the maximum heating power Q_h and cooling power Q_c coincide with the simultaneous powers Q_h* and Q_c*, there is no need for the supplementary boilers and refrigerators.
If it is not possible, on the other hand, to exploit to the full and at the same time the two power outputs of the GAHP-WS system, it is then necessary to identify the heating/cooling power to be exchanged with the renewable energy source and calculate the data required for sizing the plant as illustrated above.

3 DESIGNING OPEN LOOP GEOTHERMAL SYSTEMS

3.1 TYPES OF OPEN LOOP GEOTHERMAL SYSTEMS

Open loop geothermal systems are systems which exploit the renewable energy source represented by underground and surface aquifers. Underground aquifers are all those water sources located underground, including:

Water table aquifers

Water table aquifers are soils, sands or gravels which are saturated with water and often with a flow of water towards the porosities of the subsoil, thus with a hydrological flow of a certain speed and direction. Water table aquifers are not at a higher pressure than atmospheric, and hence the water must always be pumped out of the well boring for use. In some cases this type of aquifer has a minimal or even zero flow speed, and this makes them very suitable to plants with interseasonal energy accumulation.

Artesian aquifers

Artesian aquifers are layers of soil, sand, gravel or fractured rock which are saturated with water and often with a flow of water towards the porosities of the subsoil. Such layers of ground are pressurised above atmospheric pressure, and are often overlaid by impermeable layers of ground or rock, such as clays or argillites. In artesian wells, the water always rises above the level of the aquifer due to the pressure at which it is contained. But this physical phenomenon is almost never suited to extraction of the flow of water from the well boring.

Cavities and karstic streams

Cavities and karstic streams are genuine underground lakes and water courses created by the mechanical and chemical erosion of dolomite, limestone or carbonate rock by water. This type of aquifer is not generally easy to exploit.

Surface aquifers

Surface aquifers are surface expanses or courses of water such as seas, lakes, rivers, streams and canals.

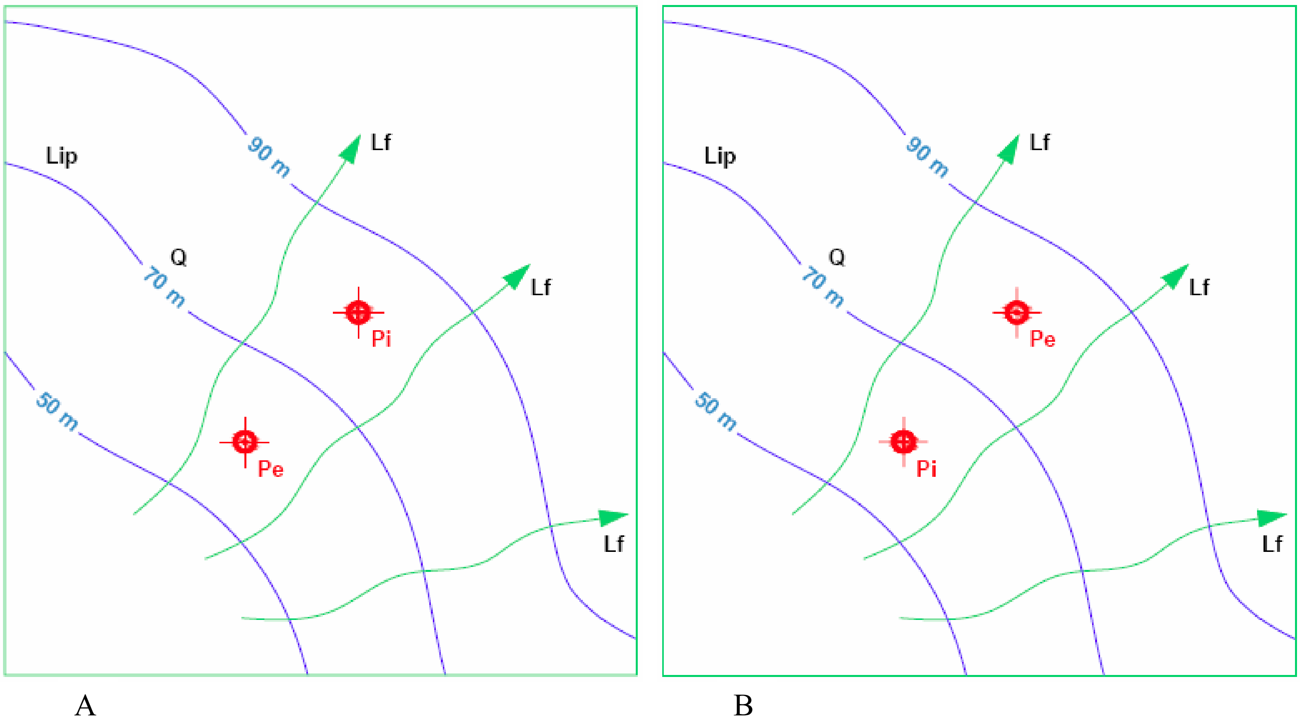
This manual deals solely with the design of systems which extract their water from a well boring (generally in the water table) and, briefly, with systems which exchange their heat with surface water of any kind and type.

3.2 WELLS

If there is no existing well due to the previous need for a heating/conditioning plant, boring a new well requires determination of the most advantageous position as well as the need for legal permission to do so, in terms of local regulations regarding the exploitation of underground water resources.
In order to exploit an aquifer, we must know the height of its "water table" and, in some cases, the orientation and direction of its flow lines.
The "water table" is the interface between ground saturated with water and ground which is not affected by the aquifer. Since the upper surface of the phreatic aquifer constitutes its position relative to ground level, it is also defined as the depth at which the aquifer can be intercepted and, in general, the depth to which the well must be bored.

The lines of flow, with their orientation and direction, identify the direction of flow of the water in the subsoil, which is extremely important when the plant is to extract water from the aquifer and then return it after having extracted thermal energy from it.
Both the above parameters can be determined by geologists and water drilling companies, and it is advisable to consult with them as part of the design process.
These data are also noted on the "isopiezometric" maps, and can be derived from them very precisely.
The "isopiezometric" lines marked on topographical maps, are the conventional graphic lines which unit the points at a given depth at which the aquifer can be intercepted.
The lines of flow which define the flow of the water inside the aquifer, are always orthogonal to the isopiezometric lines, and have the same direction as the slope of the water table (they always travel from shallower to deeper isopiezometric lines).

Figure 3.1 – Positioning of extraction wells



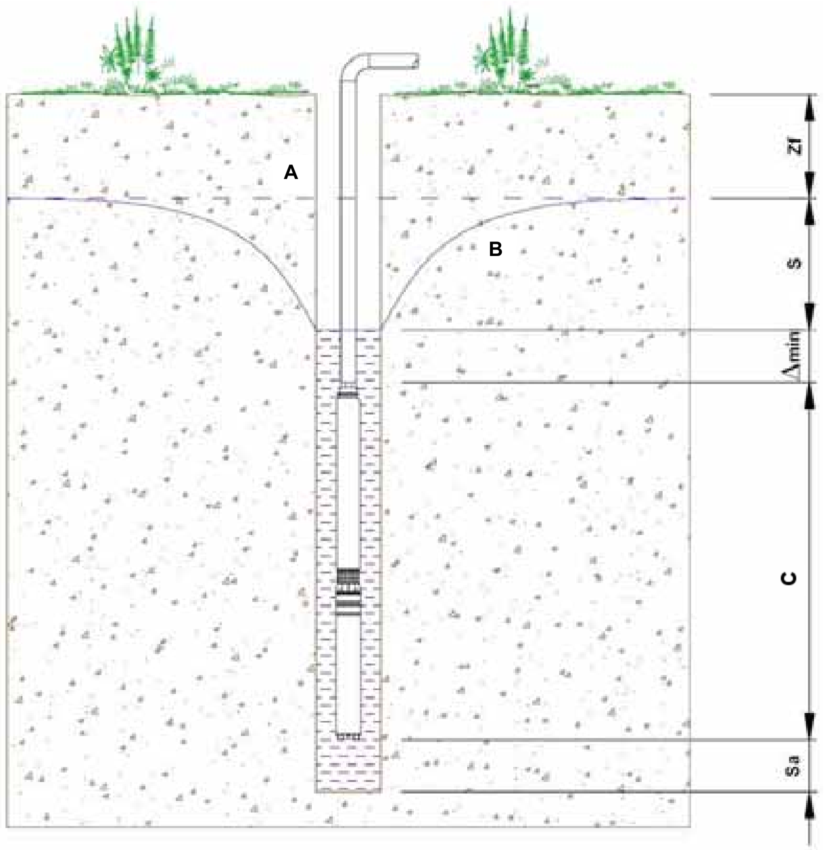
LEGEND
A CORRECT POSITIONING
B INCORRECT POSITIONING

Correct and incorrect positioning (plane view) of extraction and return wells on isopiezometric maps

In the figure on Figure 3.1 Positioning of extraction wells → 20 we show two identical sections of a simplified isopiezometric map, on which are marked two contrasting positionings of extraction and return wells.
Generally, the water is returned to the aquifer in order to reduce the hydrological environmental impact of the energy plant, although this is not strictly necessary.
Reading the isopiezometric lines "Lip", we can trace the lines of flow "Lf" of the aquifer water and hence graphically determine the direction of flow of the water underground.
The code "Q" identifies the depth of the water table relative to the external surface of the terrain, "Pe" is the extraction well and "Pi" the return well.
The first section (on the left) shows a correct positioning of the wells, since the extraction well is upstream of the return well in relation to the direction of flow of the water in the aquifer.

An incorrect positioning of the wells, as shown in the second section, results in the water arriving at the extraction well with altered thermal characteristics.
Another phenomenon to be borne in mind is the creation of the depression which is always created around a well due to the forced extraction of the water itself. When the well starts to pump water, the water starts to flow faster around the well, since the extracted water leaves gaps in the porous structure of the terrain which are quickly filled by other water.
The hydrological phenomenon results in a local depression and inclination of the water table.
The cone of depression can have a considerable effective radius. Furthermore, when two such cones coalesce and interact, they tend to lower the local aquifer level, thus negatively affecting the hydrology of the area.
From the practical point of view of designing the extraction system, the local effect of cones of depression is very important, since the level of the water in the extraction well drops when pumping is active. This drop is not immediate and does not disappear immediately when pumping is halted.
The water level lowers gradually until the well establishes a new hydrological equilibrium.
Clearly, the position of the extraction well is linked to the amplitude "S" of this lowering effect.
In Figure 3.2 Extraction well in a phreatic aquifer → 21 we show a sectional view of an aquifer well along with the relative positions of the water table, cone of depression and other dimensions to be considered when designing the extraction system.

Figure 3.2 – Extraction well in a phreatic aquifer



LEGEND
A Water table
B Cone of depression
C Filter pipe and pumping section

Sectional view

In Figure 3.2 Extraction well in a phreatic aquifer → 21 we show the clearances inside the extraction well. Dimension "S_a", technically known as the drawdown, is generally fixed at around a metre; "Δ_{min}" is the clearance to be maintained between the free surface of the water in the well (during pumping) and the top of the submerged pumping system, generally fixed at a metre; the dimension "Z_f" is the depth at which the aquifer is intercepted; the dimensions "S" is the drop in the free surface of the water in the well during pumping due to the creation of the cone of depression.

The variable "S" which defines the drop of the water level in the well is linked to the extraction flow rate (m^3/s), the hydraulic conductivity K of the surrounding terrain (m/s) and the transmissivity T of the terrain (m^2/s), as follows:

$$S = \frac{G}{2 \cdot \pi \cdot T} \cdot \ln \frac{R}{r}$$

The transmissivity of the terrain is calculated on the basis of our knowledge of the hydraulic conductivity and the thickness of the aquifer layer "b" (thickness of the water-bearing layer of ground).

$$T = K \cdot b$$

The variable "R" identifies the effective radius of the cone of depression, whereas "r" is the radius of the well itself.

The radius of the cone of depression is not calculable from first principles and can be estimated to be around 50 metres as a first approximation. The thickness of the aquifer can only be determined by boring a core and running stratigraphic studies.

Due to their experience, geologists and the drilling company will have all the data required for calculation of the areas with which they are familiar.

The flow rate at which the well is to be calculated is selected on the basis of the admissible thermal differential ΔT, as specified by local regulations. The verification must be done for both the winter and summer seasons if the system is to be used also for summer conditioning.

$$\dot{m}_{ws-inverno} = \frac{\dot{q}_{ci} \cdot N_{wi}}{\rho \cdot \Delta T \cdot C_p} \quad \text{[kg/s]} \quad ; \quad \dot{m}_{ws-estate} = \frac{\dot{q}_{ce} \cdot N_{we}}{\rho \cdot \Delta T \cdot C_p} \quad \text{[kg/s]}$$

Obviously, the greater of the two calculated flow rates must be the one selected, if the well is to be sized to satisfy the maximum design conditions.

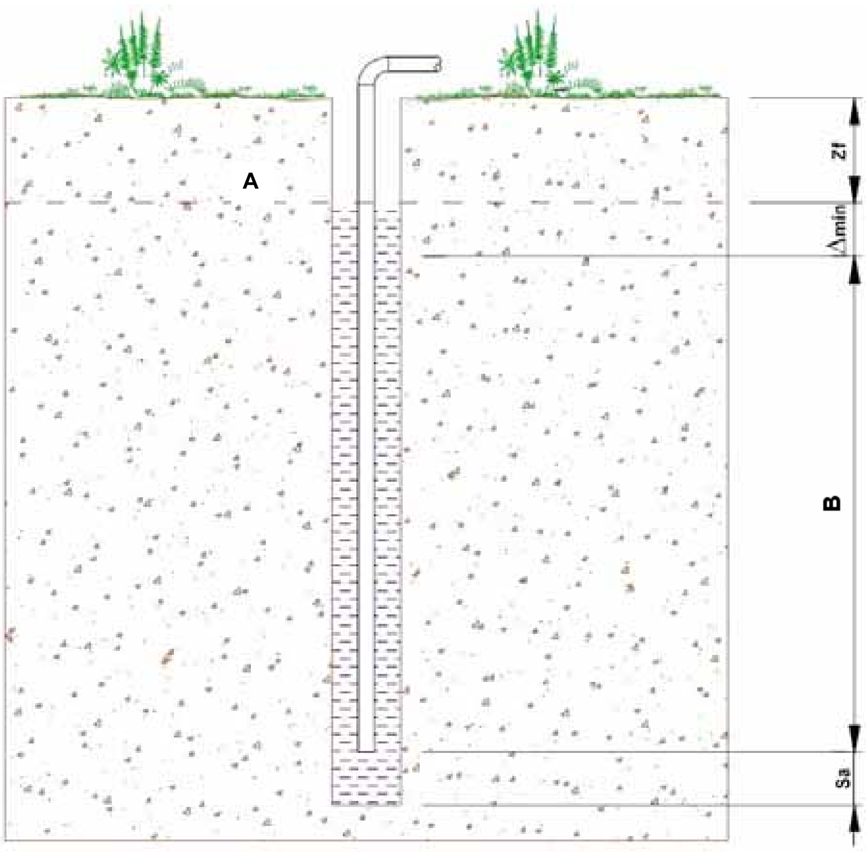
Table 3.1 – Table of hydraulic conductivity of various rocks and terrains

HYDRAULIC CONDUCTIVITY "K" FOR DIFFERENT TYPES OF ROCK		
ROCK / TERRAIN	MINIMUM CONDUCTIVITY Kmin [m/day]	MAXIMUM CONDUCTIVITY Kmax [m/day]
Gravel	10^{2}	10^{4}
Fine clean sand	10^{-1}	10
Coarse clean sand	10	10^{2}
Silty sand	10^{-1}	10
Glacial deposit	10^{-7}	10^{-1}
Clay	10^{-8}	10^{-4}
Non-fractured argillites	10^{-8}	10^{-6}
Fractured argillites	10^{-6}	10^{-4}
Fractured carbonate rock	10^{-4}	1
Karstic carbonate rock	1	10^{3}
Fractured slate	10^{-5}	10^{-3}
Semi-consolidated slate	10^{-3}	1

If the plant is to include a return well, one generally uses sections of perforated pipe called "draining pipe" located inside a well filled with draining gravel. An example of this type of system is given in Figure 3.3 Return well in a phreatic aquifer → 23. Dimension "S_a", technically known as the "drawdown", is generally fixed at around a metre; "Δ_{min}" is the clearance to be maintained between the free surface of the water in the well (water table) and the start of the perforated section of the drain pipe, generally fixed at a metre; the dimension "Z_f" is the depth at which the aquifer is intercepted.

If the flow of water in the aquifer is negligible or zero, it is energetically advantageous to implement interseasonal energy accumulation systems. This type of system uses two distinct wells which operate both in extraction and return modes. The winter-time extraction well can be used for return during the summer and vice-versa.

Figure 3.3 – Return well in a phreatic aquifer



LEGEND

A	Water table
B	Drain pipe

Sectional view

3.3 SURFACE AQUIFERS

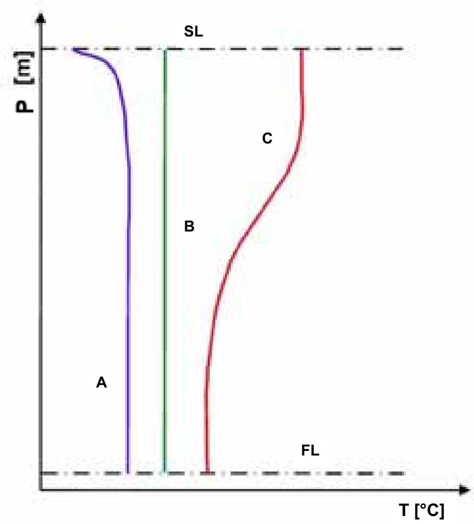
In order to exploit the potential of surface aquifers we must use a suitable heat exchanger, located either inside the aquifer or external to it. The exchanger can either be submerged in the lake, sea or ground water course, and the vector fluid from the GAHP-WS be run directly through it, or it can be located in the machine room and receive fluid from both the aquifer and the heat pumps.

In both cases, sizing a system required to exploit surface water as a renewable energy source reduces to the design of a heat exchanger.

We do not deal with the case of heat exchangers located in the machine room in this manual, and rather deal with the rough design criteria for heat exchangers submerged in the aquifer itself.

