PH-DT Detector Technologies
ICALEPCS 2013

THE CONTROL SYSTEM FOR THE CO2 COOLING PLANTS FOR PHYSICS EXPERIMENTS

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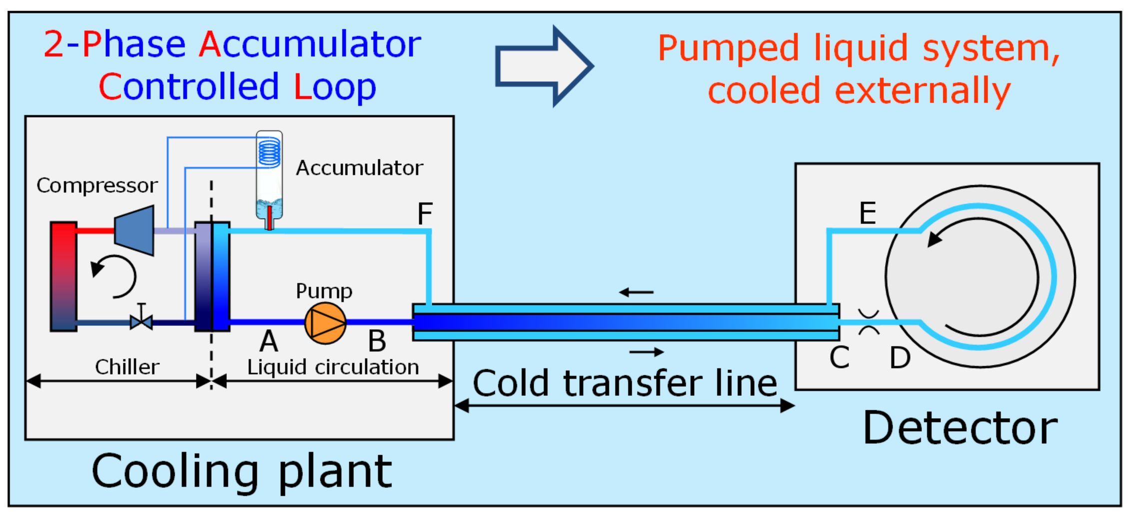
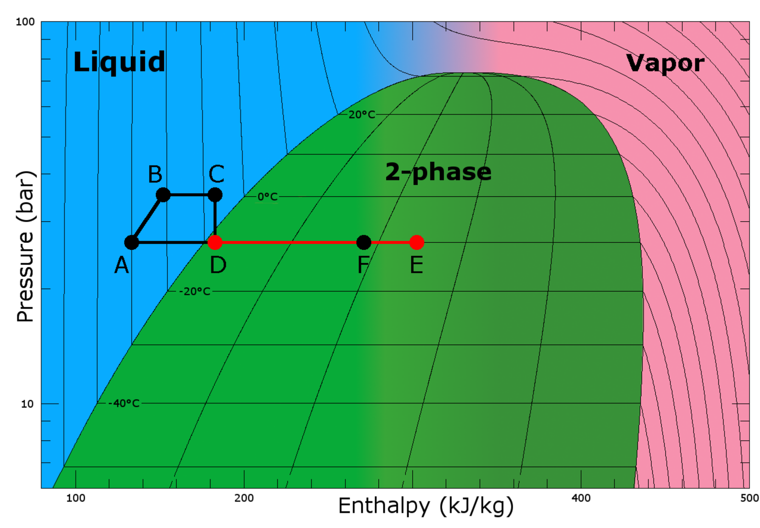
ABSTRACT

CO_2 cooling has become interesting technology for current and future tracking particle detectors. A key advantage of using CO_2 as refrigerant is the high heat transfer capabilities allowing a significant material budget saving, which is a critical element in state of the art detector technologies. Several CO_2 cooling stations, with cooling power ranging from 100W to several kW, have been developed at CERN to support detector testing for future LHC detector upgrades. Currently, two CO_2 cooling plants for the ATLAS Pixel Insertable B-Layer and the Phase I Upgrade CMS Pixel detector are under construction.

