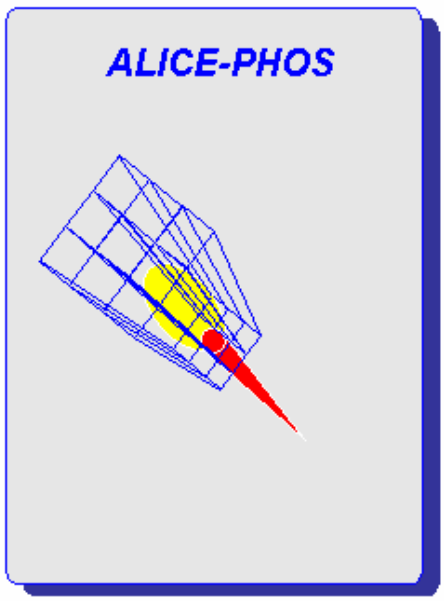




AliPhosCool: short manual for PHOS cooling experts.

Draft



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CERN, Nov 2009.

Content

INTRODUCTION **3**

NETWORK AND LOGIN **8**

IMPORTANT NOTE BEFORE YOU START **11**

SIMPLE CONTROL PANEL: PHOS.FSM.CTRL WINDOW **11**

EXPERT CONTROL PANEL: PHOS.COOL.CTRL WINDOW **13**

SAFE DATA VIEW: WEB ASSESS **27**

TEMPERATURE STABILIZATION ALGORITHM **30**

ALARM SYSTEM AND INTERLOCK **32**

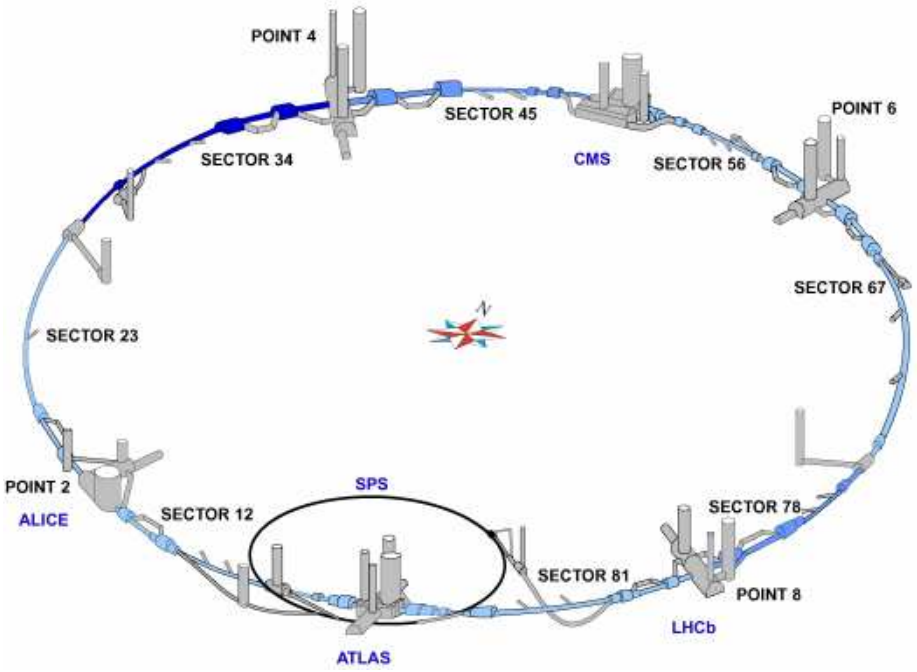
"HOW TO" AND "WHAT TO DO" **38**

HOW TO LOGIN … 38
HOW TO KNOW WHAT IS T1, T2 ETC … 38
HOW TO KNOW WHY INTERLOCK HAPPENED… 38
WHAT TO DO IF INTERLOCK HAPPENED… 39
HOW TO COOL DOWN PHOS TO WANTED TEMPERATURE…. 39
WHY "FORBIDDEN IN FSM MODE" WARNINGS APPEARS? 39
WHERE I CAN FIND MORE DETAILS ON COOLING SYSTEM? 40
WHAT TO DO IF NOTHING HELP…. 40

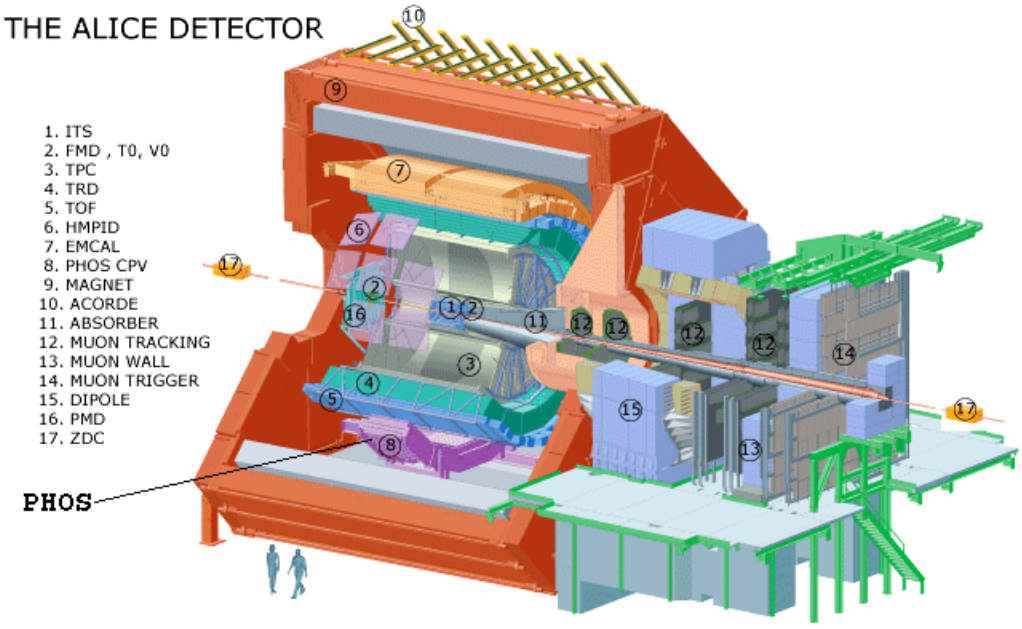
Introduction

This manual describes **ALICE PHOS** detector crystal cooling system and **AliPhosCool** program. It's not manual for **DCS** shifters who should work only with **PVSS GUI** with limited functions. It's manual for "cooling experts" who have to support and tune cooling system. First, let's remind some basic items.

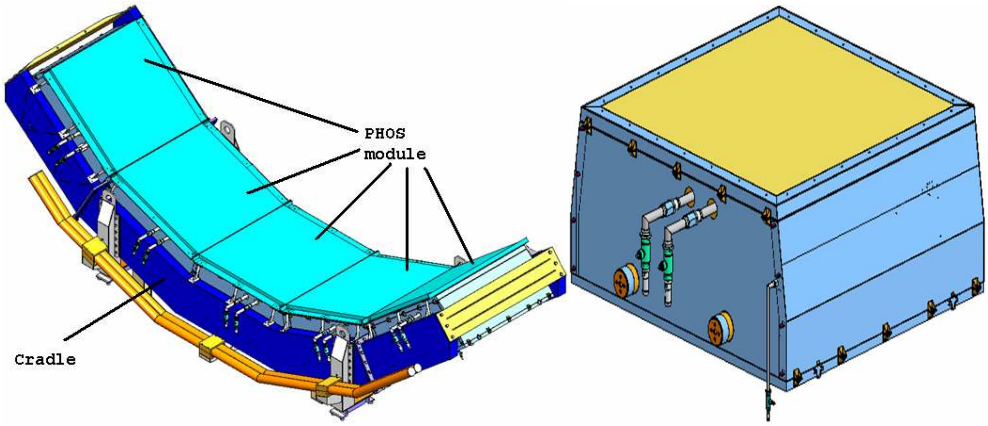
ALICE (a large ion collider experiment) at **CERN** is one of 4 big experiments on **LHC** (large hadron collider) (Picture 1, Picture 2).



Picture 1. The LHC experiments.

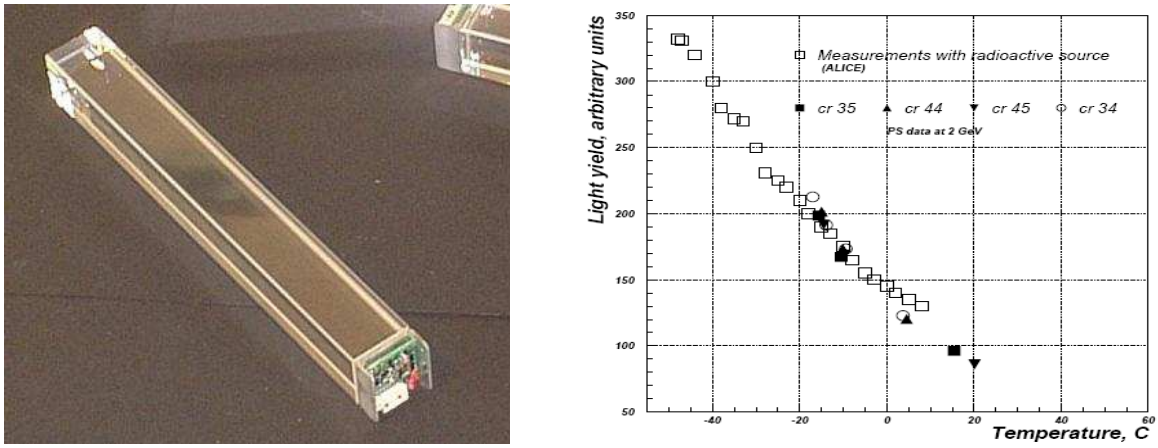


Picture 2. The ALICE detector.



Picture 3. PHOS detector (left) and PHOS module (right).

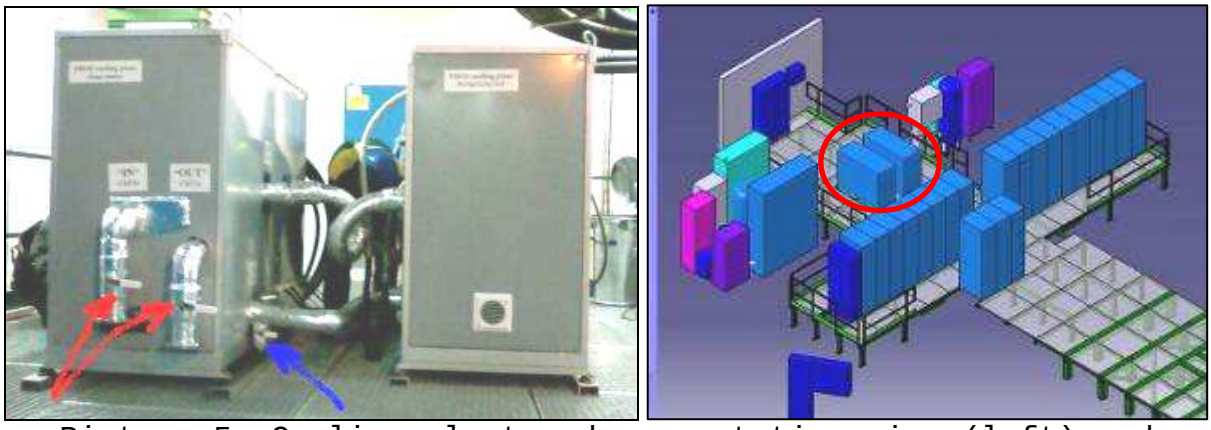
PHOS detector (Picture 3) is photon spectrometer which consists of 5 (at the moment 3) modules. Each module contains matrix of 64*56=3584 crystals of lead tungstate ($PbWO_4$) scintillators (22×22×180 mm) or (in abbreviated form) **PWO** matrix.



Picture 4. View and light yield of PWO crystal.

One of important **PWO** property (Picture 4) is strong temperature dependence of light yield, **~2%** per **1°C**. Amplification of **APD** (avalanche photo diodes) which uses to detect light is also depends on temperature. To achieve **ALICE** requirements (energy resolution **ΔE/E≈1%**, **0..100 GeV** range) the **PHOS PWO** temperature should be **-25°C** with stability **±0.1°C**. The main purpose of **PHOS** crystal cooling system is to meet this condition. Another purpose is to remove **FEE** (front-end electronics) heat from **PWO** matrix and to guarantee safe operation (overheat protection).

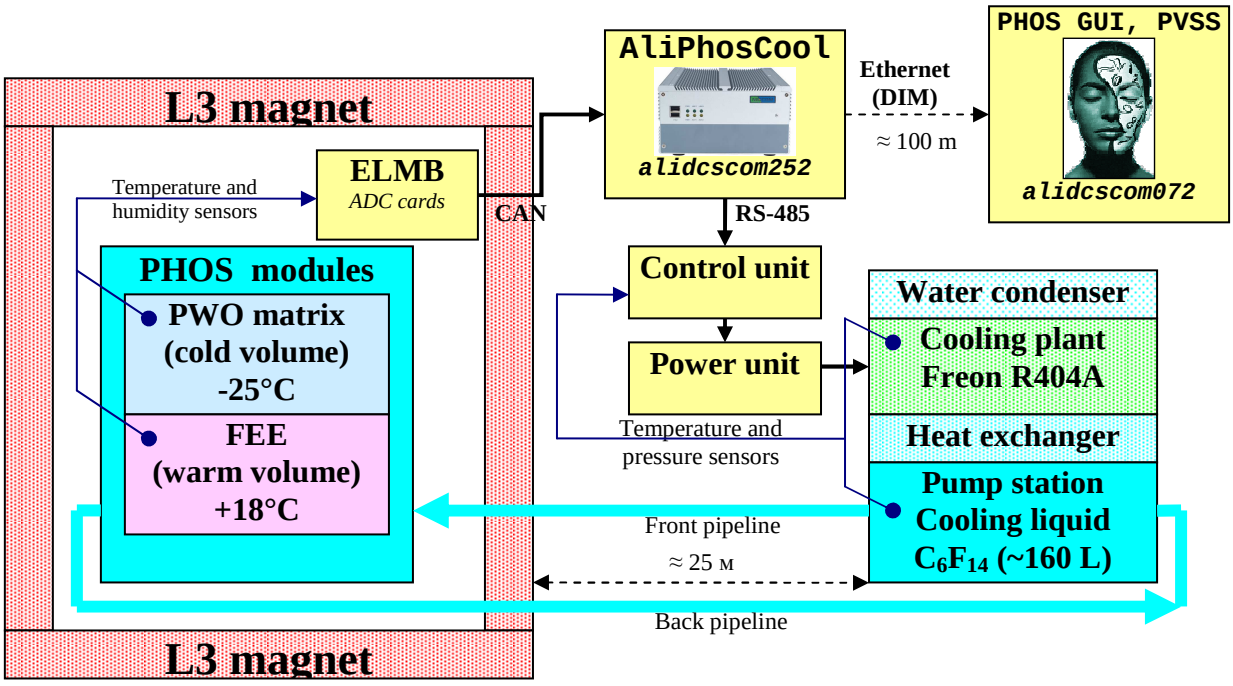
Cooling system (Picture 5) includes cooling plant with **R404A** freon contour, heat exchanger and pump station to flow C_6F_{14} cooling liquid thru pipes to remove heat from **PWO**. Cooling server **alidcscom252** uses to control cooling.



Picture 5. Cooling plant and pump station view (left) and location in UX25 cavern (right).

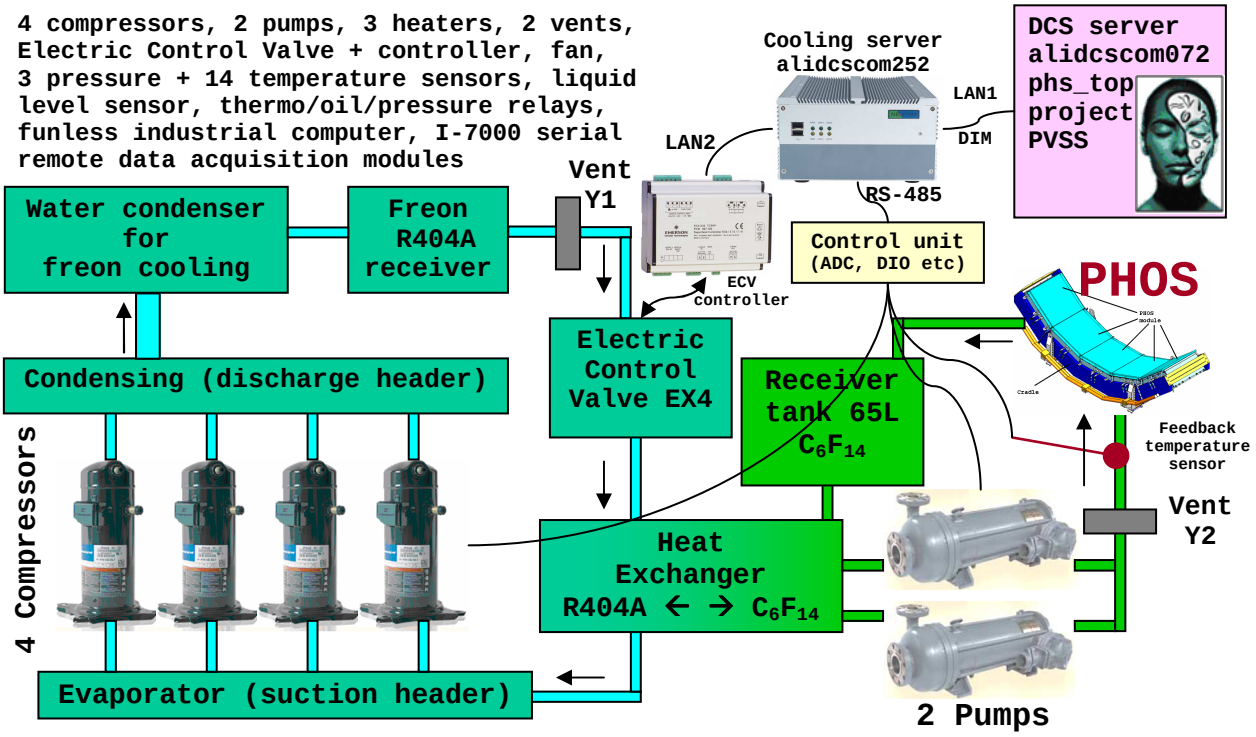


Picture 6. Left to right: Compressor COPELAND ZF 09K4E-TFD, pump "MoldovaGidroMash" ЦГ 6,3/32-2,2-2(5), Electrical Control Valve of type EX4, ECV controller Emerson EC3-X32.



