SUMMARY OF SESSION 3: CRYOGENIC AND VACUUM ISSUES AFFECTING BEAM COMMISSIONING

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INTRODUCTION

The operation of LHC at cryogenic temperatures raise a number of new issues which could lead to difficulties during the commissioning and operation of the LHC. Session 3 was devoted to some of these vacuum and cryogenic questions with the aim to clarify the limits they set in terms of performance or scheduling. Six presentations were made:

- How to deal with leaks in the QRL and magnet insulation vacuum, P. Cruikshank, G. Riddone
- How to deal with leaks in the Beam vacuum, V. Baglin, R. van Weelderen
- Shortcuts during installation and commissioning: risks and benefits H. Gruehagen, G. Riddone
- Commissioning the DFB, A. Perin, V. Benda
- The cryogenics system in pt 4: possible options, S. Claudet, U. Wagner
- Issues concerning the reliability of the cryogenic system M. Sanmarti, L. Serio

VACUUM ISSUES

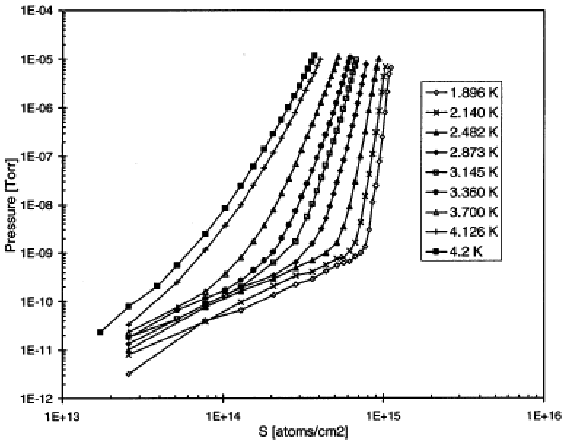

Figure 1: Helium adsorption isotherms [1]

The two first talks were addressing the question of leaks and of their impact on LHC operation. Most of the LHC vacuum system has a large area held at very low temperature. This fact determines the behaviour of the vacuum system in presence of leaks:

- With the exception of helium, all gases have negligible vapour pressure: An air leak is very efficiently pumped and results in a local condensation of gas.
- Even helium can be condensed in non negligible amount at 1.9 K (figure 1). Helium leaks generate a local pressure bump which propagate with the saturation of the surfaces.
- The presence of thick thermal insulation layers reduces drastically the conductance to the pumping stands and hence the propagation of tracer gas to the leak detector.

The size of a tolerable leak can be defined the following way:

A limit pressure P_l is defined based on operational constraints (e.g. maximum cryogenic losses tolerable, quench level…). As helium is condensing the saturated vapour pressure increases locally and reaches P_l. When this limit is reached, the coverage of he condensing surface must be decreased by warming up the condensing surface (4K is sufficient in the case of He) and pumping away the released gas. The duration between two consecutive pumping is a function of the total leak rate. The highest acceptable leak rate is determined by the shortest tolerable pumping interval.

Leaks in the Isolation vacuum

Above a pressure of 10^{-2} Pa the insulation properties of the cryostats are degraded and the heat flux to the cold surfaces increases drastically. In the case of a helium leak, LHC operation is perturbed when this pressure is reached, a warming up to 4K of the condensing area and a re-pumping of the liberated gas is then necessary. In the absence of pumping,, a leak greater than 3.10^{-6} Pa.m^{3}s^{-1} , respectively 10^{-6} Pa.m^{3}s^{-1} necessitates a warming up of a cryomagnet, respectively of the QRL between 2 shutdowns. The operation of the installed pumping stations allows increasing the acceptable leak to 10^{-3} Pa.m^{3}s^{-1} for the cryomagnets or 10^{-4} Pa.m^{3}s^{-1} in the case of the QRL, because of a strong conductance limitation due to the super-isolation. In the case of an air leak, the helium partial pressure fixes the size of the tolerable air leak. If this partial pressure is 5ppm, the maximum air leak that can be tolerated is 0.1 Pa.m^{3}s^{-1}.

Because of the conductance limitation the localization of leaks within a cryomagnet, is difficult. Remote observation allows to locate the leak within a vacuum sub-sector. A more precise localization necessary for a repair needs a warming up of the cryo-system. In the case of the QRL that localisation, even after warming up is extremely difficult if at all possible because of the very limited longitudinal conductance.

The minimum time needed for repair is 13 days minimum and could reach 38 days when a fast warming-up is not possible.

Leaks in the beam vacuum

Two type of leaks could be a concern in the beam vacuum: air leaks close to a cold/warm transition and helium leaks.

In case of an air leaks a thick gas coverage is produced in the vicinity of the leak. This condensation could affect the electron cloud activity by changing the surface secondary electron yield. Because of the high desorption yields of condensed gases, the impact of energetic particles on the layer leads to a quick redistribution of the gas. Hence such leaks lead after each period without beam, to a transient pressure increase altering temporarily the machine performance. The localisation and repair of such leaks are classic.