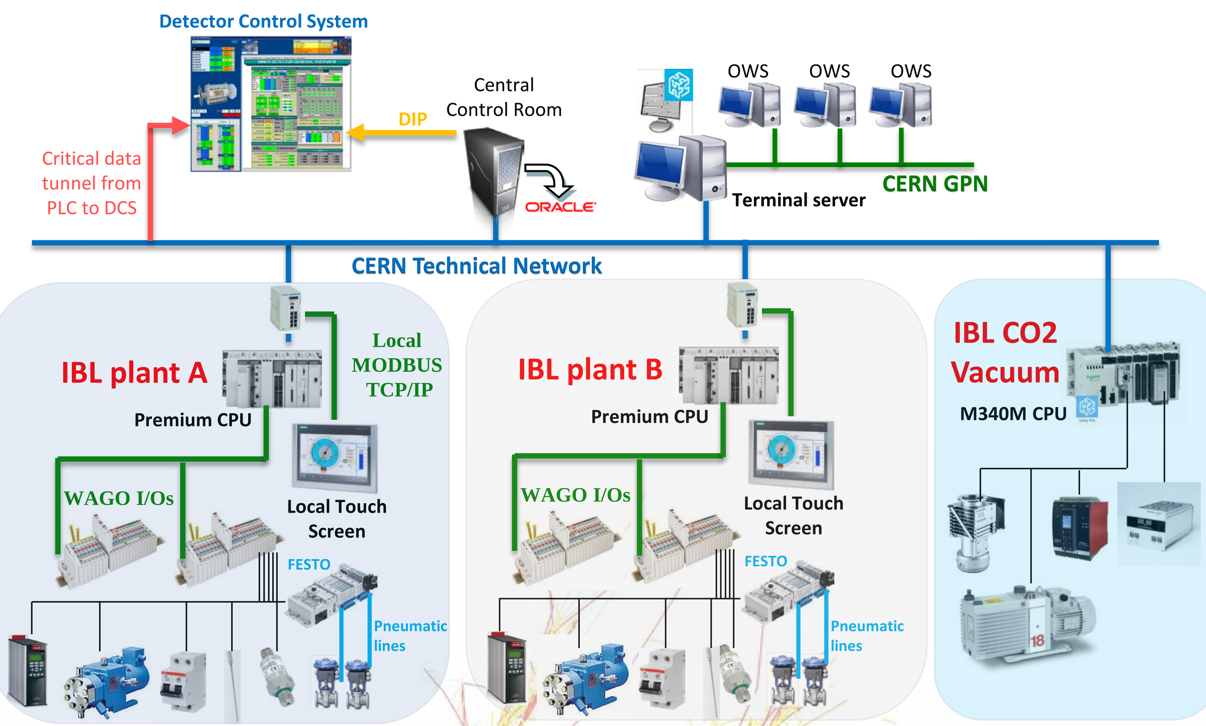




Controls Architecture

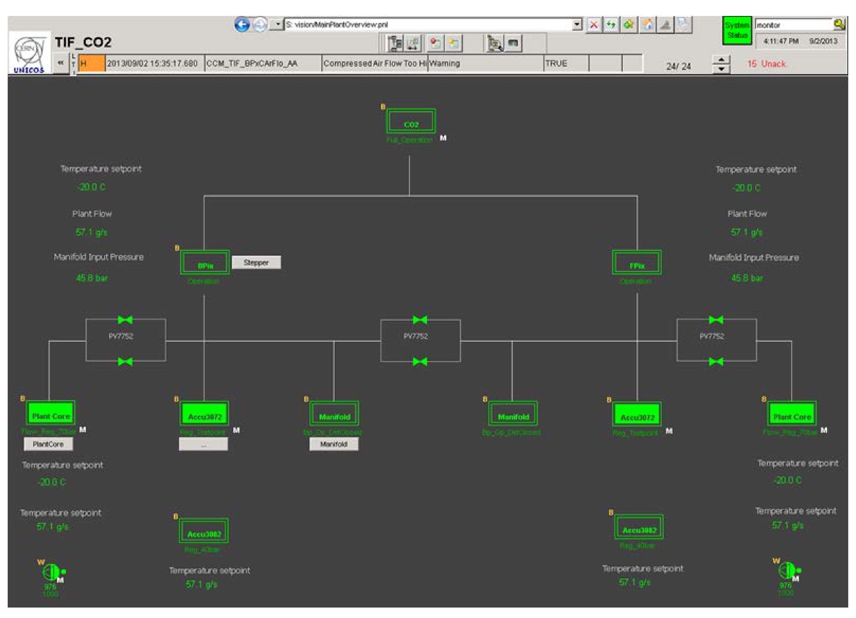
- Each cooling unit is equipped in about 330 I/Os
- **ETHERNET IP** field network connects independent system elements equipped with WAGO and FESTO ETHERNET IP couplers
- **Schneider Premium PLC** runs about 16 control loops and 360 alarms and interlocks

