Natural Refrigerant Training Summit

Building a Sustainable Workforce

Rack Control Introduction

Chris Butler

Application Specialist - CAREL

NORTH AMERICAN Sustainable Refrigeration Council

Natural Refrigerant Training Summit

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Who We Are

A 501c3 nonprofit working to create a sustainable future for supermarket refrigeration by removing barriers to natural refrigerant adoption.

160+
member companies

55K+
food retail locations

Goals

- Build a sustainable technician workforce
- Increase funding for natural refrigerant equipment
- Improve technology options, education, and awareness

What are Natural Refrigerants?

CO_2	C_3H_8	NH_3
R744 Carbon Dioxide	**R290** Propane	**R717** Ammonia

NORTH AMERICAN
Sustainable Refrigeration Council

Rack Control Training

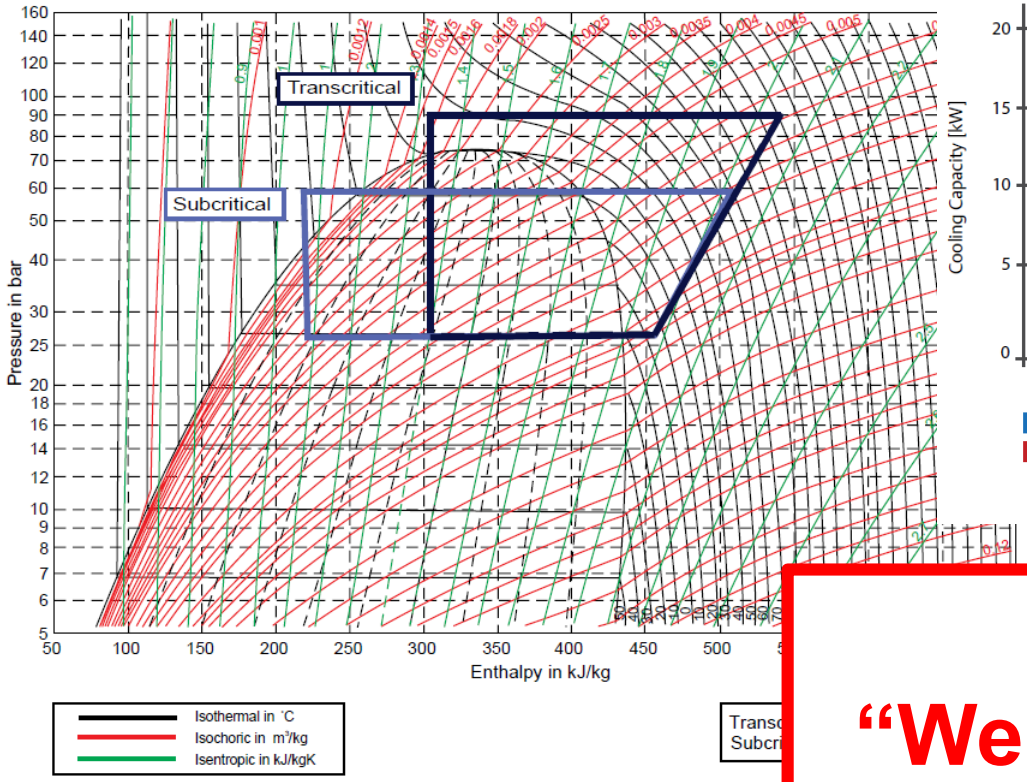
pR300T

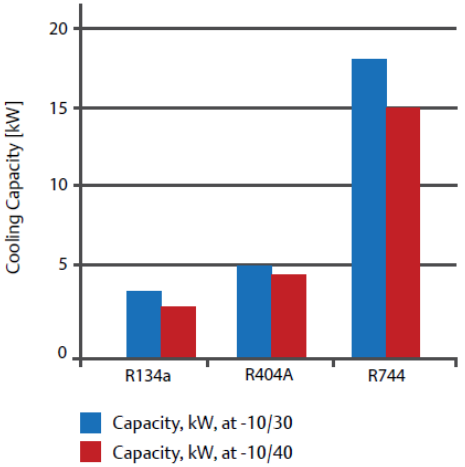
Chris Butler

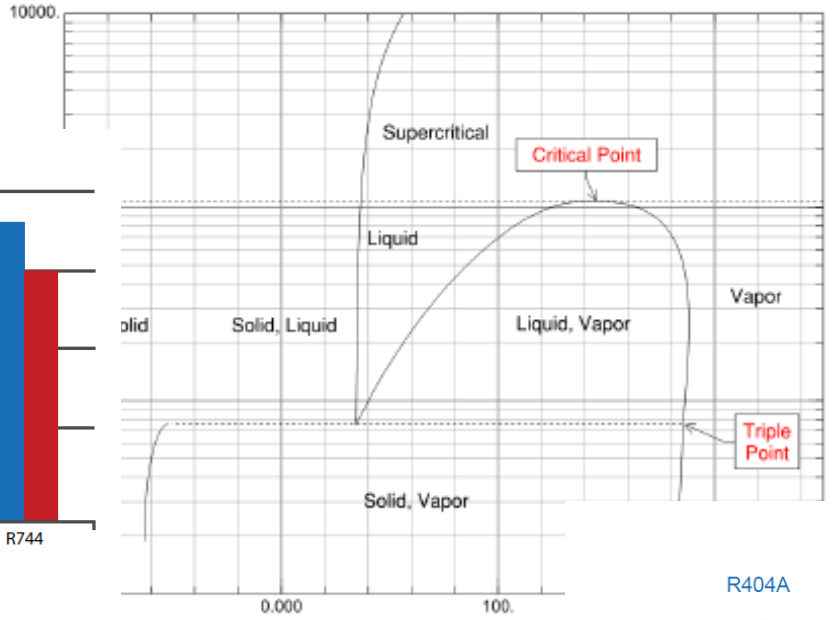
Nov. 2023

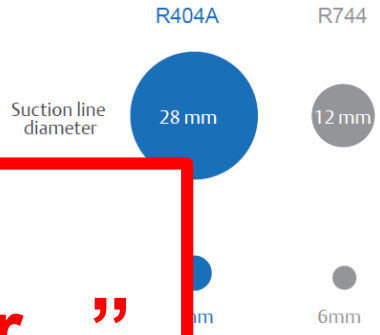
Holup, boss...

What we are sorta NOT covering…









“Well this other controller…”

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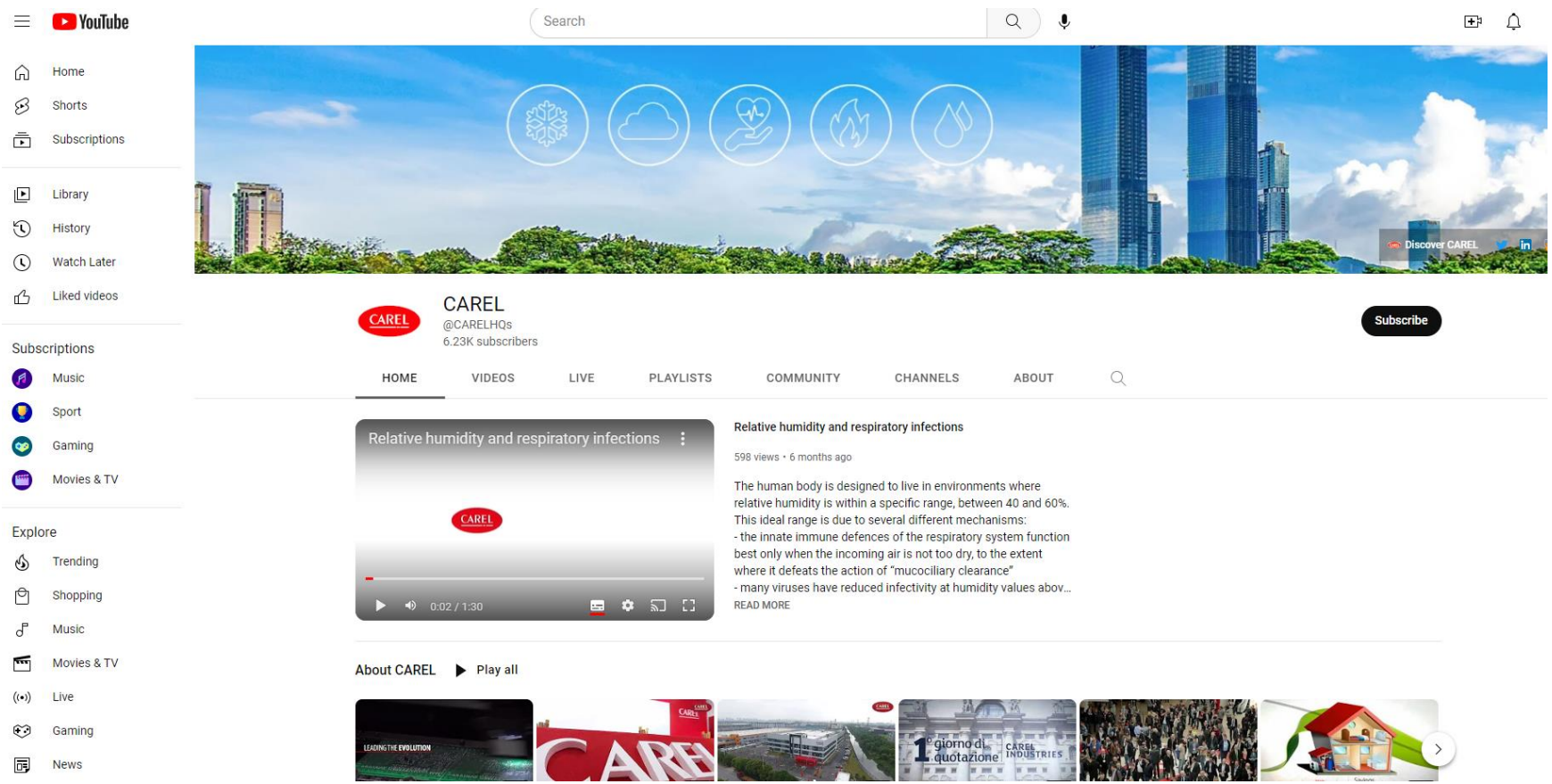

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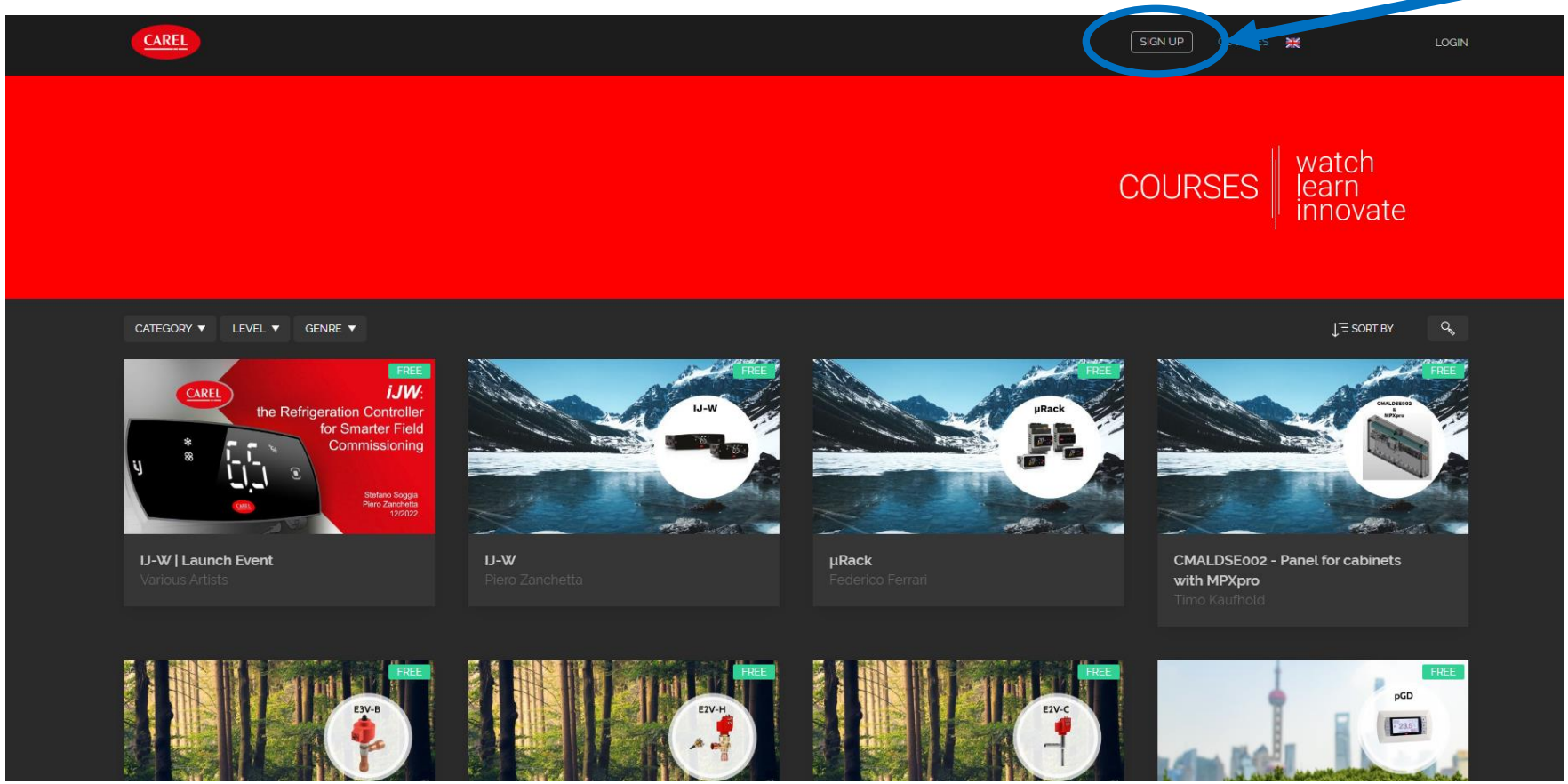
Be sure to click the "SIGN UP" button



SCAN ME

Technical Services
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- **US Based Customers:**
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Where are we and what are we controlling?

Rack control!

CO2, Parallel compression, Loop Piping

Gas Cooler

Dual Temp Parallel Compression Rack

Low Temp Loop (-21*F SST)

EEPR Valve

Medium Temp Loop (+25*F SST)

Medium Temp

Medium Temp
+20*F SST

Low Temp

Distributed Control

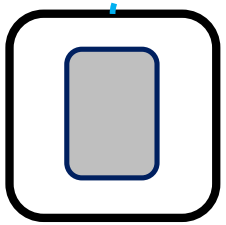
Gas Cooler

Rack Controller

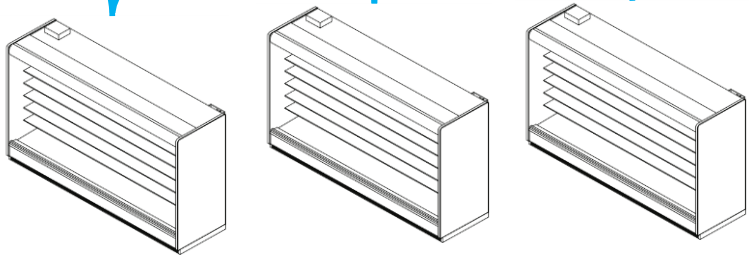
Rack doesn't care what the cases are doing and the cases don't care what the rack is doing…most of the time!

Case Controllers

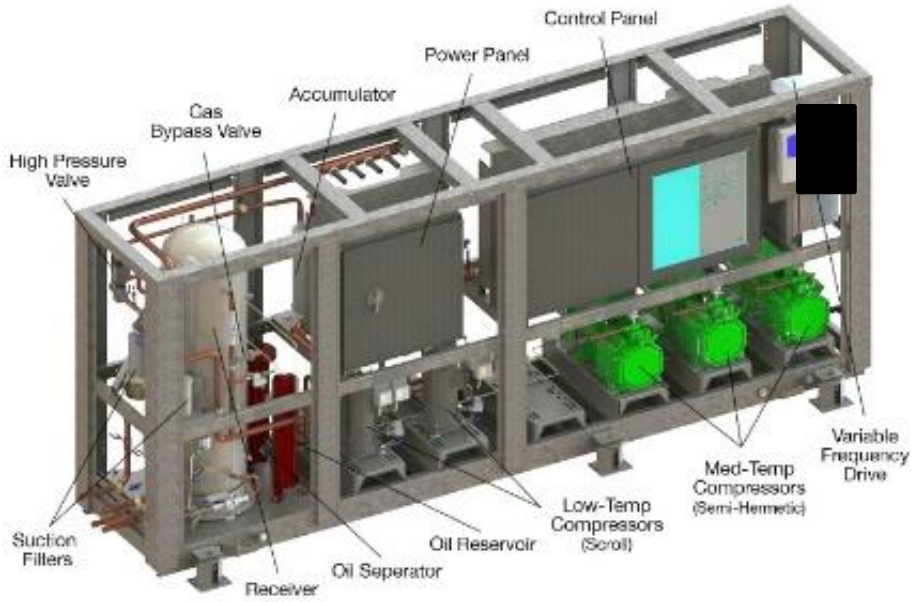
Case Controllers



Supervisory System



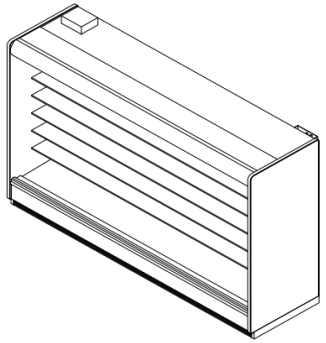
Decentralized Control System



The job of the rack controller is to:

- **Provide quality liquid**
- **Provide quality suction**

A break in comms? So what! Things should keep running!



The job of the case controller is to:

- **Cool or not. Can regulate temperature**

We work together!

The job of the superheat controller is to:

- **Regulate superheat**
- **Smooth Lines! No on/off control. "Floating" superheat.**

What are we using for rack control?

pR300T!

pR300T Hardware

pR300T Quick Summary

- **Transcritical/Subcritical CO2**
- **Booster system**
- **Built in display and/or a handheld display**
- **Optional on board valve control**
- **Multiple boards can be connected together**
- **Wizard for initial programming/parameter setting**
- **Backup to controller, laptop, or USB drive**
- **Configurable I/O**
- **What you don’t use you can’t see**
- **Configurable to your application: Dual Temp (CO2 Booster) Medium Temp, Low Temp, Condenser Control**
- *****Can be used as standalone HPV/Flash Gas valve controller*****

WATCH OUT!!
L1 = Medium Temp
L2 = Low Temp
…always!

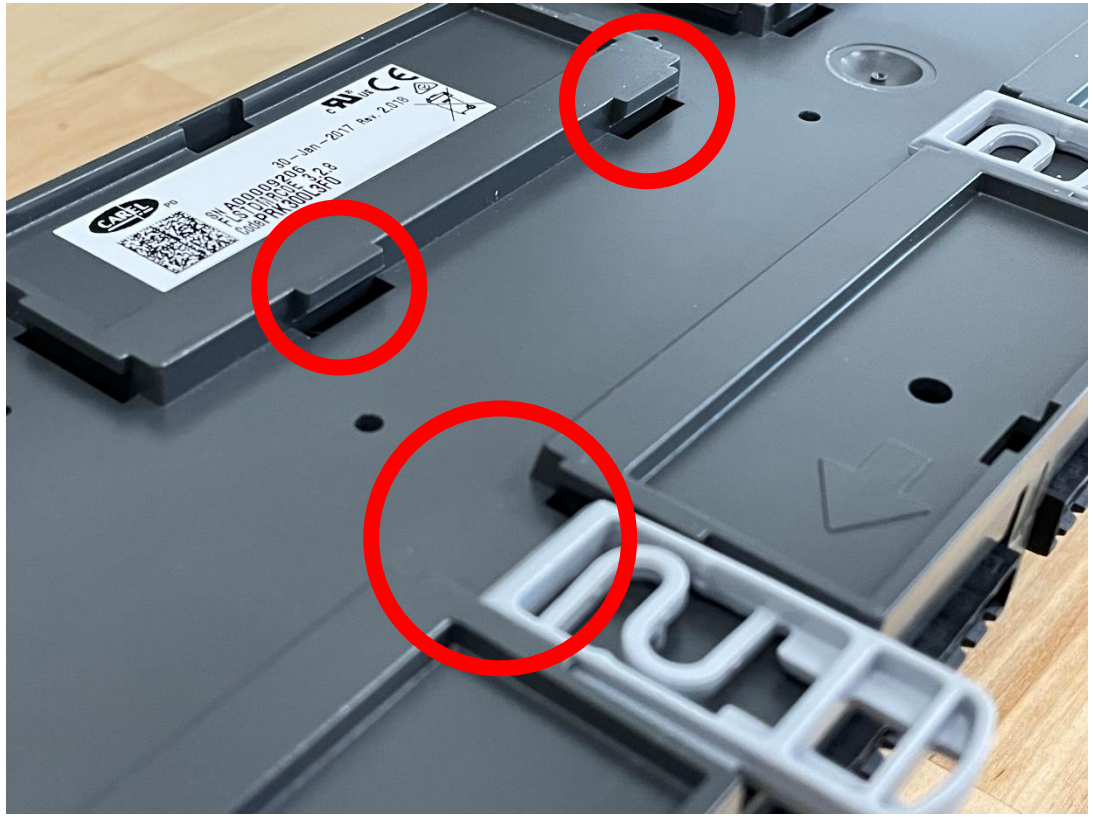
pR300T

pR300T

pR300T w/ Driver and Ultracap

Watch Out!

Upper retaining tabs are fixed!



A few examples...

pR300T

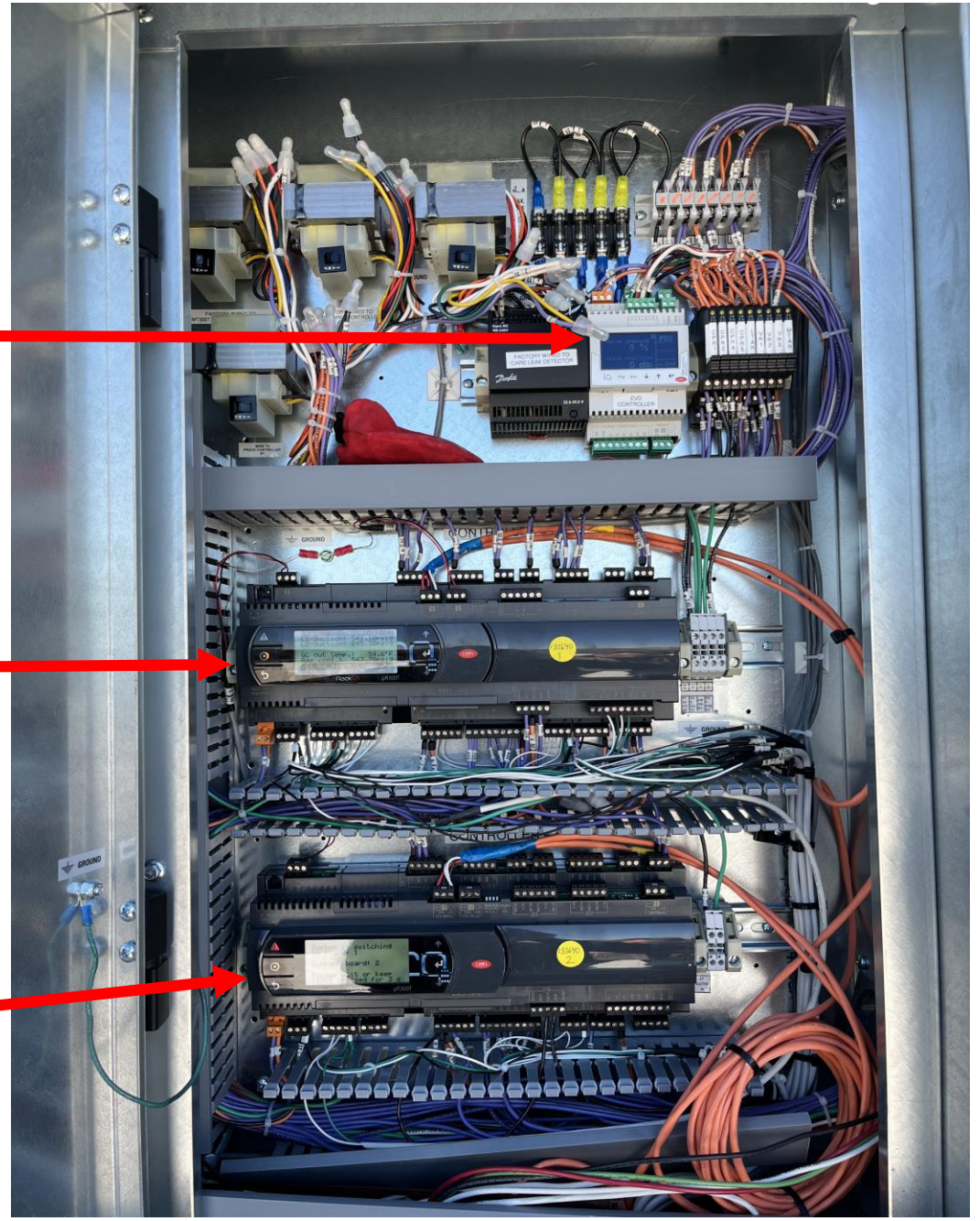
Hmmmm….

What's in the panel?

