Operating Manual
D-EOMCP00112-20_02EN

Air Cooled chiller/heat pump with screw compressors

EWYD_BZ

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1   SAFETY CONSIDERATIONS

1.1   General

Installation, start-up and servicing of equipment can be hazardous if certain factors particular to the installation are not considered: operating pressures, presence of electrical components and voltages and the installation site (elevated plinths and built-up up structures). Only properly qualified installation engineers and highly qualified installers and technicians, fully trained for the product, are authorized to install and start-up the equipment safely.
During all servicing operations, all instructions and recommendations, which appear in the installation and service instructions for the product, as well as on tags and labels fixed to the equipment and components and accompanying parts supplied separately, must be read, understood and followed.
Apply all standard safety codes and practices.
Wear safety glasses and gloves.

> *Do not operate on a faulty fan, pump or compressor before the main switch has been shut off. Overtemperature protection is auto-reset, therefore the protected component may restart automatically if temperature conditions allow it.*

In some unit a push button is placed on a door of the unit electrical panel. The button is highlighted by a red color in yellow background. A manual pressure of the emergency stop button stops all loads from rotating, thus preventing any accident which may occur. An alarm is also generated by the Unit Controller. Releasing the emergency stop button enables the unit, which may be restarted only after the alarm has been cleared on the controller.

> *The emergency stop causes all motors to stop, but does not switch off power to the unit. Do not service or operate on the unit without having switched off the main switch.*

1.2   Before switching the unit

Before switching on the unit read the following recommendations:

- When all the operations and all the settings have been carried out, close all the switchbox panels
- The switchbox panels can only be opened by trained personnel
- When the UC requires to be accessed frequently the installation of a remote interface is strongly recommended
- LCD display of the unit controller may be damaged by extremely low temperatures (see chapter 2.4). For this reason, it is strongly recommended to never power off the unit during winter, especially in cold climates.

1.3   Avoid electrocution

Only personnel qualified in accordance with IEC (International Electrotechnical Commission) recommendations may be permitted access to electrical components. It is particularly recommended that all sources of electricity to the unit be shut off before any work is begun. Shut off main power supply at the main circuit breaker or isolator.
IMPORTANT: This equipment uses and emits electromagnetic signals. Tests have shown that the equipment conforms to all applicable codes with respect to electromagnetic compatibility.

> *Direct intervention on the power supply can cause electrocution, burns or even death. This action must be performed only by trained persons.*

> *RISK OF ELECTROCUTION: Even when the main circuit breaker or isolator is switched off, certain circuits may still be energized, since they may be connected to a separate power source.*

> *RISK OF BURNS: Electrical currents cause components to get hot either temporarily or permanently. Handle power cable, electrical cables and conduits, terminal box covers and motor frames with great care.*

> *ATTENTION: In accordance with the operating conditions the fans can be cleaned periodically. A fan can start at any time, even if the unit has been shut down.*

2   ABOUT THIS DOCUMENT

2.1   Contents

This document contains information and instructions to operate the control panel of EWYD_BZ units starting from application software version ASDU30A.

2.2   Revision history

Version	Date	Validity
D-EOMCP00104-14_02EN	December 2020	Application software version ASDU30A and further. The following sections have been modified: 5.12 Oil Heating 5.13 Energy Savings Mode
D-EOMCP00104-14_01EN	November 2020	Application software version ASDU30A and further
D-EOMCP00104-14EN	April 2014	Application software versions up to ASDU29A

2.3   Abbreviations used

A/C	Air Cooled
CP	Condensing Pressure
CSRT	Condensing Saturated Refrigerant Temperature
DSH	Discharge Superheat
DT	Discharge Temperature
E/M	Energy Meter Module
EEWT	Evaporator Entering Water Temperature
ELWT	Evaporator Leaving Water Temperature
EP	Evaporating Pressure
ESRT	Evaporating Saturated Refrigerant Temperature
EXV	Electronic Expansion Valve
HMI	Human Machine Interface
MOP	Maximum operating pressure
SSH	Suction SuperHeat
ST	Suction Temperature
UC	Unit controller (Microtech II)
W/C	Water Cooled

2.4   References

- *pCO5plus +0300020EN rel. 1.6* - 10.07.2019 – Carel S.p.A
- "EVD evolution" +0300005EN - rel. 3.7 - 16.12.2019 – *Carel S.p.A*
- cod. +050003265 rel. 1.1 - 31.03.2004 – Carel S.p.A.

3   CONTROL SYSTEM DESCRIPTION

3.1   Architecture

The overall control system architecture is described in the following picture:
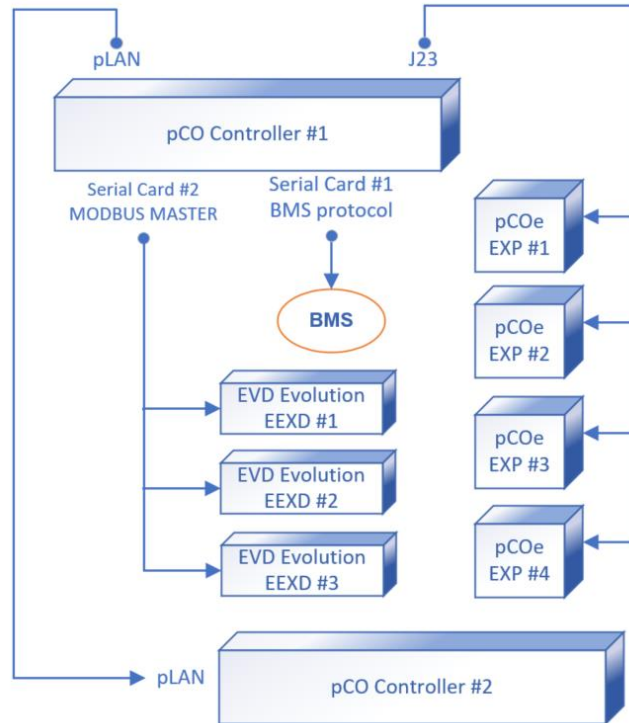
Board	Model	Function	Mandatory
pCO Controller #1	pCO5+ "Large" Built In display (*)	Unit control Compressors #1 & #2 control	Y
pCO Controller #2	pCO5 "Small"	Compressors #3	Yes on 3 compressors units
pCO^e EXP #1	pCOe	Additional hardware for compressors #1 & 2 or for compressors #3	N
pCO^e EXP #2	pCOe	Heat recovery or Heat pump control	N
pCO^e EXP #3	pCOe	Water pump control	N
pCO^e EXP #4	pCOe	Additional fan steps for compressors #1 & #2 or for compressors #3	N
EEXV driver #1	EVD Evolution	Electronic expansion valve control for compressor #1	Y
EEXV driver #2	EVD Evolution	Electronic expansion valve control for compressor #2	Y
EEXV driver #3	EVD Evolution	Electronic expansion valve control for compressor #3	Yes on 3 compressors units
Additional display	PGD	Special characters or additional display	N

(*) The contemporaneous presence of built-in display and additional PGD may be accepted.

⚠ *CAUTION: Maintain the correct polarity when connecting the power supply to the boards, otherwise the peripheral bus communication will not operate and the boards may be damaged.*

3.2 Main components

Unit controller

Ref.	Description
1	POWER CONNECTOR [G(+), G0(-)]
2	+Vterm: power to additional terminal
	+5 VREF power to ratiometric probes
3	Universal inputs/outputs
4	+VDC: power to active probes
5	Button for setting pLAN address, secondary display, LEDs
6	VG: voltage A(*) to optically-isolated analogue output
	VG0: power to optically-isolated analogue output, 0 Vac/Vdc
7	Analogue outputs
8	ID: digital inputs at voltage A(*)
9	ID..: digital inputs at voltage A(*)
	IDH..: digital inputs at voltage B(**)
10	pLAN telephone connector for terminal/downloading application program

(*) Voltage A: 24 Vac or 28 to 36 Vdc; (**) Voltage B: 230 Vac - 50/60 Hz.

Ref.	Description
11	pLAN plug-in connector
12	Reserved
13	Reserved
14	Reserved
15	Relay digital outputs
16	BMS2 connector
17	Fieldbus2 connector
18	Fieldbus/BMS selector microswitch
19	Fieldbus2 connector

"EVD Evolution" - Electronic Expansion Valves controller

Terminal	Description
G, G0	Power supply
VBAT	Emergency power supply
⏚	Functional earth
1,3,2,4	Stepper motor power supply
COM1, NO1	Alarm relay
GND	Earth for the signals
VREF	Power to active probes
S1	Probe 1 (pressure) or 4 to 20 mA external signal
S2	Probe 2 (temperature) or 0 to 10 V external signal
S3	Probe 3 (pressure)
S4	Probe 4 (temperature)
DI1	Digital input 1
DI2	Digital input 2
▨	Terminal for tLAN, pLAN, RS485, Modbus® connection
✚	Terminal for tLAN, pLAN, RS485, Modbus® connection
⊟	Terminal for pLAN, RS485, Modbus® connection
aa	service serial port (remove the cover to access)
b	serial port

"EVD Evolution" - Electronic Expansion Valves controller – Graphic Display	
1 1st variable displayed 2 2nd variable displayed 3 relay status 4 alarm (press "HELP") 5 protector activated 6 control status 7 adaptive control in progress	
"pCOe" - I/O Expansion board	
1. power supply connector [G (+), G0 (-)]; 2. analogue output 0 to 10 V ; 3. network connector for expansions in RS485 (GND, T+, T-) or tLAN (GND, T+); 4. 24Vac/Vdc digital inputs; 5. yellow LED showing power supply voltage and 3 signalling LEDs; 6. serial address; 7. analogue inputs and probe supply; 8. relay digital outputs.	

3.3   Components operating limits

Component	Temperature [°C]	r.H. non-condensing [%]
pCO5+ (built-in display)	-20 ÷ 60	< 90
pCO5+	-40 ÷ 70	< 90
EVD Evolution	N.A.	< 90
pCOe	-10 ÷ 60	< 90

4   USING THE CONTROLLER

Two types of user interface are implemented in the software: built-in display and PGD; the PGD display is used as optional remote display.

Both interfaces have a 4x20 LCD display and a 6 keys keypad.
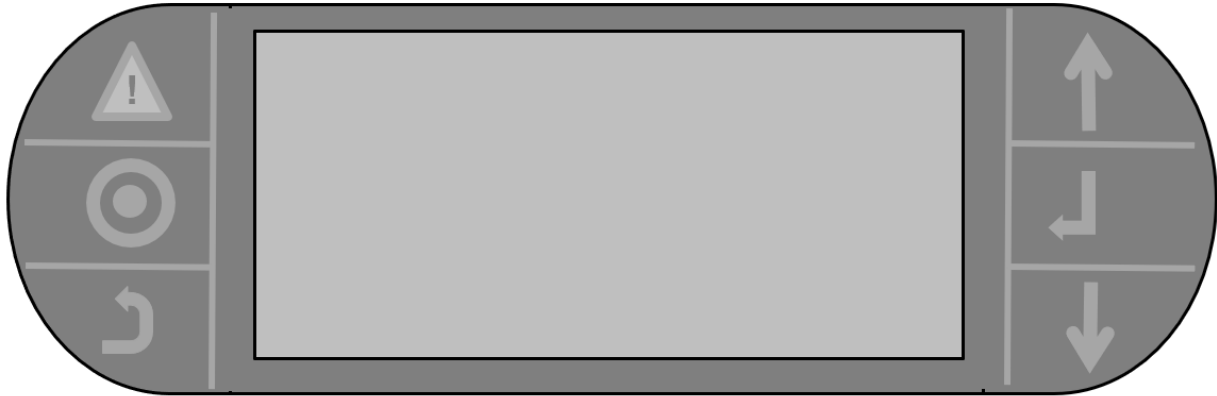
Built-In Display

PGD Display

Key	Built-In	PGD	From Main Menu go-to
Alarm			Alarms submenu
Program			View submenu
Up			Settings submenu
Down			Maint submenu

Built-In & PGD navigation

Entering any other section different menus or mask loops are shown. From every loop with [⤺] or [Esc] key it is possible to access the father menu and so on until main menu is reached.
In each loop horizontal navigation have been introduced.