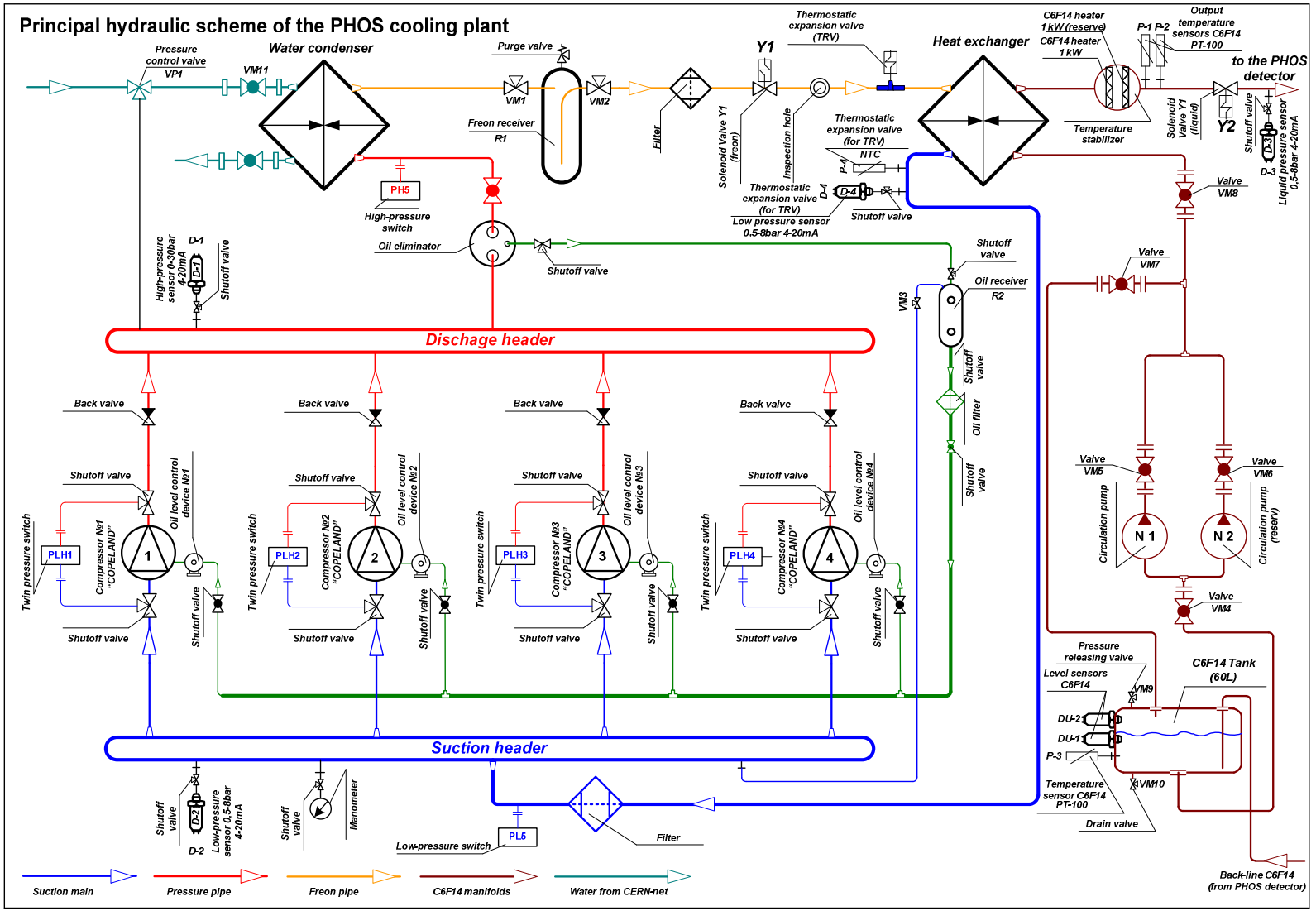
Picture 7. Principal scheme of **PHOS** cooling system.

AliPhosCool is program to control **PHOS** cooling plant, pump station and **PHOS** temperature and humidity measurements (Picture 7). It works on **alidcscom252** server (funless industrial computer inside cooling plant) which connected to **PVSS** via **DIM**.



Picture 8. Principal scheme of cooling plant and pump station.

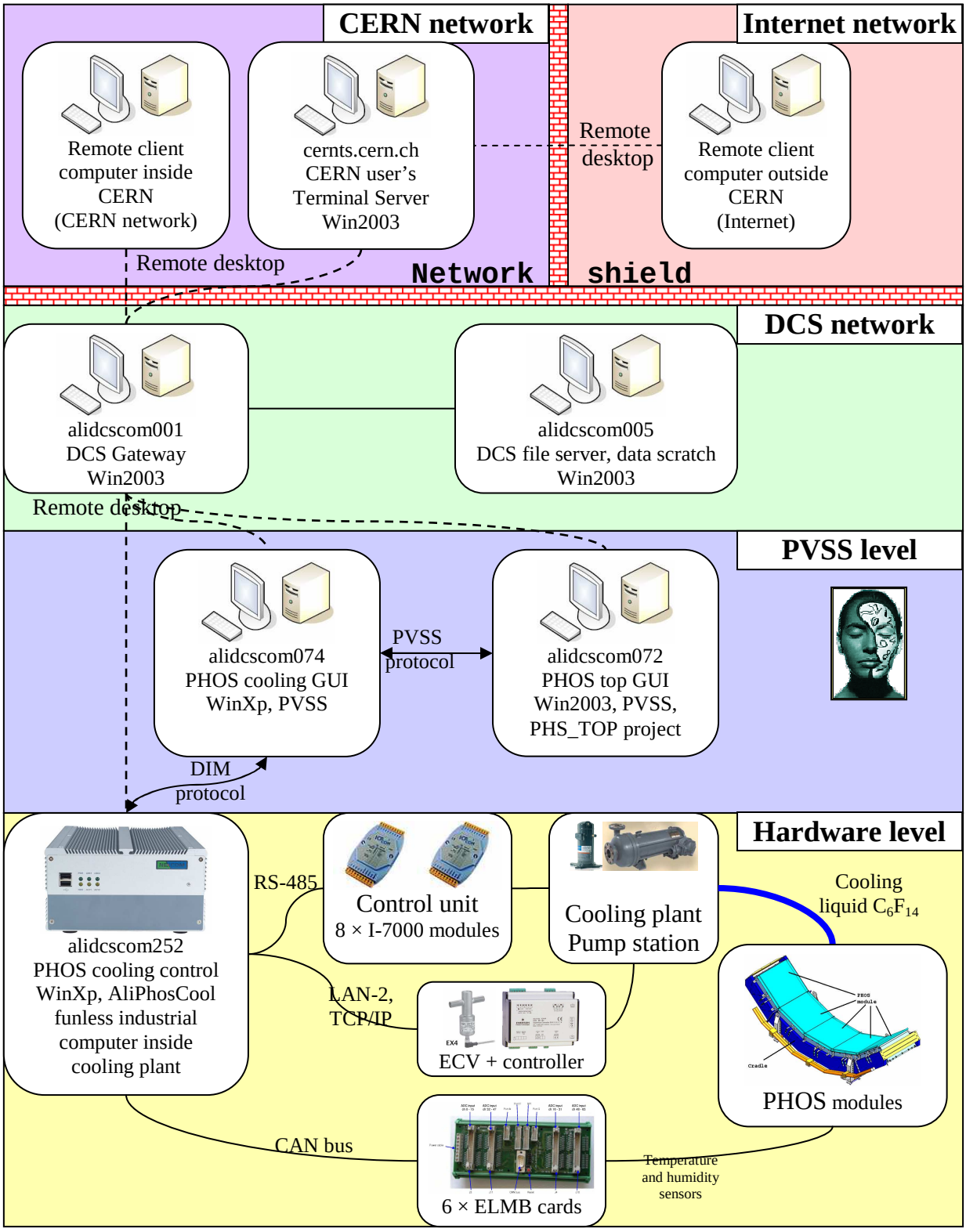
Cooling plant based on next principles. Freon (**R404A**) flows from receiver thru electrical vent **Y1** and electrical control valve (with valve opening controlled by **ECV** controller) and thru heat exchanger to evaporator tube (suction header). Four compressors (Picture 6) pump out this freon to condenser tube (discharge header). Water condenser uses to remove heat from hot freon coming from condenser tube. Second contour with cooling liquid (**C_6F_{14}**) uses to remove heat from **PHOS** and transport this heat to cooling contour thru heat exchanger. Cooling liquid flows from receiver (65 L) thru heat exchanger and electrical vent **Y2** by using of two pumps. Cooling server **alidcscom252** controls all compressors, pumps, vents and valves via special **control unit** and **ECV** controller. Special temperature sensor (Pt-100) in feedback control loop uses to stabilize cooling liquid with high accuracy (about **±0.1°C**). This sensor located in cooling plant output pipe and measure temperature of cooling liquid coming to **PHOS** modules. See page 23 and page 30 to understand temperature stabilization algorithm. See also hydraulic scheme (Picture 9).



Picture 9. Principal hydraulic scheme of the PHOS cooling plant.

Network and login

First, let's have a look at network structure of **PHOS** cooling control system (Picture 10).

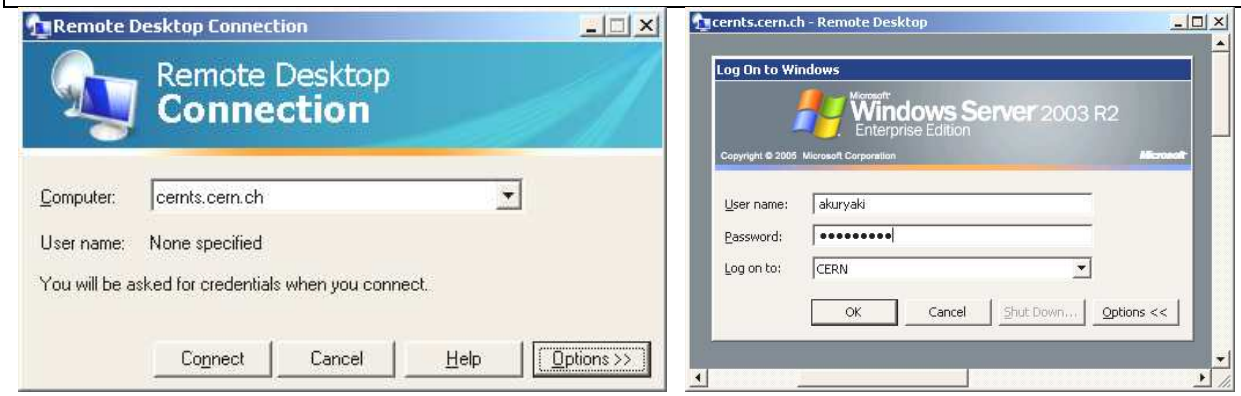


Picture 10. Network scheme of cooling control system.

On top **GUI** level we have end-user client computer. It can be **CERN** inside computer with **NICE** login, or **CERN** outside (**Internet**)

computer which should be connected thru special terminal server **cernts.cern.ch** who works as **CERN** network gateway, to overpass **CERN** network shield safely. So, first step for **CERN** outside clients is remote desktop connection (Picture 11):

mstsc.exe /v:cernts.cern.ch	*with NICE login*



Picture 11. Login to cernts.cern.ch

From **CERN** network client computer, i.e. from **NICE** session or from **cernts.cern.ch** remote desktop session, user should login to **alidcscom001** (**DCS** gateway server), to overpass **ALICE DCS** network shield safely:

mstsc.exe /v:alidcscom001	*with NICE login*

Two common **DCS** computers important for **PHOS**: 1)**alidcscom001** as gateway terminal server to login to **DCS** network, and 2)**alidcscom005** as file server with (temporary) scratch space uses for file transfers (\\alidcscom005\Scratch\phs\ALIDCSCOM252 is recommended scratch folder). Note that for safety reason direct file copy between **Internet** or **CERN** computer and **DCS** computers forbidden. To transfer files, 3-step procedure required. For example, file copy from **alidcscom252** to **Internet** computer looks like that:

```
1. Login and execute on alidcscom252:
   copy \\alidcscom252\Daq32\PHOS_DATA\example.txt
        \\alidcscom005\Scratch\phs\ALIDCSCOM252\PHOS_DATA\example.txt
2. Login and execute on alidcscom001:
   copy \\alidcscom005\Scratch\phs\ALIDCSCOM252\PHOS_DATA\example.txt
        \\cern.ch\dfs\scratch\akuryaki\PHOS_DATA\example.txt
3. Execute on remote client computer:
   copy \\cern.ch\dfs\scratch\akuryaki\PHOS_DATA\example.txt
        \\localhost\postbox\example.txt
```

So file copied from **alidcscom252** to **alidcscom005** scratch, then to **DFS** scratch, then to remote client computer.

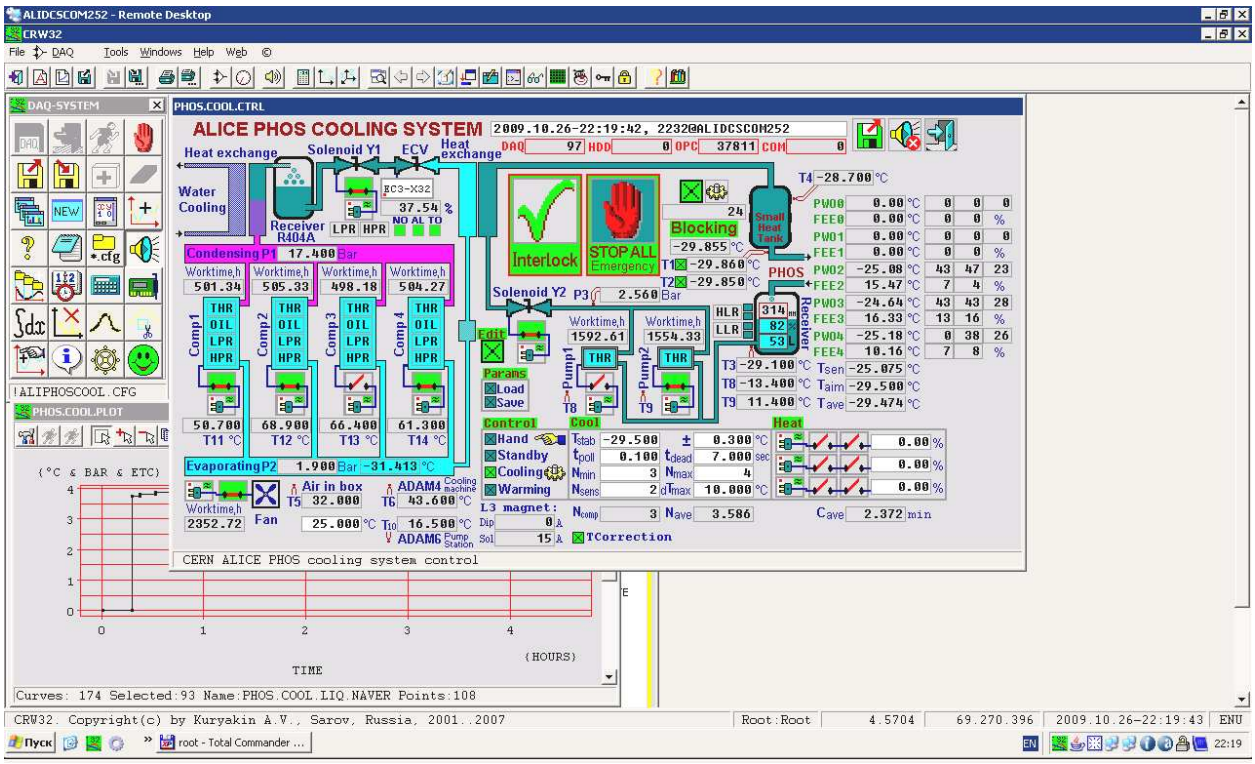
After **DCS** gateway logon, there are two ways: **alidcscom072** for **PHOS** shifters and **alidcscom252** for cooling experts.

