PROTECTION OF UNDERGROUND AREAS AND HE RELEASE TO SURFACE

S. Weisz, CERN, Geneva, Switzerland

Abstract

This paper reviews the status of the separation of underground areas from the LHC tunnel and the present pressure release paths in case of a large He leak. It also describes the shortfalls of the present situation and presents the strategy for the upgrade/consolidation of the overpressure and He release in case of a Maximum Conceivable Incident (MCI).

INTRODUCTION

A set of recommendations was issued by the Task Force on Safety of Personnel in LHC underground areas following the accident of 19th September [1]. All safety measures required to run the LHC in 2009/10 have been implemented. The main effort concerned the sealing of the experimental areas to insure a safe access to the detectors while the LHC magnets are powered. In addition, the release to the surface of the overpressure and helium flow in case of a MCI involved the installation or modification of ventilation doors around the LHC ring. Preference was given to the limitation of overpressure rather than to structural reinforcement, and the present release paths use the machine access shafts whose hearth cavities allow for the evacuation of massive gas flows.

The sealing of the LHC tunnel towards other underground areas must be pursued together with the study of alternate guided release of the overpressure and helium flow to the surface: the sealing of the LHC underground service areas is required for radio-protection, ODH and fire hazard mitigation [2] and to insure a full control of the underground ventilation [3]; A risk of an helium release in the access shafts appears when any test current in a sector exceeds the powering phase II thresholds defined in [4], and this also precludes access to the adjacent sectors during such tests [5].

PROTECTION OF THE EXPERIMENTAL UNDERGROUND PREMISES

The LHC machine areas and the underground experimental premises present interfaces on the beam line, at the survey galleries and on passages to detector or experimental service caverns. All these interfaces have been made air tight, pressure and fire resistant: detailed description of the corresponding work can be found in the minutes of the control visits made to access the readiness for powering phase II while access is permitted to the experimental areas [6,7,8,9]. A short review of the protections in the various configuration encountered is given below.

Separation on the beam line

The natural interface for the high luminosity experiments is at the TAS level: ATLAS has developed a kind of bell fixed to the beam pipe and to the outer casing of the TAS (see Fig 1) that seals the air gap left for the fine alignment of the TAS. Such a bell is designed for an overpressure of 110mb, providing a substantial margin since 32mb are expected in case of a MCI [10]. The system can stand a 200K lower temperature and allows for a ±15mm lateral adjustment of the TAS. CMS has installed a Z-stopper to prevent longitudinal movements of the TAS and a clapper that seals the air gap around the TAS in case of rapid rising overpressure from the LHC tunnel side.

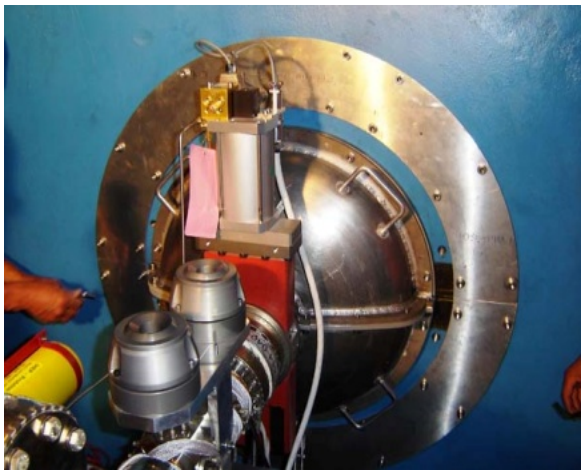

Figure 1: Sealing at TAS level around ATLAS

For the lower luminosity experiments, the interfaces with the machine are materialised by thick shielding walls left of ALICE and on both sides of LHCb, that have been completed by a sealing around the beam pipe. A pressure resistant partition was installed right of ALICE to complete the separation along the beam line: the structure and anchoring of this partition (see Fig 2) is designed to stand an overpressure of 76mb while less than 40mb are expected in case of an MCI [10]. This structure is dressed with steel plates that are sealed to the tunnel vault and floor on the outer edge, and to the beam pipe at the inner edge.