EVDevo

pR300T PR1 L1 Medium Temp and Gas Cooler

pR300T PR2 L2 Low Temp



Networking

Distributed Control

Gas Cooler

0 – 10V Signal

Rack Controller 1

Rack Controller 2

- **Each pRR300T has it's own Modbus address**
- **Belden 8761, 8762; 22, 20 AWG 1 single pair**
  2 insulated wires + 1 uninsulated wire
- **Belden 9841; 24 AWG 1 single pair**
  2 insulated wires + 1 uninsulated wire
- **Belden 3106A; 22 AWG 1.5 single pair**
  3 insulated wires + 1 uninsulated wire

BMS Network Modbus RTU over RS485

Supervisory System

Main Case Controller

Main Case Controller

Secondary Case Controller

LOCAL M/S Case Net

Main Walk in Controller

Main Walk in Controller

Secondary Walk in Controller

LOCAL M/S Case Net

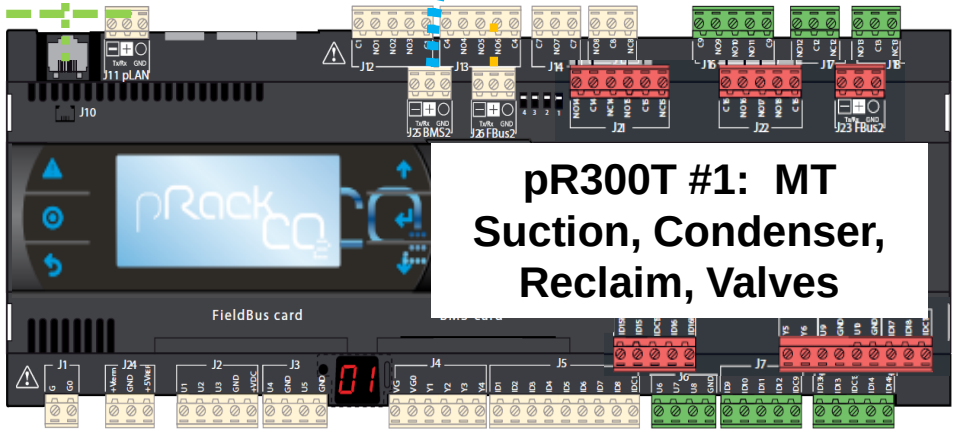
Network Example: pR300T Multi Board

J25 BMS2 Modbus RTU over RS485 (RS485 - Line 2)

GLOBAL

LOCAL

J26 Fieldbus to EVD valve driver



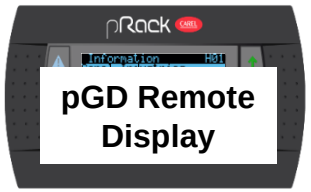
pR300T #1: MT Suction, Condenser, Reclaim, Valves

EVD Evo for RPRV control

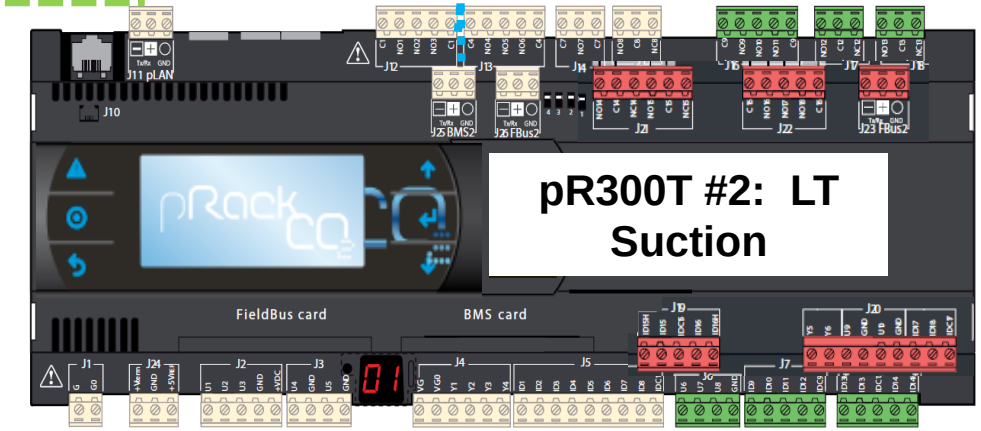
J10 pLan to pGD

J11 pLAN to 2nd pR300T

LOCAL



pGD Remote Display



pR300T #2: LT Suction

J25 BMS2 Modbus RTU over RS485 (RS485 - Line 2)

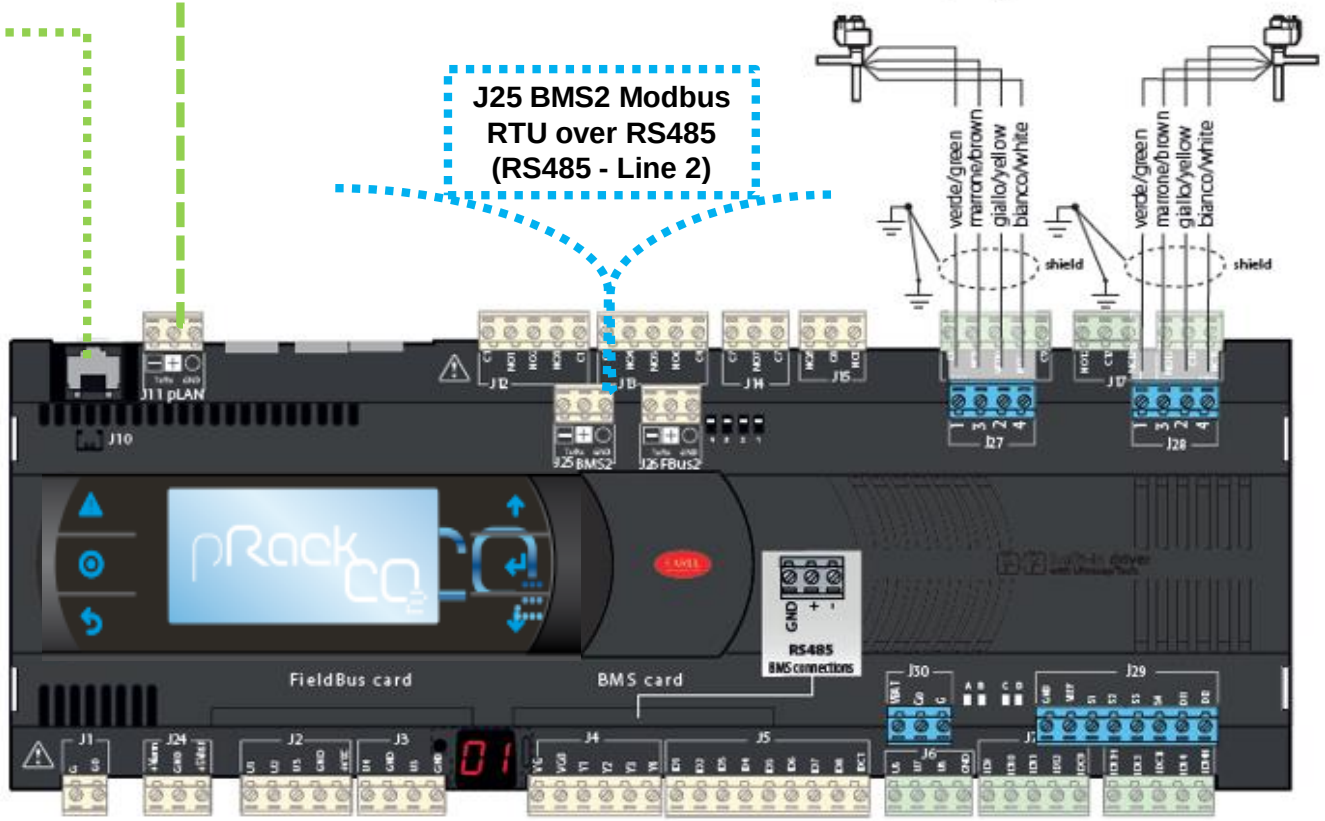
Network Example: pR300T w/ Driver & Exp. Board

J10 pLan to pGD

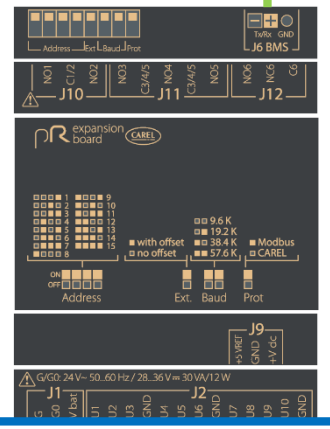
J11 pLAN Expansion Board

Carel or 3rd party HPV and Flash Gas Valve

J25 BMS2 Modbus RTU over RS485 (RS485 - Line 2)



pR300T: MT/LT Suction, Condenser, Reclaim, Valves



Expansion Board (only 1 allowed per configuration)

Wiring: I/O

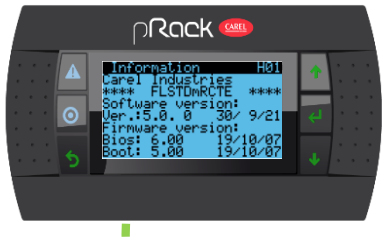
pRack – I/O Overview

- Universal I/O can be configured for different uses:
  - Temperature probes: NTC, PTC, PT1000
  - Active pressure/temperature/humidity probes
  - Ratiometric pressure probes 0 – 5 V
  - Current inputs, 0 to 20 mA or 4 to 20 mA
  - Voltage inputs, 0 to 1 Vdc or 0 to 10 Vdc
  - “Wet” and “dry” digital inputs
  - Analogue outputs, 0 to 10 Vdc, 10 Vdc to 0 or PWM
- Digital Outputs:
  - most, but not all, are Form A (normally open)
  - Optional SSR’s

- **Each connector is grouped by J##**
- **J## and individual pins are identified by silk screen on controller**
- **Where a wire lands is up to the programming and can be moved in most cases**
- **Yes, the gold silkscreen is hard to read**

pR300T: Layout

pGD Remote Display



pLan to pGD

J11 pLAN to 2nd pR300T

J11 pLAN

J25 BMS2 Modbus RTU over RS485 (RS485 - Line 2)

Outputs

J26 or J23 Fieldbus to EVD valve driver

FieldBus card

BMS card

Temperature probes

NTC

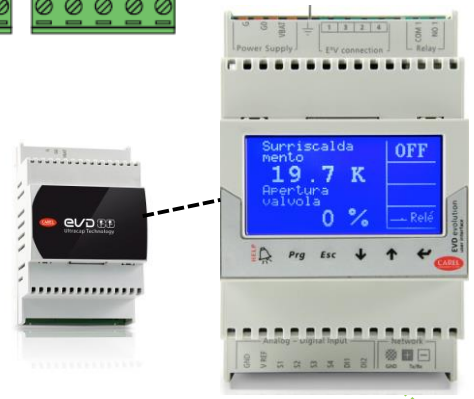
NTC HT

Pressure probes

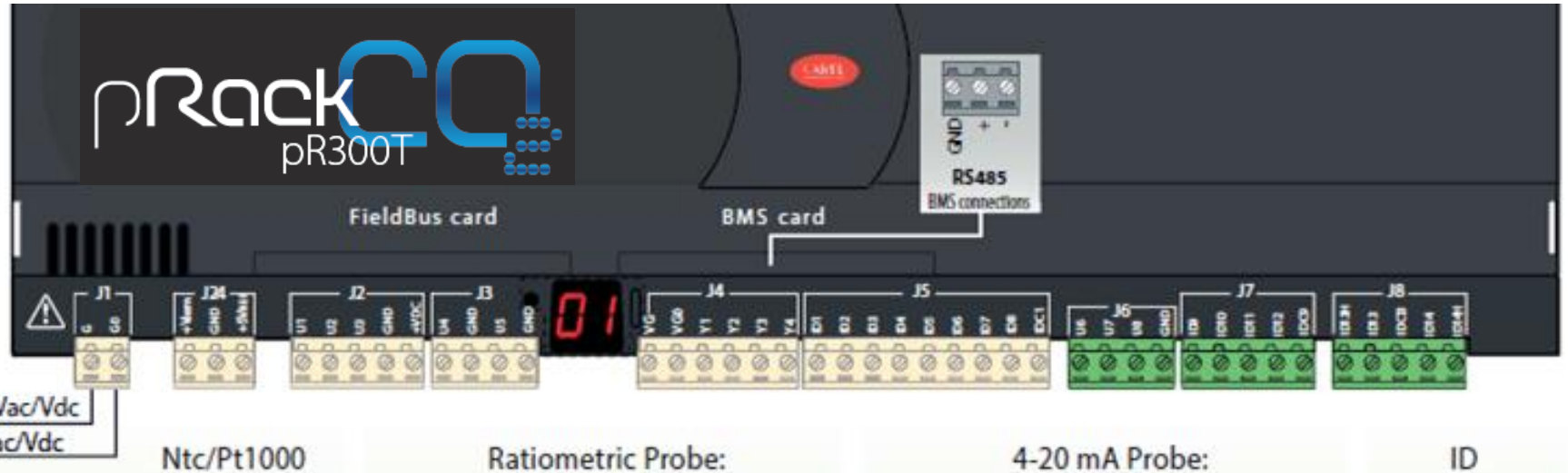
4-20 mA

0-5 Vdc

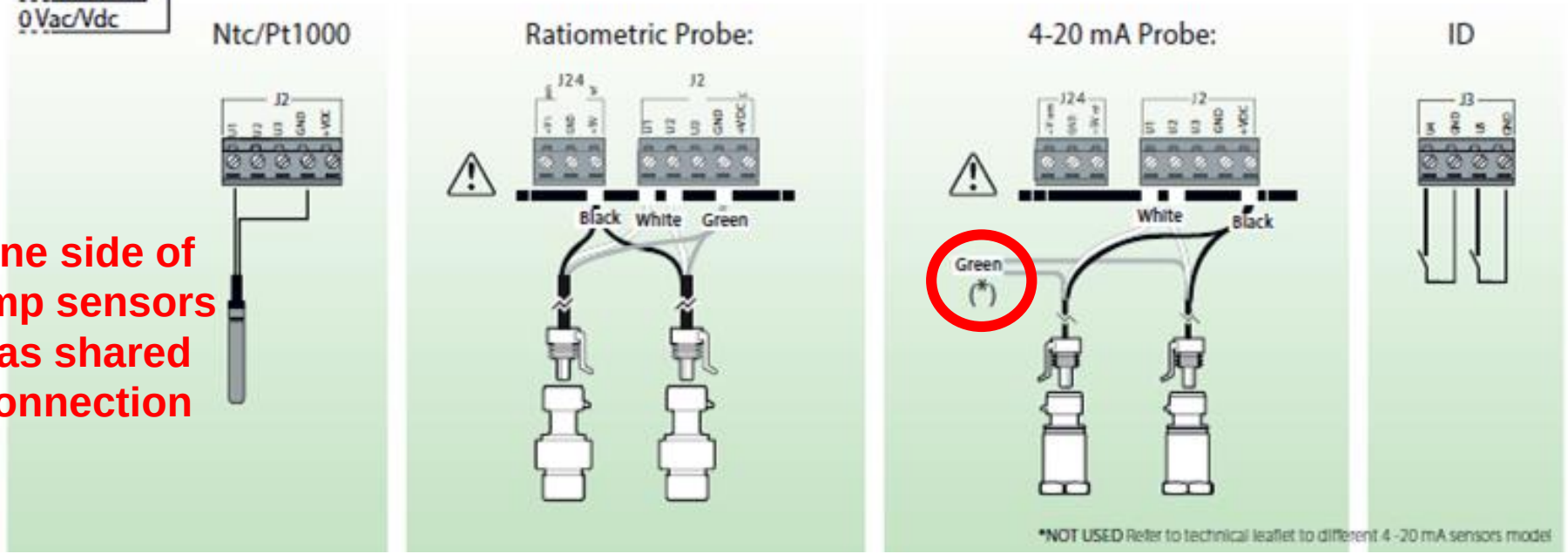
24 Vac/Vdc
0 V



Analog Inputs



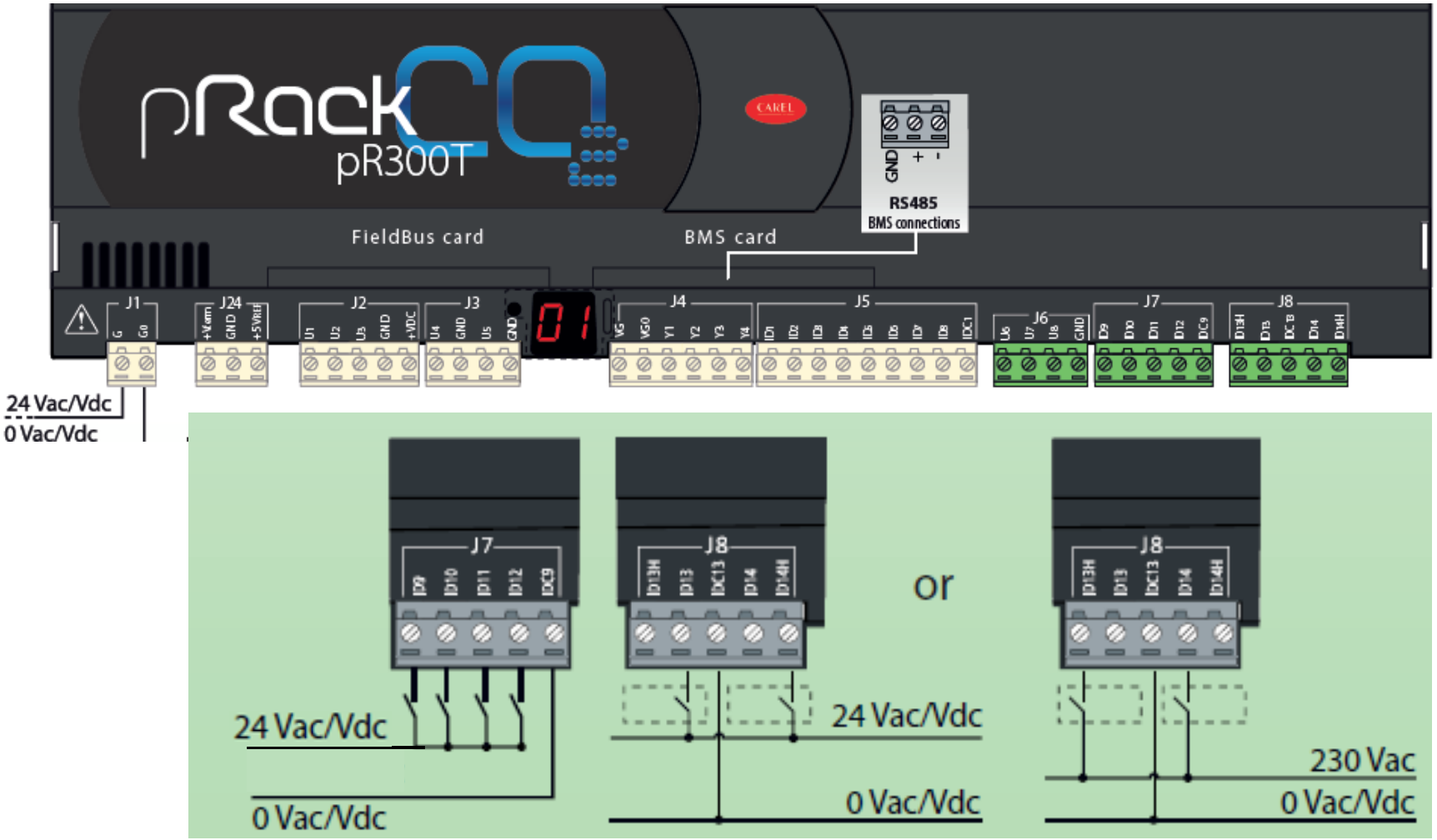
- “U” means “Universal”
- U1
- U2
- And so on…



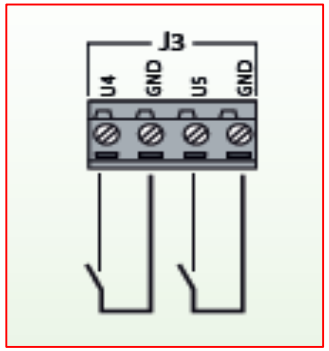
One side of temp sensors has shared connection

- +VDC = ~24Vdc (4-20 mA)
- +5V = 5Vdc
- Vterm = ~21Vdc (terminal)

Digital Inputs

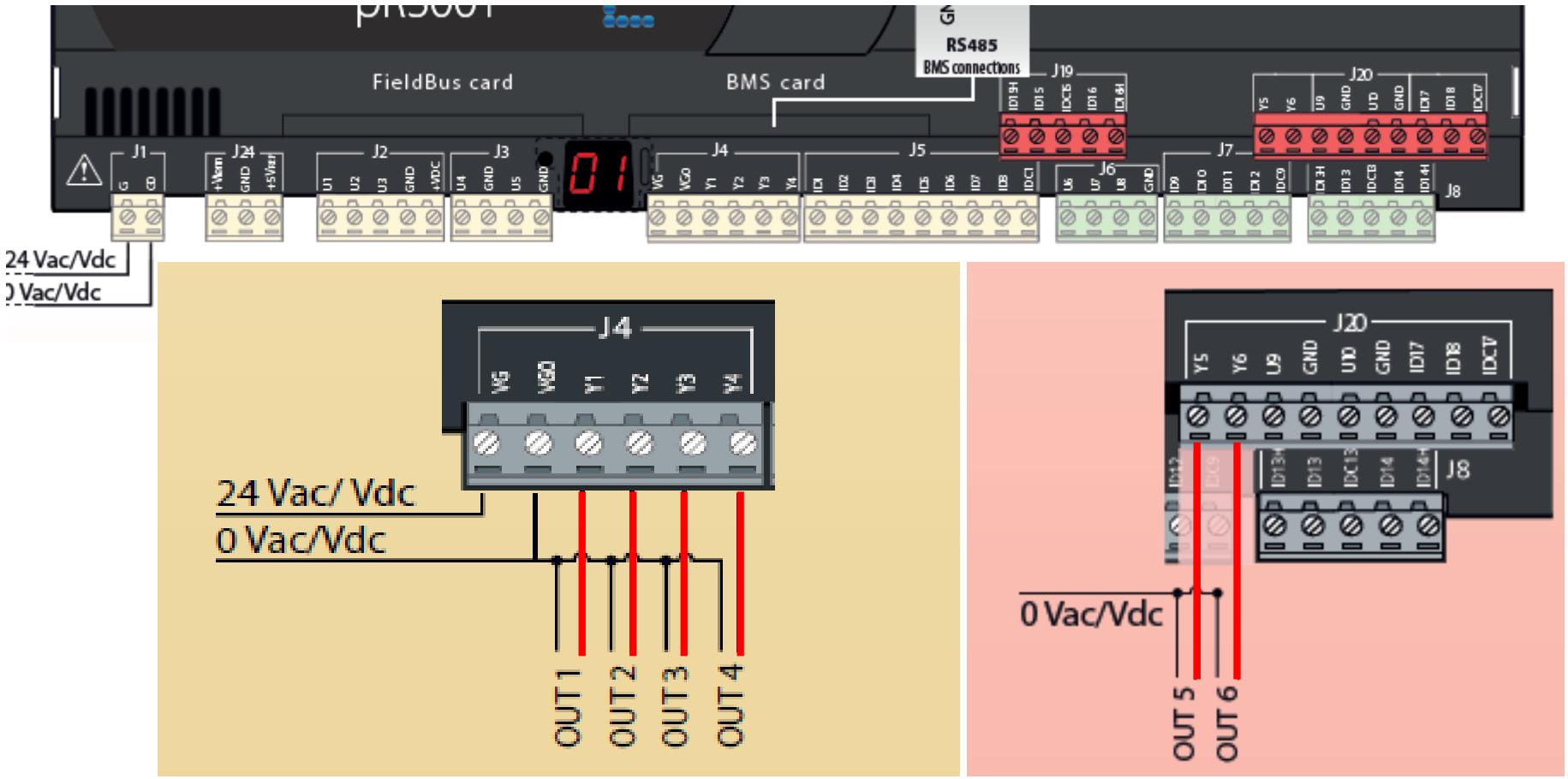


- **Most of the Digital Inputs are “wet”, however, J3 and J20…**



- **Silk screened and identified in manual as “ID”**

Analog Outputs



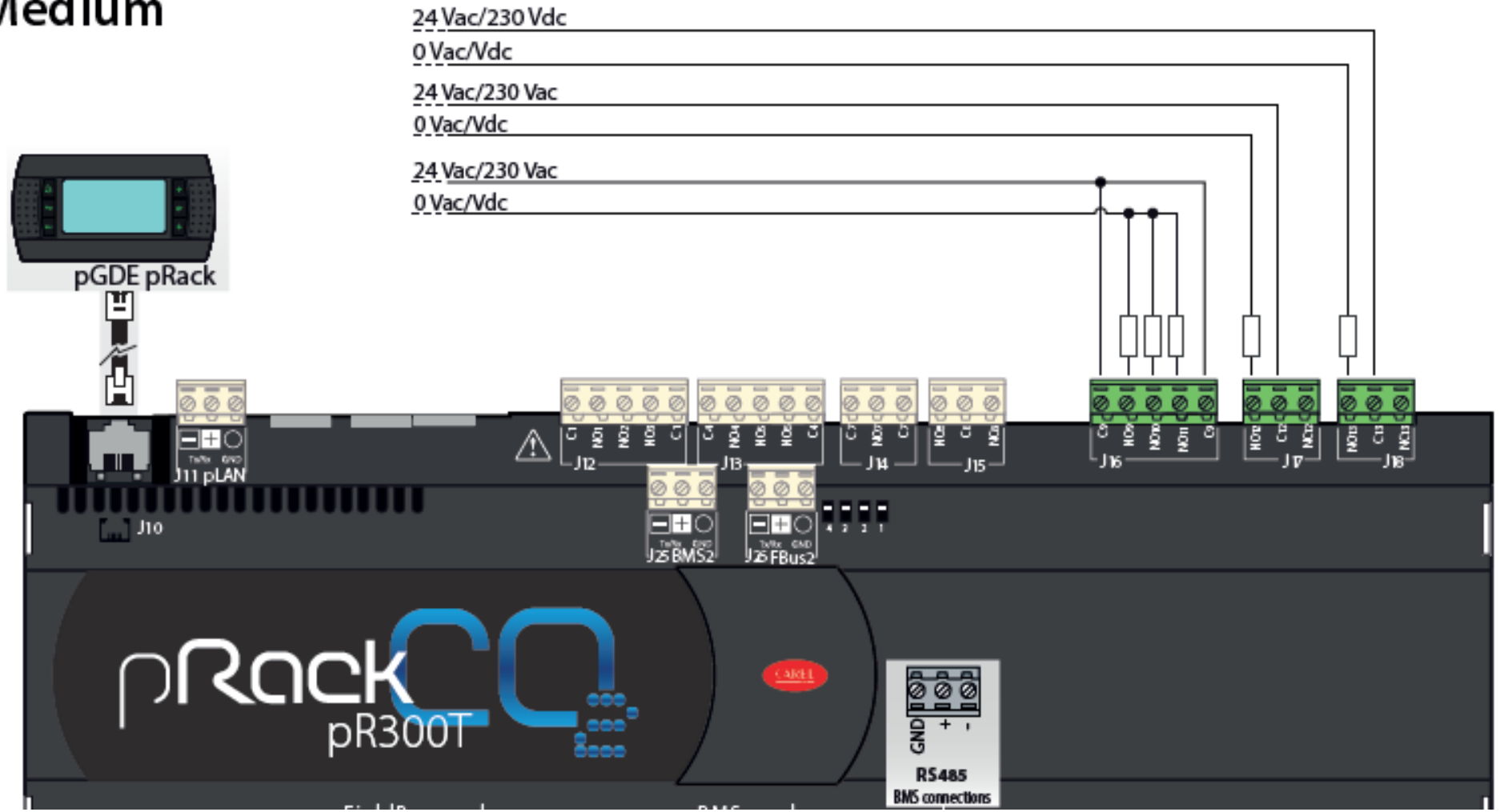
Identified as “Y#” on controller

“VG” is the voltage source for all Analog Outputs. Voltage at VG is regulated and output from each Y#

Use your meter to measure between VG0 and Y# to read the DC output

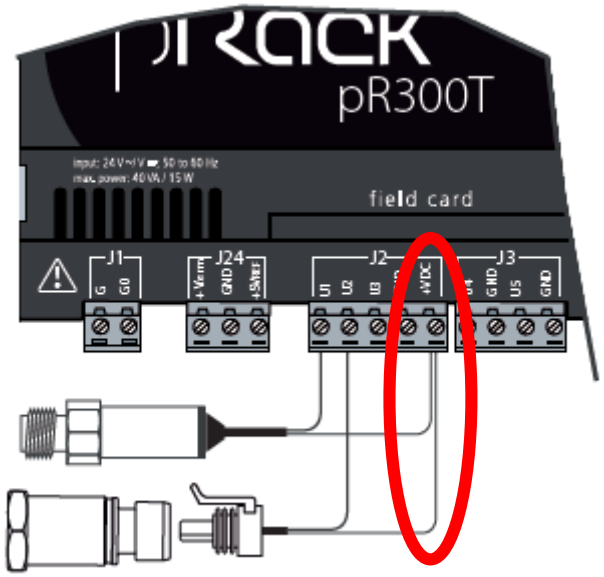
Relays

Medium



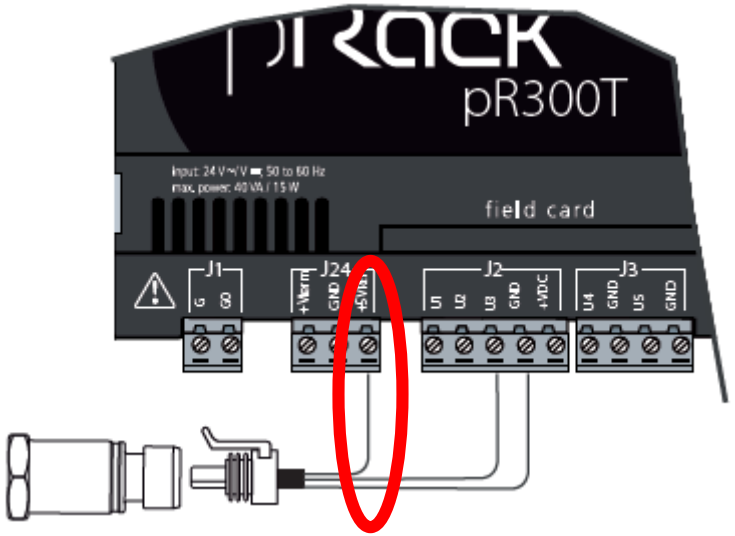
Sensor Connections

4 – 20 mA Pressure Sensors



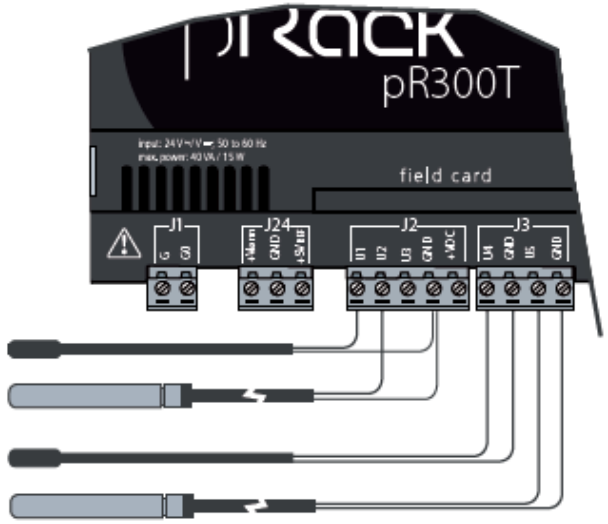
DO NOT CONNECT GREEN WIRE; CAP OFF. **Power from +VDC terminal**

0 – 5 V Pressure Sensors



REMEMBER TO MATCH UPPER AND LOWER LIMITS IN CONTROLLER. **Power from +5VRef**

NTC Temperature Sensors



NOTE GND CONNECTIONS

Pressure Sensors

To protect the sensor against damage from inducted overvoltage and incorrect use, the following measures are recommended:

Pressure transducers require removal **prior to vacuum test and cannot be exposed to a deep vacuum**

Avoid winding the cable in spirals, and adequately separate the cable from the power cable.