In a mask with different I/O fields, with *ENTER* key is possible to access the first one, then with *UP* and *DOWN* it is possible to increase and decrease respectively the value.The possibility of change values is subordinated to passwords of different levels depending on the sensibility of the value.

When a password is active, pressing *UP+DOWN* it is possible to reset all passwords (to make the access to protected values not accessible anymore without the re-insertion of the password). In any main loops it is possible to change the password for the corresponding level (Unit Config for Tech password, User Setpoint for Operator password and Maint Setpoint for Manager password).

4.1   Mask tree

In the picture below the structure of the mask tree beginning from the main menu is shown. Masks loops of the same group of parameters can be accessed using left and right arrows creating also horizontal loops. Parameters within a same horizontal loop could accessed with a unique password. In violet the loop horizontally linked are shown. All loops could be accessed directly from the main menu. Once in the selected loop the other loops, with the same colour in the previous scheme, could be reached with left and right arrows. This will mean for example that from the loop Unit Configuration it will be possible to move to Unit Setpoint pressing the right arrow. Loops with no link with other loops could be accessed only from the menu.

HMI structure
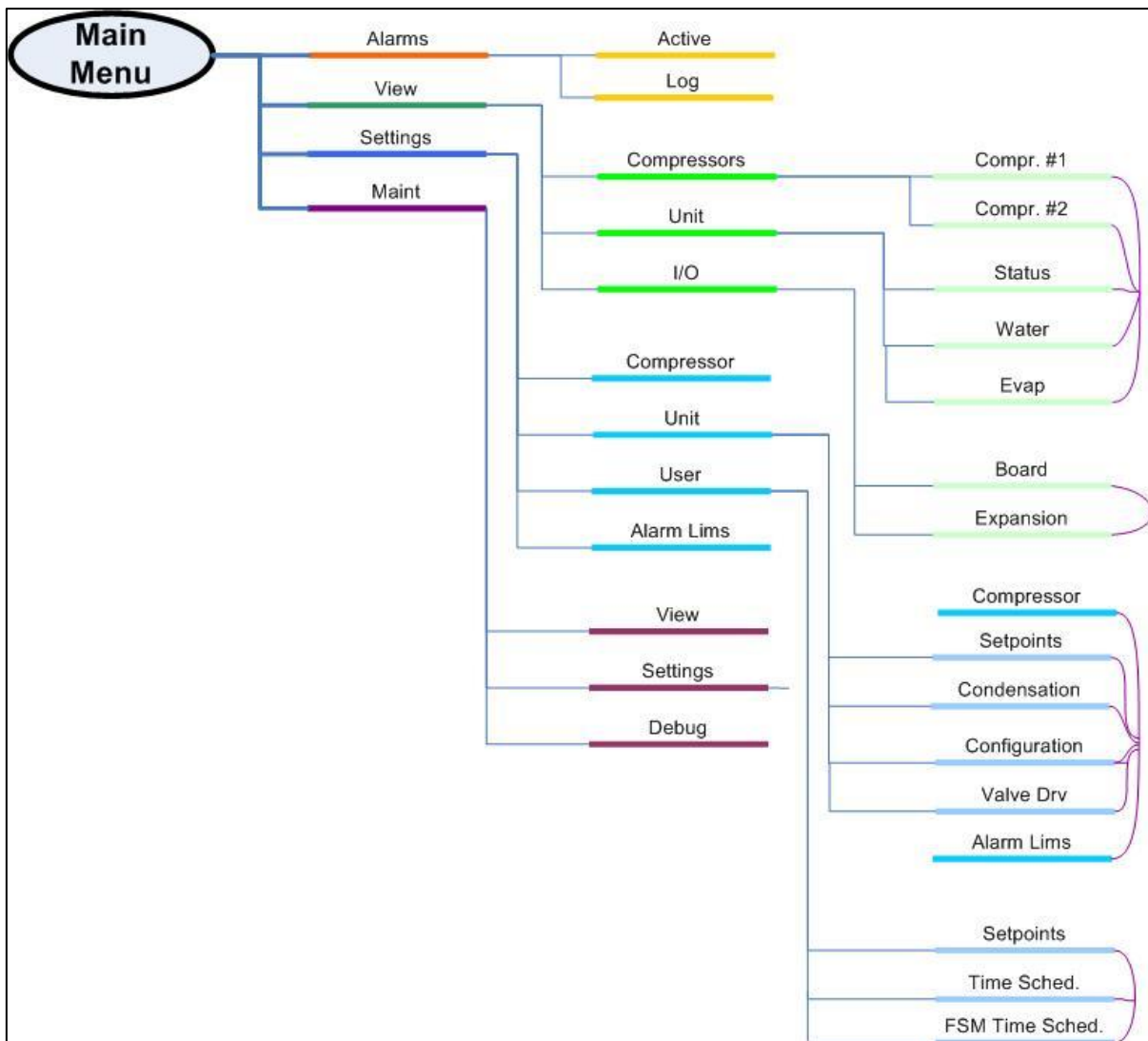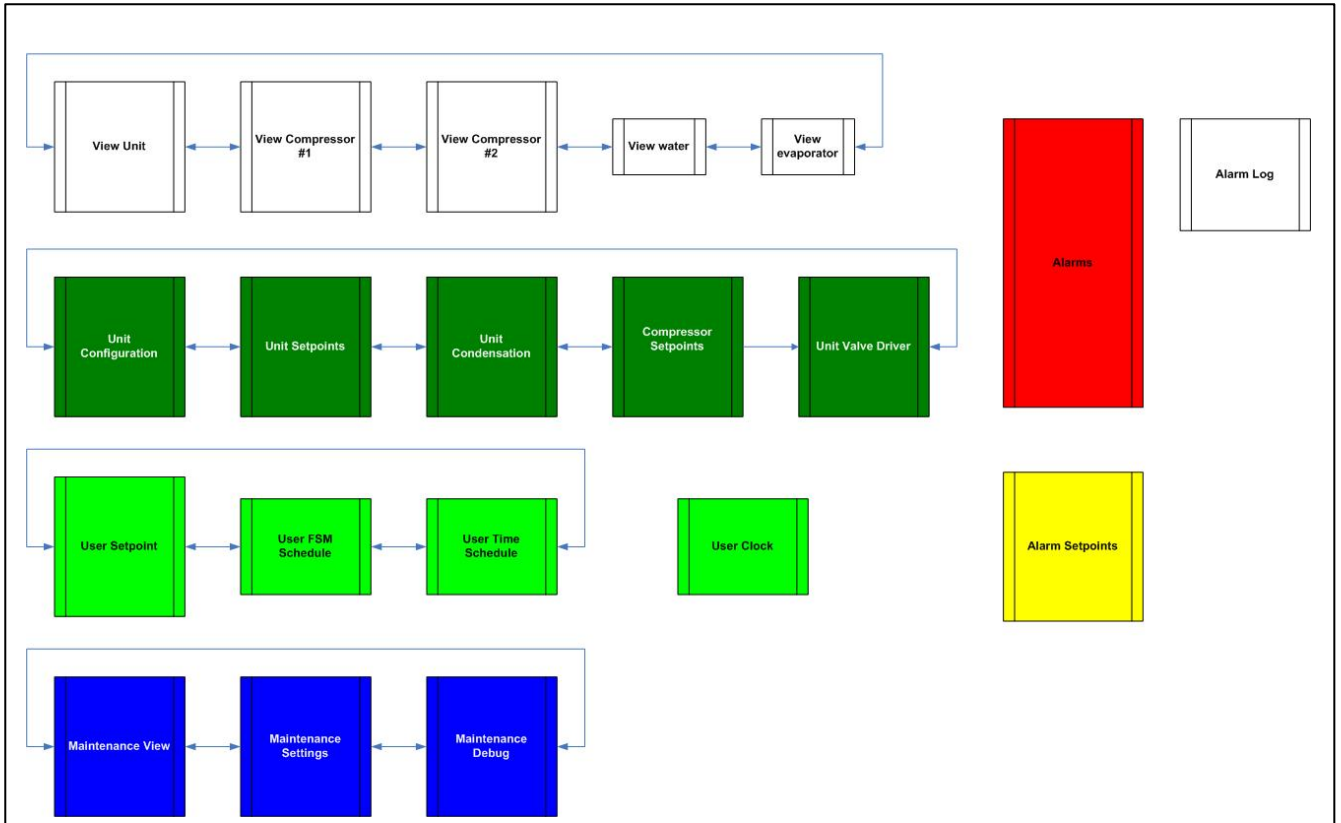
4.2   Measure units

The interface is able to work using SI and Imperial units. In the the following units are used:

Measurement	Units	
	SI system	Imperial system
Pressure	bar	psi
Temperature	°C	°F
Time	sec	sec

As far as pressure is concerning, the interface shows if shown data are gauge or absolute using the postfix "g" or "a" respectively.

4.3   Default passwords

Several levels of passwords for each subsection are available. Subsections are listed in the table below.

Section	Password
Super User	Daikin Use Only
Technician	Authorized Personnel can Contact Factory
Operator	0100

5   WORKING WITH THIS UNIT

5.1   Controller purpose

Then system will control the evaporator leaving water temperature to keep it at a setpoint value.

The system operates to optimize components performances from the point of view of their efficiency and of their duration.

The system assures a safe operation of the unit and of all components and prevents dangerous situations.

5.2   Unit enabling

The control allows different ways to enable/disable the unit:

- Keypad: Enter key on the keypad allows to switch between "Power OFF" mode and "Unit On" if other signals allows this state

- Local Switch: when the digital input "Unit On/Off" is open the unit is in "Local switch Off"; when the digital input "Unit On/Off" is closed the unit may be in "Unit On" or "Remote switch Off" on the basis of the "Remote On/Off " digital input

- Remote Switch: when the local switch is On ("Unit On/Off" digital input closed) if the digital input "Remote On/Off " is closed the unit is in "Unit On", when digital input "Remote On/Off " is open the unit is in "Remote switch Off"

- Network: a BAS or a Monitoring system may send an On/Off signal trough the serial line connection to put the unit on or in "Rem. Comm. Off"

- Time schedule : a timetable allows to program "Time Schedule Off" on a week base; several holiday days are include.

- Ambient LockOut : the unit is not enabled to operate unless the ambient temperature is higher than an adjustable value (default 15.0°C (59.0 F))

To be in "Unit On" all the allowed signals must enable the unit.

5.3   Unit modes

The unit is able to work in the following modes:

- *Cooling*. When this mode is selected the control will operate to cool the evaporator water; the setpoint range is +4.0 ÷ +14.0 °C, (39.2 ÷ 57.2 F) a freeze alarm setpoint is set to 2 °C (34.6 F) (adjustable by the operator in the range +1 ÷ +3 °C (33.8 ÷ 37.4 F)) and a freeze prevent setpoint is set to 3 °C (37.4 F) (adjustable by the operator in the range: "freeze alarm setpoint" + 1 ÷ +3 °C ("freeze alarm setpoint" + 1.8 F ÷ 37.4 F)).