PHOS shifter, who works on **PVSS** level, should login to **alidcscom072** to start **PHOS DCS** top **GUI** project (**phs_top**). This way described in **PHOS DCS** shifter's manual.

Cooling experts should login to **alidcscom252** instead:

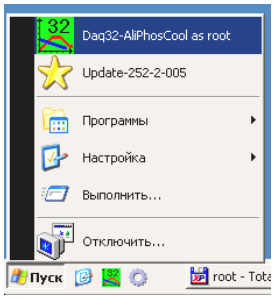
mstsc.exe /v:ALIDCSCOM252 /w:1280 /h:750 *Login as daq 123*

After **alidcscom252** logon, **CRW32** window should be opened on the screen (Picture 12) to control cooling system (note that **AliPhosCool** program works under control of **CRW32** framework):



Picture 12. AliPhosCool program view (screenshot).

If this window hidden, please run **Start** menu command "**Daq32-AliPhosCool as root**" like shown below:



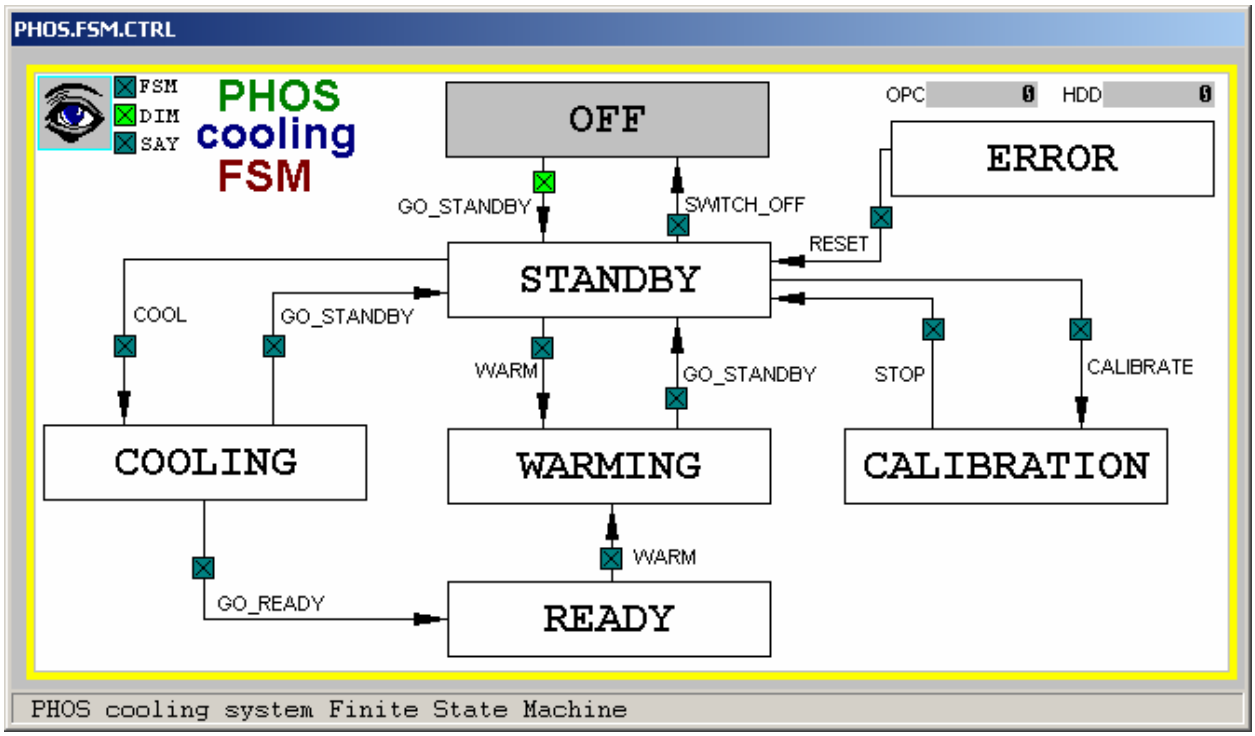
Important note before you start

Please be very careful when you working with AliPhosCool program in alidcscom252 remote session! Expert's errors may cause unwanted interlock, cooling plant failure or lost control over cooling system. Please don't do anything if you're not sure you know what to do! Please don't panic, PWO cooling is slow enough, you have a time to think before do something.

Simple control panel: PHOS.FSM.CTRL window

AliPhosCool program has two control modes: simple (or **FSM**) mode for "shifters" and expert mode for "cooling experts". Simple mode has limited functionality but more safe. Expert mode gives full control over cooling system but caution required.

Simple control realized in **PHOS.FSM.CTRL** window (Picture 13).



Picture 13. Simple FSM control panel.

Remind that **FSM** is Finite State Machine, basic concept of **ALICE DCS** system to describe devices and control units.



- **FSM** control flags.

- **FSM** – enables simple **FSM** control over cooling system. If **FSM** control is **OFF**, then **FSM** state have no influence on cooling system and operator should use control panel **PHOS.COOL.CTRL** instead of **PHOS.FSM.CTRL**.
- **DIM** – enable to change **FSM** state via **DIM** to control cooling from **PVSS** level. If **DIM** control disabled, **PVSS** can only view (but not change) **FSM** state.

OFF - All devices is **OFF**. No cooling, safe state.

STANDBY - "neutral" (preparing) state. Parameters of this state should be specified in control panel **PHOS.COOL.CTRL**.

COOLING - "cooling in progress" state. Parameters of this state should be specified in control panel **PHOS.COOL.CTRL**.

READY - "normal cooling" state. Parameters of this state should be specified in control panel **PHOS.COOL.CTRL**.

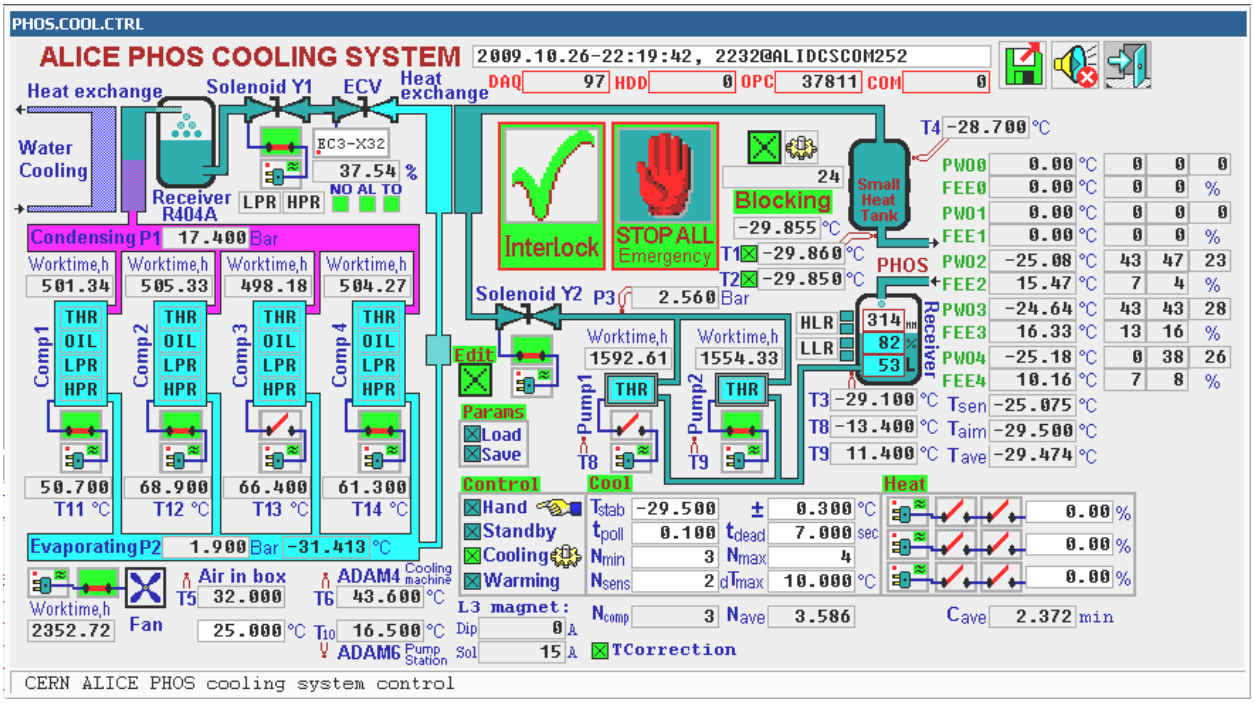
WARMING - "warming in progress" state. Parameters of this state should be specified in control panel **PHOS.COOL.CTRL**.

CALIBRATION - "manual control" state. In this state operator can control cooling system devices manually in panel **PHOS.COOL.CTRL**.

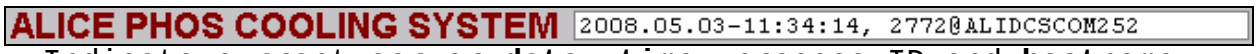
ERROR - error state, cause **Interlock** signal and all devices **OFF**. To switch cooling again, **RESET** command required from operator. System going to **ERROR** state when some alarm (fatal error or failure) happened and cooling could not continue safely.

Expert control panel: PHOS.COOL.CTRL window

Control panel **PHOS.COOL.CTRL** gives full control over cooling system and parameters (Picture 14).



Picture 14. Expert control panel.



- Indicate current server **date**, **time**, process ID and **hostname**.

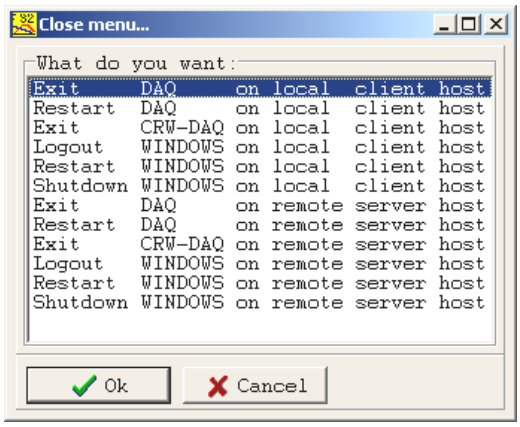


- Indicate **error counters**: **DAQ** – all data acquisition errors, **HDD** – hard drive data save errors, **OPC** – errors coming from **ELMB OPC** server, **COM** – errors coming from **RS-485** communication port (**ADAM** devices). In normal operation state errors are zero or near zero. Some errors (for example, communication errors due to electrical noise) may happen sometimes. But if error counters increase for a long time, it means some failure happened and may cause **Interlock**.

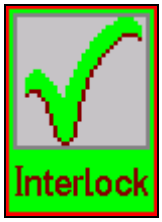


- Command to **Exit** program or system (Picture 15). Allow to stop, restart data acquisition session (**DAQ**), control program (**CRW-DAQ**), or **Windows** system on local client host, or on remote server **alidcscom252**. Be careful, this command may also shutdown

remote server. After shutdown server can be switched on only manually. **Please don’t shutdown remote server if cavern access is closed**.



Picture 15. Exit command menu.





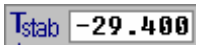
- Indicate and switch on/off **Interlock**. **Interlock** can be switched on via button or by alarm system. When interlock is **ON**, all devices blocked, i.e. system switched **OFF**. Moreover, cooling could not be started while **Interlock** is **ON**. To start cooling again, operator should switch off **Interlock**. Of course, if **Interlock** was switched on by alarm system, the reason of this alarm should be fixed first. In **FSM** mode **Interlock** also cause **ERROR** state.



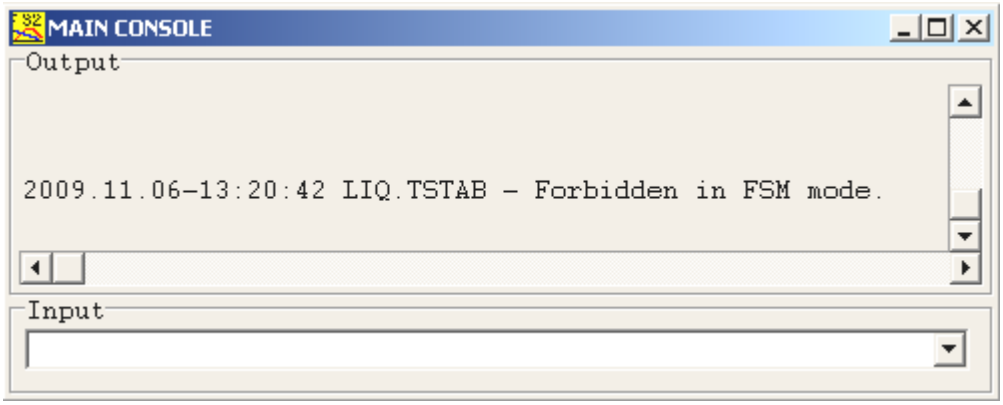


- **Halt** button (Stop All), to switch **OFF** all devices. If **Interlock** is on, then cooling system halted immediately. System also can be halted by this button.



- This button uses to edit cooling control parameters in **FSM** mode (see page 12). In “simple control” mode (when **FSM** flag is **ON**) parameters editing and most part of commands is forbidden. When operator click some button or edit some field (for example, 

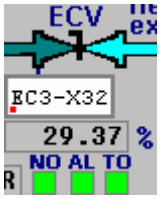
), warning arrears (Picture 16).



Picture 16. Warning on parameters editing in “simple” FSM mode.

This warning means that parameters editing and command execution is forbidden in “simple” **FSM** mode (for safety reason). To edit parameters or to run command operator should click **Edit** button and then immediately (during 3 seconds) click command to run or field to edit. This method gives to operator possibility to edit parameters and to run commands, but protects operator from mistakes (like fortuitous mouse clicks).

Note that **Edit** command not uses if “expert” mode (when **FSM** flag is **OFF**). In this case editing is enabled without **Edit** command.

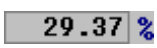


- Display **ECV** (electric control valve) status. This valve uses to control freon (**R404A**) flow.

NO is “Not Ok” flag (■=Ok, ■=Error: ECV is not connected).

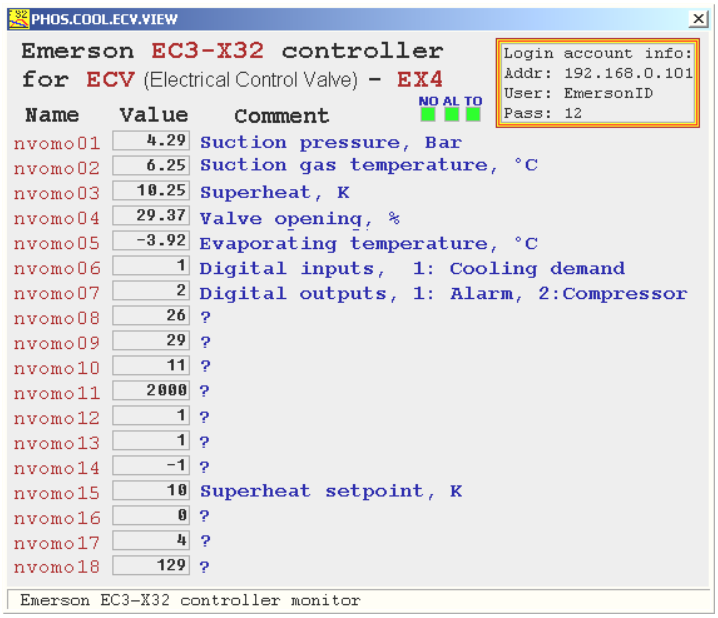
AL is “ECV Alarm” flag (■=Ok, ■=Error: ECV alarm detected).

TO is “Time-Out” flag (■=Ok, ■=Error: ECV network time-out).

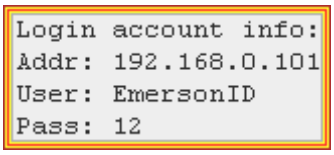


- Shows valve opening in percents.