Receiver pressure: (SPKT00G1S0) 0–60 bar, 0–870 psig, **0-5V**

MT Suction pressure: (SPKT00B6P0) 0-45 BARG, 0-650 PSIG, **0-5V**

MT Discharge pressure: (SPKT00D8C0), 0-150 bar, 0-2175 psig, **4 – 20ma**, Gas 1/4 MPT (straight thread, o-ring included)

Temperature Sensors

NTC**WF** -- Standard Temp

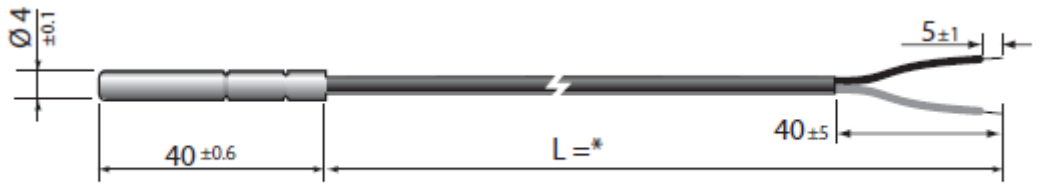


Fig. 2.c

STANDARD TEMP. RESISTANCE READINGS ARE DIFFERENT THAN THE NTC**HT** SENSOR. **NTC 10K, BETA 3435**

5.1 Table of temperature-resistance values for NTC sensor 10K@25°C ß 3435

Temp.	Resistance value		
	Max.	Typical	Min.
°C	KΩ	KΩ	KΩ
-50	344,60	329,50	314,90
-49	325,00	310,90	297,30
-48	306,60	293,50	280,90
-47	289,40	277,20	265,40
-46	273,40	262,00	251,00
-45	258,30	247,70	237,40
-44	244,20	234,30	224,70
-43	231,00	221,70	212,80
-42	218,60	209,90	201,60
-41	207,00	198,90	191,00
-40	196,00	188,50	181,10
-39	185,50	178,50	171,60
-38	175,60	169,00	162,60
-37	166,30	160,20	154,20
-36	157,60	151,90	146,30
-35	149,40	144,10	138,80
-34	141,70	136,70	131,80
-33	134,50	129,80	125,20
-32	127,70	123,30	119,00
-31	121,20	117,10	113,10
-30	115,20	111,30	107,50
-29	109,40	105,70	102,20
-28	103,90	100,50	97,20
-27	98,68	95,52	92,45
-26	93,80	90,84	87,97
-25	89,20	86,43	83,73
-24	84,85	82,26	79,74
-23	80,76	78,33	75,96
-22	76,89	74,61	72,39
-21	73,23	71,10	69,01
-20	69,77	67,77	65,82
-19	66,44	64,57	62,74
-18	63,30	61,54	59,83
-17	60,32	58,68	57,07
-16	57,51	55,97	54,46
-15	54,85	53,41	51,99
-14	52,33	50,98	49,65
-13	49,95	48,68	47,43
-12	47,69	46,50	45,32
-11	45,55	44,43	43,33
-10	43,52	42,47	41,43
-9	41,55	40,57	39,60
-8	39,69	38,77	37,86
-7	37,92	37,06	36,21
-6	36,25	35,44	34,64
-5	34,66	33,90	33,15
-4	33,15	32,44	31,73
-3	31,72	31,05	30,39
-2	30,36	29,73	29,11
-1	29,06	28,48	27,89
0	27,83	27,28	26,74

Temp.	Resistance value		
	Max.	Typical	Min.
°C	KΩ	KΩ	KΩ
1	26,65	26,13	25,62
2	25,52	25,03	24,55
3	24,44	23,99	23,54
4	23,42	23,00	22,57
5	22,45	22,05	21,66
6	21,53	21,15	20,78
7	20,64	20,30	19,95
8	19,81	19,48	19,15
9	19,01	18,70	18,39
10	18,25	17,96	17,67
11	17,51	17,24	16,97
12	16,81	16,56	16,30
13	16,14	15,90	15,67
14	15,50	15,28	15,06
15	14,89	14,69	14,48
16	14,31	14,12	13,92
17	13,75	13,58	13,39
18	13,22	13,06	12,89
19	12,72	12,56	12,40
20	12,24	12,09	11,94
21	11,77	11,63	11,50
22	11,32	11,20	11,07
23	10,90	10,78	10,66
24	10,49	10,38	10,27
25	10,10	10,00	9,90
26	9,73	9,63	9,53
27	9,38	9,28	9,18
28	9,04	8,94	8,84
29	8,72	8,62	8,52
30	8,41	8,31	8,21
31	8,11	8,01	7,92
32	7,83	7,73	7,63
33	7,55	7,45	7,36
34	7,29	7,19	7,10
35	7,04	6,94	6,85
36	6,79	6,70	6,61
37	6,56	6,47	6,37
38	6,34	6,25	6,15
39	6,12	6,03	5,94
40	5,92	5,83	5,74
41	5,72	5,63	5,54
42	5,53	5,44	5,35
43	5,34	5,26	5,17
44	5,17	5,08	4,99
45	5,00	4,91	4,83
46	4,83	4,75	4,67
47	4,68	4,59	4,51
48	4,52	4,44	4,36
49	4,38	4,30	4,22
50	4,24	4,16	4,08
51	4,10	4,03	3,95
52	3,97	3,90	3,82
53	3,85	3,77	3,70
54	3,73	3,65	3,58
55	3,61	3,54	3,46

Temp.	Resistance value		
	Max.	Typical	Min.
°C	KΩ	KΩ	KΩ
56	3,50	3,43	3,35
57	3,39	3,32	3,25
58	3,28	3,22	3,15
59	3,18	3,12	3,05
60	3,09	3,02	2,95
61	2,99	2,93	2,86
62	2,90	2,84	2,77
63	2,82	2,75	2,69
64	2,73	2,67	2,61
65	2,65	2,59	2,53
66	2,57	2,51	2,45
67	2,50	2,44	2,38
68	2,42	2,36	2,31
69	2,35	2,30	2,24
70	2,28	2,23	2,17
71	2,22	2,16	2,11
72	2,15	2,10	2,05
73	2,09	2,04	1,99
74	2,03	1,98	1,93
75	1,98	1,92	1,87
76	1,92	1,87	1,82
77	1,87	1,82	1,77
78	1,81	1,77	1,72
79	1,76	1,72	1,67
80	1,72	1,67	1,62
81	1,67	1,62	1,58
82	1,62	1,58	1,53
83	1,58	1,53	1,49
84	1,54	1,49	1,45
85	1,49	1,45	1,41
86	1,45	1,41	1,37
87	1,42	1,37	1,33
88	1,38	1,34	1,30
89	1,34	1,30	1,26
90	1,31	1,27	1,23
91	1,27	1,23	1,19
92	1,24	1,20	1,16
93	1,21	1,17	1,13
94	1,17	1,14	1,10
95	1,14	1,11	1,07
96	1,12	1,08	1,04
97	1,09	1,05	1,02
98	1,06	1,02	0,99
99	1,03	1,00	0,97
100	1,01	0,97	0,94
101	0,98	0,95	0,92
102	0,96	0,92	0,89
103	0,93	0,90	0,87
104	0,91	0,88	0,85
105	0,89	0,86	0,83
106	0,87	0,84	0,81
107	0,84	0,82	0,79
108	0,82	0,80	0,77
109	0,80	0,78	0,75
110	0,79	0,76	0,73

Tab. 5.a

User Interface

Demo too!

Display: Buttons and Terminology

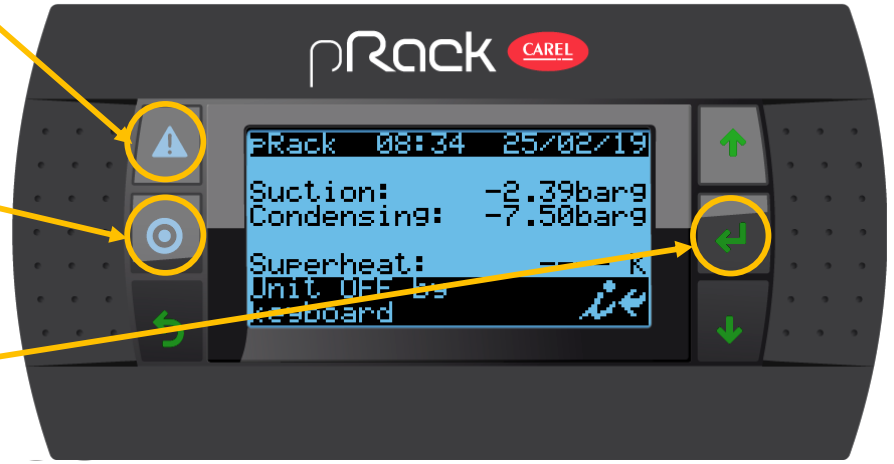
View alarms: press the alarm button once and use the scroll up or down button if multiple alarms are present.
Reset alarms: press the alarm button again for 3 seconds

Pressing the menu button and entering the user password will allow you to access the IO list and functions. The default OEM password is 1234.

Pressing the enter button after the parameters are selected will allow you to make changes to the values.

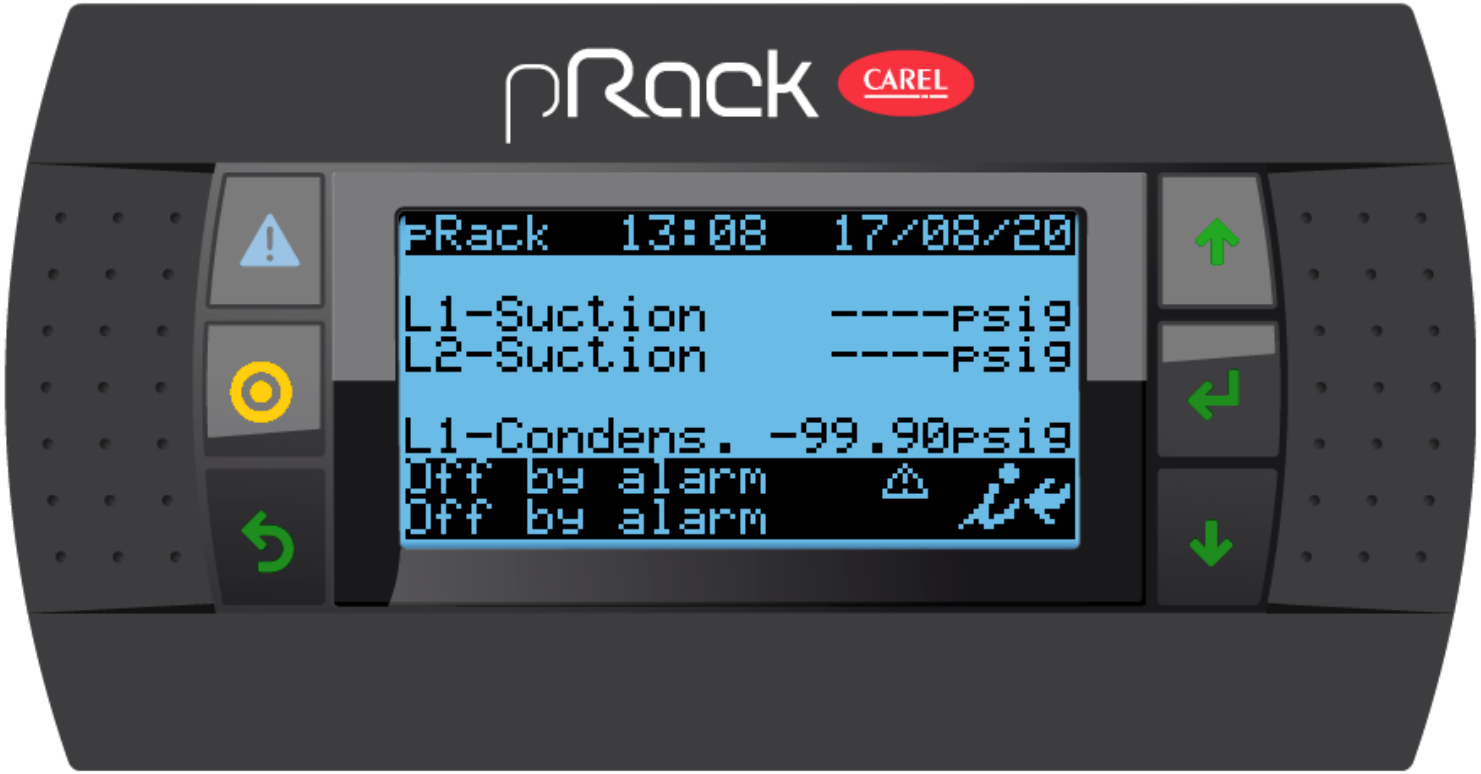
Terminology:

- **Mask**: Display screen
- **Line**: Group
- **L1**: Line 1, or Group 1

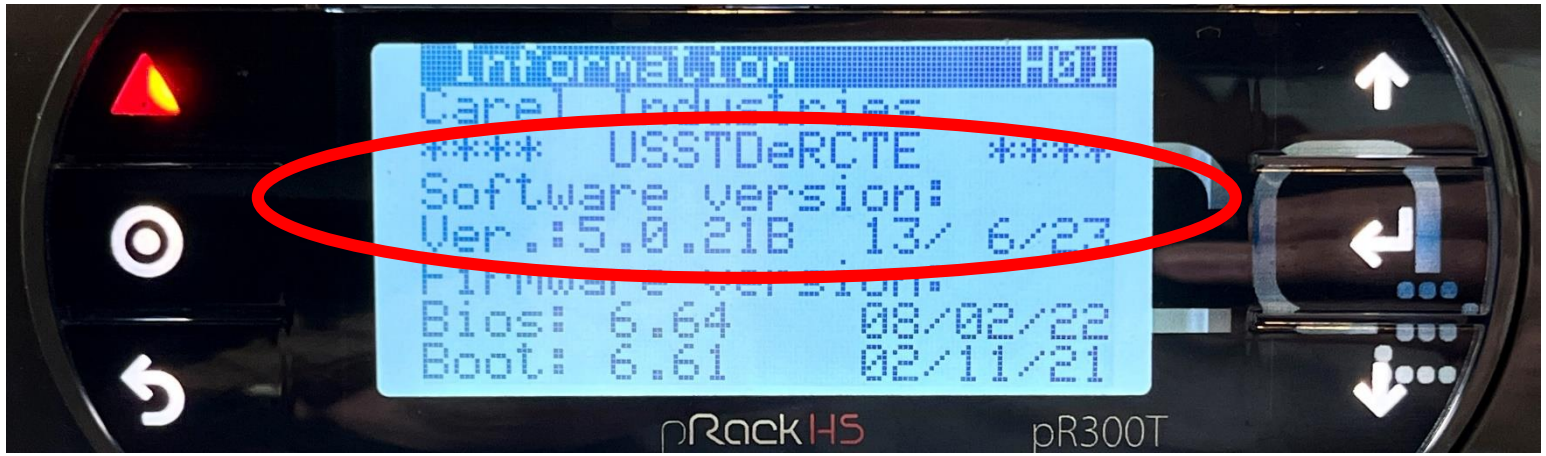


Display: Rack Operation Overview Screens

Unit Overview Screens: Press enter then use the up or down arrows to view pressures, temperatures, and other operating values without logging in. Super helpful!



LOOK OUT!!!



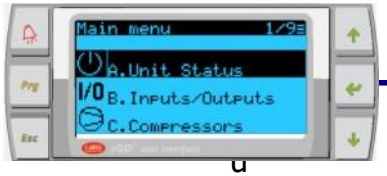
Software Versions!

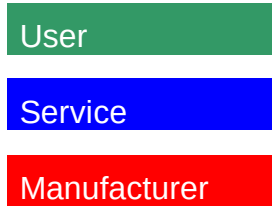
Password and Menus

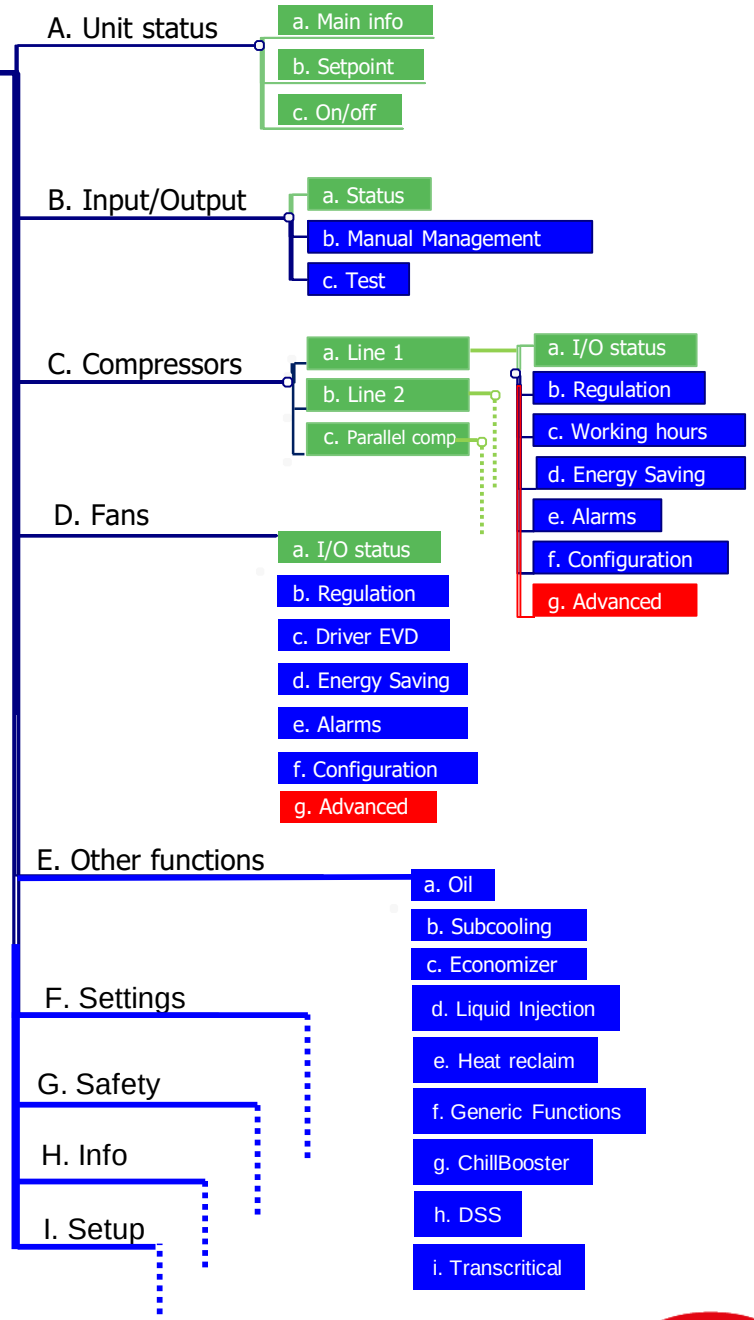
pR300T manages three levels of passwords:

- 1. User
- 2. Maintenance
- 3. Manufacturer
- Each level includes the same rights as the lower levels
- Configurable
- Mess up? You can log in/out via F. Settings
- No.

User	User password	0000
Service	Service password	1234
Manufacturer	Manufacturer password	1234





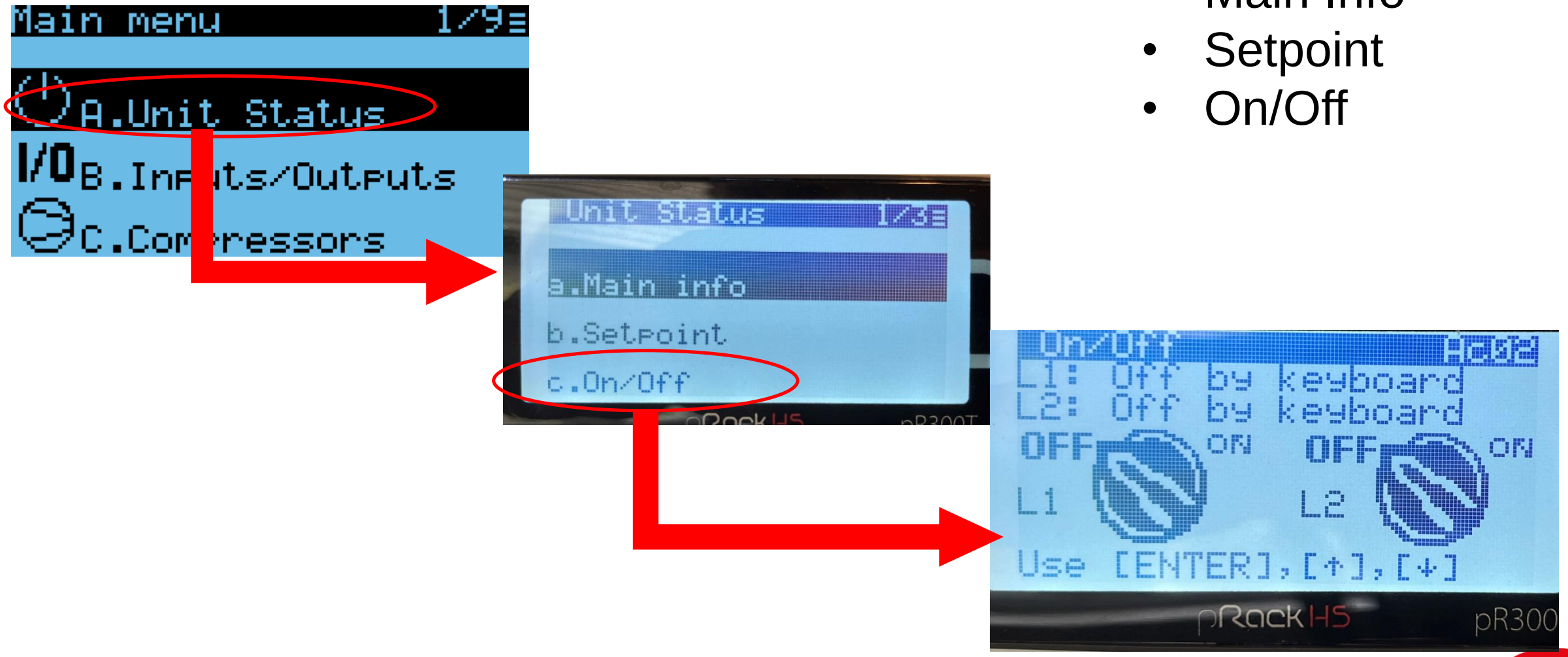


Menus:

Branches of menu divided per functions: inside every branch there are parameters and variables relative to the specific function.

Y'all remember (Day Date x 4) + 12?

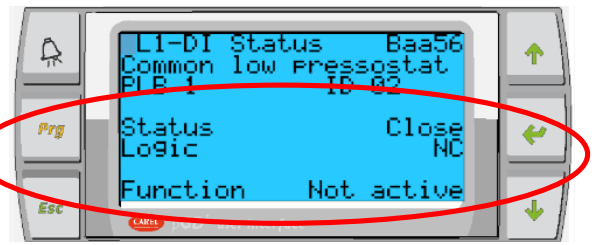
Main Menu – A. Unit Status

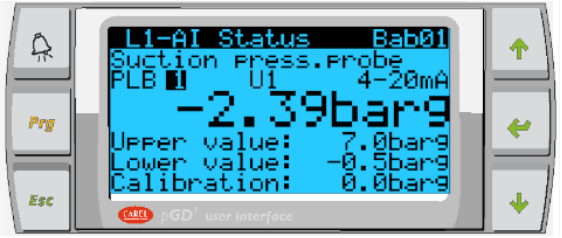


- Main Info
- Setpoint
- On/Off

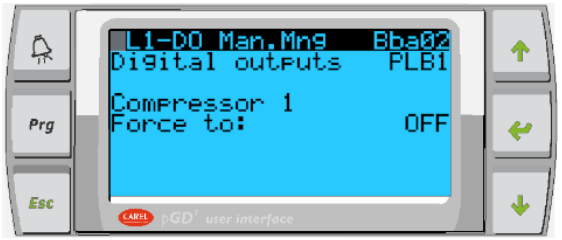
Main Menu – B. Inputs/Outputs

- **Status**: to see status and change configuration of all enabled inputs and outputs. The logic (NO/NC) can be changed. You'll see the status (what the controller is seeing at the input) change AND you can see if the function is Active or Not Active.

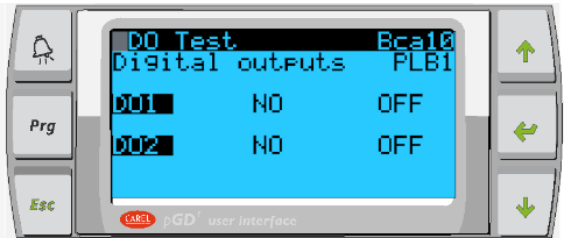




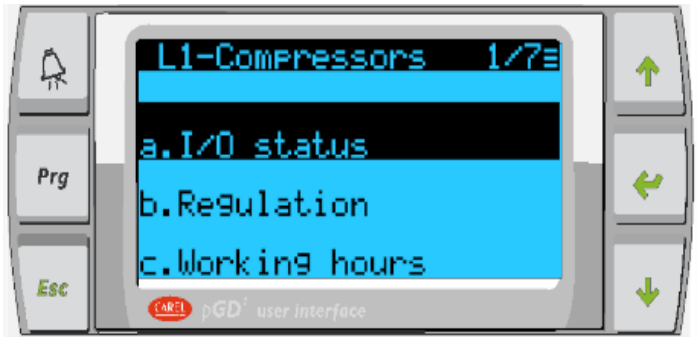
  - **Manual management**: bypass *enabled* outputs, respecting alarms, safety times, and start procedures. ***Only allowed if the controller is in the OFF mode.*** **Includes vacuum function. Allows you to manually open HPV and Flash Gas Valve. Also helpful to verify wiring.**



- **Test**: to bypass *any* output **without** timing, protection or safety function. ***Only allowed if the controller is in the OFF mode. Mode has adjustable timeout.***



Main Menu – C. Compressors

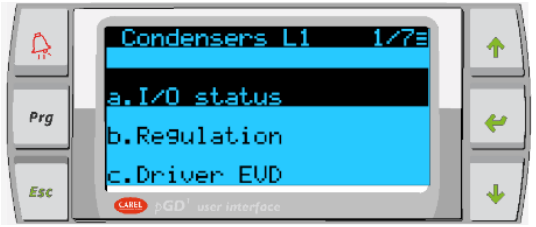


- **I/O status**: all I/O related to the compressors, check status and change settings.
- **Regulation**: regulation settings such as setpoint, differential, type of regulation, timings, etc.
- **Working hours**: to see number of hours the compressors are working or reset the counters.
- **Energy Saving**: Energy Saving Suite. All settings related to compressors energy saving functions.
- **Alarms**: all settings related to compressor alarms, both digital input and probes
- **Configuration**: all standard configuration parameters, timings, etc.
- **Advanced**: contain advanced parameters. Frequencies, non standard configuration, etc.