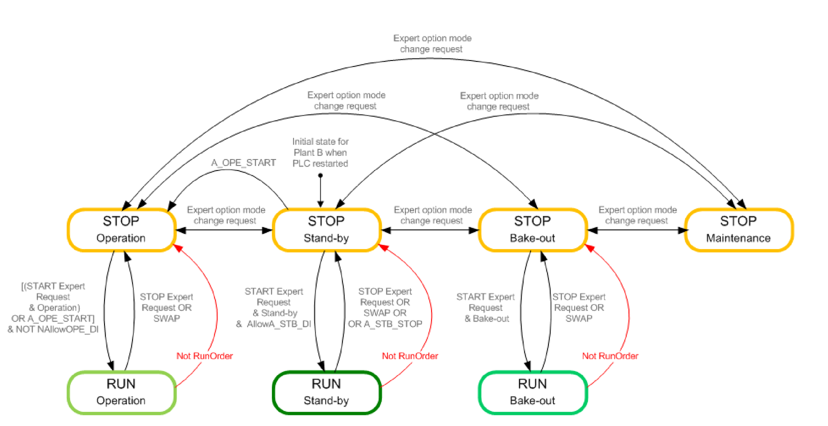
The user interface is based on a SCADA build on **Siemens WinCC OA**.
The control software conforms to the **UNICOS CPC6** (Unified Industrial Control System Continuous Process Control) framework of CERN.



Operability – PCO structure

The process logic is supervised by the hierarchy where the master is the CO_2 system Process Control Object (PCO). Below, there is one PCO per subsystem. The system PCO handles several operational option modes with an associated allowance table. This table defines permitted option mode changes when the system is running



