WPI-UT 0141	RAILWAY PACKAGE HVAC SYSTEM – WRM236 OPERATION AND MAINTENANCE MANUAL

Latest revision

Rev.	Date	Revised by	Approved by
01	04.05.2008	S. Anello	A. Fontana

Changes

Rev.	Date	Description
00	01.04.2008	First issue
01	04.05.2008	General updated

CONTENTS

1 INTRODUCTION

This manual has the purpose to describe the structure of the railway package HVAC system WRM236 installed on the passenger compartments of the DMU trains ATR220 and contains all the technical information for the operation and maintenance staff.

1.1 ACRONYMS

HP	High Pressure
HVAC	Heating, Ventilation and Air Conditioning
LP	Low Pressure
T_{AMB}	Internal temperature
T_{DIFF}	Temperature difference
T_{DIFF-}	Temperature difference in order to activate the heating mode
T_{DIFF+}	Temperature difference in order to activate the cooling mode
T_{EST}	External temperature
T_{RIF}	Reference temperature

1.2 SUPPLY

The supply includes the complete package unit, ready for the installation.
The accessory materials supplied are:

- four electrical connectors,
- two internal temperature sensors.

2 GENERAL INFORMATION

2.1 DESCRIPTION AND LOCATION OF THE SYSTEM

This section describes the structure of the package HVAC system WRM236 and its installation on the passenger compartments of the DMU trains ATR220.

The package HVAC system is located on the train roof of each coach, above the passenger compartment. The only openings on the roof are the ones for the aeraulic interface.

The three HVAC systems installed on a train are not equal: in the central compartment there is a complete HVAC system WRM236; in the side compartments, instead, the HVAC systems installed are a simplified version of the central one (without heaters and without compressors inside), called WRM236SC.

For the central compartment, the compressors are electrical and mounted inside the package HVAC system, for the side compartments the compressor is installed underframe and moved by the diesel engine.

The heating is realized, in the central compartment, by means of electrical heaters installed inside the package HVAC system; in the side compartments, instead, there are water heaters.

The temperature control is obtained by using three environment probes, one inside the HVAC unit and the others inside the coach.

2.2 PACKAGE HVAC SYSTEM

2.2.1 PACKAGE HVAC UNIT LAY-OUT

The units are made up of the following main sections:

2.2.1.1 Compressors area

This area houses the compressors and components requiring a frequent maintenance or checking (pressure switches, liquid sight-glass, filters driers, etc.). This area is accessible through a grilled cover.

The compressors mounted are of a scroll type, which means that they are suitable for working under the conditions specific to the railway sector. They also guarantee low noise and vibration levels.

The refrigerant used is R407C and its total quantity has been optimized in order to reduce the environmental impact of the HVAC.

2.2.1.2 Condensing area

This area houses two horizontal imbricated condensers and the condenser fans. The fans and condensers can be accessed easily for maintenance and cleaning purposes, by opening the hinged covers.

2.2.1.3 Air treatment area

This area, thermally insulated from the condensing one, houses the thermostatic expansion valves, the evaporators and the heaters (when provided) and the air treatment fans. Also this area is easily accessible by opening a cover. This allows maintenance (e.g. replacing filters) or cleaning operations to be carried out on the heat exchangers.

2.2.1.4 Electrical panel

A proper section houses the electrical command and control components and the electronic control board.

2.2.1.5 External air mixing area

The fresh air is mixed to the recirculated one using continuously controlled air locks.

For the lay-out of the different components, see the Fig. 2.

2.2.2 ELECTRICAL AND MECHANICAL INTERFACE

Each air-conditioning package unit is provided with 3 appropriate M16 holes to which the ringbolts can be attached, in order to uplift the unit by means of belts (see the assembly drawing nr. PGD-WPI-UT-023-06, sheet 4).

Once the HVAC package unit has been placed in the opportune position on the roof of the passenger area, the frame can be fixed by means of 12 bolts M12x35 with nut vargal M12, such as shown in the drawings nr. 60ACB7338 – 60ACB7339, sheet 1.

No antivibration mounts have to be interposed between the HVAC package unit and the train roof. The vibrations decoupling is made between the compressors and the HVAC frame by using antivibration mounts inside the package unit.

The interface with the air distribution system is granted by the HVAC treated and recirculated air outlets and inlets. An appropriate silicon gasket is put between the HVAC treated and recirculated air outlets and inlets and the openings on the train roof.

The electrical connection with the train system is possible by means of three electrical connectors (MV connector XC1, LV connector XC2 and CAN BUS connector XC3) located on the HVAC frame and accessible by opening the electrical panel cover. Moreover it's necessary to connect the 2 ground blocks.

The condensate drainage is possible by means of 4 condensate discharges provided of goose lips (see the assembly drawings nr. 60ACB7338 – 60ACB7339, sheet 1) in case that there isn't on the train a condensate drainage circuit with an appropriate siphon pipe in order to avoid the entrance of air.

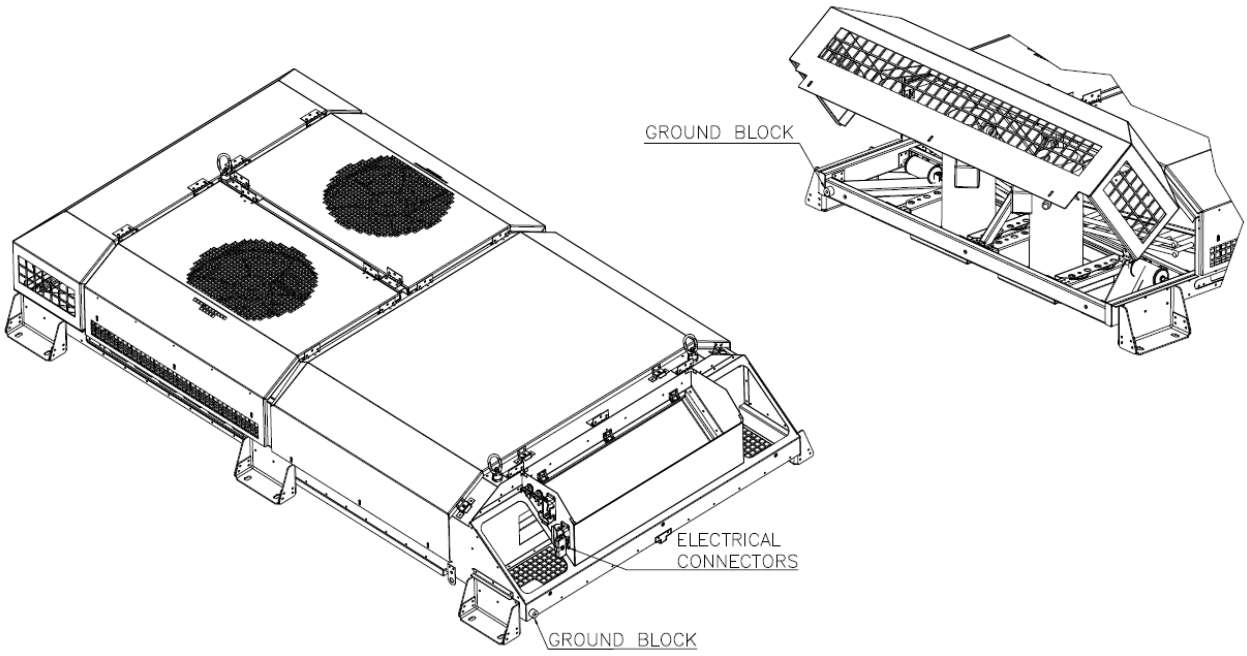
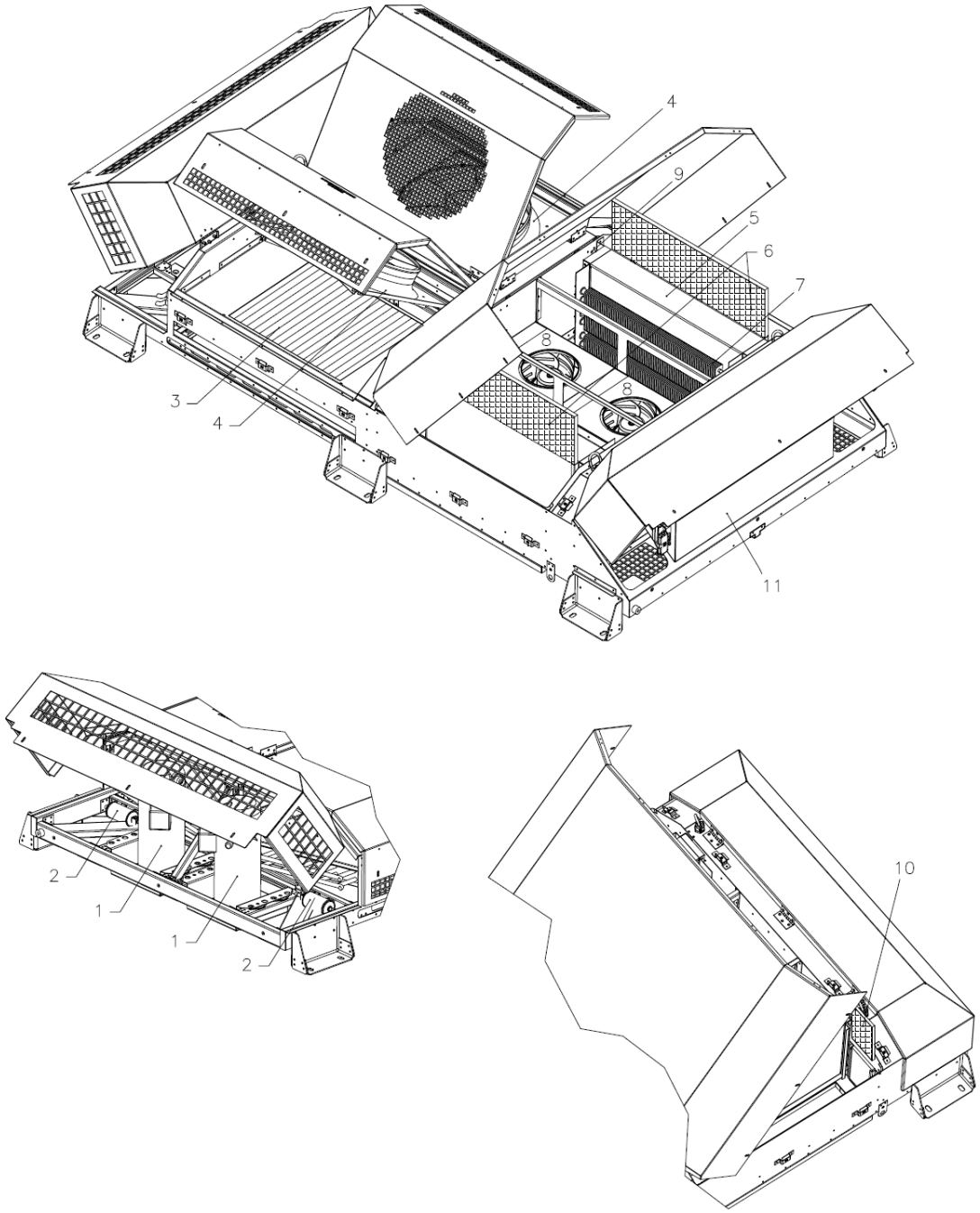


Fig. 1 Electrical interface



1. Compressor
2. Filter drier and moisture indicator
3. Condenser
4. Condenser fan
5. Evaporator
6. Recirculated air filter
7. Electrical heaters with 1st and 2nd level protection thermostats
8. Air treatment fan
9. Thermostatic expansion valve
10. External air filter
11. Electrical panel
12. Electrical connectors

Fig. 2 Package HVAC unit lay-out

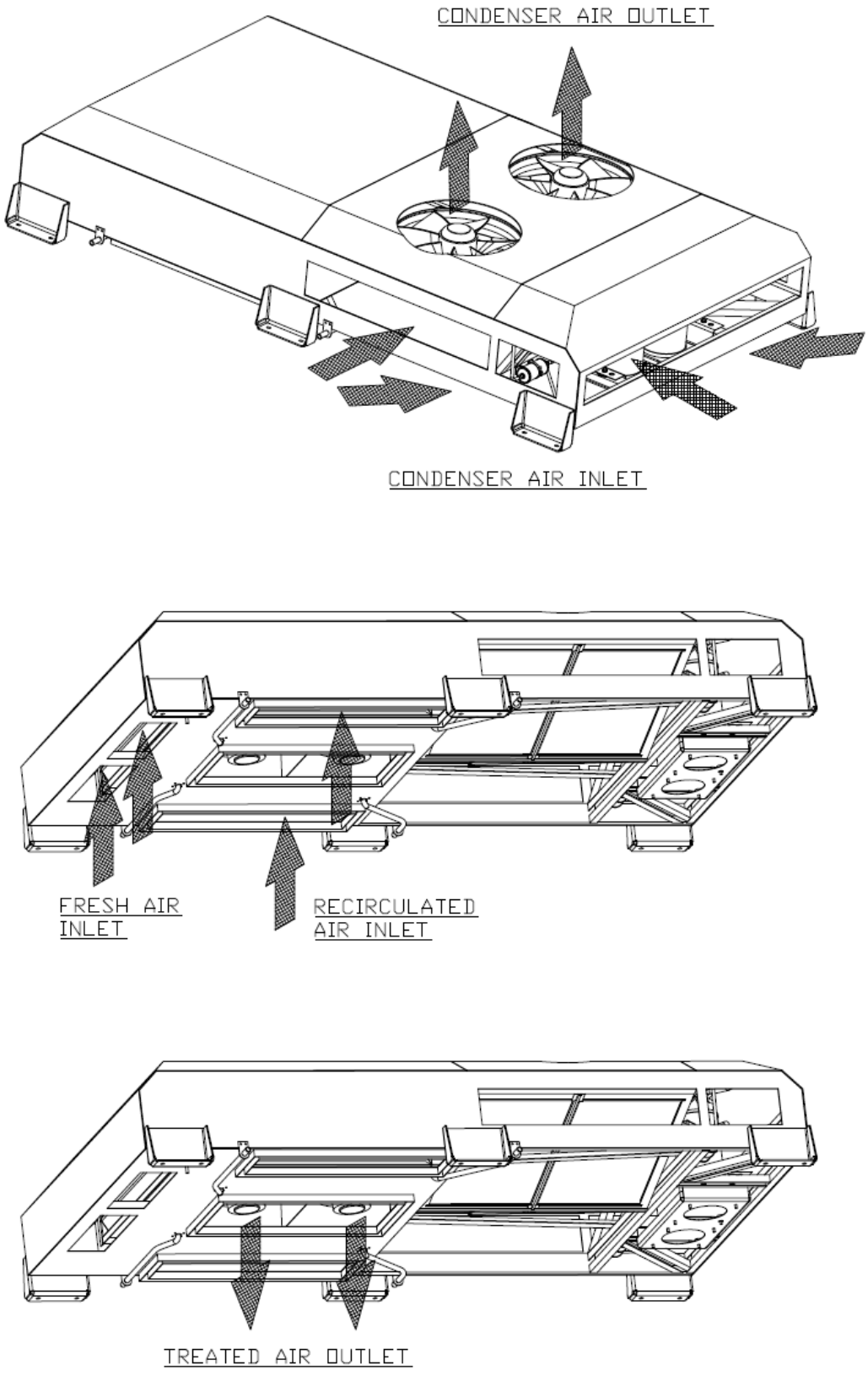


Fig. 3 Air flows (condenser air - recirculated air - fresh air - treated air)

2.2.3 FUNCTIONING CONDITIONS

2.2.3.1 External thermoigrometric conditions

T_{est} min	-20°C
T_{est} max	+40°C
Relative humidity Hr	40%
T_{est} extreme condition	+45°C
Solar radiation	800 W/m^2
Incidence	30°

2.2.3.2 Internal conditions

The internal temperature will be conform to EN 14750 standard, both in summer and in winter conditions.

2.2.3.3 Electrical power supply

Power supply	380Vac±10% / 3ph+N / 50Hz
Auxiliary power supply	24Vdc (from a battery – 18÷36V)

2.2.3.4 Refrigerant

The refrigerant fluid used is R407C. It's a blend of three hydrofluorocarbon (HFC) refrigerants with ODP (ozone depletion potential) = 0.

2.2.4 PERFORMANCES AND TECHNICAL DATA

Cooling capacity	36 kW with 40°C and 40% Hr
Heating capacity	15 kW

2.2.4.1 Cooling conditions

Electrical power supply	380V / 3ph+N / 50Hz
Electrical power consumption	15 kW

2.2.4.2 Heating conditions

Electrical power supply	380V / 3ph+N / 50Hz
Electrical power consumption	16kW

2.2.5 INDICATIVE DIMENSIONS AND INTERFACE WITH THE COACH

The overall dimensions, as in the assembly drawings nr. 60ACB7338 – 60ACB7339, sheet 1, are:

	WRM236	WRM236SC
length:	2753 mm	2753 mm
height:	501,5 mm	501,5 mm
width:	1658 mm	1658 mm
weight:	518 kg	410 kg

2.3 COMMANDS AND OPERATING MODES

The command of the air conditioning system is possible from the driving cab using the monitor on the instrument panel. The command and control signals reach the electronic control board of the HVAC through a CAN BUS protocol.

The user can switch on and off the system, choosing a functioning mode (air-conditioning, heating or ventilation) and setting a temperature value (± 2°C relative to the set-point temperature; see paragraph 3.3.2.2 for further details).