Main Menu – D. Fans, E. Other Functions

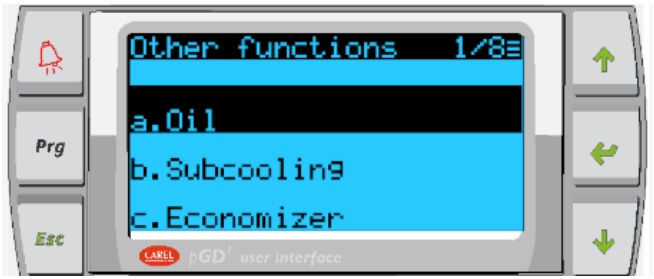
D. Fans:

- **I/O status**: all I/O related to the fans, check status, and change settings.
- **Regulation**: regulation settings such as setpoint, differential, type of regulation, timings, etc.
- **Driver EVD**: Not used.
- **Energy Saving**: All settings related to compressors energy saving functions.
- **Alarms**: all setting related to condenser alarms, both digital input and probes.
- **Configuration**: all standard configuration parameters, timings, etc.
- **Advanced**: contain all advanced parameters. Frequencies, non standard configuration, etc.



E. Other Functions

- **Oil**
- **Subcooling**
- **Economizer**
- **Liquid Injection**
- **Heat Reclaim**
- **Generic Functions**
- **ChillBooster**
- **DSS**
- **Transcritical Settings**



pR300T More Menus

F. Settings

Contains all the parameters for the main settings of the controller: passwords, language, supervisor parameters, etc.

G. Safety

All settings for common alarms, prevent, etc.

H. Info

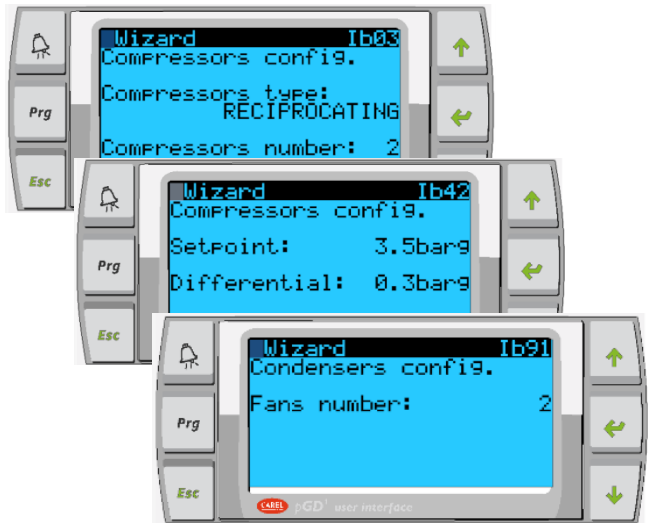
Contains information about software version, firmware, BIOS and BOOT.

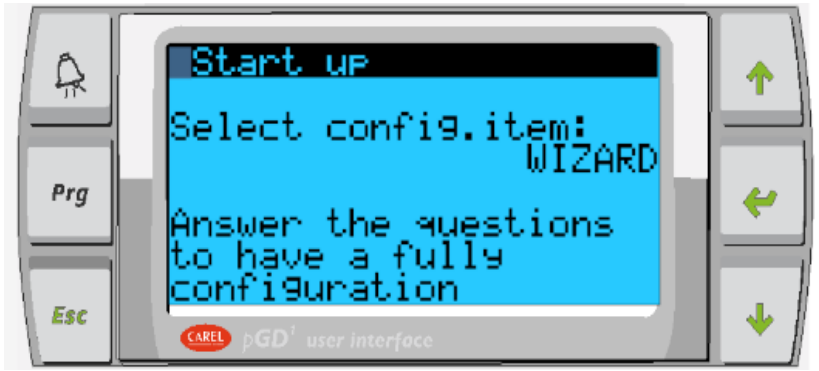
I. Setup

Contains all the parameters to reset the default configuration or re-start from the start up. ***Most of this section requires the unit to be switched OFF via the software switches, Mask Ac02**

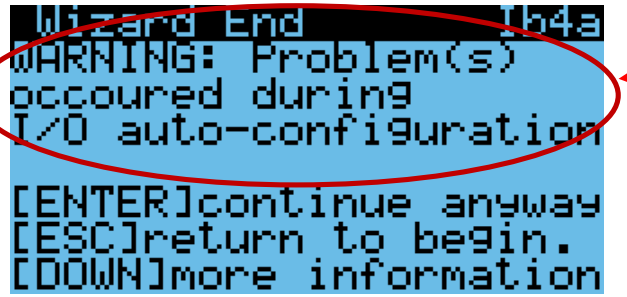
First Power Up

Wizard





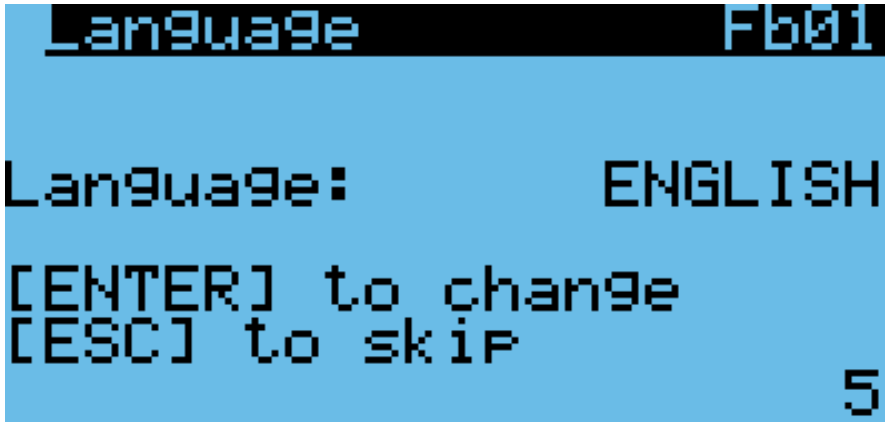
- Step-by-step guided procedure
- **After the Wizard is complete, the controller is ready for work!**

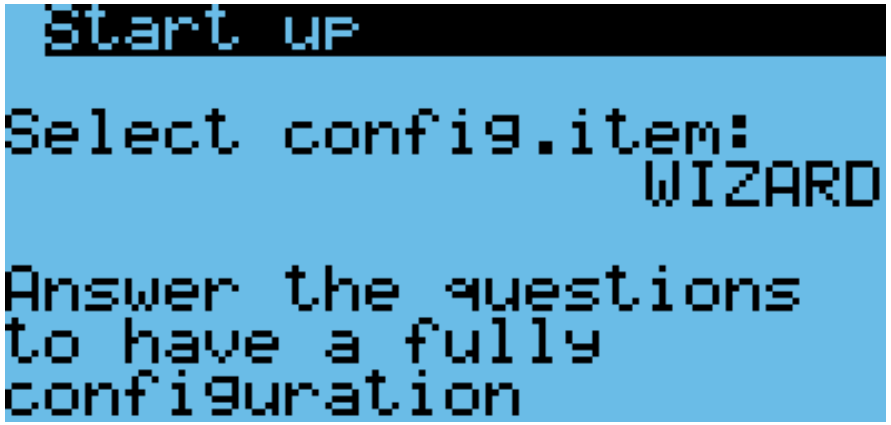


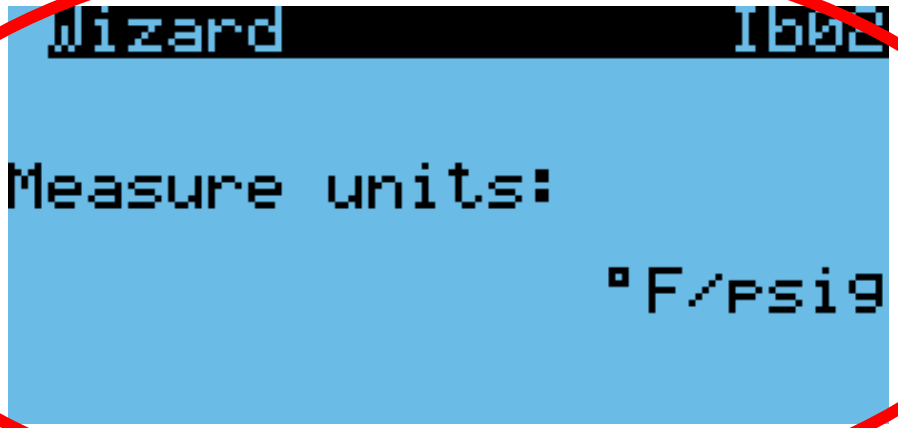
WARNING: if the boards do not have all the I/O needed for the selected configuration, wizard will signal error and users can decide if to continue or modify configuration.

WATCH OUT!!!
SYSTEM OF UNIT MEASUREMENT CANNOT BE CHANGED AFTER WIZARD! METRIC (SI) OR IMPERIAL (US)

Wizard Step by Step

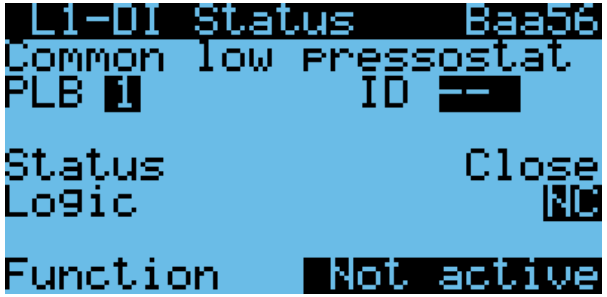


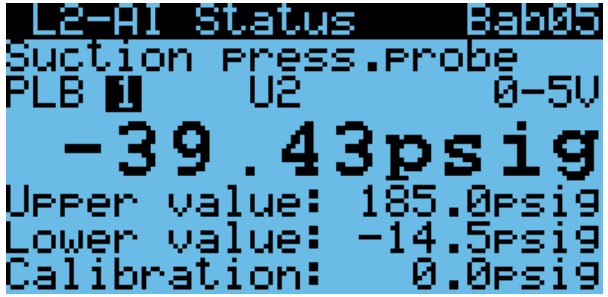


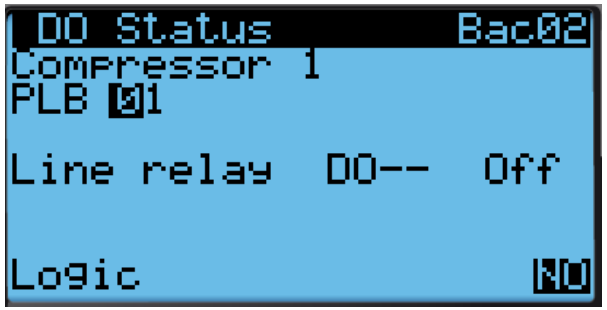


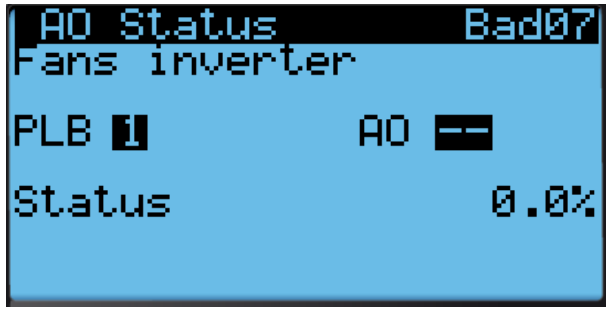
After the Wizard…

By going to *main menu -> inputs/outputs -> status ->* you can configure all of the inputs and outputs.





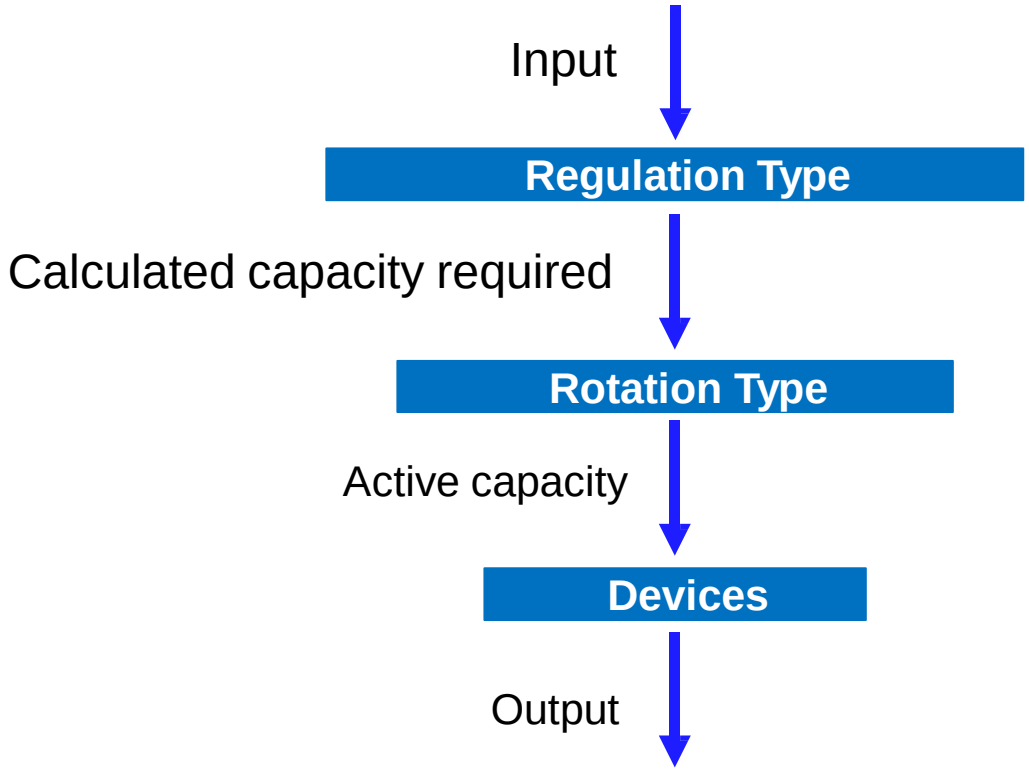




Watch out! Some I/O can be accessed from multiple menus OR only from one menu!

Regulation & Rotation

Regulation & Rotation



Regulation Type

- Neutral zone, proportional band, proportional & integral band

Rotation Type, Timings, etc.

- FIFO, LIFO, Running time, custom
- Variable speed comp is ALWAYS first on, last off.
- Modulating devices ramp down as stages increase, providing a full spectrum of system capacity.

Devices Controlled

- Compressors, fans

Regulation: Neutral Zone 1/3

Neutral Zone:

Used for both compressors and fans

A central zone in which:

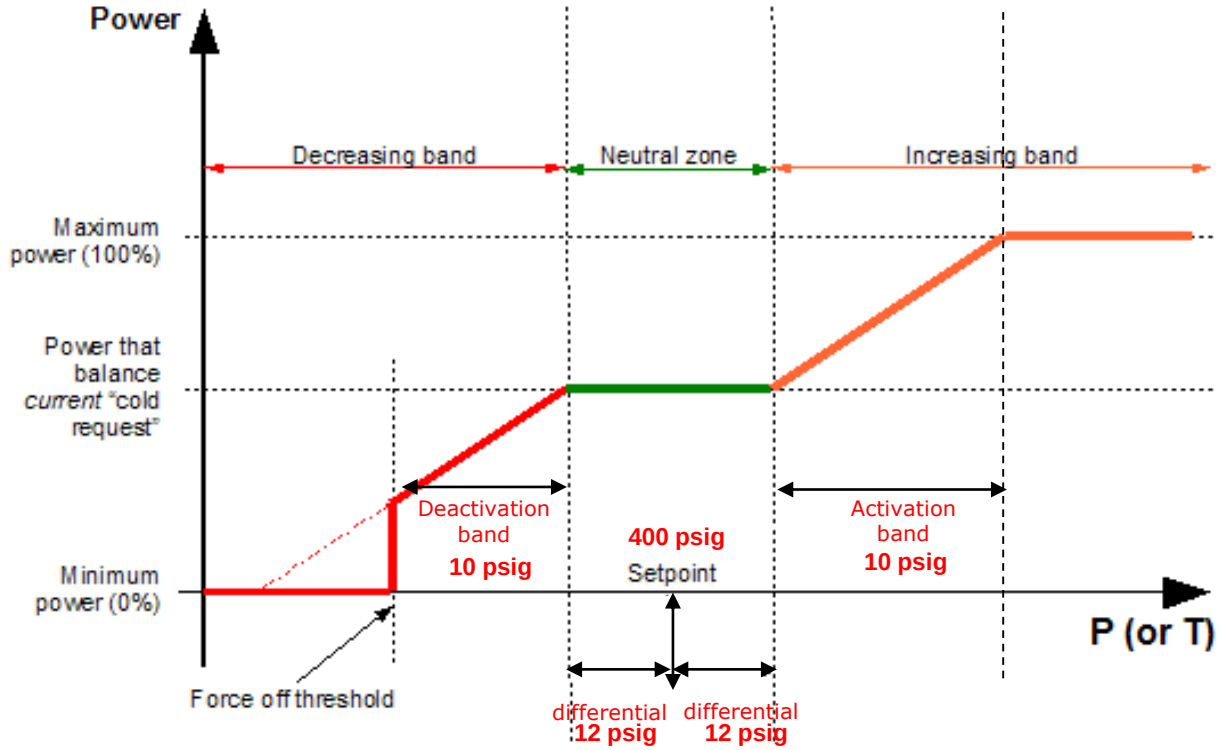
- Compressors/fans are not activated or deactivated
- Central set point with differential on both sides
- Timings of starting and stopping
- **Variable speed devices ARE modulated within this zone**

Regulation: Neutral Zone 2/3

The required capacity depends on:

- setpoint
- Differential - your parameter is NOT divided by 2!
- activation band
- deactivation band

Outside of these zones, the required capacity reaches the maximum (100%) or minimum (0%)



Narrow bands = fast and reactive systems, possible swings

Wide bands = slow and stable systems

Regulation: Neutral Zone 3/3

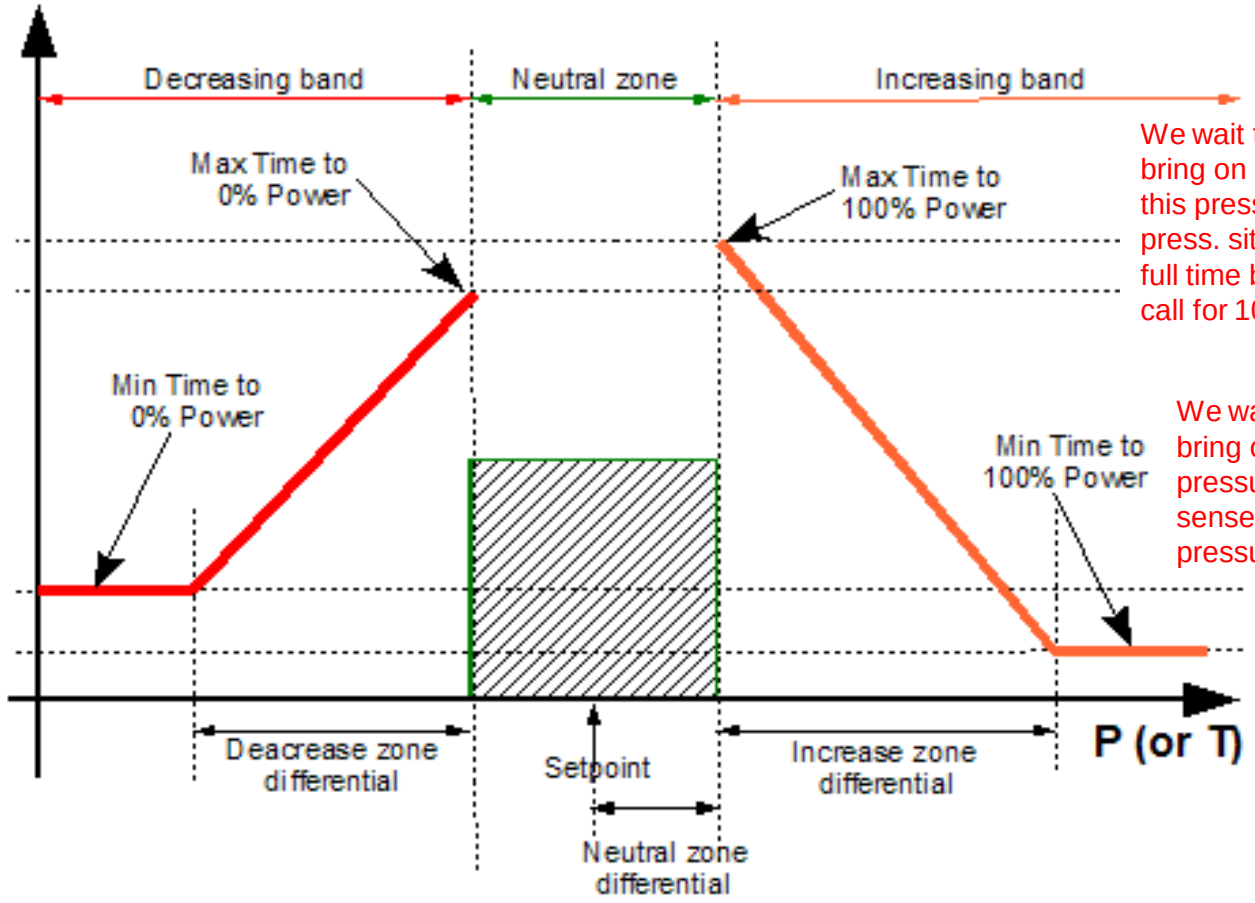
Based on the current system operating point, the required CAPACITY the controller is calling for (remember, this is NOT the # of compressors) depends on TIMINGS. Since the controller is looking at the total capacity, the timings you enter are TOTALS, and therefore divided by the # of compressors you have.

Activation Zone ("Power load…")

- Minimum activation time from 0 to 100%
- Maximum activation time from 0 to 100%

Deactivation Zone (Power unload…")

- Minimum deactivation time from 100 to 0%
- Maximum deactivation time from 100 to 0%



We wait the Max time to bring on 100% capacity at this pressure. So if the press. sits here, we wait the full time before we go to a call for 100% capacity.

We wait the Min time to bring on a comp at this pressure. This makes sense because the pressure is climbing rapidly.

Based on the specific configuration of compressors or fans (number, sizes, etc.) the activation/deactivation times of the different compressors depend on how far the value is from the set point.

Regulation: Prop.+ Integral Band

Required capacity depends on the proportional and integral (adjustable).

Parameters:

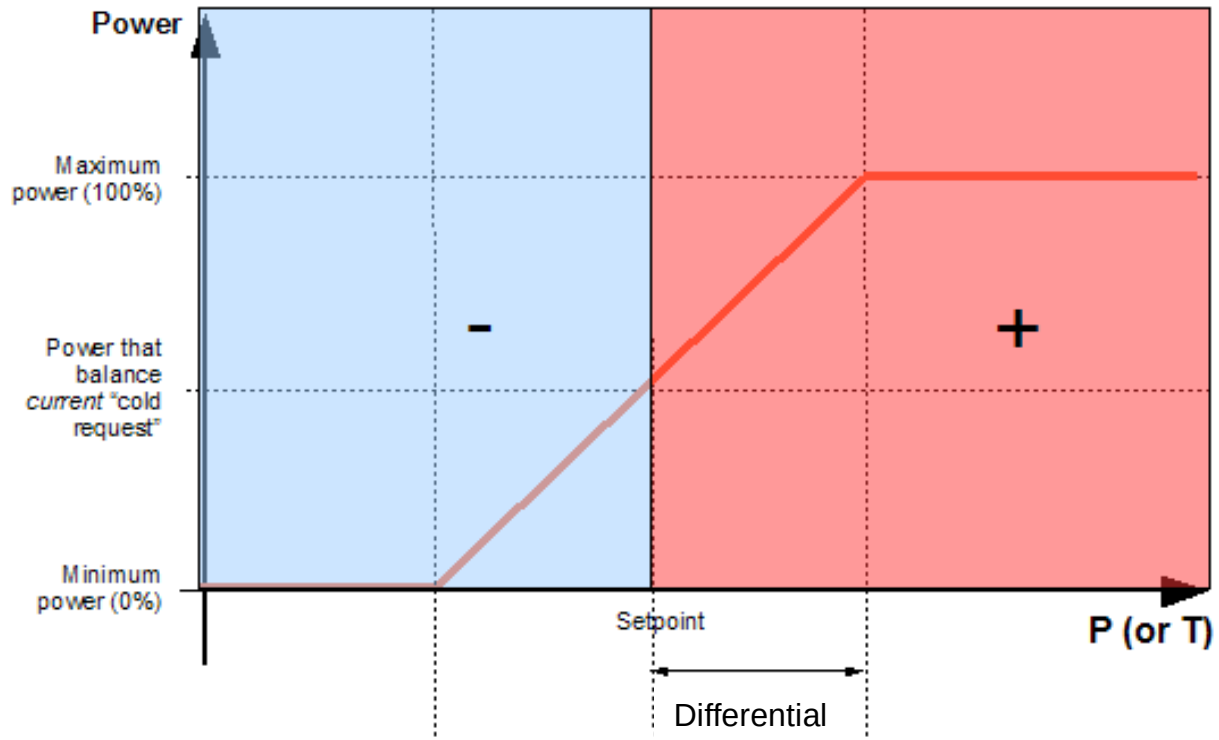
- Setpoint
- Differential (this won't be divided by 2!)
- Time (in seconds)

High Differential (psig) = system slow and not reactive

Low Differential (psig) = system fast and reactive, possible instability

High Integral Time (seconds) = system slow to respond to instability

Low Integral Time (seconds) = system fast and reactive, possible instability



Rotation

Part of the SW that reads the power capacity request from the regulation and tries to activate the right type or number of devices to make the active capacity as close as possible to the capacity request… **In other words, lets match what we have to what we need.**

Uses:

- Rotation type. FIFO, LIFO, running time, custom
- number and type of device available
- actual status of devices
- timings
- alarms
- sequence of activation and deactivation

Required capacity refers to:

- 0% = all available compressors off
- 50%= half of available compressors on
- 100% all available compressors on

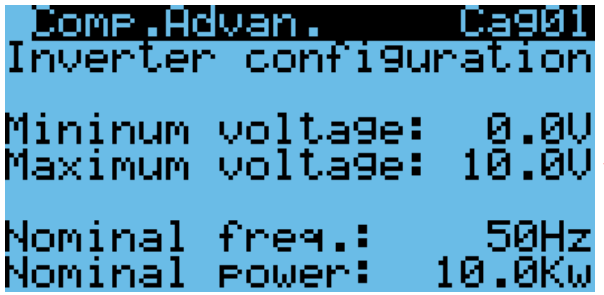
Rotation of Variable Capacity Compressors

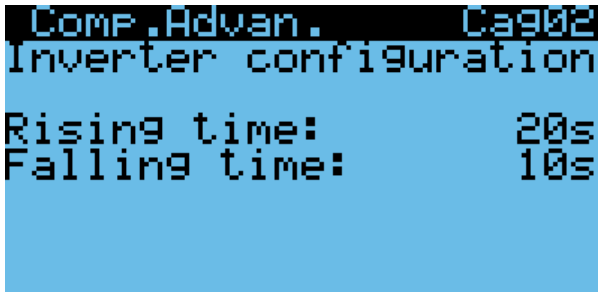
The rotation manages the activation of the **speed modulating device** considering

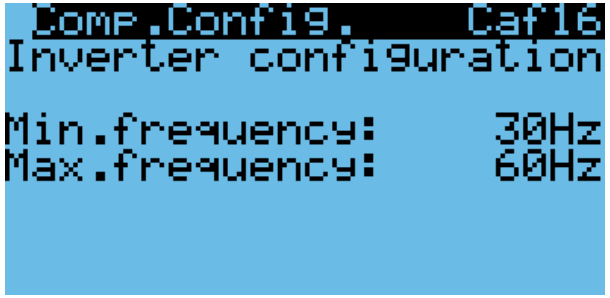
- minimum activation (min frequency)
- maximum activation (max frequency)
- nominal capacity
- nominal frequency
- increase and decrease times

The management is the same in case of:

- inverter
- digital scroll



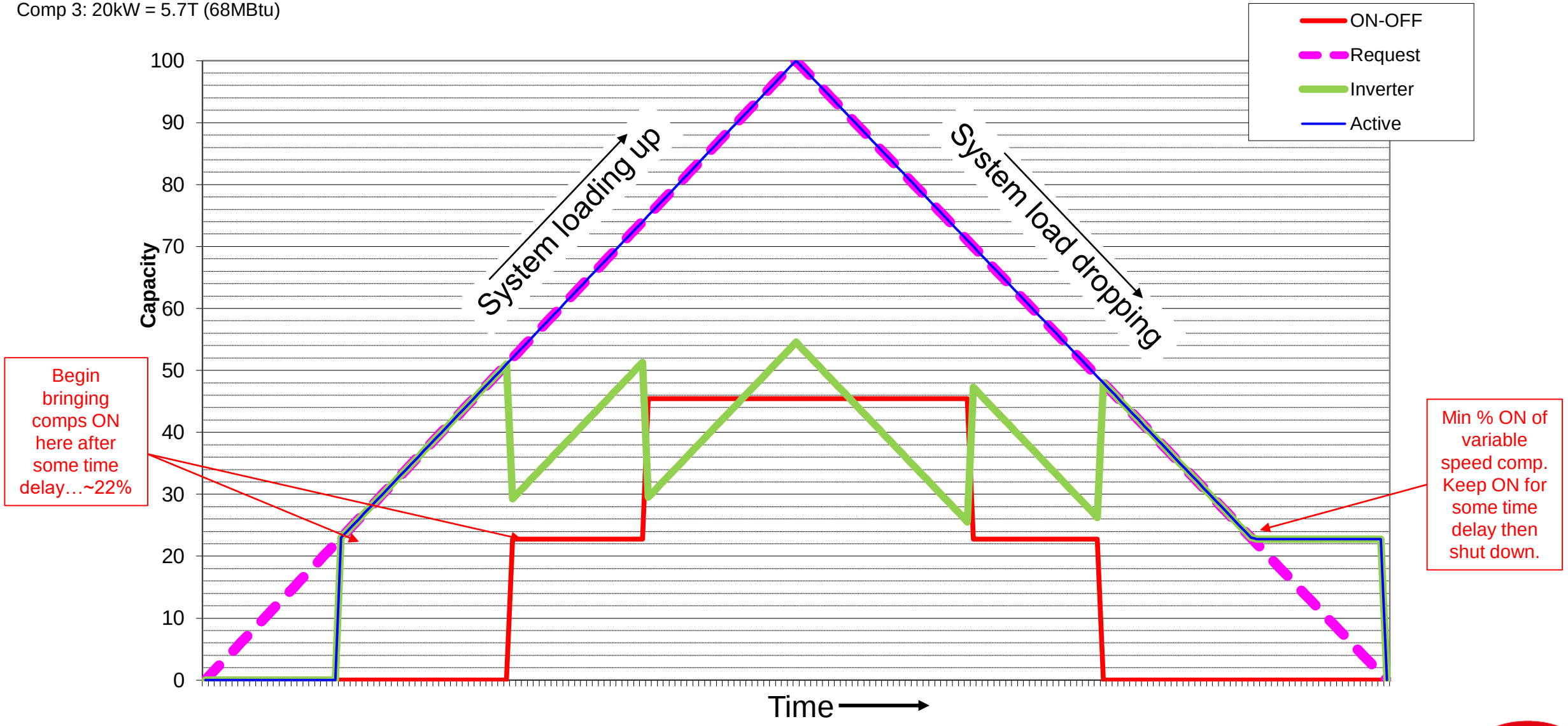




Min/Max voltage should "match" Min/Max frequency. In other words, if you want 2.5V (25%) as your minimum voltage, then your minimum frequency should be 15Hz (25% of 60Hz).