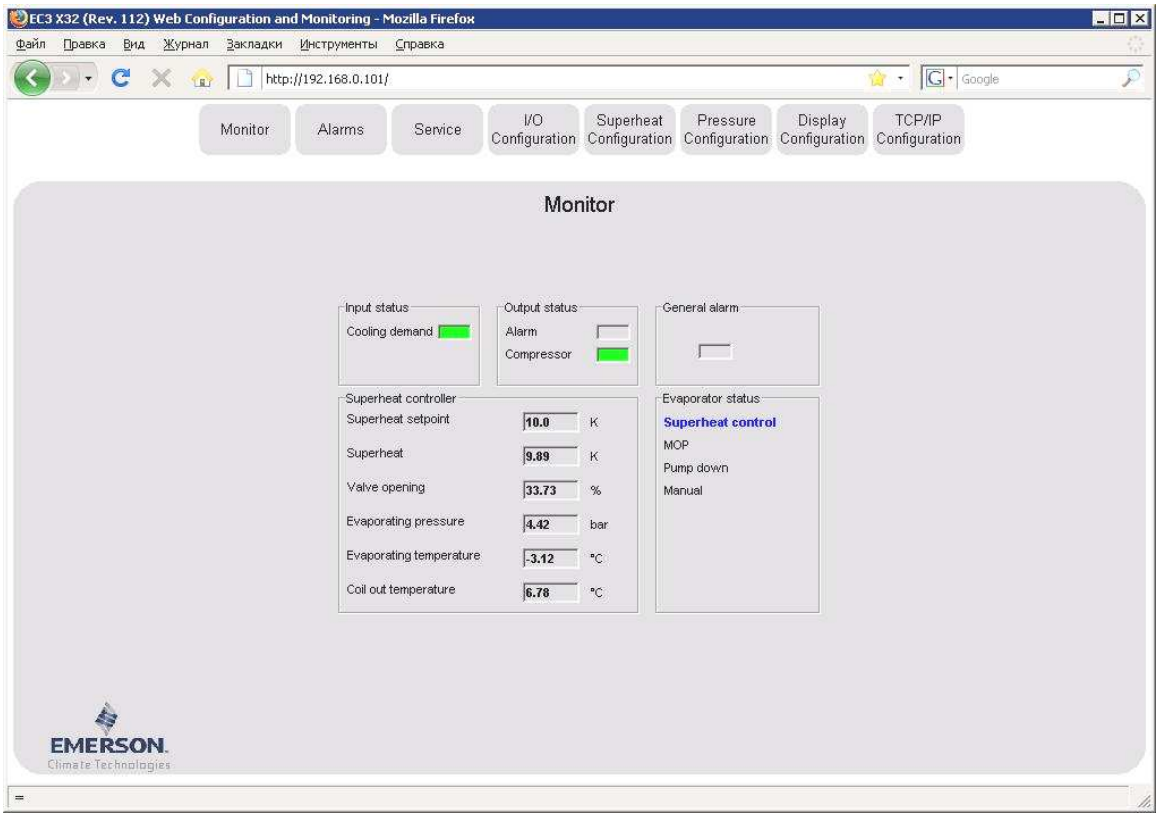
EC3-X32 - Opens **PHOS.COOL.ECV.VIEW** window (Picture 17).



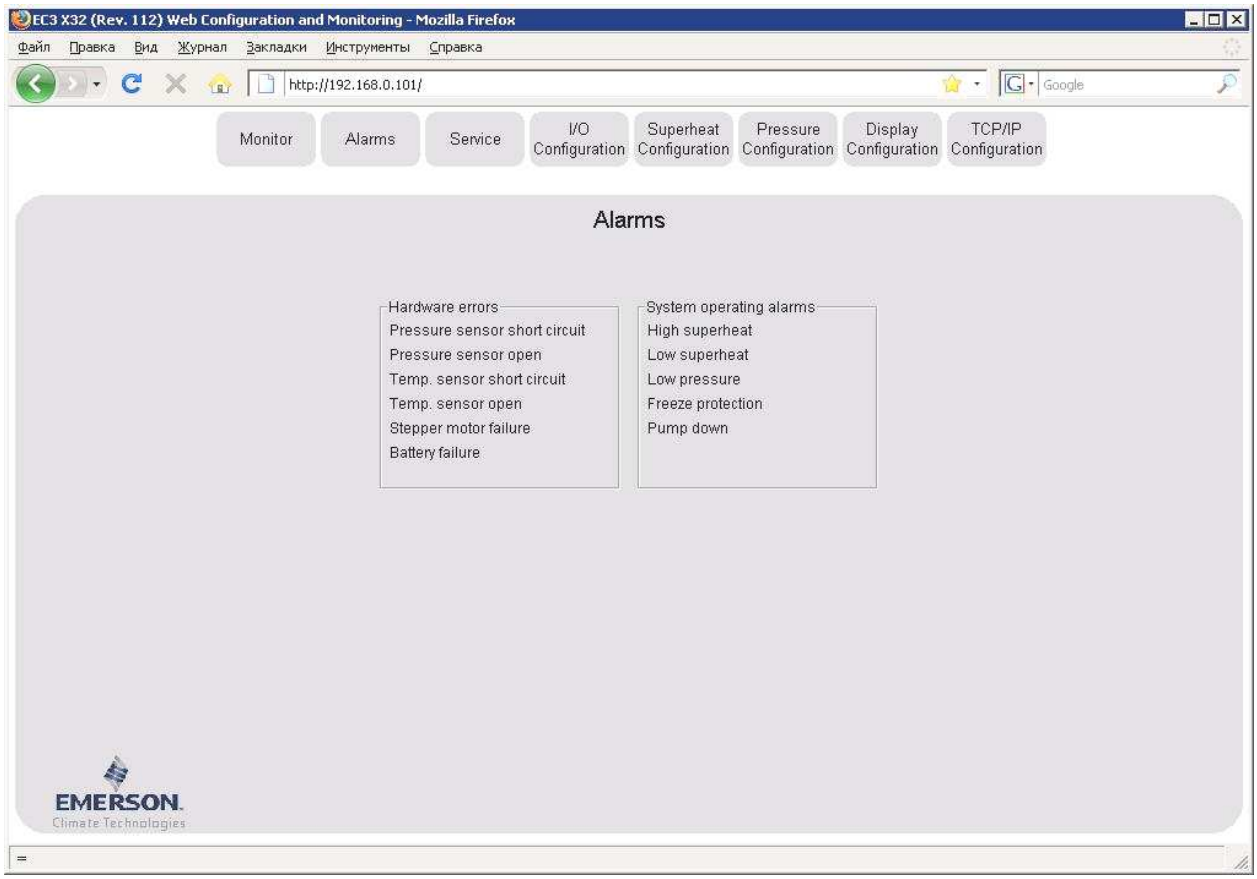
Picture 17. ECV controller state view window.



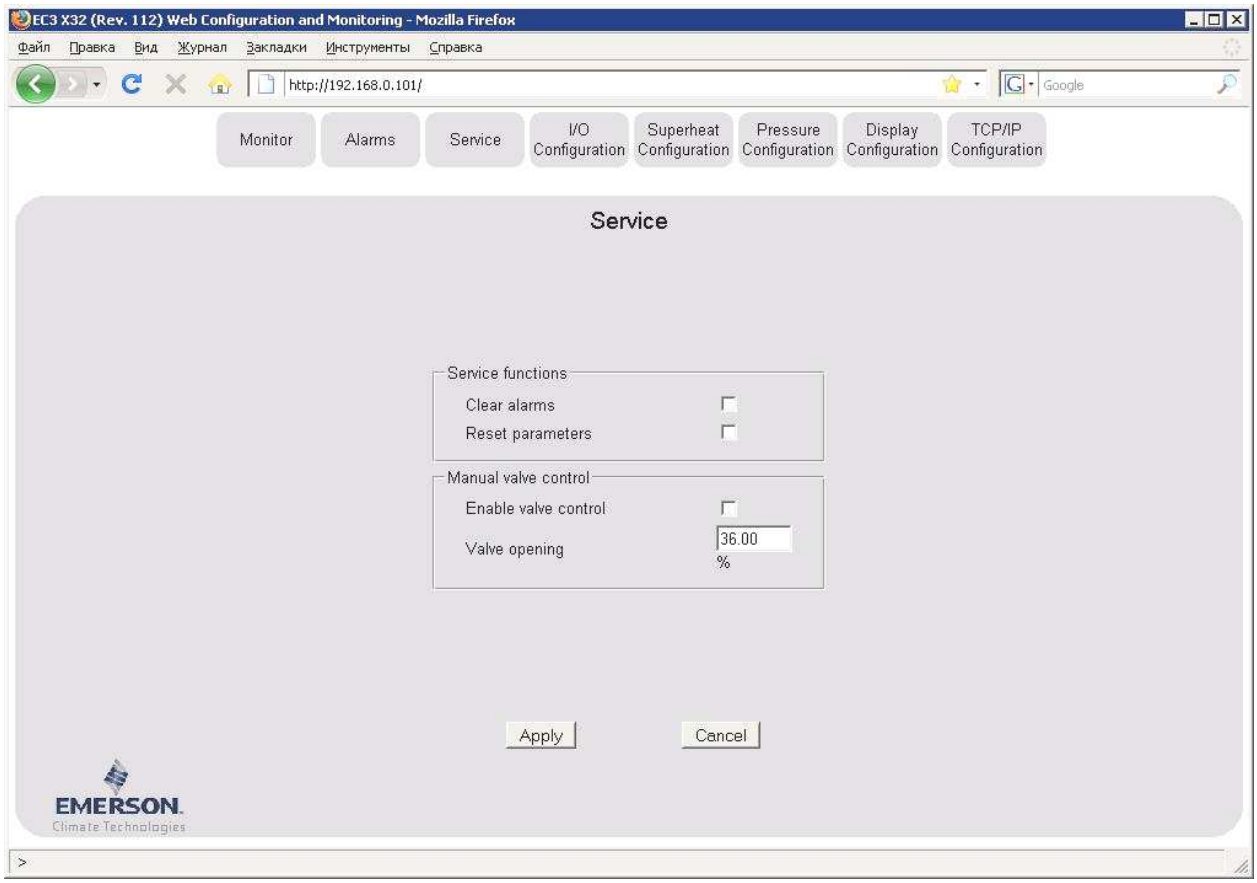
- Opens **Web** browser to monitor and edit **ECV** controller parameters. See **Emerson EC3-X32** controller manual for details. Main **ECV** settings shown on next screenshots:



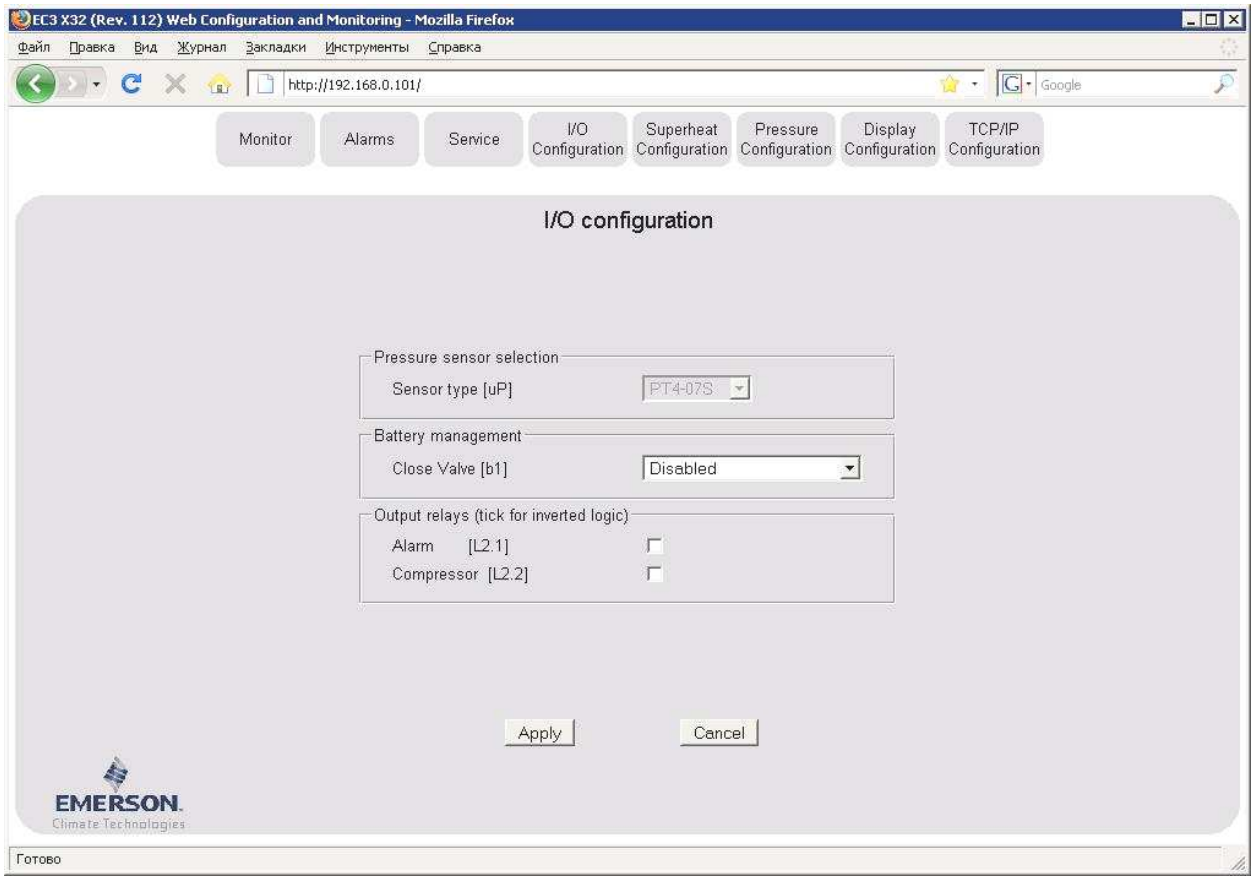
Picture 18. ECV controller browser (Monitor page).



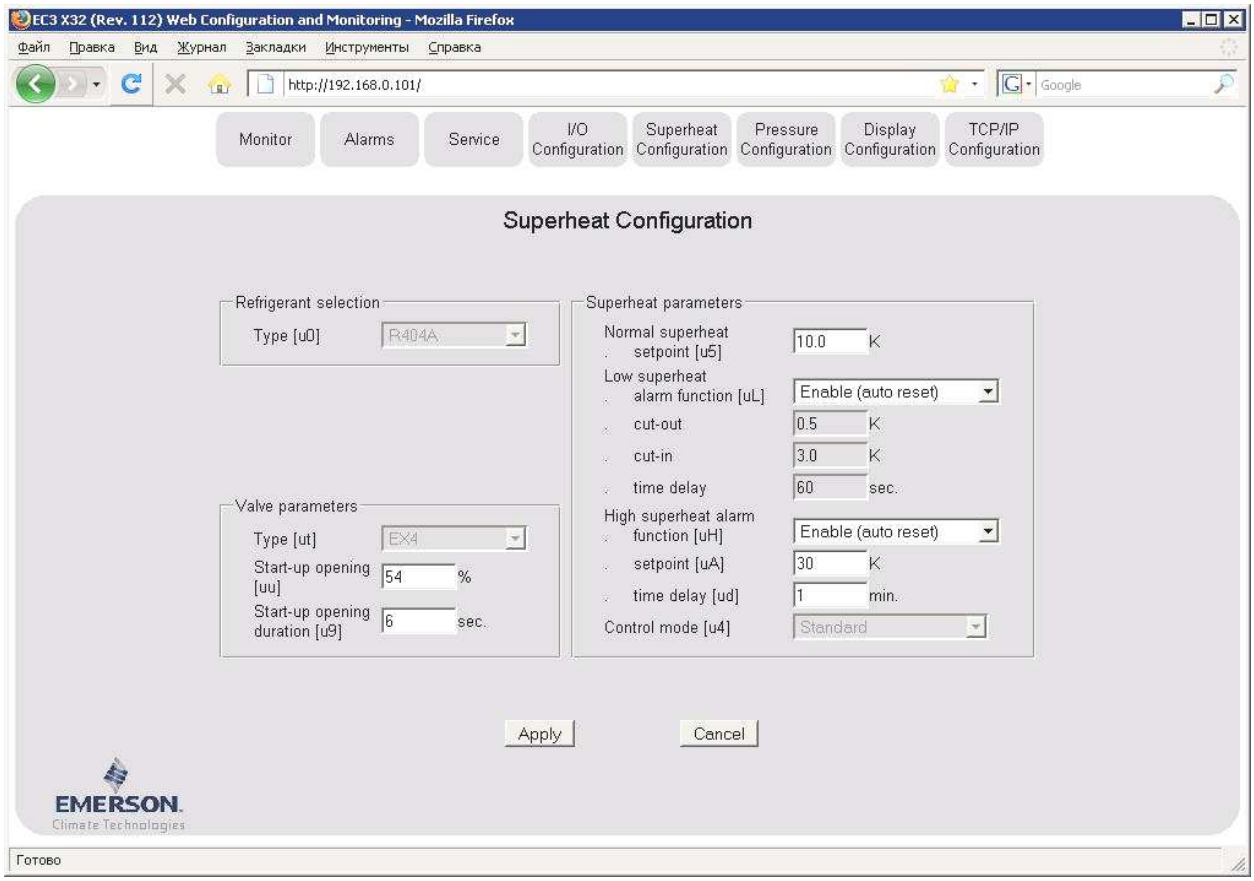
Picture 19. ECV controller browser (Alarm page).



