Cryomodule Workshop – November 2013

Minutes

Meeting Date: 2013-11-21 and 22

Location: IPN Orsay and CEA

Chairperson: CD

Minutes: CD, PA, PB, PD, JF, FG, PDF, BR

Attendees:
Philipp Arnold (PA), Jean Belorgey (JB), Pierre Bosland (BP), Christine Darve (CD), Patxi Duthil (PD), Jarek Fydrych (JF), Francoise Gougnaud (FG), Gilles Olivier (GO), Daniel Piso Fernandez (DPF), Bertrand Renard (BR), Denis Reynet (DR), Jean-Pierre Thermeau (JPT), Piotr Tereszkowski (PT)

For information:

Sebastien Bousson (SB), Guillaume Devanz (GD), Nuno Elias (NE), Anders Johansson (AJ), Mats Lindroos (ML), Dave McGinnis (DmG), Steve Molloy (SM), Anders Sunesson (AS), Garry Trahern (GT), John Weisend (JW).

Agenda

See : http://indico.esss.lu.se/indico/conferenceDisplay.py?confId=138#
WP4/WP5 Audit Indico page at: https://indico.in2p3.fr/conferenceDisplay.py?confId=9118
Password: essaudit

Thursday November 21 @ IPNO - Workshop on WP4/5 and WP11 interfaces

10:30-10:45: Goals of workshop - CD

10:45-11:45: ESS cryo-operating modes – JF

11:45-12:45: ESS infrastructures (CTL, valve box, VB) – JF, PA, CD

- Cryogenic infrastructures; Cryomodule handling, alignment, interfacing in the tunnel

14:00-14:30: Cryomodule cryogenic design – CEA, IPNO

- Cryogenic distribution; Valves and Instrumentation; Interface valve box / jumper

14:30-17:00: Discussion – Open topics (among others):

- Positions of heat exchanger (HX), cryogenic valves, vacuum barrier; Temperatures, pressures and distribution lines of the CTL; MAWP pressure.

Friday November 22 @ CEA - Instrumentation and Control Command

Topics to be discussed:

Feed-back July 17-18th CEA meeting; Details on PLCs architecture; Definition of the ECCTD control command (EPICS, PLC, databases); Definition of the ESS control command (EPICS, PLC, databases); ESS Control box integration; Stepper motor and CTS (slow) control card; Interlock system and MPS; Tracking open issue using JIRA; Cabling (power supply, PLC); Visit of the test stands

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Thursday November 21 @ IPNO - Workshop on WP4/5 and WP11 interfaces

1- Goals of the workshop

Following the WP4/WP5 audit, which took place on October 27-28, the main objective of this workshop is to define interfaces between the WP4 (Spoke cryomodules and cavities), WP5 (Elliptical cryomodules and cavities) and WP11 (Cryogenics). The WP11 involves the Cryoplant (CP) and the Cryogenic Distribution System (CDS). Operating modes and requirements will drive the choice of the Process and Instrumentation in order to operate the cryomodules (Spoke and Elliptical).

Note that the global integration of Paris's task (leading WP4 and WP5) are beyond the scope of this workshop and shall involve WP6, WP7, WP8, WP11, WP12, WP13, WP15 and WP99 (see slides for detail). All WPs shall use the same assumptions. Requirements need to be agreed by all parties.

The contexts for the given interface shall apply to 1) Elliptical Cavity Cryomodule Technology Demonstrator (ECCTD) and 2) ESS tunnel.

The tests of the ECCTD that will be done at Saclay require the development of a control system with PLCs. CEA agreed to develop these systems in coherence with the ESS needs when it is possible. For example CEA agrees to manufacture the valve box designed by ESS and to develop the EPICS C/C system on the basis of the ESS choices: control box, PLC, tuner motor drivers etc. The development for ECCTD will be made with the goal of a possible reuse on the ESS accelerator.

However if the choices are not made in time by ESS, or if the proposed solution is not compatible with the ECCTD environment, CEA will make its own choices.

The same valve box (VB) would be preferred for the spoke and elliptical cryomodules. Several reasons are driving this preference, e.g. similar operating mode process, spare part, WPs organizational, standardization cost and schedule advantages.