Rotation – An Example

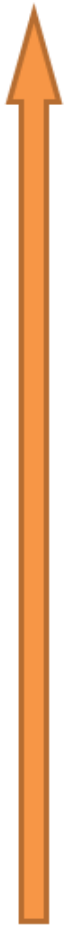
Comp 1: 30-60kW = 8.5-17T (102-205MBtu)
Comp 2: 20kW = 5.7T (68MBtu)
Comp 3: 20kW = 5.7T (68MBtu)



Compressor Alarms

Main Alarm Steps

		Example of value for MT side
HP Pressostat Switch	→	115 barg (define by OEM)
HP Gas Cooler Alarm (by probe)	→	110 barg
Prevent	→	107 barg
P100%	→	106 barg
Pmax		103 barg
HPV Setpoint	→	
Min HPV Setpoint	→	50 barg
Low GC pressure alarm	→	20 barg
Comp. regulation Setpoint	→	26 barg
Cut-OFF/Pump-down	→	22 barg
Low Suction Pressure Alarm	→	20 barg
LP Pressostat Switch	→	18 barg (defined by OEM)



The bookends in the setting of software thresholds are:

- HP Pressure Switch
- LP Pressure Switch

Compressor Safety

- Compressors have individual alarms: Overload, Oil, H.P., L.P. and Generic.
- System Alarms: System HP, LP, Oil, Liquid Level, Inverter fault.
- Suction Superheat alarm: By strapping an NTC sensor to the compressor inlet, the pRack can monitor floodback. It can be set to turn the system off in the event of low superheat.
- H.P. Prevent feature: The pRack can be set to prevent the system from going off due to high discharge pressure.
    - At a preset pressure the controller will engage heat reclaim (if configured), then it will begin unloading the Rack to prevent shutdown. Additional measures also taken within programming dependent upon configuration.
- **Anti Liquid Return feature: if no compressor is operable, the anti liquid return relay remains disabled.**

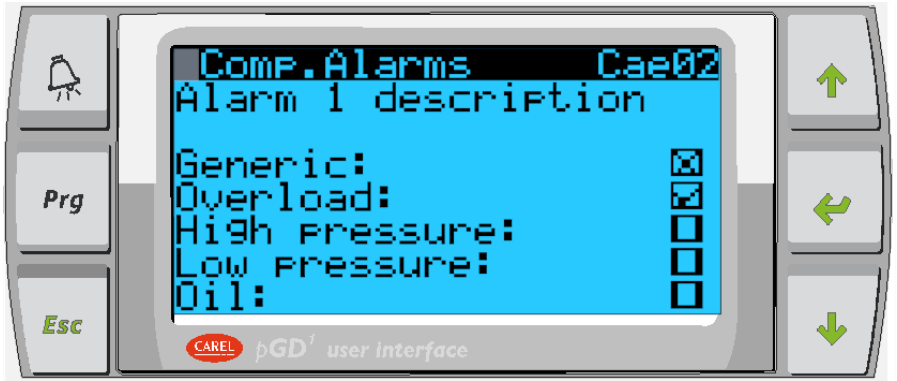
pR300T: Compressor Alarms

Piston or scroll compressors:

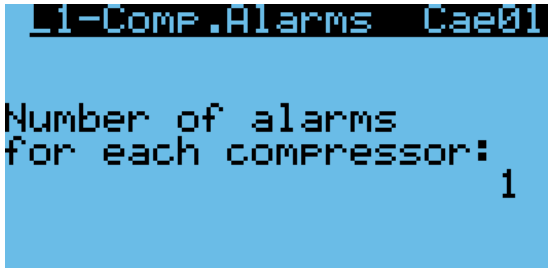
- maximum 4 alarms (DI) per compressor
- Generic, HP, LP, overload/Klixon, oil
- the alarms can be grouped as desired on the same DI: 2 digital inputs
  ID1 = HP+LP
  ID2 = overload/Klixon + oil
- **What the heck does this mean? All you're doing is grouping the alarms for display purposes**

Common features

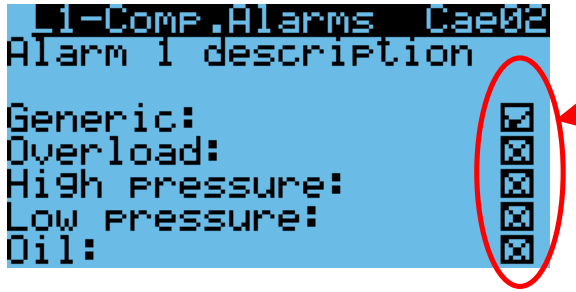
- All alarms can have automatic or manual reset
- All alarms are enabled also if compressor is off
- All alarms have start up delay and activation delay
- Start-up delay is reset at every switch on of the compressor
- Settable priority of alarms: SERIOUS – WARNING, activation of different alarm relays
- Only two different alarms to supervisor SERIOUS – WARNING, description of alarms is conveyed by dedicated variable.



pR300T: Compressor Alarms

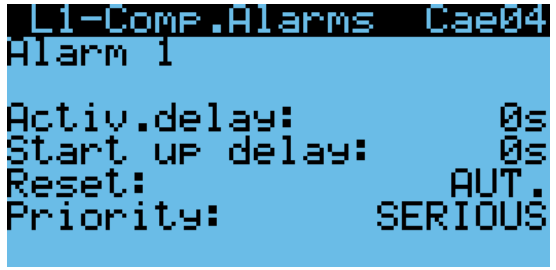


- Up to 4 alarms by DI can be configured for each compressor



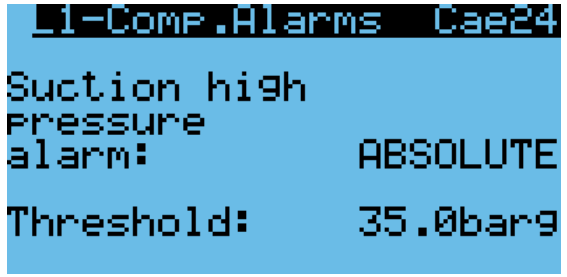
Watch out! Look closely…there are check marks and "X's"!!

- For each alarm it is possible to associate the description

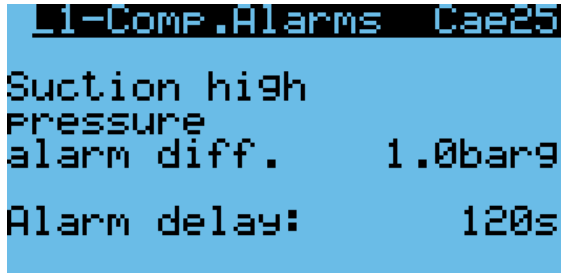


- Configure the delay, type of reset (auto or manual) and Alarm Digital Output (Serious or normal). Alarm code: from ALC90 to ALC99

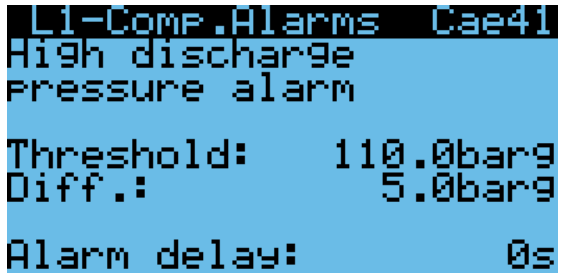
pR300T: Compressor Alarms



- High Suction pressure alarm by probe (threshold and type threshold: ABSOLUTE or RELATIVE)

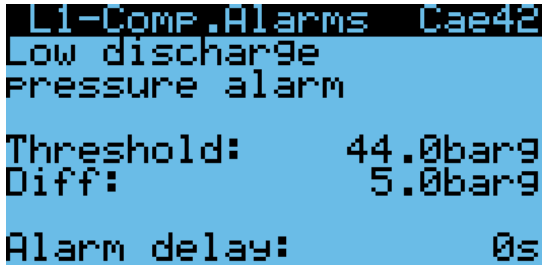


- Alarm will be issued at pressure > 35 barg and it will be reset at 34 barg.
- **This alarm forces the compressors at max power**

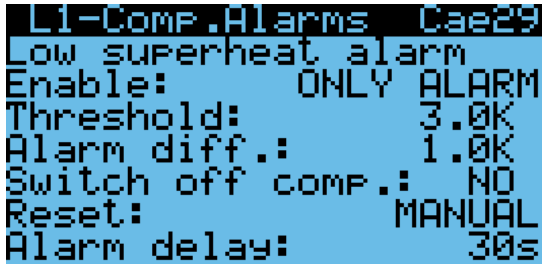


- High Discharge pressure Alarm by probe (threshold, differential and delay).
- This mask appear ONLY if a discharge pressure probe has been configured.
- **This alarm forces OFF the compressor.**

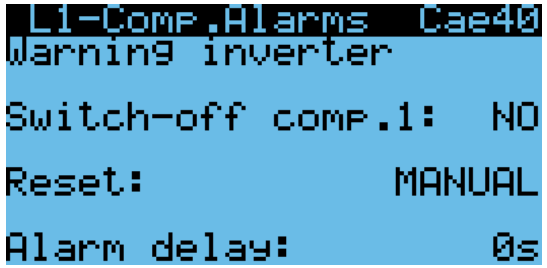
pR300T: Compressor Alarms



- Low Discharge pressure Alarm by probe
- This mask appear ONLY if a discharge pressure probe has been configured.
- **This alarm does not do any actions**



- Low SH alarm: disabled, ONLY ALARM, or WARNING + ALARM
- **Alarm**: Low SH with Comps running (delay will be Alarm delay).
- **Warning**: Low SH with Comps running (delay will be half of Alarm delay)

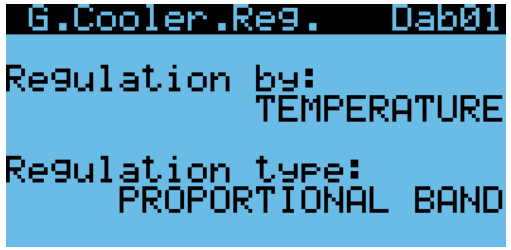


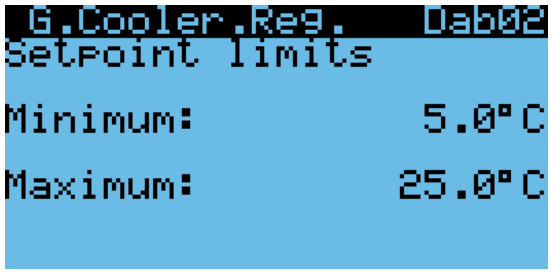
- Warning Inverter Alarm

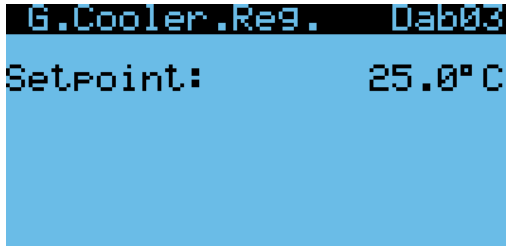
Gas Cooler Control

Gas Cooler Control

- Fan operation can be tied directly to compressor operation or as stand alone devices.
- Fans may be managed with LIFO, FIFO, Time, or custom rotation in the same way as the compressors.
- **Controlled by Gas Cooler Outlet temperature in current applications.**







When outlet at this temperature fans are running 100%

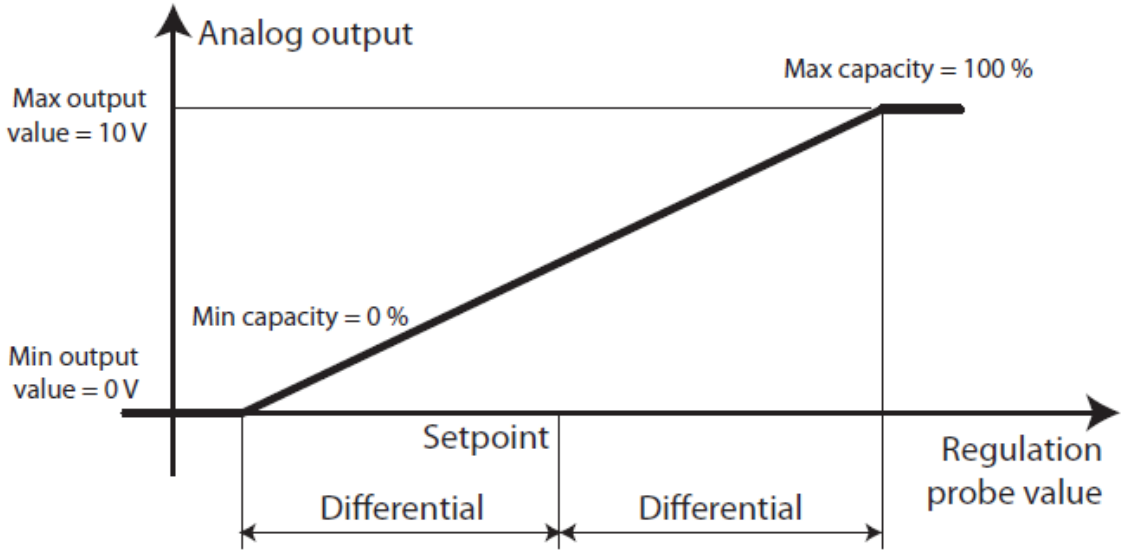
Fan operation with modulating device

Fans can be controlled by a modulating device.

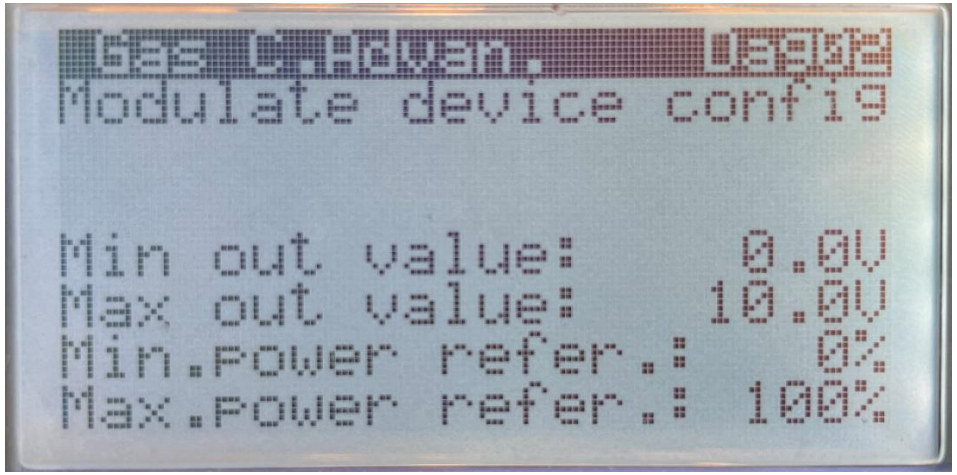
Parameters can be set on screens Dag02 and Dbg02

Minimum modulating output value 0 V, maximum value 10 V, or vice versa

Minimum modulating device capacity 0 %, maximum 100 %.



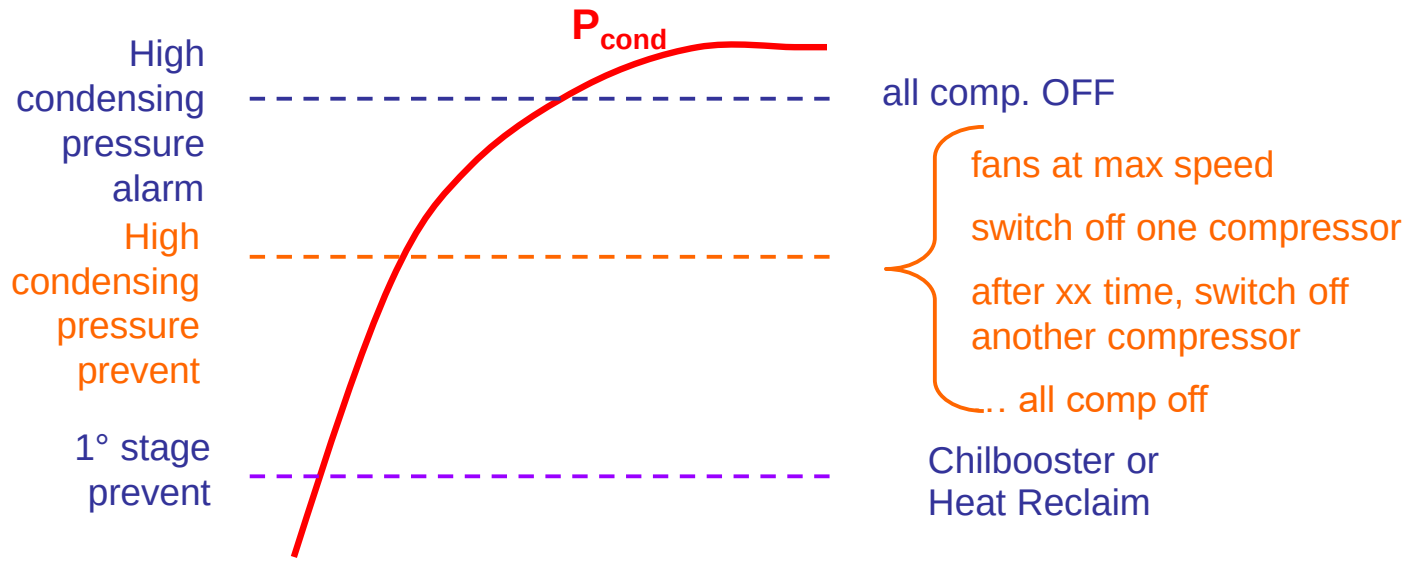
Reversing Max/Min power refer. will change the output to a 10 – 0 Vdc signal



High Pressure Prevention

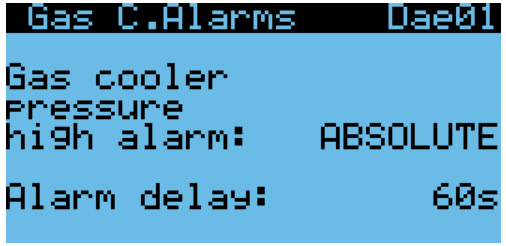
- Controller does what it can to prevent high pressure switch from tripping

Prevent procedure to avoid high condensing pressure alarm

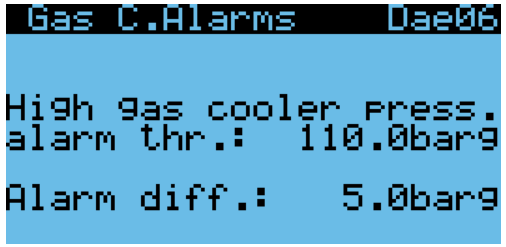


In case there are heat reclaim or chillbooster, they can be used as first stage of prevent.

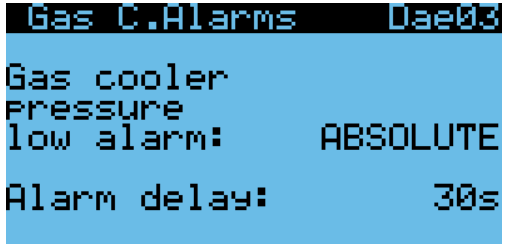
pR300T: Gas Cooler Alarms



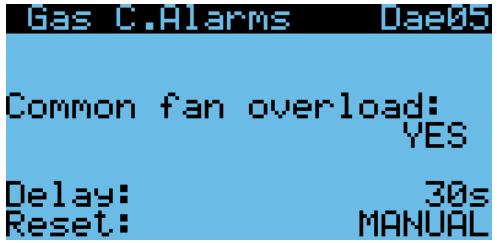
- High Gas Cooler pressure alarm by probe (threshold and type threshold: ABSOLUTE or RELATIVE)



- **This alarm force the GC fans at max power and shut off the compressors**



- Low Gas Cooler pressure Alarm by probe
- This mask appears ONLY if discharge press probe is configured.
- **This alarm does not do any actions**

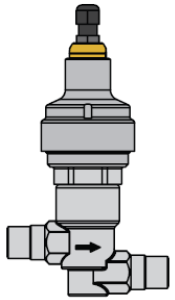


- Fan Common Overload by DI
- YES: only one common overload available and NO action to fans in alarm state
- NO: can be configured an Overload DI for each Fan.
- The Fan1 Overload shuts off the fan output only if it is not common with other fans

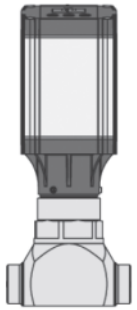
High Pressure Valve (HPV)

How do we drive valves?

pR300T CO_2 can control HPV/RPRV (Flash Gas Bypass) valves via an EVD Evo driver, an onboard driver, or via a 0 -10Vdc signal.

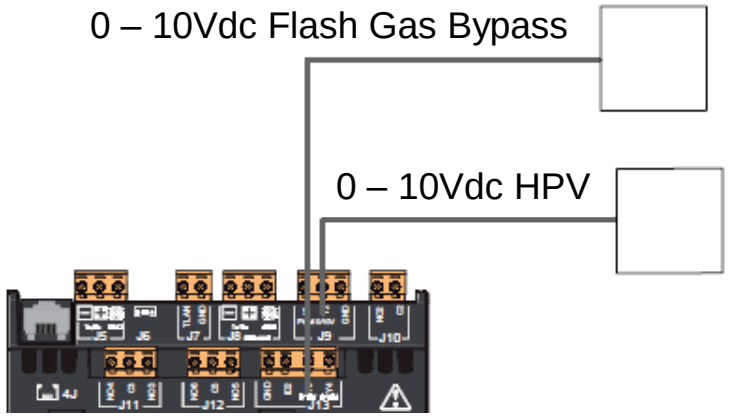


CCMT

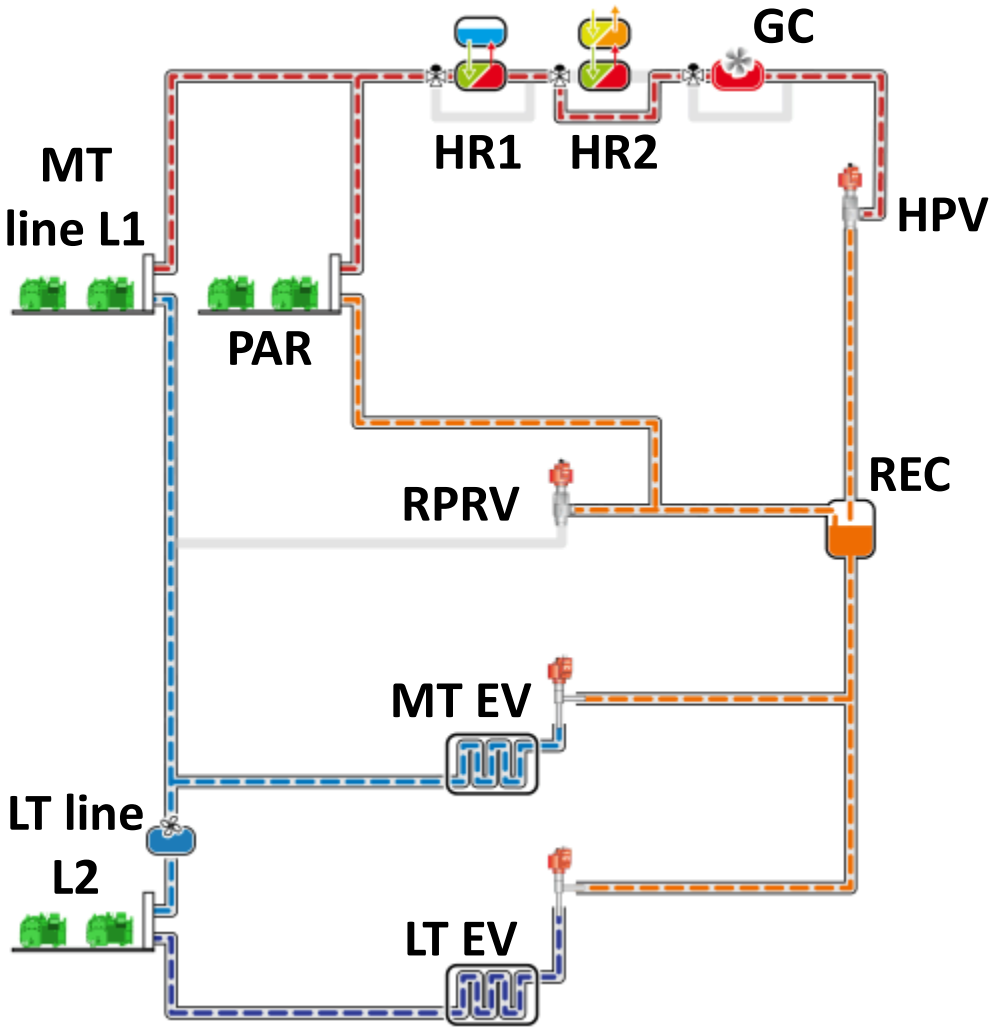


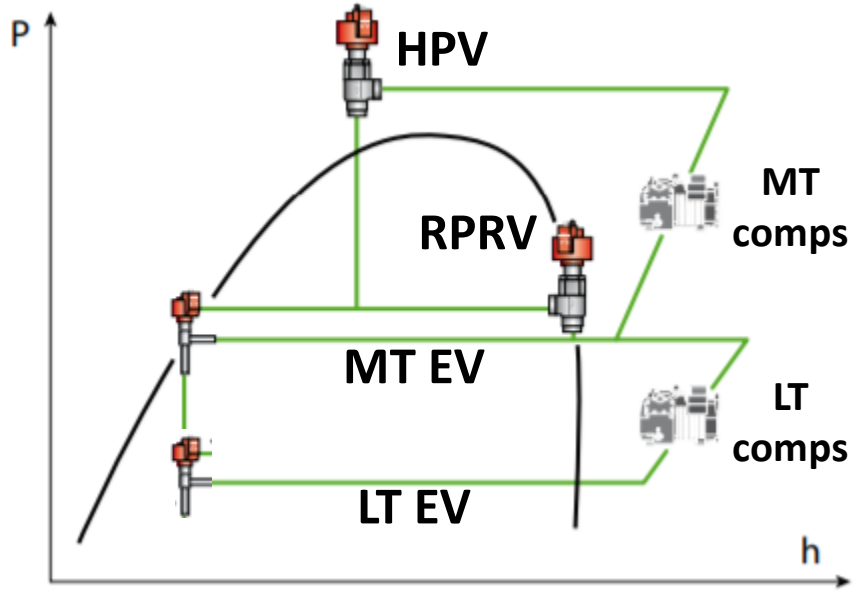
ICMTS

built-in driver with Ultracap Tech.