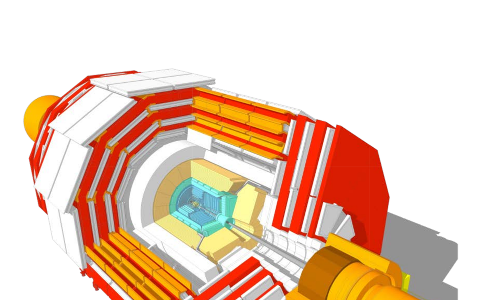


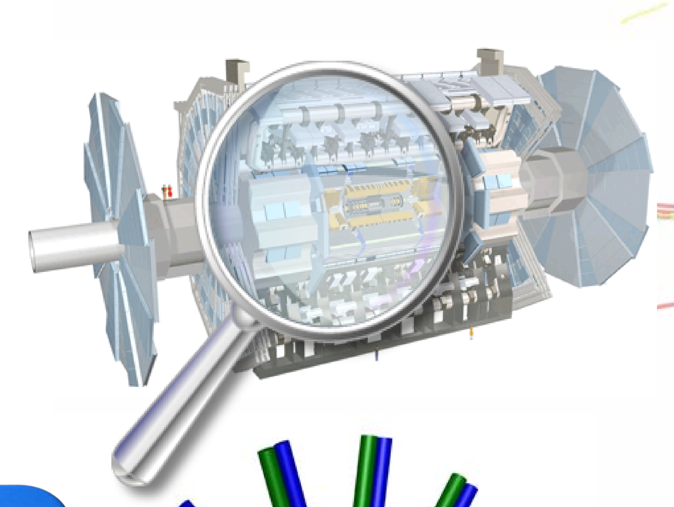
CO_2 cooling systems developed at CERN

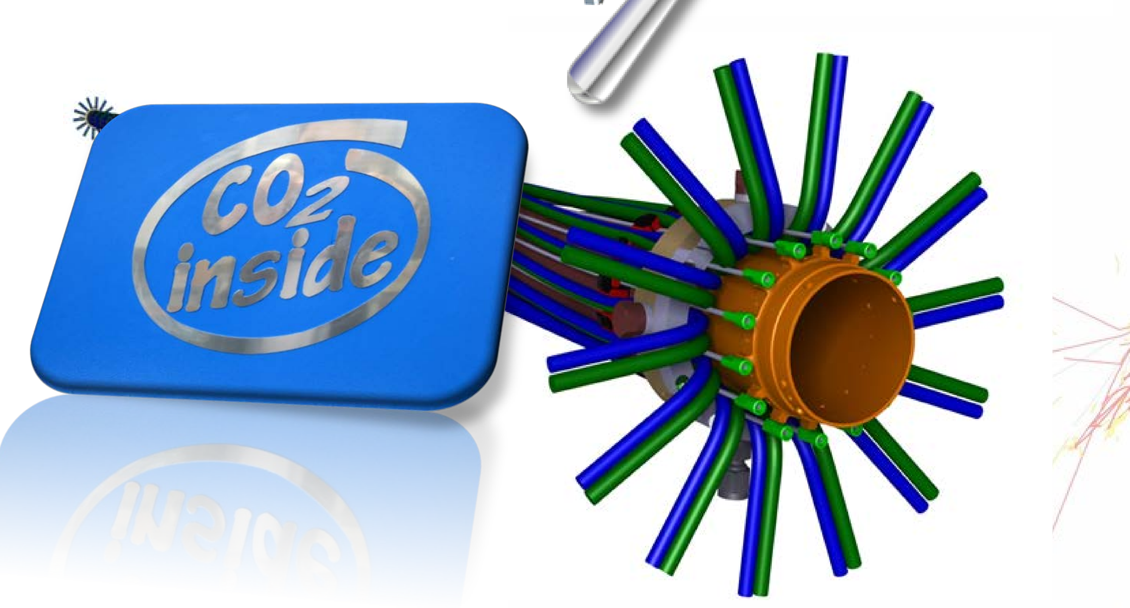
Experiment	Project name	PLC/DAQ Brand	Project status	Cooling power
ATLAS	SR1	Siemens	Completed	2kW
	IBL	Schneider	Under development	2x3.3kW
CMS	TIF	Schneider	Completed	8kW
	Pixel phase 1	Schneider	Under development	15kW
General purpose ATLAS & CMS	CORA	Siemens	Completed	2kW
ATLAS & Belle	MARCO	Siemens	Completed	1kW
ATLAS & CMS & LHCb ILC-PPC founded by AIDA project	TRACI	Siemens NI LabVIEW DAQ	Completed	100W

IBL A UNICOS object list

AnaDO	5
Analog	13
AnalogAlarm	43
AnalogDigital	12
AnalogInput	90
AnalogInputReal	51
AnalogOutput	16
AnalogOutputReal	10
AnalogParameter	100
AnalogStatus	10
Controller	16
DigitalAlarm	319
DigitalInput	149
DigitalOutput	68
DigitalParameter	20
Local	20
OnOff	32
ProcessControlObject	4
WordStatus	12