- *Cooling/Glyco*. When this mode is selected the control will operate to cool the evaporator water; the setpoint range are -8°C ÷ +14.0°C (17.6 ÷ 57.2 F) , a freeze alarm setpoint are set to –10 °C (14.0 F) (adjustable by the operator in the range –12 °C ÷ -9°C (10.4 ÷ 15.8 F)) and a freeze prevent setpoint are set to –9 °C (15.8 F) (adjustable by the operator in the range "freeze alarm setpoint" + 1°C ÷ -9 °C ("freeze alarm setpoint" + 1.8 F ÷ 15.8 F))

- *Ice.* When this mode is selected the control will operate to cool the evaporator water; the setpoint range are   -8°C ÷ +14.0°C (17.6 ÷ 57.2 F) , a freeze alarm setpoint are set to –10 °C (14.0 F) (adjustable by the operator in the range –12 °C ÷ -9°C (10.4 ÷ 15.8 F)) and a freeze prevent setpoint are set to –9 °C (15.8 F) (adjustable by the operator in the range "freeze alarm setpoint" + 1°C ÷ -9 °C ("freeze alarm setpoint" + 1.8 F ÷ 15.8 F)). While working in ice mode compressors are not be allowed to unload but are stopped using a step procedure (se § 5.5.1)

- *Heating*. When this mode is selected the control will operate to heat the evaporator water; the setpoint range is +30 ÷ +45°C (86 ÷ 113°C), a hot water alarm setpoint are set to 50°C (adjustable by the operator in the range +46 ÷ +55°C (114.8 ÷ 131 F)) and a hot prevent setpoint are set to 48°C (118.4 F) (adjustable by the operator in the range +46°C ÷ "hot water alarm setpoint" + 1°C (114.8 F ÷ "hot water alarm setpoint" + 1.8 F)).

- *Cooling + Heat Recovery*. Setpoints and freeze protection are managed as described in the cooling mode; in addition the control will enable the heat recovery input and outputs foreseen on the expansion #2

- *Cooling/Glycol + Heat Recovery.* Setpoints and freeze protection are managed as described in the cooling/glycol mode; in addition the control will enable the heat recovery input and outputs foreseen on the expansion #2.

- ***Ice + Heat Recovery****. Setpoints and freeze protection are managed as described in the ice mode; in addition the control will enable the heat recovery input and outputs foreseen on the expansion #2.

The selection between cooling, cooling/glycol and ice mode are performed by the operator using the interface under password. The switching between cooling and ice and heating modes will cause the unit shutdown and than the switching between the two modes.

5.4 Setpoints management

The control is able to manage the evaporator leaving water temperature on the base of several inputs:

- Changing the setpoint from the keypad
- Switching between the main setpoint (set by keypad) and an alternative value (set by keypad to) on the base of a digital input state (double setpoint function)
- Receiving a setpoint by a monitoring system or a BAS connected via serial line
- Resetting the setpoint of the base of analogic inputs

The control shows the source of the used (Actual) setpoint:

Local	the main setpoint set by keypad is being used
Double	the alternative setpoint set by keypad is being used
Reset	the setpoint is being reset by external input

The following setpoint reset methods are available to modify the local or double setpoint:

|	
None	local or double setpoint are used on the base of the double setpoint digital input. This is called "base setpoint"
4-20mA	base setpoint is modified on the base of an user analog input
OAT	base setpoint is modified on the base of outside ambient temperature (if available)
Return	base setpoint is modified on the base of evaporator entering temperature
Network	the setpoint sent by serial line is used

In the case of a failure in the serial connection or in the 4-20mA input the base setpoint is used. In case of a setpoint reset, the system display will show the type of reset.

5.4.1   4-20mA setpoint override

The base setpoint is modified on the base of the value of the analog input and of a max reset value, as shown in the picture below:
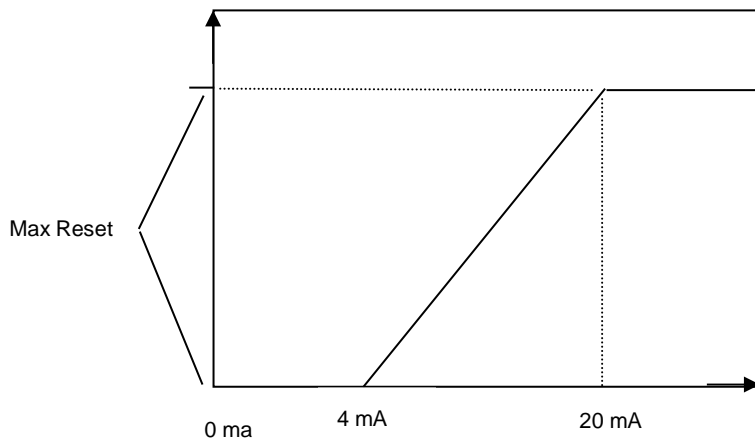
5.4.2   OAT setpoint override

To enable the OAT setpoint override the unit limiting control expansion board pCO^e#2 is required, with the ambient sensor installed. The base setpoint is modified on the base of outside ambient temperature and of a max reset value, of a value of OAT to start reset and a value of OAT to apply max reset, as shown in the picture below:
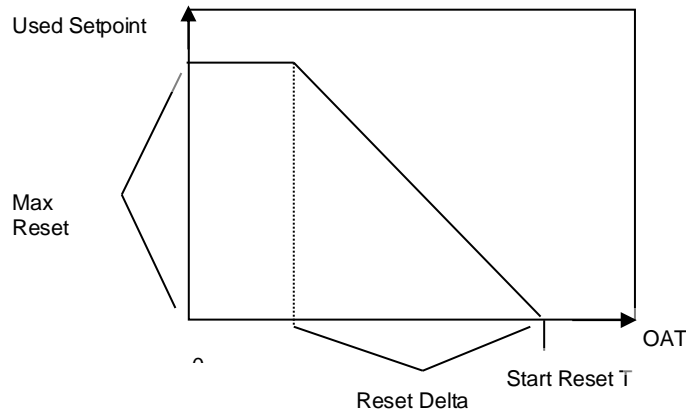
5.4.3   Return setpoint override

The base setpoint is modified on the base of evaporator ΔT and of a max reset value, of a value of OAT to start reset and a value of OAT to apply max reset, as shown in the picture below:
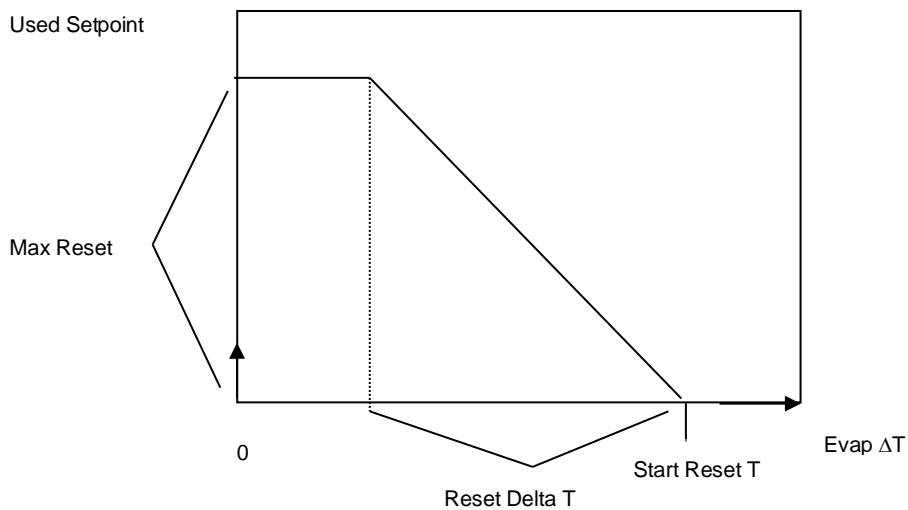
5.5 Compressors capacity control

Two types of capacity control are implemented:

- Automatic: the compressor start/stop and its capacity are automatically managed by the software to allow the setpoint respect
- Manual: the compressor is started by the operator and its capacity is managed by the operator acting on the system terminal. In this case the compressor will not be used by the software to allow the setpoint respect.

Manual control is automatically switched to Automatic control if any safety action is required on the compressor (safety standby or unloading or safety shutdown). If this case the compressor remains in Automatic and must be re-switched to Manual by the operator if required. Compressors in manual mode are automatically switched in automatic mode at their shutdown. The compressor load by may be evaluated on the basis of:

- Calculation of loading and unloading pulses
- Analogic slide valve position signal (optional)

5.5.1   Automatic Control

A specialized PID algorithm is used to determinate the magnitude of corrective action on capacity control solenoid. The compressor loading or unloading is obtained keeping the loading or unloading solenoid energized for a fixed time (pulse duration), while the time interval between two subsequent pulses are evaluated by a PD controller. If the output of the PD algorithm doesn't change, the time interval among pulses is constant; this is the integral effect of the controller, at a constant error the action is repeated with a constant time (with the additional feature of a variable integral time). The

compressor load evaluation (based on analog slide valve position or calculation[1]) is used to allow the start of another computer or the stop of a running one. It is required to define the proportional band and the derivative time of the PD control, together with the pulse duration and a minimum and maximum value for pulses interval.

The minimum pulse interval is applied when the maximum correction action is required, while the maximum interval is applied when the minimum correction action is required. A dead band is introduced to allow to reach a stable compressor condition. Fig. 12 shows the proportional action of the controller as a function of the input parameters.

The proportional gain of the PD controller is given by:

$$K_p = \text{Max} \cdot \frac{\text{RegBand}}{2}$$

The derivative gain of the PD controller is equal to:

$$K_d = K_p \cdot T_d$$

where T_d is the input derivative time.

In addition to the specialized PID controller, a max pull-down-rate is introduced in the control; this meanings that if the controlled temperature is approaching the setpoint with a rate greater than a set value, any loading action is inhibited, even if require by the PID algorithm. This makes the control slower but allows to avoid oscillations around setpoint. The controller is designed to act both as a "chiller" and as a "heat pump"; when the "chiller" option is selected the controller will load the compressor if the measured temperature is above the setpoint and will unload the compressor if the measured temperature is below the setpoint. When the "heat pump" option is selected the controller will load the compressor if the measured temperature is below the setpoint and will unload the compressor if the measured temperature is above the setpoint. The starting sequence of compressors is selected on the base of lower working hours amount (it means that the first compressor that is started is the one with the lower amount of working hour); between two compressors with the same operating hours, the compressor with minimum number of starts will start first. A manual sequencing of compressors is possible. The start of the first compressor is allowed only if the absolute value of difference between the measured temperature and the setpoint exceeds a Startup ∆T value. The stop of the last compressor is allowed only if the absolute value of the difference between the measured temperature and the setpoint exceeds a Shutdown ∆T value.

A FILO (First In - Last Off) logic is adopted.

The start/loading and unloading/stop sequence will follow the schemes in table 2 and table 3, where RDT is the Reload/Reunload ∆T, a set value (that represent the minimum difference between the evaporator leaving water temperature and its setpoint) that will a running compressor to be reload when a compressor is shutdown or a running compressor to be unload when a new compressor is started.

This is made to keep the unit total capacity at the same level when the evaporator leaving water temperature is close to the setpoint and a compressor stops, or another compressor starts, is required.

In Ice mode, while the compressor loading is not affected, the compressors downloading is inhibited. When downloading is required compressors are shutdown on the basis of the evaporator leaving water temperature. In particular, said Stp the evaporator leaving temperature setpoint, SDT the shutdown ∆T value and n the number of compressors, the scheme in table 6 is used. In addition when the heat pump option is installed, the compressor could be managed using a variable speed driver (inverter). An analog output of pCO[3] board is used to control the compressor speed with a 0-10V signal. Load management will still determine the time distance between load/unload pulses where pulse in this case means relative variation of the output voltage. The magnitude of the variation could be adjusted under manufacturer password.

When the unit is working in heating mode the maximum speed will be the nominal speed (default value 67Hz).