Also the alarm signals from the HVAC system are transferred onto CAN BUS and are displayed on the monitor.

The ON-OFF and ± 2°C commands, necessary for the functioning of the HVAC, can also come from two selectors located inside the passengers area (if installed). These selectors can be used only in the case the CAN BUS doesn't work. In fact the system, after 5 minutes it doesn't receive a life signal on CAN BUS, switches on the manual commands.

When the *air-conditioning* mode is selected, the system automatically chooses the ventilation, cooling or heating functions depending on the temperature difference between the set-point temperature and the internal one.

If the *ventilation* mode is selected the system is forced to function in ventilation only with the fans at a fixed speed.

In the *heating* mode the system automatically chooses the ventilation or heating functions depending on the temperature difference between the set-point temperature and the internal one. It cannot use the cooling function.

2.4 ALARMS

This section contains a list of the alarms that can be sent on the CAN BUS and displayed on the monitor.

2.4.1 CENTRAL COMPARTMENT

ALARM CODE	TYPE OF ALARM	ACTION
1	SMOKE ALARM	The system is switched off.
2	NO VOLTAGE / WRONG PHASE SEQUENCE CIRCUIT 1	Circuit 1 is switched off.
3	NO VOLTAGE / WRONG PHASE SEQUENCE CIRCUIT 2	Circuit 2 is switched off.
4	AIR DIFFERENTIAL PRESSURE SWITCH ALARM	Cooling and heating completely stopped.
5	AIR TREATMENT FAN 1 CIRCUIT BREAKER ALARM	Cooling and heating completely stopped – ventilation possible with only one fan.
6	AIR TREATMENT FAN 2 CIRCUIT BREAKER ALARM	Cooling and heating completely stopped – ventilation possible with only one fan.
7	COMPRESSOR 1 CIRCUIT BREAKER ALARM	Circuit 1 is switched off in cooling mode – cooling with half the power.
8	COMPRESSOR 2 CIRCUIT BREAKER ALARM	Circuit 2 is switched off in cooling mode – cooling with half the power.
9	CONDENSER FAN 1 CIRCUIT BREAKER ALARM	Circuit 1 is switched off in cooling mode – cooling with half the power.
10	CONDENSER FAN 2 CIRCUIT BREAKER ALARM	Circuit 2 is switched off in cooling mode – cooling with half the power.
11	HEATER 1 CIRCUIT BREAKER OR 2nd LEVEL THERMOSTAT ALARM	Circuit 1 is switched off in heating mode – heating with half the power.
12	HEATER 2 CIRCUIT BREAKER OR 2nd LEVEL THERMOSTAT ALARM	Circuit 2 is switched off in heating mode – heating with half the power.
13	CIRCUIT 1 HIGH PRESSURE OR LOW PRESSURE SWITCH ALARM	Circuit 1 is switched off in cooling mode – cooling with half the power.
14	CIRCUIT 2 HIGH PRESSURE OR LOW PRESSURE SWITCH ALARM	Circuit 2 is switched off in cooling mode – cooling with half the power.
15	REPEATED CIRCUIT 1 HIGH PRESSURE ALARM	Circuit 1 is switched off in cooling mode – cooling with half the power.

ALARM CODE	TYPE OF ALARM	ACTION
16	REPEATED CIRCUIT 2 HIGH PRESSURE ALARM	Circuit 2 is switched off in cooling mode – cooling with half the power.
17	REPEATED CIRCUIT 1 LOW PRESSURE ALARM	Circuit 1 is switched off in cooling mode – cooling with half the power.
18	REPEATED CIRCUIT 2 LOW PRESSURE ALARM	Circuit 2 is switched off in cooling mode – cooling with half the power.
19	REPEATED TREATED AIR HIGH TEMPERATURE ALARM	Heating completely stopped.
20	REPEATED TREATED AIR LOW TEMPERATURE ALARM	Cooling completely stopped.
21	REPEATED HEATER 1st LEVEL THERMOSTAT ALARM	Only signalling.
22	HEATERS NO WORKING	Only signalling.
23	EXTERNAL TEMPERATURE PROBE OUT OF RANGE	Regulation possible with the medium set-point temperature value.
24	ENVIRONMENT TEMPERATURE PROBE 1 OUT OF RANGE	Regulation possible with the others two environment temperature probes.
25	ENVIRONMENT TEMPERATURE PROBE 2 OUT OF RANGE	Regulation possible with the others two environment temperature probes.
26	ENVIRONMENT TEMPERATURE PROBE 3 OUT OF RANGE	Regulation possible with the others two environment temperature probes.
27	TREATED AIR TEMPERATURE PROBE OUT OF RANGE	Probe non considered in the algorithms.
28	LOW PRESSURE TRANSDUCER 1 OUT OF RANGE	Transducer non considered in the algorithms.
29	HIGH PRESSURE TRANSDUCER 1 OUT OF RANGE	Transducer non considered in the algorithms.
30	LOW PRESSURE TRANSDUCER 2 OUT OF RANGE	Transducer non considered in the algorithms.
31	HIGH PRESSURE TRANSDUCER 2 OUT OF RANGE	Transducer non considered in the algorithms.

2.4.2 SIDE COMPARTMENT

ALARM CODE	TYPE OF ALARM	ACTION
1	SMOKE ALARM	The system is switched off.
2	NO VOLTAGE / WRONG PHASE SEQUENCE	The system is switched off.
3	-	-
4	AIR DIFFERENTIAL PRESSURE SWITCH ALARM	Cooling and heating completely stopped.
5	AIR TREATMENT FAN 1 CIRCUIT BREAKER ALARM	Cooling and heating completely stopped – ventilation possible with only one fan.
6	AIR TREATMENT FAN 2 CIRCUIT BREAKER ALARM	Cooling and heating completely stopped – ventilation possible with only one fan.
7	-	-
8	-	-
9	CONDENSER FAN 1 CIRCUIT BREAKER ALARM	Circuit 1 is switched off in cooling mode – cooling with half the power.
10	CONDENSER FAN 2 CIRCUIT BREAKER ALARM	Circuit 2 is switched off in cooling mode – cooling with half the power.
11	-	-
12	-	-
13	HIGH PRESSURE OR LOW PRESSURE SWITCH ALARM	Cooling completely stopped.
14	-	-
15	REPEATED HIGH PRESSURE ALARM	Cooling completely stopped.
16	-	-
17	REPEATED LOW PRESSURE ALARM	Cooling completely stopped.
18	-	-
19	-	-
20	REPEATED TREATED AIR LOW TEMPERATURE ALARM	Cooling completely stopped.
21	-	-
22	-	-
23	EXTERNAL TEMPERATURE PROBE OUT OF RANGE	Regulation possible with the medium set-point temperature value.

ALARM CODE	TYPE OF ALARM	ACTION
24	ENVIRONMENT TEMPERATURE PROBE 1 OUT OF RANGE	Regulation possible with the others two environment temperature probes.
25	ENVIRONMENT TEMPERATURE PROBE 2 OUT OF RANGE	Regulation possible with the others two environment temperature probes.
26	ENVIRONMENT TEMPERATURE PROBE 3 OUT OF RANGE	Regulation possible with the others two environment temperature probes.
27	TREATED AIR TEMPERATURE PROBE OUT OF RANGE	Probe non considered in the algorithms.
28	LOW PRESSURE TRANSDUCER OUT OF RANGE	Transducer non considered in the algorithms.
29	HIGH PRESSURE TRANSDUCER OUT OF RANGE	Transducer non considered in the algorithms.

2.5 AERAULIC CIRCUIT

2.5.1 FRESH AIR INLET

The fresh air is sucked up through a motorized air lock and mixed to the recirculated air into the two mixing areas before the exchangers.

2.5.2 AIR FLOWS MIXING

There is a servo-controlled air lock between the fresh air suction area and the air treatment area. A continuous variation of the mixing ratio is provided in order to obtain a continuous regulation and to reduce the start and stop frequency of the compressors improving the passengers comfort conditions.

During the transient pre-cooling and pre-heating phases, the system functions with the air lock completely closed.

3 FUNCTIONAL DESCRIPTION

3.1 COOLING CIRCUIT

The cooling circuits of the WRM236 and WRM236SC units are described in the drawings RMB8175 and RMB8176 respectively.

3.1.1 REFRIGERATION CYCLE DESCRIPTION

The refrigeration cycle uses a circulating liquid refrigerant as the medium which absorbs and removes heat from the space to be cooled and subsequently rejects that heat elsewhere.

All such systems have four components: a compressor, a condenser, an expansion valve and an evaporator. Circulating refrigerant enters the compressor in the thermodynamic state known as a *saturated vapour* and is compressed to a higher pressure, resulting in a higher temperature as well. The hot, compressed vapour is then in the thermodynamic state known as a *superheated vapour* and it is at temperature and pressure at which it can be condensed. That hot vapour is routed through a condenser where it is cooled and condensed into a liquid by flowing through a coil or tubes with air flowing across. This is where the circulating refrigerant rejects heat from the system and the rejected heat is carried away by the air.

The condensed liquid refrigerant, in the thermodynamic state known as a *saturated liquid*, is next routed through an expansion valve where it undergoes an abrupt reduction in pressure. That pressure reduction results in the adiabatic flash evaporation of a part of the liquid refrigerant. The auto-refrigeration effect of the adiabatic flash evaporation lowers the temperature of the liquid and vapour refrigerant mixture to where it is colder than the temperature of the enclosed space to be refrigerated.

The cold mixture is then routed through the coil or tubes in the evaporator. A fan circulates the warm air in the enclosed space across the coil or tubes carrying the *cold refrigerant liquid and vapour mixture*. That warm air evaporates the liquid part of the cold refrigerant mixture. At the same time, the circulating air is cooled and thus lowers the temperature of the enclosed space to the desired temperature. The evaporator is where the circulating refrigerant absorbs and removes heat which is subsequently rejected in the condenser and transferred elsewhere by the air used in the condenser.

To complete the refrigeration cycle, the refrigerant vapour from the evaporator is again a *saturated vapour* and is routed back into the compressor.

NOTE

Saturated vapours and saturated liquids are vapours and liquids at their saturation temperature and saturation pressure. A superheated vapour is at a temperature higher than the saturation temperature corresponding to its pressure.

3.2 HVAC COMPOSITION AND MAIN COMPONENTS

This section describes the functioning of all the main (mechanical or electrical) parts of the HVAC system.

3.2.1 STRUCTURE

The assembly technology used for the stainless steel structure is structural rivets, without using any welds that can cause tension and deformations of the structures.

Such structural solution, enabled by the reduced height of the unit and by the arrangement of the inner components, allows to realize a sensitive reduction of weight.

The components of the cooling circuit are inspectable by opening or removing the cover panels in aluminium. The cover of the condensing section is constituted from two hinged panels. The access to the air treatment section is possible by means of an only central panel that can be completely opened through two gas springs limiting considerably its vertical encumbrance when opened. Accessibility to the compressors and to the electrical panel is granted through two hinged covers.

The upper covers, in aluminium, are strong enough to withstand accidental loads, even though these are not designed to avoid damage to the seals if they are walked on or to guarantee that they are safe to walk on.

3.2.2 COMPRESSORS AREA

In the WRM236 units, this area contains:

- two vertical scroll compressors,
- LP and HP pressure switches,
- LP and HP transducers,
- Schrader service valves,
- vibration limiters on the connections of the compressor to the refrigerant circuit,
- two filters driers including a sight glass with moisture indicator.

In the WRM236SC units, this area contains:

- two liquid receivers,
- LP and HP transducers,
- Schrader service valves,
- two filters driers including a sight glass with moisture indicator,
- two solenoid valves,
- two shut-off valves for the connection to the refrigerant circuit.

The discharge of the rain from the compressor area is directly on the roof because this area is opened at the bottom.

3.2.2.1 Compressors

The compressors have the function to suck the gas from the evaporators, to compress it and to convey it towards the condensers.

The compressors used are scroll type, which means that they are suitable for working under the conditions specific to the railway sector. They also guarantee low noise and vibration levels. At this purpose the compressors are also mounted on vibration-dampings.

They use a polyester lubricant (POE). Each compressor is equipped with a crankcase heater, an electric resistance wrapped as a belt around the compressor, that contrasts the process of solubilisation of the refrigerant in the oil. In this way the heated refrigerant evaporates and it is reduced to a quantity that does not give worry for the good operation of the compressor.

In the HVAC version WRM236SC the compressor is not inside the unit but under the train; it is an open type compressor moved directly from the diesel engine. The control of this compressor is anyway from the HVAC.

3.2.2.2 Compressor pressure switches

The HP pressure switches are located on the discharge pipes of the compressors, so as the unit is stopped if the value of the pressure goes over an established maximum. The LP ones are located, instead, on the suction pipes in order to stop the unit if the value of the pressure goes down under the project value. The intervention of a pressure switch during the normal operation determines the immediate cut of the electric power supply to the compressor, stopping its operation without switching off the condenser fans. The two LP pressure switches cut-off at 0,5 bar and cut-in at 2 bar while the HP ones cut-off at 29 bar and cut-in at 25 bar. Both the pressure switches have a fixed calibration and need only a control during the normal preventive scheduled maintenance.

3.2.2.3 Pressure transducers

The pressure transducers are located on the suction and discharge pipes of the compressors, such as the pressure switches, and allow the acquisition of the low and high pressure values. Those values are used by the control software of the HVAC as first level safety devices in order to prevent the pressure switches intervention. The high pressure transducers are also used for the management of the condenser fans (as described in paragraph 3.3.7.3). All the transducers used are 4-20 mA (range 0-35 bar).

3.2.2.4 Vibration limiters

Each compressor is connected to the refrigerant pipes by means of appropriate flexible pipes preventing the transmission of vibrations to the frame of the air conditioner.

3.2.2.5 Filter driers with sight glass and moisture indicators

The filter driers are installed on the line of the liquid and permit to retain the moisture and the impurities present in the frigorific circuit that, in their lack, would be accumulated at the income of the thermostatic valve compromising the correct operation. Such filters contain a cylindrical cartridge, with high superficial area, chemically inert, not deliquescent and not reagent with the refrigerant, able to block not only the moisture, always present in the circuit (dehydrating action) but also all the products of division of the lubricant oil of the compressor (antacid action).

On each filter drier, a sight glass is present with the function to make visible the refrigerant flow circulating in the system. Through the sight glass it is possible to observe that the refrigerant is in the liquid state. The refrigerant under form of bubbles (that is not liquid) is index of bad operation of the system. The moisture presence is instead indicated through a chromatic scale. When the indicator is green the percentage of moisture in the system is in the norm, if it is yellow the percentage of moisture is above the accepted limit and the replacement of the filter drier is therefore necessary. When the indicator is translucent or brown, there is oil in excess circulating in the system. The indicator, in such case, temporary loses its ability to change colour but it has not to be considered permanently damaged. The refrigerant fluid in circulation is able to remove the oil excess and to restore the normal condition of operation of the indicator.

3.2.2.6 Solenoid valves

The solenoid valves, present only in the WRM236SC permit the pump-down procedure when the compressor is stopped in order to avoid that the liquid refrigerant present inside the evaporator goes to the compressor.

3.2.2.7 Liquid receivers

The liquid receivers, present only in the WRM236SC and located downstream the condenser, collect the refrigerant when the pump-down procedure is activated.

3.2.3 CONDENSING AREA

This area houses the condensers and the condenser fans. These components can be accessed easily for maintenance and cleaning purposes, by opening the hinged covers.

In the WRM236 units, this area contains:

- two horizontal condensers with copper pipes, aluminium fins and aluminium frame,
- two axial fans with an electrical motor whose windings and insulation are proper for the power supply from a converter.

In the WRM236SC units, this area contains:

- one imbricated double circuit horizontal condenser with copper pipes, aluminium fins and aluminium frame,
- two axial fans with an electrical motor whose windings and insulation are proper for the power supply from a converter.

The discharge of the rain from the condensing area is directly on the roof because this area is opened at the bottom.

3.2.3.1 Condensers

The units are equipped with copper/aluminium condensers.

They are realized with pipes in copper that are mechanically expanded in a finned aluminium package with which they finally constitute a single thing. In the condenser the gas gives back the heat necessary in order to return to the liquid state (to condense). So it has to pass from the superheated state, as it comes from the compressor, to the saturated one, in order then to condense (normally at a temperature between 11 and 15 °C greater than that of the air entering the condenser).

The air, that has to carry away heat from the refrigerant, is conveyed towards the condensers by two axial fans.

3.2.3.2 Condenser fans

The fans enable the cooling of the condenser of the circuit refrigerator for means of external air. They are axial fans directly coupled to an asynchronous three-phase electric motor. Such fans provide large air flows also having low static pressure. A high pressure would be useless in this case having the air to pass exclusively through a finned battery and nothing else.

3.2.4 AIR TREATMENT AREA

Also this area is easily accessible by opening a cover and contains:

- two thermostatic expansion valves with external pressure equalisation,
- two imbricated double circuit evaporators with copper pipes, aluminium fins and aluminium frame,
- a stainless steel pan for the condensate,
- two electrical heaters groups constituted from three resistances each for a total of 7,5 KW each and protected by means of two safety thermostats (the first level one with automatic reset and the second level one with manual reset) and a temperature circuit breaker.
- two radial fans with an electrical motor whose windings and insulation are proper for the power supply from a converter,
- two recirculated air filters in polyester, filter class G3 according to standard EN779,
- two external air filters in polyester, filter class G3 according to standard EN779,
- two NTC temperature probes for the measure of the recirculated air temperature and of the treated air temperature,
- a differential air pressure switch.