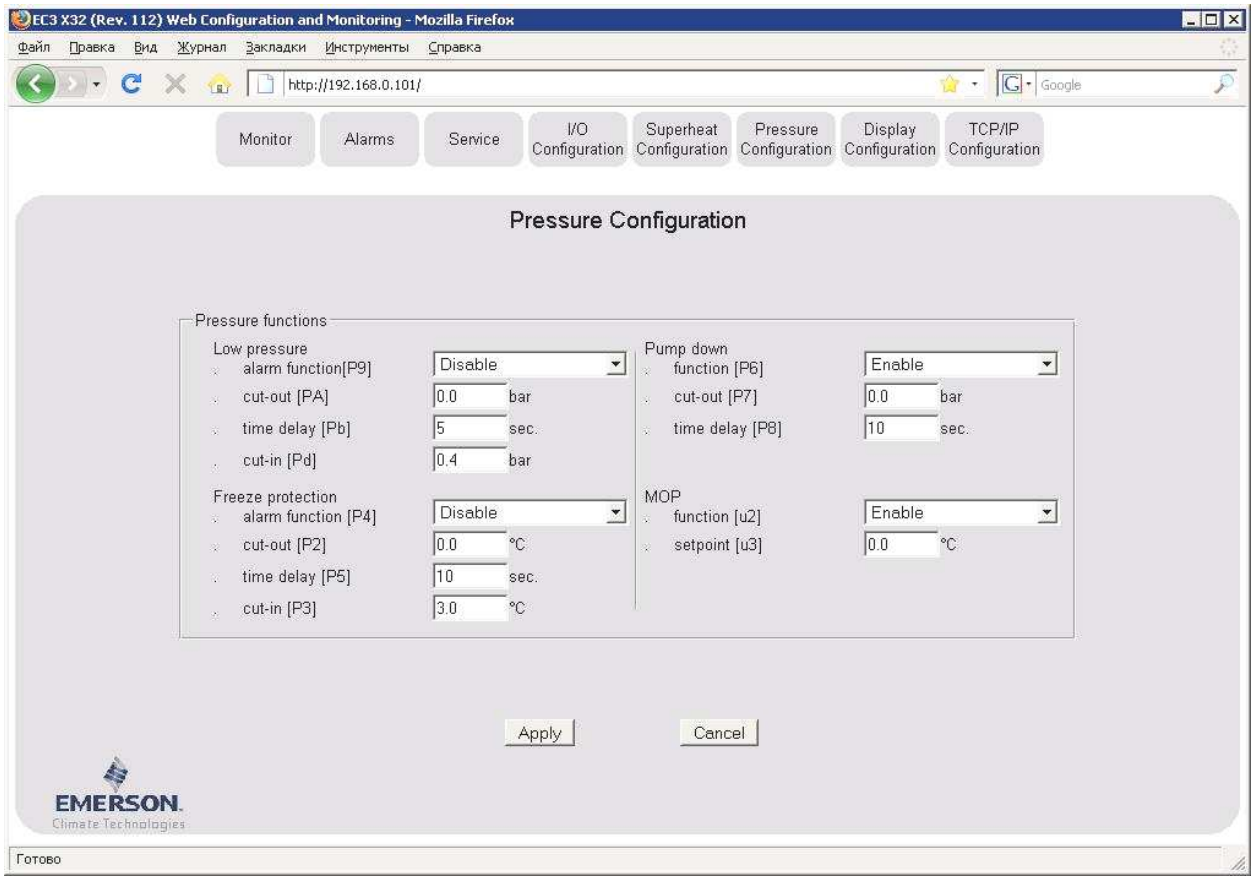
Picture 20. ECV controller browser (Service page).



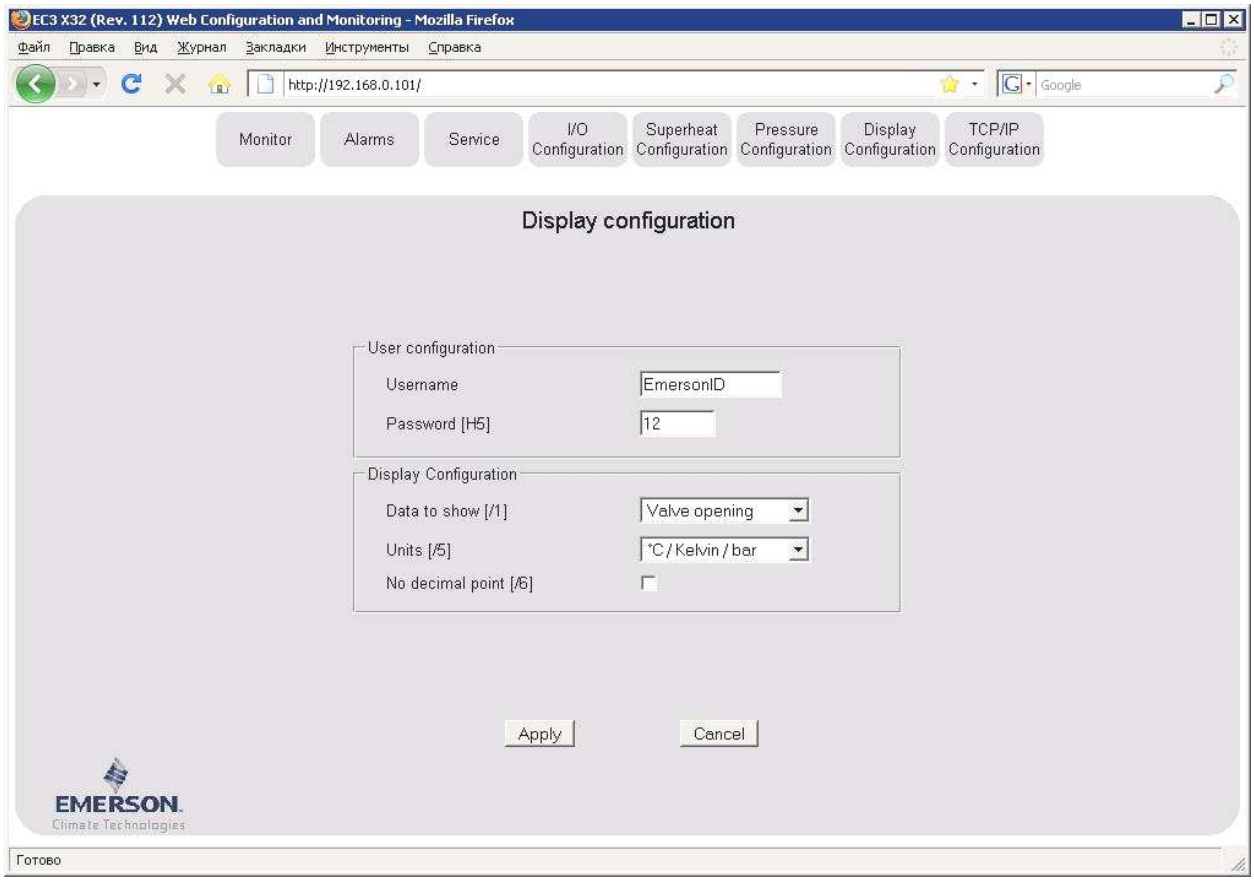
Picture 21. ECV controller browser (I/O configuration page).



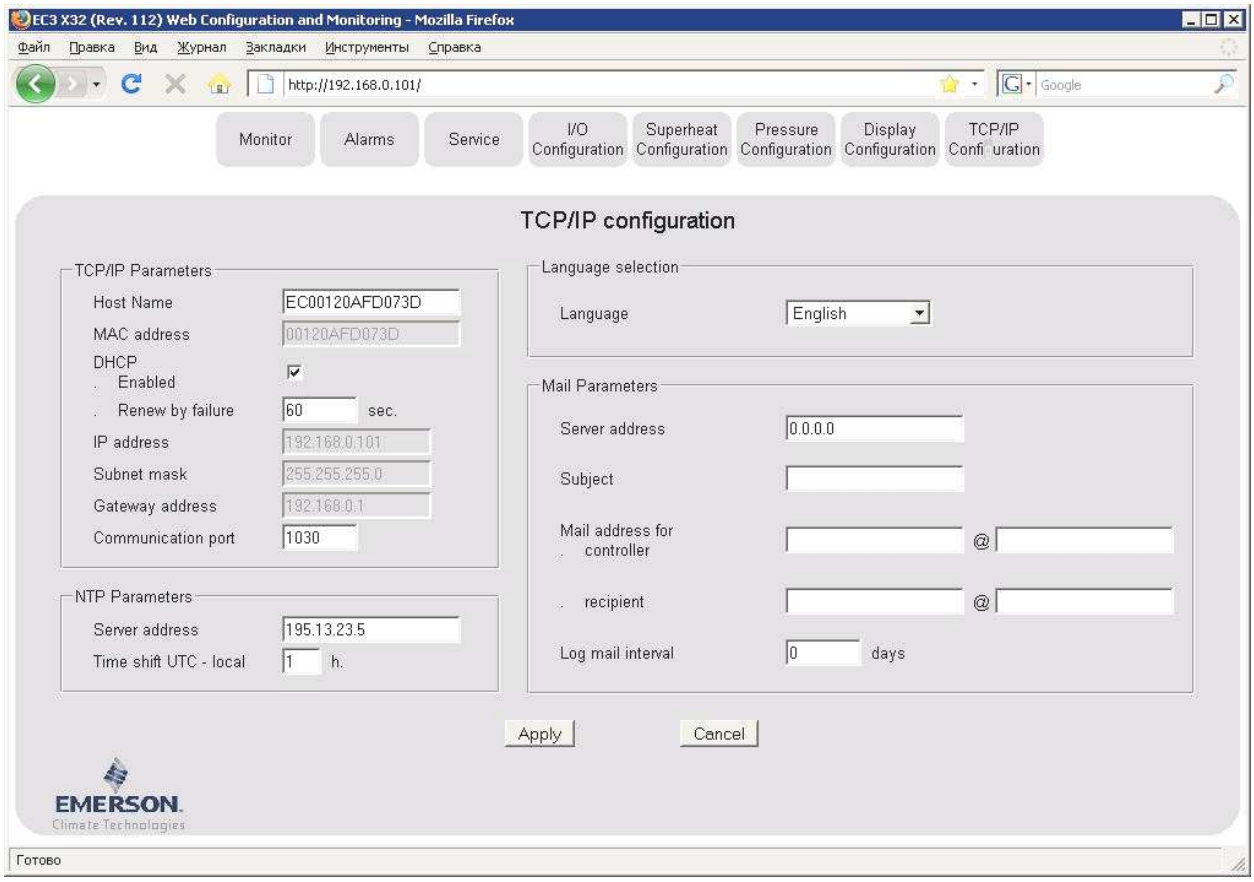
Picture 22. ECV controller browser (Superheat configuration).



Picture 23. ECV controller browser (Pressure configuration).



Picture 24. ECV controller browser (Display configuration).

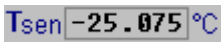


Picture 25. ECV controller browser (TCP/IP configuration).

Note that all **ECV** browser pages (except Monitor page) require login and password (User: Emerson, Password: 12).

Also note that **Battery Management** disabled (Picture 21) because of problems with battery installed inside controller. If battery management enabled then “Battery failure” alarm (Picture 19) may happens sometimes and this alarm cause unwanted **Interlock**. To avoid this **Interlock** battery management disabled.



, 

etc - Display actual measured (monitored) parameters, see Table 1.

Table 1. Main cooling monitored parameters.

Name	Comment
P1	Pressure sensor in Condensing tube, Bar (absolute).
P2	Pressure sensor in Evaporating tube, Bar (absolute).
P3	Pressure sensor in cooling liquid pipe, Bar (absolute).
T1	Temperature of cooling liquid output, °C. Main feedback parameter to control liquid temperature.
T2	Temperature of cooling liquid output, °C. Reserved feedback parameter to control liquid temperature.
T3	Temperature of cooling liquid in Receiver (big tank), °C.
T4	Temperature of Heater 1, °C.
T5	Temperature of Air inside cooling machine cover, °C.
T6	Temperature of Control unit inside cooling machine, °C.
T7	Temperature of freon evaporating, °C. Calculated by P2 via R404A table.
T8	Temperature of Pump1 cover, °C.
T9	Temperature of Pump2 cover, °C.
T10	Temperature of Air inside pump station cover, °C.
T11	Temperature of compressor 1 cover, °C.
T12	Temperature of compressor 2 cover, °C.
T13	Temperature of compressor 3 cover, °C.
T14	Temperature of compressor 4 cover, °C.
Tsen	Temperature of sensor **Nsens** (to calculate **Taim**), °C.
Taim	Actual stabilization temperature, °C. This temperature depends on nominal stabilization temperature **Tstab**, on parameter **dTmax** and on **Tsen**.
Tave	Average temperature of cooling liquid (by T1) over cooling control cycle, °C.
Ncomp	Current number of switched compressors, 0..4.
Nave	Average number of switched compressors over cooling control cycle, in [0..4] range. This value proportional to average (over cycle) cooling power, value Nave=4 corresponding to 100% of cooling power.
Cave	Duration of cooling control cycle, minutes.
Dip	Dipole L3 magnet current, A.
Sol	Solenoid L3 magnet current, A.
EC3-X32	Electrical control valve opening, percent. This valve uses to control freon R404A flow.

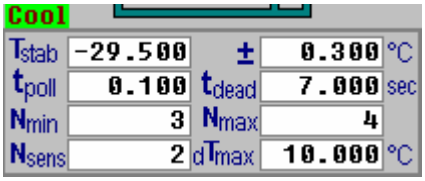
See also Table 2 to see main control parameters (to be set by operator).



- Select control mode.

Hand is manual control mode, when operator can switch devices as independent items. It's corresponding to **FSM** state **CALIBRATION**. This mode uses for tests and special technical operations, like cooling liquid filling etc.

Standby, **Cooling** and **Warming** is three different modes of automatic cooling (or warming) which has the same stabilization algorithm (see page 30) but different control parameters.

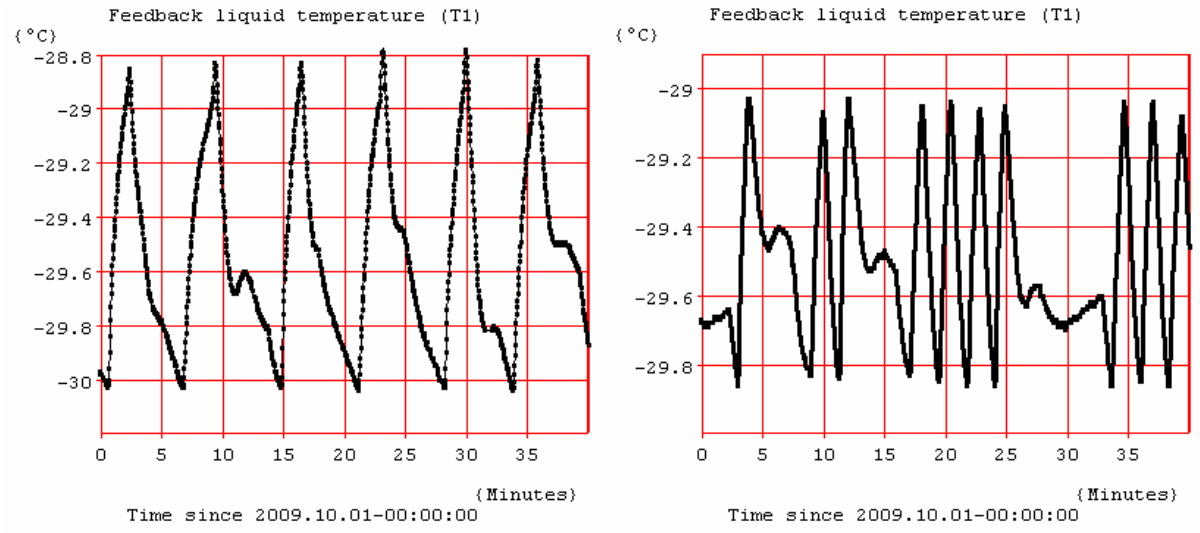


- Set stabilization control parameters for selected cooling mode (Table 2).

Table 2. Main cooling control parameters.

Name	Comment
Tstab	Nominal (wanted) stabilization temperature of cooling liquid (by feedback sensors **T1**, **T2**). Note that actual stabilization temperature **Taim** depends on **Nsens** and **dTmax** to limit cooling speed (for safety reason): **Taim=Max(Tpwo-dTmax,Min(Tpwo+dTmax,Tstab))** where **Tpwo** is temperature of **PWO** by sensor number **Nsens**. After some time of cooling (when **Tpwo** became closer to **Tstab**) expected to be **Taim=Tstab**.
Delta (±)	Temperature corridor for feedback temperature to switch compressors **ON/OFF**. When feedback liquid temperature **T<Taim-Delta**, then **Nbmin** compressors switched. When feedback liquid temperature **T>Taim+Delta**, then **Nbmax** compressors switched.
Nbmin	Minimal number of compressors. That is number of switched compressors when **T<Taim-Delta**.
Nbmax	Maximal number of compressors. That is number of switched compressors when **T>Taim+Delta**.
Nsens	Sensor (module) number (0..4) by which **PWO** temperature **Tpwo** calculated for cooling speed control.
dTmax	Maximal difference between **PWO** temperature and current stabilization temperature **Taim**. If **dTmax** is zero, cooling speed protection is off and **Taim=Tstab**.

Note that **Tstab** is independent parameter, but **Delta**, **Nbmin**, **Nbmax** depend on **Tstab**. They choose to have stable (periodic) control cycle (Picture 26).