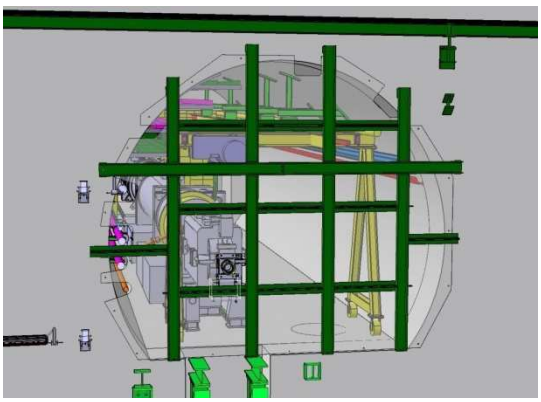

Figure 2: Partition frame right of ALICE

Separation of the survey galleries

Points 1 and 5 have survey galleries to align accurately the low-β triplets on both sides of the experiments. Doors are situated on both ends of these galleries, with access from the experimental caverns and emergency exits to the tunnel. Ducts allows for the passage of invar rods that deport the position of the quadrupoles in the tunnel to the alignment wires located in the galleries.

Metallic pressure resistant boxes have been installed on the LHC tunnel vault around point 1 (see Fig 3) to seal the survey ducts and leave the passage of the invar rods. Consistently, the emergency exit doors have been replaced by pressure and fire resistant doors so that the survey galleries on both sides of ATLAS are protected from overpressure and helium leak from the LHC tunnel.

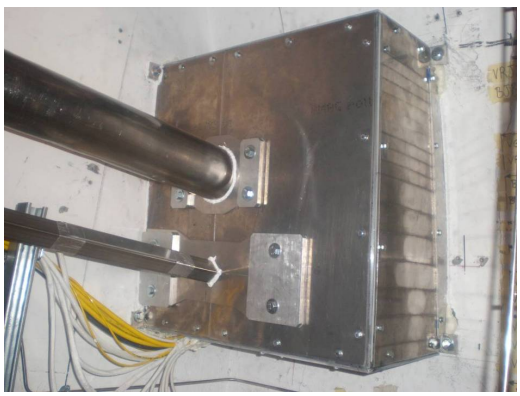

Figure 3: Sealing of survey ducts left/right of ATLAS

The case of CMS was handled in a rush and it is the access doors from the experimental cavern to the survey galleries that have been replaced by pressure and fire resistant doors. This situation does insure the protection of people inside the CMS cavern, but it makes the access to the survey galleries very cumbersome: the access system allows going into the survey galleries when the experiment is in access mode, but the situation would not be safe in these galleries when powering tests are in progress. This actually forces to lock the access doors to the survey galleries. Safe access to a survey gallery requires to physically block the power converter of the corresponding sector and the procedure to deliver the key of the access door is thus rather tedious.

Passages to the experimental caverns

Passages between the areas at the bottom of the LHC access shaft and the experimental caverns are available at Points 1, 2 and 8. These are essentially used as emergency exits when the LHC is not in shutdown mode. The corresponding doors have been replaced by air tight, pressure and fire resistant doors. The case of ALICE is particular since a material access point (MAD) of the interlock access system is the emergency passage between the experimental cavern and the LHC machine area: in this case, a pressure and fire resistant door was added in front of the MAD (see Fig 4) to protect the ALICE cavern.

Figure 4: Additional pressure resistant door for ALICE

There are also numerous passages of services, cables and pipes between the LHC machine areas and the experiments. These have all been sealed with reinforced foam to insure the protection of the experimental cavern in case of an MCI. The passage of the QRL between the LHCb cavern and the straight section left of point 8 (see Fig 5) is one among the most impressive of these sealing.