When the unit is working in cooling mode an overboost option (activated either with the digital input 2 on the expansion board #2 or automatically if the outside ambient temperature is greater than 35°C and disabled when it falls below 34°C) is managed. It allows the compressor to run at its full speed of 90Hz if the maximum available capacity is reached. When the overboost is disabled the valve opening (if the electronic expansion valve).

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[1] The calculation is based on the load increase (or decrease) associated to each pulse:

$$Load\ Inc\ per\ pulse\ (\%) = \frac{100 - 25}{n\ load\ pulse} \qquad Load\ Dec\ per\ pulse\ (\%) = \frac{100 - 25}{n\ unload\ pulse}$$

Being "n load pulses" and "n unload pulses" the number of pulses to load and unload the compressor.

Counting the number of pulses given to the compressor its load is evaluated.

Fixed pulse duration

Variable pulse interval
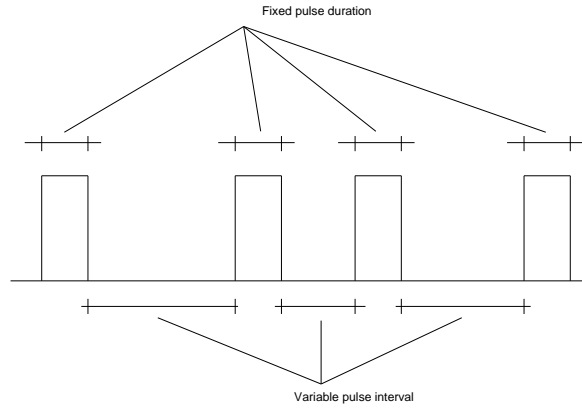
Loading or unloading pulses
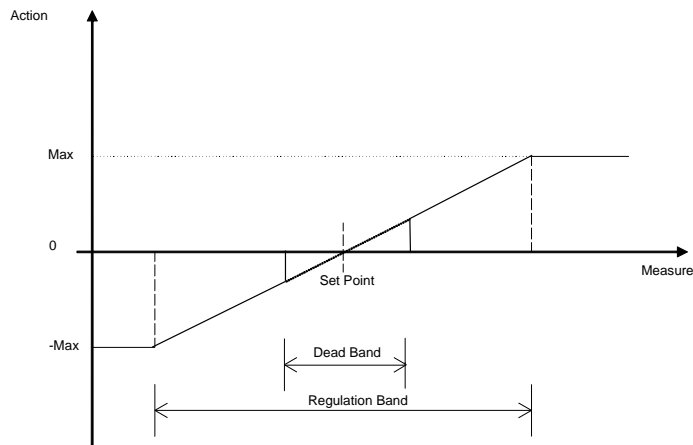
PD controller proportional action

5.5.2   Manual Control

The control will apply a fixed duration pulse (the magnitude is the pulse duration set in the automatic control) for each manual (by keyboard) load or unload signal.

In the manual control the load/unload action follows any pressing of defined up/down keys.

Load/Unload key press

Load/Unload pulse
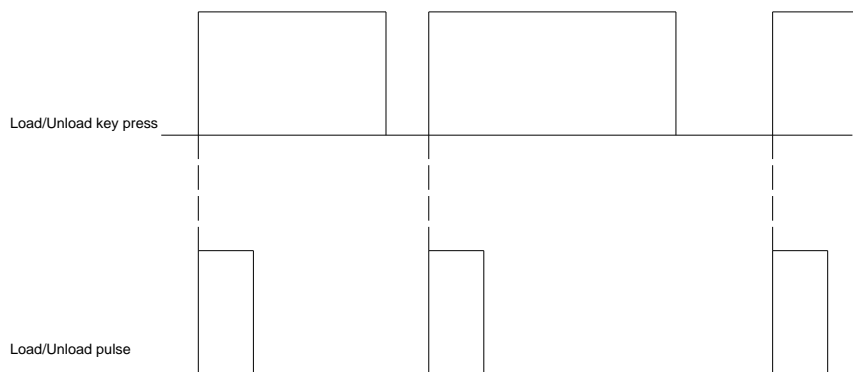
Table 2 - **Compressors startup and loading management (4 compressors unit)**

| Step n.	Leader Comp.	Lag 1 Comp.	Lag 2 Comp.	Lag 3 Comp.
0	Off	Off	Off	Off
1	If (T – SetP) < Startup DT & Cooling or (SetP - T) < Startup DT & Heating … Waiting …			
2	Start	Off	Off	Off
3	Load up to 75%	Off	Off	Off
4	If T in Regulation Band … Wait interstage time …			
5	If T is approaching SetP … Waiting …			
6a SetP-RDT<T< SetP-RDT	Unload up to 50%	Start	Off	Off
6b SetP-RDT<T or T> SetP-RDT	Fixed at 75%	Start	Off	Off
7	Fixed at 75% or 50%	Load up to 50%	Off	Off
8 (if leader at 50%)	Load up to 75%	Fixed at 50%	Off	Off
9	Fixed at 75%	Load up to 75%	Off	Off
10	If T in Regulation Band … Wait interstage time …			
11	If T is approaching SetP … Waiting …			
12a SetP-RDT<T< SetP-RDT	Fixed at 75%	Unload up to 50%	Start	Off
12b SetP-RDT<T or T> SetP-RDT	Fixed at 75%	Fixed at 75%	Start	Off
13	Fixed at 75%	Fixed at 75% or 50%	Load up to 50%	Off
14 (if lag1 at 50%)	Fixed at 75%	Load up to 75%	Fixed at 50%	Off
15	Fixed at 75%	Fixed at 75%	Load up to 75%	Off
16	If T in Regulation Band … Wait interstage time …			
17	If T is approaching SetP … Waiting …			
18a SetP-RDT<T< SetP-RDT	Fixed at 75%	Fixed at 75%	Unload up to 50%	Start
18b SetP-RDT<T or T> SetP-RDT	Fixed at 75%	Fixed at 75%	Fixed at 75%	Start
17	Fixed at 75%	Fixed at 75%	Fixed at 75% or 50%	Load up to 50%
18 (if lag2 at 50%)	Fixed at 75%	Fixed at 75%	Load up to 75%	Fixed at 50%
19	Fixed at 75%	Fixed at 75%	Fixed at 75%	Load up to 75%
20	Load up to 100%	Fixed at 75%	Fixed at 75%	Fixed at 75%
21	Fixed at 100%	Load up to 100%	Fixed at 75%	Fixed at 75%
22	Fixed at 100%	Fixed at 100%	Load up to 100%	Fixed at 75%
23	Fixed at 100%	Fixed at 100%	Fixed at 100%	Load up to 100%
24	Fixed at 100%	Fixed at 100%	Fixed at 100%	Fixed at 100%

Table 3 - Compressors unloading and shutdown management (3 compressors unit)

Step n.	Leader Comp.	Lag 1 Comp.	Lag 2 Comp.
0	100%	100%	100%
1	Fixed at 100%	Fixed at 100%	Fixed at 100%
2	Fixed at 100%	Fixed at 100%	Unload up to 75%
3	Fixed at 100%	Unload up to 75%	Fixed at 75%
4	Unload up t75%	Fixed at 75%	Fixed at 75%
5	Fixed at 75%	Fixed at 75%	Fixed at 75%
6	Fixed at 75%	Fixed at 75%	Unload up to 50%
7	Fixed at 75%	Fixed at 75%	Fixed at 50%
8	If T is approaching SetP … Waiting …		
9a SetP-RDT<T< SetP-RDT	Fixed at 75%	Fixed at 75%	Load up to 75%
9b SetP-RDT<T or T> SetP-RDT	Fixed at 75%	Fixed at 75%	Fixed at
10 (if lag2 at 75%)	Fixed at 75%	Fixed at 75%	Fixed at
11	Fixed at 75%	Unload up to 50%	Fixed at 50%
12	Fixed at 75%	Fixed at 50%	Fixed at 25%
13	If T is approaching SetP … Waiting …		
14a SetP-RDT<T< SetP-RDT	Fixed at 75%	Load up to 75%	Stop
14b SetP-RDT<T or T> SetP-RDT	Fixed at 75%	Fixed at 50%	Stop
15 (if lag1 at 75%)	Fixed at 75%	Unload up to 50%	Off
16	Unload up to 50%	Fixed at 50%	Off
17	Fixed at 50%	Unload up to 25%	Off
18	If T is approaching SetP	… Waiting …	
19a SetP-RDT<T< SetP-RDT	Load up to 75%	Stop	Off
19b SetP-RDT<T or T> SetP-RDT	Fixed at 50%	Stop	Off
20	Unload up to 25%	Off	Off
21	If T is approaching SetP … Waiting …		

22	If (SetP - T) < Shutdown DT & Cooling
	OR
	If (T – SetP)< Shutdown DT & Heating THEN….Wait….		

23	Stop	Off	Off
24	Off	Off	Off

Table 4 - Compressors shutdown scheme in Ice mode (3 compressors unit)

Evap Lvg Temp	Compressors status
SetP – SDT/n < Evap Lvg Temp < SetP	All compressors allowed to run
SetP – 2*SDT/n < Evap Lvg Temp < SetP– SDT/n	(n-1) compressors allowed to run
SetP – 3*SDT/n < Evap Lvg Temp < SetP – 2*SDT/n	(n-2) compressors allowed to run
SetP – 4*SDT/n < Evap Lvg Temp < SetP – 3*SDT/n	No compressor allowed to run

5.6   Compressors timing

Compressors operation will meet four timer requirements:

- Minimum time between a same compressor starts (start to start timer): it is the minimum time between two starts of the same compressor
- Minimum time between different compressor starts: it is the minimum time between two starts of two different compressors
- Minimum time compressor on (start to stop timer): it is the minimum time the compressor may run; the compressor cannot be stopped (unless an alarm occurs) if this timer is not expired
- Minimum time compressor off (stop to start timer): it is the minimum time the compressor may be stopped; the compressor cannot be start if this timer is not expired

The minimum time compressor off (stop to start timer) will has two different settings; one applicable to cooling, cooling/glycol and heating mode and the other one applicable in ice mode.

5.7   Compressors protection

To protect compressor against loss of lubrication, the compressor pressure ratio is continuously checked; a minimum value is set for compressor minimum and maximum load; for intermediate compressor loads a linear interpolation are executed. The low pressure ratio alarm will occur if pressure ratio remains lower than the minimum value at rated compressor capacity while a timer expiration.
At the startup the compressor is completely downloaded and its loading will not be enabled up to the pressure ratio exceeds a set value (default equal to 2).

5.8   Compressors startup procedure

Before to start compressors the unloading solenoid valve is energized up to a timer is expired (default 60 sec).
At compressor startup the control will executed a series of prepurge procedure to evacuate evaporator; the prepurge procedure will depend on the expansion valve type.
Prepurge procedure will not be executed if the evaporating pressure is below the low pressure alarm setpoint (vacuum conditions inside the evaporator).
The compressor will not be allowed to load up to the discharge superheat exceeds a set value (default 12.2 °C, 22 F) for a time longer than a set value (default 30 sec) .

5.9   Fan pre-starting in heating mode

When the unit is operated in heating mode, if the outside ambient temperature is lower than an fixed threshold of 10.0°C (50.0F) before the compressor is started and the start-up procedure is initiated all fans are started with a constant delay between each other.

5.10 Prepurge procedure with electronic expansion

At the compressor start the EEXV are completely closed up to the saturated temperature at the evaporator pressure reaches the value of –10 °C (14 F) (adjustable in the range –12 ÷ -4 °C (10.4 ÷ 24.8 F)), then the valve are opened at a fixed position (adjustable by the manufacturer with a default value equal to 20%) up to a timer is expired (default 30 sec).