If the renewable energy source is river or canal water, one generally uses heat exchangers external to the aquifer. A single water intake extracts the water and delivers it to the heat exchanger in the machine room.
The location of the intake in the river must be carefully identified to prevent changes in the level of the water leaving it high and dry. One must also consider that the intake itself will be soiled and suffer blockages, and equip it to prevent the pipes and plant components from blocking.
In the case of lakes, on the other hand, one generally uses submerged heat exchangers rather than external ones. The submerged heat exchanger is generally composed of a plastic pipe, coiled in a spiral or similar path. The energy extraction method provides for the location of one or more heat exchangers at a suitable depth, connected in parallel at a distance of at least 6 m.
The use of such (very briefly outlined) spiral heat exchangers, in comparison to external heat exchangers, has the advantage of enabling the use of less powerful circulation pumps, and also provides a much cleaner installation than when the water is drawn directly from water courses. It is nonetheless essential to evaluate the potential for algae formation on the exterior of the pipes, which tends to build up and thus reduce the efficiency of the heat exchangers.
A first parameter to be determined when designing heat exchangers (whether submerged in or external to the renewable source) is obviously the temperature of the aquifer in question "T_l". In the following, we summarise the thermal curve of a hypothetical lake. The aim of the following description is simply to illustrate the fundamental parameters required to correctly determine the temperatures of the fluids circulating in the plant as well as the dimensions of the heat exchangers.
The temperature of the lake water at any time of year depends on its thermal equilibrium, in other words, the difference between its inputs and the heat dispersed. If one measures the temperature of lake from its surface to the bottom, we obtain very different profiles during the course of the year (Figure 3.4 Thermal profiles of a lake → 25). In particular, there are periods in which the column of water has the same temperature from the surface to the bottom, and other in which there is a pronounced thermal gradient. Before considering these phenomena, we must note a particular physical property of water. It density is at a maximum at 4°C: water colder than 4°C is less dense, and thus lighter in weight. Above 4°C, water becomes less dense (lighter) in relation to the temperature.
The waters of a hypothetical lake in a temperate region has a similar temperature at all depths at the end of the winter. If the lake is no more than 20 m deep, this temperature is close to 4°C. As spring comes on, the injection of thermal energy due to solar radiation raises the temperature of the surface water.

Figure 3.4 – Thermal profiles of a lake



LEGEND

P	Depth
T	Temperature
A	Winter
B	Spring and autumn
C	Summer
FL	Bottom of lake
SL	Surface of lake

The mechanical effect of the wind may result in the surface water (hotter and therefore less dense) mixing with that directly beneath it (colder and hence more dense), thus distributing the heat from the upper to the lower layers.

However, as the warm season goes on, a thermal (and hence density) gradient of increasing intensity is created between the surface and deeper water, which prevents remixing by the wind, or at least renders it ineffective.

In the warm season the lake will have a warm surface layer (called the epilimnion) separated from the colder deeper water (in the hypolimnion layer), maintained in the bottom layer by an intermediate layer (metalimnion), characterised by a rapid drop in temperature as depth increases.

In the epilimnion the temperature of the water, in temperate region lakes of a depth of around 20 m, varies in the summer from around 10°C to around 20°C. The temperature in the hypolimnion varies from around 7°C to around 10°C. In autumn the surface water cools off and, becoming more dense, descends towards the bottom. This lowers and thins out the metalimnion layer, in which the temperature differential occurs.

The wind's mixing action intensifies until a complete circulation called autumnal circulation sets in, similar to that in the spring.

In winter the density of the water decreases due to further cooling. If the lake is around 20 m deep, an unstable inverse stratification occurs, with a colder surface layer over a deeper layer at 4°C. When ice forms, it covers the surface of the lake because its density at 0°C is less than that of the water.

In the case of shallow lakes (around 20 m), the heat exchangers should be submerged to an intermediate depth, such as not to fall in the range of sudden winter time temperature drops, nor in the range in which summer temperatures are particularly high. This depth is usually in the middle of the summer epilimnion layer.

In any case, it is not advisable to place the heat exchangers on the bottom of the lake since over time they may be covered with too much sediment, thus loosing their design heat exchange characteristics.

The calculation of the thermal power of helical heat exchangers can be done as a first approximation with the well-known formula for heat exchange via the walls of a circular pipe.

$$\alpha_i = \frac{Nu \cdot \lambda_f}{d}$$

In the preceding formula, the thermal power Q_{se} exchanged through the walls of the helical heat exchanger is calculated with the following parameters: overall length "l" of the heat exchanger pipe; mean temperature "T_{se}" of the vector fluid inside the heat exchanger; temperature "T_l" of the body of water or water course; internal radius of the pipe "r_i"; external radius of the pipe "r_e"; convection coefficient "α_i" for the vector fluid flowing in the heat exchanger (forced convection); convection coefficient "α_e" for the body of water (natural convection); coefficient of conductivity "λ_{se}" of the material of which the heat exchanger pipe is made; soiling factor "F_{sp}" presumed for the heat exchanger. For the convection coefficient for the water in the lake, we can take the figure for water in natural convection 250 ÷ 750 W/m^{2}K. For the convection coefficient for the vector fluid flowing in the heat exchanger pipe, if this is pure water (without chemical additives), it can be considered to be in the following range: 1000 ÷ 12000 W/m^{2}K. Otherwise the value of "α_i", can be calculated with the following analytical procedure.

$$\alpha_i = \frac{Nu \cdot \lambda_f}{d}$$

Where "λ_f" is the conductivity coefficient of the fluid, "d" is the diameter of the pipe and "Nu" is the Nusselt number, which is calculated as follows:

$$Nu = 0{,}023 \cdot \mathrm{Re}^{0,8} \cdot \mathrm{Pr}^{0,4}$$

In the preceding formula, "Re" is the Reynolds number and Pr is the Prandtl number, which can be calculated on the basis of the characteristics of the fluid in used and the geometry of the pipe.

$$\mathrm{Re} = \frac{w \cdot d \cdot \rho}{\mu} \qquad \mathrm{Pr} = \frac{c_p \cdot \mu}{\lambda_f}$$

In the preceding two formulas, the Reynolds and Prandtl numbers are calculated on the basis of the following variables: speed "w" of the vector fluid; internal diameter "d" of the pipe; density "ρ" of the fluid; viscosity "μ" of the fluid; specific heat of the fluid "c_p", conductivity coefficient "λ_f".

4 PLANT DESIGN

4.1 GENERAL DESIGN CRITERIA

Types of plant

GAHP-WS absorption heat pumps can be used effectively with all types of hydronic heating and, eventually, conditioning plant. Note, however, that since these systems are of very high efficiency, it is advisable to evaluate the use in the winter of vector fluids temperatures T_{hm} in the medium to low range, in other words, in the range 30°C to 50°C. The use of medium high temperatures (50°C to 60°C, or even peaks of 65°C), should be reserved for installations equipped with relatively inefficient heat delivery equipment (such as radiators), for which it is essential not to drop below delivery temperature of 50°C. To this end, we note the option of reducing the delivery temperature to radiators in three situations: a) increased hours of operation of the heating system; b) reduced energy requirement of the building (improved building insulation); c) modified radiators (increased exchange surfaces).

Inertial volume

The inertial tank, although specifically required, can be usefully included in the circuit as a thermal energy accumulator when the water delivery temperature is less than or equal to 50°C, thus reducing the number of ignition cycles of the units composing the system.
The volume in litres of the inertial tank can be determined using the following formula, in which "t" is the accumulation time in seconds, "Q_s" is the heating power in kW transferred to the accumulation tank in the time "t", ρ is the density of the vector fluid in use, C_p is the specific heat of the water (4.187 kJ/kg K) and ΔT is the thermal differential of the vector fluid expressed in degrees Kelvin (K).

$$V = \frac{\dot{Q}_s}{\rho \cdot C_p \cdot \Delta T} \cdot t \qquad \text{(I)}$$

The power "Q_s" to be transferred in the predetermined time t is equal to that not used by the system when characterised by average climatic conditions other than the design specification. In this case "Q_s" is calculated as the month-by-month difference between the power required for the average climatic conditions "Q_{hm}" and the power offered by the GAHP-WS system.
A simple way of determining the power Q_s, is to select the minimum seasonal load factor F_c and apply it in the following formula.

$$\dot{Q}_s = \dot{Q}_h - \left(\dot{Q}_h \cdot F_c \right) \qquad \text{(kW)}$$

Where the heating power Q_h is the heating power delivered by the installed unit
Fc is the minimum seasonal load factor calculated as follows:

$$F_c = \frac{\dot{Q}_{hm}}{\dot{Q}_h} = \frac{T_i - T_{am}}{T_i - T_a}$$

with:
T_i is the internal air temperature of the heated rooms
T_a is the external design temperature

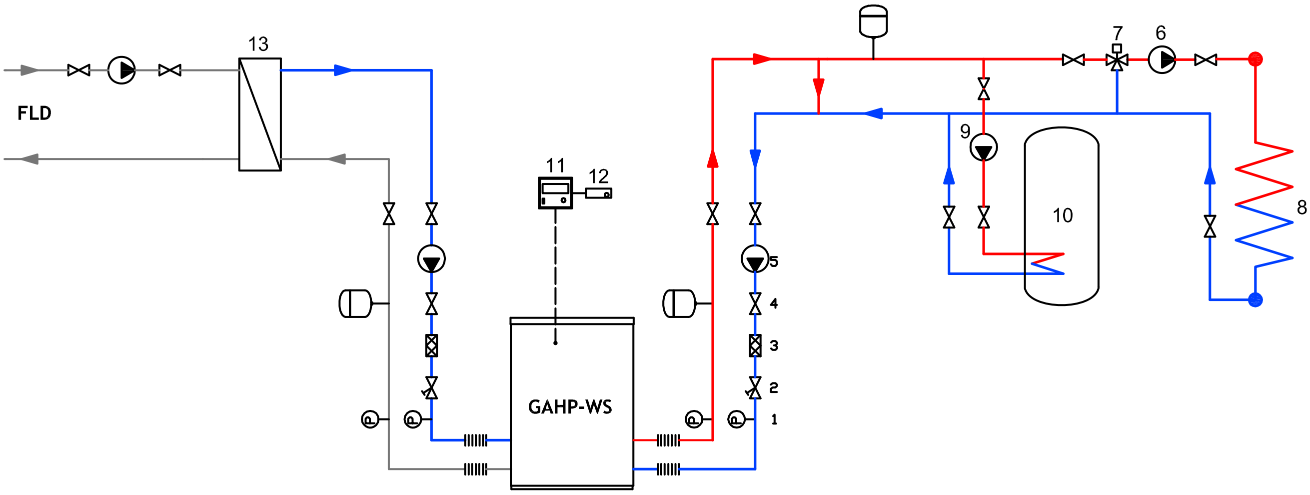
![ROBUR logo]

Production of domestic hot water

Domestic hot water can be provided by GAHP-WS heat pump units, bearing in mind the maximum return temperature to the condenser (55°C). One should thus implement an accumulation system with temperature close to the service temperature (e.g. 45°C) or a system with direct heat exchange at the same working temperature. To control the anti-legionella function one must install equipment suited to run the anti-legionella cycle in accordance with applicable legislation.

In Figure 4.1 Use of single unit → 28 we give an example of a single GAHP-WS unit combined with a heating system with radiant panels and domestic hot water production plant with accumulator. The heat pump, when the domestic hot water service is not required, sends the vector fluid to the system at the user conditions required by the radiant panels (low temperature). When the boiler requires power for domestic hot water production the RB100 plant interface changes the unit's temperature setpoint. A three-way mixer valve controls the delivery temperature to the radiator coils.

Figure 4.1 – Use of single unit



LEGEND
FLD AQUIFER PLANT

Schematic for the use of a single unit for supplementary production of domestic hot water at max 45°C

In the schematic given in Figure 4.1 Use of single unit → 28 the represented components have the following meanings: "1" pressure gauge; "2" flow regulator valve; "3" water filter; "4" shut-off valve; "5" internal circuit constant rate pump; "6" external service circuit constant rate pump; "7" three-way regulator/mixer valve; "8" heating system services; "9" hot water production external circuit constant rate pump; "10" boiler for domestic hot water production; "11" Direct Digital Controller. "12" RB100 system interface; "13" aquifer water heat exchanger.

Other types of plant can be created than those described in this paragraph: see the system sheets at the end of this manual.

Characteristics of plant water supply

Robur units, by their very nature, do not require evaporator towers to operate. There is thus no need for topping up the water circuit. Furthermore, for the same reason, there are no special requirements or restrictions on the plant water quality, so that one need only refer to the normal values adopted for the physical and chemical properties of vector fluids in traditional conditioning and heating systems.

You need only observe established standards regarding the treatment of water for heating/cooling systems.

The optimal chemical and physical specifications for the water are given in Table 4.1 Chemical and physical parameters of water → 29.

Table 4.1 – Chemical and physical parameters of water

CHEMICAL AND PHYSICAL PARAMETERS OF WATER IN HEATING/COOLING SYSTEMS		
PARAMETER	**OPTIMAL VALUE**	**UNIT OF MEASUREMENT**
pH	6,5 - 8,0	\
Chlorides	< 125	mg/L
Total chlorine	< 5	mg/L
Total hardness ($CaCO_3$)	10 - 15	°F
Iron	< 50	mg/L
Copper	< 3	mg/L
Aluminium	< 3	mg/L
Langelier's index	0	\
SUBSTANCES HAZARDOUS EVEN AT VERY LOW CONCENTRATION		
Free chlorine	ABSENT	
Fluorides	ABSENT	
Sulphides	ABSENT	

Physical and chemical properties of the system water.

4.2 INSTALLATION CRITERIA

- GAHP-WS units can be installed either indoors or outdoors.
- The unit GAHP-WS must be installed in such a way that the exhaust fumes outlet is not in the immediate vicinity of any external air inlets of a building. Observe established standards in regard to the discharge of fumes.
- GAHP-WS units are homologated for connection of their combustion products evacuation pipe to a flue for direct connection to the exterior of type C_{13}, C_{33}, C_{43}, C_{53}, C_{63} or C_{83}. The units are equipped with a fitting of diameter Ø 80 mm (with gasket) at the left side (see Figure 1.2 Drain outlet → 12). If the type of installation or established legislation requires combustion products to be conveyed away, refer to Table 4.2 Combustion products table → 29 for the dimensions of the duct.

Table 4.2 – Combustion products table

COMBUSTION PRODUCTS TABLE FOR A SINGLE GAHP-A UNIT				
-	**UNIT OF MEASUREMENT**	**NATURAL GAS G20**	**LPG. G30**	**LPG. G31**
EXHAUST GAS FLOW	kg/h	42	43	48
EXHAUST GAS TEMPERATURE	°C	65	65	65
CARBON DIOXIDE CO_2	%	9,1	10.4	9,1

Fumes flow rate and temperature.

- The flue and its fumes duct may be made in polypropylene and the high available head (80 Pa) enables considerable versatility in installation.
- Each unit is equipped with a condensation discharge system, which must be connected to the drain system by the installer. If local legislation permits, it can be discharged directly into the sewers, otherwise a system to neutralise the condensation before disposal must be installed. Depending on the type of installation it may also be necessary to install a condensation return pump, available from Robur.

Plumbing plant and gas circuit

- The sizing of the plumbing pipes and pump must guarantee the nominal water flow required for correct operation of the GAHP-WS unit (for calculation of pressure drops in the GAHP-WS, refer to Table 1.1 TECHNICAL DATA → 6).

- The hydraulic plant may be created using pipes in stainless steel, black steel, copper or crosslinked polyethylene for heating/cooling plants. All water pipes and pipe connections must be adequately insulated in accordance with current regulations, to prevent heat loss and the formation of condensate.
- When rigid pipes are used, in order to prevent the transmission of vibrations, we recommended connecting the water inlet and outlet of the appliance with anti-vibration joints.
- When filling the hydraulic circuit, ensure the minimum water content in the plant, and add, in case of outdoors installation, to the plant water (free of impurities) a quantity of inhibited monoethylene glycol in proportion with the minimum winter temperature in the installation zone (see Table 4.3 Percentage of monoethylene glycol → 30). The glycol may be necessary in any case, if the delivery temperature of the refrigerated water is the minimum admitted for the unit (3°C).
- If glycol antifreeze is to be used, DO NOT USE galvanised pipes, as they are potentially subject to corrosion in the presence of glycol.

Table 4.3 Percentage of monoethylene glycol → 30 gives the approximate freezing temperature of the water and consequent increased drop in pressure of the GAHP-WS and system circuit as a function of the percentage of monoethylene glycol employed.
This table should be borne in mind when sizing the pipes and water circulator.

- Nevertheless, it is advisable to consult the technical specifications of the monoethylene glycol used.

Table 4.3 – Percentage of monoethylene glycol

% of MONOETHYLENE GLYCOL	**10**	**15**	**20**	**25**	**30**	**35**	**40**
WATER FREEZING POINT TEMPERATURE	-3°C	-5°C	-8°C	-12°C	-15°C	-20°C	-25°C
PERCENTAGE OF INCREASE IN PRESSURE DROPS	--	6%	8%	10%	12%	14%	16%
LOSS OF EFFICIENCY OF UNIT	--	0,5%	1%	2%	2,5%	3%	4%

Technical data for filling the hydraulic circuit

- The pressure of the gas supplied by the mains must be within the range of 17 and 25 mbar for natural gas (G20), and between 25 and 35 mbar for LPG, (whether G30 or G31).
- The gas supply system must be correctly rated for the capacity required by the appliance and must be equipped with all safety and control devices prescribed by current regulations.
- Clean the plant of any waste or process residue before commissioning the units, to prevent the filters blocking and reducing the circulation of water.

4.3 POSITION OF THE APPLIANCE

Lifting and positioning

The GAHP-WS unit can be installed at ground level, or on a terrace or roof (if they are able to sustain its dimensions and weight, see Table 1.1 TECHNICAL DATA → 6).

The hoist and all accessory equipment (braces, cables, bars) must be of adequate dimensions in relation to the load to be lifted.

Supporting base

Always position the GAHP-WS unit on a flat level surface constructed in fireproof material and able to sustain the weight of the appliance itself.

Installation at ground level

If a horizontal base is not available (see also Supports and levelling), it is necessary to create a flat level base in concrete, larger than the base of the GAHP-WS itself: at least 100-150 mm larger than the dimensions of the base of the appliance on each side.
The dimensions of the GAHP-WS unit are given in Table 1.1 TECHNICAL DATA → 6.

Installation on middle floors or on the roof

Position the GAHP-WS on a levelled flat surface made of fireproof material (see also "Supports and levelling" below).
The structure of the building must be able to sustain the weight of the GAHP-WS added to that of its supporting base.
The weight of the unit GAHP-WS is given in Table 1.1 TECHNICAL DATA → 6.
Although the GAHP-WS produces only moderate vibrations, the use of anti-vibration supports (available as accessories) is especially recommended in rooftop and terrace installations in which resonance phenomena may occur.
In addition, it is advisable to use flexible connections (anti-vibration joints) between the GAHP-WS and the hydraulic and gas supply pipes.

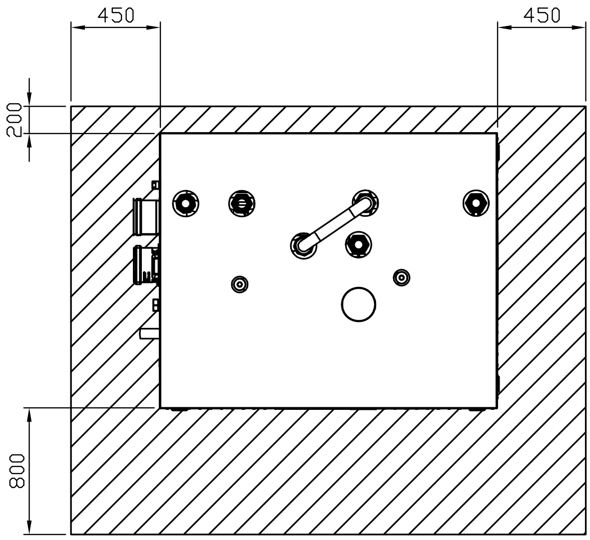
Supports and levelling

The GAHP-WS must be correctly levelled by placing a level on its top surface.
If necessary, level the GAHP-WS with metal shims, placing them appropriately in relation to its supports; do not use wooden spacers as these degrade quickly.