Figure 5: Sealing of the QRL left of LHCb

Passages to the experimental service caverns

The layout of point 5 presents many passages between the LHC machine area and the CMS service caverns.

Doors from USC55 to the UL bypass can be both access to the LHC tunnel and emergency exits; A service gallery left of point 5 allows to access directly to the low-β triplet and is used to pass the corresponding powering cables. All interface doors have been replaced by pressure and fire resistant doors, and many cable passages have been sealed with pressure and fire resistant rock wool loaded foam (see Fig 6): these are air tight, can stand an overpressure of 110mb and resist to fire for 90mn.

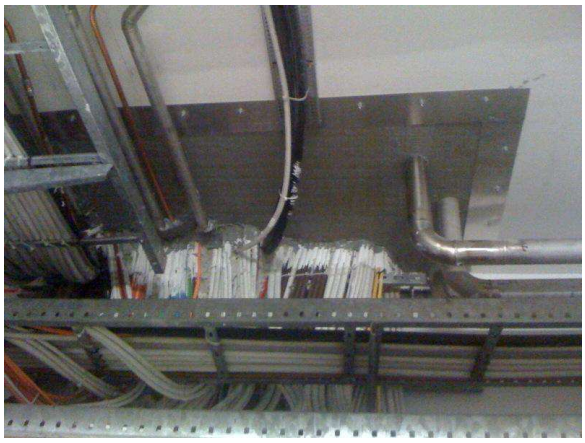

Figure 6: Sealed cables to the CMS service cavern

GUIDED RELEASE OF OVERPRESSURE AND HELIUM TO THE SURFACE

The release of overpressure to the surface uses the LHC access shafts situated at points 1,2,4,6 and 8. The helium flow in case of a MCI is 166m^3/s during ~½minute, requiring a low impedance exhaust path to limit the pressure rise. For instance, with a release at one extremity of a sector, a MCI occurring at the other extremity would result in a static overpressure in excess of 100mb: in order to avoid such pressure rise that could result in collateral damages, there is a release path to the surface at both extremities of the LHC sectors. There are only 5 LHC access shafts equipped with hearth cavities, and thus suited for the extraction of massive gas flow. Several adjacent sectors would need to be linked together through so called "saloon" doors: these doors maintain the separation of the ventilation sectors under normal condition but open in case of overpressure (threshold of 10mb) from any side to allow a free passage of the gas flow. A schematic of the overpressure and helium guided release system is given on Figure 7. The doors located at the bottom of the shafts, giving access to the LHC sectors, have been modified to act as pressure valve and open under a 10mb overpressure from the tunnel side; They have also been reinforced to stand an overpressure of 30mb from the other side, to prevent that the gas flow enters the adjacent sector (see Fig 8).