5.11 Prepurge procedure with thermostatic expansion

At the compressor start the liquid line solenoid is completely closed up to the saturated temperature at the evaporator pressure reaches the value of –10°C (14 F) (adjustable in the range –12 ÷ -4 °C (10.4 ÷ 24.8 F)), then the valve is opened up to a timer is expired; this procedure is repeated for a number of times adjustable by the operator (default is 1 time).

5.12 Oil heating

The compresso startup is allowed if one or both of the following conditions are true:

DischTemp – TOilPress > 5 °C
OR
DischTemp > 30.0 °C

Where:
DischTemp is the compressor discharge temperature
TOilPress is the saturated temperature at the oil pressure

5.13 Energy Saving mode

The energy saving function reduces the power consumption deactivating the compressors crankcase heater, when the unit is Disabled.

Unit disabled by switch/remote/supervisor

- Heaters are ON when OAT < Min OAT lim OR DischSH<1.0 dk
- Heaters are OFF when OAT > (Min OAT lim + 2.0) AND (DischSH>5.0 dk)

Unit disabled by thermostat

- Heaters are ON when DischSH<10.0 dk
- Heaters are OFF when DischSH>15.0 dk)

This mode implies that the time needed to start the compressors, after an Off period, could be delayed until a maximum of 90 minutes.
For time critical application, the energy saving function can be disabled by the user to ensure the compressor start within standard time from unit On command.

5.14 Pumpdown

As a compressor stop request is recorded (and if the request doesn't originate from an alarm), before to proceed, the compressor is fully discharged and operated for a certain amount of time with a closed expansion valve (in the case of electronic expansion valve) or closed liquid line valve (in the case of thermostatic expansion valve).
This operation, known as "pumpdown", is used to evacuate the evaporator avoiding that in a following restart the compressor will such liquid.
Pumpdown procedure will end after a user defined timer is expired (adjustable, default 30 sec.) or the saturated temperature at the evaporator pressure reaches the value of –10°C (adjustable in the range –12 ÷ -4 °C (10.4 ÷ 24.8 F)).
After compressor stop the unloading solenoid valve are energized for a time equal to the minimum compressor off time to assure the complete unloading also in case of non-normal stop procedure completion.

5.15 Low ambient temperature start

Units working in cooling, cooling/glycol or ice mode has to manage start-up with low outside ambient temperature.
A low OAT start is initiated if, at the compressor start up, the condenser saturated temperature is less than 15.5 °C (60 F). Once this happens, 3 seconds after the end compressor startup procedure (end of prepurge cycles) low pressure events are disabled for a time equal to the low OAT time (setpoint has an adjustable range from 20 to 120seconds, defaults 120 sec.).
The absolute low pressure limit (the threshold which has no time delay) is still enforced. If this limit pressure is reached a Low Ambient Start-Up low pressure alarm is issued.
At the end of the low OAT start, the evaporator pressure is checked. If the pressure is greater than or equal to the evaporator pressure stage down setpoint, the start is considered successful. If the pressure is less than this, the start is not successful and the compressor shall stop. Three start attempts are allowed before tripping on the restart alarm.
The restart counter should be reset when either a start is successful or the circuit is off on an alarm.

5.16 Economizer valve

If the option is present (expansion board 1) and enabled under manufacturer password, when the compressor's load percentage is greater than an adjustable threshold (default is 90%) and if the saturated condensing temperature is lesser than an adjustable setpoint (default is 65.0°C) the economizer valve is energized. The valve is deenergized if either the compressor's load percentage falls below another adjustable threshold (default is 75%) or if the saturated condensing temperature falls below the setpoint minus an adjustable differential (default is 5.0 °C).

5.17 Switch between cooling and heating mode

Any time the switching of a compressor between cooling (or cooling/glycol or ice) and heating mode is require, either if this is required by unit switching form one mode to other or to start defrost or to end defrost, the following procedures are followed.

5.17.1　Switching from cooling modes to eating mode

5.17.1.1　Compressor running in cooling mode

A compressor running in cooling mode (four-way valve de-energized) is switched off without executing pumpdown, the four-way valve is energized 5 seconds after the compressor has been switched off, than the compressor is switched on after the minimum time compressor off is expired and the standard prepurge procedure is executed.

5.17.1.2　Compressor stopped in cooling mode

If a compressor that was stopped in cooling mode is required to start in heating mode it is switched on in standard cooling mode (with four-way valve de-energized and executing the standard prepurge procedure), it is kept running for 120 seconds in cooling mode and than is switched off without pumpdown, the four-way valve is energized 5 seconds after the compressor has been switched off, than the compressor is switched on after the minimum time compressor off is expired.

5.17.2　Switching from heating modes to cooling modes

5.17.2.1　Compressor running in heating mode

A compressor running in heating mode (four-way valve energized) is switched off without executing pumpdown, the four-way valve is de-energized 5 seconds after the compressor has been switched off, than the compressor is switched on after the minimum time compressor off is expired and the standard prepurge procedure is executed.

5.17.2.2　Compressor stopped in heating mode

If a compressor that was stopped in heating mode (four-way valve energized) is required to start than then four-way valve is de-energized and the compressor is switched on after the 20 sec.

5.17.3　Additional consideration

The previous procedures relay on the fact that the cooling or heating state is a property of the compressor regardless the fact it is switched on or off. This meanings that, if a compressor is switched of in heating mode its four-way valve remains energized (at the same manner a compressor switched off in cooling mode has the four-way valve de-energized). If the unit power is removed the four-way valves are automatically de-energized (it is an hardware characteristic of the valves); this meanings that also compressors switched off in heating mode goes in cooling mode. So the heating mode of each compressor is reset if the unit power is removed.

5.18　Defrost procedure

In units configured as heat pumps running in heating mode a defrost procedure are executed. Two compressors will not execute the defrost procedure at the same time. A compressor will not execute the defrost procedure unless an adjustable timer (default 30 min) is expired since its startup and will not execute two defrost time before another adjustable timer (default 30 min) is expired (if this is required a warning message are generated). The defrost procedure are based on the measure of ambient temperature (Ta) and the suction temperature measure by the defrost sensors (Ts). When the Ts remains below Ta by an amount greater than a value, depending from ambient temperature and coil design, for a time longer than an adjustable (default 5 min) value the defrost will start.

The formula to evaluate needs for defrost is:

$$Ts < 0.7 \times Ta - \Delta T \qquad \& \qquad Ssh < 10\ °C\ \text{(adjustable value)}$$

Where ΔT is the adjustable coil design approach (default=12°C) and Ssh is the suction superheat.

Defrost procedure will never be executed if Ta > 7 °C (adjustable under maintenance password).
Defrost procedure will never be executed if Ts > 0 °C (adjustable under maintenance password).

During defrost the circuit are switched in "cooling mode" for an adjustable time (default 10 min) if Ta < 2 °C (adjustable under maintenance password), otherwise the compressor are stopped and fans are kept at maximum speed for another adjustable time (default 15 min). Defrost procedure are stopped if evaporator outlet temperature fall below a set value or if discharge pressure reaches a set value. During defrost procedure "Low pressure switch alarm" and "Low suction pressure alarm" are disabled. If the switch in "cooling mode" is required, it are executed only if the pressure difference between compressor discharge and suction exceeds 4 bar; if this isn't the compressor are loaded to reach such a condition. After

the switching compressor fans are switched off and a pre-purge procedure are executed (at minimum compressor load). After prepurge the compressor are loaded energizing the loading solenoid with an adjustable number of pulse (default 3). At the end of defrost procedure executed in "cooling mode" compressor are switched off after its complete download without execution of pumpdown; than the 4-way valve are deenergized; than the compressor are available for temperature control system ignoring the start to start timer.

5.19   Liquid injection

Liquid injection in the discharge line is activated both in cooling/ice and heating mode if the discharge temperature exceeds an adjustable value (default 85°C). Liquid injection in the suction line are activated, only in heating mode, if the discharge superheat exceeds an adjustable value (default 35°C).

5.20   Heat Recovery procedure

The heat recovery procedure is available only in units configured as chillers (not available for heat pumps). The manufacturer will select the circuits equipped with heat recovers.

5.20.1   Recovery pump

When heat recovery is activated the control will start the recovery pump (if the second pump is foreseen the pump with low operating hours is selected, a manual pump sequencing is foreseen); within 30 sec a recovery flow switch must close otherwise and "Recovery Flow Alarm" will rise and the heat recovery function is disabled; the alarm is automatically reset for three times if the evaporator flow switch closes for more than 30 seconds. Starting from the fourth alarm it has to be reset manually. No recovery circuit must be activated if a flow switch alarm occurs. In case of a flow switch alarm during recovery circuit operation, the related compressor will trip and the alarm reset will not be allowed up to the flow is recovered (otherwise recover heat exchanger freeze will occur).

5.20.2   Recovery control

When heat recovery is activated the control will activate or deactivate recovery circuits with a step logic. In particular a next heat recovery stage is activated (a new heat recovery circuit is inserted) if the heat recovery leaving water temperature remains below the setpoint by an amount greater than an adjustable regulation band for a timer greater than an adjustable value (heat recovery interstage). When a recovery stage is requested, the relative compressor is completely downloaded and then the recovery valve is energized. After recovery valve switches the compressor load is inhibited until the saturated condensing temperature is lower than an adjustable threshold (default is 30.0°C).

At the same manner a heat recovery stage is deactivated (a heat recovery circuit is removed) if the heat recovery leaving water temperature remains above the setpoint by an amount greater than an adjustable dead regulation band for a timer greater than the previous defined value. An high temperature setpoint is active in the recovery loop; it will disable all recovery circuits at the same time if the heat recovery water temperature rises above an adjustable threshold (default 50.0°C). A three-way valve is used to increase recovery water temperature at startup; a proportional control is used to establish valve position; at low temperature the valve will recirculate recovery water, while at temperature increasing the valve will bypass a portion of the flow.
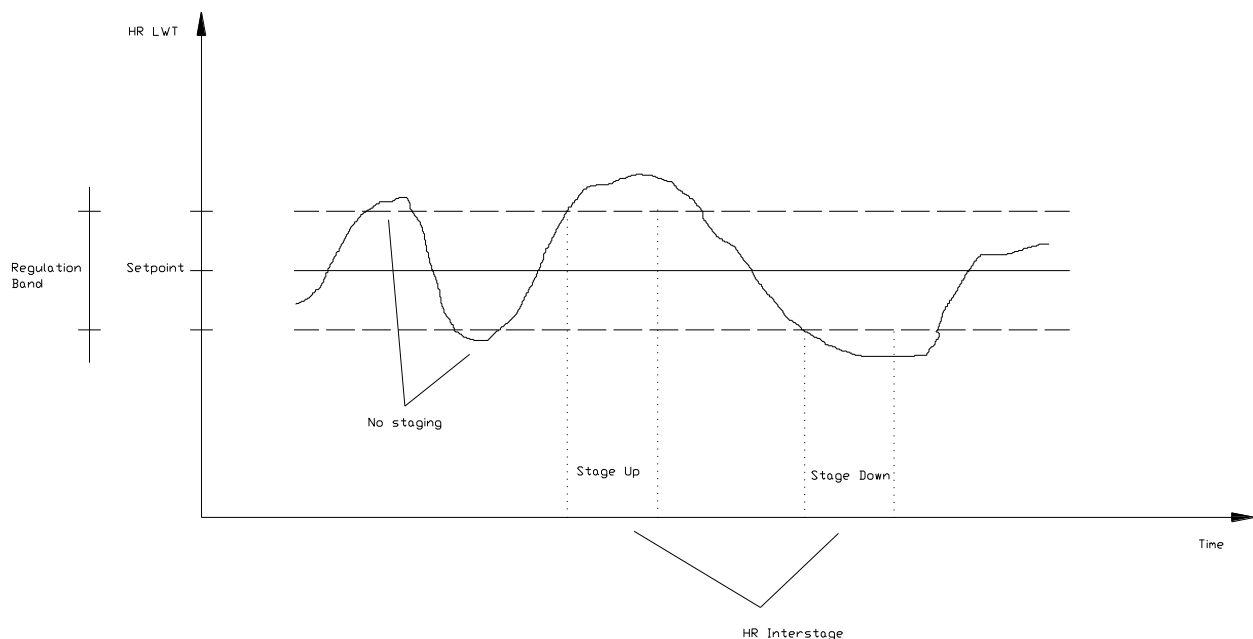
5.20.3   Compressor limiting

Two levels of limits are included in the control:

- *Load inhibit.* The load is not allowed; another compressor may start or may be loaded.
- *Forced unload.* The compressor is unloaded; another compressor may start or may be loaded

The parameters that may limit compressors are :

- *Suction pressure*

   The compressor load is inhibited if the suction pressure is lower than a "stage-hold" setpoint

   The compressor is unloaded if the suction pressure is lower than a "stage-down" setpoint

- *Discharge pressure*

   The compressor load is inhibited if the discharge pressure is higher than a "stage-hold" setpoint

   The compressor is unloaded if the discharge pressure is higher than a "stage-down" setpoint

- *Evaporator outlet temperature*

   The compressor is unloaded if the evaporator outlet temperature is lower than a "stage-down" setpoint

- *Discharge Superheat*

   The compressor load is inhibited if, the discharge superheat is below an adjustable threshold (default 1.0°C) for an adjustable time (default 30s) from the compressor starts at the end of prepurge procedure.