Clearances

Locate the GAHP-WS in such a way as to maintain the minimum specified clearances from combustible surfaces, walls or other equipment, as given in Figure 4.2 Clearances → 31.
Minimum clearances are necessary in order to be able to carry out maintenance operations.

Figure 4.2 – Clearances



Regulations regarding the machine room

In regard to the execution of the machine rooms in which GAHP-WS units are to be installed and all regulatory references regarding centralised systems (electric and hydronic), the requirements of local regulations and standard EN 378-3 must be observed.

4.4 HYDRAULIC PLANT COMPONENTS

The components described below, to be fitted in proximity to the GAHP-WS, are illustrated in the typical hydraulic plant schematics in section "7 PLANT SCHEMATICS → 41".

- ANTI-VIBRATION JOINTS at the gas and water fittings
- PRESSURE GAUGES at the water inlet/outlet pipes
- FLOW REGULATION VALVE (shutter or balancing) at the water inlet pipe
- WATER FILTER at the water inlet pipe, mesh MIN 0.7 mm, MAX 1 mm
- BALL CHECK VALVE on the water and gas pipes
- SAFETY VALVE 3 bar on the water outlet pipe
- EXPANSION TANK (sole ISPESL safety unit) on the water outlet pipe
- PLANT WATER CIRCULATION PUMP on the water inlet pipe, rated for the installation in question
- Systems for BLEEDING AIR from the water pipes
- DRAIN COCK on the water pipes
- PLANT FILLING SYSTEM: if automatic filling systems are used, it is advisable to carry out a seasonal check of the percentage of monoethylene glycol contained in the plant
- CONDENSATION COLLECTION AND DISPOSAL SYSTEM connected to the condensation drain provided on the unit, complete with eventual neutralisation system as per established legislation and eventual condensate pump

If more than one GAHP-WS unit is connected to a single hydraulic circuit, the following must also be installed:

- WATER CIRCULATION PUMP for each unit, on the water inlet pipe, with delivery towards the GAHP-WS unit, rated for the installation in question
- HYDRAULIC SEPARATOR complete with air vent valve and drain cock
- PLANT WATER CIRCULATION PUMP on the plant delivery pipe, with delivery towards the plant

5 ELECTRICAL DESIGN

The following specifications must be observed in the electrical power section of the plant:

- Power supply 230 V 1N - 50 Hz.
- The electrical components used for the hookup (circuit breakers, fuses, relays, etc.) must be mounted in an external electrical cabinet located by the installer in the vicinity of the GAHP-WS unit.

The electrical connection schematics are given in Section "7 PLANT SCHEMATICS → 41".

5.1 CONNECTION TO THE UNIT

To hook up one or more GAHP-WS units, the following will be required:

- A connection cable, FG7(O)R 3Gx1.5.
- An external bipolar circuit breaker with 2 5A type T fuses with minimum airgap 3 mm or a 10 A magnetothermic switch.

5.2 CONNECTING THE CONTROLLER

The unit GAHP-WS can be controlled with the accessory Direct Digital Controller (DDC). For a total cable run of ≤ 200 m and up to 5 units connected, use a simple 3x0.75 mm2 shielded cable; otherwise use a CAN-BUS cable as specified by the Honeywell SDS standard, as given below:

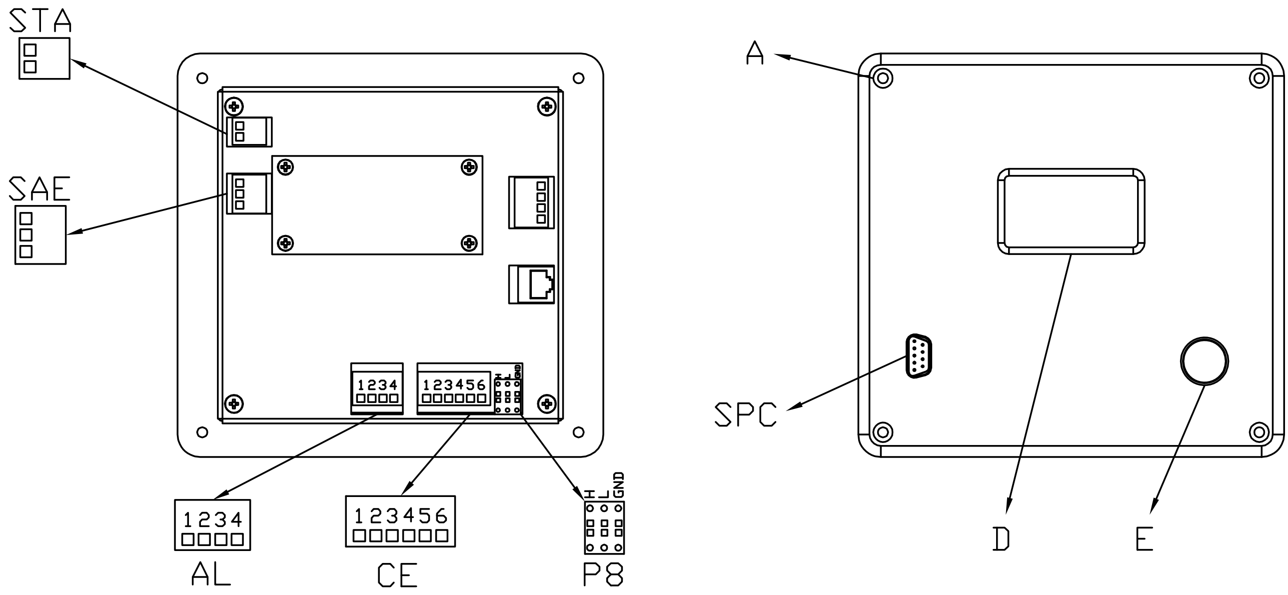
- Robur Netbus (Robur, maximum cable run 450 m).
- Belden 3086A (Honeywell SDS 1620, maximum cable run 450 m).
- Turck 530 (Honeywell SDS 1620, maximum cable run 450 m).
- Turck 5711 (DeviceNet Mid Cable, maximum cable run 450 m).
- Turck 531 (Honeywell SDS 2022, maximum cable run 200 m).

6 REGULATOR SYSTEM

6.1 DIRECT DIGITAL CONTROLLER (DDC)

The fundamental component for the control and regulation of GAHP systems is the Direct Digital Controller (DDC).
The Direct Digital Controller is a device which displays, on a backlit graphic LCD display of 128x64 pixels, all the status, operating and error conditions of each individual unit to which it is linked. The DDC controls water thermostating by controlling the switch-on and switch-off of the units connected to it.
Each DDC is able to control up to sixteen GAHP-WS modules, beyond which another DDC must be used in combination with the first to control the system.
For pre-assembled units, the DDC is already supplied as part of the equipment. In the case of single GAHP-WS unit, not pre-assembled Robur, the DDC is available as an optional accessory.
The DDC is designed for indoors installation (ambient air temperature in the range 0°C to 50°C), mounted to an electrical cabinet in a hole measuring 155 x 151 mm.
The front of the DDC mounts a graphic display on which all the parameters necessary to control, program and configure the machine are shown (see detail D, Figure 6.1 Direct Digital Control (DDC) → 36); a selector knob (Encoder) used to select options, parameter settings, etc. (detail E, Figure 6.1 Direct Digital Control (DDC) → 36); an RS 232 serial port for connecting the DDC to a PC (see detail SPC, Figure 6.1 Direct Digital Control (DDC) → 36), used for technical service.
The rear of the DDC mounts all the electrical and CAN-BUS connections required for its operation. Furthermore, it also features contacts for additional DDC on/off options using enabling signals from external regulator systems, alarm lamps and buzzers for remote installation, and contacts for connection to an ambient sensor (optional).

Figure 6.1 – Direct Digital Control (DDC)



LEGEND

STA ambient temperature probe - 2-pole connector
SAE external alarm systems - 3-pole connector
AL power supply 24 V ac - 4-pole connector
CE external consents - 6-pole connector
P8 CAN BUS network connector (orange)
SPC 232 serial connection to PC - 9-pole connector
A mounting holes DDC
E Encoder
D Display

Front and rear views with detail of electrical connections.

6.2 CONTROL AND REGULATION OF THE SYSTEM

For the control and regulation of the system, install one or more DDC's, which serve to obtain full system diagnostics and control and regulate the operation of the system itself. In particular, they are used to set the winter-time vector fluid differential and setpoint, with the option to control either the delivery or return temperature. The above settings can be made for four daily time bands, with the option of using four different setpoints. The Robur plant concept, which also includes multiple units, has the certain benefit of enabling completely independent operation of the component modules, so as to deliver the heating power strictly required to handle the real time load, thus preventing frequent operational variations and consequent wasted fuel consumption.
Installation of units in cascade, up to five power steps, is featured on the DDC.

Figure 6.2 – Example of winter operation power steps

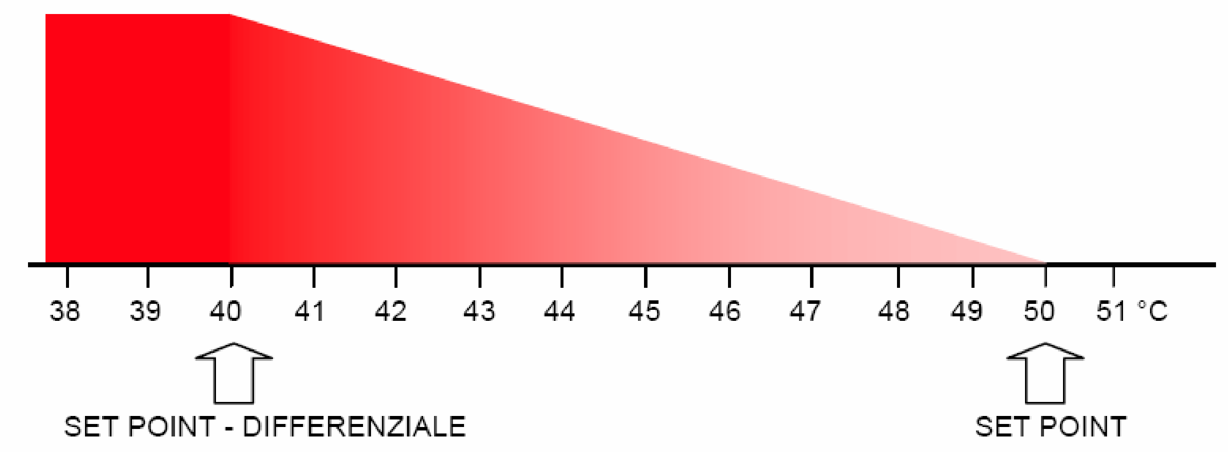
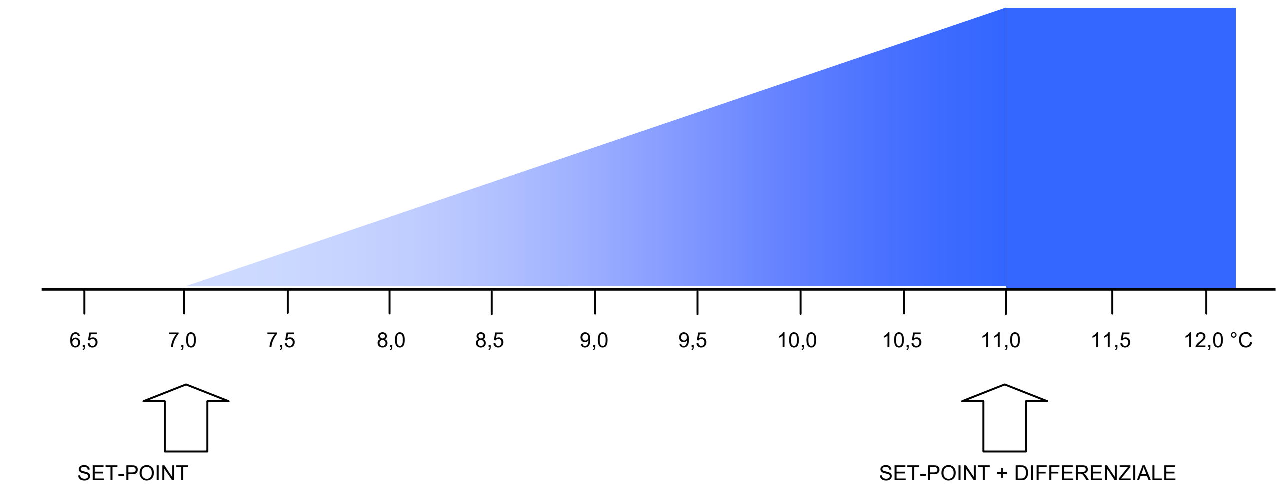


Figure 6.3 – Example of summer operation power steps



The regulation system, during the first daily power on, powers up all modules, which are then gradually switched off starting from the setpoint temperature minus the differential set on the DDC.
The system does not provide for sensors on the plant delivery or return pipes, since the GAHP-WS units are equipped with sensors which enable direct measurement on-board of the vector fluid temperature.

6.3 "SLIDING TEMPERATURE"

The ??? delivery/return temperature can be regulated continuously as a function of an external parameter controlled by another electronic system. In particular, it may be useful to vary the vector fluid delivery temperature as a function of the external air temperature, or another plant parameter which is significant in the application in question.
This option is provided by the optional RB100 plant interface, connected by a can-bus cable to the DDC. The RB100 can receive a 0 ÷ 10 V digital signal from an electronic regulator, so as to continuously modulate the delivery or return temperature.
The RB100 device has the function of interfacing the requests coming from one or more external control systems with the DDC.

It has the following functions: it controls the connected Robur units with a continuously variable temperature setpoint (sliding temperature) as well as domestic hot water production, which also requires actuation of the three-way diverter valves (see also Paragraph 6.4 CONTROL OF DOMESTIC HOT WATER (DHW) PRODUCTION → 38).
RB100 board dimensions: width 158 mm, depth 74.6 mm height 106.5 mm. The weight of the component is 0.320 kg and it must be mounted to the cabinet on a 35 mm DIN rail (EN 60715).

6.4 CONTROL OF DOMESTIC HOT WATER (DHW) PRODUCTION

The domestic hot water production service can be provided using only the GAHP-WS units when the system includes medium to low temperature accumulator boilers (45°C - 48°C) or when the production is handled directly by suitably dimensioned heat exchangers (external circuit delivery temperature 45°C - 48°C).
If the plant is to be equipped with one or more heat pumps in combination with one or more Robur AY condensation boilers, this service can be provided at any temperature of the DHW production boilers (accumulation temperature greater than 50°C), using the AY boilers for this purpose.
In any case, in order to use absorption heat pumps to produce DHW, the controller must be equipped with a DDC and an "RB100" system interface.
If GAHP-WS heat pumps are to be used for producing DHW under the above-mentioned conditions (accumulation temperature close to user temperature - max 48°C), the RB100 interface is required to raise the unit's delivery temperature, if this is not already set to the maximum working temperature.
If Robur AY condensing boilers are also to be used, the RB100 module connected with a CAN-BUS cable to the DDC can be used to deviate the vector fluid flow (with appropriate diverter valves, not supplied) to a heat exchanger for direct or accumulation production of DHW.
Once the heating circuit has been deviated to DHW production, the RB100 module modifies the setpoint only of the Robur AY condensing boilers involved in this service. The adjustment of the DHW setpoint of the Robur AY condensing boilers can be done with an ON-OFF analogue signal originated by a thermostat, or by a 0 - 10 V digital signal from an electronic controller.
The advantage of the RB100 unit is that there is no need to include other boilers for DHW production, so that all the Robur AY condensing units can be used, which would otherwise be kept switched off most of the time during the winter.
Clearly the DHW production service has operational priority, so that if the system is operating under maximum design conditions, the boilers dedicated to the dual service will nonetheless be switched from heating mode to DHW production for the duration of the period for which the service is required.
For existing plant for which the user wishes to implement such a remote control system, the firmware must be compatible with the components - contact Robur S.p.A. presales.

6.5 REMOTE CONTROL - “WISE” (WEB INVISIBLE SERVICE EMPLOYEE)

The WISE unit provides remote control of the major functions of the DDC and thus of the Robur units and plant controlled by the latter, over a common cellphone line equipped with WAP browser or using a point-to-point connection with a PC with a PSTN or GSM modem, so as to implement tele-control and teleassistance applications. The system is controlled by means of a web browser, while alarms are sent to the user by SMS.

The WISE device is composed of: n.1 WISE device; n.1 antenna; n.1 RS232 null-modem serial cable for device configuration; n.1 WISE - DDC communications cable with phone plug connection to the rear of the DDC; n.1 CD-ROM.
For existing plant for which the user wishes to implement such a remote control system, the firmware must be compatible with the components - contact Robur S.p.A. presales.

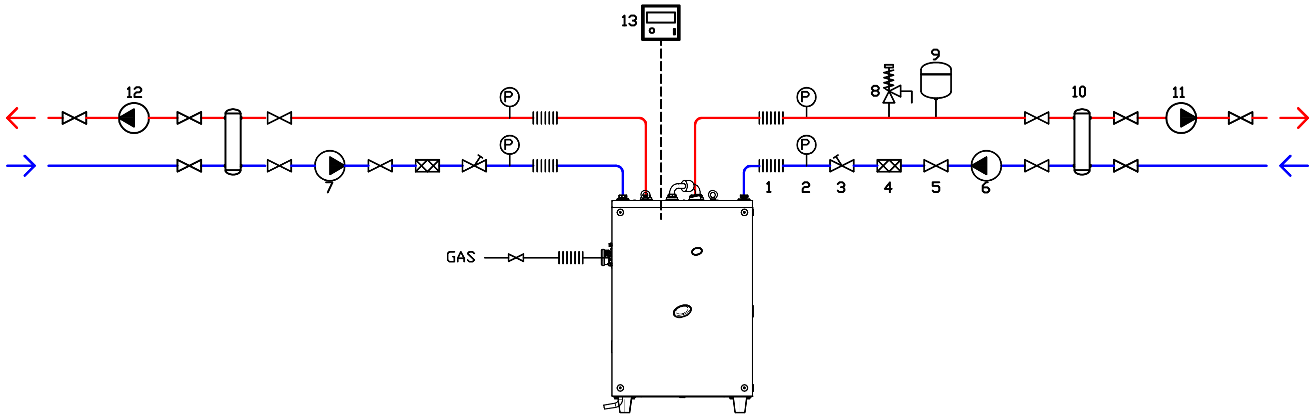
6.6 MOD BUS

The DDC supports interfacing with external equipment (BMS, PLC, SCADA, etc.) via the Modbus RTU protocol.
The Modbus protocol makes it possible to acquire data regarding the operation of the units and the plant controlled by the DDC (temperatures, statuses, counters, etc.).
It can also acquire information regarding alarms, both current and registered in the alarms log.
It can also act on the plant to set a variety of operational parameters such as unit On/Off, hot/cold inversion, setpoints, differentials, power steps, and operating time bands.
The DDC implements the Modbus RTU protocol as a slave device, in the following modes: 19.200 8N1; 19200 8E1; 19200 8N2; 9600 8N1; 9600 8E1; 9600 8N2.
The default modbus address is 1, and can be configured via the DDC's display which supports the following modbus function codes: (01) Read Coil Status; (02) Read Discrete Input; (03) Read Holding Register; (04) Read Input Register; (05) Write Single Coil; (06) Write Single Register; (15) Write Multiple Coil; (16) Write Multiple Register; (23) Read/Write Multiple Register.
The DDC is equipped to support broadcast messages.