__Action items:__

1. Endorsed decision for similar valve box by WP4 and WP5 leaders in collaboration with ESS liaisons for standard modular valve boxes – SB and PB
2. Complete and communicate requirements - CD

2- ESS cryo-operating modes

JF defined eight normal operating modes and eight abnormal operating modes for the Cryogenic Distribution System (CDS). Five normal modes are used for operating the whole string of cryomodules, whilst the last three for operating one separated cryomodule. The cool-down of the entire linac is done with variable temperature GHe, using the VLP line for transfering GHe back to the cryoplant. The warm-up makes use of the variable temperature He recovery line. JF has identified constraints of operational modes imposed to design the cryomodules. The CDS for the Optimus Linac includes the Cryogenic Transfer Line (50 m long), Cryogenic Distribution Line (350 m long) with 43 Valve Boxes to supply LHe to corresponding CMs individually via so called jumper connections. BR proposed to add a separate subcooler along the CDS. But no intermediate subcooler is forseen to keep the CDS as simple as possible. Instead the CDS End box is equipped with a JT valve, phase separator and heater in order to 1) add extra supercritical helium flow into He supply line in order to keep a temperature low enough at the inlet of the spoke cryomodules, 2) keep a temperature low enough at the cold compressor inlet (3.9 K). An additional vessel and heater could be added upstream of the compressor to allow its proper operation. No intermediate vacuum barrier is foreseen to minimize heat loads to the CDS.

The cryoplant will permit the cool down of all 43 CM simultaneously which is beyond the requirement (capacity to cool individual CM at a time in less than 48 hours). PB stated that we may need to test the CM as soon as they are installed in the tunnel, i.e. one module at a time. Nonetheless, this WP11 larger capacity definition targets an improvement of the CP efficiency. This cool-down procedure, cooling down with helium flow of decreasing temperature instead of liquid helium from the beginning, will particularly be applicable for the test plant and illustrates the possible pressure variation in the VLP line (25 mbar – 1.3 bar). Power-couplers and helium tanks are expected to be cooled at the same time. The complete system warm up is estimated to happen once a year. The 4.5 K stand-by mode is necessary. The 50-80 K stand-by mode was discussed w.r.t. the expected SRF cavity heat treatment.

Two CDS helium circuits to support CM operations with: 1) high pressure helium for the thermal shield (supply: 19 bar, 40 K) and 2) supercritical helium for the cold helium circuit to be expanded to saturated He II. The high pressure is driven by the preferred large compression ratio of the CP.

The accelerator is configured so that it could be feasible to operate the cryomodules at 4.5 K (e.g. in case of temporary pumping unit failure).

Action items:

3. Freeze the heat load estimate in order to size the CP capacity. PD and JPT.
4. Capture the possible requirement of the CTL helium flow quantity and the need of a possible vessel with heater upstream of the cold compressor.
5. Propose local and global mass-flow rates according to operation modes in order to size pipes.

3- ESS infrastructures (CTL, valve box) – JF, PA, CD

PT and JF presented the conceptual 3D model of the prototype VB including a long section of the CTL. The proposition for the cryogenic test of a prototype VB with the CTL long section raises space concerns for test area at CEA. PB recommended the removal of this long section.

The pressure and leak tightness tests of the prototype VB components were discussed. Dedicated CTL heat load measurement campaigns are expected to validate the CDS flow capacity and thermal behaviour. BR disagrees because linear CTL consumption can be calculated with precision and represents high cost and congestion of a test facility for little benefit. An independent test of the vacuum barrier leak tightness is suggested.

The WP5 DN100 VLP line and DN300 vacuum jacket of the jumper connection, are due to the size and installation of the heat exchanger on the top of the CM. Beam position requirement is +/- 1,5 mm. Maximum force, angle (or moment) and displacement in all directions must be defined by CM conception. The forces will be defined by the maximum values of gravity, pressure and thermal loads and misalignments. The vacuum barrier is a mechanical fixed point. The current prototype VB design accounts for a tolerance of dx=dy=+/-20 mm, dz=+/-5 mm. Lateral compensators are preferred for adjusting mechanical misalignments between jumpers and cryomodules. For the process pipes metal flexible hoses are applied. DR suggested to use two short bellows on the horizontal process pipe sections instead of one long flexible hose. Those tolerances were identified as acceptable except for the dz=+/-5 which seems too small. The diameter of the jumper and its sliding sleeves could be optimized once these tolerances are frozen.

JF calculated that a DN50 on the Vapour Low Pressure line (VLP) is sufficient to operate the CM in all possible modes, in accordance with the CDS and CP preferred operating modes.

Since EPDM O-ring gaskets are used for the CM side doors, this type of o-ring should be acceptable for the jumper external envelope. ESS asks for information about flanges in order to use the same standard gaskets.