- *Absorbed inverter current*

   The compressor load is inhibited if, the absorbed inverter current is above an adjustable threshold .

   The compressor is unloaded if the absorbed inverter current is above the inhibit threshold of an adjustable percentage.

5.21   Unit limiting

Unit load may be limited by the following inputs:

- *Unit current*

   The unit load is inhibited if the absorbed current is near to a maximum current setpoint (within -5% from setpoint)

   The unit is unloaded if the absorbed current is higher than a maximum current setpoint

- *Demand limit*

   The unit load is inhibited if the unit load (measured by slide valve sensors or calculated as described) is near to a maximum load setpoint (within -5% from setpoint)

   The unit is unloaded if the unit load is higher than the maximum load setpoint.

   The maximum load setpoint may be derived by a 4-20 mA input (4mA $\rightarrow$ limit=100%; 20 mA $\rightarrow$ limit=0%); or from a numeric input coming from monitoring system (network demand limit).

- *SoftLoad*

   At unit startup (when the first compressor stats) a temporary demand limit may be set up to a time expired.

5.22   Evaporator pumps

An evaporator pump is foreseen in the base configuration while a second pump is an optional. When the two pumps are selected, the system will automatically start the pump with lower operating hours each time a pump has to be started. A fixed starting sequence may be set. A pump is started when the unit is switched on; within 30 sec an evaporator flow switch must close otherwise and "Evaporator Flow Alarm" will rise. The alarm is automatically reset for three times if the evaporator flow switch closes for more than 30 seconds. Starting from the fourth alarm it has to be reset manually.

5.23   Fans control

Fans control is used to manage condensation pressure in cooling, cooling glycol or ice mode and evaporating pressure in heating mode. In both cases the fans may be managed to control:

- Condensation or evaporation pressure,

- Pressure ratio,
- Pressure difference between condensation and evaporation.

Four control methods are available:

- Fantroll,
- Variable speed driver,
- Speedtroll.

5.23.1 Fantroll

A step control is used; fan steps are activated or deactivated to keep compressor operating conditions within the allowed envelope. Fan steps are activated or deactivated keeping condensing (or evaporating pressure) change to a minimum; to do this one next fan is started or stopped at time. Fans are connected to steps (digital outputs) according to the scheme in table below

Fans connection to steps

	N° of fans per circuit							
	2	3	4	5	6	7	8	9
Step	Fans on the step							
1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2
3		3	3,4	3,4	3,4	3,4	3,4	3,4
4				5	5,6	5,6	5,6	5,6
5						7	7,8	7,8,9

Fan steps are activated or deactivated on the base of the staging table below

Steps staging

	N° of fans per circuit							
	2	3	4	5	6	7	8	9
Stage	Active step							
1	1	1	1	1	1	1	1	1
2	1+2	1+2	1+2	1+2	1+2	1+2	1+2	1+2
3		1+2+3	1+3	1+3	1+3	1+3	1+3	1+3
4			1+2+3	1+2+3	1+2+3	1+2+3	1+2+3	1+2+3
5				1+2+3+4	1+3+4	1+3+4	1+3+4	1+3+4
6					1+2+3+4	1+2+3+4	1+2+3+4	1+2+3+4
7						1+2+3+4+5	1+3+4+5	1+2+3+5
8							1+2+3+4+5	1+3+4+5
9								1+2+3+4+5

5.23.1.1 Fantroll in cooling mode

5.23.1.1.1 Control of condensing pressure

A stage up is executed (the next stage is activated) if the condensing saturated temperature (saturated temperature at discharge pressure) exceeds the target setpoint (default 43.3 °C (110 F)) by an amount equal to a stage up dead band by a time depending by the difference between the reached values and the target setpoint plus stage up dead band (high condensing temperature error). In particular the stage up is executed when the integral of the high condensing temperature error reaches the value 50 °C x sec (90 Fxsec). At the same manner a stage down is executed (the previous stage is activated) if the condensing saturated temperature falls below the target setpoint by an amount equal to a stage down dead band by a time depending by the difference between the reached the target setpoint minus the stage down dead band values and the reached value (low condensing temperature error). In particular the stage down is executed when the integral of the low condensing temperature error reaches the value 14 °Cxsec (25.2 Fxsec). The condensing temperature error integral is reset to zero when condensing temperature is within the deadband or a new stage is activated. Each fan stage will have its own adjustable stage up (default 4.5 °C (8.1F)) and stage down (default 6.0 °C (10.8 F)) deadband.

5.23.1.1.2 Control of pressure ratio

The control will operate to keep pressure ratio equal to a target adjustable value (default 2.8). A stage up is executed (the next stage is activated) if the pressure ratio exceeds the target pressure ratio by an amount equal to an adjustable stage up dead band by a time depending by the difference between the reached values and the target value plus stage up dead band (high pressure ratio error). In particular the stage up is executed when the integral

of the pressure ratio error reaches the value 25 sec. At the same manner a stage down is executed (the previous stage is activated) if the pressure ratio falls below the target setpoint by an amount equal to a stage down dead band depending by the difference between the target setpoint minus the stage down dead band values and the reached value (low pressure ratio error). In particular the stage down is executed when the integral of the low pressure ratio error reaches the value 10 sec. The pressure ratio error integral is reset to zero when condensing temperature is within the deadband or a new stage is activated. Each fan stage will have its own adjustable stage up (default 0.2) and stage down (default 0.2) deadband.

5.23.1.1.3   Control of temperature difference

The control will operate to keep difference between the condensing temperature (saturated temperature at discharge pressure) and evaporating temperature (saturated temperature at suction pressure) equal to an adjustable target value (default 40°C (72 F)). A stage up is executed (the next stage is activated) if the pressure difference exceeds the target pressure difference by an amount equal to an adjustable stage up dead band by a time depending by the difference between the reached values and the target value plus a stage up dead band (high pressure difference error).In particular the stage up is executed when the integral of the pressure difference error reaches the value 50 °C x sec (90 Fxsec). At the same manner a stage down is executed (the previous stage is activated) if the pressure difference falls below the target setpoint by an amount equal to a stage down dead band depending by the difference between the target setpoint minus the stage down dead band values and the reached value (low pressure difference error). In particular the stage down is executed when the integral of the low pressure ratio error reaches the value 14 °C x sec (25.2 Fxsec). The pressure ratio error integral is reset to zero when condensing temperature is within the deadband or a new stage is activated. Each fan stage will have its own adjustable stage up (default 4.5 °C (8.1F)) and stage down (default 6.0 °C (10.8 F)) deadband.

5.23.1.2   Fantroll in heating mode

5.23.1.2.1   Control of evaporation pressure

A stage up is executed (the next stage is activated) if the evaporating saturated temperature (saturated temperature at suction pressure) is below the target setpoint (default 0 °C (32 F)) by an amount equal to a stage up dead band by a time depending by the difference between the reached values and the target setpoint plus stage up dead band (high condensing temperature error). In particular the stage up is executed when the integral of the high condensing temperature error reaches the value 50 °C x sec (90 F x sec). At the same manner a stage down is executed (the previous stage is activated) if the evaporating saturated temperature exceeds the target setpoint by an amount equal to a stage down dead band by a time depending by the difference between the reached the target setpoint minus the stage down dead band values and the reached value (low condensing temperature error). In particular the stage down is executed when the integral of the low condensing temperature error reaches the value 14 °C x sec (25.2 Fxsec). The condensing temperature error integral is reset to zero when condensing temperature is within the deadband or a new stage is activated. Each fan stage will have its own adjustable stage up (default 3 °C (5.4F)) and stage down (default 3 °C (5.4 F)) deadband.

5.23.1.2.2   Control of pressure ratio

The control will operate to keep pressure ratio equal to a target adjustable value (default 3.5). A stage up is executed (the next stage is activated) if the pressure ratio exceeds the target pressure ratio by an amount equal to an adjustable stage up dead band by a time depending by the difference between the reached values and the target value plus stage up dead band (high pressure ratio error). In particular the stage up is executed when the integral of the pressure ratio error reaches the value 25 sec. At the same manner a stage down is executed (the previous stage is activated) if the pressure ratio falls below the target setpoint by an amount equal to a stage down dead band depending by the difference between the target setpoint minus the stage down dead band values and the reached value (low pressure ratio error). In particular the stage down is executed when the integral of the low pressure ratio error reaches the value 10 sec. The pressure ratio error integral is reset to zero when condensing temperature is within the deadband or a new stage is activated. Each fan stage will have its own adjustable stage up (default 0.2) and stage down (default 0.2) deadband.

5.23.1.2.3   Control of temperature difference

The control will operate to keep difference between the condensing temperature (saturated temperature at discharge pressure) and evaporating temperature (saturated temperature at suction pressure) equal to an adjustable target value (default 50°C (90 F)). A stage up is executed (the next stage is activated) if the pressure difference exceeds the target pressure difference by an amount equal to an adjustable stage up dead band by a time depending by the difference between the reached values and the target value plus a stage up dead band (high pressure difference error). In particular the stage up is executed when the integral of the pressure difference error reaches the value 50 °C x sec (90 Fxsec). At the same manner a stage down is executed (the previous stage is activated) if the pressure difference falls below the target setpoint by an amount equal to a stage down dead band depending by the difference between the target setpoint minus the stage down dead band values and the reached value (low pressure difference error). In particular the stage down is executed when the integral of the low pressure

ratio error reaches the value 14 °C x sec (25.2 Fxsec). The pressure ratio error integral is reset to zero when condensing temperature is within the deadband.

5.23.2   Variable Speed Driver

A continuous control is used; fans speed is modulated to keep saturated condensation pressure at a setpoint; a PID control is used to allow a stable operation.A Fan Silent Mode function (FSM) is implemented on unit with Variable Speed Driver (VSD) to keep fan speed below a set value during some periods.