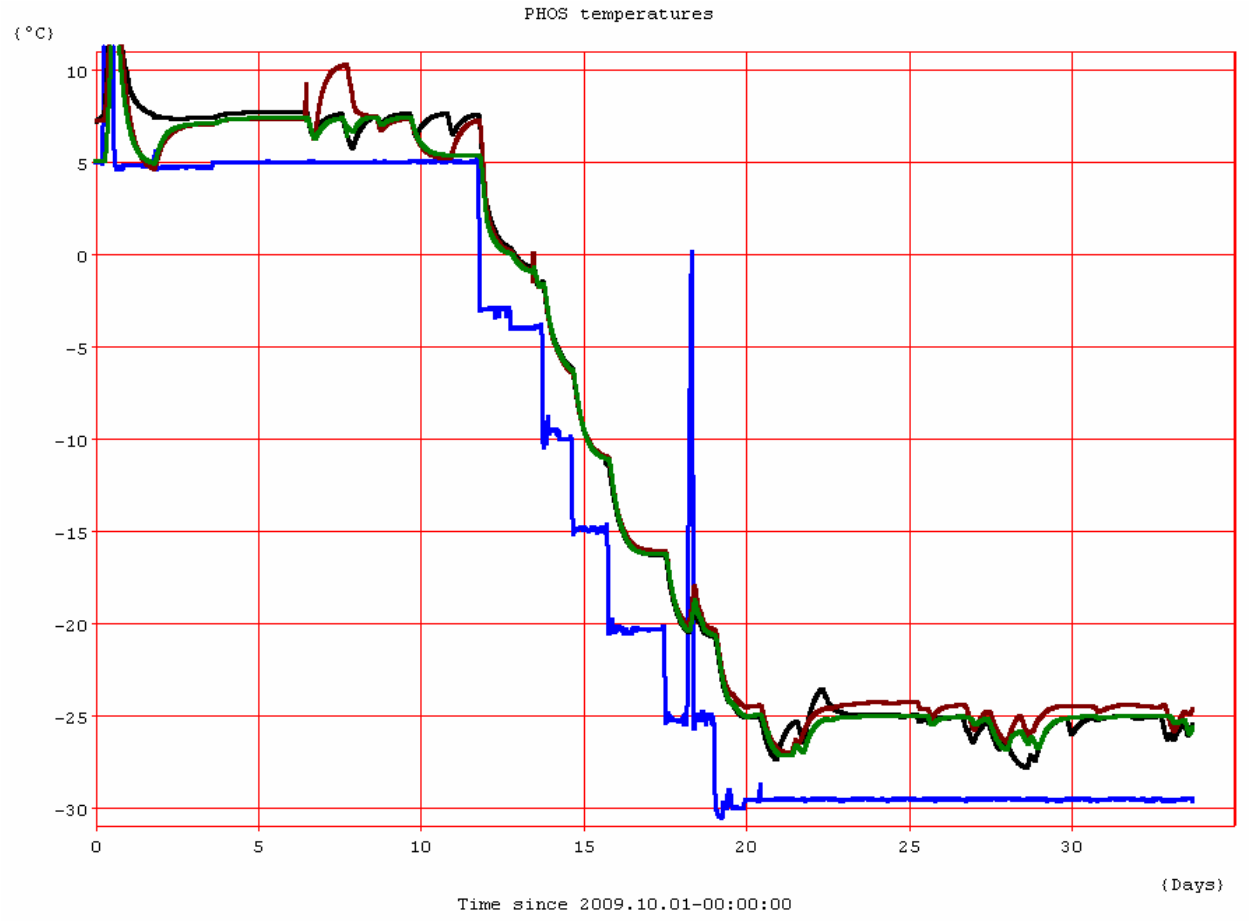


Picture 26. Example of stable (left) and unstable (right) control cycle of temperature stabilization.

To cool down **PHOS** from room temperature down to nominal operation temperature **-25°C** and back it is recommended to make cooling step by step, from one stabilization point to another. For example, stabilization points during cooling Oct/Nov 2009 shown in Table 3. Each stabilization point takes about 1 day, so all cooling process takes ~10-12 days (Picture 27). Note that there was 3 **PHOS** modules, and temperature difference between cooling liquid and **PWO** matrix was **≈4.5°C**, so **Tstab=-29.5°C** uses to achieve temperature **-25°C** in **PWO** matrix.

Table 3. Control parameters during cooling Oct/Nov 2009.

Tstab °C	**Delta °C**	**NbMin**	**NbMax**	**Taver °C**	**Caver minutes**	**Naver**
+17	1	0	1	17.18 ± 0.13	3.09 ± 1.19	0.31 ± 0.08
+5	1	0	1	5.01 ± 0.01	6.11 ± 0.05	0.45 ± 0.02
+3	1	0	1	2.99 ± 0.01	6.25 ± 0.04	0.51 ± 0.02
-3	1.5	0	2	-2.94 ± 0.17	6.71 ± 1.50	0.79 ± 0.06
-4	1.5	0	2	-3.97 ± 0.03	7.10 ± 0.19	0.82 ± 0.04
-10	1	0	2	-9.99 ± 0.03	2.24 ± 0.11	1.16 ± 0.04
-15	1	1	3	-14.94 ± 0.19	7.44 ± 5.65	1.69 ± 0.24
-20	1	1	3	-20.31 ± 0.02	5.32 ± 0.30	2.55 ± 0.02
-25	1	2	4	-25.21 ± 0.09	4.81 ± 0.82	3.43 ± 0.12
-30	0.2	3	4	-29.97 ± 0.05	6.43 ± 3.53	3.85 ± 0.09
-29.5	0.3	3	4	-29.50 ± 0.06	4.64 ± 2.74	3.74 ± 0.13
-29.4	0.6	3	4	-29.53 ± 0.04	10.58 ± 1.13	3.82 ± 0.04



Picture 27. Typical cooling process (Oct/Nov 2009).

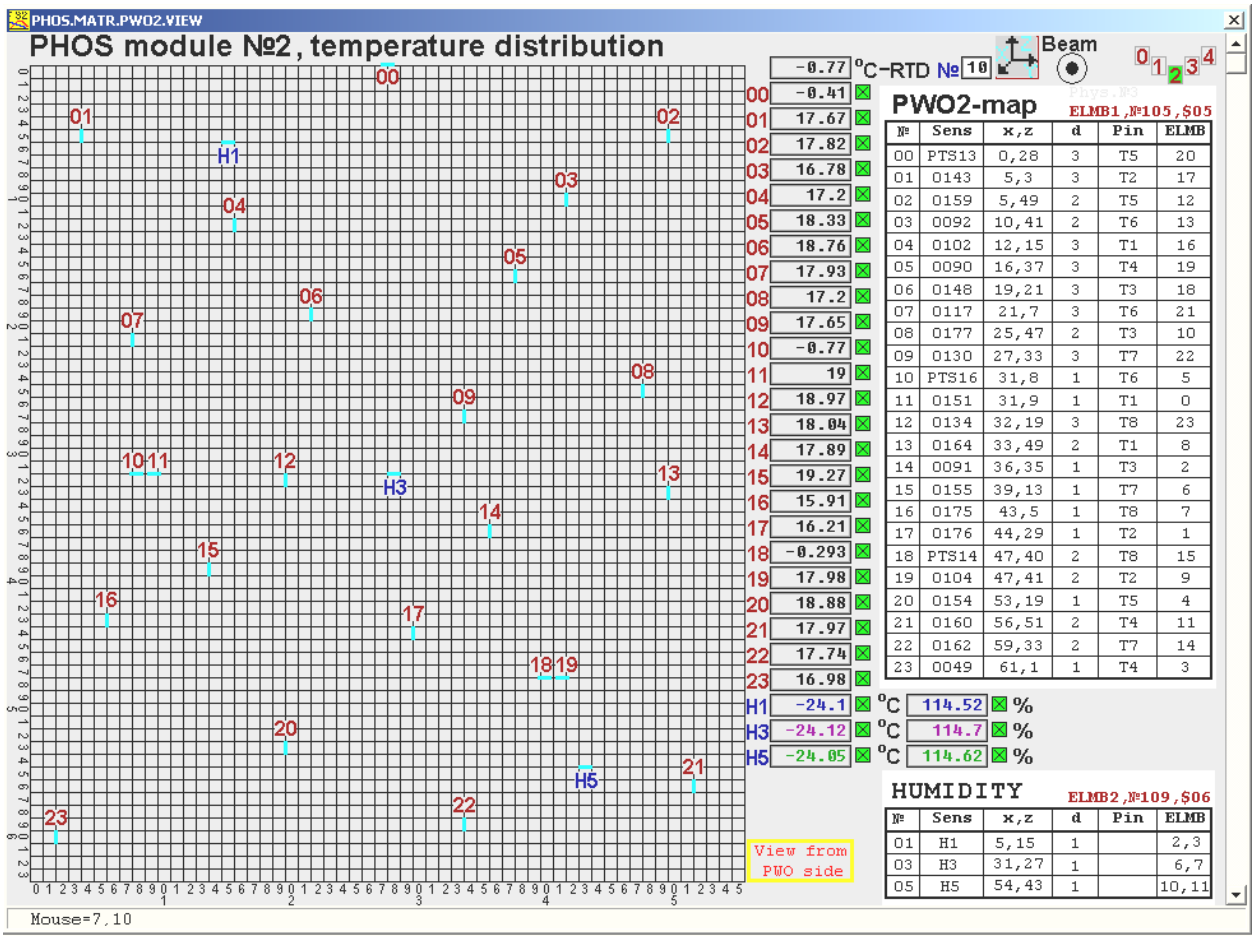


- Alarm system settings.

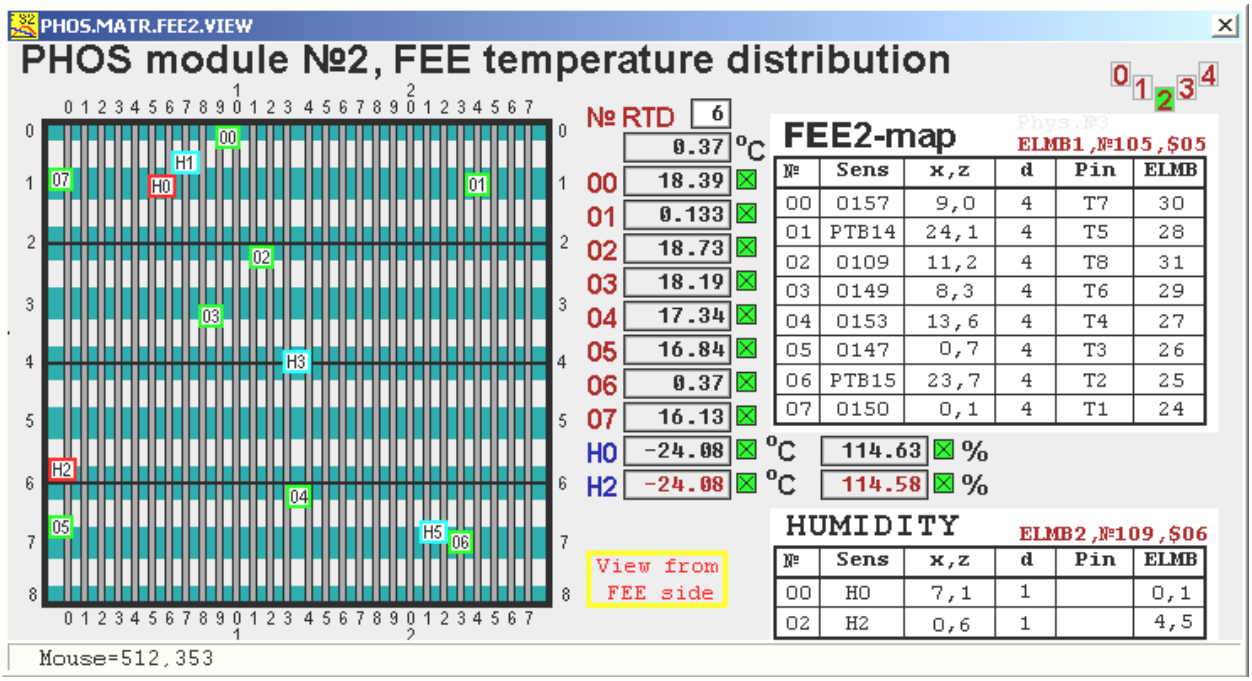
Checkbox uses to switch alarm system on/off (available only in **Hand** operation mode). Display 24 shows counter of detected alarms. Button uses to call dialog to set alarm system parameters, see page 32.

PWO2	-25.08	°C	43	47	23
FEE2	15.47	°C	7	4	%
PWO3	-24.64	°C	43	43	28
FEE3	16.33	°C	13	16	%
PWO4	-25.18	°C	0	38	26
FEE4	10.16	°C	7	8	%

- Display **PWO** and **FEE** temperatures and humidity of **PHOS** modules. Each module has 5 humidity sensors, 3 in **PWO** and 2 in **FEE** volume. Mouse clicked on display field cause opening of **PWO** (Picture 28) or **FEE** (Picture 29) view window.



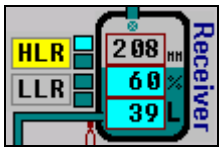
Picture 28. PWO temperature view window for PHOS module 2.



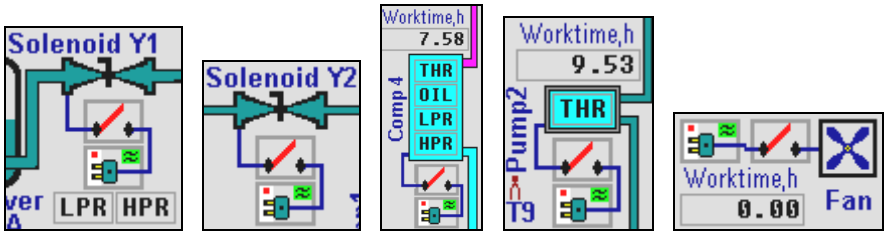
Picture 29. FEE temperature view window for PHOS module 2.



- Buttons to save or load set of control parameters from initialization file. After operator switch on cooling and set all parameters, current state of all control parameters can be saved to **INI** file. After system restart (for example, after power cut) this control parameters will be load from **INI** file and cooling system will return to the same conditions. Be careful, don't save **INI** file if current cooling control state is not stable enough.



- Display **LLS** (liquid level sensor) status - cooling liquid level in C_6F_{14} receiver tank. Liquid level shown in millimeters, in percents (relative to tank volume 65 L), and in liters.



- Display items to view state and to control solenoids **Y1**, **Y2**, compressors **Comp1-Comp4**, pumps **Pump1-Pump2** and **Fan**. In **Standby**, **Cooling** and **Warming** mode devices controlled automatically and items uses only to display state of devices. In **Hand** mode operator can switch devices on/off by mouse clicks. The items have next fields:

- THR, OIL, LPR, HPR, HLR, LLR - thermo relay, oil level relay, low pressure relay, high pressure relay, high liquid level relay, low liquid level relay. When relay is closed, it became yellow, for example THR. This relays uses for alarms (see page 32).
-  - device enable button. Enabled device looks like . Disabled - like .
-  - device power switch. Device can be powered only if it is enabled and not blocked by alarm system. Powered device looks like , not powered – like .

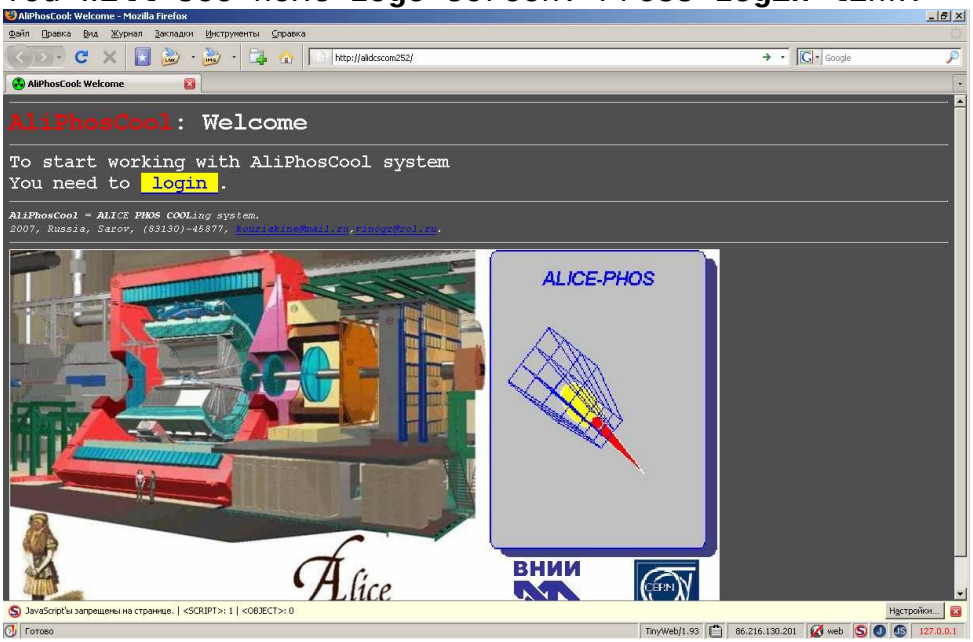
Safe data view: Web assess

It is potentially dangerous to login directly to cooling server **alidcscom252** because wrong editing or button click may harm system. For safety reason it is recommended to use **Web** access instead, if you want to view data only but not to edit. Web access has no possibility to edit parameters, so **Web** user can't harm system. **Web** access is available only inside **DCS** network (in control room).