Action items:

6. Minimize the size (diameter and length) of the CTL to be fabricated/tested at CEA to the VB. Interfaces to be completed by CEA.
7. The tolerances of the interface flange is requested to design jumper connection and VB compensation system - GO
8. The position of the interface flange is requested to design jumper connection and VB compensation system – PT
9. Optimize the design of the jumper connection, according to the requirements.
10. Optimize the size of the valve box design (if necessary).
11. Include a dedicated leak-tightness verification of the vacuum barrier.
12. Propose the tunnel escape path and check CTL height from the floor.

4- Cryomodule cryogenic design – CEA, IPNO

PD presented the details of the Spoke CM cryogenic distribution and GO presented the detail of the mechanical structures for the Elliptical CM. Both the spoke and elliptical are designed using the same engineering principles.

PD showed 2 possible implementations of the HX for the Spoke CM, one in horizontal in the jumper connection, alternatively the heat exchangers were shown in the valve box.

No proof of the proper operation of the HX in its horizontal position has been provided yet. The cooling path for the helium tank is privileged if the HX is located in the VB. In this later case, the 2 K supply-piping route is twice shorter and the distribution is optimized. In addition, the JT and cool-down valves are on the side of the VB, which simplifies the integration of all CM equipment (reduce the need/time of leak check, prevent contamination) and limit risks in a clean environment. The installation of cryo-valves is easier and we can install 43 less cryo-valves. Still this configuration adds heat load to the VB system. According to CERN example, a smaller VB volume with individual insulation chimneys is possible. More economical, this configuration is thermally less optimal (to be proved: (1) surface of the thermal shield seems to be lowered in the chimney configuration; (2) radiation on the 2K of the cryogenic valves is marginal).

The HX could be installed upstream of the vacuum barrier inside the valve box. If not, the dimension of the VB could be minimized according to IPNO and CEA.

PA stated that if the HX were located in the valve box, then the scope and responsibility split between CM supplier and VB supplier (e.g. responsibilities split for IKC for delivery, installation, leak-checking) would be very hard to handle, since the HX is the “ownership” of the WP4 and WP5, whereas the valve box is designed by WP11. Also the risk of not meeting the schedule will increase significantly with the additional interfaces.

PB answered that ESS shall mainly look at long-term technical advantages in order to freeze the overall functional design.

CD mentioned that the location of the HX above the elliptical CM was driven by possible instabilities mainly due to possible micro-phonics phenomena. In the light of the detailed design and more understanding on the impact on series production, a comparative analysis shall be conducted and the final solution frozen asap. Project considerations could be mitigated by further agreements between stakeholders (moving “ownership of HX and 2 valves from CM/WP4/5 to VB/WP11). Organizational impacts need to be assessed and may drive the decisions as per WP11.

JW stated that the 2K heat exchanger shall remain in the CM and not be shifted to the valve box as mutually agreed on previous occasions. See action item #1 to support this statement.

GO shows Elliptical CM detail. The vacuum barrier is not removable, but it could be inside the VB or in the Jumper fixed side. The vacuum barrier is proposed to be installed above the VB.

The sizing of the safety valve (SV90) assumes the static heat loads and one mis-functioning or operator “error” (e.g. CM inlet valve fails open, or electrical heaters fail on, etc.). The sizing of the rupture disc is completed according to the worst-case scenario, i.e. air loss in the cavity space. In WP11 flow schematic, the helium recovery line “80-300K, 1.05-1.3 bar” is independently vacuum isolated and separated from the CTL. The HP and purge lines need no insulation. GO and JPT propose to separate the safety valve recovery line from the power coupler recovery line, which flow at room temperatures outside the CM vacuum vessel. GO shows that the valve box is on the way of the wave-guides for both the spoke and the elliptical CMs. JF suggested to shift the VB of the CM line, towards the LWU (Warm Unit) but it may create conflict with vacuum equipment, plus the escape passage may be limited.