Safety

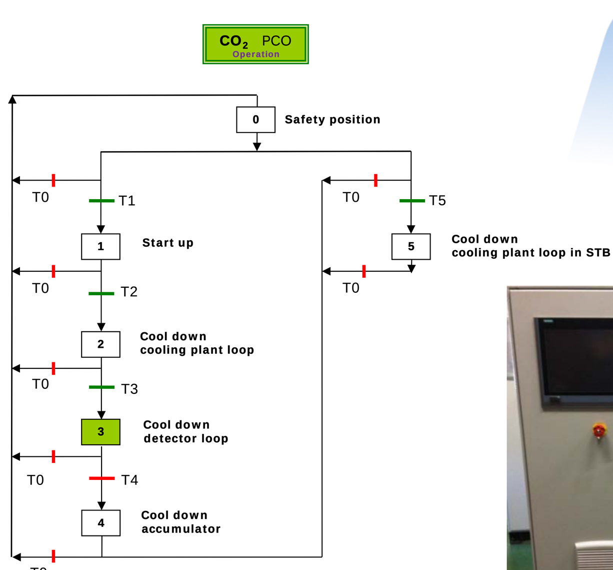
Mechanical protections: all valve's safe state position protects against trapped liquid in closed volumes; safety valves protects against overpressure created by evaporation of the trapped liquid.
Control protections: Each cooling unit is usually equipped with several direct heaters in the range of few kW, closed in small volume and thoroughly covered with thermal insulation. In order to avoid over heating due to insufficient cooling a three level safety interlock philosophy has been introduced:

1. The first interlock (software), stops single heater when first level temperature threshold is exceeded. The temperature is measured at the heater surface with a thermocouple type K.
2. The second interlock (software), stops all system heaters when second level temperature threshold is exceeded (measured on the same sensor as first interlock).
3. The third interlock (hardware), thermal protection switch, which cuts power to all system heaters when sensor contact opens.

In case an interlock is triggered the operation team is always informed by email or SMS notifications. All individual alarms and interlocks are grouped in the functional sections and send to CCC, Detector Control System (DCS) and Detector Safety System (DSS).

Operability phase sequencer

The "operation" and "stand-by" modes are equipped with a sequencers designed for safe system start-up and operation handling different system phases and the transitions in between them.