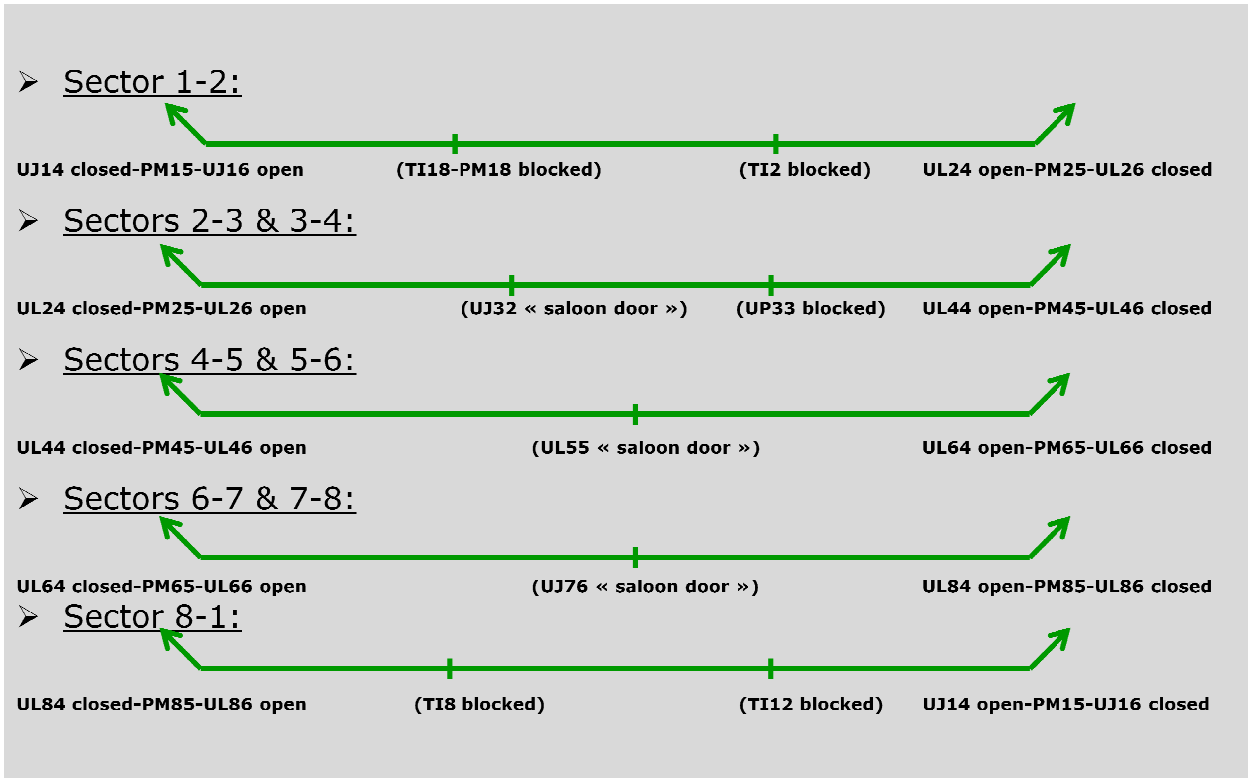

Figure 7: Schematic of the overpressure and helium release to the surface for the 8 sectors of the LHC.

This ensures that the gas flow is ejected to the surface through the shaft's hearth cavities; a 10mb pressure difference is expected between the top and the bottom of the shafts.

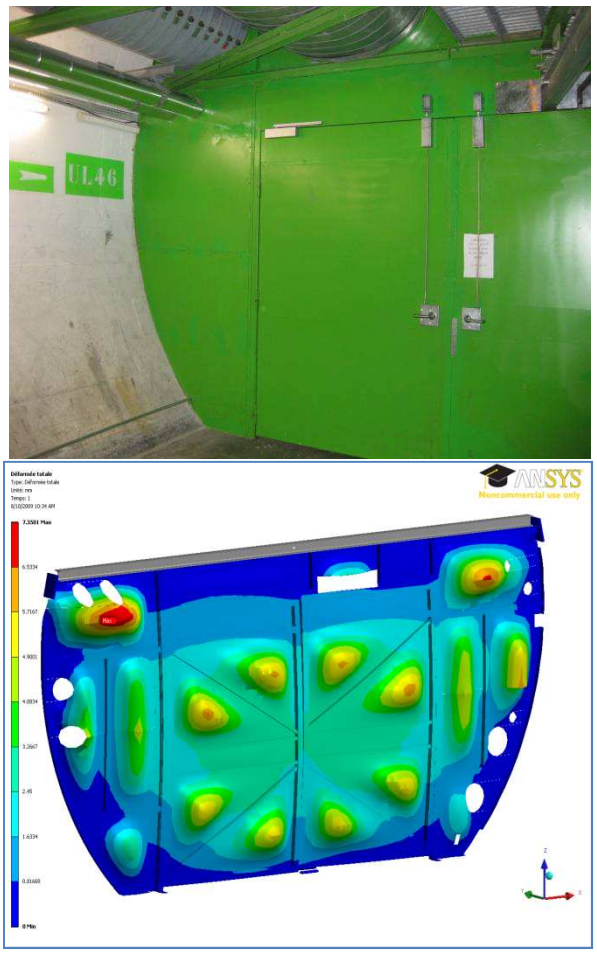

Figure 8: Door in UL46 acting as pressure relief valve. The lower part is a simulation of the deformation under a 30mb overpressure (deformation = 7.4mm max.)

