Summary of 2009 PH/DT activity on cooling.

DCP

The work of the newly formed inter-departmental Detector Cooling Project (DCP: http://project-detector-cooling.web.cern.ch/project-Detector-Cooling/), gathering around the same table representatives of the EN and PH Departments together with the "Cooling Coordinators" of the 4 LHC experiments moves on smoothly in a constructive atmosphere. We have in place the possibility of a real coordination of the distribution of efforts for the maintenance, operation and consolidation of the different experiments. In order to help EN/CV-DC in its effort, each experiment is setting up means to make specialized personnel available to work in connection with EN/CV personnel. PH/DT contributes with the activity of the cooling coordinators of ATLAS and CMS, with a large fraction of time of two fellows and with punctual interventions of one doctoral student.

The switch of the control philosophy for the cooling plants from the present one to the generally adopted "CERN standard" (PVSS + UNICOS) is now officially planned and will be directly supervised by EN/ICE. The expertise available in PH/DT on this issue will be exploited as from the starting phase.

Now that the situation of the M&O work for all experiments seems to be relatively stable, the DCP plans to focus its activity more on the R&D WP's for 2010.

An extremely positive outcome of the set-up of the DCP has been the possibility of simplified working relationship between institutes across the experiments. The availability of this transversal channel of collaboration is being particularly beneficial on the CO2 activity and has allowed for a simplified and enhanced circulation of information between institutes belonging to the CMS and ATLAS collaborations.

LABORATORY INFRASTRUCTURE

The large hall at 168/R-F005 (the "Crystal Palace") has been recuperated and transformed in a multi-activity cooling lab. Furniture has been procured in order to have a first area - towards the entrance - with working stations for the lab users and a second area hosting 4 to 5 different test stands at the same time. Space in the she small room at the end of the large hall has been recuperated and will be soon transformed into a technical (noiseless) room hosting the different cooling machines in use (job already agreed and launched).

Electrical power, light and Ethernet connection have been brought to both sides of the hall and a telephone line has been activated.

Pictures of the new PH/DT Cooling Lab at 168/R-F005

LABORATORY EQUIPMENT

A third of the budget expenditure for 2009 has been dedicated to the equipment for the new laboratory, through refurbishment of existing equipment and procurement of new one. The laboratory can presently count on:

- 3 PC for data acquisition, analysis and processing and for general purpose engineering (one is at the moment dedicated to the engineering design of the CO2 cooling unit in installation at the Cryolab).
- A multi-purpose NI (LabView-based) acquisition system offering 2 separated 8-slots UBS 2.0 chassis for NI modules, 8 x 24bits universal channels, 16 x 12bits -20/+20 mA channels, 8 x 24bits specialized RTD channels, 16 x 12bits general purpose -10/+10 V channels.
- Several miniaturized RTD sensors (PT100) for temperature measurement and capacitive sensors (Honeywell HIH4100 and Precon HS2000) for relative humidity measurement.
- A small portable dew point meter (Xentaur LTDP).
- A -70 °C dew point dry air source.
- A new temperature controlled sealed box connected to a gas mixer for full calibration of relative humidity sensors (including low temperature behaviour).
- One *ad hoc* light attenuation interrogation/DAQ system for tip-coated optical fibre sensors (planned for substitution with a new wavelength interrogation/DAQ system for multiple FBG or LPG sensors in 2010).
- Two small water-glycol cooling units, each capable of few hundred Watts cooling power at -20 °C.
- A large C6F14 cooling unit with cooling power in excess of 3kW and 6 bar head loss capacity, pressure-boosted up to 15 bars for reduced flow rates.
- Owned set of tools for piping, circuitry preparation and small electro-mechanical works.
- Programmable RTD and signal simulators for the commissioning of new PLC-based control loops.

Furthermore, thanks to an additional funding made available by the PH Department, it has been possible to equip the laboratory also with two cutting-edge instruments:

- A high precision capacitive absolute manometer MKS “Baratron” (precision: 0.08% of reading up to 15 bar).
- An EdgeTech “Dewmaster DM-C1” hygrometer with a 3 stage Peltier-cooled chilled mirror head for precise absolute humidity reference down to dew points of the order of -75 ˚C.

PERSONNEL

The human resources presently involved in cooling activities in PH/DT are:

- 100% of 3 engineer staff (J. Godlewski from Oct 09, P. Petagna from Jan 09, P. Tropea from Oct 09)
- 100% of 2 engineer applied fellows (J. Daguin from Sep 09, L. Zwalinski from Oct 09)
- 100% of one engineer doctoral student (A. Moraux from Nov 09)
- 100% of one engineer technical student (J. Noite from Jan 09)
- 70% of one engineer from Louvain on NA62 GTK (G. Nussle)
- 50% of one engineer PhD student at EPFL on micro-channel cooling and new materials (A. Mapelli)
- ~50% of two technician staff (R. Dumps from Jul 09 and J. Noël from Nov 09): percentage still T.B.D.