7 PLANT SCHEMATICS

7.1 SYSTEM OF A SINGLE GAHP-WS UNIT

Figure 7.1 – Hydraulic plan

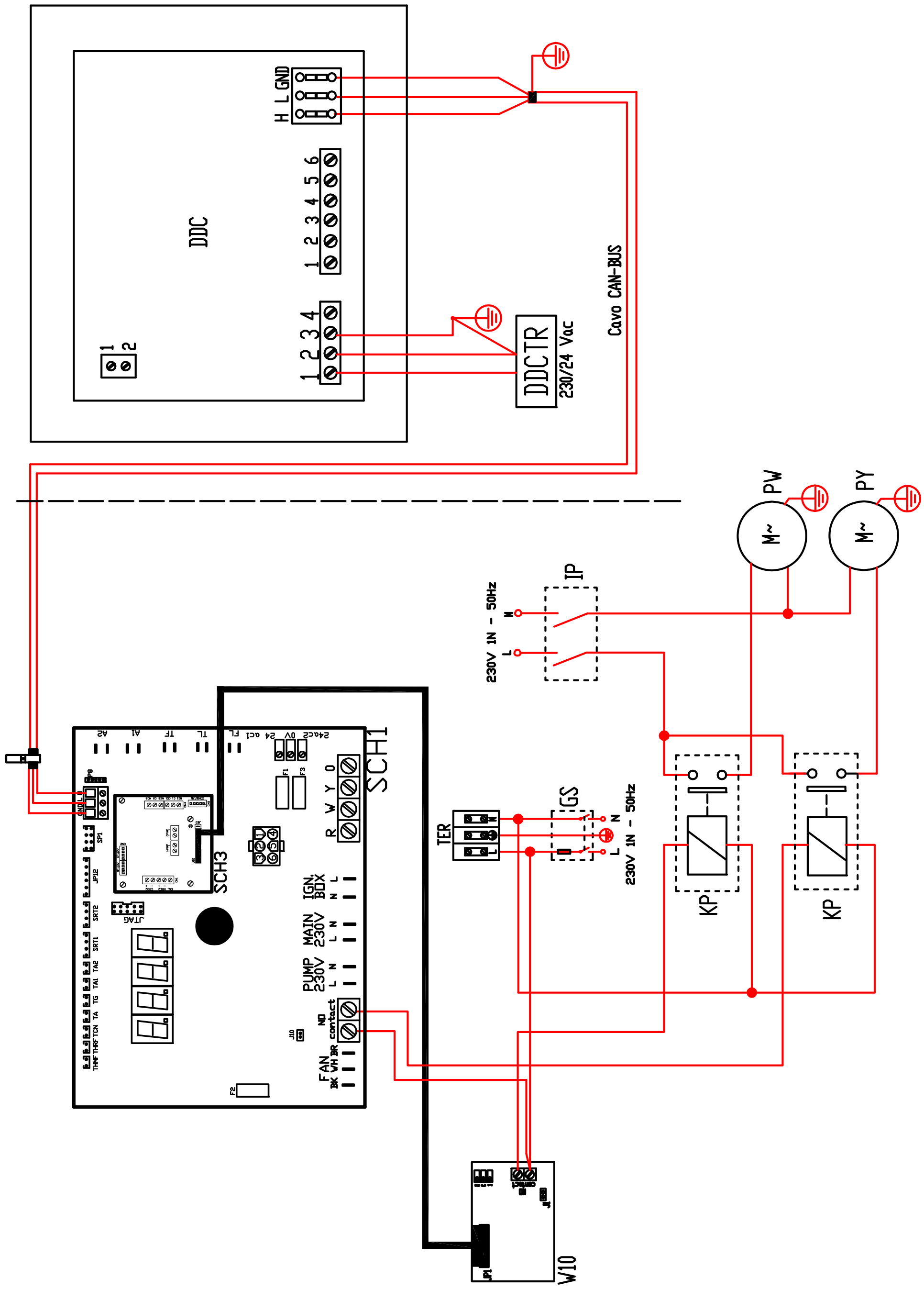


LEGEND

1	ANTI-VIBRATION COUPLING
2	PRESSURE GAUGE
3	FLOW REGULATOR VALVE
4	WATER FILTER
5	SHUT-OFF VALVE
6	HOT WATER PUMP (internal circuit)
7	COLD WATER PUMP (internal circuit)
8	SAFETY VALVE 3 bar
9	EXPANSION TANK
10	HYDRAULIC SEPARATOR
11	HOT WATER PUMP (external circuit)
12	COLD WATER PUMP (external circuit)
13	DIRECT DIGITAL CONTROLLER

Example of hydraulic connection of a single unit.

Figure 7.2 – Electrical system



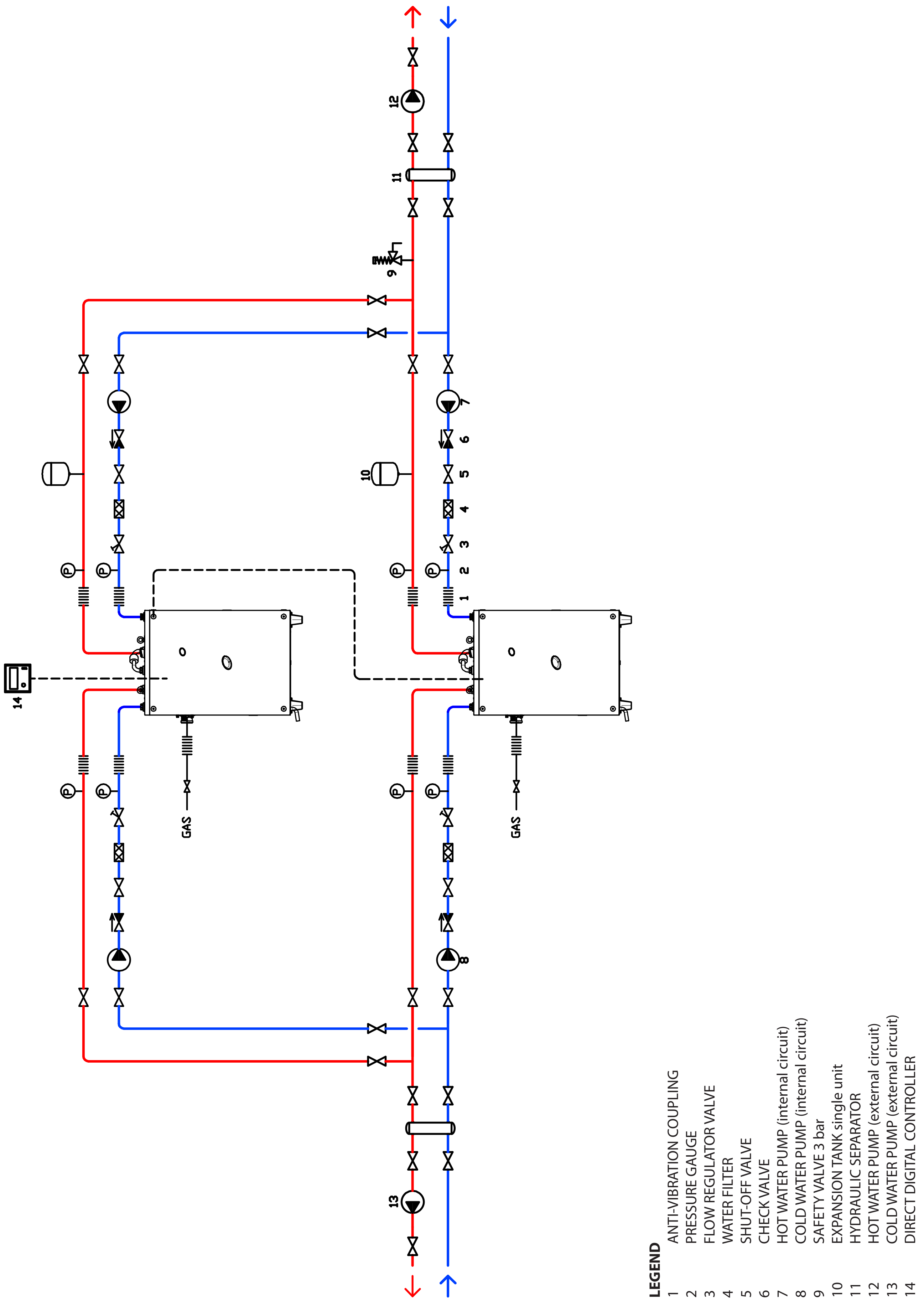
LEGEND

DDCTR secondary safety transformer SELV 230/24 V AC,50/60 Hz (not supplied)
IP two-pole pump power breaker (not supplied)
GS master bipolar breaker with fuse (not supplied)
PY cold water pump [230 V AC; <700W] (non fornita)
PW hot water pump [230 V AC; <700W] (non fornita)
KP N.O. relay for water pump control (not supplied)
TER 9-pole on-board terminal block, of unit
DDC Direct Digital Controller (not supplied)
SCH1 unit on-board logic
W10 unit auxiliary on-board logic
L line terminal (single phase)
N Neutral terminal

Example of electrical connection of a single unit.

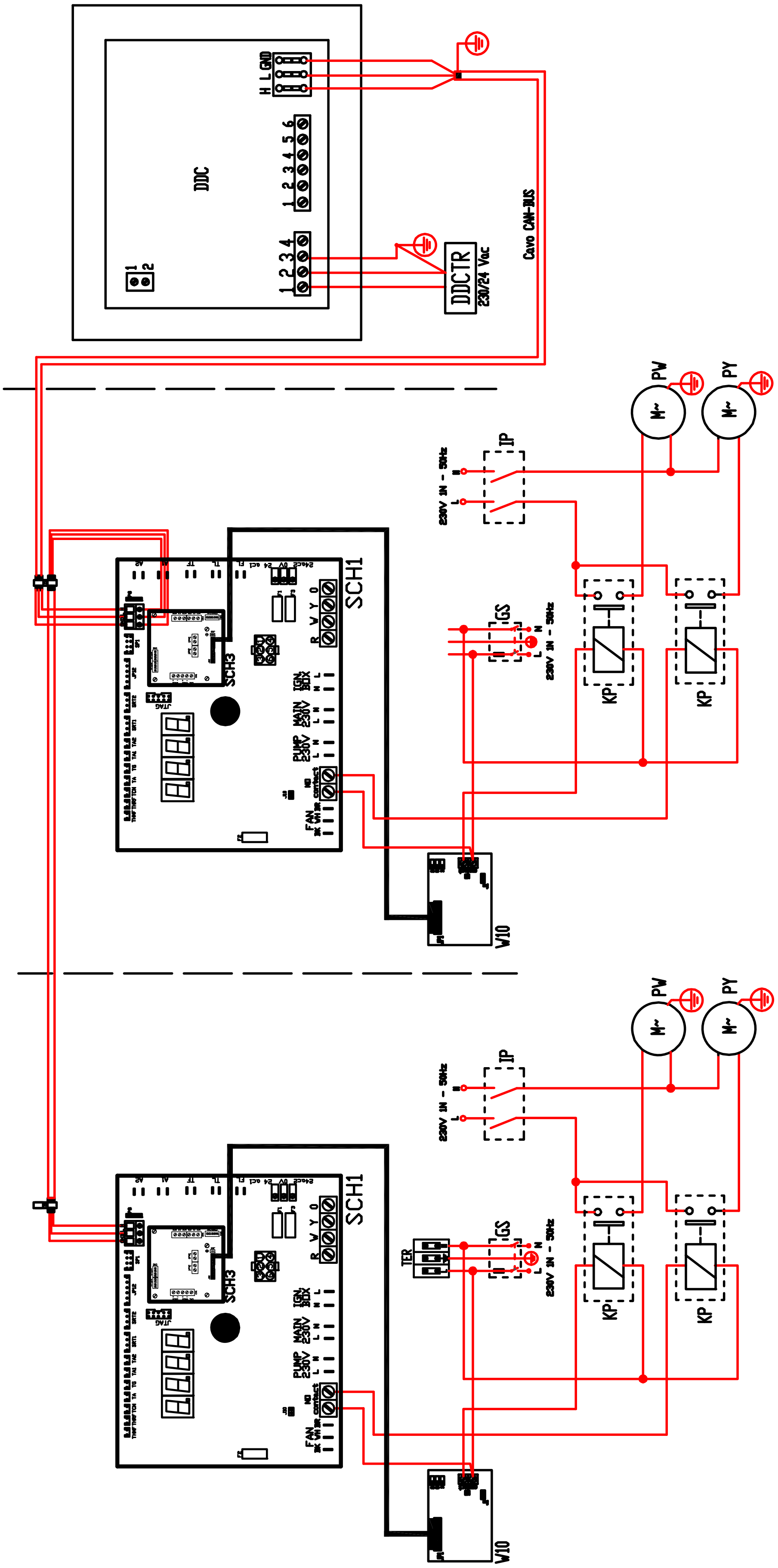
7.2 SYSTEM WITH MULTIPLE GAHP-WS UNITS - INDEPENDENT CIRCULATORS

Figure 7.3 – Hydraulic plan



Example of hydraulic connection of multiple units with independent circulators.

Figure 7.4 – Electrical system



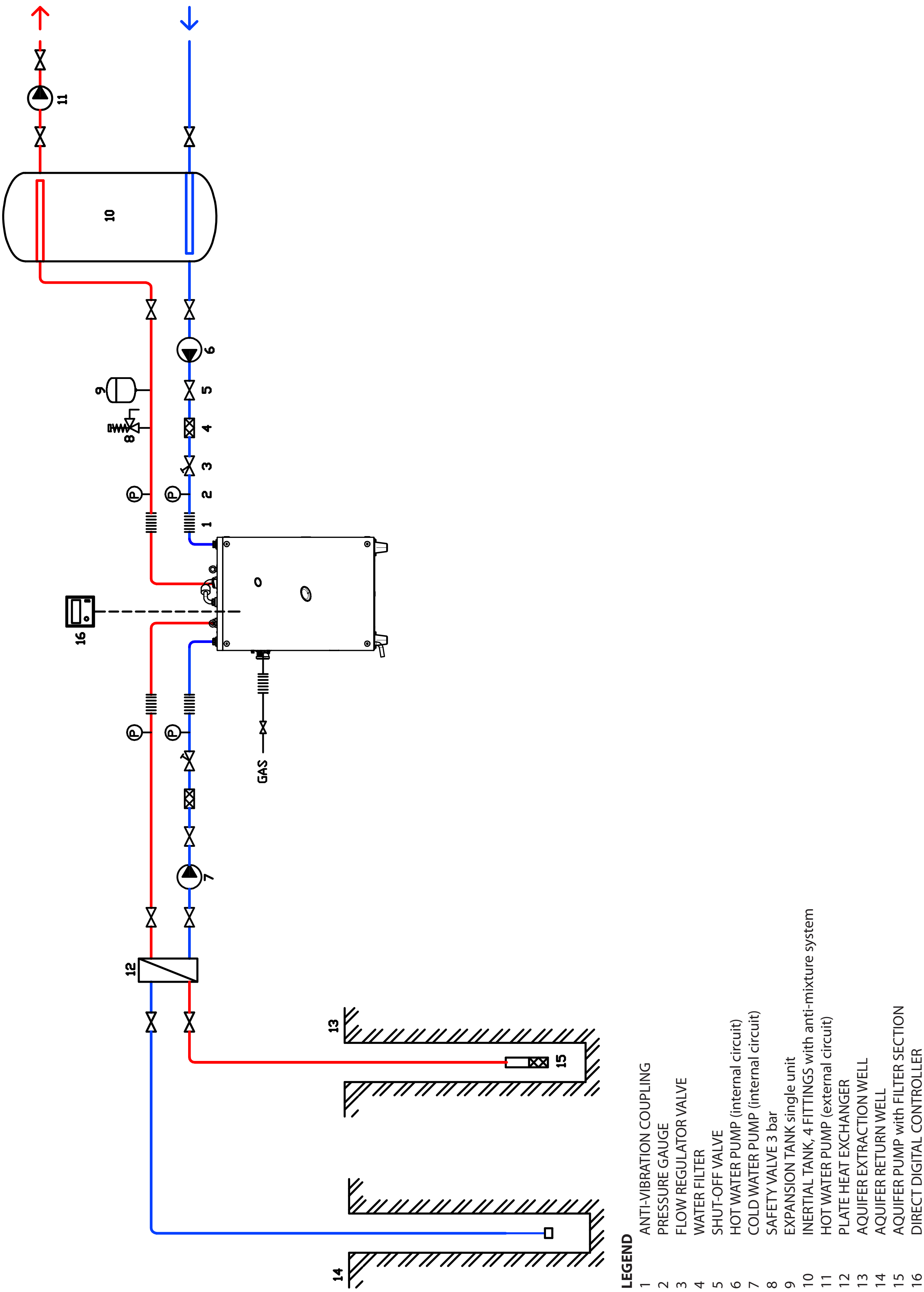
LEGEND

- DDCTR secondary safety transformer SELV 230/24 V AC,50/60 Hz (not supplied)
- IP two-pole pump power breaker (not supplied)
- GS master bipolar breaker with fuse (not supplied)
- PY cold water pump [230 V AC; <700W] (non fornita)
- PW hot water pump [230 V AC; <700W] (non fornita)
- KP N.O. relay for water pump control (not supplied)
- TER 9-pole on-board terminal block, of unit
- DDC Direct Digital Controller (not supplied)
- SCH1 unit on-board logic
- W10 unit auxiliary on-board logic
- L line terminal (single phase)
- N Neutral terminal

Example of electrical connection of multiple units with independent circulators.