3.2.4.1 Thermostatic expansion valves

The expansion valve is a component able to take the refrigerant from the condensation pressure to the evaporation one. The refrigerant upstream the valve is at the liquid state. A sudden reduction of pressure turns it into the saturated liquid state with a little vapour quality. At this point the process of boiling of the refrigerant inside the evaporator begins. The thermostatic expansion valve rules the influx of the refrigerant into the evaporator on the basis of the overheating of the refrigerant at the end of the evaporator itself. The thermostatic valve permits the flow to the evaporator of the refrigerant amount that, based on the established conditions of exercise, is in a position to evaporate; the heat exchange surface of the evaporator therefore is used in the better way.

3.2.4.2 Evaporators

The units are equipped with copper/aluminium evaporators.

The evaporators are the components giving the cooling effect to the environment. They are conceptually identical to the condenser and with an exactly symmetric function; in fact the refrigerant accomplishes the inverse transformation and passes from the liquid state to the vapour state absorbing heat from the atmosphere. Inside of the bundle of pipes the fluid evaporates completely and overheats.

Every evaporator is constituted by two imbricated circuits with pipes in copper, expanded mechanically in a finned aluminium package. Since it dehumidifies the air and therefore gets wet, it is protected from a filter that prevents dust from adhering to it.

The air is moved through the evaporators from two radial fans.

3.2.4.3 Condensate drainage system

Under the evaporators there is condensate pan with two discharge holes so that the drainage is granted in every situation.

3.2.4.4 Electrical heaters

Heating (where available) is provided by electrical heaters.

The heaters have the function to heat the air sent from the air treatment fans in the passenger compartment. In the system there are two 7,5 kW electrical heaters groups constituted from three electric resistances each, supplied at 380Vca and connected in star (Y) configuration. Every heaters group is protected from over temperature through two thermostats, the first level one with automatic reset and intervention temperature 90°C and the second level one with manual reset and intervention temperature 130°C.

3.2.4.5 Air treatment fans

The two air treatment fans have the purpose to send in the passenger compartment the treated air. They are radial fans. The radial fans in fact have not excessive air flow but good static pressure. They must be able to overcome not only the charge losses that the air meets in the evaporator but also all the losses of pressure taking place in the ducts convoying the air into the compartment. The static pressure must be such, moreover, to give a residual pressure to the air, so that the last one could exit from the channels with a speed neither so high to cause annoying air flows to the passengers, nor so low not to succeed in distributing itself all around the compartment to be conditioned (giving origin to stratifications of the temperature in vertical sense).

3.2.4.6 Air filters

The air filters have the function to prevent dust from adhering to the evaporators. There are two recirculated air filters upstream the evaporators and two filters for the external air.

All of them are in polyester and have a filter class G3 according to the standard EN 779.

3.2.4.7 Temperature probes

In the package HVAC there are three NTC temperature probes (10 kΩ ± 1% at 25°C), with protection of the sensing element in stainless steel; one is located into the air treatment area for the measurement of the treated air temperature and one is placed in correspondence of the recirculated air inlet for the measurement of the environment temperature.

The third one is located into the external mixing area, near the inlet of the external air for the measurement of the external temperature.

3.2.4.8 Differential air pressure switch

This pressure switch, placed in the air treatment fan space, has a connection to a capillary in its turn connected to the point in which the pressure has to be controlled, in this case the pressure downstream the air treatment fans. The pressure switch finds a change in the differential pressure when the air flow changes. It sends a signal to the electronic board in the situation of ventilation absent or reduced.

3.2.5 FRIGORIFIC CIRCUIT

All the frigorific circuit pipes are copper-made and all the connections are welded: in this way there aren't critical points in which a refrigerant loss is more probable. The insulation of the refrigerant pipes (suction line of the compressors) is granted from an insulating closed-cell expanded material in synthetic rubber (elastomer).

The refrigerant used is R407C and its total quantity has been optimized in order to reduce the environmental impact.

3.2.6 ELECTICAL PANEL AND WIRING

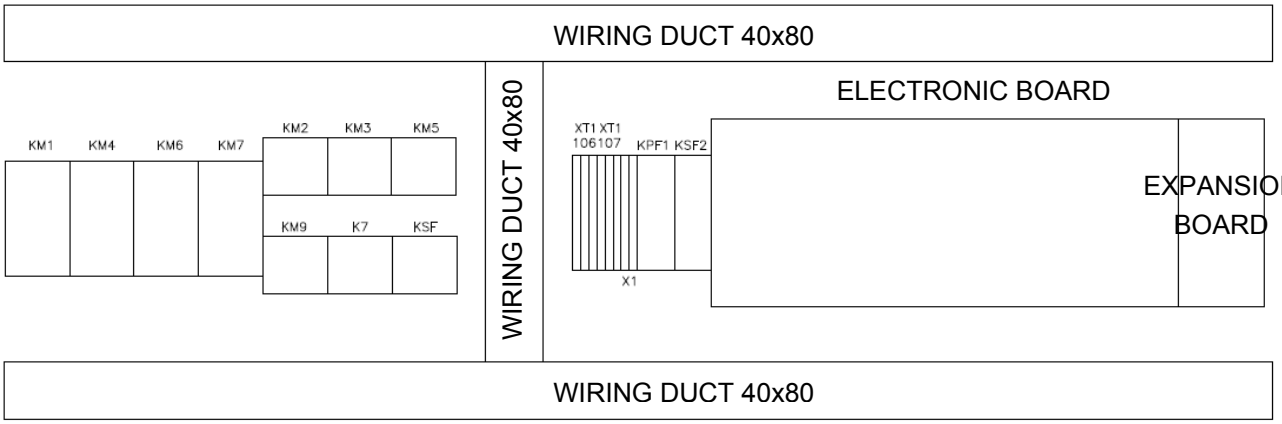
The air-conditioners includes an electrical panel containing all the electromechanical control equipment and electrical safety devices with the exception of the circuit breakers that are installed into the train electrical panel inside the driving cabin.

The control is realized using an electronic control board connected to the vehicle CAN BUS.

So, in the electrical panel there are:

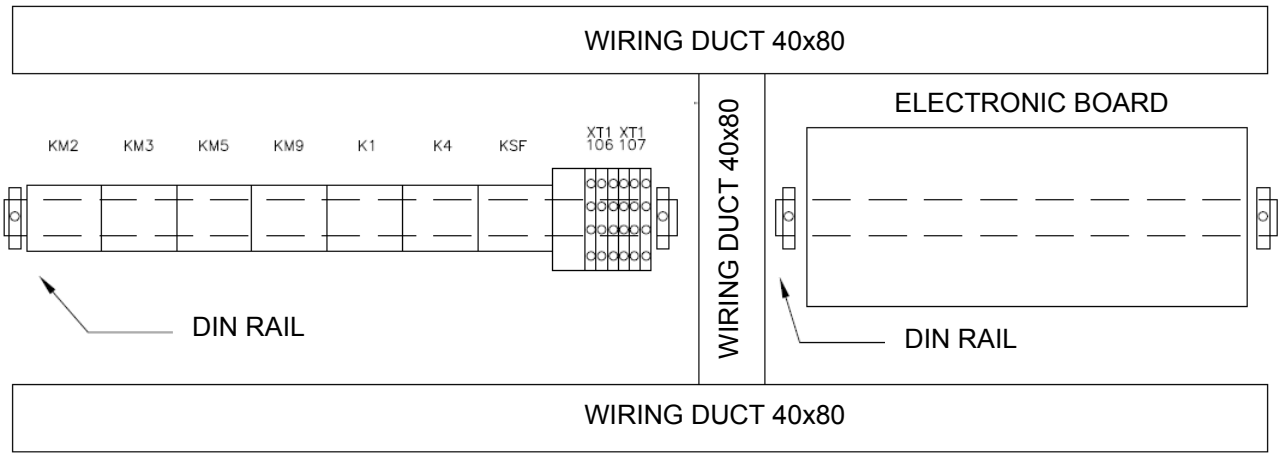
- the contactors of all the components,
- the reverse phase relay,
- the electronic board commanding and controlling the system; this board has a CAN BUS interface for the connection to the vehicle communication network and also a connector for an interface terminal or for downloading the application program.

In the Fig. 4 and Fig. 5 the disposition of the components inside the switchboard is shown. The complete electrical drawings of the units (drawings nr. RMB77851 - RMB7852) are attached.



KM1 Compressor 1 contactor
KM2 Condenser fan 1 contactor
KM3 Air treatment fan 1 contactor
KM4 Compressor 2 contactor
KM5 Condenser fan 2 contactor
KM6 Electrical heater 1 contactor
KM7 Electrical heater 2 contactor
KM9 Air treatment fan 2 contactor
K7 Oil heaters contactor
KSF Smoke detector contactor
KPF1 Reverse phase relay circuit 1
KPF2 Reverse phase relay circuit 2
XT1 Terminal blocks
X1 Terminal blocks

Fig. 4 WRM236 electrical panel lay-out



KM2 Condenser fan 1 contactor
KM3 Air treatment fan 1 contactor
KM5 Condenser fan 2 contactor
KM9 Air treatment fan 2 contactor
K1 Compressor clutch contactor
K4 Compressor solenoid valve contactor
KSF Smoke detector contactor
KPF1 Reverse phase relay
XT1 Terminal blocks

Fig. 5 WRM236SC electrical panel lay-out

3.2.6.1 Electrical connectors

On the electrical panel frame there are four electrical connectors:

- XC1 - MV connector for the power supply,
- XC2 - LV connector for the auxiliary supply,
- XC3 - connector for the CAN BUS interface,
- XC4 - connector available for the connection of a telephone cable RJ25 for an external terminal.

3.2.6.2 Electrical wiring

The wiring from the connectors to the different users doesn't use, if not strictly necessary, blocks, so that the space is optimized and the problems on the connection points are minimized.

3.2.7 EXTERNAL MIXING AREA

Under the electrical panel there is an area where the external air is sucked up.

This area contains:

- an air lock,
- a servocommand supplied at 24Vdc and with a continuous 0÷10V command,
- one NTC temperature probe for the measure of the external air temperature.

3.2.7.1 Air lock

The fresh air is mixed to the recirculated one using a continuously controlled air lock.

This air lock, in aluminium, is moved by a servocommand supplied at 24Vdc and with a continuous 0÷10V command.

3.2.8 ENVIRONMENT TEMPERATURE PROBES

The HVAC uses other two NTC probes for the acquisition of the internal temperature, located inside the passenger compartment (apart from the one inside the unit, near the recirculated air inlet).

3.2.9 SAFETY DEVICES

Every compressor is protected by two pressure switches, a low pressure one and a high pressure one. The pressure is also controlled by means of transducers, for both low and high pressure.

A differential pressure switch invested by the treated air is provided in order to detect the ventilation loss. This pressure switch detects a pressure difference between two points and verifies, consequently, the presence of ventilation.

Every electrical heater (when present) is protected against the over-temperature through two thermostats, a first level thermostat with automatic reset and a second level one with manual reset. The last safety level is a temperature circuit breaker with an eutectic phial.

For the electrical protection there are magnetothermic circuit breakers for the compressors, the fans and the heaters (installed inside the vehicle electrical panel).

3.2.9.1 Safety devices intervention threshold

The intervention thresholds of the safety devices are:

- two thermostats with automatic reset 90°C,
- two thermostats with manual reset 130°C,
- a differential air pressure switch 0,5 mbar,
- two low pressure switches 2 bar (reset 0,5 bar),
- two high pressure switches 29 bar (reset 25 bar).

3.3 HVAC SYSTEM FUNCTIONING

3.3.1 ELECTRONIC BOARD INPUTS AND OUTPUTS

In this paragraph all the electronic board input and output signals are listed. All input signals, both digital and analogical are filtered.

3.3.1.1 Digital inputs

POSITION	NORMAL CONDITION	DESCRIPTION	ACTION
ID1 (J5)	NO	Smoke detector signal (KSF).	Alarm signal. Cooling, heating and ventilation are stopped.
ID2 (J5)	NC	Reverse phase relay circuit 1 signal (KPF1).	The absence of this signal activates the alarm signal and the functioning with only one circuit is allowed.
ID3 (J5)	NO	Air treatment fan 2 circuit breaker opened (QM9).	Alarm signal. Cooling and heating are stopped, ventilation with only one fan at the maximum speed.
ID4 (J5)	NC	Reverse phase relay circuit 2 signal (KPF2).	The absence of this signal activates the alarm signal and the functioning with only one circuit is allowed.
ID5 (J5)	NO	Compressor 1 circuit breaker opened (QM1)	Alarm signal. The compressor 1 is stopped. The condenser fan goes on functioning. The other cooling circuit is in function. The heater section remains enabled.
ID6 (J5)	NO	Condenser fan 1 circuit breaker opened (QM2).	Alarm signal. The compressor 1 is stopped. The other cooling circuit is in function. The heater section remains enabled.
ID7 (J5)	NO	Air treatment fan 1 circuit breaker opened (QM3).	Alarm signal. Cooling and heating are stopped, ventilation with only one fan at the maximum speed.
ID8 (J5)	NO	Compressor 2 circuit breaker opened (QM4)	Alarm signal. The compressor 2 is stopped. The condenser fan goes on functioning. The other cooling circuit is in function. The heater section remains enabled.

POSITION	NORMAL CONDITION	DESCRIPTION	ACTION
ID9 (J7)	NO	Condenser fan 2 circuit breaker opened (QM5).	Alarm signal. The compressor 2 is stopped. The other cooling circuit is in function. The heater section remains enabled.
ID10 (J7)	NO	Electrical heater 1 circuit breaker opened or protection 2nd level thermostat opened (QM6-STS1-2).	Alarm signal. The electrical heater 1 is stopped. The ventilation remains enabled.
ID11 (J7)	NO	Electrical heater 2 circuit breaker opened or protection 2nd level thermostat opened (QM7-STS2-2).	Alarm signal. The electrical heater 2 is stopped. The ventilation remains enabled.
ID12 (J7)	NO	LP pressure switch circuit 1 or HP pressure switch circuit 1 opened (SPBP1-SPAP1).	The compressor 1 is stopped. The condenser fan goes on functioning. The other cooling circuit is in function. The heater section remains enabled. After N interventions: alarm signal.
ID13 (J8)	NO	LP pressure switch circuit 2 or HP pressure switch circuit 2 opened (SPBP2-SPAP2).	The compressor 2 is stopped. The condenser fan goes on functioning. The other cooling circuit is in function. The heater section remains enabled. After N interventions: alarm signal.
ID14 (J8)	NO	Configuration (ID1), together with ID2 and ID3.	Cabin 1: ID1=1, ID2=0, ID3=0; Compartment 1: ID1=0, ID2=1, ID3=0; Compartment 2: ID1=1, ID2=1, ID3=0; Compartment 3: ID1=0, ID2=1, ID3=0; Cabin 2: ID1=1, ID2=0, ID3=0;
ID15 (J19)	NO	Configuration (ID2), together with ID1 and ID3.	Cabin 1: ID1=1, ID2=0, ID3=0; Compartment 1: ID1=0, ID2=1, ID3=0; Compartment 2: ID1=1, ID2=1, ID3=0; Compartment 3: ID1=0, ID2=1, ID3=0; Cabin 2: ID1=1, ID2=0, ID3=0;
ID16 (J19)	NO	Configuration (ID3), together with ID1 and ID2.	Cabin 1: ID1=1, ID2=0, ID3=0; Compartment 1: ID1=0, ID2=1, ID3=0; Compartment 2: ID1=1, ID2=1, ID3=0; Compartment 3: ID1=0, ID2=1, ID3=0; Cabin 2: ID1=1, ID2=0, ID3=0;

POSITION	NORMAL CONDITION	DESCRIPTION	ACTION
ID17 (J20)	NO	Electrical heaters (1 or 2) protection 1st level thermostat opened (STS1-1-STS2-1).	No action. After S interventions: alarm signal.
ID18 (J20)	NC	Differential pressure switch signal (SPDS).	The absence of this signal activates the alarm signal. Cooling and heating are stopped.
ID1 (EXP-J4)	NO	Command selection (SB2/1), together with SB1/2.	OFF: SB2/1=0, SB1/2=0; Ventilation: SB2/1=1, SB1/2=0; Air conditioning: SB2/1=0, SB1/2=1; Heating: SB2/1=1, SB1/2=1. Used when CAN BUS doesn't work: after 5 minutes the electronic board doesn't receive a life signal on CAN BUS, it switches on the manual commands.
ID2 (EXP-J4)	NO	Set-point + 2°C (SB1/+2)	Set-point curve change. Used when CAN BUS doesn't work: after 5 minutes the electronic board doesn't receive a life signal on CAN BUS, it switches on the manual commands.
ID3 (EXP-J4)	NO	Set-point - 2°C (SB1/-2)	Set-point curve change. Used when CAN BUS doesn't work: after 5 minutes the electronic board doesn't receive a life signal on CAN BUS, it switches on the manual commands.
ID4 (EXP-J4)	NO	Command selection (SB1/2), together with SB2/1.	OFF: SB2/1=0, SB1/2=0; Ventilation: SB2/1=1, SB1/2=0; Air conditioning: SB2/1=0, SB1/2=1; Heating: SB2/1=1, SB1/2=1. Used when CAN BUS doesn't work: after 5 minutes the electronic board doesn't receive a life signal on CAN BUS, it switches on the manual commands.