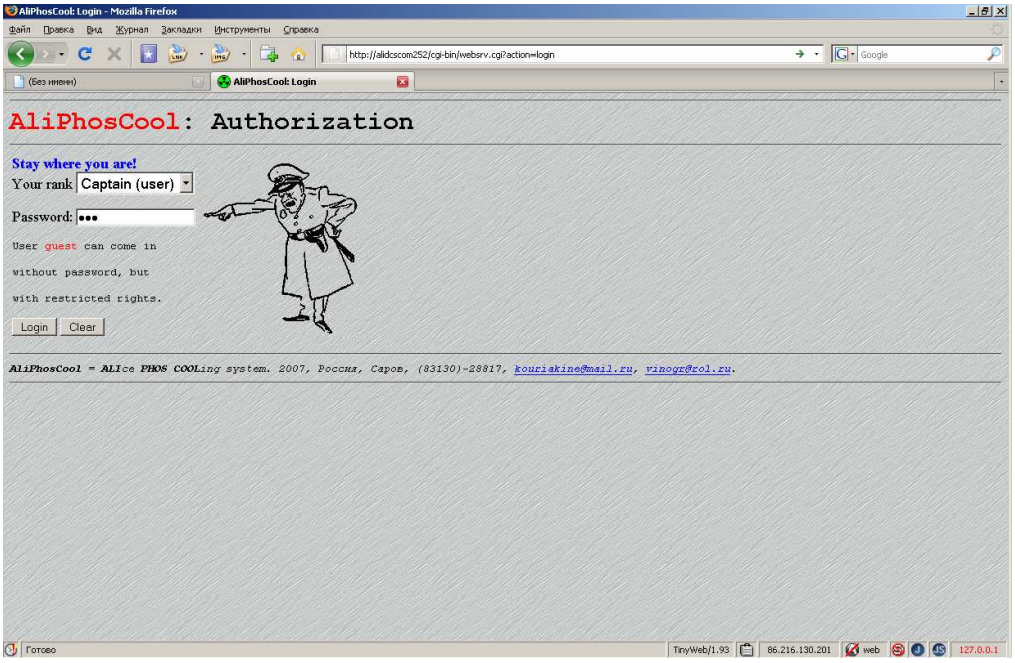
Open Web browser, for example, Mozilla Firefox, type next:

http://alidcscom252/

You will see next **Logo** screen. Press **Login** link.



You will see authorization screen.



Three accounts available:

1. Soldier (Guest) - no password
2. Captain (User) - password 123
3. General (Root) - password ***

Each account has different rights. Guest can view table of parameters. User can also view **PHOS.COOL.CTRL** window. Root also can view data plots.

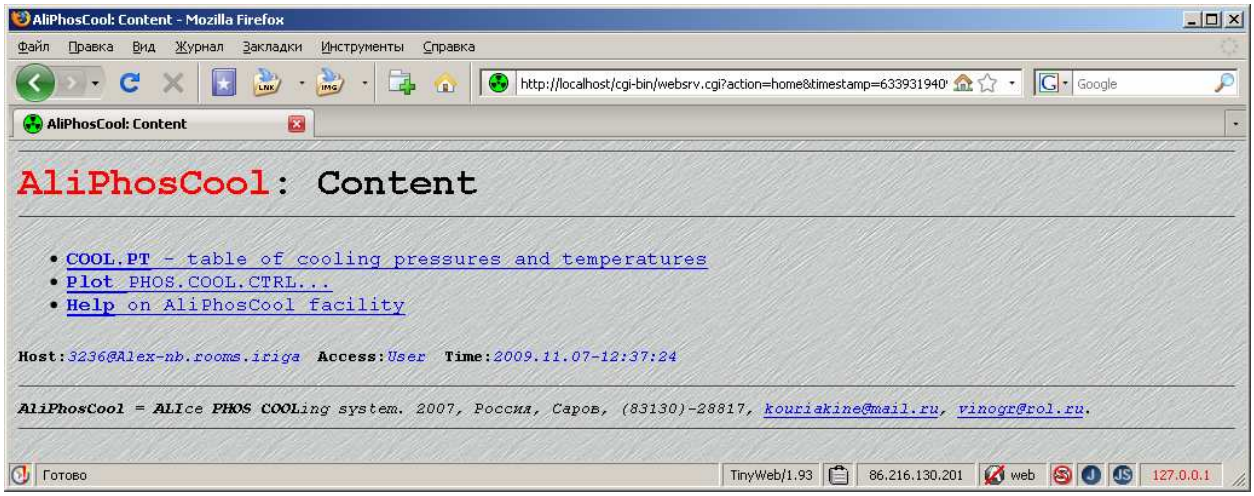
Enter account and press **Login** button.

You will see confirmation page:

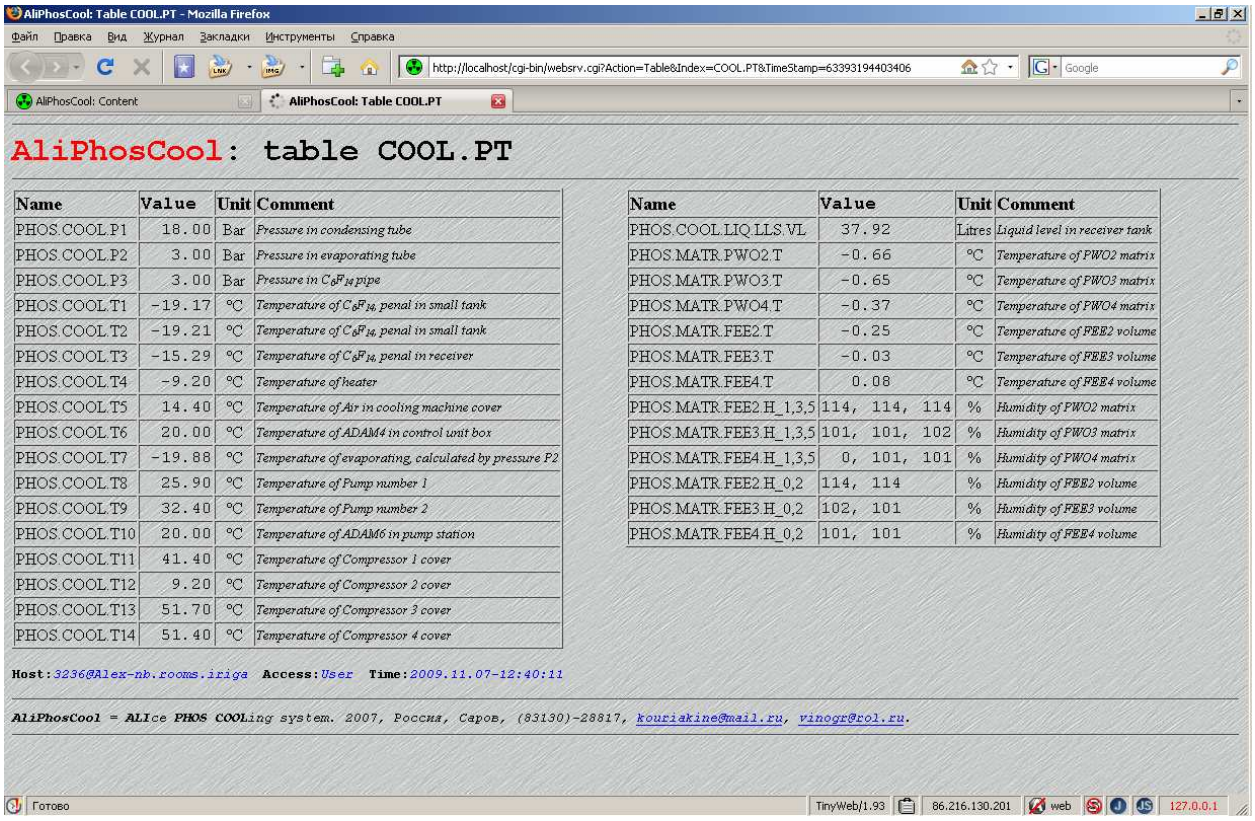


Press **Come In** link to continue.

You will see **Menu** screen.



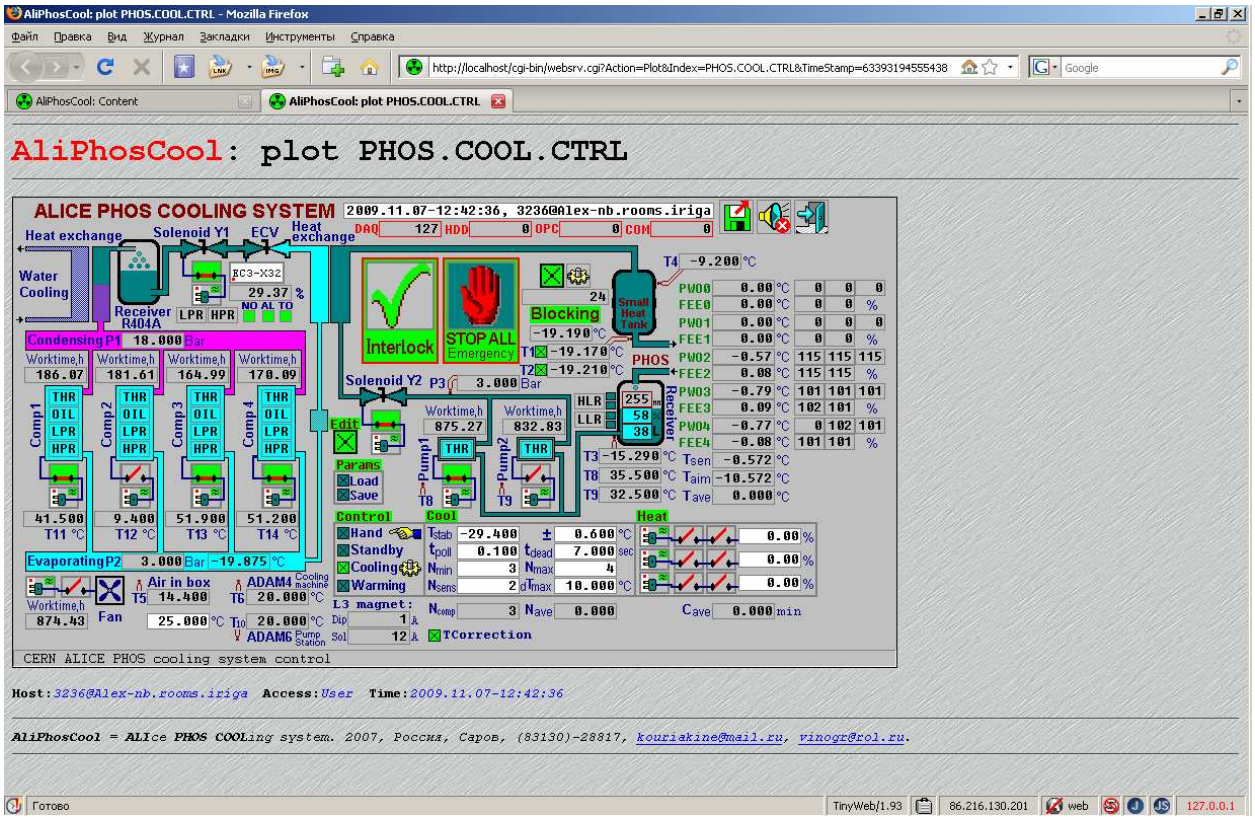
If “**COOL.PT – table**” link selected, then you will see table of main cooling parameters as shown below.



Name	Value	Unit	Comment
PHOS.COOL.P1	18.00	Bar	*Pressure in condensing tube*
PHOS.COOL.P2	3.00	Bar	*Pressure in evaporating tube*
PHOS.COOL.P3	3.00	Bar	*Pressure in C_6F_{14} pipe*
PHOS.COOL.T1	-19.17	°C	*Temperature of C_6F_{14}, penal in small tank*
PHOS.COOL.T2	-19.21	°C	*Temperature of C_6F_{14}, penal in small tank*
PHOS.COOL.T3	-15.29	°C	*Temperature of C_6F_{14}, penal in receiver*
PHOS.COOL.T4	-9.20	°C	*Temperature of heater*
PHOS.COOL.T5	14.40	°C	*Temperature of Air in cooling machine cover*
PHOS.COOL.T6	20.00	°C	*Temperature of ADAM4 in control unit box*
PHOS.COOL.T7	-19.88	°C	*Temperature of evaporating, calculated by pressure P2*
PHOS.COOL.T8	25.90	°C	*Temperature of Pump number 1*
PHOS.COOL.T9	32.40	°C	*Temperature of Pump number 2*
PHOS.COOL.T10	20.00	°C	*Temperature of ADAM6 in pump station*
PHOS.COOL.T11	41.40	°C	*Temperature of Compressor 1 cover*
PHOS.COOL.T12	9.20	°C	*Temperature of Compressor 2 cover*
PHOS.COOL.T13	51.70	°C	*Temperature of Compressor 3 cover*
PHOS.COOL.T14	51.40	°C	*Temperature of Compressor 4 cover*

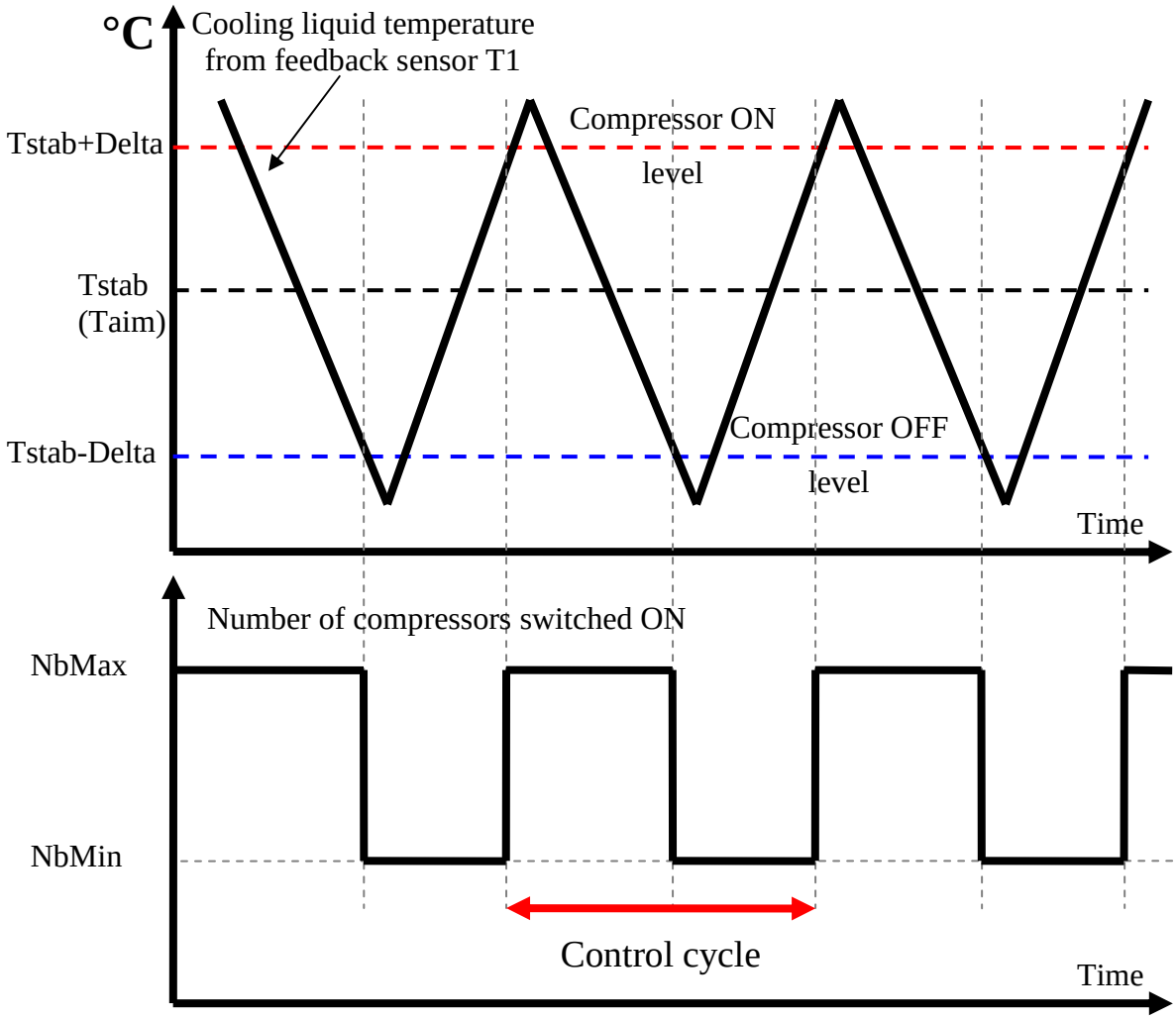
Name	Value	Unit	Comment
PHOS.COOL.LIQ.LLS.VL	37.92	Litres	*Liquid level in receiver tank*
PHOS.MATR.PWO2.T	-0.66	°C	*Temperature of PWO2 matrix*
PHOS.MATR.PWO3.T	-0.65	°C	*Temperature of PWO3 matrix*
PHOS.MATR.PWO4.T	-0.37	°C	*Temperature of PWO4 matrix*
PHOS.MATR.FEE2.T	-0.25	°C	*Temperature of FEE2 volume*
PHOS.MATR.FEE3.T	-0.03	°C	*Temperature of FEE3 volume*
PHOS.MATR.FEE4.T	0.08	°C	*Temperature of FEE4 volume*
PHOS.MATR.FEE2.H_1,3,5	114, 114, 114	%	*Humidity of PWO2 matrix*
PHOS.MATR.FEE3.H_1,3,5	101, 101, 102	%	*Humidity of PWO3 matrix*
PHOS.MATR.FEE4.H_1,3,5	0, 101, 101	%	*Humidity of PWO4 matrix*
PHOS.MATR.FEE2.H_0,2	114, 114	%	*Humidity of FEE2 volume*
PHOS.MATR.FEE3.H_0,2	102, 101	%	*Humidity of FEE3 volume*
PHOS.MATR.FEE4.H_0,2	101, 101	%	*Humidity of FEE4 volume*

If “**Plot PHOS.COOL.CTRL**” link selected then you will see current state of cooling control panel as shown below.