Transcritical CO_2 cycle



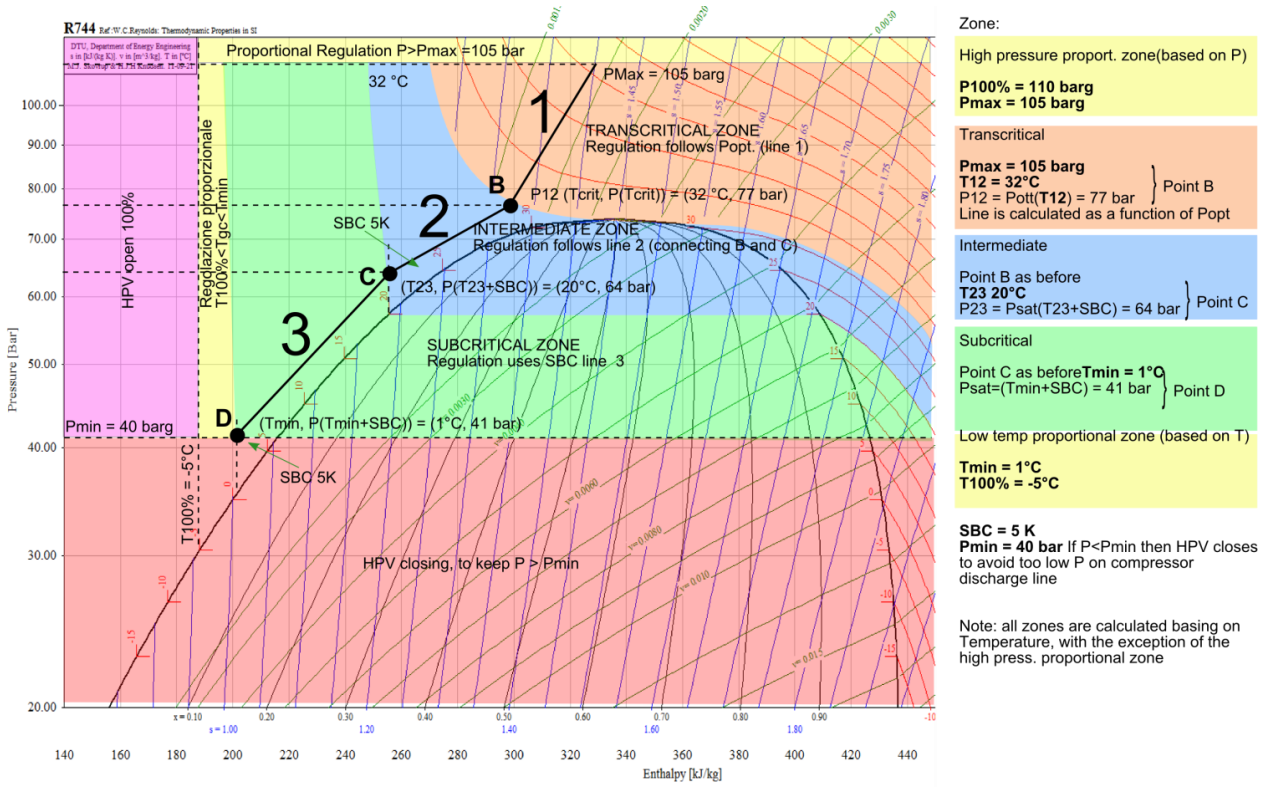


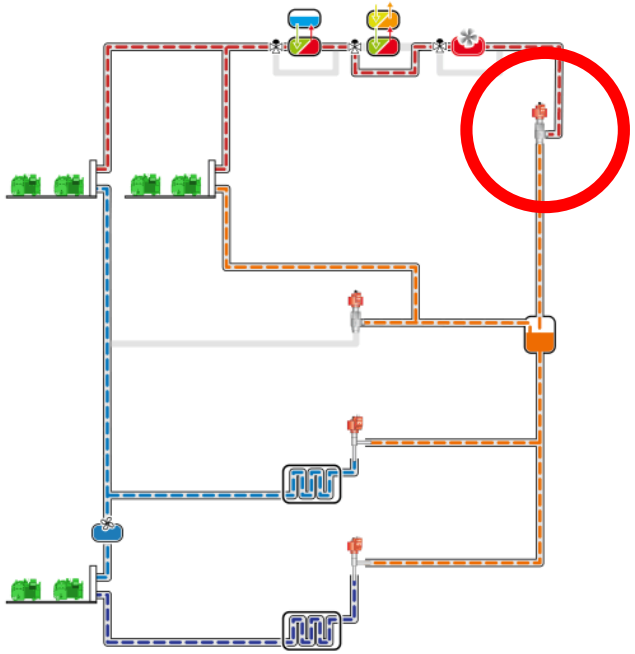
CO_2 specific components

- **Gas cooler**: equivalent of condenser, so called because in transcritical conditions there is no condensation but gas cooling
- **High pressure valve (HPV)**: controls gas cooler pressure
- **Receiver pressure regulation valve (RPRV)**: also called flash gas valve, controls receiver pressure
- **Optional - Parallel compressor**: controls receiver pressure in behalf of the RPRV

High Pressure Valve management

- HPV managed according to the zone identified based on Gas Cooler outlet temp and gas cooler pressure
- Minimum gas cooler pressure, less compressor work
- Adjustable limits, speed, standby, and backup positions of the HPV
- Alarms for troubleshooting and monitoring





1. Transcritical Zone

Calculation of the optimal Gas Cooler pressure to maximize COP.
PI regulation to keep HPV pressure optimal setpoint

2. Intermediate Zone

PI regulation for a smooth transcritical to subcritical transition

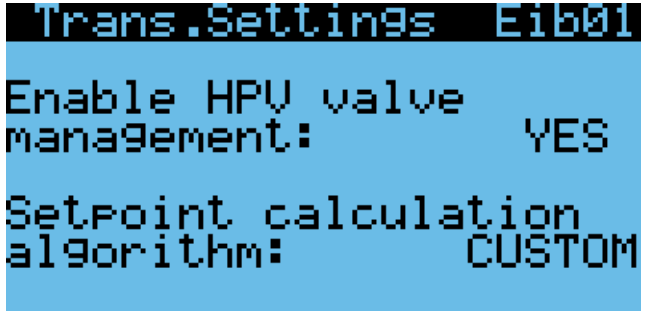
3. Subcritical Zone

PI regulation of the HPV valve to keep a subcooling setpoint

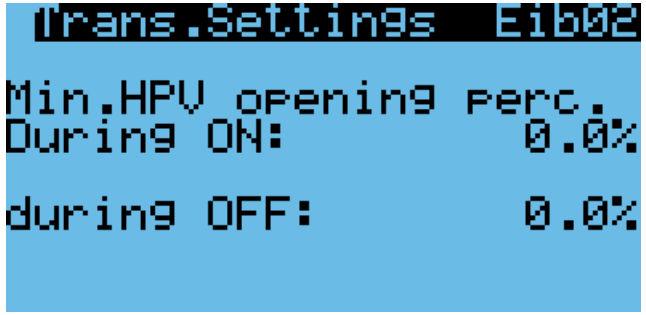
Safety zone

Above a set pressure the HPV valve open proportionally to avoid pressure increase

Transcritical Settings (HPV)

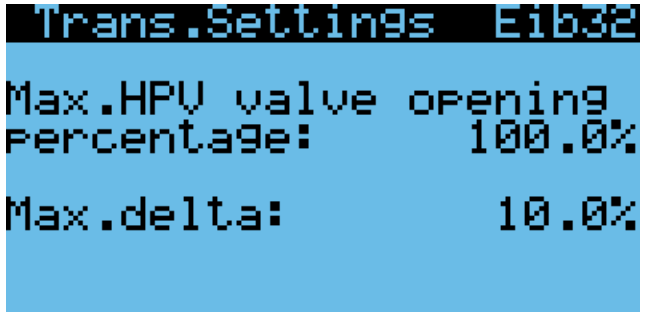


- Enable/disable HPV management.
- Setpoint calculation is CUSTOM and cannot be modified.



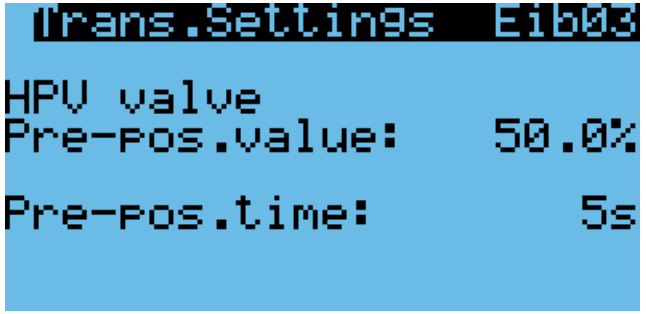
Minimum Opening %:

- **During ON**: while the UNIT is ON (by parameters, DI or supervisor)
- **During OFF:** while the UNIT is OFF (by parameters, DI or supervisor)

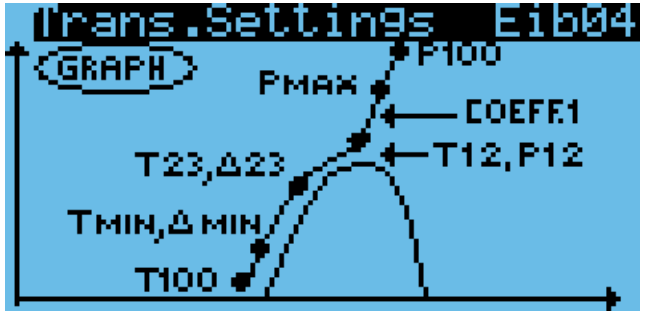


- Max opening percentage that can be taken on by HPV valve during the regulation (while the UNIT is ON).
- **Max delta** Max allowed variation of the valve position in one shot.

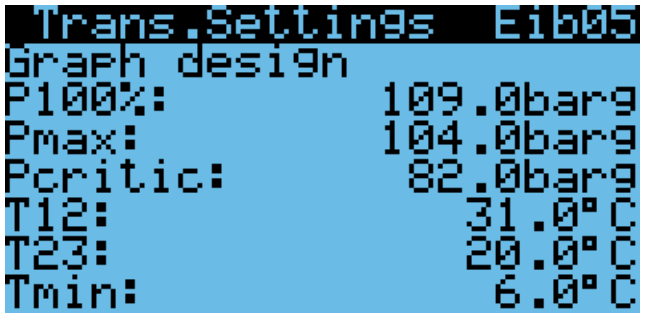
Transcritical Settings (HPV)



- Prepositioning of HPV valve after that unit enters in ON status.
- HPV valve remains at a fixed position for the pre-positioning time.
- *This procedure is reactivated whenever the unit goes into OFF status or the HPV valve moves into the minimum position due to all compressors being turned off (optional).*

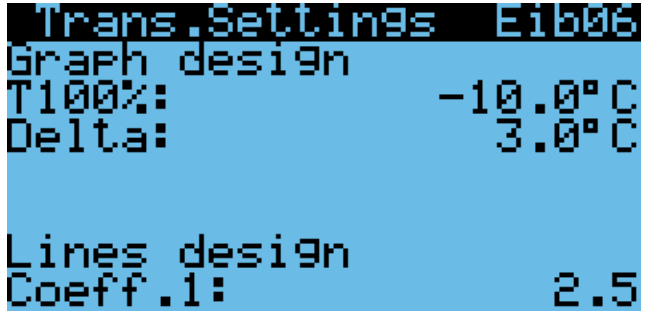


- Graph that summarize the different regulation zones of HPV valve.

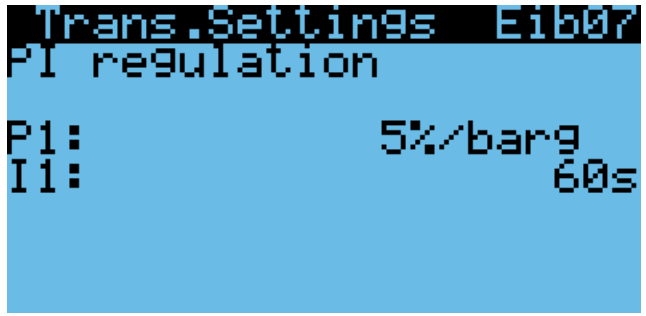


- Modify each regulation zone of HPV valve.

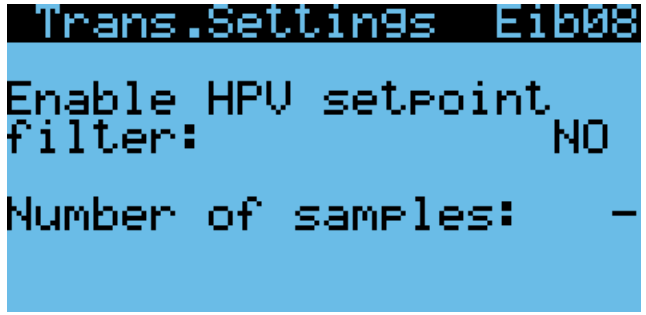
Transcritical Settings (HPV)



- "**Delta**" is the subcooling used by the system to calculate the setpoint in the subcritical zone.
- "**Coeff.1**" is the line design ratio. By decreasing the ratio, with the same Tgc_out, the optimal HPV setpoint will decreases.

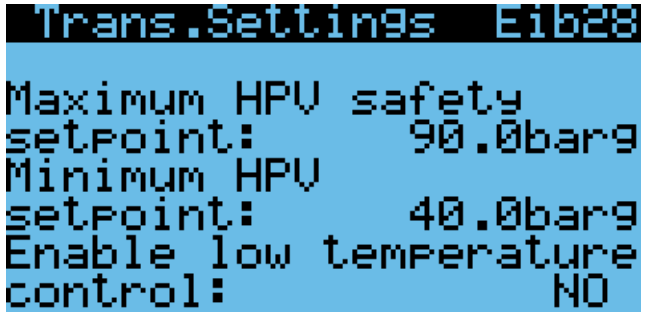


- Proportional and Integral time used to control the HPV.
- Proportional identifies the HPV valve opening variation for every 1 barg change in the Gas Cooler pressure.

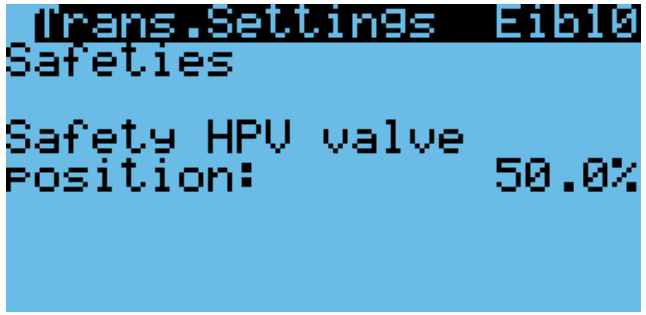


- Filter that can be enabled to avoid fluctuations in the Gas Cooler pressure. Could be used to correct any electromagnetic noises presented in the GC_Out_temperature.

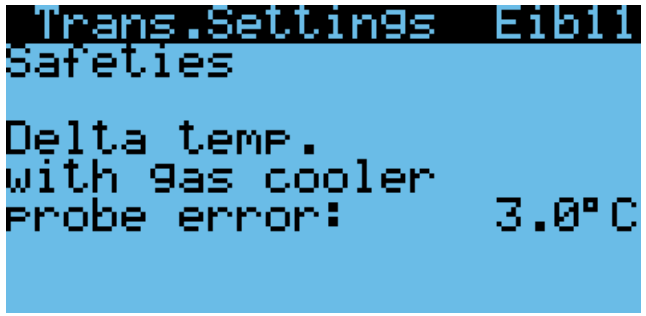
Transcritical Settings (HPV)



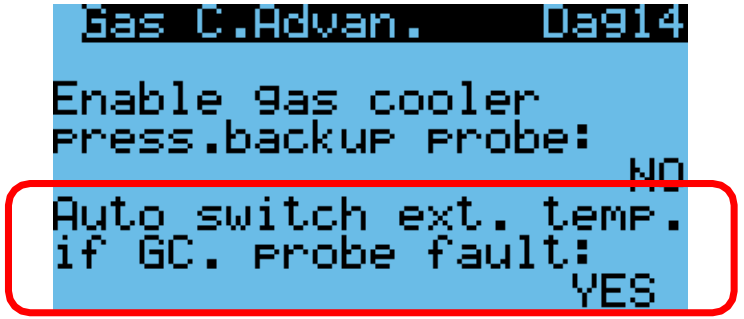
- **Max HPV safety setpoint:** max allowed value other functions try to increase the setpoint (protections of the receiver pressure by HPV). In normal operating conditions this can be up to Pmax (Fhb25).
- **Min HPV setpoint:** min value allowed in running mode.
- **Enable low temperature control** enable the Low temp proportional zone.



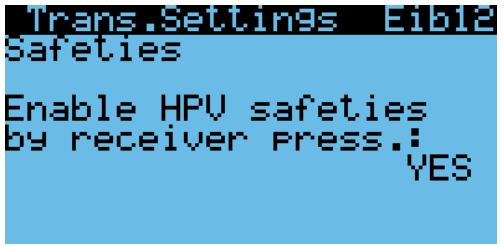
- Safety position of HPV in case of some fault (broken Gas Cooler outlet temp. probe or broken Gas Cooler pressure probe)



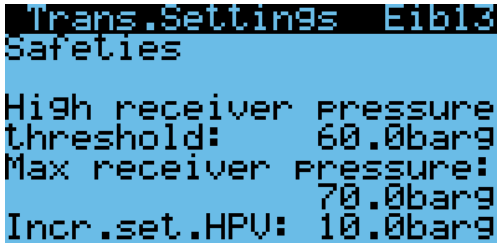
- Offset to add to the External Temperature reading in case of Gas Cooler temp. probe error.
- Auto switch on ext. temp. must be enabled on mask Dag14.



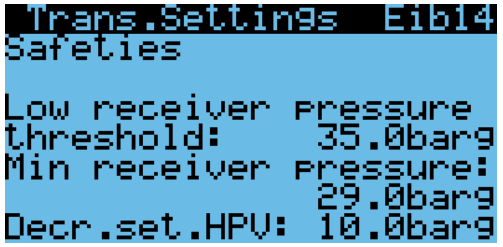
Transcritical Settings (HPV)



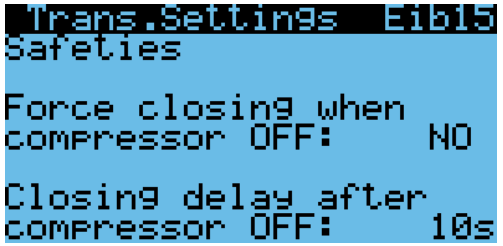
- Parameter to enable some actions in the HPV valve to prevent High and Low pressure conditions in the receiver (see masks Eib13 and Eib14)



- If the receiver pressure will rises above the threshold, a proportional offset will be added to the HPV setpoint in order to close the HPV. For example: start at a 0 bar offset @60barg and scale up to a max 10 bar offset @70barg.



- If the receiver pressure falls below the threshold, a proportional offset will be subtracted to the HPV setpoint in order to open the HPV. For example: start at a 0 bar offset @35barg and scale up to a max 10bar offset @29barg.

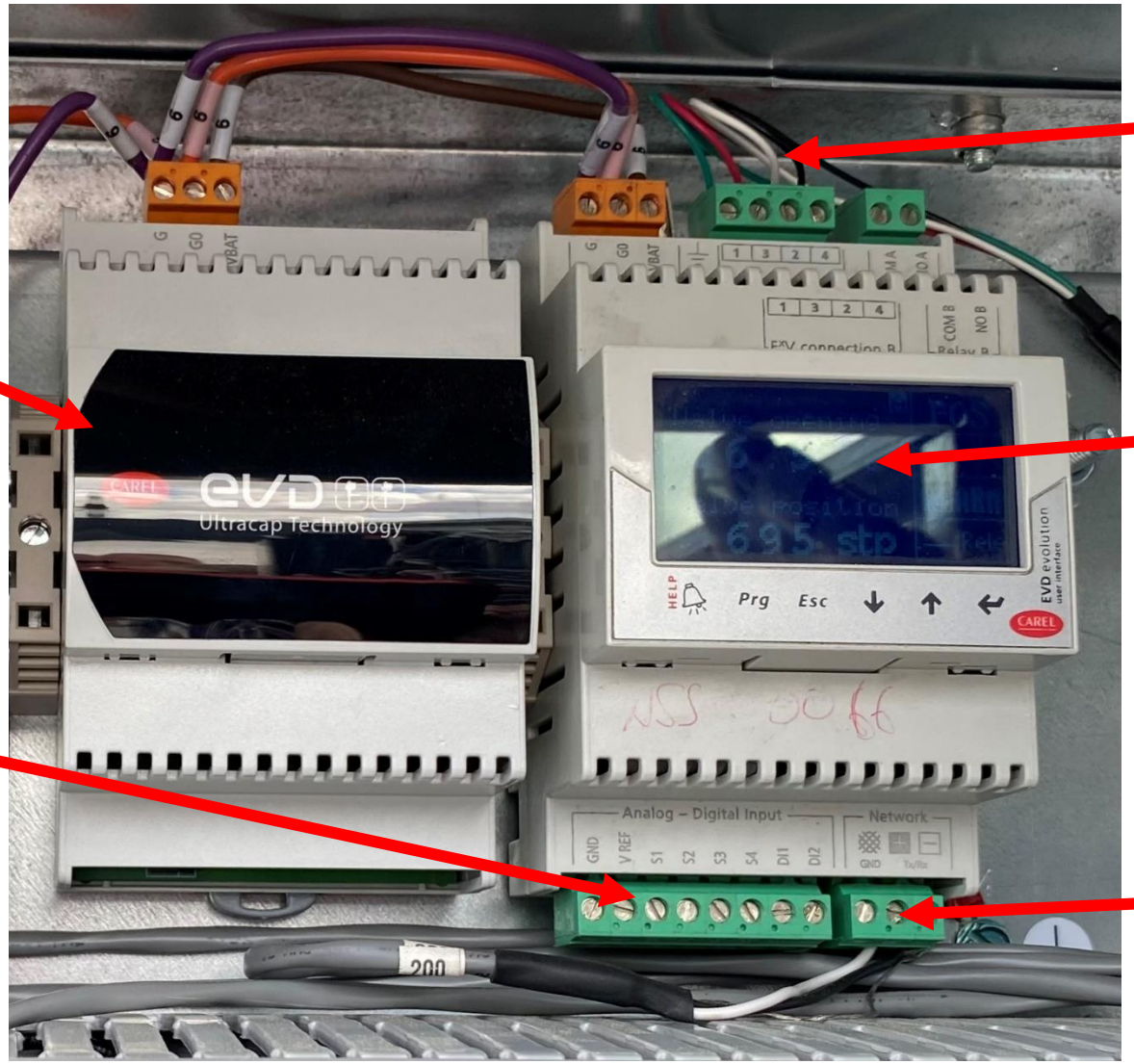


- Parameter to **enable** closure of HPV when compressor is OFF. The HPV closing position will match the value set as min HPV position during OFF.
- **Delay** to close the HPV valve after the compressor switch OFF.

Flash Gas Bypass Valve

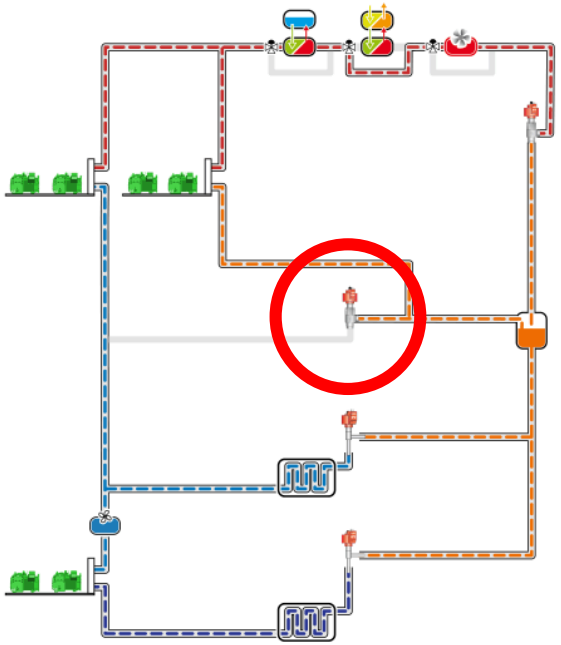
(RPRV, Receiver Pressure Regulating Valve)

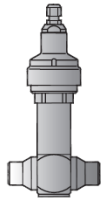
Transcritical Settings (Flash Gas Bypass)



Receiver Pressure Regulation Valve management

- **PI regulation** to maintain receiver pressure at settable setpoint
- **Settable limits**, speed and stand-by and backup positions of the valve
- **Debug** and monitoring alarms
- High and low receiver pressure **safety functions**
- High receiver pressure **alarm cut off compressors**
- Embedded algorithm with 0-10V output, **compatibility with all kind of valve in the market** using EVD EVO driven by 0-10V input
- **Backup/integration function of a secondary RPRV valve**

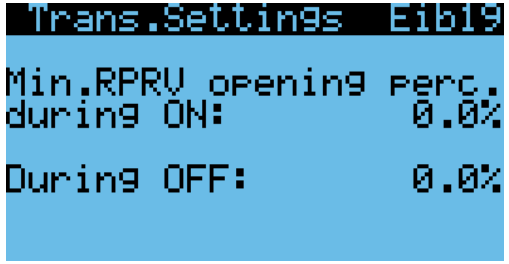




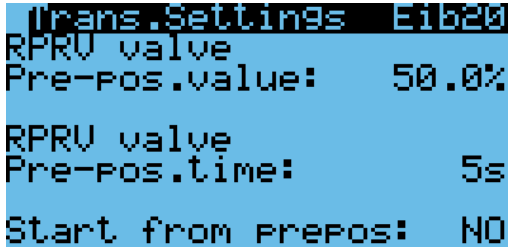
CCM

Transcritical Settings (Flash Gas Bypass)

- Mask where it is possible to enable/disable the RPRV management.