NO = normally open, NC = normally closed

3.3.1.2 Analogical inputs

POSITION	DESCRIPTION	ACTION
B6 (J6)	Low pressure transducer circuit 1 (BPBP1).	It measures the suction pressure on the compressor circuit 1.
B7 (J6)	High pressure transducer circuit 1 (BPAP1).	It measures the discharge pressure on the compressor circuit 1.
B8 (J6)	Low pressure transducer circuit 2 (BPBP2).	It measures the suction pressure on the compressor circuit 2.
B1 (J2)	High pressure transducer circuit 2 (BPAP2).	It measures the discharge pressure on the compressor circuit 2.
B2 (J2)	Treated air temperature probe (STC).	It measures the treated air temperature.
B4 e BC4 (J3)	Internal temperature probe 1 (STA1).	It measures the internal air temperature inside the passenger compartment.
B5 e BC5 (J3)	Internal temperature probe 2 (STA2).	It measures the internal air temperature inside the passenger compartment.
B9 e BC9 (J20)	Internal – recirculated temperature probe 3 (STA3).	It measures the internal air temperature near the recirculated air inlet.
B10 e BC10 (J20)	External temperature probe (STE).	It measures the external air temperature.

3.3.1.3 Digital outputs

POSITION	NORMAL CONDITION	DESCRIPTION	ACTION
NO1 (J12)	NO	Condenser fan 1 command (KM2).	Condenser fan 1 insertion.
NO2 (J12)	NO	Condenser fan 2 command (KM5).	Condenser fan 2 insertion.
NO3 (J12)	NO	Crankcase heaters command (K7).	Compressors crankcase heaters insertion.
NO7 (J14)	NO	Compressor circuit 1 command (KM1).	Circuit 1 compressor insertion.
NO8 (J15)	NO	Compressor circuit 2 command (KM4).	Circuit 2 compressor insertion.
NO12 (J17)	NO	Electrical heater 1 command (KM6).	Electrical heater 1 insertion.
NO13 (J18)	NO	Electrical heater 2 command (KM7).	Electrical heater 2 insertion.
NO14 (J21)	NO	System OK signal (H1).	Normal functioning green lamp switched on (if connected).
NC14 (J21)	NO	General alarm signal (H2).	Alarm red lamp switched on (if connected).

3.3.1.4 Analogical outputs

POSITION	DESCRIPTION	ACTION
Y1 (J4)	Air treatment fan 1 (EVTA1).	Air treatment fan 1 speed setting.
Y2 (J4)	Air treatment fan 2 (EVTA2).	Air treatment fan 2 speed setting.
Y3 (J4)	External air lock 1 (MS1).	External air lock opening setting.
Y4 (J4)	External air lock 2 (MS2). NOT USED	External air lock opening setting.

3.3.2 THERMOREGULATION

When the system is switched on in the *air-conditioning* mode, the software evaluates the temperature required for the internal environment. In order to obtain this value, the software:

- reads the external temperature value,
- reads the internal temperature value (evaluated as the mean value of the temperature values from three different probes, see paragraph 3.3.2.1),
- reads the value selected from the user (set-point, set-point + 2°C, set-point - 2°C),
- evaluates the reference temperature (see paragraph 3.3.2.2),
- evaluates the difference between the reference temperature and the internal one (see paragraph 3.3.2.3),
- activates the cooling, heating or ventilation function on the basis of the difference above.

The cooling phase is activated is the internal temperature is 1°C above the reference temperature, the heating phase if it's 1°C under the reference temperature.

3.3.2.1 Evaluation of the internal temperature

The mean internal temperature is evaluated, as a function of the values from the probes STA1 (T_1), STA2 (T_2) e STA3 (T_3), with the following formula:

$$T_{AMB} = \frac{T_1 + T_2 + T_3}{3}.$$

3.3.2.2 Evaluation of the reference temperature

The set-point temperature has, in function of the external temperature, the progress shown in Fig. 6. The curve is completely defined by four parameters:

- minimum internal temperature,
- maximum internal temperature,
- minimum external temperature regulated,
- maximum external temperature regulated.

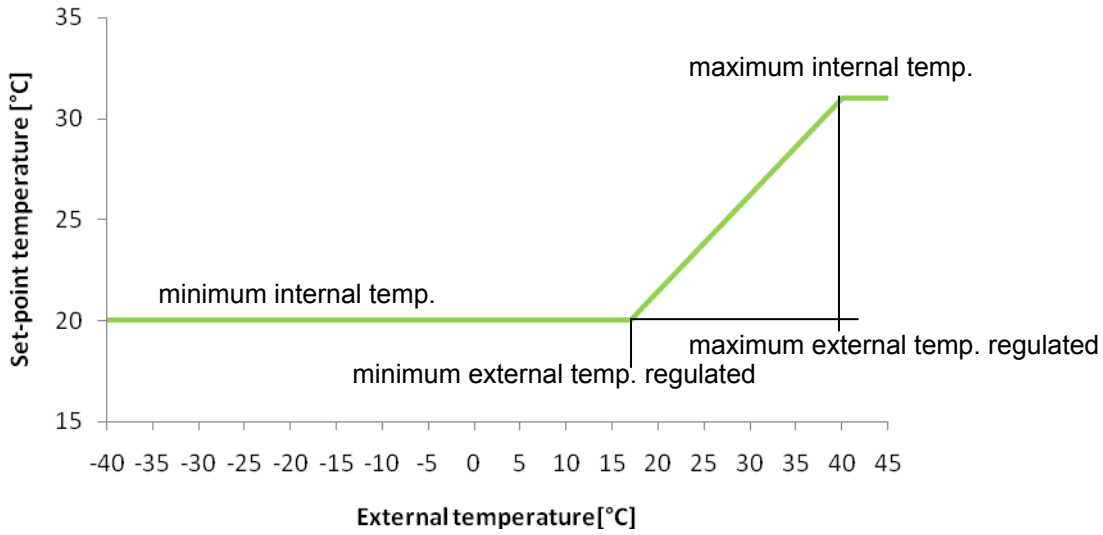


Fig. 6 Set-point temperature versus external temperature

The user can select other curve progresses using the monitor in the driving cab; Fig. 7 shows the other possible settings.

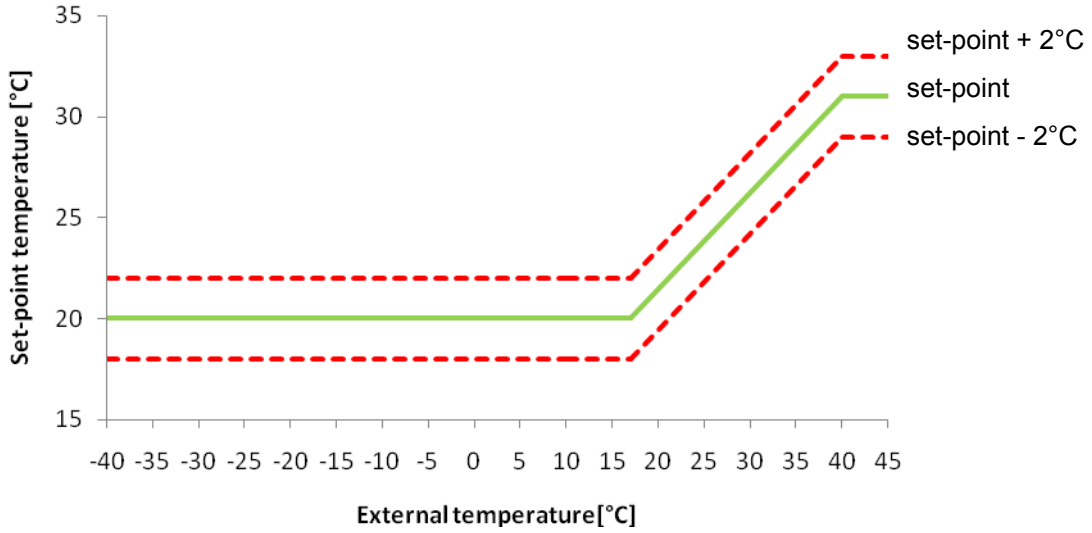


Fig. 7 Possible settings selected from the user

So, once the set-point temperature curve has been defined, the reference temperature is evaluated in base of:

- external temperature,
- settings from the user (set-point, set-point + 2°C, set-point - 2°C).

3.3.2.3 Evaluation of the temperature difference

The temperature difference has to be evaluated depending on:

- reference temperature (evaluated as shown in the paragraph 3.3.2.2),
- internal temperature (evaluated as shown in the paragraph 3.3.2.1).

The difference between the internal temperature and the reference (T_{DIFF}) is evaluated with the following formula:

$$T_{DIFF} = T_{AMB} - T_{RIF} .$$

3.3.3 FUNCTIONING MODE SETTING

The functioning mode is defined in function of the difference from the reference temperature, as defined in Fig. 9.

The regulation isn't activated if $T_{DIFF-} < T_{DIFF} < T_{DIFF+}$.

When $T_{DIFF} > T_{DIFF+}$ the cooling mode is activated, when $T_{DIFF} < T_{DIFF-}$ the heating mode is activated instead. In the transition from one mode to the other an hysteresis band ΔT_{HYST} (toward the inside) is considered.

The system can be described as a finite state machine with the following functioning states:

- ventilation,
- pre-heating,
- heating,
- post ventilation,
- pre-cooling,
- cooling.

The transition from one state to another happens in a completely automatic way according to the Fig. 8.

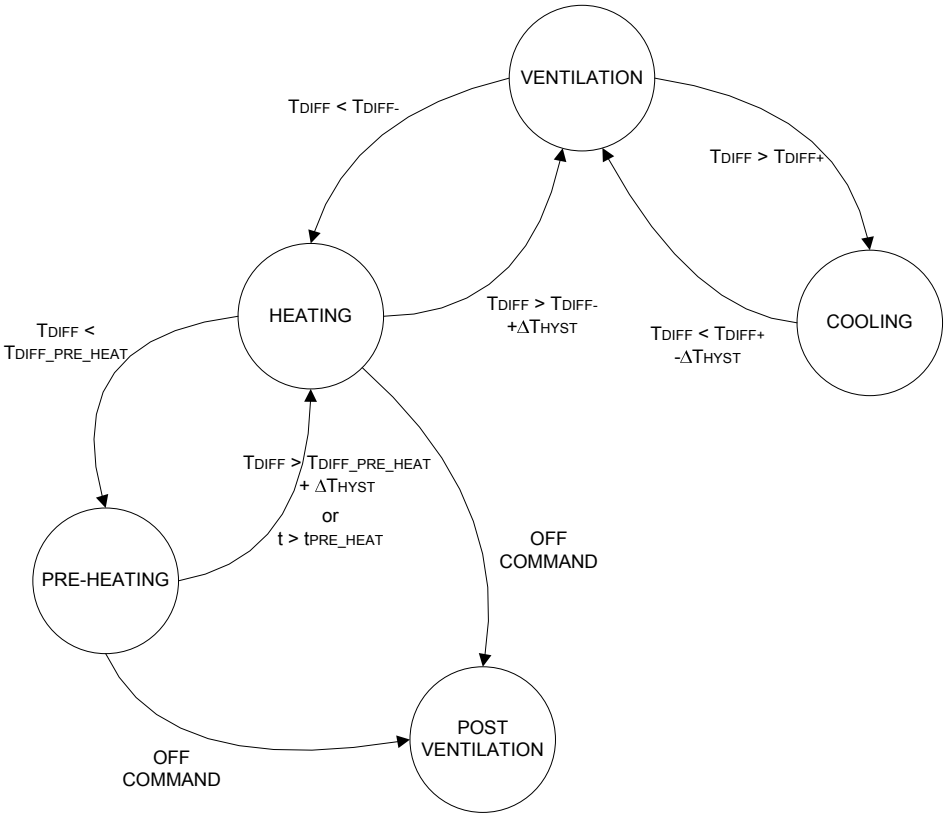


Fig. 8 Functioning mode setting

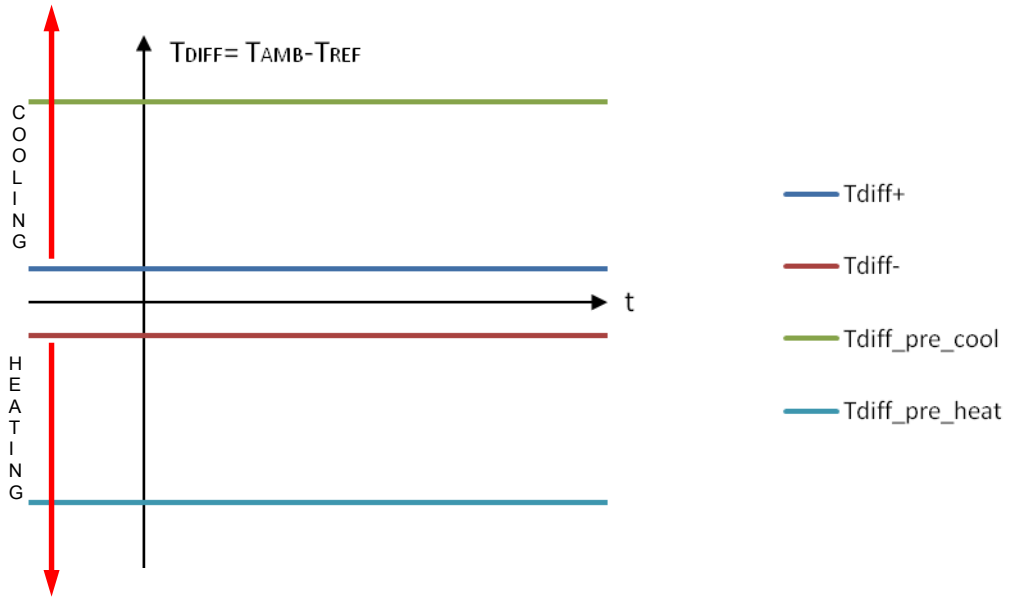


Fig. 9 Determination of the functioning mode in function of the temperature difference from the reference temperature

In this application T_{DIFF+} = 0,5°C, T_{DIFF-} = -0,5°C, $T_{DIFF\_PRE\_COOL}$ = 5°C, $T_{DIFF\_PRE\_HEAT}$ = -5°C and ΔT_{HYST} = 0,5°C.

In the following the different functioning modes are described in details.

3.3.4 VENTILATION

The ventilation is always in function, also in presence of alarm signals.

3.3.4.1 Fans speed regulation

The two air treatment fans are always controlled in parallel.

When the *air-conditioning* mode or *heating* mode are selected, the ventilation speed changes, depending on the distance from the reference temperature (see paragraph 3.3.2.2), between a maximum and a minimum speed.

The regulation algorithm, in base of the distance from the reference temperature, sends to the fans a 0-10V signals as shown in the Fig. 10.

When the *ventilation* mode is selected, the fans has instead a fixed speed V_{VENT}.

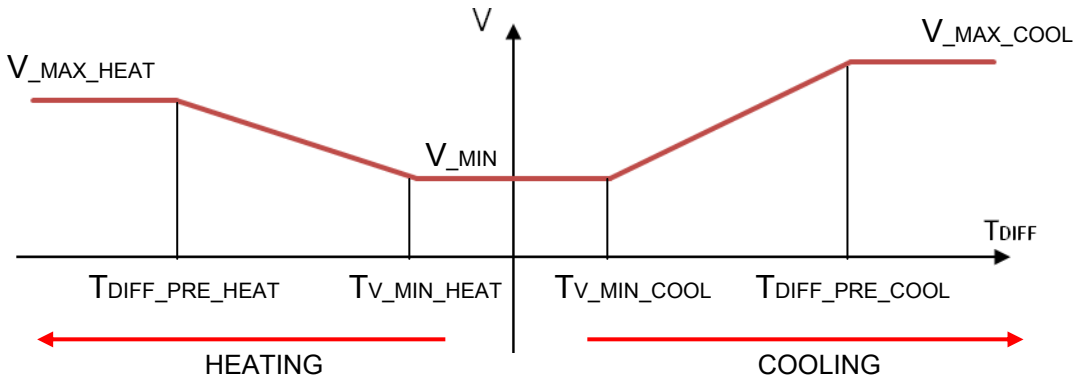


Fig. 10 Fans speed regulation

In this application V_{MAX_HEAT} = V_{MAX_COOL} = 10V, V_{MIN} = 5V, $T_{V\_MIN\_HEAT}$ = -1°C, $T_{V\_MIN\_COOL}$ = 1°C, V_{VENT} = 5V.

3.3.4.2 Air lock regulation

The air lock opening changes (through a variable 0-10V signal) depending on the distance from the reference temperature (see paragraph 3.3.2.2).

When the *air-conditioning* mode or *heating* mode are selected, the air lock opening angle can vary between $\alpha_{\_MIN}$ and $\alpha_{\_MAX}$ in function of the distance from the reference temperature (as shown in Fig. 11).

When the *ventilation* mode is selected, the air lock opening angle has instead the maximum value.