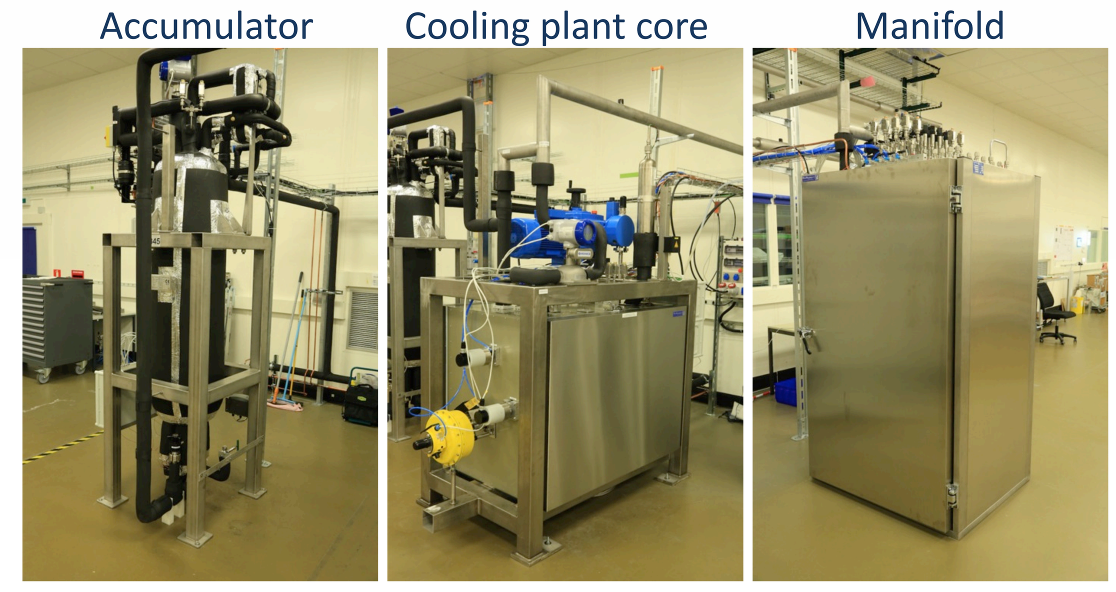


Control racks

Cooling plant core

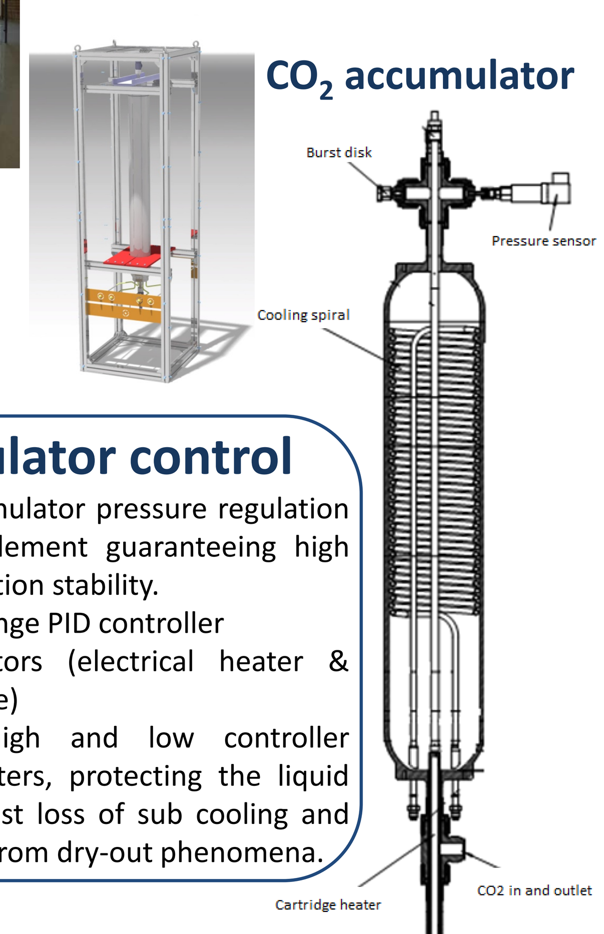
ATLAS IBL CO_2 cooling system

Accumulator Cooling plant core Manifold



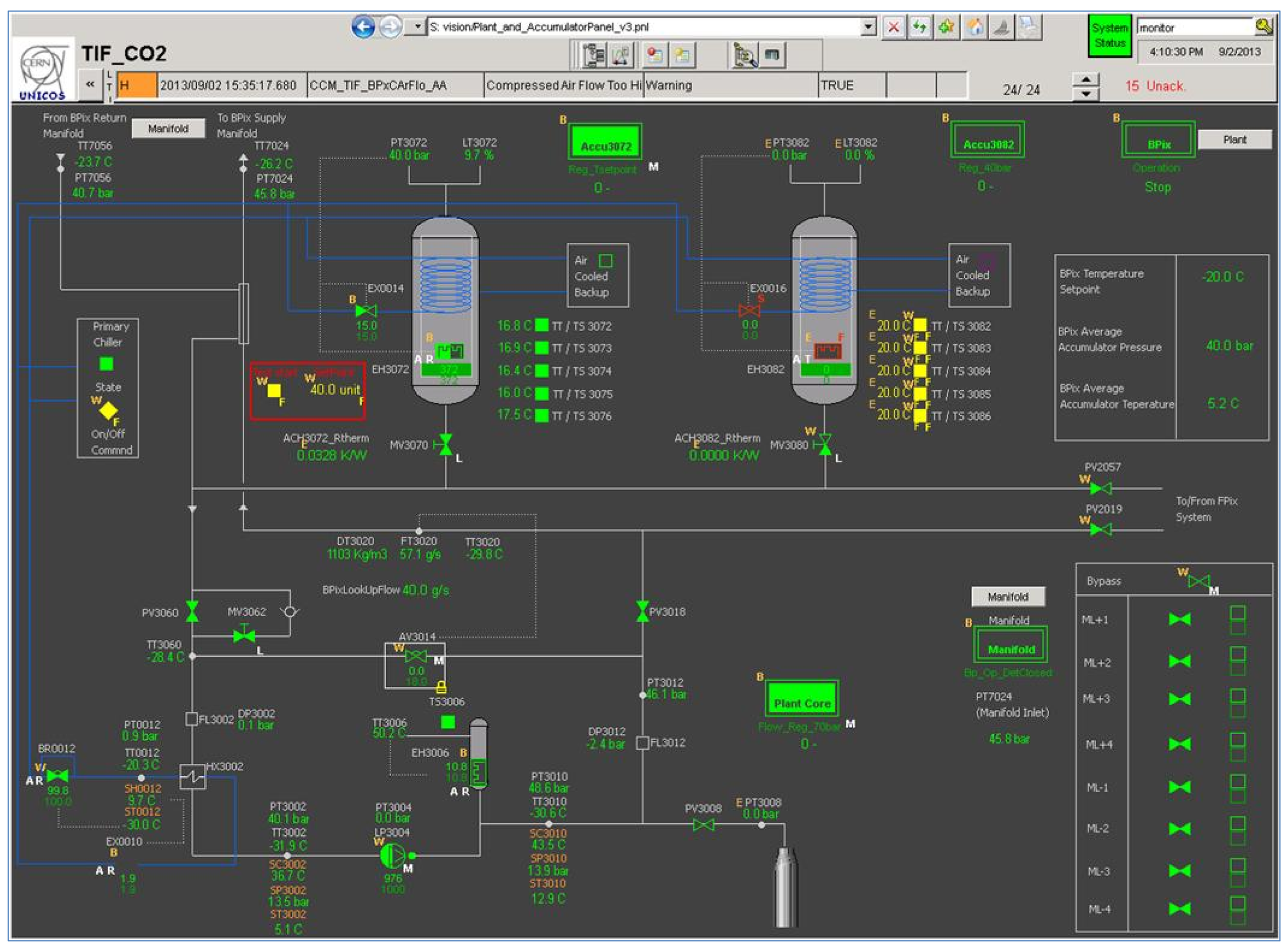
CMS TIF CO_2 cooling system

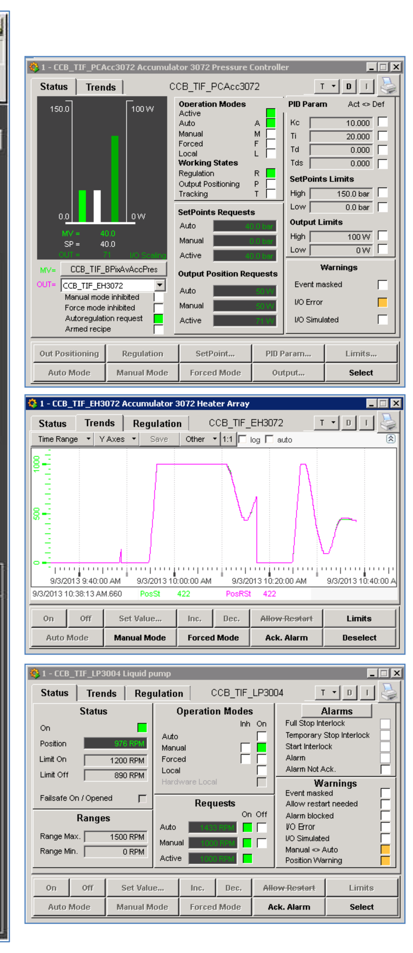
CO_2 accumulator



User interface

The CO_2 cooling control system user interface is composed of several synoptic panels, with navigation in between, allowing for controlling and monitoring of all instrumentation. The main panel represents the simplified mechanical Process and Instrumentation Diagram, with a graphical representation of the real system components. The other panels bring more detailed views of subsystems electrical and alarm diagnostics. Each instrument is represented by an independent widget with associated faceplate holding all status information e.g. current value, error, mode, historical trend etc.