Finally, the surface buildings are equipped with pressure relief windows of $2m^2$ that open under an overpressure of 5mb to let the flow out into the atmosphere.

It is important to note (see Fig 9) that there is no flow restriction between the tunnel and the UL galleries at the even points: the doors separating the UA service galleries from the LHC tunnel have in fact been removed to ease the release of overpressure.

DRAWBACKS OF THE PRESENT SITUATION

As mentioned previously, there is no separation between the LHC tunnel and the service galleries at the even points. The air of these volumes can mix through the UP galleries, the UJ junctions or the numerous ducts that are used to bring services into the LHC tunnel (see Fig 9). Such air mix is not compatible with the mitigation of fire and Oxygen deficiency hazards and does not allow for a full control of the underground ventilation flux. In particular, one cannot exclude uncontrolled release of air activated in the LHC tunnel: the estimated equivalent dose to the public could reach 4µSv/y with 5TeV beams at 10% of the nominal beam intensity. CERN took a commitment that the equivalent dose to the public resulting from its activities remains below 10µSv/y, and this requires a tight separation of the tunnel and service areas volumes under nominal running conditions.

The release paths for overpressure and helium in case of a MCI use the PM shafts, each giving access to two adjacent sectors of the LHC. The risk of oxygen deficiency in a PM shafts, during powering phase II in one sector, thus forbids the access to the adjacent sectors. When powering any of the sectors 2-3, 3-4, 4-5, 5-6, 6-7 or 7-8 above the phase II thresholds, about half of the machine becomes un-accessible when taking into account the presence of "saloon" doors as sketched on Figure 7. Such restrictions are very cumbersome during tests and hardware commissioning, and results in additional time requirements to perform preparation works.

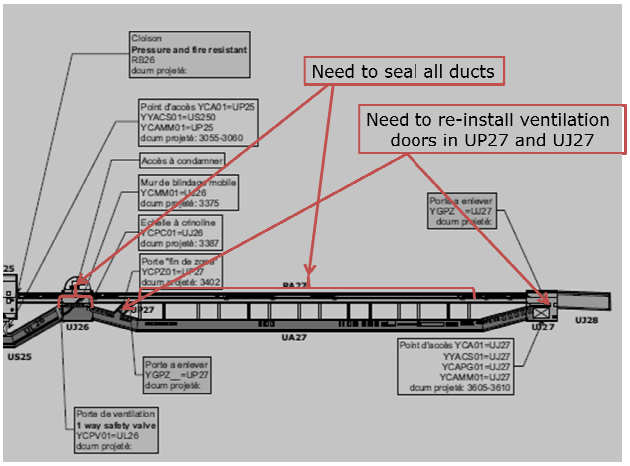

Figure 9: Layout of the service galleries at even point. The right side of Point 2 is shown as a generic case.

STRATEGY FOR UPGRADE AND CONSOLIDATION

Separation of underground ventilation sectors

The first priority is to insure a tight separation between the LHC tunnel and the service galleries at the even points. It was already underlined that it is required to reduce the release of radioactive elements and to mitigate fire and Oxygen deficiency hazards. New doors acting as pressure relief valves in case of a MCI will be re-installed in the UP's and UJ's (see Fig 9). The ducts between the LHC tunnel and the machine service areas also need to be sealed. The main technical difficulty is to seal the passage of power cables whose heat loads must be carried away by some air flow in the duct. A possibility would be to implement boxes, as the one shown on Figure 3 for the survey ducts, with a blower that insure an air flow from the UA gallery to the LHC tunnel. Such a solution also needs to be compliant with the mitigation of fire hazard and must be extensively validated before implementation.