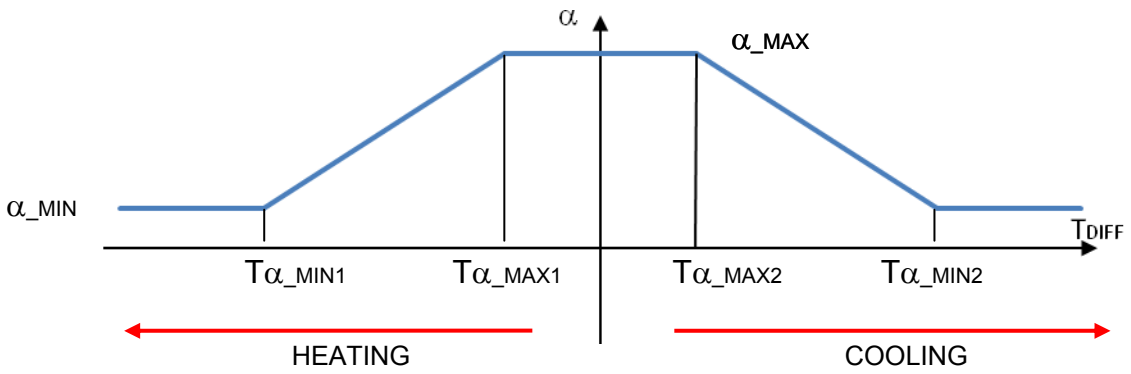


Fig. 11 Air lock opening angle regulation

In this application $\alpha_{\_MIN}$ = 0V, $\alpha_{\_MAX}$ = 9V, T_{α_MIN1} = -5°C, T_{α_MAX1} = -1°C, T_{α_MAX2} = 1°C and T_{α_MIN2} = 5°C.

3.3.4.3 Air lock regulation during the initial transient

If the difference between the internal temperature and the reference temperature is really high (pre-cooling and pre-heating phases), the software controls the external air lock as illustrated in the paragraphs 3.3.6 and 3.3.8 respectively.

3.3.5 POST VENTILATION

This function is activated every time the heating phase finishes or the system is stopped with the heating still on.

The ventilation remains on (at the minimum speed) for a defined time t_{POST_FAN} so that the heat on the electrical heaters is evacuated.

In this application t_{POST_FAN} = 10 min.

3.3.6 PRE-COOLING

The pre-cooling phase is activated when the difference between the internal temperature and the reference temperature is really high.

This functioning phase is different from the cooling phase only for the air lock regulation: if the internal temperature is higher than the external one, the software completely opens the external air lock. If the internal temperature is lower or equal than the external one, the air lock is closed and the unit functions with recirculated air only.

The pre cooling phase goes on till the temperature difference has a defined value ($T_{DIFF\_PRE\_COOL}$- ΔT_{HYST}) or, anyway, for a defined time (t_{PRE_COOL}). When these values have been reached, the software enables the cooling phase and start modulating the external air quantity as defined at the paragraph 3.3.4.2.

In this application t_{PRE_COOL} = 90 min.

3.3.7 COOLING

In this phase the unit has to implement the following functions:

- compressors insertion/uninsertion,
- air treatment fans speed regulation (as shown in the paragraph 3.3.4.1),
- external air lock control regulation (as shown in the paragraph 3.3.4.2),
- condenser fans control.

Two equal compressors are used (contactors KM1 and KM4), activated with a regulation depending both on the temperature difference from the set-point and on the time.

It's possible the half power functioning or the full power functioning: the half power functioning is achieved with a single compressor (the one with less working hours), the full power functioning is achieved using both the compressors.

The parameters in the regulation are:

- DIFF_COOL: wideness of the temperature difference band (straddling T_{DIFF+}, as shown in Fig. 12) in which no action is required. If the temperature difference reaches the value T_{DIFF+} + DIFF_COOL, the first compressor is started (half power functioning),
- t_{ON_COOL}: permanence time above the threshold after which the second compressor is started (full power functioning),
- the transition to the half power functioning occurs when the temperature difference reaches the value corresponding to the transition from cooling to ventilation (T_{DIFF+}),
- t_{OFF_COOL}: permanence time under the threshold after which the second compressor is stopped (complete OFF).

In this application DIFF_COOL = 1°C, t_{ON_COOL} = 60 sec and t_{OFF_COOL} = 180 sec.

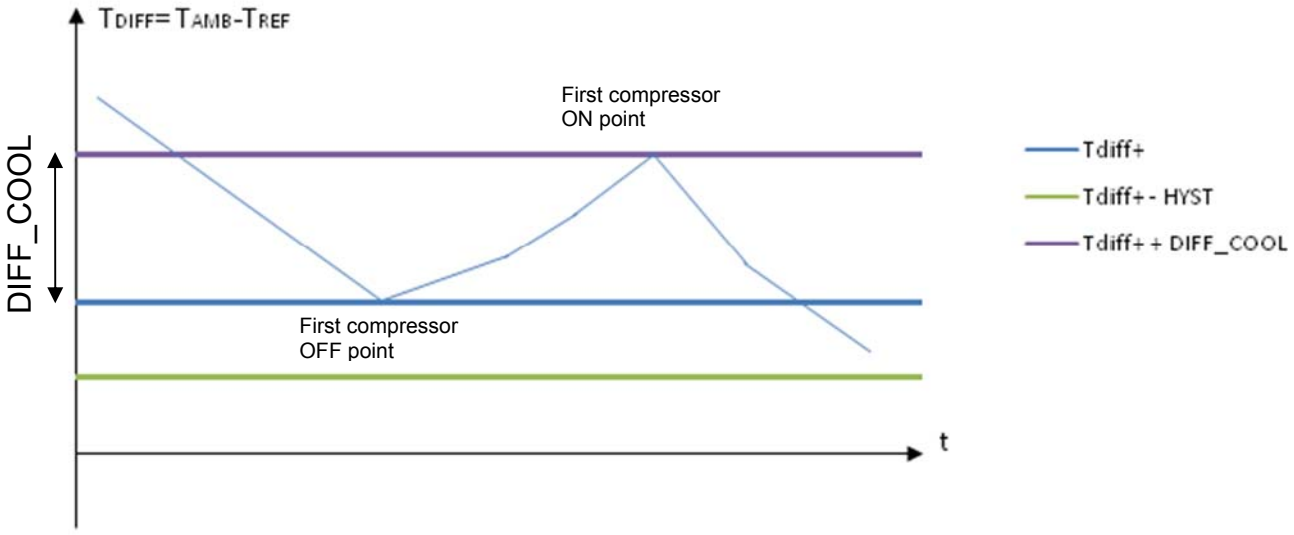


Fig. 12 First compressor regulation

During the pre-cooling and cooling phases, also these functions are implemented:

- compressors stop for low external temperature,
- compressors working hours balance.

These control functionalities have the priority on the regulation requirements.

3.3.7.1 Compressor insertion

Every time the compressor is inserted a minimum off time (t_{MIN_OFF}) and a minimum time between following insertions (t_{LAST_ON}) have to be respected, in order to avoid too much strain.

The software remembers the moment of the last insertion and uninsertion and, every time the compressor is required, verifies the correct waiting times are respected.

In this application t_{MIN_OFF} = 1 minute and t_{LAST_ON} = 3 minutes.

3.3.7.2 Compressor uninsertion

Every time the compressor is uninserted a minimum on time (t_{MIN_ON}) has to be respected, in order to avoid too much strain.

The software remembers the moment of the last insertion and, every time the compressor has to be stopped, verifies the correct waiting time is respected.

In this application t_{MIN_ON} = 1 minute.

3.3.7.3 Condenser fans control

Each condenser fan is regulated in function of the high pressure in the frigorific circuit.

When the pressure is higher than the value P_{FAN_ON}, the condenser fan is started and when the pressure decreases till $P_{FAN\_ON} - \Delta P_{FAN}$, it is arrested.

In this application P_{FAN_ON} = 14 bar and ΔP_{FAN} = 2 bar.

3.3.7.4 Compressors stop for low external temperature

The compressors can't start if the external temperature is lower than a value T_{EXT_MIN} and, even during the functioning, the compressors are stopped if the external temperature decreases under this limit.

3.3.7.5 Compressors working hours balance

The compressors working hours have to be balanced and, in case of half power functioning, the compressor that worked less is started.

3.3.8 PRE-HEATING

The pre-heating phase is activated when the difference between the internal temperature and the reference temperature is really high.

This functioning phase is different from the heating phase only for the air lock regulation: the software completely closes the external air lock and the unit functions with recirculated air only till the temperature difference has a defined value ($T_{DIFF\_PRE\_HEAT}$- ΔT_{HYST}) or, anyway, for a defined time (t_{PRE_HEAT}). When these values have been reached, the software enables the heating phase and start modulating the external air quantity as defined at the paragraph 3.3.4.2.

In this application t_{PRE_COOL} = 60 min

3.3.9 HEATING

In this phase the unit has to implement the following functions:

- heaters insertion/uninsertion,
- air treatment fans speed regulation (as shown in the paragraph 3.3.4.1),
- external air lock control regulation (as shown in the paragraph 3.3.4.2).

Two equal heaters are used (contactors KM6 and KM7), activated with a regulation depending both on the temperature difference from the set-point and on the time.

It's possible the half power functioning or the full power functioning: the half power functioning is achieved with a single heater (the one with less working hours), the full power functioning is achieved using both the heaters.

The parameters in the regulation are:

- DIFF_HEAT: wideness of the temperature difference band (straddling T_{DIFF-}, as shown in Fig. 13) in which no action is required. If the temperature difference reaches the value T_{DIFF-} - DIFF_HEAT, the first heater is started (half power functioning),
- t_{ON_HEAT}: permanence time above the threshold after which the second heater is started (full power functioning),
- the transition to the half power functioning occurs when the temperature difference reaches the value corresponding to the transition from heating to ventilation (T_{DIFF-}),
- t_{OFF_HEAT}: permanence time under the threshold after which the second heater is stopped (complete OFF).

In this application DIFF_HEAT = 1°C, t_{ON_HEAT} = 60 sec and t_{OFF_HEAT} = 180 sec.

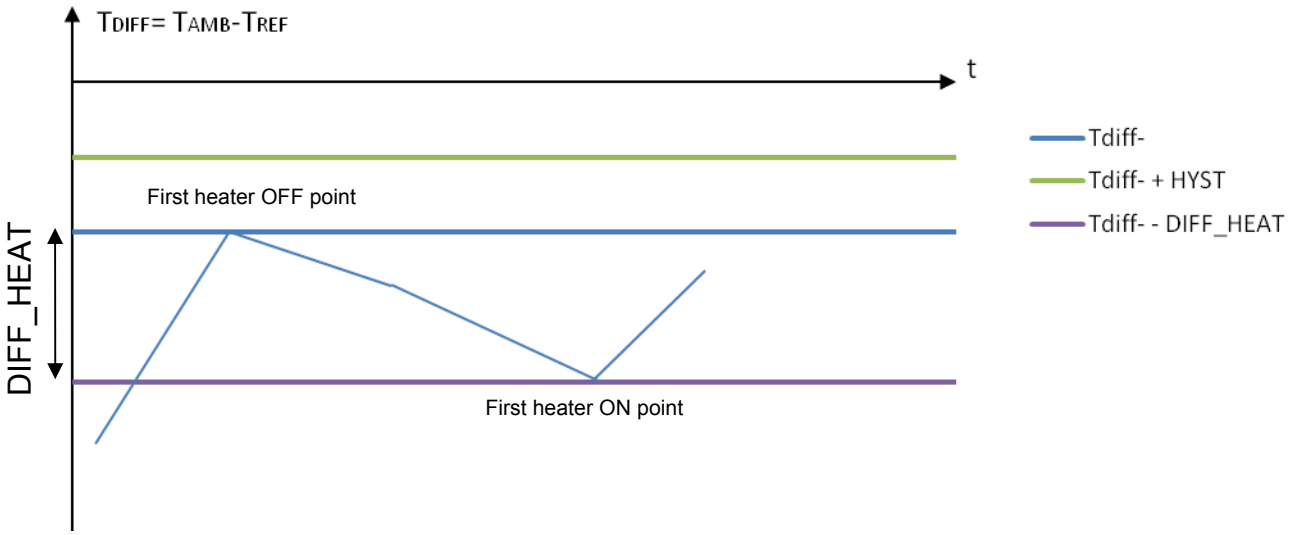


Fig. 13 First heater regulation

During the pre-heating and heating phases, also these functions are implemented:

- heaters working hours balance,
- heaters functioning control.

These control functionalities have the priority on the regulation requirements.

3.3.9.1 Heaters working hours balance

The heaters working hours have to be balanced and, in case of half power functioning, the heater that worked less is started.

3.3.9.2 Heaters functioning control

After the heaters are started, the treated air temperature is controlled and, if it doesn't raise by a value T_{HEAT_FUNC} in a time t_{HEAT_FUNC}, an alarm signal is sent.
In this application T_{HEAT_FUNC} = 2°C and t_{HEAT_FUNCT} = 10 min.

4 INTERFACE WITH THE ELECTRONIC BOARD

It is possible to interface to the electronic board through an external terminal that can be connected directly to the electronic board (connector J10) or to the connector XC4 on the unit electrical panel. The cable to be used is a telephone cable RJ 12.

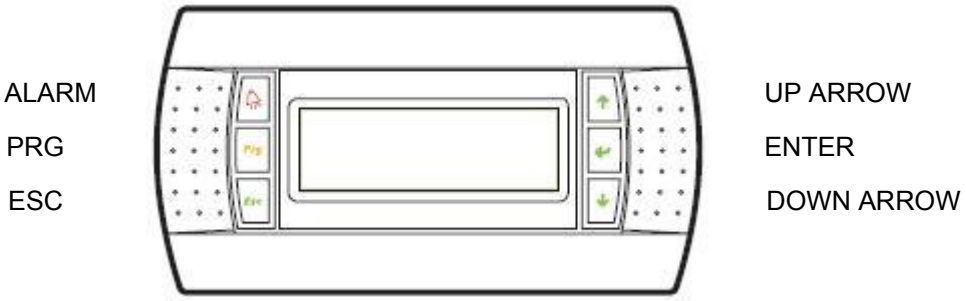


Fig. 14 External terminal

ALARM: used to display some alarms and delete them.

PRG: it is used to enter the list of screens: once you have displayed the list, use the arrow buttons to select the desired loop (branch) and confirm by pressing ENTER.

ESC: it is used to return to the previous branch.

UP: it has two functions, a) scroll to the previous screens in the same branch when the cursor is in the home position (top left corner); b) increase the value of a setting field when the cursor is inside the field; for selection fields, on the other hand, pressing the arrow button displays the previous option.

DOWN: it has two functions, a) scroll to the next screens in the same branch when the cursor is in the home position (top left corner); b) decrease the value of a setting field when the cursor is inside the field; for selection fields, on the other hand, pressing the arrow button displays the next option.

ENTER: used to move the cursor between the home position (in the top left) and the setting or selection fields, or to save the values set for the parameters after the cursor has left the setting fields.

UP + ENTER + DOWN: pressing these buttons together accesses the screen for setting the address of the external terminal.

4.1.1 Setting of the address of the terminal

The address of the terminal can be set in the range between 0 and 32; addresses from 1 to 32 are used by the pLAN protocol, while address 0 identifies the Local terminal protocol, used for point-to-point connections. The default address is 32. The address can only be set after having powered up the terminal via the RJ12 connector. To access configuration mode, press the UP, ENTER and DOWN buttons together for at least 5 seconds; the terminal will display a screen similar to the one shown below, with the cursor flashing in the top left corner.

```
+--------------------+
|Display address     |
|setting.....:32|
|                    |
|I/O Board address:xx|
+--------------------+
```

To change the address of the terminal (“Display address setting”), proceed as follows.

- Press the ENTER button once: the cursor will move to the “Display address setting” field.
- Select the desired value using the UP and DOWN buttons, and confirm by pressing ENTER again.

If the value selected is different from the value previously saved, the following screen will be displayed and the new value will be saved to the permanent memory.

```
+--------------------+
|Display address     |
|changed             |
|                    |
|                    |
+--------------------+
```

NOTE

Set the address field to 0 in order to use the Local terminal protocol. The “I/O Board address” field is no longer shown, as it has no meaning.

4.1.2 List of screens

The user interface of this application is divided into loops (branches) of screens.
All the accessible screens are shown in the following. On the right there is the explanation of the values. Those screens are the ones related to the WRM236 unit; the ones shown connecting to a WRM236SC unit are similar but not all the values are present.

4.1.2.1 Main screen

The main loop of screens on the display shows the temperature and pressure values.
As already explained, the HVAC uses the following transducers:

- o temperature:
  - nr. 3 inside each HVAC — recirculated (internal) air temperature probe
    external air temperature probe
    treated air temperature probe
  - nr. 2 inside the passenger area — internal air temperature probe
- o pressure:
  - nr. 2 inside each HVAC — high pressure transducers
  - nr. 2 inside each HVAC — low pressure transducers

```
main
+--------------------+
| 00:00      00/00/00|          TIME          DATE
|T.Rif.       000.0°C|          REFERENCE TEMPERATURE
|T.ambiente   000.0°C|          INTERNAL TEMPERATURE
|Sistema ON          |          SYSTEM CONDITION
+--------------------+
```

The system condition can be: ON, OFF, OFF DA ALLARME (OFF caused by an alarm).
The symbol ⍈ near the system condition means that the control of the unit is from CAN BUS.

```
main_a
+--------------------+
|T.diff.      000.0°C|          DIFFERENCE BETWEEN INTERNAL AND REFERENCE TEMP.
|Set.comp.    000.0°C|          COMPRESSORS SET TEMPERATURE
|Set.res.     000.0°C|          HEATERS SET TEMPERATURE
|T.canale     000.0°C|          TREATED AIR TEMPERATURE
+--------------------+
```

```
main_b
+--------------------+
|Freecooling No      |          FREECOOLING (NOT APPLICABLE)
|                    |
|Stato sys           |          SYSTEM STATUS
|Stato reg PCool     |          REGULATION STATUS
+--------------------+
```

The system status can be: OFF, CLIMA (air-conditioning), HEAT (heating), VENT (ventilation).