In addition to this, specific agreements for manpower contribution from the experiments have been settled with ATLAS and CMS for the end of 2009 and for 2010. In particular:

- ATLAS presently supports the work at CERN of a young designer from Krakow (J. Swierblewski) devoted to the detailed engineering (CATIA) of the prototype CO2 plant in construction at Cryolab.
- Two Russian technicians supported by ATLAS have been used for specific mechanics needs for the preparation of test stands (mounting, dismounting, welding).
- The formalization of a new general agreement for the support in 2010 of technical/engineering personnel from Krakow under the supervision of J. Godlewski is presently in discussion with ATLAS.

- CMS agreed to make available for R&D work within PH/DT as from Jan 2010 a relevant fraction of the PH/CMX engineer (V. Delachenal) and technician (N. Frank) presently working with P. Tropea and J. Daguin on maintenance, operation and consolidation of the CMS cooling plant.

M&O AND R&D ACTIVITIES IN 2009

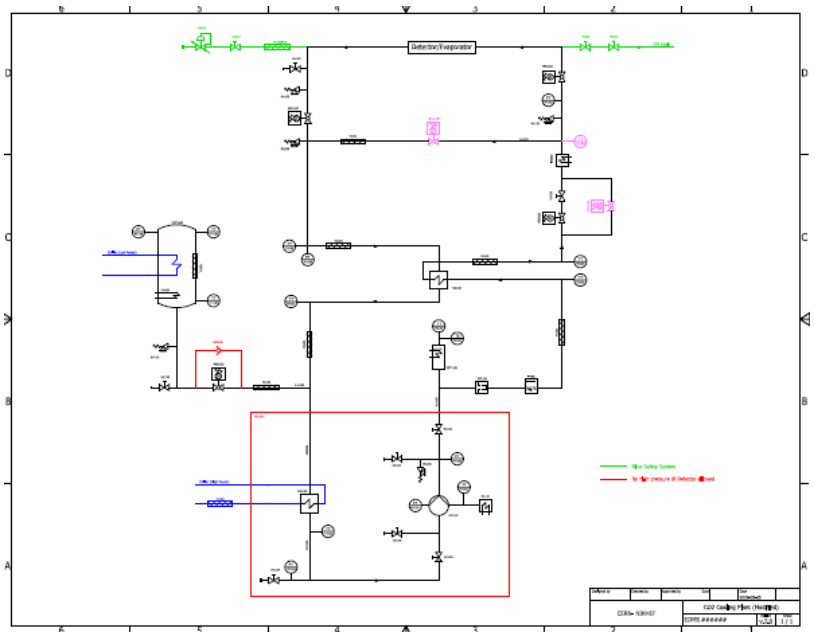
1) ATLAS and CMS Maintenance, Operation and Consolidation.

Two "mini teams" naturally formed to follow the specific needs of the two large experiments: Godlewski + Zwalinski on ATLAS and Tropea + Daguin on CMS. This is at present the largely dominant activity of this 4 people, making of PH/DT, in connection with EN/CV, a primary partner of both experiments for the existing cooling plants. This also includes for CMS the preparation of the consolidation phase foreseen for the next shut-down and the specific R&D targets for ATLAS, like the preparation of the test stand for cooling through circulation of evaporative C3F8/C2F6 blends.
It is assumed that this activity will progressively decrease in time, but its level will likely not pass below a threshold of the order of 50% for the years to come.
In addition to the above-mentioned personnel, A. Moraux has been very active in 2009 as PH/DT PJAS with several specific interventions on control problems both on ATLAS and CMS, in the frame of the collaboration with EN/CV. He also contributed to the design and procurement phase of the "thermo-siphon" test for an alternative concept proposed for the cooling plant of the ATLAS ID. It is intended that the level of direct implication of Moraux in M&O-related activities will sensibly decrease with the start of his PhD programme. However, he will be constantly kept in close contact with the developments of the main experimental cooling plants.