Temperature stabilization algorithm

Operator set **Tstab** (wanted cooling liquid temperature), **Delta** (temperature corridor), **NbMin**, **NbMax** (minimal and maximal compressor number).



Picture 30. Temperature stabilization algorithm.

Stabilization algorithm (Picture 30) uses feedback temperature sensor T1, located at cooling liquid output (Picture 8). When temperature became higher then **Tstab+Delta**, **NbMax** compressors switches **ON**. When temperature became lower then **Tstab-Delta**, **NbMin** compressors switches **ON**. When temperature is inside (**Tstab-Delta, Tstab+Delta**) range, then compressor number is not changes.

Tstab is independent parameter, while **Delta**, **NbMin**, **NbMax** – chosen empirically, to have stable control cycle, see Table 3, page 23. It is recommended to choose **Delta**, **NbMin**, **NbMax** by next empirical criteria's:

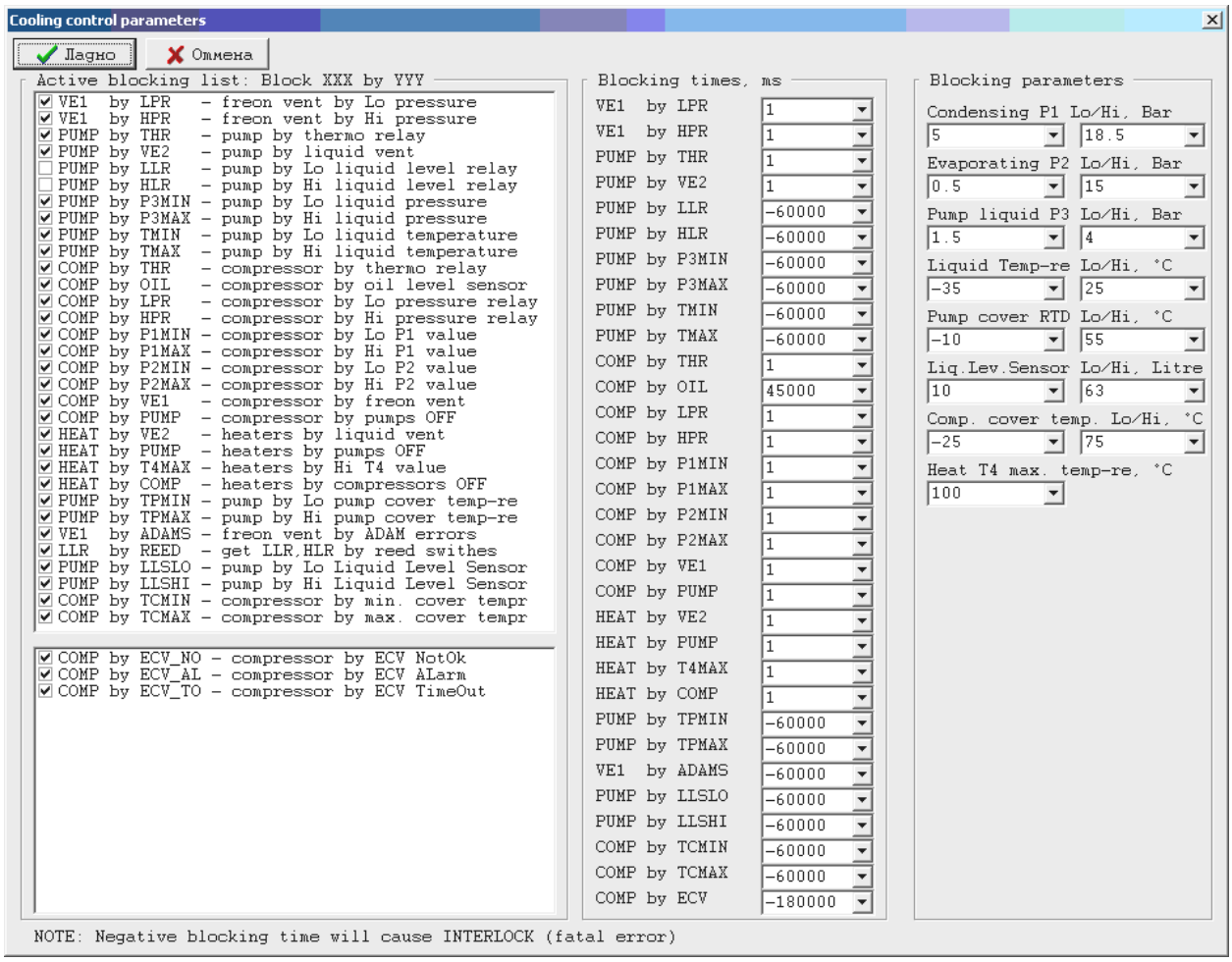
1. Control cycle is periodic and stable.
2. Cycle period is not less then 2 minutes (5…10 recommended).
3. Deviation of control cycle period not more then 10…20% of average cycle period, i.e. cycle period stable enough.
4. Average (over control cycle period) cooling liquid temperature is stable enough, i.e. deviation not more ±0.1°C.
5. **NbMax-NbMin** should be 1 or 2. Choose **NbMax-NbMin=1** if fractional part of average compressor number (over cycle) is inside [0.25,0.75] range or if **NbMax=4**. Choose **NbMax-NbMin=2** if fractional part of average compressor number (over cycle) is outside [0.25,0.75] range.

Empirical parameters during cooling Oct/Nov 2009 shown in Table 3, page 23. This table can be used as reference point for selection of cooling control parameters.

Keep in mind that **Tstab** is wanted cooling liquid temperature, not **PWO** temperature. **PWO** temperature will be some higher then **Tstab**, because of **FEE** heat. For example, **Tstab** should be **-29.5°C** to achieve **-25°C** inside **PWO** matrix.

Alarm system and Interlock

AliPhosCool program has 35 alarms to guarantee safe cooling plant operation. Each alarm (by some condition) has **Flag**, **Timeout** (“blocking time”) and (optional) **Threshold**.



Picture 31. Dialog window to setup alarm system parameters.

Flag enables or disables alarm via checkbox (see Picture 31). Timeout is time (milliseconds) to accumulate alarm condition: if alarm condition stay **TRUE** during **Abs(Timeout)**, then alarm happens. The sign of Timeout means class of alarm. If Timeout is positive, alarm is temporary: device blocked, but cooling continues (if possible) and alarm auto-reset after alarm condition disappear. If Timeout is negative, alarm cause **Interlock** flag and cooling system **halt**. Operator should send **Reset** command manually to start or continue cooling after **Interlock**. So **Interlock** means hardware failure or fatal error when cooling plant operation is not safe enough.

Optional **Threshold** parameter is threshold value for corresponding alarm condition parameter, for example, “cooling liquid temperature T1 less then low threshold T1min”.

List of all cooling system alarms shown in table below.

Table 4. List of cooling system alarms.

Alarm name *Condition*	**Description**
VE1 by LPR *LPR=1*	Solenoids vent Y1 blocked by low pressure relay. Freon (R404A) flow stopped. Possible reason is insufficient freon in system (freon leak).
VE1 by HPR *HPR=1*	Solenoids vent Y1 blocked by high pressure relay. Freon (R404A) flow stopped. Possible reason is insufficient water cooling of water condenser (freon overheats).
PUMP by THR *THR=1*	Pump blocked by thermo relay. Possible reason is pump overload or overheats.
PUMP by VE2 *VE2=0*	Pump blocked by solenoid vent Y2 for cooling liquid (C_6F_{14}). Pump forbidden while vent closed.
PUMP by LLR *LLR=1*	Pump blocked by low liquid level relay. Possible reason – insufficient liquid level (liquid leak).
PUMP by HLR *HLR=1*	Pump blocked by high liquid level relay. Possible reason – too high liquid level (liquid overful).
PUMP by P3MIN *P3<P3min*	Pump blocked by low threshold for P3 liquid pressure. Possible reason - insufficient liquid level (liquid leak) or wrong threshold value “Pump liquid P3 Lo”.
PUMP by P3MAX *P3>P3max*	Pump blocked by high threshold for P3 liquid pressure. Possible reason – pipe or vent closed (liquid not flow) or wrong threshold value “Pump liquid P3 Hi”.
PUMP by TMIN *T1<T1min*	Pump blocked by low threshold for T1 liquid temperature. Possible reason – pump frozen or wrong threshold value “Liquid temp-re Lo”.
PUMP by TMAX	Pump blocked by high threshold for T1 liquid

T1>T1max	temperature. Possible reason – pump overheat or wrong threshold value “Liquid temp-re Hi”.
COMP by THR *THR=1*	Compressor blocked by thermo relay. Possible reason is compressor overload or overheats.
COMP by OIL *OIL=1*	Compressor blocked by low oil level relay. Possible reason – insufficient oil level in compressor, frozen compressor or freon overflow.
COMP by LPR *LPR=1*	Compressor blocked by low pressure relay. Possible reason is insufficient freon in system (freon leak) or ECV failure (no freon flow).
COMP by HPR *HPR=1*	Compressor blocked by high pressure relay. Possible reason is insufficient water cooling of water condenser (freon overheats).
COMP by P1MIN *P1<P1min*	Compressor blocked by low threshold of condenser pressure P1. Possible reason is insufficient freon in system (freon leak) or wrong threshold “Condensing P1 Lo”.
COMP by P1MAX *P1>P1max*	Compressor blocked by high threshold of condenser pressure P1. Possible reason is freon overpressure (freon overheat) or wrong threshold “Condensing P1 Hi”.
COMP by P2MIN *P2<P2min*	Compressor blocked by low threshold of evaporator pressure P2. Possible reason is insufficient freon in system (freon leak due to insufficient water cooling), ECV failure (no freon flow) or wrong threshold “Evaporating P2 Lo”.
COMP by P2MAX *P2>P2max*	Compressor blocked by high threshold of evaporator pressure P2. Possible reason is freon overpressure (freon overheat due to insufficient water cooling) or wrong threshold “Evaporating P2 Hi”.
COMP by VE1 *VE1=0*	Compressor blocked by closed freon vent Y1. It is forbidden to switch on compressor while freon vent Y1 is closed.
COMP by PUMP	Compressor blocked by pump. It is forbidden to

PUMP1,2=0	switch compressor on while pump is switched off.
HEAT by VE2 *VE2=0*	Heater blocked by cooling liquid vent Y2. It is forbidden to switch on heater while vent Y2 is closed.
HEAT by PUMP *PUMP1,2=0*	Heater blocked by pump. It is forbidden to switch on heater while pump is switched off.
HEAT by T4MAX *T4>T4max*	Heater blocked by T4 sensor threshold (to avoid heater overheat).
HEAT by COMP *COMP1..4=0*	Heater blocked by compressors. It is forbidden to switch on heater while all compressors is switched off.
PUMP by TPMIN *T8,9<Tpmin*	Pump blocked by low threshold for pump cover temperature (T8, T9). Possible reasons – pump frozen or wrong threshold value “Pump cover RTD Lo”.
PUMP by TPMAX *T8,9>Tpmax*	Pump blocked by high threshold for pump cover temperature (T8, T9). Possible reasons – pump overheat or wrong threshold value “Pump cover RTD Hi”.
VE1 by ADAMS *RS-485 errors*	Solenoids vent Y1 blocked by ADAM communication errors. Possible reasons are ADAM (I-7000) remote control modules failure or RS-485 network failure.
LLR by REED	Flag means that LLR, HLR signals generated by reed switches REED0…REED3 instead of optical sensors. This flag uses because optical liquid level sensors works unstable.
PUMP by LLSLO *LLS<LLSmin*	Pump blocked by low threshold for liquid level sensor (LLS). Possible reasons are low liquid level (cooling liquid leak) or wrong threshold value “Liq.Lev.Sensor Lo”.
PUMP by LLSHI *LLS>LLSmax*	Pump blocked by high threshold for liquid level sensor (LLS). Possible reasons are high liquid level (receiver tank overfull) or wrong threshold value “Liq.Lev.Sensor Hi”.

COMP BY TCMIN *T10…T14<Tcmin*	Compressor blocked by low threshold of compressor cover temperature. Possible reasons are compressor frozen or wrong threshold “Compressor cover temp. Lo”.
COMP BY TCMAX *T10…T14>Tcmax*	Compressor blocked by high threshold of compressor cover temperature. Possible reasons are compressor overheat or wrong threshold “Compressor cover temp. Hi”.
COMP BY ECV_NO *ECV not Ok*	Compressor blocked by “ECV Not Ok” relay. Possible reason is ECV controller not connected.
COMP BY ECV_AL *ECV alarm*	Compressor blocked by “ECV Alarm” relay. Possible reason is ECV controller generate ALARM signal. ECV alarm means freon don’t flow, so system should stop cooling.
COMP BY ECV_TO *ECV timeout*	Compressor blocked by “ECV TimeOut” signal. Possible reasons are ECV controller fails or network connection lost.

Note that alarm system protects cooling plant and pump station from damage or hardware failure, but it not protect PHOS modules, front-end electronics etc. **PHOS** protection is job for high level **DCS** alarm system. Cooling system provides **Interlock** flag for this high level **DCS** system to use in high level alarms.

To reset system after **Interlock** happened, **Interlock** flag should be clear first. To clear **Interlock** flag, press 

button. The button will show **Interlock** is Ok 

.

Important note: keep in mind that detected reason of alarm may be “visible manifestation” of real “remote cause”. Moreover, alarm may have multiple reasons. For example, “PUMP BY TPMAX” alarm may be because of 1)insufficient cooling liquid flow rate (liquid leak or pump mechanics damage) 2)cooling liquid overheat 3)temperature sensor damage 4)insufficient pump cooling due to high air temperature etc. Another example: “PUMP BY TMAX” interlock in real incident which happened 1 Oct 2009 has reason in ECV controller battery failure: compressors worked as usually, but electric valve was closed due to ECV controller’s battery alarm, so liquid temperature grow up to threshold value. The “visible manifestation” (liquid overheat) was far enough from real reason (ECV controller failure).

Each alarm is “detective story” which should be explained by using many possible reasons and visible features. That is why it is not easy to answer “what to do” if some alarm detected, because this alarm may have many different reasons or even “remote cause” which far enough from detected alarm reason.

“How to” and “What to do”

This section contains short questions-and-answers about how to do something or what to do if something happened.

How to login …

See chapter “Network and login”, page 9.

mstsc.exe /v:cernts.cern.ch *with NICE login (from CERN outside)*

mstsc.exe /v:alidcscom001 *with NICE login (from CERN)*

mstsc.exe /v:ALIDCSCOM252 /w:1280 /h:750 *Login as daq 123*

How to know what is T1, T2 etc …

See Table 1, page 21. Also you can look at status bar on bottom of **PHOS.COOL.CTRL** window while mouse is over indicator (T1, T2 etc) which you want to see.

How to know why Interlock happened…

Interlock may have many reasons. If power off or server hang, hardware interlock happens. In this case **alidcscom252** server is not available. If cooling power is on and **alidcscom252** server connection available, look at last record in log file:

\\alidcscom252\Daq32\PHOS_DATA\ALARM.LOG

This file shows time and reason of **Interlock**, for example:

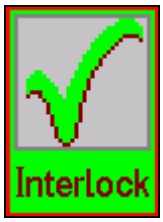
INTERLOCK FROM ALIDCSCOM252
TIME: 2009.10.20-10:16:51
REASON: PUMP1 by TPMAX.
ACTION: COOLING SYSTEM HALTED FOR SAFETY

Interlock reason is also shown in main console window (menu “Windows\System console”).

To understand interlock reason, see Table 4, page 33.

What to do if Interlock happened…

If you see **Interlock** 

, click it to reset 

. Then try to understand what reason of **Interlock**. You can find it in \\alidcscom252\Daq32\PHOS_DATA\ALARM.LOG file or in main console window (menu "Windows\System console"). To understand interlock reason, see Table 4, page 33. Then try to fix this reason. When **Interlock** reason fixed, you should select **Cooling** operation mode (see page 21).

How to cool down PHOS to wanted temperature…

Switch on **Cooling** mode, see page 21. Then set parameters **Tstab**, **Delta**, **NbMin**, **NbMax** (Table 2, page 22). Note that **Tstab** is independent parameter, but **Delta**, **NbMin**, **NbMax** depends on **Tstab**.

It is strongly recommended to cool down step by step, about 1 day per step, as listed in Table 3, page 23, and shown on Picture 27, page 24. During cooling or warming look for humidity, because **Interlock** can happen if humidity will be higher then 50%.

Note that **Tstab** sets stabilization temperature for cooling liquid, not for **PWO**. **PWO** temperature is some higher then temperature of cooling liquid due to **FEE** heat. For nominal temperature **-25°C** difference will be about **4.5°C**, so **Tstab** should be about **-29.5°C** to achieve **-25°C** in **PWO**.

Why "Forbidden in FSM mode" warnings appears?

In "simple" **FSM** mode (page 12) most part of editing fields and commands are forbidden for safety. See page 15 to learn how to edit parameters in this mode.

Where I can find more details on cooling system?

AliPhosCool program has **Help** system ( button or menu **Daq\Help**). This help contains a lot of important technical information about cooling (including this manual).

Also see http://public.crw-daq.ru/public/projects/phos/ site where a lot of documents on cooling system can be found.

What to do if nothing help…

Call cooling system experts:

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