The regulation status can be: PCOOL (pre-cooling), COOL (cooling), HEAT (heating), PHEAT (pre-heating), VENT (ventilation).

```
main_c
+--------------------+
|T.Ambiente 1 000.0°C|          INTERNAL TEMPERATURE 1
|T.Ambiente 2 000.0°C|          INTERNAL TEMPERATURE 2
|T.Ambiente 3 000.0°C|          INTERNAL (RECIRCULATED)TEMPERATURE 3
|T.Esterna    000.0°C|          EXTERNAL TEMPERATURE
+--------------------+

main_d
+--------------------+
|Alta Prs.1  000.0bar|          HIGH PRESSURE CIRCUIT 1
|Alta Prs.2  000.0bar|          HIGH PRESSURE CIRCUIT 2
|Bassa Prs.1 000.0bar|          LOW PRESSURE CIRCUIT 1
|Bassa Prs.2 000.0bar|          LOW PRESSURE CIRCUIT 2
+--------------------+

m_history
+--------------------+
|       N°0000       |          ALARM NUMBER
|Codice allarme   000|          ALARM CODE
|Ora            00:00|          TIME
|Data        00/00/00|          DATE
+--------------------+
```

In the alarm history 1000 alarm codes can be recorded. In this screen the first one is shown, the ENTER button has to be used in order to enter the list, the UP and DOWN buttons in order to glance through the list. The alarm codes are listed in paragraph 2.4.

```
m_default1
+--------------------+
|Reset storico       |          RESET ALARM HISTORY
|degli allarmi  N    |
|                    |
|                    |
+--------------------+
```

In order to reset the alarm history:

- press the ENTER button,
- use the UP or DOWN button in order to change the value into Y,
- press the ENTER button again.

All the alarms will be deleted.

4.1.2.2 Alarm screens

The alarm screens are shown by pressing the ALARM button.

Only the alarms related to the temperature or pressure transducers or to the expansion board are displayed on this screen. All the other alarms are only registered in the alarms history (see paragraph 4.1.2.1).

```
alarm0
+--------------------+
|                    |
|   NESSUN ALLARME   |        NO ALARMS
|       ATTIVO       |
|                    |
+--------------------+

al_1
+--------------------+
|               AL01|
|   ALLARME SONDA    |        ALARM - HIGH PRESSURE
|  ALTA PRESSIONE 2  |        TRANSDUCER 2 BROKEN
|ROTTA O NON CONNESSA|        OR NOT CONNECTED
+--------------------+

al_2
+--------------------+
|               AL02|
|   ALLARME SONDA    |        ALARM - TREATED AIR
| TEMPERATURA CANALE |        TEMPERATURE PROBE BROKEN
|ROTTA O NON CONNESSA|        OR NOT CONNECTED
+--------------------+

al_3
+--------------------+
|               AL03|
|   ALLARME SONDA    |        ALARM – INTERNAL
|  TEMP. AMBIENTE 1  |        TEMPERATURE PROBE 1
|ROTTA O NON CONNESSA|        BROKEN OR NOT CONNECTED
+--------------------+
```

al_4

AL04
ALLARME SONDA TEMP. AMBIENTE 2 ROTTA O NON CONNESSA

ALARM – INTERNAL TEMPERATURE PROBE 2 BROKEN OR NOT CONNECTED

al_5

AL05
ALLARME SONDA BASSA PRESSIONE 1 ROTTA O NON CONNESSA

ALARM – LOW PRESSURE TRANSDUCER 1 BROKEN OR NOT CONNECTED

al_6

AL06
ALLARME SONDA ALTA PRESSIONE 1 ROTTA O NON CONNESSA

ALARM – HIGH PRESSURE TRANSDUCER 1 BROKEN OR NOT CONNECTED

al_7

AL07
ALLARME SONDA BASSA PRESSIONE 2 ROTTA O NON CONNESSA

ALARM – LOW PRESSURE TRANSDUCER 2 BROKEN OR NOT CONNECTED

al_8

AL08
ALLARME SONDA TEMP. AMBIENTE 3 ROTTA O NON CONNESSA

ALARM – INTERNAL TEMPERATURE PROBE 3 BROKEN OR NOT CONNECTED

al_9

AL09
ALLARME SONDA TEMPERATURA ESTERNA ROTTA O NON CONNESSA

ALARM – EXTERNAL TEMPERATURE PROBE BROKEN OR NOT CONNECTED

al_10

AL10
ALLARME ESPANSIONE OFFLINE

ALARM – EXPANSION BOARD OFFLINE

4.1.2.3 Menu screen

This menu is used to access all the other loops of screens. It is shown by pressing the button PRG.

```
menu
+--------------------+
|Utente              |        USER
|Costruttore         |        MANUFACTURER
|Manutenzione        |        MAINTENANCE
|In/Out              |        IN/OUT
+--------------------+

menu1
+--------------------+
|Setpoint            |        SETPOINT
|Versione            |        VERSION
|Orologio            |        CLOCK
|Stato unita'        |        UNIT STATUS
+--------------------+
```

USER loop of screens is not used, MANUFACTURER loop of screens is not accessible, all the other loops of screens are detailed in the following.

4.1.2.4 Maintenance screen

```
manut
+--------------------+
|                    |
|Inserire password   |        INSERT MAINTENANCE
|Manutenzione...0000 |        PASSWORD
|                    |
+--------------------+
```

For the access to the maintenance section a password is required.

In order to insert the password:

- press the ENTER button,
- use the UP or DOWN button in order to change the password value,
- press the ENTER button again.

```
menu_manut
+--------------------+
|Manutenzione        |        MAINTENANCE
|Calibrazione sonde  |        PROBES CALIBRATION
|Password            |        PASSWORD
|                    |
+--------------------+
```

By entering the menu MAINTENANCE there is the possibility to set a value for the outputs of the controller. The unit has to be in the condition OFF in order to use the manual settings. The outputs screens are detailed in the following.

In order to switch on a component:

- press the ENTER button,
- use the UP and DOWN button in order to move on the required output,
- press the ENTER button,
- use the UP or DOWN button in order to change the value into YES (for digital outputs) or to set the required percentage (for analogical 0÷10 V outputs),
- press the ENTER button again.

```
manut2
+--------------------+
|Forzature manuali:  |        MANUAL SETTINGS
|01:V.Cond.1      No |        01: CONDENSER FAN 1
|02:V.Cond.2      No |        02: CONDENSER FAN 2
|03:Res.Carter    No |        03: CRANCASE HEATER
+--------------------+

manut3
+--------------------+        07: COMPRESSOR 1
|07:Compressore 1 No |        08: COMPRESSOR 2
|08:Compressore 2 No |        12: HEATER 1
|12:Batteria 1    No |        13: HEATER 2
|13:Batteria 2    No |
+--------------------+

manut4
+--------------------+
|14:Impianto ON   No |        14: UNIT ON
|01:Vent.TA 1  000.0%|        01: AIR TREATMENT FAN 1
|02:Vent.TA 2  000.0%|        02: AIR TREATMENT FAN 2
|03:Serranda 1 000.0%|        03: AIR LOCK 1
+--------------------+

manut5
+--------------------+
|04:Serranda 2 000.0%|        04: AIR LOCK 2
|                    |
|                    |
|                    |
+--------------------+
```

4.1.2.5 IN/OUT screen

This section allows to check all the input and output values.
The symbol C signifies presence of the 24V signal, the symbol A signifies no signal. For a detailed description of the digital inputs and outputs, see paragraph 3.3.1.

```
din
+--------------------+
|Ingressi Digitali   |        DIGITAL INPUTS
|01:Sensore Fumo  C  |        01: SMOKE DETECTOR
|02:Presenza MT 1 C  |        02: MT PRESENCE CIRCUIT 1
|03:Termico V.TA2 C  |        03: AIR TREATMENT FAN 1 CIRCUIT BREAKER
+--------------------+

din_1
+--------------------+
|04:Presenza MT 2 C  |
|05:Termico C.1   C  |        04: MT PRESENCE CIRCUIT 2
|06:Termico V.C.1 C  |        05: COMPRESSOR 1 CIRCUIT BREAKER
|07:Termico V.TA2 C  |        06: CONDENSER FAN 1 CIRCUIT BREAKER
+--------------------+        07: AIR TREATMENT FAN 2 CIRCUIT BREAKER

din_2
+--------------------+
|08:Termico C.2   C  |        08: COMPRESSOR 2 CIRCUIT BREAKER
|09:Termico V.C.2 C  |        09: CONDENSER FAN 2 CIRCUIT BREAKER
|10:Trm.Batt. 1   C  |        10: HEATER 1 CIRCUIT BREAKER
|11:Trm.Batt. 2   C  |        11: HEATER 2 CIRCUIT BREAKER
+--------------------+

din_3
+--------------------+
|12:Prst.A/B 1    C  |        12: HIGH OR LOW PRESSURE SWITCH CIRCUIT 1
|13:Prst.A/B 2    C  |        13: HIGH OR LOW PRESSURE SWITCH CIRCUIT 2
|14:Config. ID1   C  |        14: ID1 - CONFIGURATION
|15:Config. ID2   C  |        15: ID2 - CONFIGURATION
+--------------------+

din_4
+--------------------+
|16:Config. ID3   C  |        16: ID3 – CONFIGURATION
|17:Trm.Batt. 1/2 C  |        17: HEATERS THERMOSTAT
|18:Prst.Diff.    C  |        18: AIR PRESSURE SWITCH
|                    |
+--------------------+

din_5_exp1
+--------------------+        EXPANSION BOARD DIGITAL INPUTS
|Ingressi Dig. EXP1  |        01: SB2/1
|01:Comando SB2/1 C  |        02: SET-POINT TEMPERATURE + 2°C
|02:Setpoint + 2  C  |        03: SET-POINT TEMPERATURE - 2°C
|03:Setpoint - 2  C  |
+--------------------+
```

```
din_6_exp1
+--------------------+
|04:Comando SB1/2 C  |        04: SB1/2
|                    |
|                    |
|                    |
+--------------------+

dout
+--------------------+
|Uscite Digitali     |        DIGITAL OUTPUTS
|01:V.Cond.1      A  |        01: CONDENSER FAN 1
|02:V.Cond.2      A  |        02: CONDENSER FAN 2
|03:Res.Carter    A  |        03: CRANCASE HEATER
+--------------------+

dout_1
+--------------------+        04.
|04:              X  |        05:
|05:              X  |        06:
|06:              X  |        07: COMPRESSOR 1
|07:Compressore 1 A  |
+--------------------+

dout_2
+--------------------+
|08:Compressore 2 A  |        08: COMPRESSOR 2
|09:              X  |        09:
|10:              X  |        10:
|11:              X  |        11:
+--------------------+

dout_3
+--------------------+
|12:Batteria 1    A  |        12: HEATER 1
|13:Batteria 2    A  |        13: HEATER 2
|14:Impianto ON   A  |        14: UNIT ON
|15:              X  |        15:
+--------------------+

dout_4
+--------------------+
|16:              X  |        16:
|17:              X  |        17:
|18:              X  |        18:
|                    |
+--------------------+

aout
+--------------------+
|Uscite Analogiche   |        ANALOGIC OUTPUTS
|01:Vent.TA 1  000.0%|        01: AIR TREATMENT FAN 1
|02:Vent.TA 2  000.0%|        02: AIR TREATMENT FAN 2
|03:Serranda 1 000.0%|        03: AIR LOCK 1
+--------------------+
```

```
aout_1
+--------------------+
|04:Serranda 2 000.0%|        04: AIR LOCK 2
|05:           ---.-%|        05:
|06:           ---.-%|        06:
|                    |
+--------------------+
```

4.1.2.6 Set point screen

```
setp
+--------------------+
|Setpoint:           |        SETPOINT:
|Compressori  000.0°C|        COMPRESSORS:
|Resistenze   000.0°C|        HEATERS:
|                    |
+--------------------+
```

4.1.2.7 Version screen

```
version
+--------------------+
|   WEBASTO S.P.A.   |
|Codice..CWP3WEBICC0B|        SOFTWARE CODE:
|Ver.: .   00/00/0000|        SOFTWARE VERSION:
|                    |
+--------------------+

version1
+--------------------+
|                    |
|Bios:   .00 00/00/00|        BIOS:
|Boot:   .00 00/00/00|        BOOT:
|                    |
+--------------------+

version2
+--------------------+
|Scheda pCO          |        PCO ELECTRONIC BOARD
|installata          |        INSTALLED
|Scheda:             |        BOARD:
|                    |
+--------------------+
```

4.1.2.8 Clock screen

```
reg_time
+--------------------+
|Regolazione Orologio|        CLOCK SETTING
|Ora: 00:00          |        TIME:
|Data: 00/00/00      |        DATE:
|Abil. fasce   No    |
+--------------------+
```

4.1.2.9 State screen

```
unit_state
+--------------------+
|                    |
|   Stato Unita':    |        UNIT STATE:
|    Unita' OFF      |
|                    |
+--------------------+
```

5 PREVENTIVE MAINTENANCE

5.1 PREVENTIVE MAINTENANCE PLANNING

MAINTENANCE TASK FREQUENCY	*OPERATION*	*WRM236*	*WRM236SC*
2 months	AIR FILTERS CLEANING	X	X
6 months	AIR FILTERS REPLACEMENT	X	X
6 months	HVAC SEASONAL FUNCTIONING CHECK	X	X
1 year	CONDENSERS CLEANING	X	X
1 year	EVAPORATORS AND HEATERS CLEANING AND CONDENSATE DISCHARGES CONTROL	X	(X)
1 year	ELECTRICAL PANEL CLEANING AND WIRING CONTROL	X	X
1 year	CURRENT ABSORPTION MEASUREMENT	X	X
1 year	FILTER DRIERS – MOISTURE INDICATORS VISUAL CHECK	X	X
1 year	HP AND LP PRESSURE SWITCH FUNCTIONING CHECK	X	
1 year	VIBRATION LIMITERS INSPECTION AND WELDING CONTROL	X	
1 year	COMPRESSORS AND FANS CLEANING AND INSPECTION	X	(X)
5 years	REPLACEMENT OF THE PHIAL OF THE TEMPERATURE CIRCUIT BREAKERS	X	
5 years	FILTER DRIERS REPLACEMENT	X	X

5.1.1 AIR FILTERS CLEANING

Frequency:

- 2 months.

Materials/tools:

- Standard workshop tools.

Preliminary operations:

- Take off the power supply.
- Operate only on a railway track without overhead power line or ground the electrical line through an appropriate insulating rod.

Procedure:

1) Accede to the package HVAC system on the roof.
2) Open the cover air treatment side by removing the 8 M6 screws and pull it up.
3) Extract the air filters.
4) Examine the filters clogging and, if not excessive, clean with water.
5) Before the remounting the filters have to be perfectly dry.
6) Replace the air filters in case the operation hasn't removed completely the impurities.
7) Close the cover using all the bolts and washers previously removed.

5.1.2 AIR FILTERS REPLACEMENT

Frequency:

- 6 months.

Materials/tools:

Standard workshop tools.

- Nr. 2 mixed air filters.
- Nr. 2 fresh air filters.

Preliminary operations:

- Take off the power supply.
- Operate only on a railway track without overhead power line or ground the electrical line through an appropriate insulating rod.

Procedure:

1) Accede to the package HVAC system on the roof.
2) Open the cover of the air treatment area after removing the 8 M6 screws and pull it up.
3) Remove the brackets on the fresh air filters and extract them.
4) Extract the mixed air filters.
5) Replace the air filters in case the operation hasn't removed completely the impurities.
6) Close the cover using all the bolts and washers previously removed.

5.1.3 HVAC SEASONAL FUNCTIONING CHECK

Frequency:

- 6 months.

Materials/tools:

- Standard workshop tools.
- Notebook.

Preliminary operations:

- Take off the power supply.
- Operate only on a railway track without overhead power line or ground the electrical line through an appropriate insulating rod.
- Supply the HVAC through a socket.
- Switch on the air-conditioning unit.

DANGER

During this operation the system has to be supplied so the voltage is present.

Procedure:

1) Accede to the package HVAC system on the roof.
2) Open the electrical panel cover after removing the 3 M6 screws and keep it opened by using the appropriate rod.
3) Connect the external terminal to the electronic board (connector J10) using a telephone cable RJ 12.
4) Verify:

- the coherence between the requests and the functioning mode,
- the excitation of the contactors,
- eventually the intervention of circuit breakers, pressure switches and thermostats,
- the functioning of the external air lock.

5.1.4 CONDENSERS CLEANING

Frequency:

- 1 year.

Materials/tools:

- Standard workshop tools.
- Water low-pressure washer with a specific cleaning agent.

Preliminary operations:

- Take off the power supply.
- Operate only on a railway track without overhead power line or ground the electrical line through an appropriate insulating rod.

Procedure:

1) Accede to the package HVAC system on the roof.
2) Open the covers of the condensing area after removing the 3+3 M6 screws and keep them opened by using the appropriate rod.
3) Raise the condenser fans after removing the 3 M6 screws.
4) Wash the condensers by using a water low-pressure washer (maximum pressure 10 bar at a 30 cm distance) and a specific cleaning agent. Remove all the dirt in the condensers rows.
5) Wait above 30 minutes.
6) Rinse out whit the water low-pressure washer.
7) Control the welding condition.
8) Close all the covers using all the bolts and washers previously removed.