In case of helium leaks the steep variation of the equilibrium pressure with the coverage leads to the formation of a pressure front[2, 3]. This could result in a magnet quench, excessive radiation rate and increased background for the experiments.

The main diagnostics used to identify possible leaks are: the temperature of the cold mass, the power dissipated per cryo-cell. After the identification of the faulty cryo-cell, mobile loss and radiation monitors can be installed to locate more accurately the faulty magnet/interconnect. Finally mobile vacuum gauges and residual gas analyser must be used to identify without ambiguity the presence of helium. This is the only way to disentangle the many possible sources of losses e.g. aperture obstructions from a real leak. During the discussions stimulated by the presentation, F. Zimmermann proposed to collect the electrons produced, among other sources, by the ionisation of helium to locate a possible leak.

CRYOGENIC ISSUES

Shortcuts during installation and commissioning of the QRL

The impact of various shortcuts have been envisaged leading to the following classes:

- Some tests have no impact on planning and are very useful to train the manpower in view of LHC operation such as the reception tests of the refrigerator systems.
- Other tests are needed to avoid difficult repairs at a later stage and can be made during installation without interfering.
- Finally some tests might interfere with the work of other teams for safety reasons such as the pressure test (mandatory).

Some tests as the heat in-leak measurements have contractual consequences but there is limited repair possibilities, other tests like leak tests could trigger corrective actions. The combined leak and pressure tests cannot be skipped without major risks, if it is postponed any leak discovered at that stage would have major consequences on the schedule. A minimum of one thermal cycle is mandatory and not time consuming. Several cycles on equipments manufactured according to the "old scheme" are highly recommended and could be skipped for the "new production"

Commissioning the DFB's

These critical items feeding the electrical power to the cold magnet system have many variants and hence there is no spare unit. Only spare parts are available for repair: a faulty unit has to be warmed up together with the adjacent magnets to exchange the faulty component.

DFB's will be tested warm and cold before installation. If the cold tests in SM18 are not performed this will result in a longer commissioning in the tunnel. Moreover cold testing is the last opportunity before beam circulation to test the alignment of the beam pipes at He temperature together with the electrical performance of the unit.

The installation rate required at the moment cannot be ensured with the actual resources.

The cryogenic system in point 4

Superconducting cavities are installed at point 4 and connected to the QRL for their helium supply. Available cooling power being not a problem, the concerns are: the pressure stability (±15 mbar at a nominal pressure of 1.35 bar) and the maximum pressure: 2 bar. During some phases of the QRL operation e.g. initial cool down of an arc or quench of a magnet, the pressure in the QRL exceeds this limit value. Another request of the RF group is to operate the RF system while the LHC is down. Several schemes have been studied to avoid an overpressure in the cavities and to decouple the operation of the cavities from the cooling of the magnet. The actual solution operating in SM18 : return through line D with an additional control valve is the reference solution. A back up return via a warm recovery line would be a cheep solution giving a minimum of decoupling between the RF and the magnet system. Other systems providing a more independent operation for the RF systems are far more expensive and time consuming.

Issues related to the reliability of the cryogenic system

The reliability of the LHC cryogenic system is a key element to ensure an operation and commissioning of LHC. Based on the experience of LEP200 (120000 cumulated running hours) a downtime smaller than 2% of the planned operation time is expected. To keep this high availability, preventive maintenance and replacement of important items is foreseen based on a criticity analysis. After a failure, the recovery time can be estimated to 6 hours plus 3 times the stop length

Two scenarios are possible for the maintenance of the refrigerators during shut-downs. In the first scheme the cooling is completely stopped and the whole system is let to ~200K introducing the thermal stresses inherent to a thermal cycle but allowing to pump away most of the condensed gases. In the second scheme, only one cryoplant is stopped and the temperature of most of the components is kept low but condensed gases are not pumped which might be a concern after a scrubbing run. In conclusion the reliability of the cryo system should allow a good efficiency during the commissioning period. In order to maintain this reliability during the LHC operation, appropriate resources should be devoted to the maintenance activities.

CONCLUSION

This session has highlighted several aspects of the cryogenic and vacuum system. The importance of the tests to ensure a good reliability during the phase of commissioning has led to the conclusion that despite a very tight planning only a limited part of these tests could be skipped without taking excessive risks. A baseline solution to avoid overpressure in the superconducting cavities has been presented. It should be streamlined by further discussions between the ACR and RF groups to better assess the real needs and the cost of the possible solutions. Finally the peculiarities of the cold vacuum system have been underlined: One can tolerate large leaks but there is almost no margin between a leak without consequence for the operation of LHC and a leak which necessitate to warm up a complete arc of the machine.

REFERENCES

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[2] J. P. Hobson and K. M. Welch, J. Vac. Sci. Tecnol. A **11**, 1566 (1993).
[3] H. C. Hseuh and E. Wallen, J. Vac. Sci. Technol. A **16**, 1145 (1998).