5.23.2.1   VSD in cooling, cooling glycol or ice mode

When the system is operating in cooling mode, either if it is controlling the condensation pressure, the pressure ratio or the pressure difference, the PID proportional gain is positive (the higher the input the higher the output).
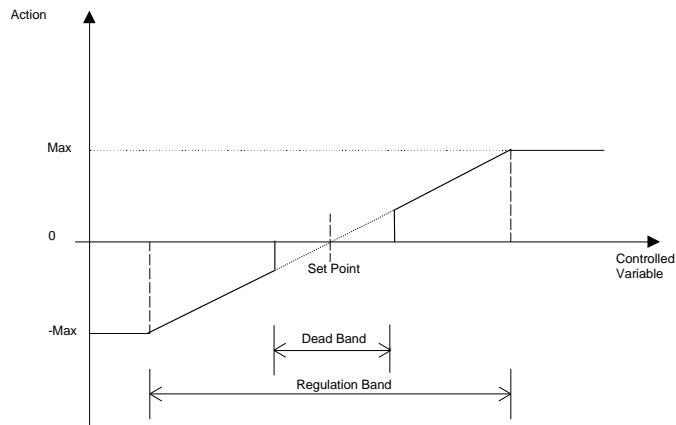
Fig. 15 – Proportional action of VSD PID in cooling/iced mode

5.23.2.2 VSD in heating mode

5.23.2.2.1   Control of evaporation temperature

When the system is operating in heating mode to control the evaporation temperature the proportional gain is negative (the higher the input the lower the output).
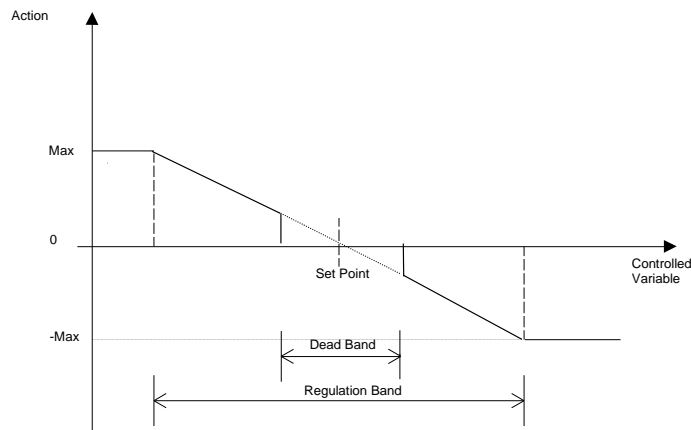
Fig. 16 – Proportional action of VSD PID in heating mode

5.23.2.2.2   Control of pressure ratio or temperature differences

When the system is operating in heating mode to control the pressure ration the proportional gain is positive (the higher the input the higher the output).

5.23.3   Speedtroll

A mixed step-VSD control are used; the first fans step are managed using a VSD (with related PID control), next steps are activated as in the step control, only if the cumulated stage-up and stage-down error is reached and the VSD output is at maximum or minimum respectively.

5.23.4   Fans control at startup in heating mode

At the compressors start in heating mode fans are started before that the compressors begin their normal start up sequence if the outside ambient temperature is below a fixed temperature of 10.0°C (50.0F). If the condensation control is either speedtroll or fantroll each step is activated after a fixed delay of 6 seconds. The control is released to automatic control if the outside ambient temperature is greater than a fixed threshold of 15.0°C (59.0F).

5.24 Other functions

The following functions are implemented.

5.24.1   Hot Chilled Water Start

This feature will allow the unit startup also in case of high evaporator outlet water temperature.
It will not allow the compressors loading above an adjustable percentage until the evaporator leaving water temperature falls below an adjustable threshold; another compressor is enabled to start when the others are limited.

5.24.2   Fan Silent Mode

This feature will allow to reduce unit noise limiting fans speed (only in case of VSD fan control) on the base of a time schedule. A maximum output voltage for the VSD could be set for FSM operations (default value 6.0V).

5.25 Unit and compressors status

In the following tables it will be possible to find all the configured unit and compressors status with some details explaining the status.

Unit Status code	Interface status label	Explanation
0	-	Not reachable.
1	Off Alarm	Unit is off due to a unit alarm.
2	Off Rem Comm	Unit is off from Remote Supervisor.
3	Off Time Schedule	Unit is off due to time schedule.
4	Off Remote Sw	Unit is off from remote switch.
5	Pwr Loss Enter Start	Power failure. Press Enter button to start the Unit.
6	Off Amb. Lockout	Unit is off due to external temperature below ambient lockout threshold.
7	Waiting Flow	Unit is verifying the flow switch status before temperature control start.
8	Waiting Load	Waiting for thermal load on water circuit.
9	No Comp Available	No compressor available (both off or in conditions that inhibits their start).
10	FSM Operation	Unit is working in Fan Silent Mode.
11	Off Local Sw	Unit is off from local switch.
12	Off Cool/Heat Switch	Unit is in idle after a Cool/Heat switch.

Compressor Status code	Interface status label	Explanation
0	-	Not reachable.
1	Off Alarm	Compressor is off due to unit alarm.
2	Off Ready	Compressor is ready but the Unit is off.
3	Off Ready	
4	Off Ready	
5	Off Ready	
6	Off Ready	
7	Off Switch	Compressor is off from switch.
8	Auto %	Automatic compressor load management.
9	Manual %	Manual compressor load management.
10	Oil Heating	Compressor is off due to Oil Heating.
11	Ready	Compressor is ready to start.
12	Recycle Time	Compressor is waiting for safety timers to expire before it could be kicked again.
13	Manual Off	Compressor is off from terminal.
14	Prepurge	Compressor is in pre-emptying evaporator before it could be automatically managed.
15	Pumping Down	Compressor is pre-emptying the evaporator before shut-down.
16	Downloading	Compressor is reaching its minimum load percentage.
17	Starting	Compressor is starting.
18	Low Disch SH	Discharge superheat is lower than a adjustable threshold
19	Defrost	Compressor is in defrosting procedure.
20	Auto %	Automatic compressor load management (Inverter).
21	Max VFD Load	Maximum absorbed current reached compressor cannot load.
22	Off Rem SV	Compressor is off from Remote Supervisor.

5.26 Start-up sequence

5.26.1 Unit start-up and shut-down flowcharts

```
          ┌──────────────────┐
          │    Unit Stop     │
          └──────────────────┘
                   │
                   ▽
          ┌──────────────────┐
          │Compressors shutdown│
          │    procedure     │
          └──────────────────┘
                   │
                   ▽
          ┌──────────────────┐   Yes
          │Evap flow switch open├──────────▷  Unit Trip
          │within timer expiration│
          └──────────────────┘
                   │ No
                   ▽
          ┌──────────────────┐
          │    Unit Off      │
          └──────────────────┘
```
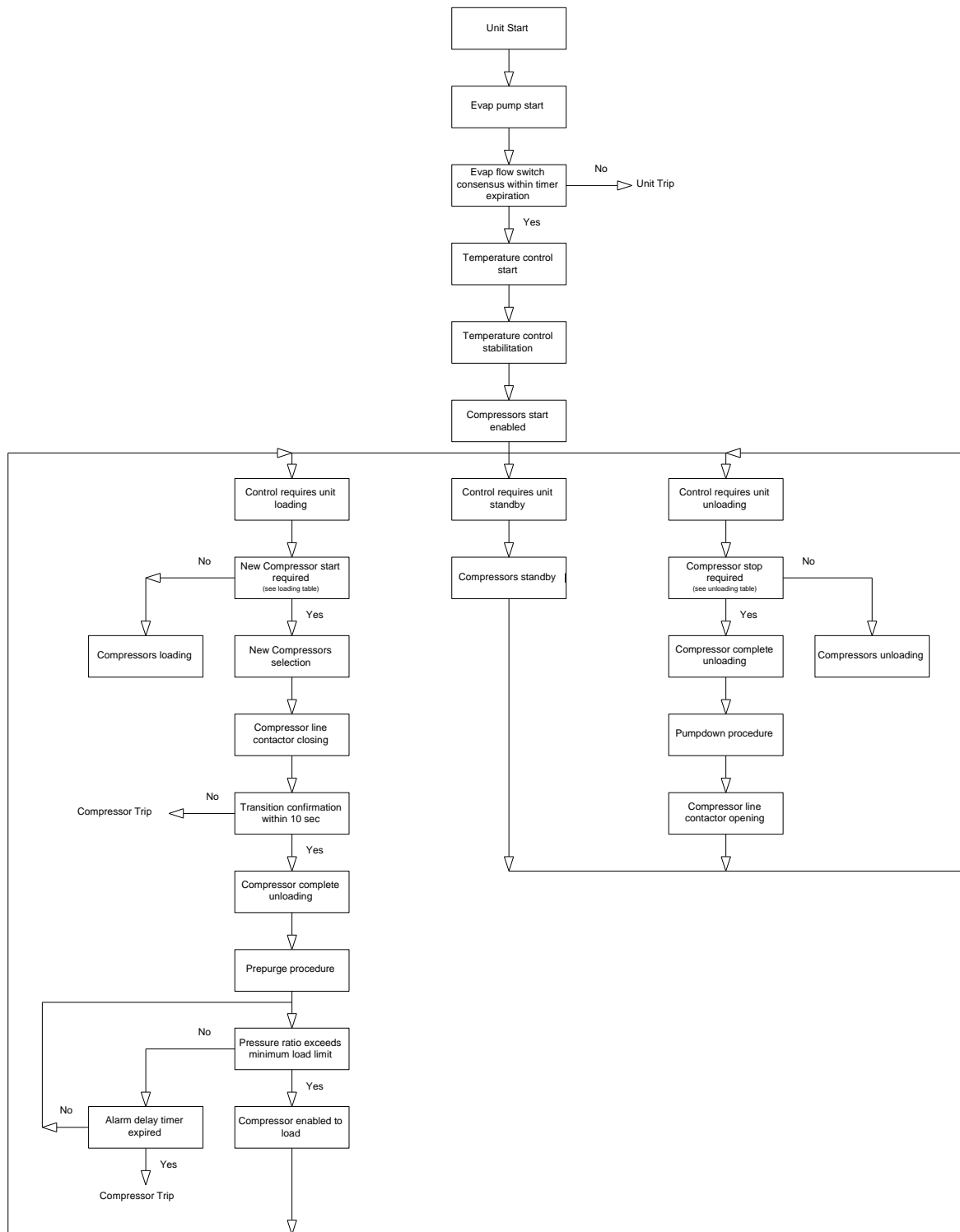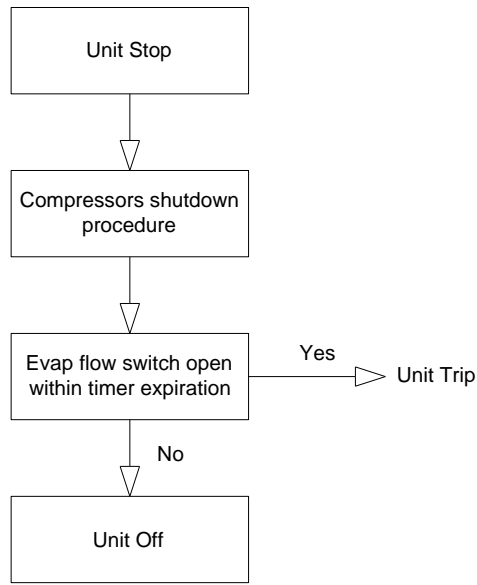
5.26.2 Heat recovery start-up and shut-down flowcharts

```
                    ┌──────────────────────────┐
                    │  Heat recovery activation │
                    └──────────────────────────┘
                                  │
                                  ▽
                    ┌──────────────────────────┐
                    │   Heat recovery pump      │
                    │         start             │
                    └──────────────────────────┘
                                  │
                                  ▽
                    ┌──────────────────────────┐    No
                    │   Recovery flow switch    │────────────▷  HR Trip
                    │  consensus within timer   │
                    │        expiration         │
                    └──────────────────────────┘
                                  │  Yes
                                  ▽
                    ┌──────────────────────────┐
                    │  HR temperature control   │
                    │          start            │
                    └──────────────────────────┘
                                  │
                                  ▽
                    ┌──────────────────────────┐
                    │  HR temperature control   │
                    │       stabilitation       │
                    └──────────────────────────┘
                                  │
                                  ▽
                    ┌──────────────────────────┐
                    │   HR circuits activation  │
                    │         enabled           │
                    └──────────────────────────┘
```

```
                    ┌──────────────────────────┐    No
                    │   HR leaving temperature  │────────────▷  HR 3Way valve
                    │        above limit        │                 modulating
                    └──────────────────────────┘
                                  │  Yes
                                  ▽
                    ┌──────────────────────────┐
                    │     HR 3Way valve         │
                    │    complete opening       │
                    └──────────────────────────┘
```