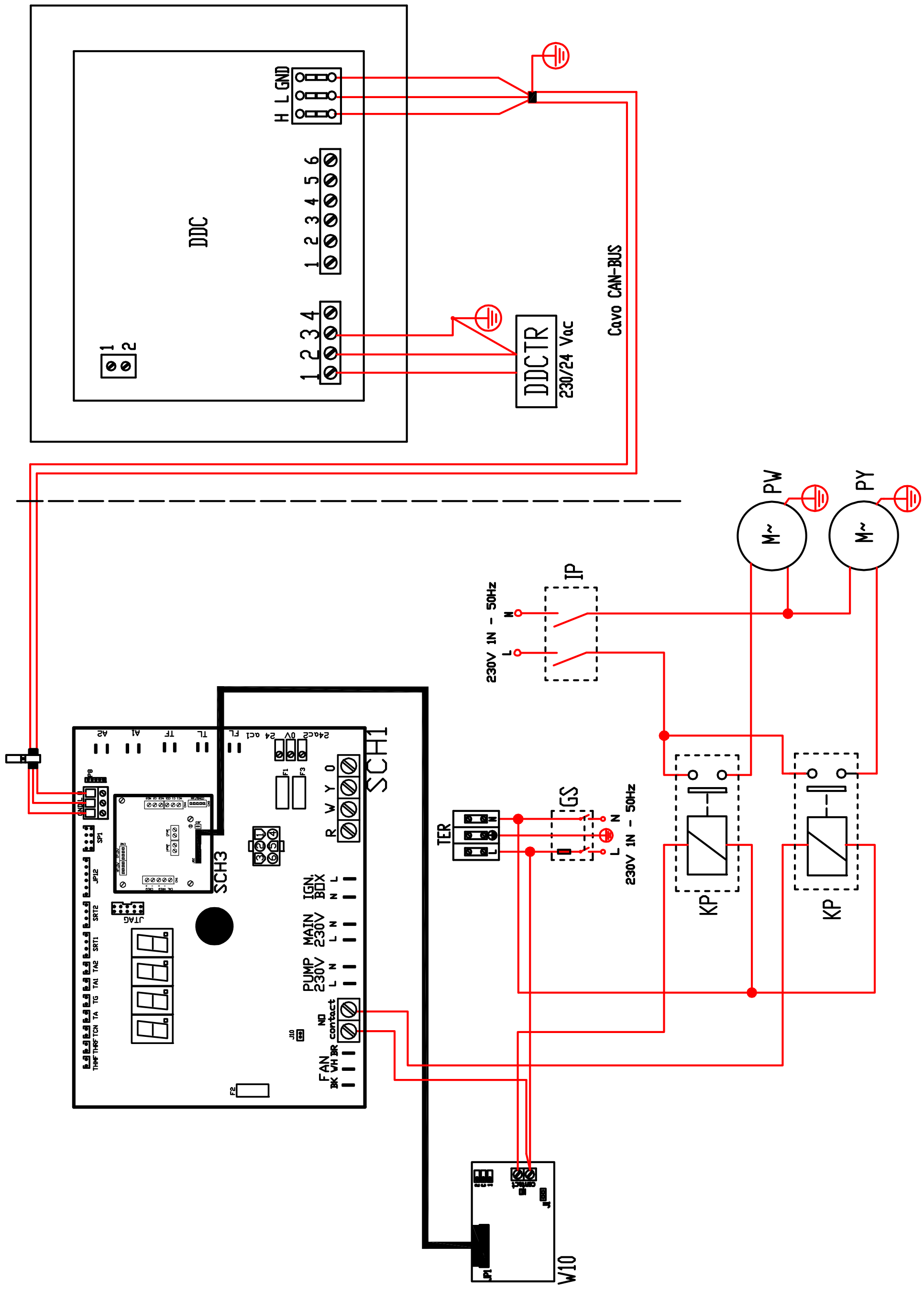
7.3 HEATING SYSTEM WITH SINGLE GAHP-WS AQUIFER RECOVERY CIRCUIT

Figure 7.5 – Hydraulic plan



Example of hydraulic connection of a single unit with aquifer recovery circuit.

Figure 7.6 – Electrical system



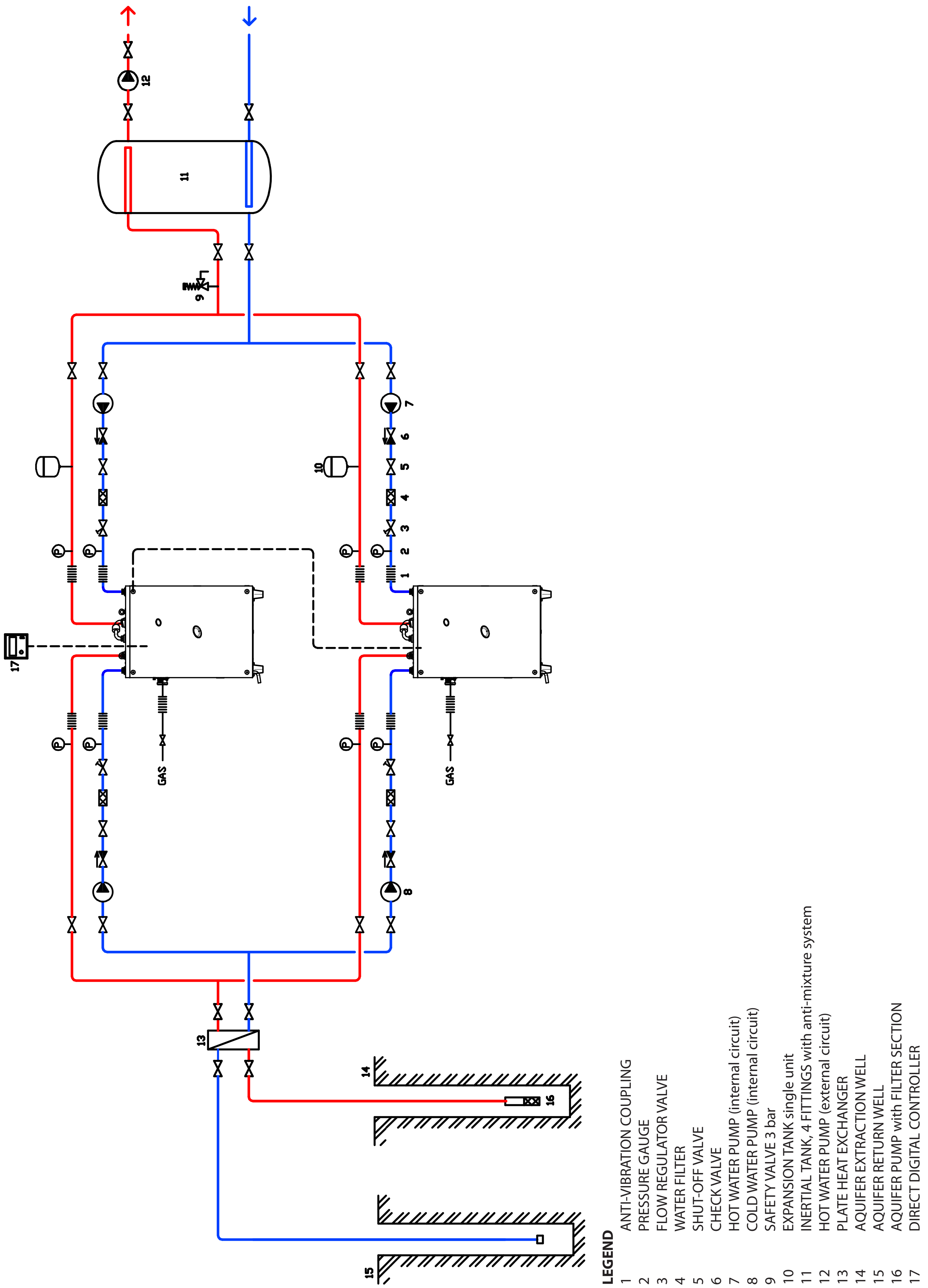
LEGEND

DDCTR	secondary safety transformer SELV 230/24 V AC,50/60 Hz (not supplied)
IP	two-pole pump power breaker (not supplied)
GS	master bipolar breaker with fuse (not supplied)
PY	cold water pump [230 V AC; <700W] (non fornita)
PW	hot water pump [230 V AC; <700W] (non fornita)
KP	N.O. relay for water pump control (not supplied)
TER	9-pole on-board terminal block, of unit
DDC	Direct Digital Controller (not supplied)
SCH1	unit on-board logic
W10	unit auxiliary on-board logic
L	line terminal (single phase)
N	Neutral terminal

Example of electrical connection of a single unit.

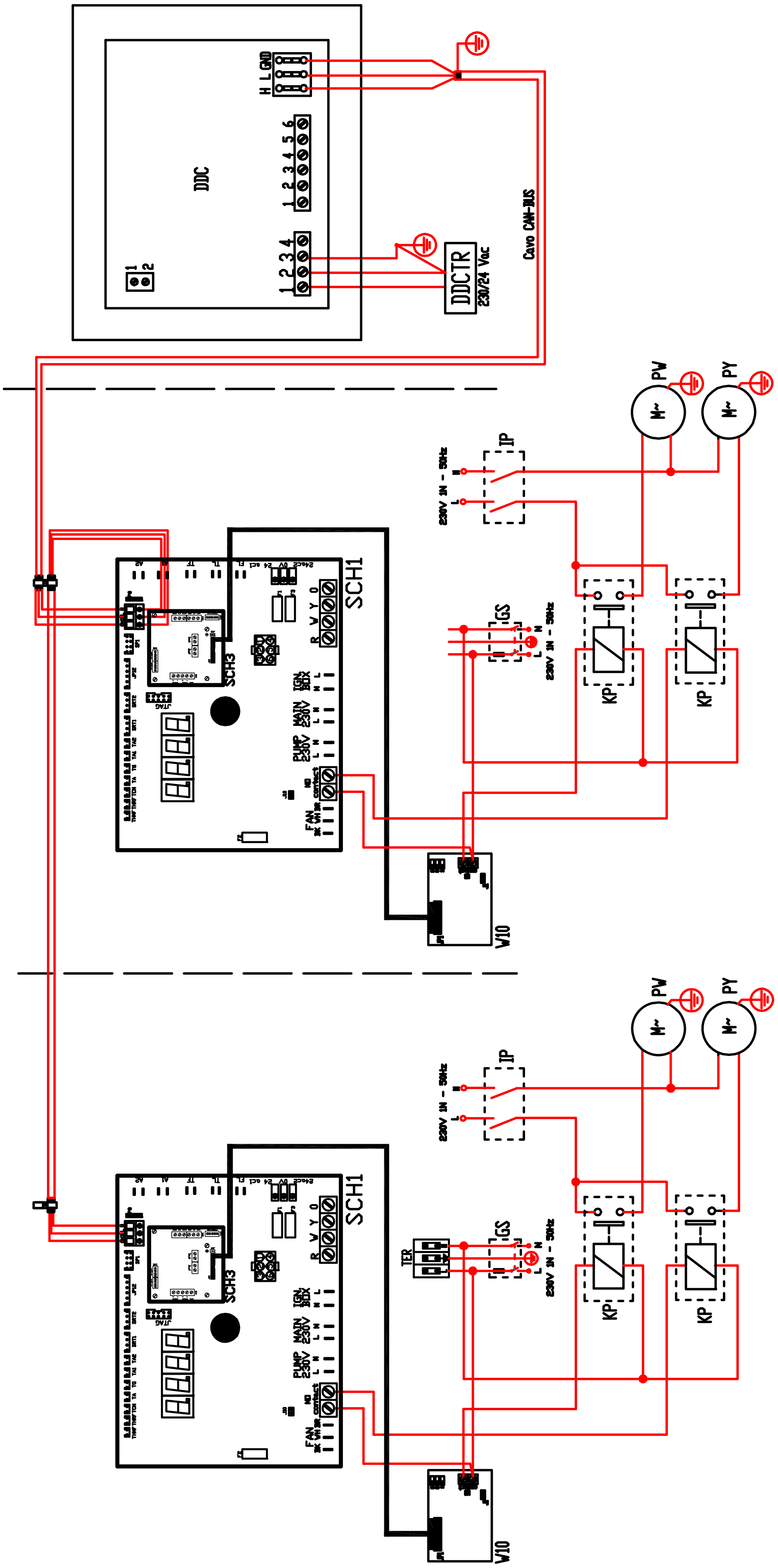
7.4 HEATING SYSTEM WITH MULTIPLE GAHP-WS UNITS WITH AQUIFER RECOVERY CIRCUIT INDEPENDENT CIRCULATORS

Figure 7.7 – Hydraulic plan



Example of hydraulic connection of multiple units with aquifer recovery circuit, with independent circulators.

Figure 7.8 – Electrical system



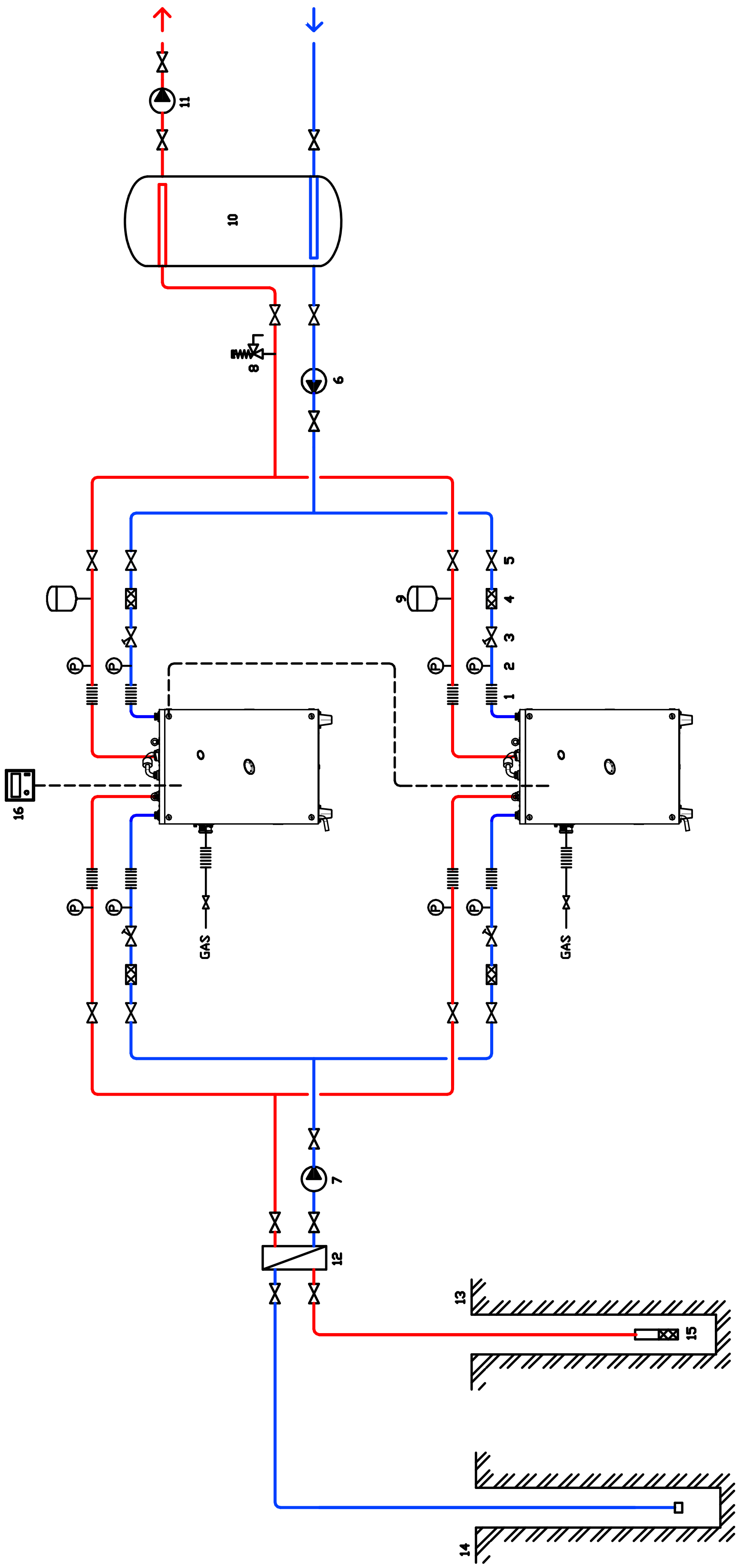
LEGEND

DDCTR	secondary safety transformer SELV 230/24 V AC,50/60 Hz (not supplied)
IP	two-pole pump power breaker (not supplied)
GS	master bipolar breaker with fuse (not supplied)
PY	cold water pump [230 V AC; <700W] (non fornita)
PW	hot water pump [230 V AC; <700W] (non fornita)
KP	N.O. relay for water pump control (not supplied)
TER	9-pole on-board terminal block, of unit
DDC	Direct Digital Controller (not supplied)
SCH1	unit on-board logic
W10	unit auxiliary on-board logic
L	line terminal (single phase)
N	Neutral terminal

Example of electrical connection of multiple units with independent circulators.

7.5 HEATING SYSTEM WITH MULTIPLE GAHP-WS UNITS WITH AQUIFER RECOVERY CIRCUIT SHARED CIRCULATOR

Figure 7.9 – Hydraulic plan

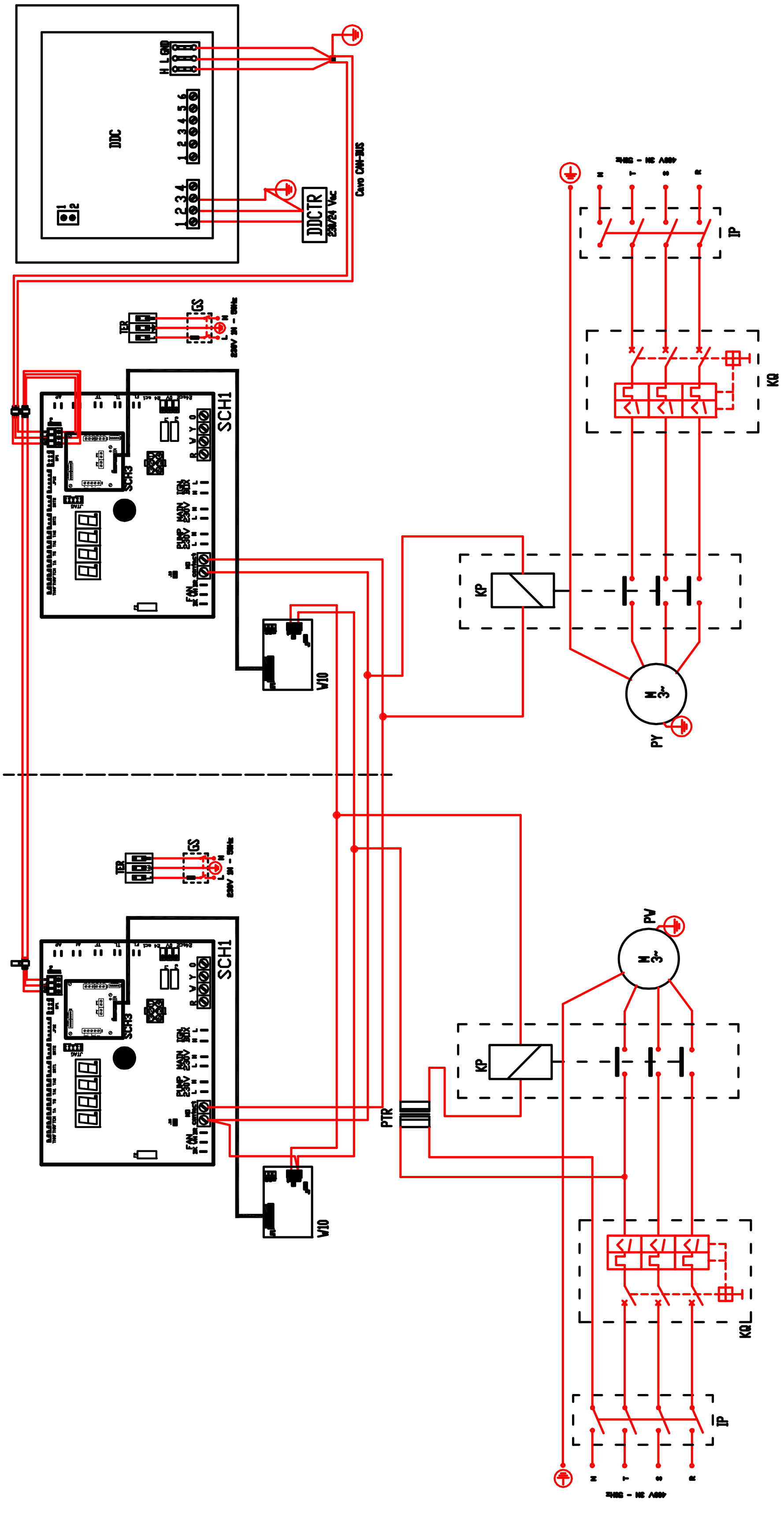


LEGEND

1 ANTI-VIBRATION COUPLING
2 PRESSURE GAUGE
3 FLOW REGULATOR VALVE
4 WATER FILTER
5 SHUT-OFF VALVE
6 HOT WATER PUMP (internal circuit)
7 COLD WATER PUMP (internal circuit)
8 SAFETY VALVE 3 bar
9 EXPANSION TANK single unit
10 INERTIAL TANK, 4 FITTINGS with anti-mixture system
11 HOT WATER PUMP (external circuit)
12 PLATE HEAT EXCHANGER
13 AQUIFER EXTRACTION WELL
14 AQUIFER RETURN WELL
15 AQUIFER PUMP with FILTER SECTION
16 DIRECT DIGITAL CONTROLLER

Example of hydraulic connection of multiple units with aquifer recovery circuit, with shared circulator.