The instrumentation list should be checked and standardized. Series instrumentation may not be as extensive as prototype instrumentation. CD reported that 4 requirements have been added for the Electro-Magnetic Resonator in accordance with WP11 needs: 1) Helium guard shall be installed downstream of every seals interfacing sub-atmospheric pressure circuits; 2) enough pressure overhead has to be between normal operating pressure in the system and blow off of safety relief valves; 3) helium gas released safety valves shall be collected to an helium return line to limit the helium gas inventory loss; 4) the operating pressure shall be as low as admissible by the CP operation. PD mentioned that nondestructive tests (e.g. x ray for 10% or 100% of weldings depending on applied standard, cryo vessels or pressure vessels) are imposed to manufacturers even for the lowest risk category. Single cavities are considered as pressure vessels, not the combination of four cavities; this means that only 50 l are taken into account instead 200 l and the MAWP could hence be defined higher, maybe up to 2 bar abs (still to be determined) without changing the risk category of the vessel. CD underlined that the enforced methodology will comply with the Project Quality Control policy. PB and CNRS mentioned that QA engineers assigned on the Spoke and Elliptical Quality Assurance starting beginning of 2014. PB described the strategy towards a CE validation by the certified authority, following the example of the IFMIF

Action items:

13. Contact HX company to verify operating conditions (horizontal or angled operation). PD.
14. Complete the study for the preferred position of the HX. PD.
15. Complete (in English) reports to summarize pressure safety calculations and sizes the rupture disc and safety valves. CNRS.
16. Write report on heat load and thermo-mechanical studies of Spoke and Elliptical CMs. CRNS.
17. Freeze the possibility to collect separately the 2 safety valves (SV01 and SV60) and the double-wall cooling system in a non-isolated recovery line in order to simplify the design.
18. Freeze the position of the vacuum barrier.
19. Optimize the position of the valve box in the tunnel: w.r.t. wave-guide route, validate the escape path.
20. Complete the instrumentation list (add water and vacuum circuits and process variables. Nuno, PD, JPT and BR.
21. Study of failure modes during the ESS risk analysis session.
22. Complete the failure mode and effect analysis for the instrumentation and valves.

Friday November 22 @ CEA - Instrumentation and Control Command

NB: Minutes compiled by DPF and CD

1. Introduction

CD initiated this meeting relating the purpose of the visit and the activities held the previous day. The main interest of the meeting is to synchronise all parties, organise the activities related to ECCTD controls and determine which ESS control standards can be early tested at ECCTD. Also, the possible solutions for the slow tuning systems of the cryomodule were analysed

2. Discussion

The ECCTD control system is based on EPICS, on an ESS control-box and on Siemens S7300 PLCs. On the upper level, there will be PCs dedicated to EPICS supervision with CSS BOY displays, archiving and trends. Other tools like logging can be provided.

Muscade is a CEA SCADA whose objectives are supervision, diagnostics and distance maintenance and its specificities are particularly convenient for cryogenics test stations, because it is already running at the test facility for this purpose. In this test bench, the choice is to run Muscade server and client on the same PC. Even when Muscade is used at Saclay, ESS would like to have all the variables in the PLC integrated in EPICS and in BOY screens. To solve this request, Irfu/SIS has foreseen to use S7PLC, communication software between Siemens PLCs and EPICS.

The microTCA ESS control-box has not been chosen yet. This control system will be able to control several stepper motors and several piezos. The stepper motor controls will be independent of the control-box.

ESS advises the using of Geo Brick (Delta Tau) for stepper motors. Therefore, FG agrees on using Geo Brick as well, to provide an early test of this solution.

To control the chosen Noliac piezo, a study is in progress.

The control-box will acquire RF signal measurements. This control-box has to be defined in cooperation with the ESS "Integrated Control System" team as several solutions and boards are possible. The choice has to satisfy ECCTD tests and ESS controls standards. Additionally, this choice needs to be done right away in order to permit CEA to procure and get the hardware in a timely manner, according to the milestones agreed (see below).

The ESS timing system could also be used. So CEA needs a timing generator and a timing receiver to synchronize the acquisition of RF parameters.

A Siemens S7300 PLC will control temperatures and vacuum through the Profibus fieldbus. This ECCTD PLC will be added and integrated in the existing control system of Supratech and will use the cryogenics utilities of this experiment zone. The different cryogenics test stands use the same Helium liquefier and pumping group.

The ECCTD PLC will communicate with the other PLCs through Profinet and with a FIP gateway if necessary. The remote I/Os and process dedicated to cryogenics have not been defined yet.