2) R&D on CO2 cooling

Following endorsement by the DCP, Jan Godlewski leads a working group coordinating common activities on CO_2 cooling at CERN (https://espace.cern.ch/CO2/default.aspx). A common P&I for the first prototype CO_2 cooling plant at CERN, satisfying the specific needs of both ATLAS and CMS, has been defined. The Cryolab will host in Bldg 158 the plant, which will be used for different purposes:

- A first test station available to users from ATLAS and CMS;
- An evolutional system to explore control and design alternatives in view of the possible future experimental cooling plants;
- A functional prototype to train technicians and engineers to the specificity of CO_2 systems.



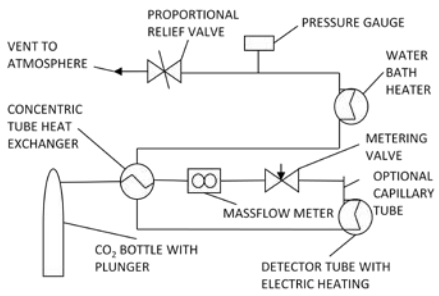
Final P&I diagram for the CO_2 pilot plant in construction in Bldg 158

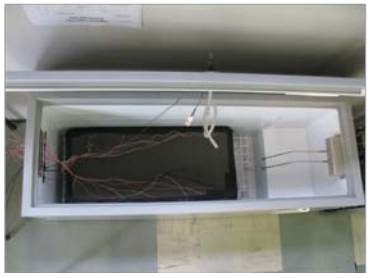
The procurement phase is completed, and almost all components have been received at CERN, except for the large CO2 accumulator, which is presently being designed at NIKHEF. NIKHEF will take care of the procurement of this critical component and will develop the full procedure of certification for it and for a smaller version to be used later on a new, more compact, “transportable” unit.
The primary chiller, provided by CMS, has been partially dismounted and prepared to accept the new components. The detailed engineering design of the new unit has been completed. The stainless steel piping has been made available by ATLAS from stock. It is foreseen that a first phase of room temperature commissioning of the plant could start by March, soon followed by the start of the cold operation at temperature down to -35 ˚C.
The status of the controls for the prototype system (hardware, action matrix, logic, software implementation) is well advanced and developed in close contact with NIKHEF, which is in parallel working on the VeLo consolidation.

A partnership agreement between PH/DT and NIKHEF for the common design and production of a few compact 1-2 kW units is now into a process of formalization.

The strong policy of cross-contacts entertained by PH/DT resulted in collaboration partnerships among EPFL (LTCM), NIKHEF, PH/DT and TE/CRG-CI (the “Cryolab”) on thermal correlations for 2-phase CO_2 flows, where EPFL works on the development of new models based on the data provided by the HEP community. Discussions with SLAC are also ongoing at the moment.

The work of J. Noite on CO_2 correlations in the specific configuration foreseen for the upgrade of the CMS PIX Barrel – requested last year by CMS – progressed very well during the year in Bldg 187. The first phase of correlation measurements in 5m-long straight pipes through a blow system has been recently completed. The second phase, involving a circuit with ten 180˚ bends and a realistic thermal simulation of the modules is now starting.






The blowing test CO_2 set-up for the CMS PIX Barrel in Bldg 187

3) R&D on optical fibre-based Relative Humidity sensors (RH-FOS)

Following the extremely positive preliminary experience in CMS with temperature and strain measurements through optical fibre sensors (FOS), a new R&D line on FOS for Relative Humidity has been launched in collaboration with a pool of 3 Italian institutes (Università di Napoli, CNR Napoli and Univesità del Sannio). Indeed, as of today, no suited solution for a miniaturized humidity sensor radiation and magnetic field resistant is available, which is a big source of concern for the present detectors: there is extremely sound hope that a good solution may come from FOS.

Before proceeding to the more complex technology of Fibre Bragg Grating (FBG) or Long Period Grating (LPG), featuring the possibility of multi-point sensors on a single fibre, it has been decided to make a first step with single sensor tip-coated fibres working in light intensity diffraction. Vapour-deposited SnO_2 has been chosen as first candidate coating and different

coating surface morphologies (thickness and roughness) have been tested. We have individuated an extremely promising candidate and its full characterization as RH sensor is presently ongoing, together with a verification of the repeatability and yield of the production process.

At the end of the year, a multi-site FP7 Marie Curie project on the use and development of Fibre Optic Sensors in High Energy Physics (the "FOS4HEP" proposal) has been submitted. If successful, PH/DT will coordinate a specific Work Package on LPG-based Relative Humidity sensors.