5.1.5 EVAPORATORS AND HEATERS CLEANING AND CONDENSATE DISCHARGES CONTROL

Frequency:

- 1 year.

Materials/tools:

- Standard workshop tools.
- Air compressor.

Preliminary operations:

- Take off the power supply.
- Operate only on a railway track without overhead power line or ground the electrical line through an appropriate insulating rod.

Procedure:

1) Accede to the package HVAC system on the roof.
2) Open the cover of the air treatment area after removing the 8 M6 screws and pull it up.
3) Extract the mixed air filters.
4) Clean the evaporators and the electrical heaters (where installed) by using an air compressor (maximum pressure 6 bar at a 30 cm distance). Remove all the dirt in the evaporators rows.
5) Accurately clean the condensate drainage basins and the discharge holes.
6) Full with water the condensate drainage basins under the evaporators and check that they correctly empty.
7) Control the welding condition.
8) Remount the mixed air filters.
9) Close the cover using all the bolts and washers previously removed.

5.1.6 ELECTRICAL PANEL CLEANING AND WIRING CONTROL

Frequency:

- 1 year.

Materials/tools:

- Standard workshop tools.
- Vacuum cleaner.

Preliminary operations:

- Take off the power supply.
- Operate only on a railway track without overhead power line or ground the electrical line through an appropriate insulating rod.

Procedure:

1) Accede to the package HVAC system on the roof.
2) Open the electrical panel cover after removing the 3 M6 screws and keep it opened by using the appropriate rod.
3) Clean every kind of dirt and debris in the electrical panel by using a vacuum cleaner.
4) Check the wiring fastening and make sure there aren't burn marks or corrosions.
5) Check the electronic board is correctly fixed.
6) Check the contactors are correctly fixed and not damaged.
7) Replace every component eventually damaged.
8) Close the electrical panel cover using all the bolts and washers previously removed.

5.1.7 CURRENT ABSORPTION MEASUREMENT

Frequency:

- 1 year.

Materials/tools:

- Standard workshop tools.
- Amperometric tester.
- Notebook.

Preliminary operations:

- Take off the power supply.
- Operate only on a railway track without overhead power line or to ground the electrical line through an appropriate insulating rod.
- Supply the HVAC through a socket.

DANGER

During this operation the system has to be supplied so the voltage is present.

Procedure:

1) Accede to the package HVAC system on the roof.
2) Open the electrical panel cover after removing the 3 M6 screws and keep it opened by using the appropriate rod.
3) Connect the external terminal to the electronic board (connector J10) using a telephone cable RJ 12.
4) Position the amperometric tester on a supply cable, in particular:

- compressors → contactors KM1 and KM4 (when provided),
- condenser fans → contactors KM2 and KM5,
- air treatment fans → contactors KM3 and KM9,
- electrical heaters → contactors KM6 and KM7 (when provided).

5) After entering the MAINTENANCE menu, start the components and measure their absorption.

ATTENTION

Always switch on the fans before switching on the compressors and the heaters.

6) Check the absorptions is under the rating values (detailed in the following); if surpassed the component has to be replaced.
7) After leaving the MAINTENANCE menu, disconnect the external terminal.
8) Close the electrical panel cover using all the bolts and washers previously removed.

Rating values:

- compressors → 13 A (when provided),
- condenser fans → 1,7 A,
- air treatment fans → 3,2 A,
- electrical heaters → 11,5 A (when provided).

5.1.8 FILTER DRIERS – MOISTURE INDICATORS VISUAL CHECK

Frequency:

- 1 year.

Materials/tools:

- Standard workshop tools.

Preliminary operations:

- Switch on the air-conditioning unit and let it works at least 5/10 minutes.
- Switch off the unit.
- Take off the power supply.
- Operate only on a railway track without overhead power line or ground the electrical line through an appropriate insulating rod.

Procedure:

1) Accede to the package HVAC system on the roof.
2) Open the cover of the compressors area after removing the 3 M6 screws and keep it opened by using the appropriate rod.
3) Visually check the moisture indicators (one for every circuit).
4) If the indicator is green, the percentage of moisture in the circuit is under the limit and no further actions are required.
5) If the indicator is yellow, the percentage of moisture in the circuit is above the limit and the filter drier has to be replaced.
6) If the indicator is translucent or brown, there is oil in excess in the circuit. The indicator, in this situation, temporarily loses its faculty to change colour but it hasn't to be considered permanently damaged. The fluid circulating is able to remove the excess of oil and to re-establish the standard functioning condition.
7) The air bubbles presence indicates the lack of refrigerant.

NOTE

Before deciding the lack of refrigerant and performing the recharge operation, the bubbles presence has to be steady; some bubbles don't prejudice the functioning.

8) Close the cover using all the bolts and washers previously removed.

5.1.9 HP AND LP PRESSURE SWITCH FUNCTIONING CHECK

Frequency:

- 1 year.

Materials/tools:

- Standard workshop tools.
- Notebook.

Preliminary operations:

- Take off the power supply.
- Operate only on a railway track without overhead power line or to ground the electrical line through an appropriate insulating rod.
- Supply the HVAC through a socket.
- Switch on the air-conditioning unit.

DANGER

During this operation the system has to be supplied so the voltage is present.

Procedure:

1) Accede to the package HVAC system on the roof.
2) In order to force the intervention of the HP pressure switch, stop the condenser fans or obstruct the condenser air inlets by means of some cardboard.
3) In order to force the intervention of the LP pressure switch, stop the air treatment fans.
4) Connect the external terminal to the electronic board (connector J10) using a telephone cable RJ 12.
5) In the I/O menu, check the intervention of the pressure switches and their re-arming.

5.1.10 VIBRATION LIMITERS INSPECTION AND WELDING CONTROL

Frequency:

- 1 year.

Materials/tools:

- Standard workshop tools.

Preliminary operations:

- Take off the power supply.
- Operate only on a railway track without overhead power line or ground the electrical line through an appropriate insulating rod.

Procedure:

1) Accede to the package HVAC system on the roof.
2) Open the cover of the compressors area after removing the 3 M6 screws and keep it opened by using the appropriate rod.
3) Visually check if there are refrigerant losses on the vibration limiters welded to the compressor suction and discharge pipes.
4) Control the welding conditions.
5) Close the cover using all the bolts and washers previously removed.

5.1.11 COMPRESSORS AND FANS CLEANING AND INSPECTION

Frequency:

- 1 year.

Materials/tools:

- Standard workshop tools.
- Air compressor.

Preliminary operations:

- Take off the power supply.
- Operate only on a railway track without overhead power line or ground the electrical line through an appropriate insulating rod.

Procedure:

1) Accede to the package HVAC system on the roof.
2) Open the cover of the compressors area after removing the 3 M6 screws and keep it opened by using the appropriate rod.
3) Clean the compressor area by using an air compressor.
4) Verify the absence of damages or burns on the compressors.
5) Control the welding conditions.
6) Open the covers of the condensing area after removing the 3+3 M6 screws and keep them opened by using the appropriate rod.
7) Clean the condenser area by using an air compressor.
8) Open the cover of the air treatment area after removing the 8 M6 screws and pull it up.
9) Clean also the air treatment area by using an air compressor.
10) Close all the covers.

5.1.12 REPLACEMENT OF THE PHIAL OF THE TEMPERATURE CIRCUIT BREAKERS

Frequency:

- 5 years.

Materials/tools:

- Standard workshop tools.
- N° 1 phial for the temperature circuit breaker.

Preliminary operations:

- Take off the power supply.
- Operate only on a railway track without overhead power line or ground the electrical line through an appropriate insulating rod.

DANGER

The heaters have to grow cold before access the temperature circuit breaker.

Procedure:

1) Accede to the package HVAC system on the roof.
2) Open the cover of the air treatment area after removing the 8 M6 screws and pull it up.
3) Unscrew the cap on the head of the circuit breaker and extract it from its side.
4) Clean the interior side and insert a new phial.
5) Restore the previous conditions repeating all the operation in the inverse sense.
6) Close the cover using all the bolts and washers previously removed.

5.1.13 FILTER DRIERS REPLACEMENT

Frequency:

- 5 years.

Materials/tools:

- Standard workshop tools.
- Refrigerant recovery system.
- Recovery cylinder.
- Welding torch.
- 4-way manifold gauge set.
- Flexible hoses.
- Nitrogen cylinder.
- Refrigerant recovery system.
- Vacuum pump.
- R407C refrigerant cylinder.
- N° 2 filter driers.

Preliminary operations:

- Take off the power supply.
- Operate only on a railway track without overhead power line or ground the electrical line through an appropriate insulating rod.

Procedure:

1) Accede to the package HVAC system on the roof.
2) Open the cover of the compressors area after removing the 3 M6 screws and keep it opened by using the appropriate rod.
3) Evacuate the frigorific circuit connecting the charging valves (low pressure charging valve EBP and high pressure charging valve EAP; see drawing nr. RMB8176: cooling circuit) and recover the refrigerant (as detailed in the par. 5.2.3).
4) Deweld the pipes of the filter drier.
5) With a flat-tip screwdriver, loosen the lock clamp on the filter drier.
6) Remove the filter drier.
7) Position the new filter drier in its location.
8) Braze the joints and, in the meantime, circulate in the frigorific circuit a nitrogen flow.
9) Clean the frigorific circuit using nitrogen. At the end, recover the nitrogen using a recovery system.
10) Evacuate the whole circuit (see par. 5.2.1).
11) Charge the refrigerant (see par. 5.2.2).

NOTE

WRM236: the refrigerant quantity is 3,2 Kg for each refrigerant circuit.

WRM236SC: the refrigerant quantity charged in the circuit depends on the length of the circuit. In this application consider a quantity of about 10,5 Kg.

12)Close the cover using all the bolts and washers previously removed.

5.2 STANDARD PROCEDURES

All these operations have to be executed by an experienced staff.

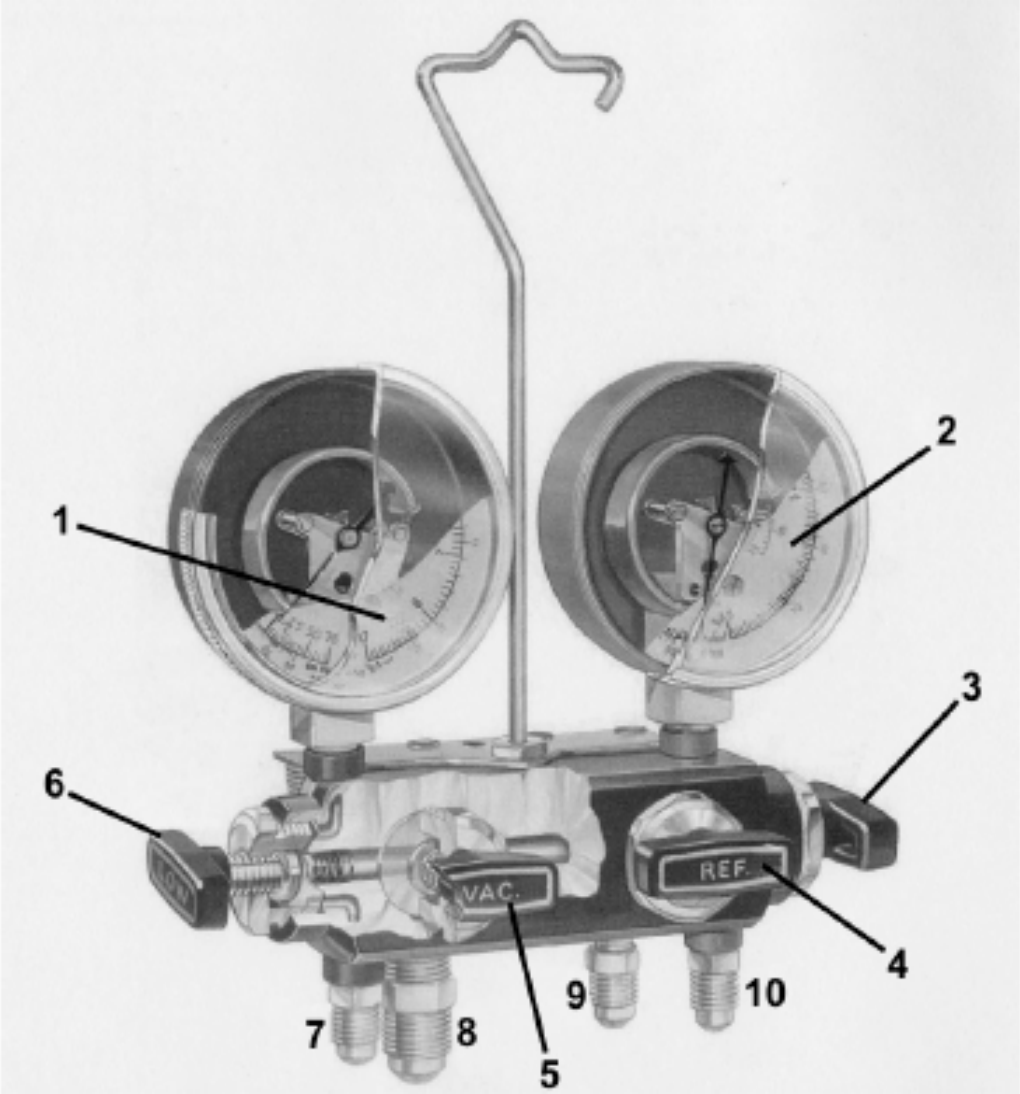
5.2.1 EVACUATION OF THE CIRCUIT

The evacuation procedure is itemized here below.

The required equipments are:

- 4-way manifold gauge set (ref. Fig. 15),
- flexible hoses,
- vacuum pump (ref. Fig. 16),
- nitrogen cylinder.

1) By means of flexible hoses, connect a manifold gauge set (ref. Fig. 15) to the charging valves of the frigorific circuit (the connection 7 has to be connected to the low pressure charging valve EBP and the connection 10 to the high pressure charging valve EAP; see drawing nr. RMB8176: cooling circuit).
2) Connect the vacuum pump (ref. Fig. 16) to the manifold gauge set (connection 8) and, after the opening of the valves 5 and 6, evacuate the circuit till a pressure < 100 Pa (with the pump ON).
3) Connect a nitrogen cylinder to the manifold gauge set (connection 9) and open the valve 4. Break the vacuum by slowly introducing in the circuit (using the cylinder regulator) some nitrogen at the pressure of 1 bar max in order to absorb the remaining moisture (with the pump OFF).
4) Evacuate another time the circuit till a pressure < 30 Pa (with the pump ON).
5) Equilibrate the internal pressure in the circuit for a 15 minutes period (with the pump OFF).
6) Measure the vacuum value; if after 15 minutes the pressure is inferior than 100 Pa go on with the following point, if it's superior restart the procedure.
7) Wait for at least 30 minutes to make sure the pressure value doesn't go back up above 50 Pa; if the test has a negative result, restart from the second evacuation.
8) Finally evacuate till a pressure < 30 Pa.
9) Detach all the hoses, except for those connected to the charging valves: close anyway the gauge set valves in order to avoid the entrance of air.



1 **Low pressure gauge**
2 **High pressure gauge**
3 **High pressure valve**
4 **Valve on the connection for the refrigerant supply tank**
5 **Valve on the connection for the vacuum pump**
6 **Low pressure valve**
7 **Connection for the low pressure side of the circuit**
8 **Connection for the vacuum pump**
9 **Connection for the refrigerant supply tank**
10 **Connection for the high pressure side of the circuit**

Fig. 15 Manifold gauge set

5.2.2 REFRIGERANT CHARGE ON THE CIRCUIT

The refrigerant charge operation is very tricky because the compressor uses a polyester oil which is more igroscopic of the mineral oil and a little quantity of air makes it not usable.

The required equipments are:

- 4-way manifold gauge set (ref. Fig. 15),
- flexible hoses,
- vacuum pump (ref. Fig. 16),
- nitrogen cylinder,
- R407C refrigerant cylinder (ref. Fig. 17).

1) With the circuit in a vacuum, connect the connection 9 of the manifold gauge set to a nitrogen cylinder.
2) Open the valves 4 e 6 and break the vacuum with some nitrogen till a pressure of 1,1 bar absolute (so 0,1 bar above the atmospheric pressure). Close the valve 6 and detach the nitrogen cylinder.
3) Connect the connection 9 of the manifold gauge set to a R407C refrigerant cylinder and charge liquid refrigerant (opening the valve 3 and 6) till the equilibrium of the pressures in the cylinder and in the circuit. The liquid refrigerant can be charged only in the condenser.

ATTENTION

The R407C refrigerant has to be charged only in the liquid state because this refrigerant is a mixture of three different gases and so, charging refrigerant in the vapour phase, there would be the risk of charging not the exact percentages of the three.

For the same reason, in a circuit using R407C refrigerant, it's not possible to top up the refrigerant: it's necessary to remove the entire charge and fully re-charge the circuit.

4) In case of a single valve cylinder, the refrigerant can be charged in the liquid state with the cylinder overturned (with the output valve down). If there is, instead, a two-valves cylinder, there is a bleu valve for the vapour phase charge and a red valve for the liquid phase charge so that it's not necessary to overturn the cylinder (ref. Fig. 17).
5) Close all valves and disconnect the manifold gauge set.

NOTE

The refrigerant quantity charged in the circuit depends on the length of the circuit. In this application consider a quantity of about 10,5 Kg.