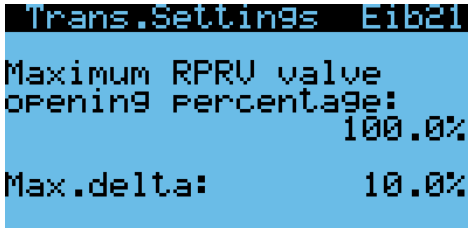


- Min. opening percentage that can be taken on by RPRV:
  During ON: while the UNIT is ON (by parameters, DI or supervisor)
  During OFF: while the UNIT is OFF (by parameters, DI or supervisor)

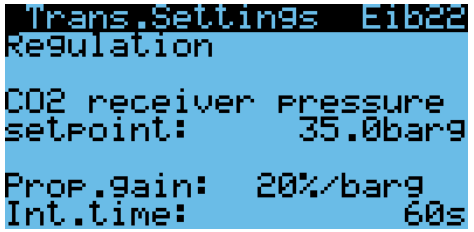


- Prepositioning of RPRV valve after that unit enters ON status. RPRV valve remains at a fixed position for the pre-positioning time.
- *This procedure is reactivated whenever the unit goes to the OFF status or the RPRV valve moves into the minimum position due to all of the compressors being turned off (optional).*

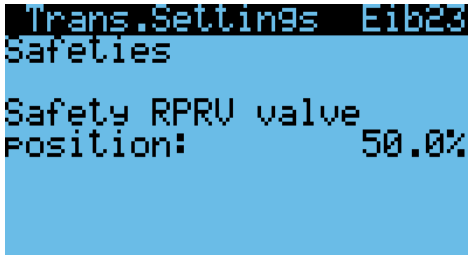
Transcritical Settings (Flash Gas Bypass)



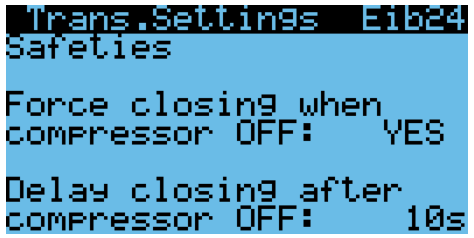
- Max opening percentage that can be taken on by RPRV valve during the regulation (while the UNIT is ON).
- Max allowed variation of the valve position in one shot.



- Receiver pressure setpoint (RPRV setpoint).
- Proportional coefficient and Integral time used for the RPRV. *Proportional coefficient identify the RPRV valve opening variation for every variation of 1barg in the receiver pressure.*

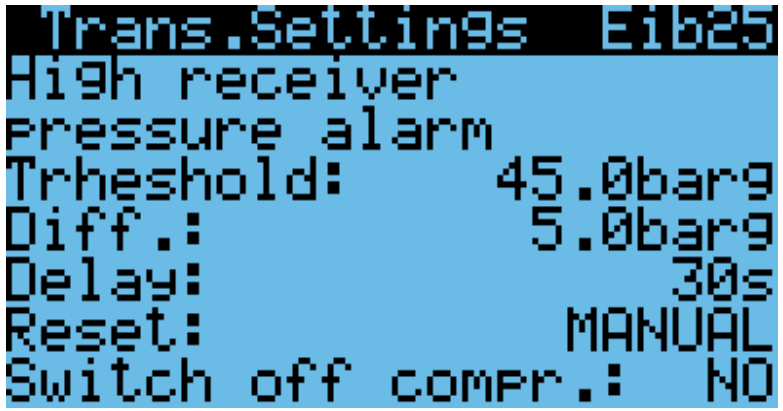


- Safety position of RPRV valve in case of a fault (Receiver pressure probe broken).



- Enables the closure of RPRV valve when comp is OFF. *The RPRV closing position will match with the value set as min RPRV position during OFF.*
- Delay to close the RPRV valve after the compressor switch OFF.

Transcritical Settings (Flash Gas Bypass)



- High receiver pressure alarm settings (threshold, differential, delay, reset).
- If “switch off compressor: NO” has been configured, no actions will be done in case of alarm.

- This mask will appear only if the “force closing of RPRV with comp. off” has been enabled (mask Eib24).
- RPRV valve will be closed only if Receiver pressure < (setpoint+1/2 offset) and it will stay closed until the pressure increases above setpoint + offset.
- As soon as the pressure reaches this value, this value becomes the new working setpoint and in 60 sec it will bring to the original value (setpoint).

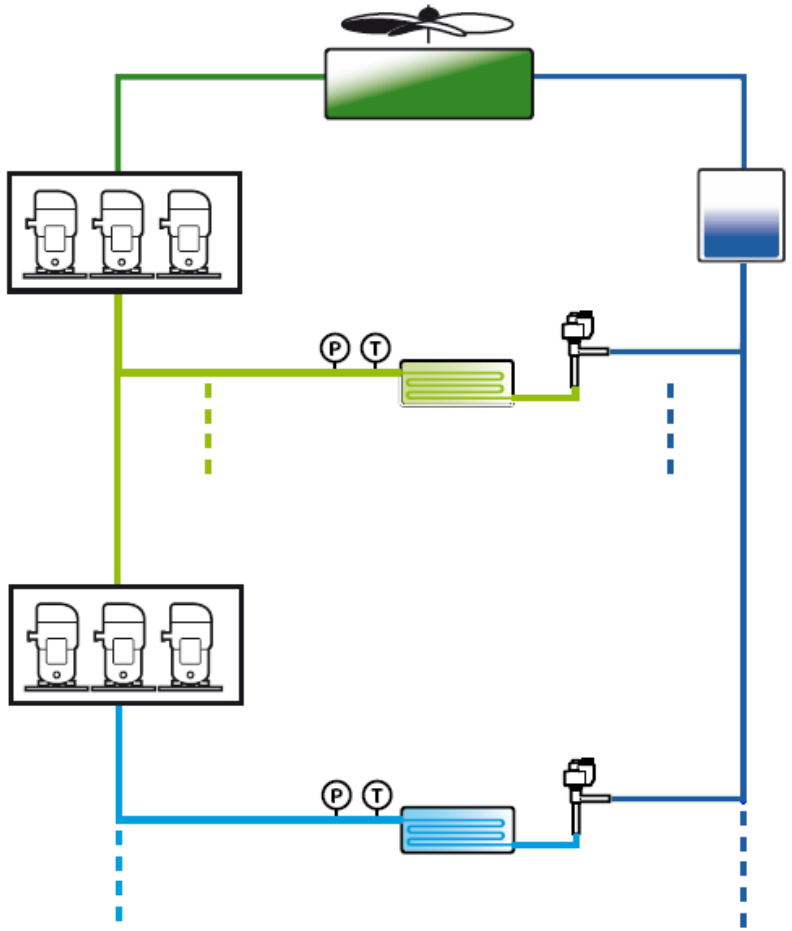
Other functions

pR300T: Double System Synchronization

- Optimization of system operation
- To avoid simultaneous peaks on different lines (3 lines)
- To synchronize the operation of two lines in booster systems:

1. if the low temperature line is active, then the medium temperature line must be active (forcing on compressors or pumping down compressors)

2. if the medium temperature line cannot be active due to technical problems/faults, then the low temperature line must **not** be active



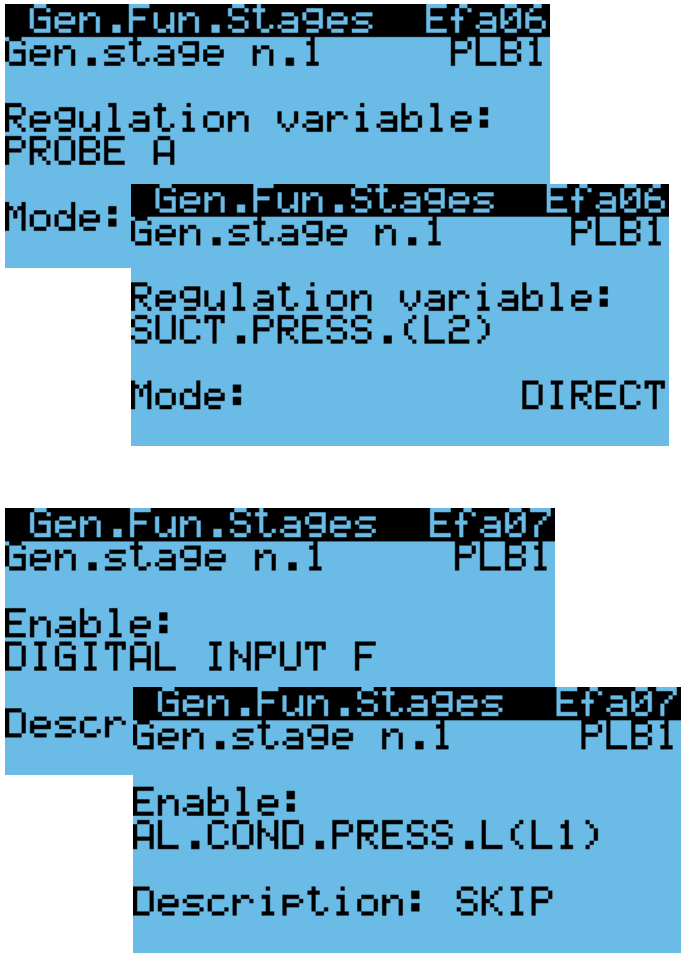
Generic Functions

The generic functions available for each board are:

- **5 digital thermostats (ON/OFF)** - DO
- **2 modulating thermostats** – AO

Regulation variables can be analog inputs not used (generic probes) or internal system variables with specific threshold and differential.

Enabling variables can be digital inputs not used (generic DI) or internal system variables (mainly alarms).

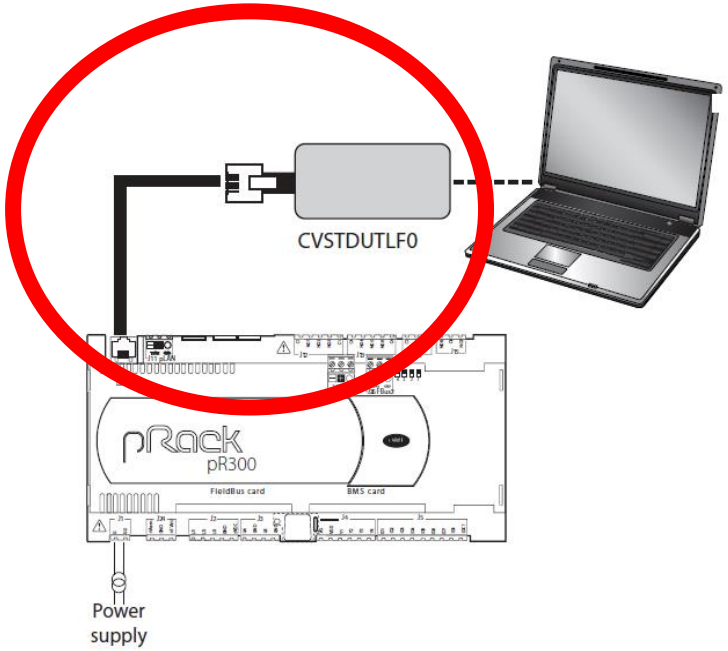


USB and RHEC Manager

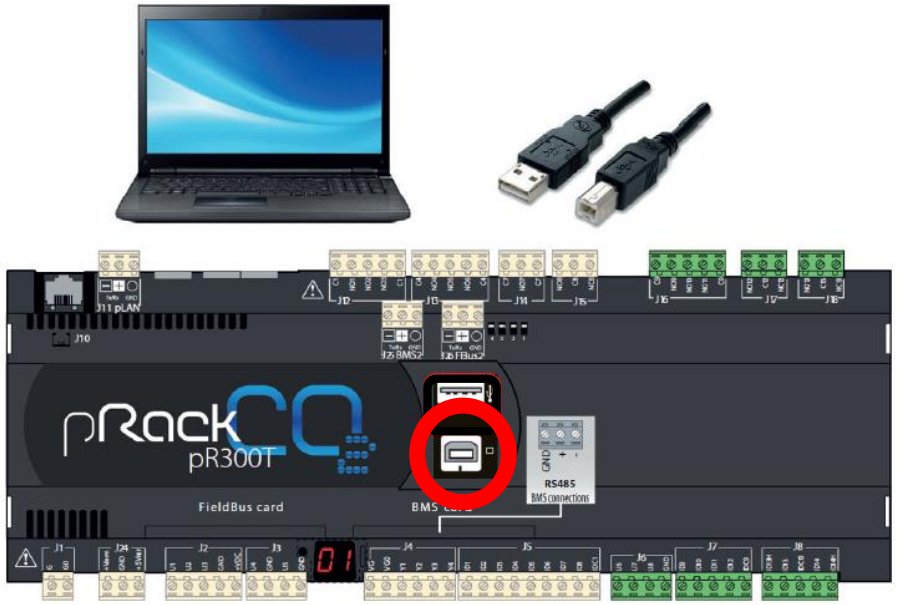
Retail High
Efficiency Controllers Manager

Connecting to pRack

RS485 Converter with telephone connector:
CVSTDUTLF0 to J10



USB-B to USB-A cable to pRack

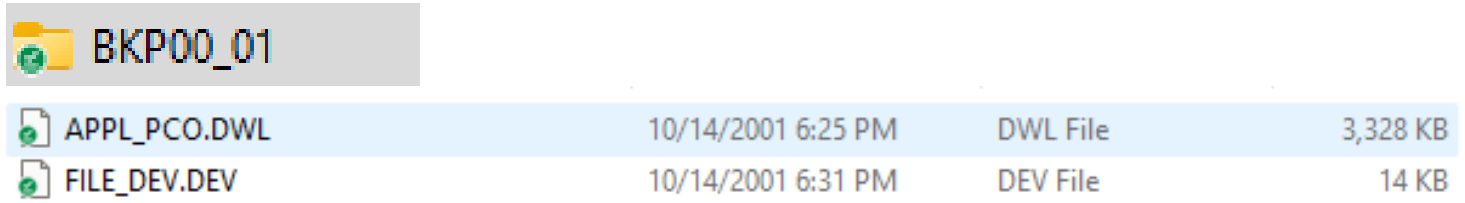


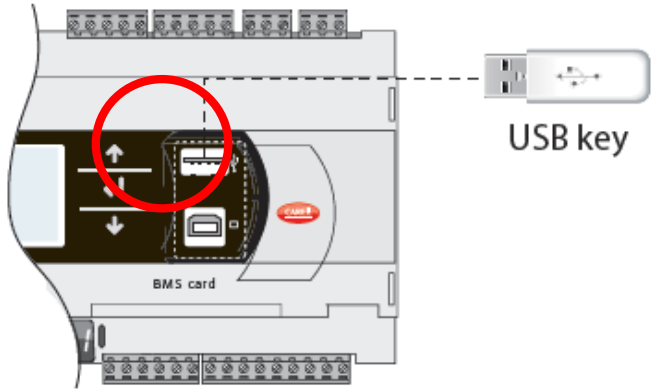
USB drive to pRack

Using USB Drive – What Can You Do?

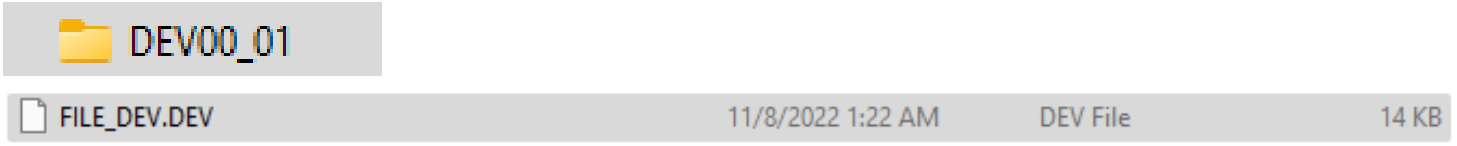
1. **Download logs from controller.**

2. **Download/Upload the Application; AKA Software.**

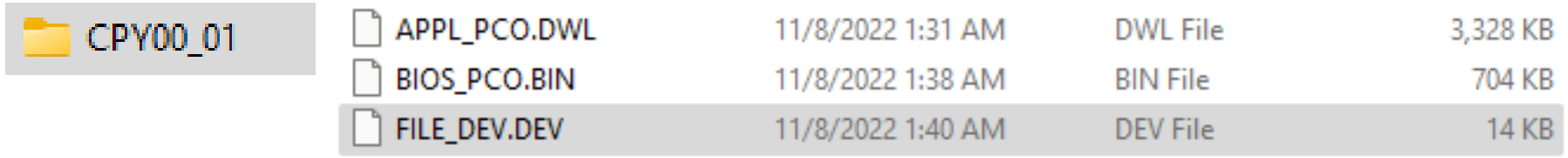




3. **Download/Upload Parameter Settings (setpoints). This is also known as the .DEV file. Shown as "Non Volatile Memory" in controller.**

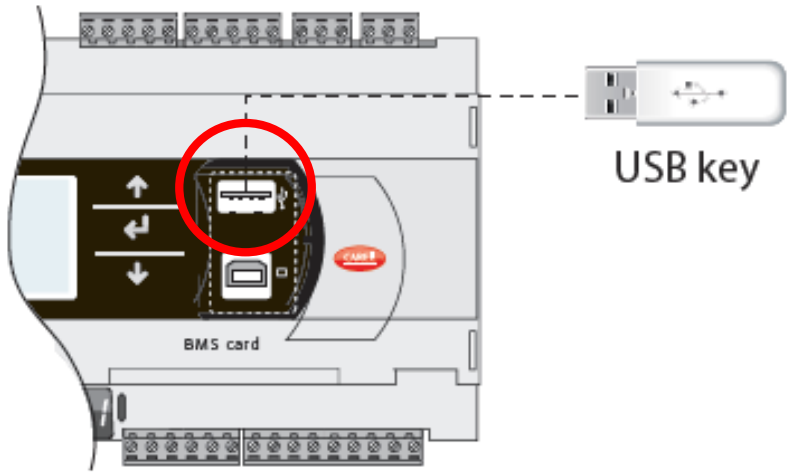


4. **Download/Upload "pCO". This is everything except logs and boot file.**



Using USB Drive - RULES

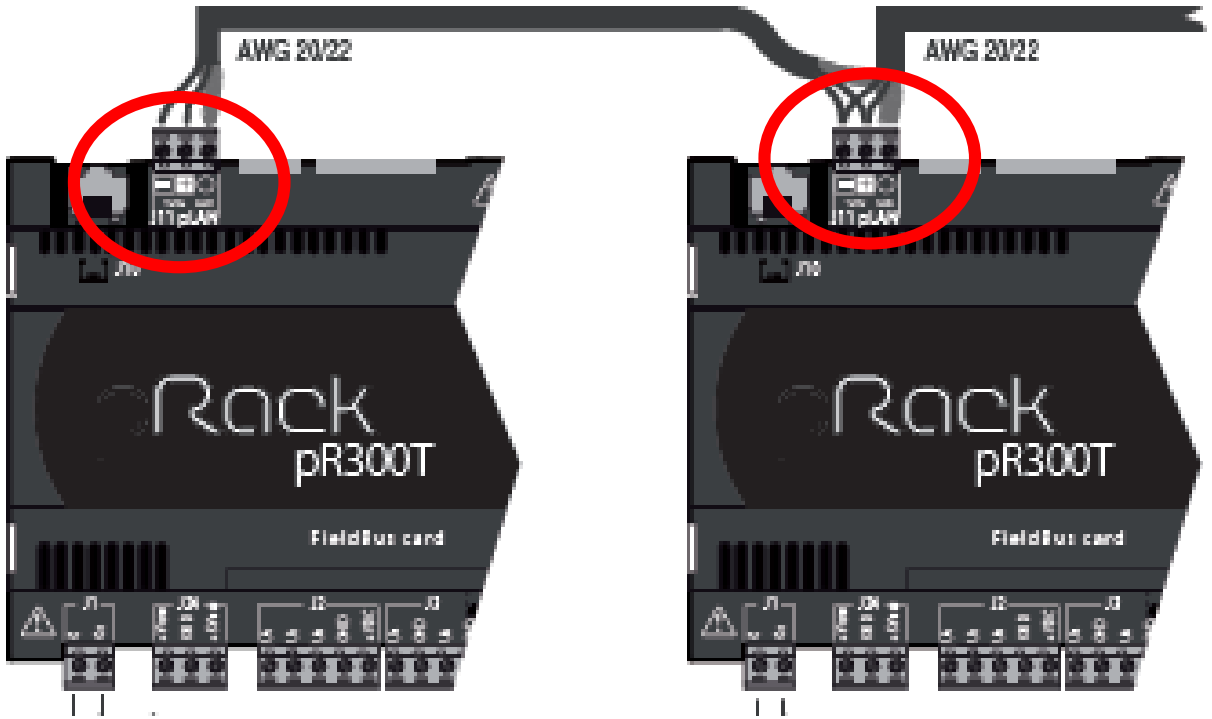
- **File names**
  In order to be recognised, the names of the directories and files on the pendrive must have no more than 8 characters; the controller makes no distinction between upper-case and lower-case characters. However, during DOWNLOAD the names of the directories created by the controller on the pendrive are always in upper-case.
    - Tested and long filenames WORK on new software! Keep directory names at 8 characters



- **Always include software version in *.dev file name**
- **If keeping backups from multiple job sites, think about how you want to name these folders**
- **ALWAYS MAKE SURE SOFTWARE VERSION (APPLICATION VERSION) AND *.DEV FILE VERSION MATCH**

LOOK OUT!!!

*****If downloading from a multi-pRack setup, you MUST switch the controller off via keyboard and disconnect the pLAN connection at one end*****

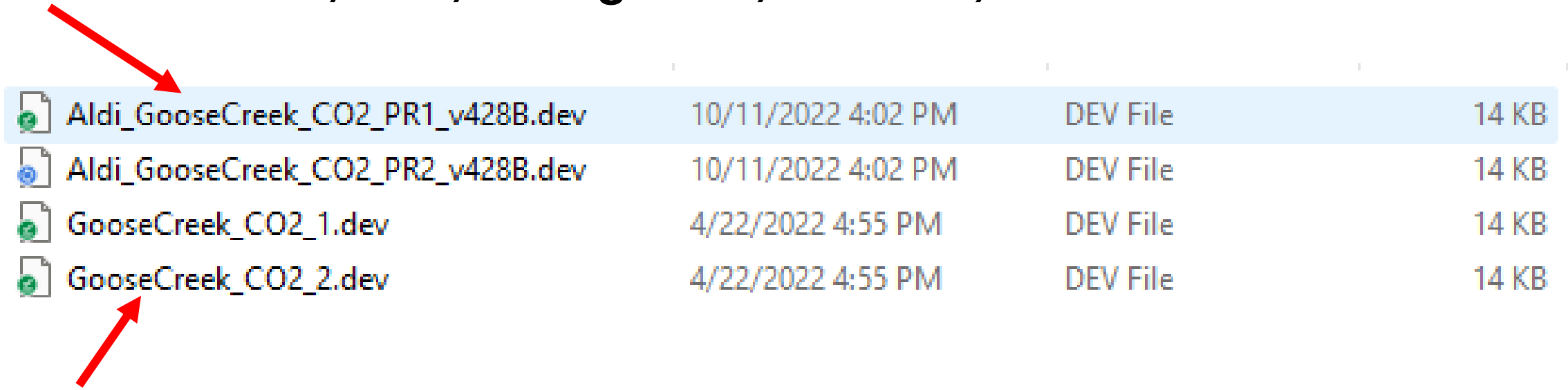


LOOK OUT!!!

File names….ALWAYS INCLUDE SOFTWARE VERSION!!

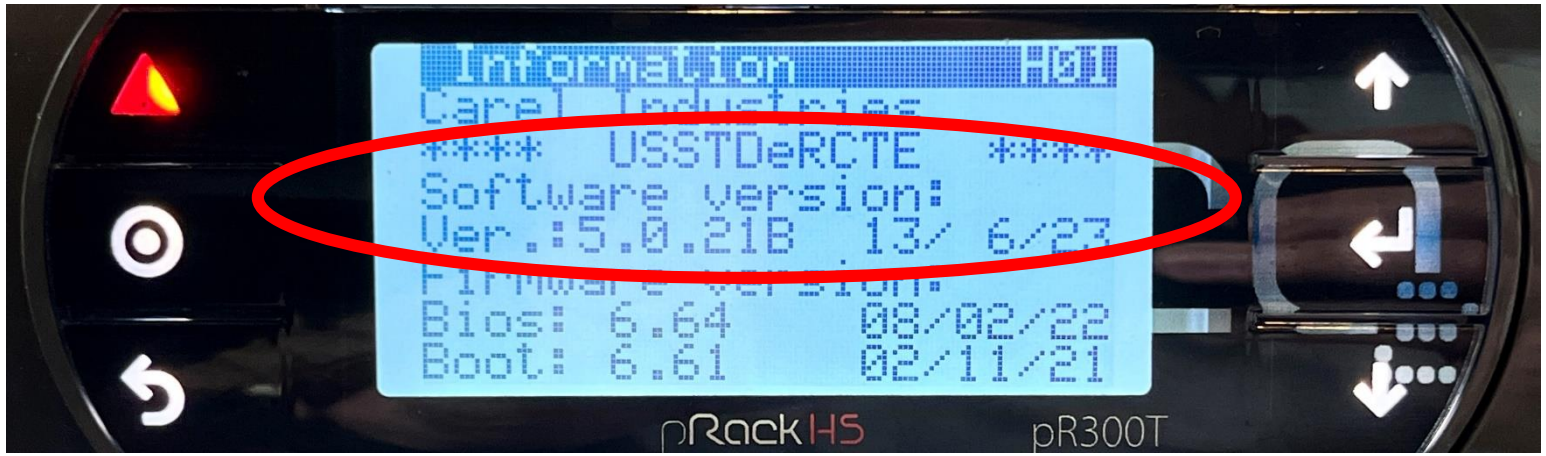
This can be found in the rack controller or from the rack manufacturer

YES!! Customer, Site, Refrigerant, Rack ID, and Software Version



NOPE!! Not specific enough!

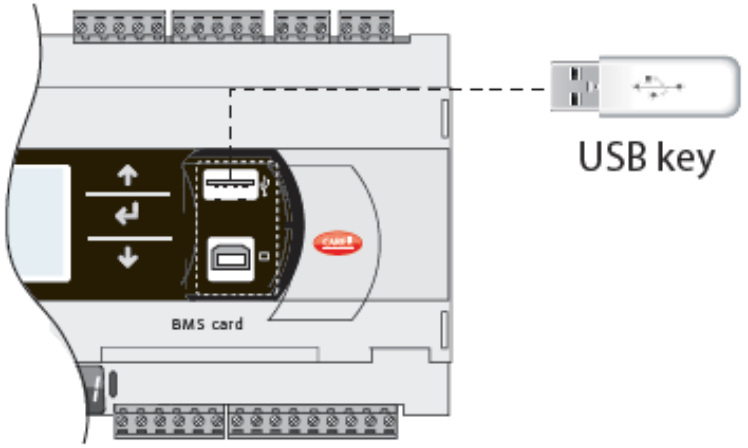
LOOK OUT!!!



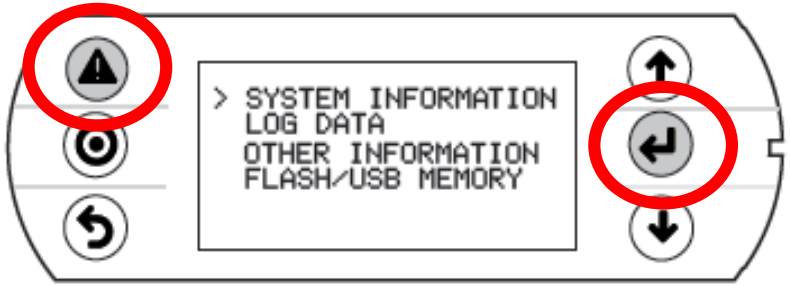
Software Versions!

Using USB Drive

1. Connect the USB drive to the pRack

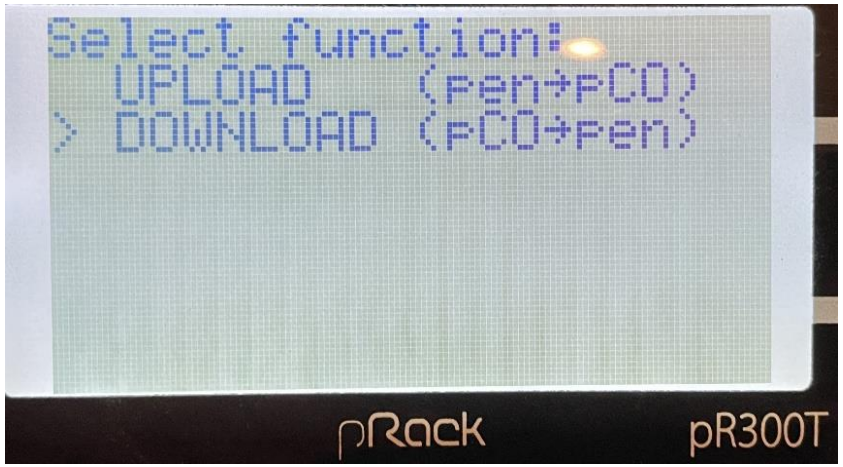


2. Press and hold the “Alarm” and “Enter” buttons together for about 3 seconds. The system option menu will display. Use the down arrow button to scroll to “Flash/USB Memory”. Press Enter.