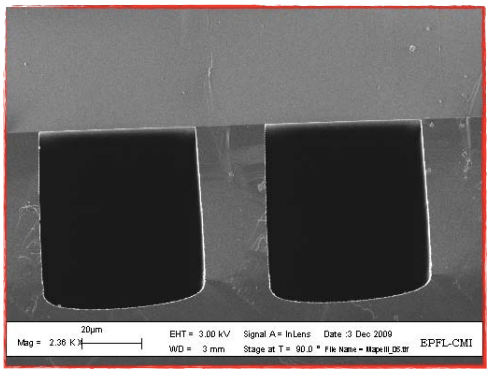
As a by-product of this R&D line, we have now an extremely powerful and flexible apparatus to create stable and controlled humidity conditions in the range 0-100% RH and -20/+30 ˚C, produced in-house by R. Dumps. This will be used for the continuation of the activity, but also for any RH calibration or test need of the experiments. A first investigation on the transient behaviour of the commercial Precon HS2000 sensor, requested by CMS, has been already performed.

The new PH/DT climatic chamber for controlled relative humidity measurements

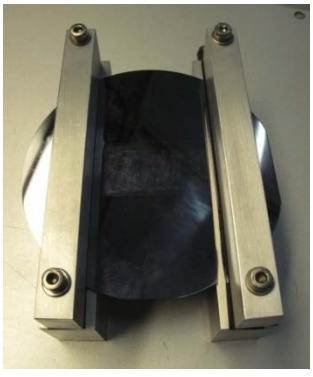
A relative humidity sensing fibre (tip-coated) in its custom produced needle housing

4) R&D on micro-channel cooling

A solution for an active cooling through micro-channels etched in silicon for the GTK of NA62 has proposed to the NA62 collaboration. G. Nuessle (Université Catholique de Louvain) is taking care of the mechanical design and of the fabrication of the test and fluid distribution system, in collaboration with J. Daguin, J. Noël and an additional help from P. Lenoir. A. Mapelli (EPFL) is taking care of the design and production of the silicon micro-channel cooling plates at the EPFL clean room facility. The first prototype chips have been successfully produced in silicon anodic-bonded to a Pyrex cover and are now available for testing, while further specimens are in production. Additional chips with different channel geometry have also been provided for mechanical testing, courtesy by EPFL.



Cross section of the 50x50 mm micro-channel chip produced at EPFL



Micro-channel Silicon on Pyrex chip ready for first pressure test

In order to reduce potential problems deriving from CTE mismatching, a Silicon on Silicon version of the micro-channel cooling plate (either through an intermediate layer or through direct fusion-bonding) is presently envisaged for the final run. Preliminary simulation studies performed at EPFL suggest that a readily available solution with liquid C_6F_{14} should already provide the required thermal performance and that the configuration appears to be optimally suited for CO_2 evaporative, while C_3F_8 evaporative would excessively suffer from the high pressure drop. A booster pump for low-flow/high-pressure suited for the C_6F_{14} cooling unit available in the lab has been procured, as well as all the components for the circuitry of the test stand. The test stand is in assembly at the moment. First tests will take place around the end of February 2010.

5) R&D on process modelling and dynamic simulation

Physical modeling coupled with mathematical analysis plays an important role in process engineering, and in the achievement of three key issues for projects: efficiency, reliability, and quality. First of all, an increased efficiency in view of multiple system dynamics and nonlinearities; then a better robustness *vis à vis* process disturbances; finally, improvement of performances and operating safety. In addition, advanced optimization methods, adaptive operating point and multivariable approach would have important consequences on energetic efficiency, and on the flexibility to cope with different scenarios. In the last two years, studies on the application of modeling and simulation to processes have been carried out for Cryogenics plants at CERN and already proved the advantages of virtual commissioning for helium liquefier and compressor plants. Achieve high fidelity simulation of large-scale systems and perform in advance an entire validation of a plant control, allow avoiding undesired process behavior. Model-based approach is now recognized in the industrial world as a proven technology, capable of dealing with a wide range of multivariable constrained control problems. The application of these techniques to cooling plants for complex HEP experimental devices will be the subject of the PhD thesis of A. Moraux within PH/DT in collaboration with the University of Grenoble.

A. Moraux has been at length directly involved in the design work and test preparation for the ATLAS ID alternative cooling based on a “thermo-siphon” cycle: this work will provide important material for the simulation of this specific process, as agreed in the PhD programme definition. In the same way, Moraux is closely following at present the preparation work of the CO_2 cooling prototype, in particular in connection with the work of L. Zwalinski on controls: the possibility of building a full dynamic simulation model in parallel to the development of the real plant, will be one the points of great interest for his thesis.

An agreement of collaboration with EPFL is under discussion on this subject too.

Advances and details on the cooling activities at PH/DT will be progressively posted at: http://ph-dep-dt.web.cern.ch/ph-dep-dt/Activities/R&D/RD4.html