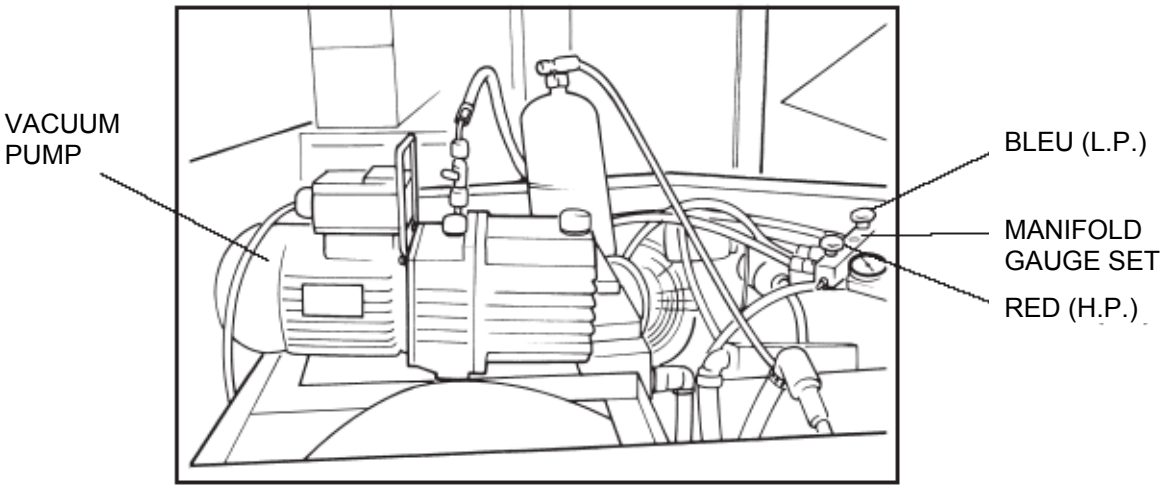
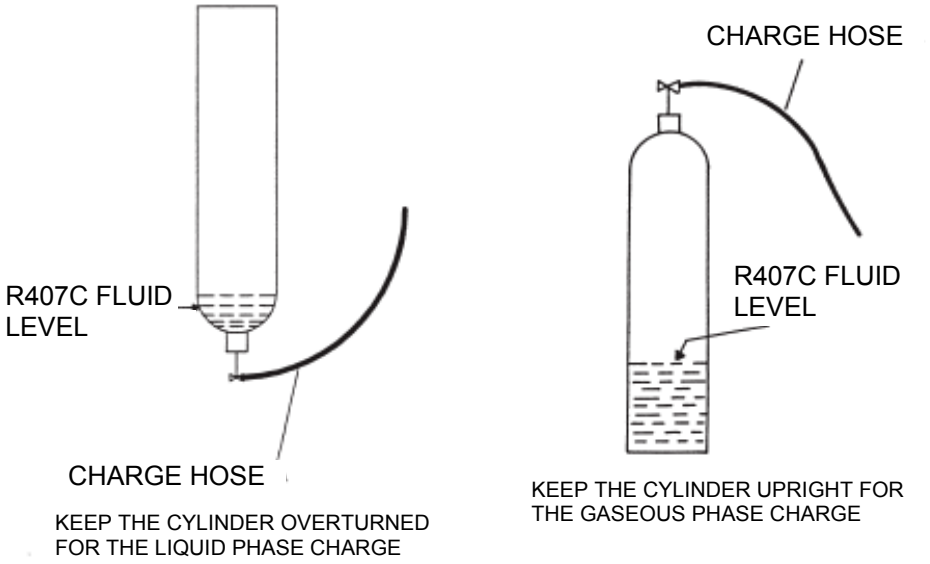
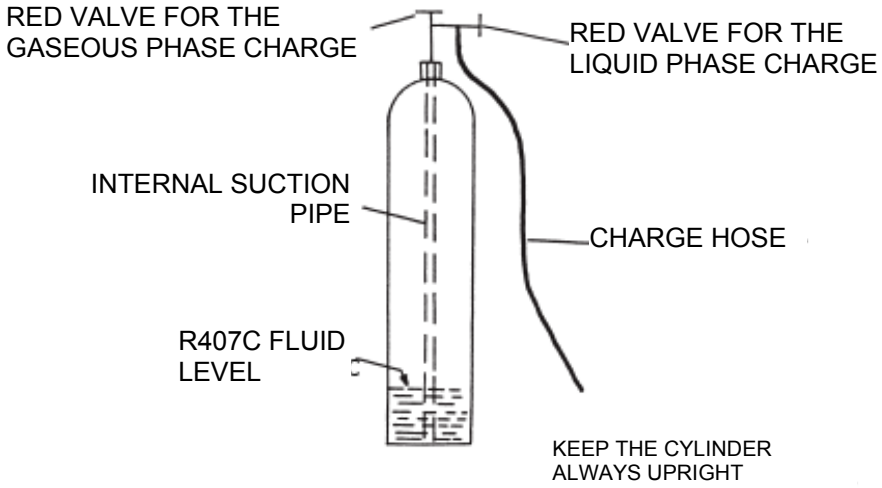


Fig. 16 Vacuum pump



SINGLE-VALVE CYLINDER



TWO-VALVES CYLINDER

Fig. 17 Refrigerant cylinder

5.2.3 REFRIGERANT RECOVERY

The refrigerant recovery is mandatory for law (Italian law 549/93 dated 20th December 1993, art. 6).

It's necessary to recover the refrigerant in the following conditions:

- if the fluid is contaminate;
- before the dismantling of the unit;
- in every case in which is necessary an intervention on the frigorific circuit.

The required equipments are:

- refrigerant recovery system,
- recovery cylinder.

The recovered fluid, if polluted, has to be delivered to the refrigerant reclaimers for the disposal.

1) Connect the vacuum pump (ref. Fig. 16) to the manifold gauge set (connection 8) and the gas valve (bleu) of the recovery cylinder to the connection 9 and, after the opening of the valves 4 and 5, evacuate the cylinder for about 10 minutes. Close the valves and disconnect the cylinder.
2) By means of flexible hoses, connect the input of the recovery system to the high pressure charging valve of the frigorific circuit (see drawing nr. RMB8176: cooling circuit) and the output of the recovery system to the gas valve (bleu) of the recovery cylinder previously evacuated.
3) Open the valves on the cylinder and on the recovery system.
4) Start the recovery system with the selector set on "liquid".
5) When the liquid refrigerant recovery is finished, move the selector on "gas".

ATTENTION

Control the weight of the refrigerant collected on the recovery cylinder; remember that its volume can be filled to the 80% at most.

6) By using the manifold gauge set on the recovery system, check when the pressure on the circuit reaches the value of about -0,3 bar and, at this moment, stop the recovery.
7) Close all the valves on the cylinder and on the recovery system.

5.2.4 REFRIGERANT LEAKS DETECTION

In order to find eventual refrigerant leaks, it's necessary to use a reliable leak detector. The presence of oil on the pipes of the refrigerant system it's the first signal of a leak.

The required equipments are:

- 4-way manifold gauge set (ref. Fig. 15),
- flexible hoses,
- R407C refrigerant cylinder (ref. Fig. 17),
- nitrogen cylinder,
- leak detector (ref. Fig. 18).

In case there has been leaks and the refrigerant has been removed from the system, the procedure is detailed in the following.

1) Control the complete system to verify a possible damage to the components.
2) By means of flexible hoses, connect a manifold gauge set (ref. Fig. 15) to the charging valves of the frigorific circuit (the connection 7 has to be connected to the low pressure charging valve EBP and the connection 10 to the high pressure charging valve EAP; see drawing nr. RMB8176: cooling circuit).
3) Connect the connection 9 of the manifold gauge set to a R407C refrigerant cylinder and open the valves 4 and 6 till the system reaches a pressure of about 345 kPa, 3.45 bar, 50 psig.
4) Verify eventual leaks with a leak detector (ref. Fig. 18) by checking all the joints and connections. If the leaks can't be found but the system lost its charge, pass to the following action.
5) Close the valve 4 and disconnect the refrigerant cylinder.
6) Connect a nitrogen cylinder to the manifold gauge set (connection 9) and open the valve 4. Break the vacuum by slowly introducing in the circuit (using the cylinder regulator) some nitrogen till the pressure of 1380 kPa, 13.80 bar, 200 psig.

ATTENTION

The nitrogen cylinders have to been used in appropriate way.

- *To always hold the protecting cap on the cylinder when it is not used.*
- *To conserve the cylinder in an appropriate area.*
- *Not to expose to an excessive heat or to the direct light of the sun.*
- *Not to bruise or to damage the cylinder and not to let it fall.*

7) Verify eventual leaks with a leak detector by checking all the joints and connections.
8) When necessary, intervene for the repair and check again the system once the repair has been completed.

NOTE

If a leak is found, diminish the pressure in the circuit and then execute the necessary repair.

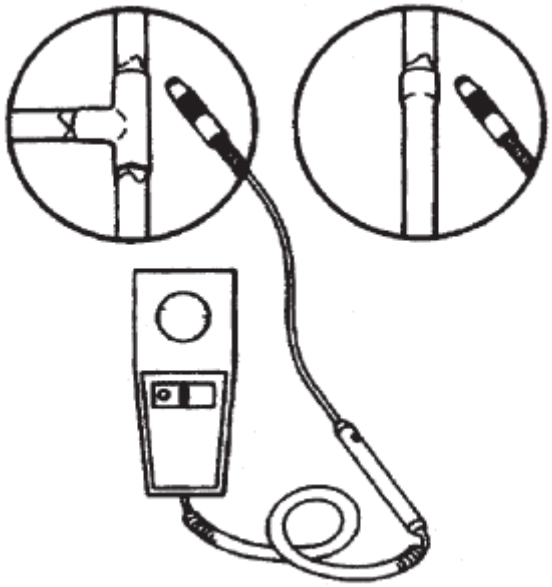


Fig. 18 Leak detector

6 MALFUNCTIONINGS AND BREAKDOWNS DIAGNOSTIC

This paragraph describes the procedures that, in case of a specific symptom, allow the location and the solution of a failure.

6.1 MALFUNCTIONINGS AND BREAKDOWNS DIAGNOSTIC TABLE

SYMPTOM	*CAUSE*	*SOLUTION*
Low refrigerant fluid level, presence of air bubbles on the level indicator of the filter drier.	Refrigerant leak through a damaged welded connection.	To find the leak and to weld the damaged connection.
LP pressure switch opened. ALARM SIGNAL	Refrigerant leak through a damaged welded connection.	To find the leak and to weld the damaged connection.
	Air filters clogging.	To clean or to replace the air filters (see paragraph 5.1.1 and 5.1.2).
	Evaporator clogging.	To clean the evaporator (see paragraph 5.1.5).
	Vibration limiter failure and refrigerant fluid leak.	To replace the vibration limiter if broken.
	Air treatment fan motor failure due to a short circuit in the windings.	To replace the air treatment fan.
	Thermostatic valve input filter partially or completely clogged.	To replace the thermostatic expansion valve.
	Failure to the thermostatic valve bulb.	To replace the thermostatic expansion valve.
HP pressure switch opened. ALARM SIGNAL	Evaporator clogging.	To clean the evaporator (see paragraph 5.1.5).
	Condenser fan motor failure due to a short circuit in the windings.	To replace the condenser fan.
	Burnt-out coil (it isn't energized) in the condenser fan contactor or burnt-out contactor.	To replace the contactor.
	Mechanical failure of the condenser fan circuit breaker.	To replace the circuit breaker.

SYMPTOM	*CAUSE*	*SOLUTION*
High moisture in the refrigerant fluid, level indicator coloured in yellow.	Moisture in the frigorific circuit.	To replace the filter drier (see paragraph 5.1.13).
Differential pressure switch opened. ALARM SIGNAL	Air filters clogging.	To clean or to replace the air filters (see paragraph 5.1.1 and 5.1.2).
	Evaporator clogging.	To clean the evaporator (see paragraph 5.1.5).
	Air treatment fan motor failure due to a short circuit in the windings.	To replace the air treatment fan.
Functioning with a low air flow and no alarm signal.	Air filters clogging.	To clean or to replace the air filters (see paragraph 5.1.1 and 5.1.2).
	Evaporator clogging.	To clean the evaporator (see paragraph 5.1.5).
	Differential pressure switch diaphragm broken.	To replace the differential pressure switch.
Ice on the evaporators or on the pipes.	Moisture in the frigorific circuit.	To replace the filter drier.
	Thermostatic valve input filter partially or completely clogged.	To replace the thermostatic expansion valve.
A compressor doesn't start.	Compressor electrical motor failure due to a short circuit in the windings (insulation breakdown).	To replace the compressor.
	Compressor mechanical failure.	To replace the compressor.
	Burnt-out coil (it isn't energized) in the compressor contactor or burnt-out contactor.	To replace the compressor contactor.
	Mechanical failure of the compressor circuit breaker.	To replace the compressor circuit breaker.
	HP pressure switch contact stuck.	To replace the HP pressure switch.
	LP pressure switch diaphragm broken.	To replace the LP pressure switch.

SYMPTOM	*CAUSE*	*SOLUTION*
Noisy functioning and vibrations of a compressor.	Loosening of the compressor anti-vibrations mounts.	To verify the condition of the anti-vibrations mounts and, if needed, to tighten or replace them.
An air treatment fan doesn't start.	Air treatment fan motor failure due to a short circuit in the windings.	To replace the air treatment fan.
	Burnt-out coil (it isn't energized) in the air treatment fan contactor or burnt-out contactor.	To replace the air tratment fan contactor.
	Mechanical failure of the air treatment fan circuit breaker.	To replace the air treatment fan circuit breaker.
Noisy functioning of an air treatment fan.	Mechanical problems at the bearings of the fan.	To replace the air treatment fan.
A condenser fan doesn't start.	Condenser fan motor failure due to a short circuit in the windings.	To replace the condenser fan.
	Burnt-out coil (it isn't energized) in the condenser fan contactor or burnt-out contactor.	To replace the condenser fan contactor.
	Mechanical failure of the condenser fan circuit breaker.	To replace the condenser fan circuit breaker.
Noisy functioning of a condenser fan.	Mechanical problems at the bearings of the fan.	To replace the condenser fan.
No temperature signal to the electronic board. ALARM SIGNAL	Failure to a temperature probe.	To replace the temperature probe.
No heating or long time to reach the set-point temperature.	Burnt out heater.	To replace the electrical heater.
	Burnt-out coil (it isn't energized) in the heater contactor or burnt-out contactor.	To replace the heater contactor.
	Mechanical failure of the heater circuit breaker.	To replace the heater circuit breaker.
Heaters no working. ALARM SIGNAL	Burnt out heater.	To replace the electrical heater.
	Burnt-out coil (it isn't energized) in the heater contactor or burnt-out contactor.	To replace the heater contactor.
	Mechanical failure of the heater circuit breaker.	To replace the heater circuit breaker.

SYMPTOM	*CAUSE*	*SOLUTION*
Heaters protection 1st level thermostat repeated opened. ALARM SIGNAL	Air filters clogging.	To clean or to replace the air filters.
	Electrical heaters clogging.	To clean the electrical heaters.
	Air treatment fan motor failure due to a short circuit in the windings.	To replace the air treatment fan.
	Mechanical failure of the air treatment fan circuit breaker.	To replace the air treatment fan circuit breaker.
Heaters protection 2nd level thermostat opened. ALARM SIGNAL	Heaters protection 1st level thermostat damaged and air filters clogging.	To replace the 1st level thermostat and to clean or to replace the air filters (see paragraph 5.1.1 and 5.1.2).
	Air treatment fan motor failure due to a short circuit in the windings.	To replace the air treatment fan.
	Mechanical failure of the air treatment fan circuit breaker.	To replace the air treatment fan circuit breaker.
Reverse phase relay opened. ALARM SIGNAL	No MV power supply. Wrong phase sequence.	To check the electrical connections.
Compressor circuit breaker opened. ALARM SIGNAL	Compressor current absorption too high.	The circuit breaker has to be rearmed: if there is another opening, the compressor has to be checked.
Condenser fan circuit breaker opened. ALARM SIGNAL	Condenser fan current absorption too high.	The circuit breaker has to be rearmed: if there is another opening, the condenser fan has to be checked.
Air treatment fan circuit breaker opened. ALARM SIGNAL	Air treatment fan current absorption too high.	The circuit breaker has to be rearmed: if there is another opening, the air treatment fan has to be checked.
Electrical heater circuit breaker opened. ALARM SIGN□AL	Electrical heater current absorption too high.	The circuit breaker has to be rearmed: if there is another opening, the electrical heater has to be checked.

SYMPTOM	*CAUSE*	*SOLUTION*
Temperature probe disconnected / out of range. ALARM SIGNAL	Temperature probe disconnected. Temperature probe broken.	To verify the connection of the probe. To replace the temperature probe.
Pressure transducer disconnected / out of range. ALARM SIGNAL	Pressure transducer disconnected. Pressure transducer broken.	To verify the connection of the transducer. To replace the transducer.

7 ATTACHEMENTS

- General WRM assembly drawings PGD-WPI-UT-023-06C sheet 1, 2, 3, 4, 5
- Assembly drawings 60ACB7338B sheet 1, 2
  60ACB7339C sheet 1, 60ACB7339B sheet 2
- Electrical wiring diagrams RMB77851H – RMB7852H
- Cooling circuit RMB8175B – RMB8176B