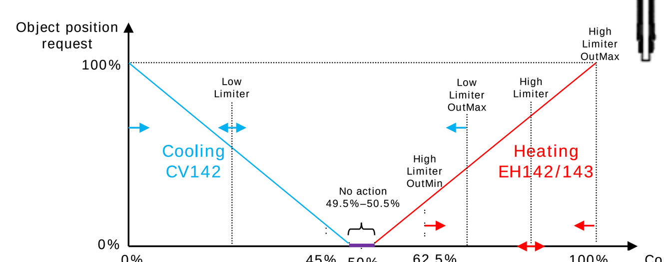




Accumulator control

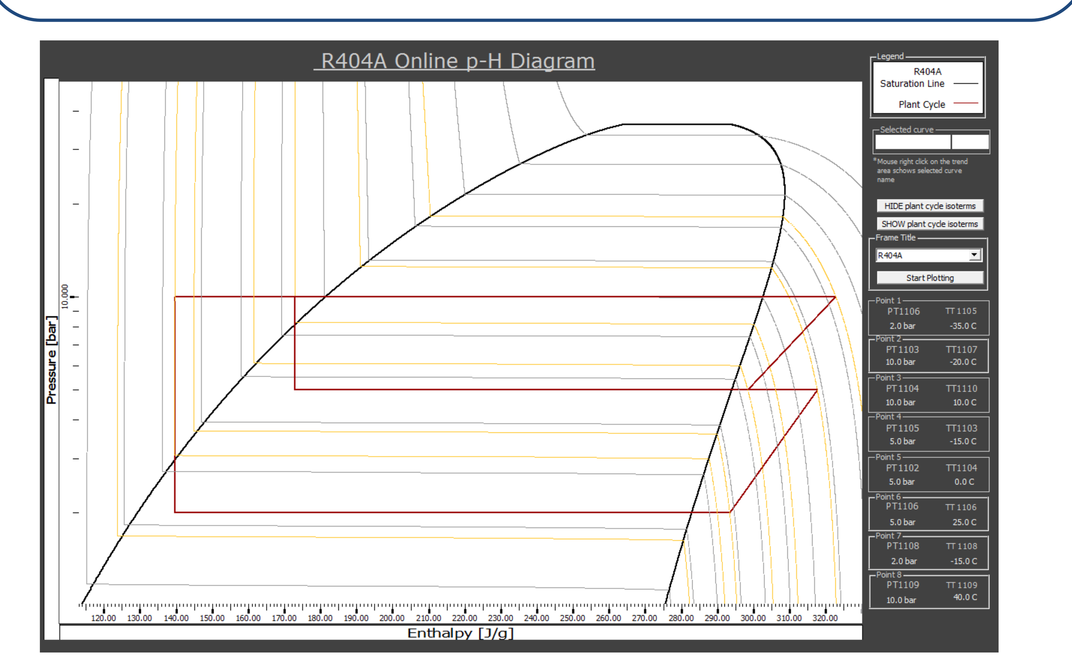
Precise accumulator pressure regulation is the key element guaranteeing high system operation stability.

- One split range PID controller
- Two actuators (electrical heater & control valve)
- Dynamic high and low controller output limiters, protecting the liquid pump against loss of sub cooling and the heater from dry-out phenomena.



On-line Pressure-Enthalpy Diagram

To monitor performance and to facilitate commissioning of the cooling plant a dedicated WinCC OA Control Extension tool has been developed. It is an on-line Pressure – Enthalpy Diagram (p-H) operational for Windows and Linux Platforms. The WinCC OA user interface panel links by dynamic libraries to NIST Reference Fluid Thermodynamic and Transport Properties Database (REFPROP) to retrieve the coolant properties.



Conclusions

CO_2 evaporative cooling is becoming the technical choice for many particle detectors, thanks to its excellent thermodynamic performances and the lightweight structures it can fit into. In this framework, a new standard for the control system of the CO_2 cooling plants has been developed and put in place at CERN. Standardized approach for user interface, communication protocol, software development framework and hardware, simplifies the operation and maintenance activities both for the experts and the basic operators. Also, using the newest solutions available for control system applications makes the CO_2 cooling control system state of the art in detector technologies.