Figure 7.10 – Electrical system



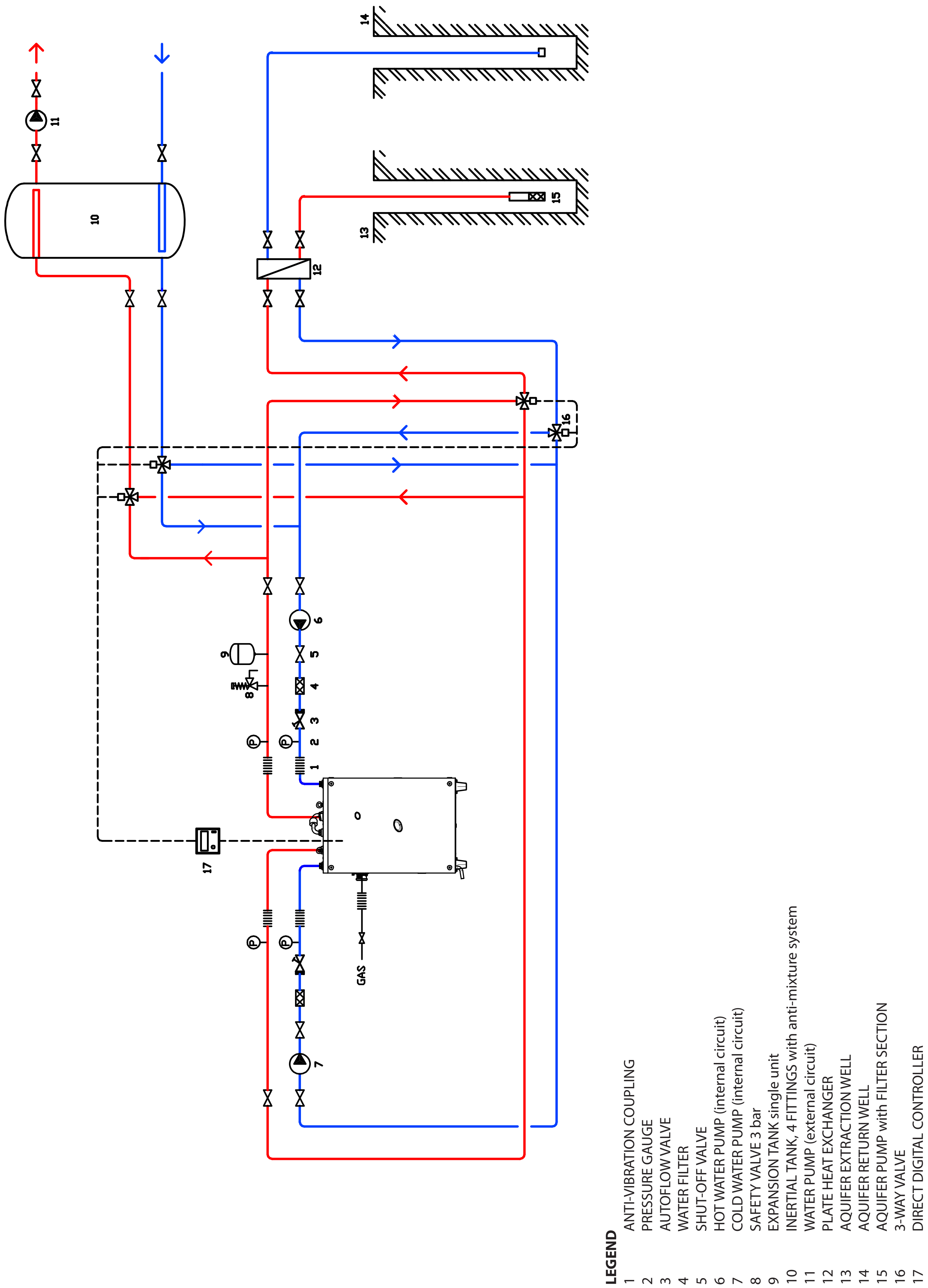
LEGEND

DDCTR	secondary safety transformer SELV 230/24 V AC, 50/60 Hz (not supplied)
IP	four-pole pump power breaker (not supplied)
GS	master bipolar breaker with fuse (not supplied)
PTR	secondary safety transformer SELV (not supplied)
PY	cold water pump [400 V AC] (not supplied)
PW	hot water pump [400 V AC] (not supplied)
KP	N.O. relay for water pump control (not supplied)
TER	9-pole on-board terminal block, of unit
KQ	thermal cutout for 400 V AC pump (not supplied)
DDC	Direct Digital Controller (not supplied)
SCH1	unit on-board logic
W10	unit auxiliary on-board logic
R,S,T	line terminals (three phase)
L	line terminal (single phase)
N	Neutral terminal

Example of electrical connection of multiple units with shared circulator.

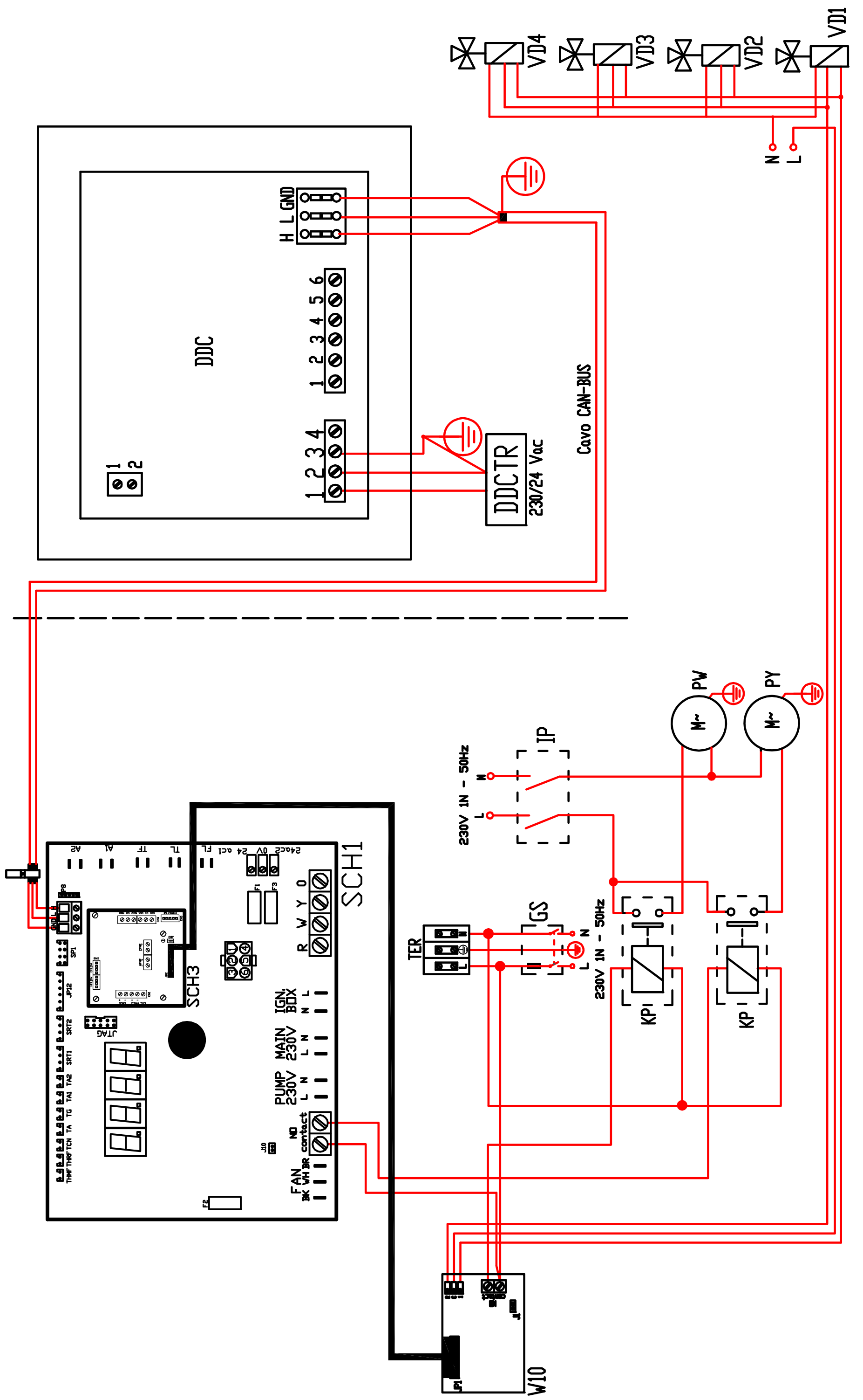
7.6 CONDITIONING SYSTEM WITH SINGLE GAHP-WS AQUIFER RECOVERY CIRCUIT

Figure 7.11 – Hydraulic plan



Example of hydraulic connection of a single unit with aquifer recovery circuit.

Figure 7.12 – Electrical system



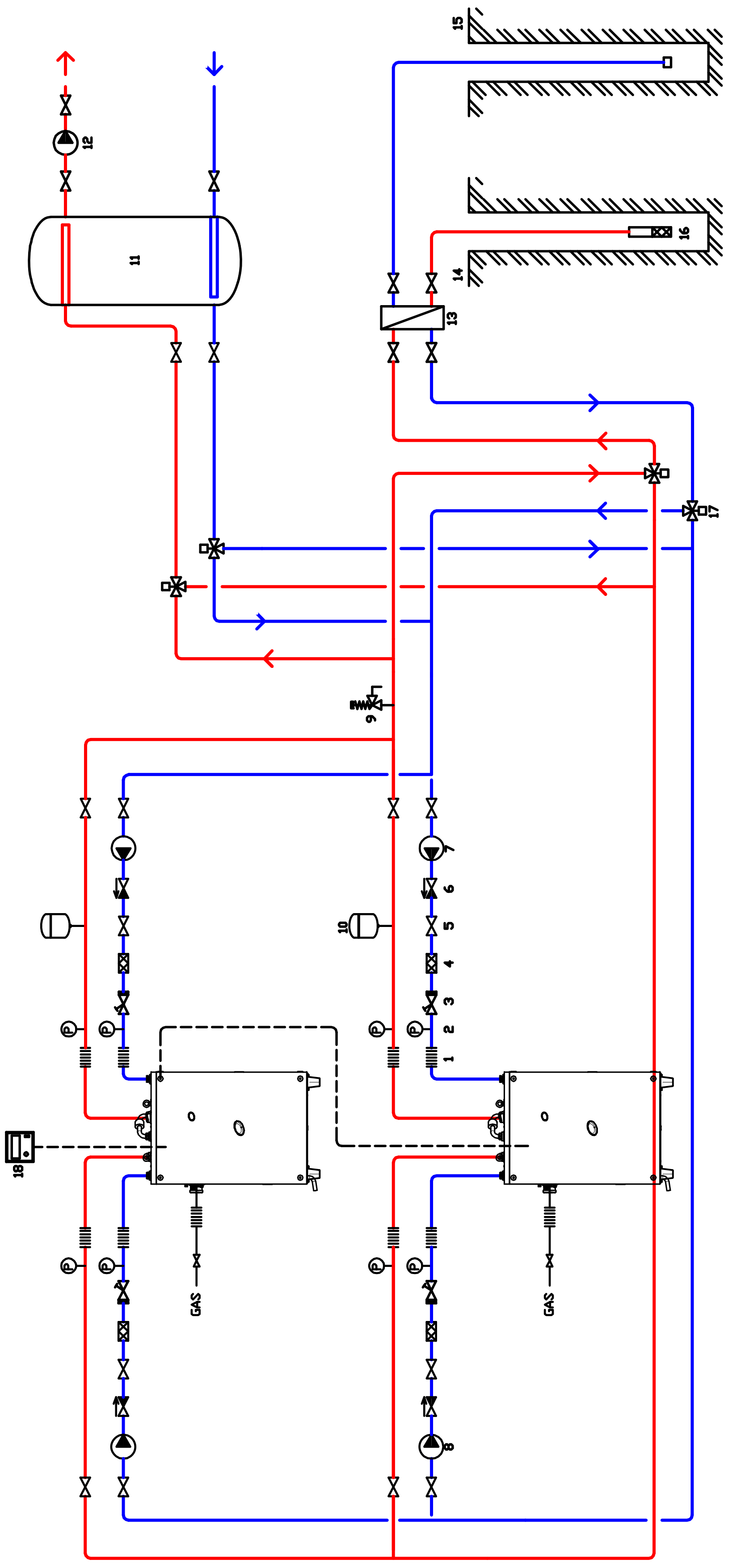
LEGEND

DDCTR secondary safety transformer SELV 230/24 V AC, 50/60 Hz (not supplied)
IP two-pole pump power breaker (not supplied)
GS master bipolar breaker with fuse (not supplied)
PY cold water pump [230 V AC; <700W] (not supplied)
PW hot water pump [230 V AC; <700W] (not supplied)
KP N.O. relay for water pump control (not supplied)
TER 9-pole on-board terminal block, of unit
DDC Direct Digital Controller (not supplied)
SCH1 unit on-board logic
W10 unit auxiliary on-board logic
L line terminal (single phase)
N Neutral terminal
VD1,2 3-way valve (not supplied)
VD3,4 3-way valve (not supplied)

Example of electrical connection of a single unit.

7.7 CONDITIONING SYSTEM WITH MULTIPLE GAHP-WS UNITS WITH AQUIFER RECOVERY CIRCUIT INDEPENDENT CIRCULATORS

Figure 7.13 – Hydraulic plan

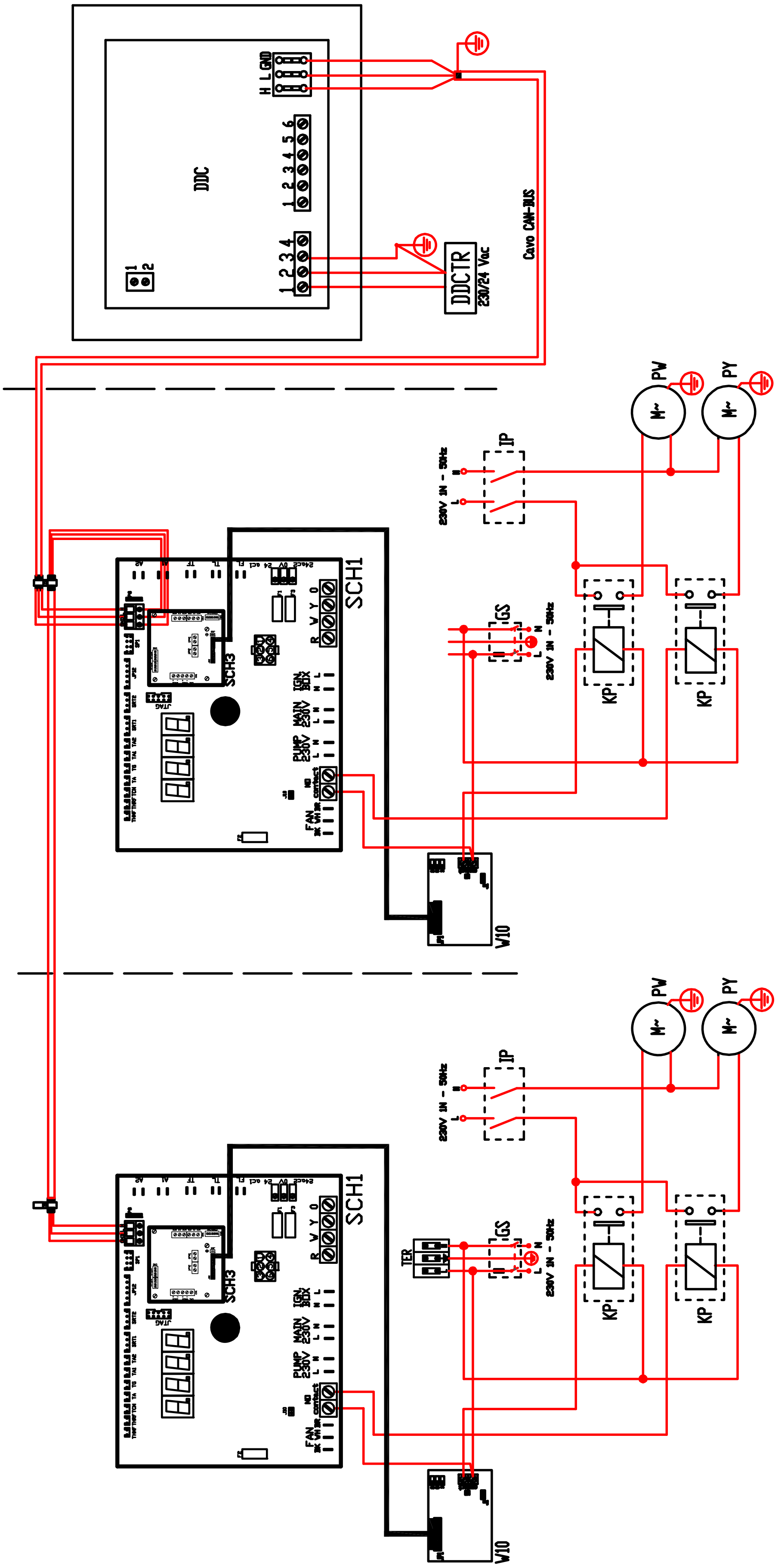


LEGEND

1 ANTI-VIBRATION COUPLING
2 PRESSURE GAUGE
3 FLOW REGULATOR VALVE
4 WATER FILTER
5 SHUT-OFF VALVE
6 CHECK VALVE
7 HOT WATER PUMP (internal circuit)
8 COLD WATER PUMP (internal circuit)
9 SAFETY VALVE 3 bar
10 EXPANSION TANK single unit
11 INERTIAL TANK, 4 FITTINGS with anti-mixture system
12 WATER PUMP (external circuit)
13 PLATE HEAT EXCHANGER
14 AQUIFER EXTRACTION WELL
15 AQUIFER RETURN WELL
16 AQUIFER PUMP with FILTER SECTION
17 3-WAY VALVE
18 DIRECT DIGITAL CONTROLLER

Example of hydraulic connection of multiple units with aquifer recovery circuit, with independent circulators.