Control requires loading	Control requires standby	Control requires unloading
Loading interstage timer expired (PID calculation)	System standby	Unoading interstage timer expired (PID calculation)
New circuit activation		Last circuit deactivation

No (from Loading interstage timer expired)

No (from Unoading interstage timer expired)

```
                        ┌─────────────────┐
                        │ Heat Recovery Stop │
                        └─────────────────┘
                                 │
                                 ▽
                        ┌─────────────────┐
                        │ Circuits deactivation │
                        │    procedure     │
                        └─────────────────┘
                                 │
                                 ▽
                        ┌─────────────────┐
                        │ 3Way valve opening │
                        └─────────────────┘
                                 │
                                 ▽
                        ┌─────────────────┐      Yes
                        │ Evap flow switch open │────────▷ HR Trip
                        │ within timer expiration │
                        └─────────────────┘
                                 │ No
                                 ▽
                        ┌─────────────────┐
                        │ Haet Recovery Off │
                        └─────────────────┘
```

6   ALARMS AND TROUBLESHOOTING

6.1   Unit trips

Unit trips are caused by:

- *Low evaporator flow rate.* A "Low evaporator flow rate alarm" will trip the whole unit if the evaporator flow switch remains open for more than an adjustable value; the alarm are automatically reset for three times if the evaporator flow switch closes for more than 30 seconds. Starting from the fourth alarm it has to be reset manually.

- *Low evaporator outlet temperature.* A "Low evaporator outlet temperature alarm" will trip the whole unit as soon as the evaporator leaving water temperature falls below the freeze alarm setpoint. A manual reset of the alarm are required to restart the unit

- *Phase-Voltage Monitor (PVM) or Ground Protection (GPF) failure.*A "Bad phase/voltage or Ground protection failure alarm" will trip the whole unit as soon as the phase monitor switch opens (if a single phase monitor is used) after the unit start request.A manual reset of the alarm will required to restart the unit

- *Evaporator leaving water temperature fault.*An "Evaporator leaving water temperature fault alarm" will trip the whole unit if the reading of evaporator leaving water temperature goes out of probe allowable range for a time longer than ten seconds.A manual reset of the alarm will required to restart the unit.

- *External alarm (only if enabled).*A "External alarm" will trip the whole unit as soon as the external alarm switch closes after the unit start request, if the unit trip on external alarm has been set. A manual reset of the alarm will required to restart the unit.

- *Probe failure.*A "Probe failure" will trip the unit if the reading of one among the following probes goes out of probe allowable range for a time longer than ten seconds.

  - Evaporator #1 leaving temperature probe (on 2 evaporators units)
  - Evaporator #2 leaving temperature probe (on 2 evaporators units)

  The controller display will show the faulted probe identification

6.2   Compressors trip

Compressor trips are caused by:

- *Mechanical High pressure.*A "High pressure switch alarm" will trip the compressor as soon as the high pressure switch opens.A manual reset of the alarm is required to restart the unit (after the manual reset of the pressure switch).

- *High discharge pressure.* A "High discharge pressure alarm" will trip the compressor as soon as the compressor discharge pressure exceeds the adjustable high pressure setpoint.A manual reset of the alarm are required to restart the unit

- *High discharge temperature.* A "High discharge temperature alarm" will trip the compressor as soon as the compressor discharge temperature exceeds the adjustable high temperature setpoint.A manual reset of the alarm are required to restart the unit.

- *Low evaporator outlet temperature.* A "Low evaporator outlet temperature alarm" will trip the compressors as soon as the evaporator leaving water temperature falls below the adjustable freeze threshold. A manual reset of the alarm are required to restart the unit

- *Mechanical Low pressure.* A "Low pressure switch alarm" will trip the compressor if the low pressure switch opens for more than 40 seconds during compressor running. Five automatic reset alarms (both from transducers and switches) are managed in all modes (cooling, cooling glycol, ice, heat pump). These alarms switch off the compressor without signalling (alarm relay is not activated). Only the sixth will be a manual reset alarm.The "Low pressure switch alarm" are disabled during prepurge cycles and during pumpdown. At compressor startup (after the end of prepurge cycles) the "Low pressure switch alarm" is disabled if a low ambient start has been recognized otherwise are delayed by 120 sec.A manual reset of the alarm are required to restart the unit

- *Low suction pressure.*A "Low suction pressure alarm" will trip the compressor if the compressor suction pressure remains below the adjustable low pressure alarm setpoint for a time longer than that listed in the following table. Low suction pressure alarm delay

Low press setpoint – Suct. press (bar / psi)	Alarm delay (seconds)
0.1 / 1.45	160
0.3 / 4.35	140
0.5 / 7.25	100
0.7 / 10.15	80
0.9 / 13.05	40
1.0 / 14.5	0

No delay is introduced if the suction pressure falls below the low pressure alarm setpoint by an amount greater or equal to 1 bar. Five automatic reset alarms (both from transducers and switches) are managed in all modes (cooling, cooling glycol, ice, heat pump). These alarms switch off the compressor without signalling (alarm relay is not activated). Only the sixth will be a manual reset alarm. The "Low suction pressure alarm" are disabled during prepurge cycles and during pumpdown. At compressor startup (after the end of prepurge cycles) the "Low suction pressure alarm" are disabled if a low ambient start has been recognized. A manual reset of the alarm are required to restart the unit.

- *Low oil pressure.* A "Low oil pressure alarm" will trip the compressor if the oil pressure remains below the following thresholds by a time longer than an adjustable value during compressors running and at compressor startup

    Suction pressure*1.1 + 1 bar at compressor minimum load

    Suction pressure*1.5 + 1 bar at compressor full load

    Interpolated values at compressor intermediate load

    A manual reset of the alarm are required to restart the unit

- *High oil pressure difference.* A "High oil pressure difference alarm" will trip the compressor if the difference between the discharge pressure and the oil pressure remains over an adjustable setpoint (default 2.5 bar) by a time longer than an adjustable value. A manual reset of the alarm are required to restart the unit

- *Low pressure ratio.* A "Low pressure ration alarm" will trip the compressor if the pressure ratio remains below the adjustable threshold at rated compressor load by a time longer than an adjustable value. A manual reset of the alarm are required to restart the unit

- *Compressor Startup failure.* A "Failed transition or starter alarm" will trip the compressor if the transition/starter switch remains open for more than 10 seconds from compressor start. A manual reset of the alarm are required to restart the unit

- *Compressor overload or motor protection.* A "Compressor overload alarm" will trip the compressor if the overload switch remains open for more than 5 seconds after the compressor start. A manual reset of the alarm are required to restart the unit.

- *Slave board failure.* A "Unit xx off-line alarm" will trip slave compressors if the master board cannot communicate with slave boards for a time longer than 30 seconds. A manual reset of the alarm are required to restart the unit

- *Master board failure or network communication.* A "Master off-line alarm" will trip the slave compressors if slave board cannot communicate with master board for a time longer than 30 seconds.

- *Probe failure.* A "Probe failure" will trip the compressor if the reading of one among the following probes goes out of probe allowable range for a time longer than ten seconds.

    - Oil Pressure probe
    - Low Pressure probe
    - Suction temperature probe
    - Discharge Temperature probe
    - Discharge Pressure probe

    The control display will show the faulted probe identification

- *Auxiliaries signal failure.* The compressor is tripped if one among the following digital inputs is opened for a timer greater than an adjustable value (default is 10 s).

    - Compressor phase monitor or Ground protection failure
    - Variable speed driver alarm

6.3 Other trips

Other trips may disable particular functions described in the following (e.g. heat recovery trips). The addition of optional expansion boards will also activate the alarms related to communication with expansion boards and to probes connected to expansion boards. For units with electronic expansion valve, all the drivers critical alarms will trip the compressors

6.4 Unit and compressors alarms and corresponding codes

In the following table the list of the managed alarms for both unit and compressors is shown.

Alarm code	Interface alarm label	Details
0	-	
1	Phase Alarm	Phase alarm (Unit or Circuit)
2	Freeze Alarm	Freeze alarm
3	Freeze Alarm EV1	Freeze alarm on Evaporator 1
4	Freeze Alarm EV2	Freeze alarm on Evaporator 2
5	Pump Alarm	Pump overload
6	Fan Overload	Fan overload
7	OAT Low Pressure	Low press alarm during low OAT start.
8	Low Amb Start Fail	Low OAT start-up failed
9	Unit 1 Offline	Board #1 offline (Master)
10	Unit 2 Offline	Board #2 offline (Slave)
11	Evap. Flow Alarm	Evaporator flow switch alarm
12	Probe 9 Error	Inlet temperature probe fault
13	Probe 10 Error	Outlet temperature probe fault
14	-	-
15	Prepurge #1 Timeout	Prepurge failed on circuit #1
16	Comp Overload #1	Compressor #1 overload
17	Low Press. Ratio #1	Low Pressure Ratio on circuit #1
18	High Press. Switch #1	High pressure switch alarm on circuit #1
19	High Press. Trans #1	High pressure transducer alarm on circuit #1
20	Low Press. Switch #1	Low pressure switch alarm on circuit #1
21	Low Press. Trans #1	Low pressure transducer alarm on circuit #1
22	High Disch Temp #1	High discharge temperature circuit #1
23	Probe Fault #1	Probes on circuit #1 failure
24	Transition Alarm #1	Transition alarm compressor #1
25	Low Oil Press #1	Low oil pressure on circuit #1
26	High Oil DP Alarm #1	High oil delta pressure alarm on circuit #1
27	Expansion Error	Expansion boards error
28	-	-
29	EXV Driver Alarm #1	EXV Driver #1 Alarm
30	EXV Driver Alarm #2	EXV Driver #2 Alarm
31	Restart after PW Loss	Restart after power loss
32	-	-
33	-	-
34	Prepurge #2 Timeout	Prepurge failed on circuit #2
35	Comp Overload #2	Compressor overload #2
36	Low Press. Ratio #2	Low Pressure Ratio on circuit #2
37	High Press. Switch #2	High pressure switch alarm on circuit #2
38	High Press. Trans #2	High pressure transducer alarm on circuit #2
39	Low Press. Switch #2	Low pressure switch alarm on circuit #2
40	Low Press. Trans #2	Low pressure transducer alarm on circuit #2
41	High Disch Temp #2	High discharge temperature circuit #2
42	Maintenance Comp #2	Maintenance required on compressor #2
43	Probe Fault #2	Probes on circuit #1 failure
44	Transition Alarm #2	Transition alarm compressor #2
45	Low Oil Press #2	Low oil pressure on circuit #1
46	High Oil DP Alarm #2	High oil delta pressure alarm on circuit #1
47	Low Oil Level #2	Low oil level on circuit #2
48	PD #2 Timer Expired	Pump down timer expired on circuit #2 (Warning not signalled as alarm condition)
49	-	
50	-	
51	-	
52	Low Oil Level #1	Low oil level on circuit #1
53	PD #1 Timer Expired	Pump down timer expired on circuit #1 (Warning not signalled as alarm condition)
54	HR Flow Switch	Heat recovery flow switch alarm.

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