Action items:

23. It has been agreed that FG keeps progressing and distributes the design document for the ECCTD when she is ready.
24. Confirm the choice and quantity of control box for the ECCTD.
25. ICS to standardize a microTCA crate to CEA.
26. Determine highest sampling rates at Ion Source and LEBT (ICS will integrate into EPICS one for Q2 2014). DFP.
27. CD to provide the list of process variables to FG.
28. DFP and FG to discuss about the timing infrastructure needed.
29. DFP to discuss within ICS how to provide FG timing infrastructure and the Geo Brick solution.
30. Identify the Process Variables and operating modes to write the EPICS synoptic.
31. How to construct standard EPICS screens that can be also used later at ESS. They need to look what effort ICS needs to provide there. FG and DFP.
32. Complete the architecture for the overall SRF control system.
33. Process cryo to be compared with SPIRAL2, XFEL, ILC, etc (synoptic).
34. Create a JIRA project for ECCT and add task items using JIRA and provide platform to communicate (Alfresco). DFP and CD.
35. Write milestones cross-correlation between ECCTD, Hardware and Software EPICS integration in ICS and LLRF.

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Annex 1: Suggested studies to complete

1. Develop the preferred strategy to cool down a given number of cryomodules in order to optimize the hardware commissioning duration and the overall reliability, availability and maintainability (testing and installation).
2. Study the possible cooling of CM one by one once installed in the ESS tunnel.
3. Study the operating conditions of CP at 20 bar, 40 K inlet, e.g. can a VFD be used to operate the compressor? Studies from company cycle optimization for high and low pressure modes and use of parallel turbines to be brought to the attention of WP4/5. WP11 for action.
4. Study the frequency of warm-up of CDS and develop a strategy for proper warm-up.
5. Study the need of a 50 K stand-by mode for maintenance modes.
6. Study the position of warm return lines (power-couplers) w.r.t. the isolated CTL, possible recovery line different for CM valves and valves of the VB.
7. Can the recovery line be different for the power-coupler supply and for the recovery of safety valves (19 bar, helium bath, valve boxes)? WP11 for action.
8. Study sequences for the cooling of power-couplers and helium tanks separately.
9. Develop a strategy to optimize the installation schedule, e.g. can preliminary tests (thermal, hydraulic, mechanical) shorten the installation and commissioning period?

Annex 2: (Item 24) Confirm the choice and quantity of control box for the ECCTD

DFP understanding:

At this point, FG could do everything without our interaction with a cPCI crate, what she already has in Saclay. For cPCI crate the standarization is already made. But we still can make some tests.

For testing microTCA standard solutions, FG needed ICS to specify a microTCA crate. This I already did on Friday. The microTCA crate will be the same as Anders is using at Uppsala. This is also why Françoise asked Anders if this microTCA motion controller could work independently of LLRF.

On top of that, AJ wants to use a microTCA crate for the motion control in the piezo tuner. This will be done with a crate from DESY (DFMC-MD22 board). If the card comes on time, Klemen ICS will develop EPICS support for this card in the first half of 2014.

TEST1: mTCA+motion controller for piezo-tuner.

Then, we agreed on testing Geo Brick for the slow tuning. This module is 'crate independent' because it is connected to the control box through the Ethernet port.

TEST 2: Geo Brick motion solution (not crate specific)

Françoise asked for a high sampling rate acquisition card. She is getting cables from RF at Saclay. So, she needs to acquire this signals. If we test a fast enough solution, could be also used at Ion Source and LEBT. I already asked this and ICS will develop EPICS support for a 10 Mhz acquisition card in cPCI form factor. This could be useful for everyone, because we already checked that should be enough. Anyway I am talking to Luigi and Benjamin in the following days. So the next test is

TEST 3: 10 MHZ acquisition card in cPCI.

To synchronise this acquisition Françoise needs timing infrastructure. In principle, if synchronisation is only needed at the cPCI crate, it would be enough with a Timing receiver cPCI card. We can still discuss this more carefully with Françoise.

TEST4: Timing receiver in cPCI card.

Conclusion: for the ECCTD, if we agree to test every system, then PB will provide FG with one crate for cPCI and one microTCA.

Annex 3: Selected Milestones for control integration

The following milestones (internal to the activity) where collected:

MILESTONE	DATE
Determine the highest sampling rate in the Ion Source and the LEBT	End of 2014
Discover roadmap for SDD	End of 2014
microTCA Box Specification	OVERDUE
Hardware Available (Control Boxes, PLCs,…..)	March of 2014
Instrumentation List	OVERDUE
Study on PLC development starts	March of 2014
Detailed I/O List	March of 2014
End of PLC development study	June of 2014
Electrical Engineering Study	June of 2014
Process Design	December of 2014
End CB Developments + Displays + PLC Communication	June of 2015
Control System ECCTD Ready	September of 2015