Study of alternate paths for the release of over-pressure and helium flow

Alternative options for the guided release of overpressure from the LHC tunnel to the surface will be studied. As pointed out by the Safety Task Force [1], one such option is to use the existing ventilation ducts equipped with overpressure relief devices and reinforced to withstand the high mass-flow rates. This would be appealing provided the ducts installed in the shafts can stand the overpressure: indeed, the replacement of these ducts would represent a major intervention, with the removal of a large quantity of cables running down the shafts to access the existing ducts.

This is why all existing paths linking the LHC tunnel to the surface will be considered. The list includes:

- UJ18 ➔ PM18 for Sector 1-2
- TI2 ➔ PMI2 for Sector 1-2
- UJ32 ➔ TZ32 ➔ PM32 for Sectors 2-3 and 3-4
- RUX45 ➔ UX45 ➔ PX46 for Sectors 3-4 and 4-5
- UP56 ➔ UJ56 ➔ PM56 for Sectors 4-5 and 5-6
- RUX65 ➔ UX65 ➔ PX64 for Sectors 5-6 and 6-7
- RA83 ➔ UGC1 ➔ PX84 for Sector 7-8
- TI8 ➔ PGC8 for Sector 8-1

And on a longer term scale (>3years), since it involves heavy civil engineering:

- Shafts close to RR13, RR17, RR53 & RR57
- PGC2 (to be emptied from rubble) for Sector 2-3

It is however important to note that the implementation of alternate paths for the release of overpressure and helium flow is essentially to add flexibility into the access matrix. The present paths fulfil all safety requirements and could be maintained for many years. The implementation of new alternative guided releases of overpressure from the LHC tunnel to the surface is thus of lower priority than the separation of underground ventilation sectors.

SUMMARY

All safety measures required to run the LHC in 2009/10 have been implemented. The main effort concerned the sealing of the experimental areas to insure a safe access to the detectors while the LHC magnets are powered. In addition, the release to the surface of the overpressure and helium flow in case of a MCI involved the installation or modification of ventilation doors around the LHC ring. The release paths use the machine access shafts whose hearth cavities allow for the evacuation of massive gas flows.

The present situation has two main drawbacks:

- The air from the tunnel can mix freely with the air of the service galleries at the even points: this limits the control of the underground ventilation flows and does not insure best practice for radio-protection, ODH and fire hazard mitigation;
- The LHC access shafts are on the release path of overpressure and helium flow to the surface in case of a MCI: this puts strong constraints on the access to underground machine areas when a sector is in powering phase II.

The sealing of the LHC tunnel towards other underground areas must be pursued with first priority during the next long shut down. The study of alternate release paths from the LHC tunnel to the surface will continue, to ease underground access during powering tests. However, a full flexibility of the access matrix is a long term objective that may require digging new dedicated shafts.

REFERENCES

[1] Safety of personnel in LHC underground areas following the accident of 19th September 2008, CERN-ATS-2009-002

[2] How radiation will change your life, D. Forkel-Wirth, Proceedings of Chamonix 2010

[3] Modification of the LHC underground ventilation system, M. Nonis, Proceedings of Chamonix 2010

[4] Access and powering conditions for the superconducting circuits in the LHC, EDMS N°1001985

[5] Access Restrictions in the LHC and SPS during the Powering Phase 2, M. Gruwe, EDMS N°1010617

[6] Readiness for powering phase 2: ATLAS, EDMS N°1027686

[7] Readiness for powering phase 2: ALICE, EDMS N°1027705

[8] Readiness for powering phase 2: CMS, EDMS N°1027714

[9] Readiness for powering phase 2: LHCb, EDMS N°1027632

[10] Technical Report on maximum pressure in the LHC tunnel and volume flow toward the different release points in case of MCI, P. Azevedo and B. Delille, EDMS N°1029391