Figure 7.14 – Electrical system

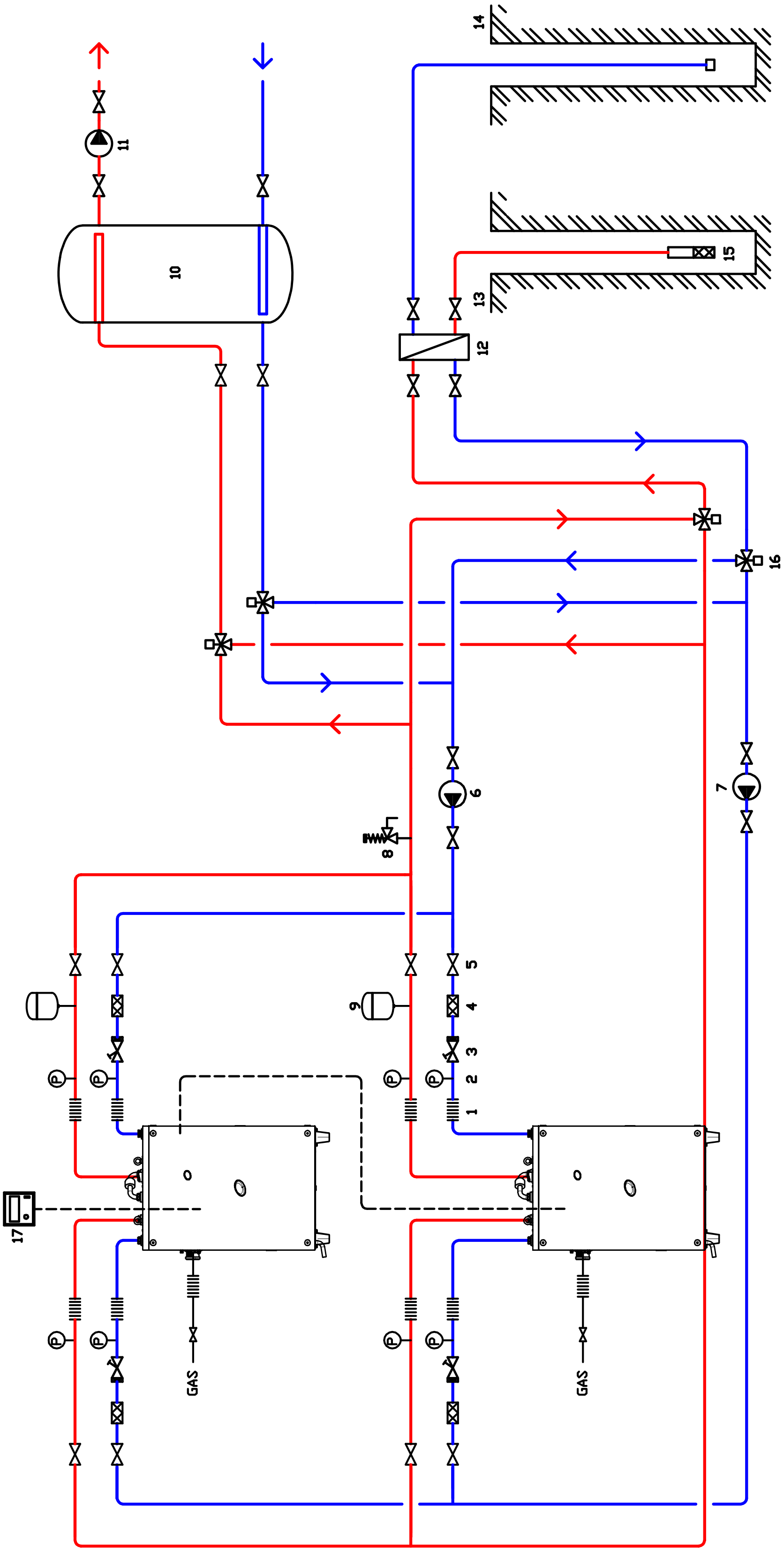


LEGEND
DDCTR secondary safety transformer SELV 230/24 V AC,50/60 Hz (not supplied)
IP two-pole pump power breaker (not supplied)
GS master bipolar breaker with fuse (not supplied)
PY cold water pump [230 V AC; <700W] (non fornita)
PW hot water pump [230 V AC; <700W] (non fornita)
KP N.O. relay for water pump control (not supplied)
TER 9-pole on-board terminal block, of unit
DDC Direct Digital Controller (not supplied)
SCH1 unit on-board logic
W10 unit auxiliary on-board logic
L line terminal (single phase)
N Neutral terminal

Example of electrical connection of multiple units with independent circulators.

7.8 CONDITIONING SYSTEM WITH MULTIPLE GAHP-WS UNITS WITH AQUIFER RECOVERY CIRCUIT INDEPENDENT CIRCULATORS

Figure 7.15 – Hydraulic plan

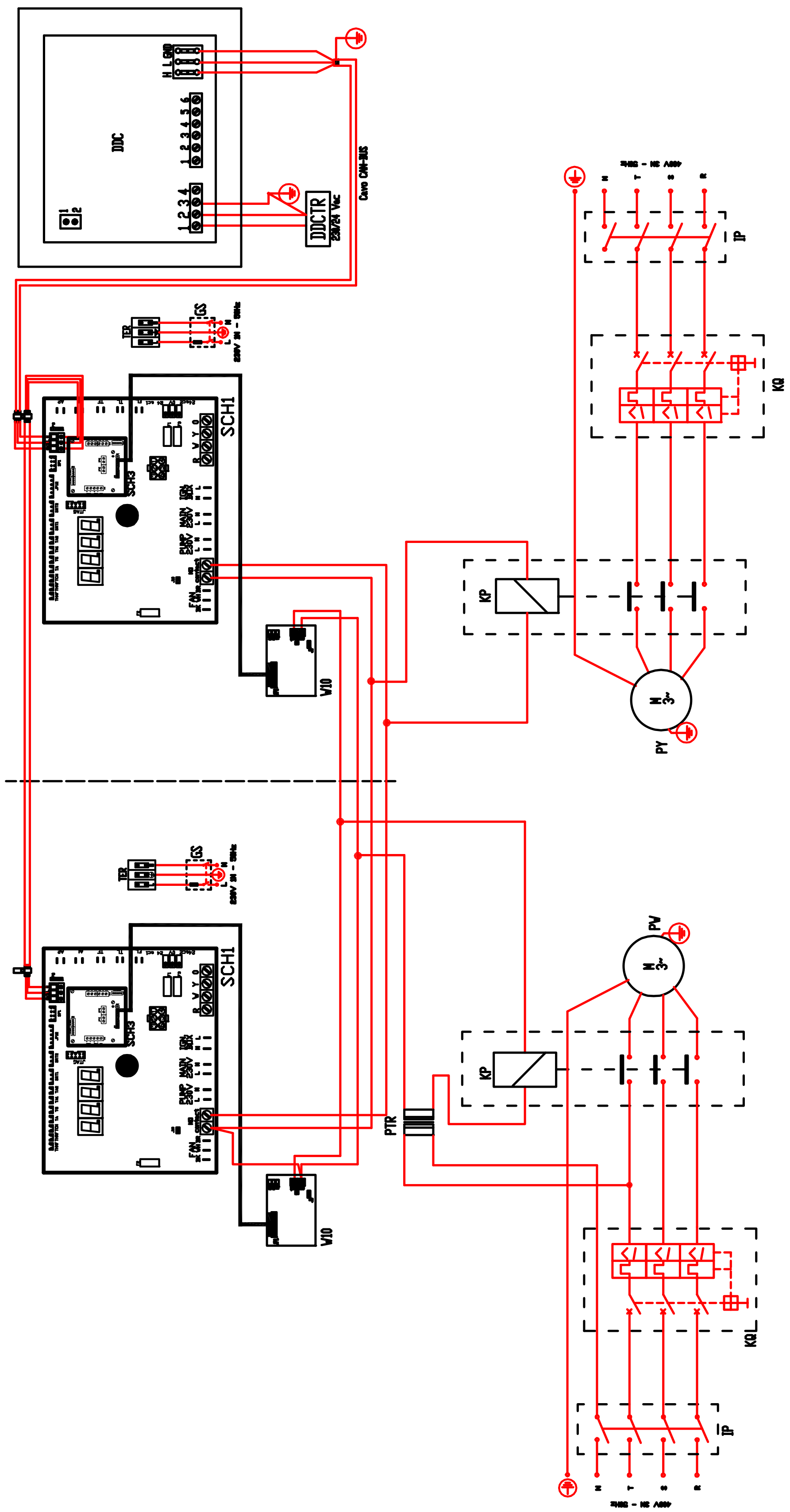


LEGEND

1 ANTI-VIBRATION COUPLING
2 PRESSURE GAUGE
3 AUTOFLOW VALVE
4 WATER FILTER
5 SHUT-OFF VALVE
6 HOT WATER PUMP (internal circuit)
7 COLD WATER PUMP (internal circuit)
8 SAFETY VALVE 3 bar
9 EXPANSION TANK single unit
10 INERTIAL TANK, 4 FITTINGS with anti-mixture system
11 WATER PUMP (external circuit)
12 PLATE HEAT EXCHANGER
13 AQUIFER EXTRACTION WELL
14 AQUIFER RETURN WELL
15 AQUIFER PUMP with FILTER SECTION
16 3-WAY VALVE
17 DIRECT DIGITAL CONTROLLER

Example of hydraulic connection of multiple units with aquifer recovery circuit, with shared circulator.

Figure 7.16 – Electrical system



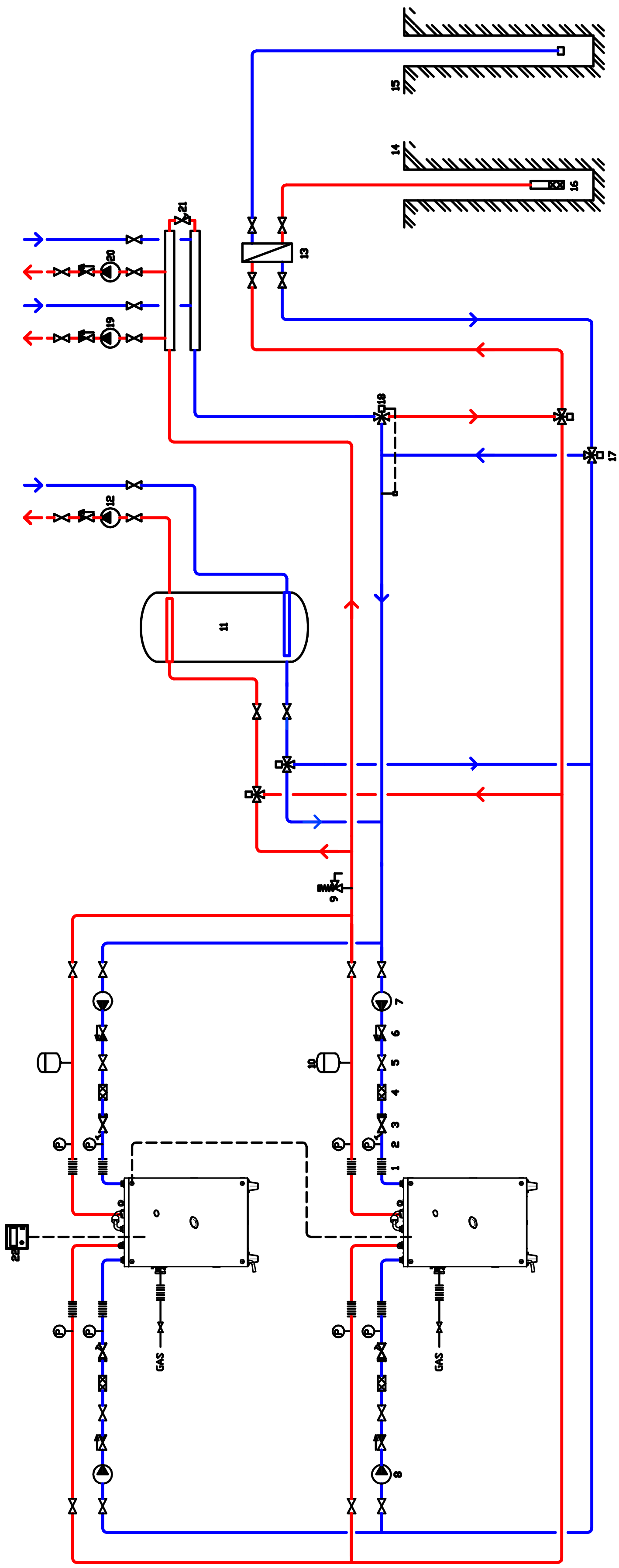
LEGEND

DDCTR	secondary safety transformer SELV 230/24 V AC, 50/60 Hz (not supplied)
IP	four-pole pump power breaker (not supplied)
GS	master bipolar breaker with fuse (not supplied)
PTR	secondary safety transformer SELV (not supplied)
PY	cold water pump [400 V AC] (not supplied)
PW	hot water pump [400 V AC] (not supplied)
KP	N.O. relay for water pump control (not supplied)
TER	9-pole on-board terminal block, of unit
KQ	thermal cutout for 400 V AC pump (not supplied)
DDC	Direct Digital Controller (not supplied)
SCH1	unit on-board logic
W10	unit auxiliary on-board logic
R,S,T	line terminals (three phase)
L	line terminal (single phase)
N	Neutral terminal

Example of electrical connection of multiple units with shared circulator.

7.9 CONDITIONING/AUXILIARY HEATING SYSTEM WITH MULTIPLE GAHP-WS UNITS WITH AQUIFER RECOVERY CIRCUIT - INDEPENDENT CIRCULATORS

Figure 7.17 – Hydraulic plan

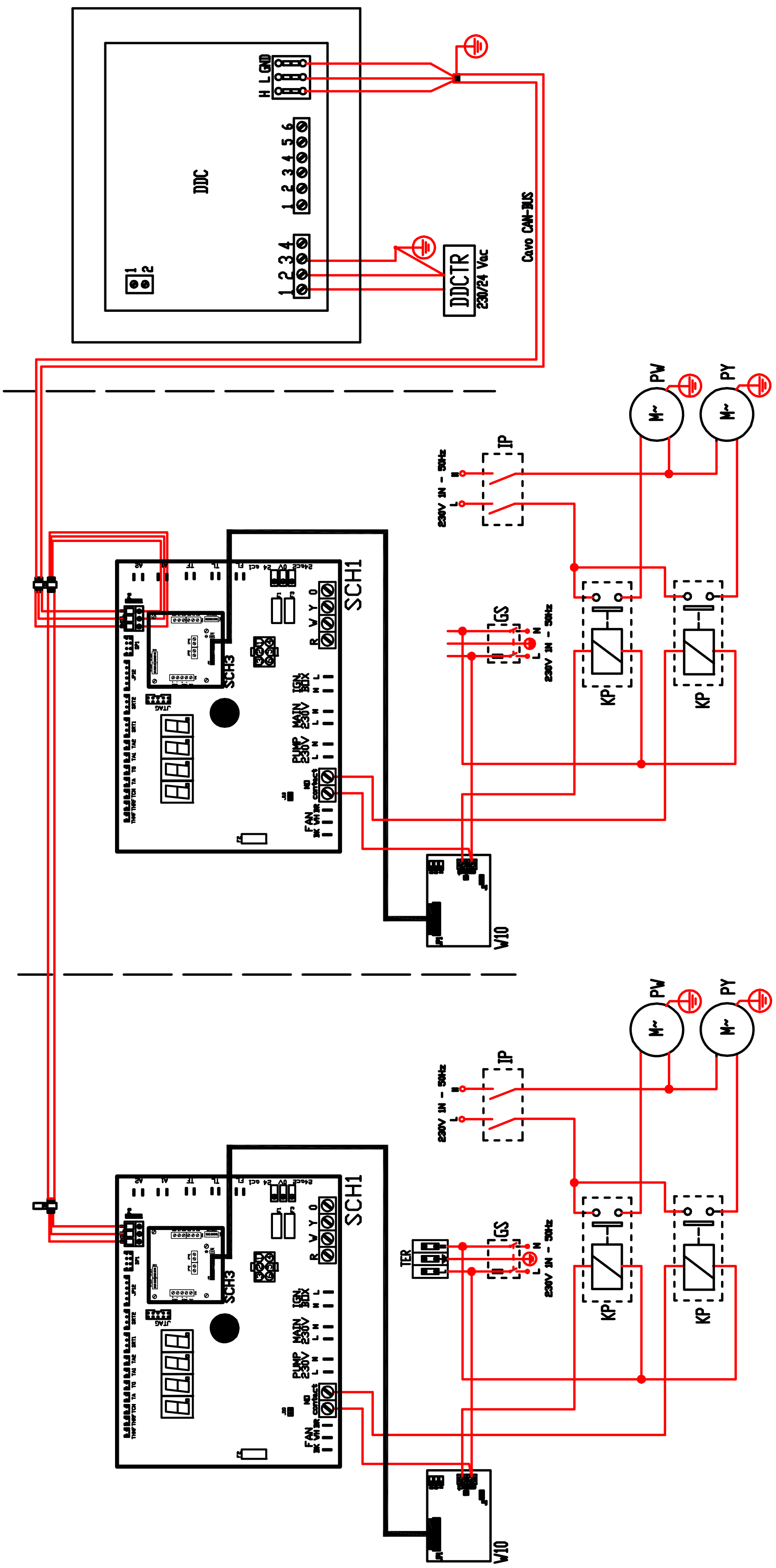


LEGEND

1 ANTI-VIBRATION COUPLING
2 PRESSURE GAUGE
3 AUTOFLOW VALVE
4 WATER FILTER
5 SHUT-OFF VALVE
6 CHECK VALVE
7 HOT WATER PUMP (internal circuit)
8 COLD WATER PUMP (internal circuit)
9 SAFETY VALVE 3 bar
10 EXPANSION TANK single unit
11 INERTIAL TANK, 4 FITTINGS with anti-mixture system
12 WATER PUMP (external circuit)
13 PLATE HEAT EXCHANGER
14 AQUIFER EXTRACTION WELL
15 AQUIFER RETURN WELL
16 AQUIFER PUMP with FILTER SECTION
17 3-WAY VALVE
18 MIXER VALVE with temperature sensor
19 AUXILIARY SERVICE PUMP N.1 (e.g.: DHW)
20 AUXILIARY SERVICE PUMP N.2 (e.g.: heating swimming pool or post-heating air handler)
21 BYPASS WITH BALANCING VALVE
22 DIRECT DIGITAL CONTROLLER

Example of hydraulic connection of multiple units with auxiliary heating and aquifer recovery circuit, with independent circulators.