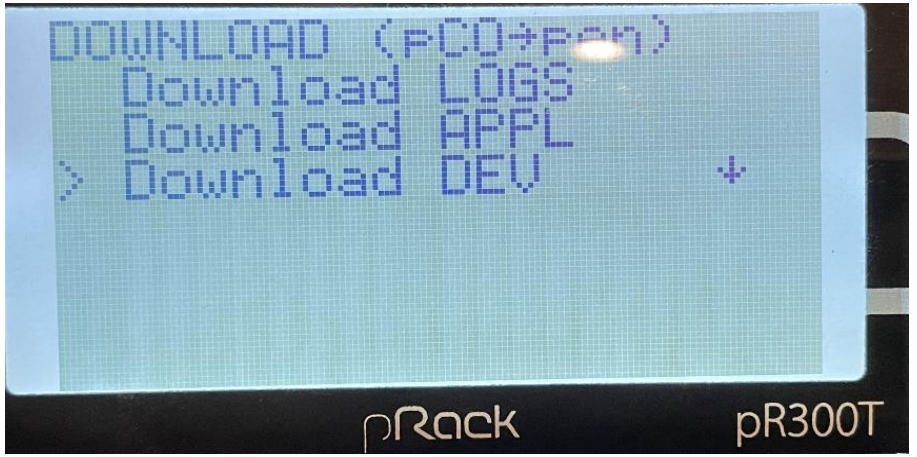


Using USB Drive – **Download – pCO to pen**

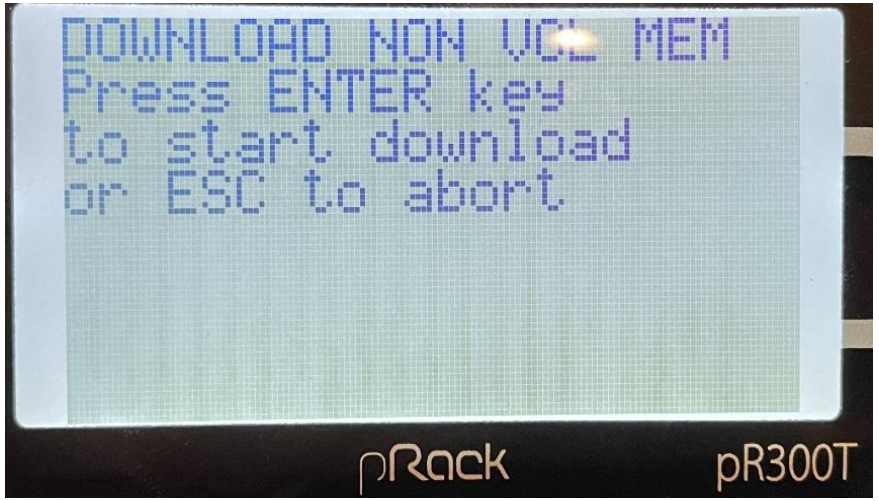
1. **Select Download**



2. **Select Download type:**



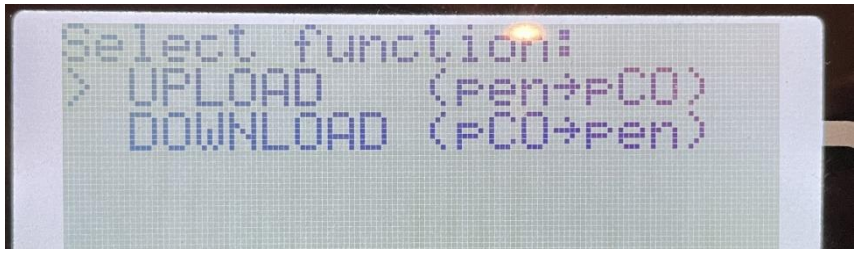
3. **Follow screen directions**



Using USB Drive – **Upload – pen to pCO**

1. **Select USB Pen Drive**

2. **Select Upload (pen -> pCO**



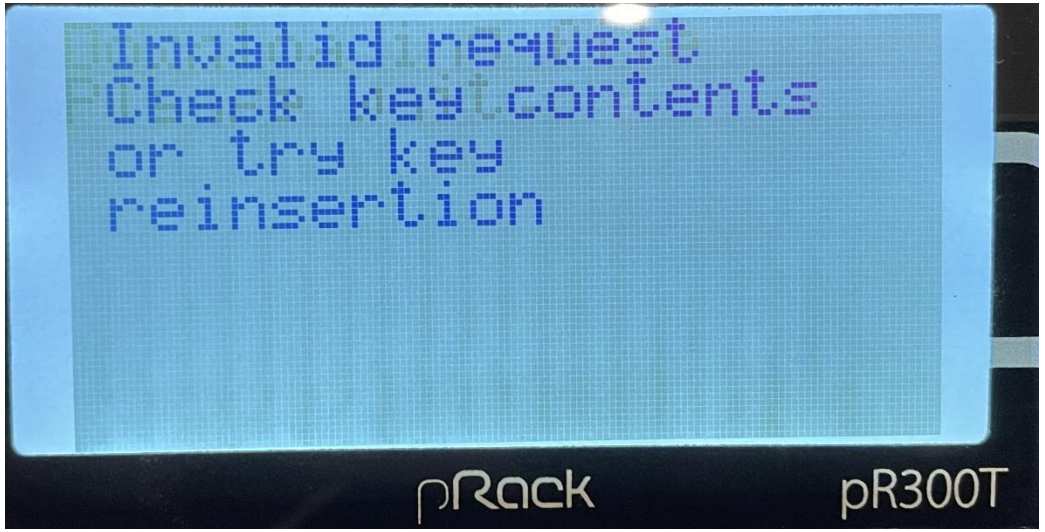
3. **Select MANUAL mode**

4. **Scroll through help screen**

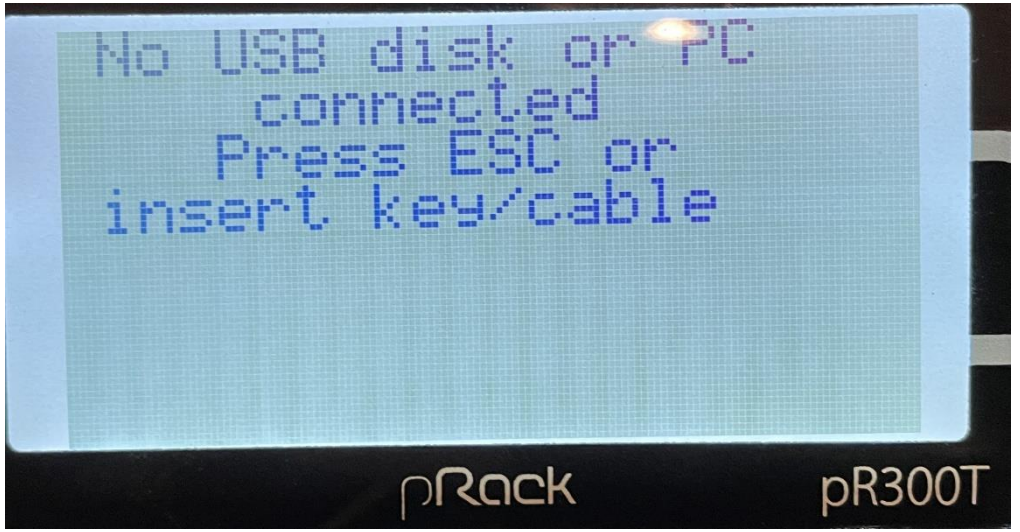
5. **Select file or folder you want to upload by pressing enter. A "✷" will appear next to the file you select. Press the PRG ("target") button**

6. **Wait and unit will reboot**

Using USB Drive - **Errors**



Try another USB drive



USB drive not connected, reinsert, or try another USB drive

Other errors may mean you're trying to load a parameter file written for a different software version

Troubleshooting

Troubleshooting

Unstable Gas Cooler pressure

EFFECT	POSSIBLE CAUSE	SOLUTION
Unstable Gas Cooler pressure	Wrong configuration of HPV PID (proportional too high and integral time too low)	• Check and adjust the HPV PID (decrease the proportional and increase the integral time)
	Ineffective filter on the reading of ToutGC probe	• Check and adjust the filter of ToutGC
	Unstable HPV set point	• Check that the calculation of HPV set point is stable; otherwise keep it stable keeping stable the Gas Cooler fans
	Wrong placement of Gas Cooler probe	• Check that gas cooler probe has been placed in the right position (not affected by external conditions)

Troubleshooting

The Gas Cooler pressure does not reach setpoint

EFFECT	POSSIBLE CAUSE	SOLUTION
The Gas Cooler pressure does not reach the set point	The type of valve set is incorrect	• Check and correct the type of valve parameter
	The HPV valve is connected incorrectly (rotates in reverse)	• Check the movement of the valve by placing it in manual control and closing or opening it completely. If the movement is reversed, check the electrical connections
	Stator broken or connected incorrectly	• (for Carel ExV only) Disconnect the stator from the valve and the cable and measure the resistance of the windings using an ordinary tester. The resistance of both should be around 36 ohms. Otherwise replace the stator. • Finally, check the electrical connections of the cable to the driver/ controller
	Wrong configuration of PID parameter	• Check and adjust the PID parameters in order to increase the speed of the valve
	Leakage from HPV valve when it is closed	• Check that there is no transit of refrigerant through the valve when it is closed. If there is a leakage replace the valve

Troubleshooting

High CO2 Receiver pressure (1/2)

EFFECT	PROBLEM/ SCENARIO	POSSIBLE CAUSE	SOLUTION
High CO2 receiver pressure (too far from the set point)	According to the pRack info the RPRV valve is working properly	The type of valve set is incorrect	• Check and correct the type of valve parameter
		The RPRV valve is connected incorrectly (rotates in reverse)	• Check the movement of the valve by placing it in manual control and closing or opening it completely. If the movement is reversed, check the electrical connections
		Stator broken or connected incorrectly	• (for Carel ExV only) Disconnect the stator from the valve and the cable and measure the resistance of the windings using an ordinary tester. The resistance of both should be around 36 ohms. Otherwise replace the stator. • Finally, check the electrical connections of the cable to the driver.
		Driver and RPRV valve are not synchronized (the valve opening shown from the driver does not match with the real position of the valve)	• Switch off and switch on the pRack or stop and then start again the pRack regulation
		Wrong sizing of the RPRV valve	• Check the RPRV valve selection

Troubleshooting

High CO2 Receiver pressure (2/2)

EFFECT	PROBLEM/ SCENARIO	POSSIBLE CAUSE	SOLUTION
High CO2 receiver pressure (too far from the set point)	According to the pRack info the RPRV valve opening is too low or it is always closed	Wrong configuration of PI parameter	• Check and adjust the PI parameters in order to increase the speed of the valve
		Receiver safety procedure not configured	• Check and configure the receiver safety procedure
		Set Point HPV too low	• Check and adjust the configuration of HPV valve in order to increase the HPV set point

Troubleshooting

Low CO2 Receiver pressure (1/2)

EFFECT	PROBLEM/ SCENARIO	POSSIBLE CAUSE	SOLUTION
Low CO2 receiver pressure (too far from the set point)	According to the pRack info the RPRV valve is working properly	The type of valve set is incorrect	• Check and correct the type of valve parameter
		The RPRV valve is connected incorrectly (rotates in reverse)	• Check the movement of the valve by placing it in manual control and closing or opening it completely. If the movement is reversed, check the electrical connections
		Stator broken or connected incorrectly	• (for Carel ExV only) Disconnect the stator from the valve and the cable and measure the resistance of the windings using an ordinary tester. The resistance of both should be around 36 ohms. Otherwise replace the stator. • Finally, check the electrical connections of the cable to the driver.
		Drive and RPRV valve are not synchronized (the valve opening shown from the driver does not match with the real position of the valve)	• Switch off and switch on the pRack or stop and then start again the pRack regulation
		Wrong sizing of the RPRV valve	• Check the RPRV valve selection
		Leakage from RPRV valve when it is closed	• Check that there is no transit of refrigerant through the valve when it is closed. If there is a leakage replace the valve

Troubleshooting

Low CO2 Receiver pressure (2/2)

EFFECT	PROBLEM/ SCENARIO	POSSIBLE CAUSE	SOLUTION
Low CO2 receiver pressure (too far from the set point)	According to the pRack info the RPRV valve opening is too High	Wrong configuration of PI parameter	• Check and adjust the PI parameters in order to increase the speed of the valve
		Receiver safety procedure not configured	• Check and configure the receiver safety procedure
		Set Point HPV too High	• Check and adjust the configuration of HPV valve in order to reduce the HPV working set point • If it happens during the commissioning, it is possible to decrease temporarily the Pcritic of transcritical zone or increase the min opening HPV during on
		Insufficient refrigerant	• Check that there is enough refrigerant inside the circuit; otherwise charge the circuit

Reference

Regulation Proportional + Integral

kp: proportional gain → is <u>inversely proportional</u> to the <u>Regulation Differential</u>

Pressure	Temperature
$kp = \frac{100}{2 \cdot Diff}\left[\%/b\,\mathrm{arg}\right]$	$kp = \frac{100}{2 \cdot Diff}\left[\%/°C\right]$

Depending on the regulation variable, ***kp*** is the request percentage variation for every variation of **1 barg** or **°C**

For example:

- **Diff = 1 barg**

  *For a pressure change of 1 barg, a power request change of <u>**50%**</u> for proportional factor*

  Low Differential → system fast and reactive, possible instability

- **Diff = 10 barg**

  *For a pressure change of 1 barg, a power request change of <u>**5%**</u> for proportional factor*

  High Differential → system slow and not very reactive

Regulation Proportional + Integral

Ti: integral time: the time of integration needed to bring back the regulation variable to the setpoint

For example:

Setpoint = 1barg
ActualPressure= 2 barg

$$Integral\_action = \frac{kp \cdot (SetP - Actua1pressure)}{Ti} \left[\%/\text{sec} \right]$$

Case 1:

- *Diff = 5 barg → Kp = 10%*
- *Ti = 10 sec → Power request will increase* ***1% every second until setpoint is reached***

Case 2:

- *Diff = 5 barg → Kp = 10%*
- *Ti = 40 sec → Power request will increase* ***0.25% every second until setpoint is reached***

high Ti → system slow to reply to system instability

low Differential → system fast and reactive, possible instability

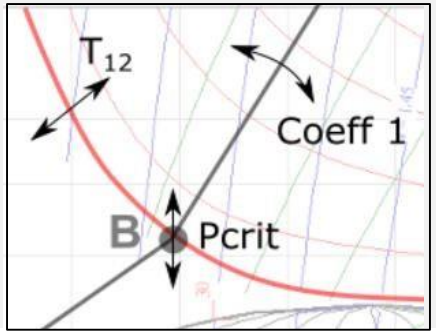
pR300T: Line 1 – Optimal pressure

Transcritical zone: line 1

$T_{GC} > T_{12}$

Optimal pressure is calculated as a function of ToutGC.

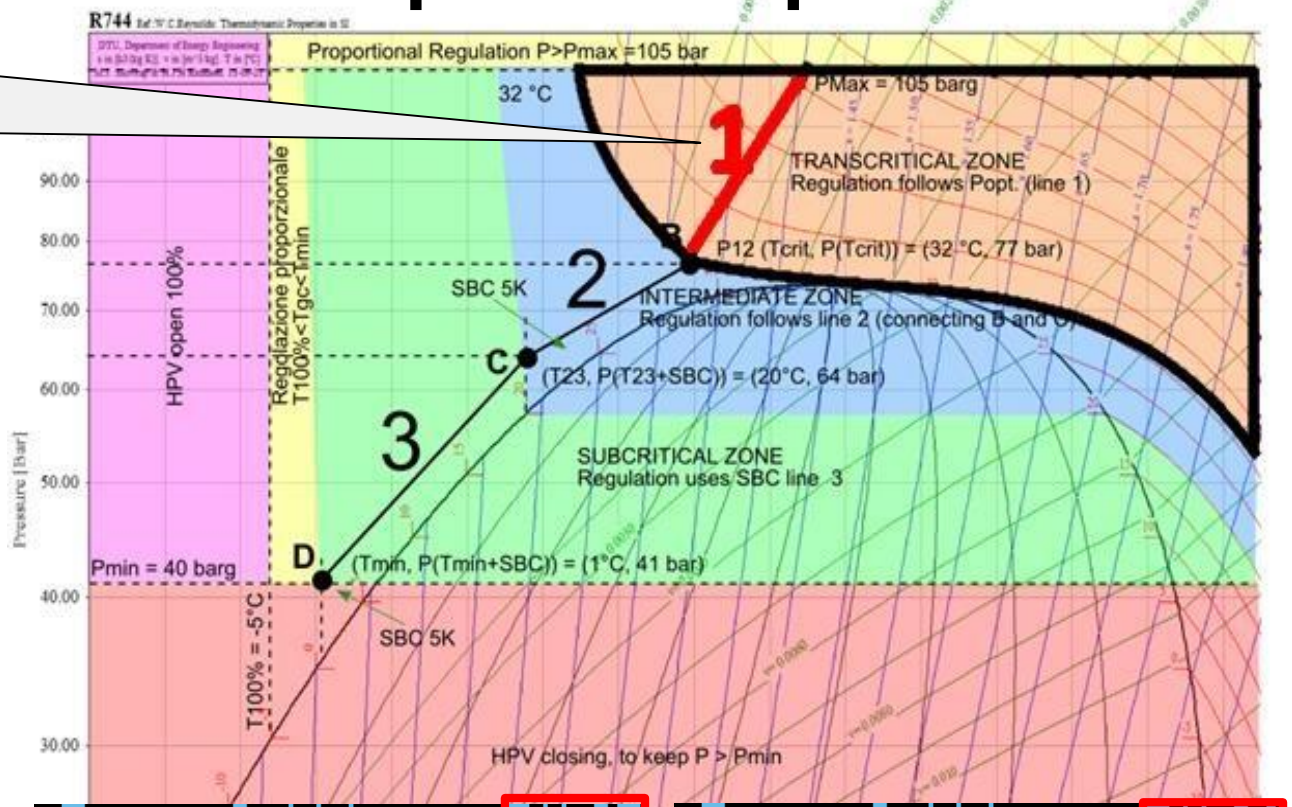
- Manual config: point B pressure and line slope (Coeff.1) are set manually

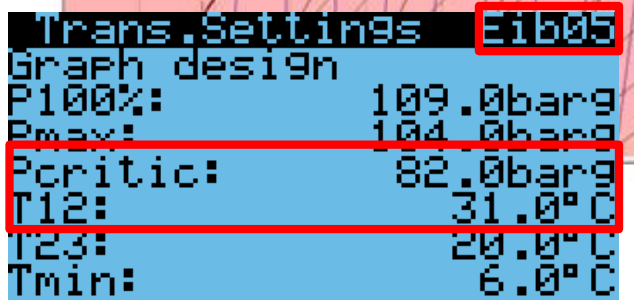


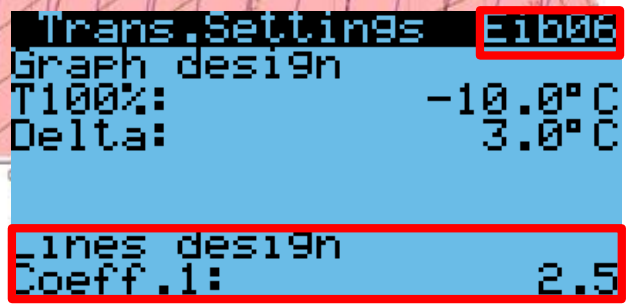
Pline1 : coeff1*(Tgc-T12)+Pcritic

Default settings are:

- coeff1=2.5
- T12=31°C
- Pcritic=82 barg





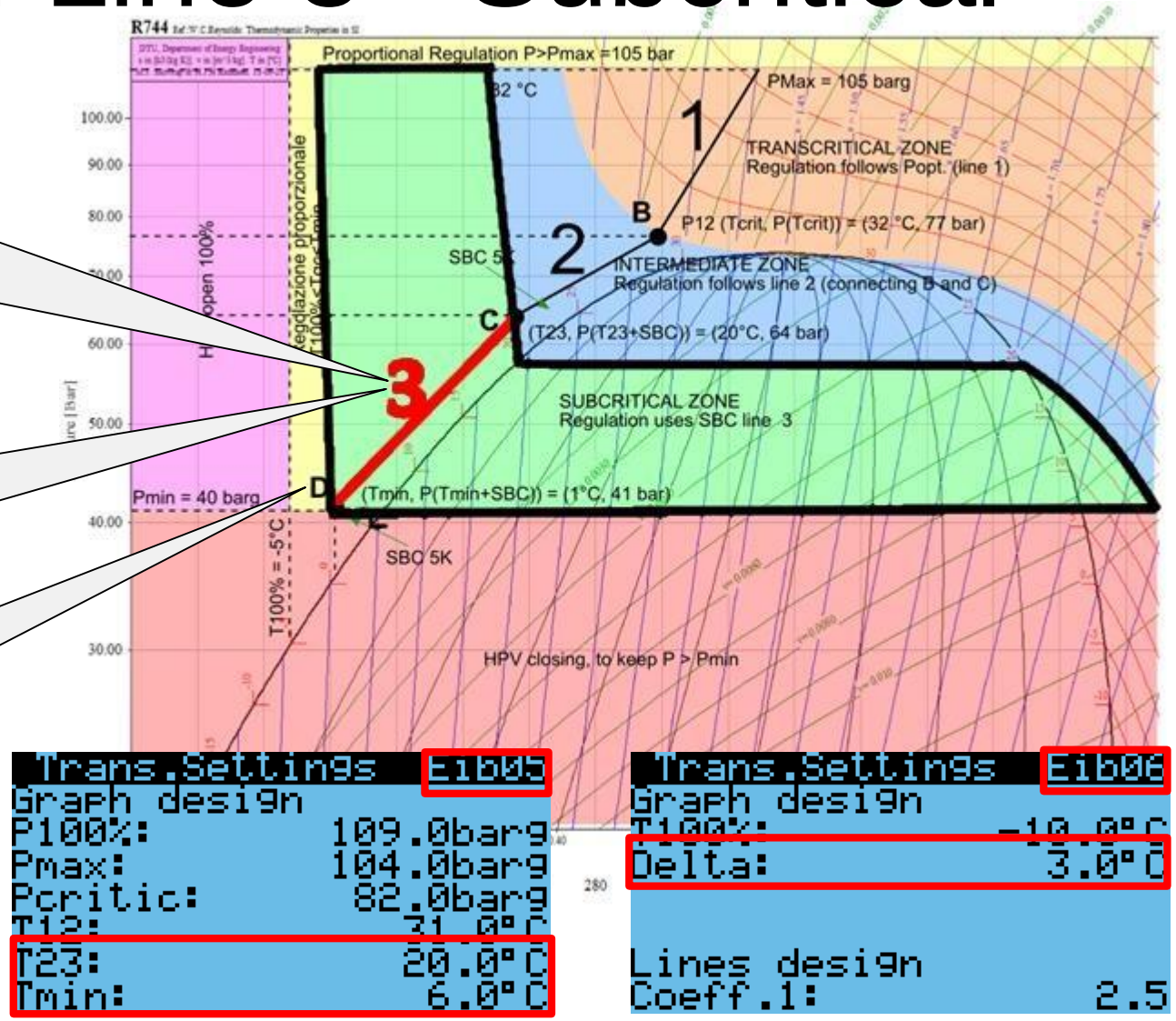


pR300T: Line 3 - Subcritical

Subcritical zone: line 3
ToutGC < T_{23}
Optimal pressure is calculated to follow the saturation curve with a user defined delta (SBC)

Pline3 : P_{sat}(Tx + delta)
Default settings are:
- Below T23 = 20°C
- Delta = 3,0°C
- Above Tmin =6.0

Lower proportional zone:
$T_{100\%} < T_{GC} < T_{min}$
The valve is opened with a proportional regulation. The valve will not reduce opening until $T_{GC} > T_{min}$



pR300T: Line 2 - Intermediate

Upper proportional zone:
$P_{max} < P_{GC} < P_{100\%}$

The valve is opened with a proportional regulation. When HP = P100%, the valve will be fully opened.
The valve will not reduce opening until HP < Pmax

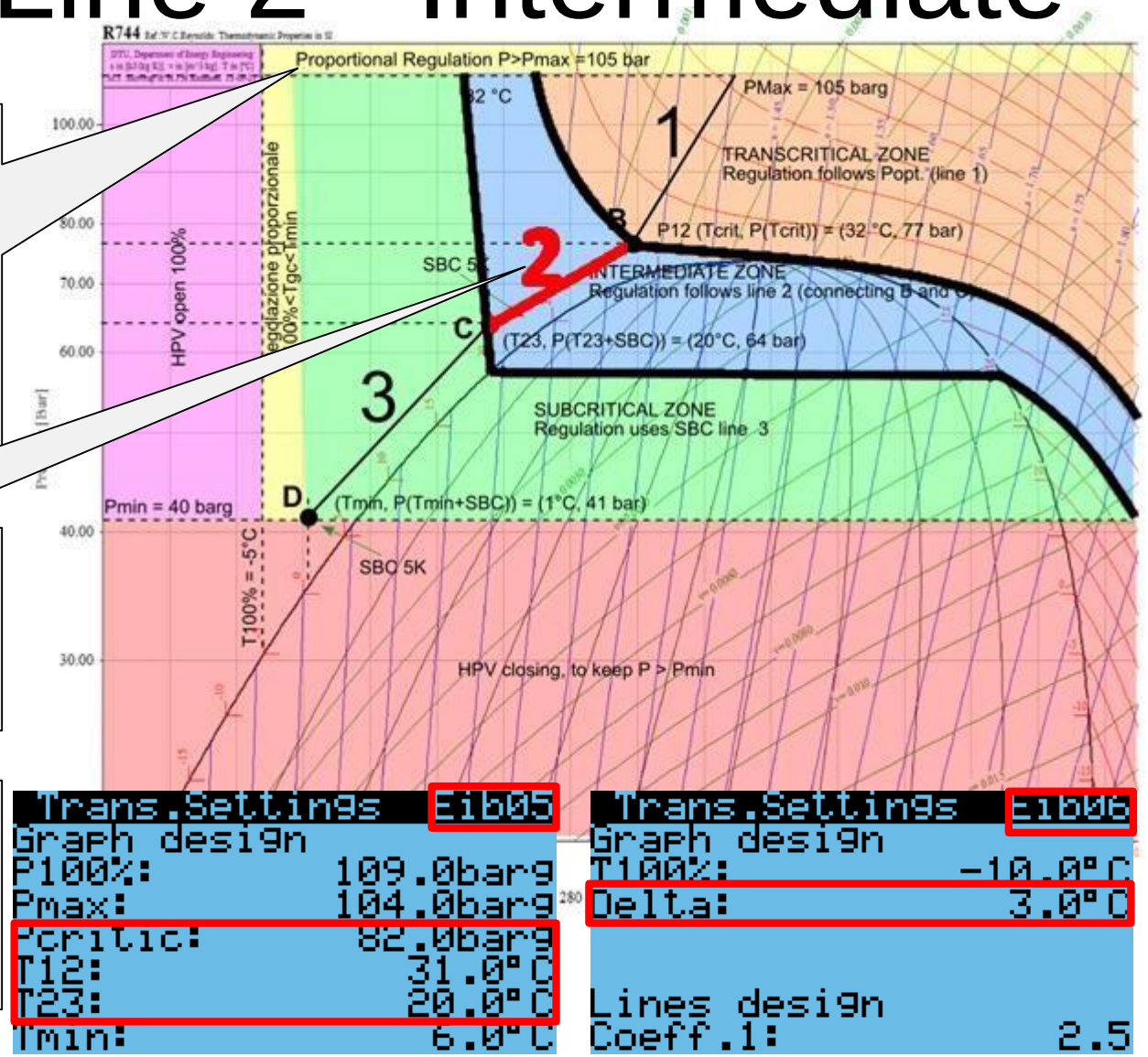
Intermediate zone: line 2
$T_{23} \leq T_{GC} \leq T_{12}$

Optimal P is calculated on a line connecting point B and C

Pline2 : $[(P_{sat}(T_{23} + delta) - P_{critic}) / (T_{23} - T_{12})] * (T_x - T_{12}) + P_{critic}$

Default settings are:

- T_{23} = 20°C
- T_{12} = 31°C
- Delta = 3,0°C



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