Figure 7.18 – Electrical system



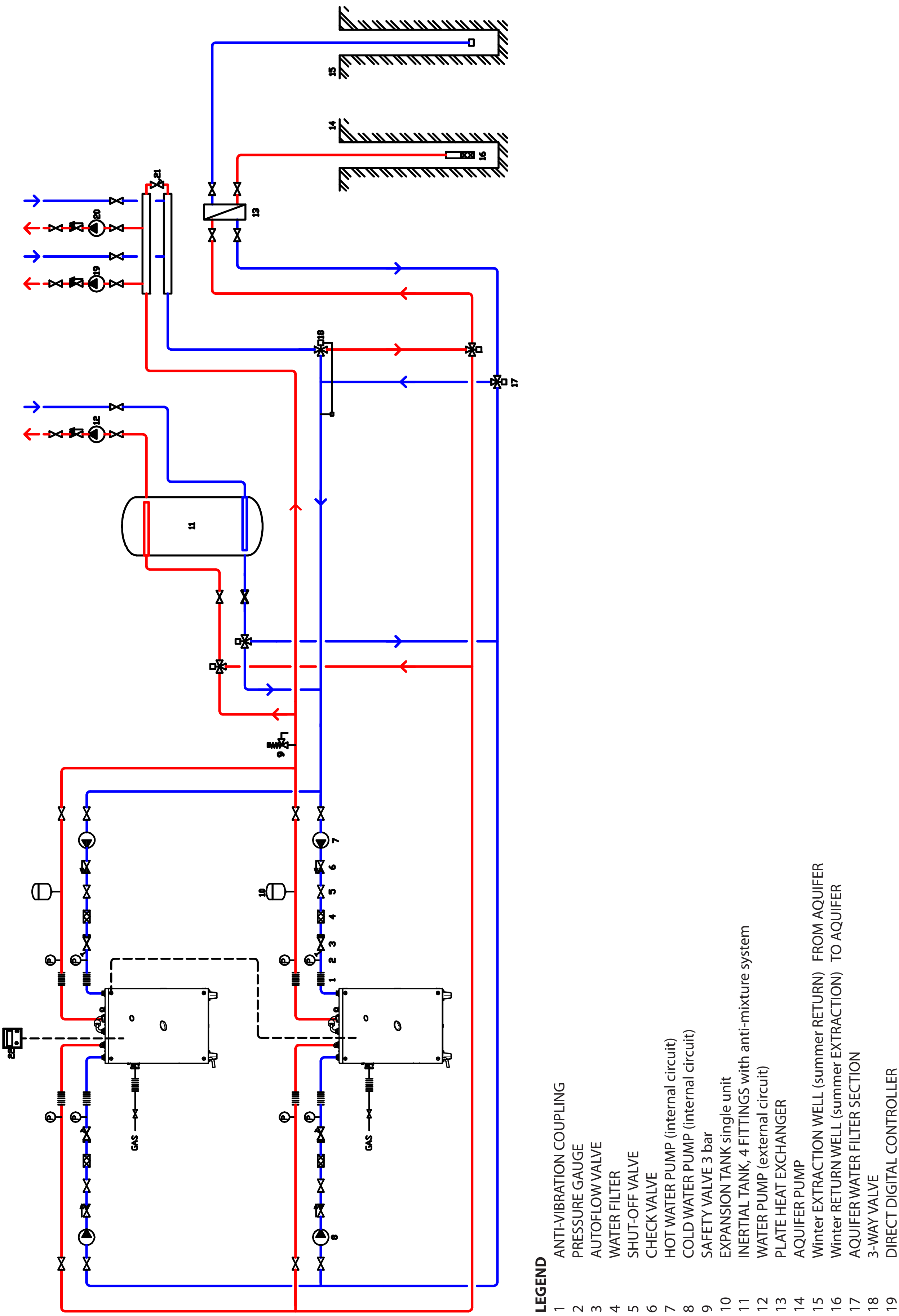
LEGEND

DDCTR	secondary safety transformer SELV 230/24 V AC,50/60 Hz (not supplied)
IP	two-pole pump power breaker (not supplied)
GS	master bipolar breaker with fuse (not supplied)
PY	cold water pump [230 V AC; <700W] (non fornita)
PW	hot water pump [230 V AC; <700W] (non fornita)
KP	N.O. relay for water pump control (not supplied)
TER	9-pole on-board terminal block, of unit
DDC	Direct Digital Controller (not supplied)
SCH1	unit on-board logic
W10	unit auxiliary on-board logic
L	line terminal (single phase)
N	Neutral terminal

Example of electrical connection of multiple units with independent circulators.

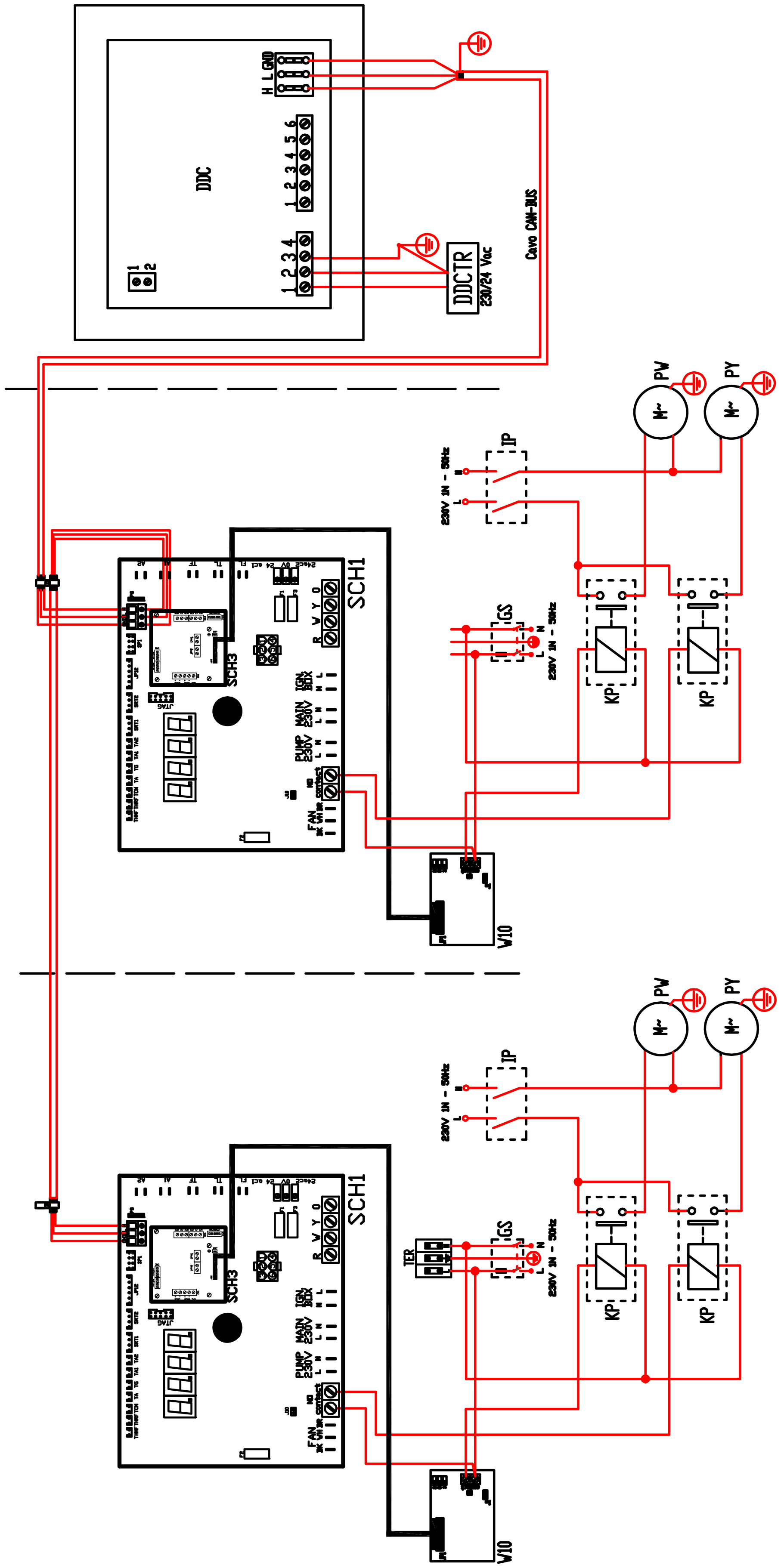
7.10 CONDITIONING SYSTEM WITH MULTIPLE GAHP-WS UNITS WITH INTERSEASONAL AQUIFER ACCUMULATION - INDEPENDENT CIRCULATORS

Figure 7.19 – Hydraulic plan



Example of hydraulic connection of multiple units with interseasonal aquifer accumulation, with independent circulators.

Figure 7.20 – Electrical system



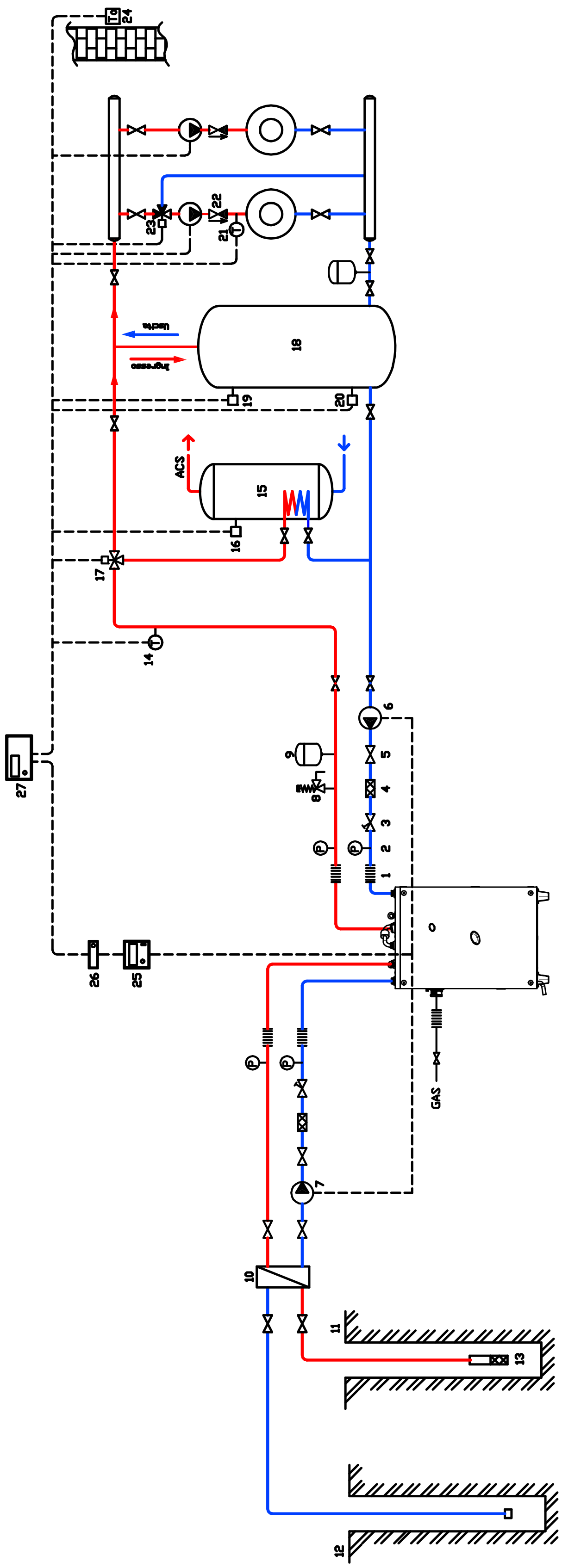
LEGEND

DDCTR	secondary safety transformer SELV 230/24 V AC,50/60 Hz (not supplied)
IP	two-pole pump power breaker (not supplied)
GS	master bipolar breaker with fuse (not supplied)
PY	cold water pump [230 V AC; <700W] (non fornita)
PW	hot water pump [230 V AC; <700W] (non fornita)
KP	N.O. relay for water pump control (not supplied)
TER	9-pole on-board terminal block, of unit
DDC	Direct Digital Controller (not supplied)
SCH1	unit on-board logic
W10	unit auxiliary on-board logic
L	line terminal (single phase)
N	Neutral terminal

Example of electrical connection of multiple units with independent circulators.

7.11 HEATING AND DHW PRODUCTION SYSTEM WITH SINGLE GAHP-WS UNIT WITH AQUIFER RECOVERY CIRCUIT AND WITH ELECTRONIC SYSTEM CONTROL

Figure 7.21 – Hydraulic plan

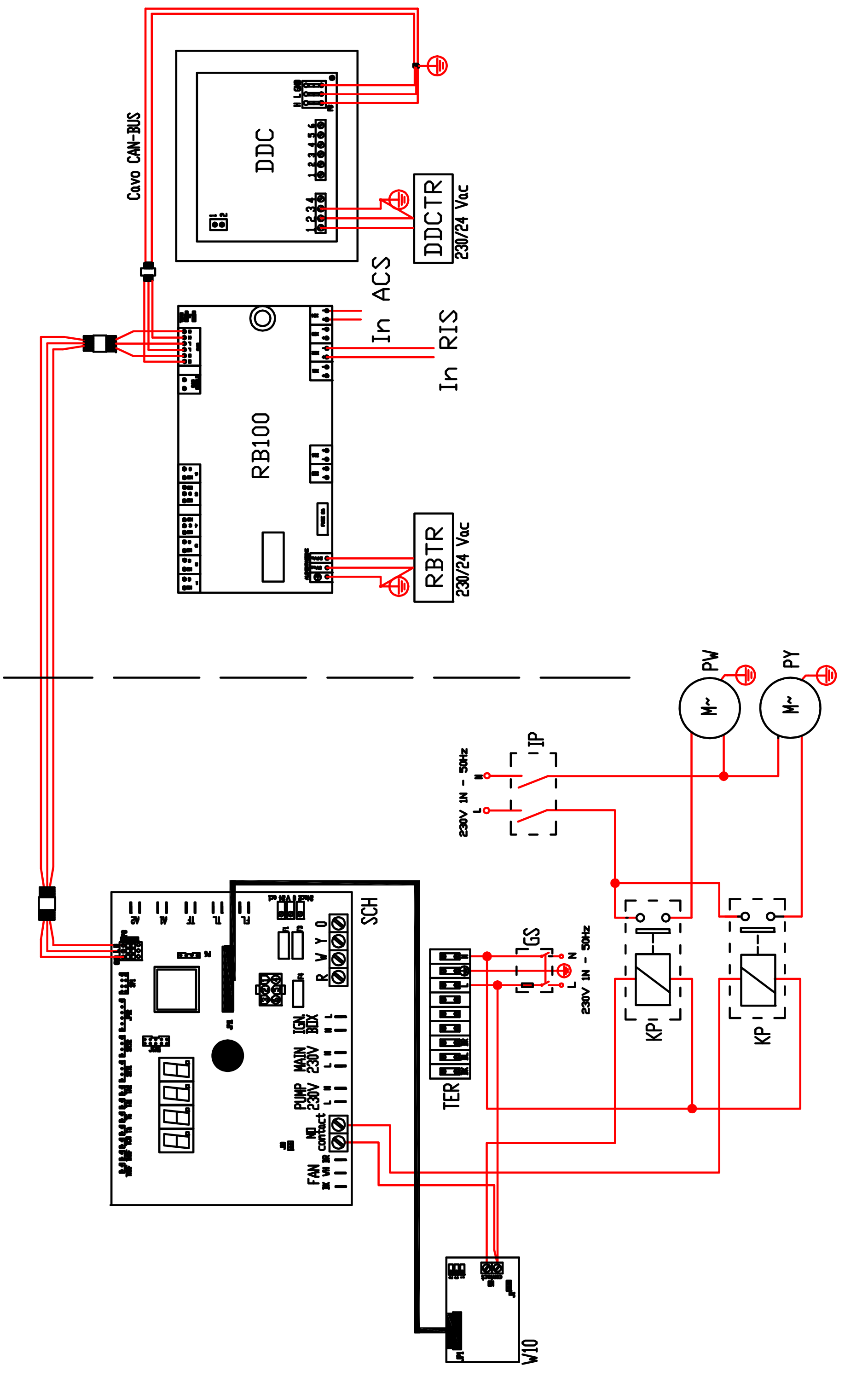


LEGEND

1 ANTI-VIBRATION COUPLING
2 PRESSURE GAUGE
3 FLOW REGULATOR VALVE
4 WATER FILTER
5 SHUT-OFF VALVE
6 HOT WATER PUMP (internal circuit)
7 COLD WATER PUMP (internal circuit)
8 SAFETY VALVE 3 bar
9 EXPANSION TANK single unit
10 PLATE HEAT EXCHANGER
11 AQUIFER EXTRACTION WELL
12 AQUIFER RETURN WELL
13 AQUIFER PUMP with FILTER SECTION
14 TEMPERATURE SENSOR internal circuit delivery
15 DOMESTIC HOT WATER ACCUMULATION TANK, with thermostat
16 TEMPERATURE PROBE on DHW accumulation tank
17 3-WAY VALVE
18 INERTIAL TANK, 3 FITTINGS
19,20 TEMPERATURE PROBE on inertial tank
21 TEMPERATURE PROBE on system deliveries
22 CHECK VALVE
23 3-WAY MIXER VALVE for system deliveries
24 EXTERNAL AIR TEMPERATURE PROBE
25 DIRECT DIGITAL CONTROLLER
26 RB100 CONTROLLER
27 PLANT CONTROLLER SYSTEM

Example of hydraulic connection of single unit with DHW production and aquifer recovery circuit, with electronic system control.

Figure 7.22 – Electrical system



LEGEND

- DDCTR secondary safety transformer SELV 230/24 V AC, 50/60 Hz (not supplied)
- RBTR secondary safety transformer SELV 230/24 V AC, 50/60 Hz (not supplied)
- IP two-pole pump power breaker (not supplied)
- GS master bipolar breaker with fuse (not supplied)
- PY cold water pump [230 V AC; <700W] (non fornita)
- PW hot water pump [230 V AC; <700W] (not supplied)
- KP N.O. relay for water pump control (not supplied)
- TER 9-pole on-board terminal block, of unit
- DDC Direct Digital Controller (not supplied)
- SCH1 unit on-board logic
- W10 unit auxiliary on-board logic
- RB100 Robur Box system interface (optional)
- L line terminal (single phase)
- N Neutral terminal

Example of electrical connection of single unit with DHW production and electronic system control.

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