THE LHC VENTILATION SYSTEM SAFETY CONSIDERATIONS

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Abstract

The present document describes the layout of the LHC main tunnel and galleries ventilation system, explaining the design criteria with regards to safety at the time of its construction, and finally providing a summary of the recent modifications approved for the LHC project.

In order to propose improvements of the existing system with respect to safety aspects, a brief review of the available international or national standards is presented, and the most relevant referential is determined and later used for comparison.

Once the referential is fixed, a number of lines of improvement are analyzed, both from the technical (possibility of implementation) and financial point of view, on the basis of which recommendations are made.

THE LAYOUT OF THE LEP HVAC SYSTEM

The ventilation of the LEP accelerator was not designed as a safety system in the late 70s and early 80s. The most significant aspect is the existence of single points of failure (single electrical cubicle, unique I/O cards and CPU in the PLC, absence of back-up electrical power supply for the tunnel units, etc.).

Nevertheless certain redundancy was considered at the time to ensure a high availability of the system. Such is the case with the most sensitive piece of equipment, the air handling units. Each LHC tunnel supply or extraction point features two units (one per sector) whose flow-rate can be increased during operation to compensate, at least partially, for a breakdown of one of them. The same applies to the shaft pressurization units and the cold smoke extraction units. It is of particular interest to point out that the cold smoke extraction units extract the air from the underground unfiltered. These units, which are cut by emergency stop, are operated from the Fire-Brigade cubicles at the entrance of the SD, SX and SDX buildings.

PLC-based control systems continuously monitor and transmit faults and statuses to the CCC for intervention of the stand-by service. In particular, the presence of air flow in the ducts is monitored but there is no verification of the flow of air in the tunnel itself. This implies that if the tunnel shielding, or the ventilation doors are not closed, the air distribution with the design velocities in the machine tunnel cannot be guaranteed.

THE UPGRADE OF THE HVAC SYSTEM FOR THE LHC ERA

It was decided at the onset of the LHC project that the ventilation system of LEP would be recuperated, in its original state, for the LHC. The LHC project has required the addition of a number of independent (post-treatment) systems, to provide cooling for the LHC installations in the underground (UAs, USs, UJs, RRs). New installations have also been purchased for the beam dump caverns at point 6, the RF area at Point 4 and the injection tunnels of the LHC, TIs 2 & 8. Air to these tunnels is supplied from the adjacent LHC even points (2 or 8) and is extracted on the SPS side although no mixing with the SPS volume exists.

The equipment installed in the UAs, (mostly power converters, electronic racks, air-cooled power cabling and some other equipment which cannot resist the activity levels in the LHC machine tunnels) required the drilling of passages for the services – mostly cabling- from the UAs to the RAs. It was later discovered that this cabling presented abnormal overheating in these narrow passages across the shielding walls during the hardware commissioning phase and as a consequence it was decided to leave these drillings unblocked, to favour the evacuation of heat. As a consequence, these two zones (UAs and RAs) are to be considered as a single volume in terms of radio protection, Helium and Fire safety point of view. The many failings in the static confinement between these two areas (which did not exist during the LEP operation time), and the characteristics of the HVAC systems in the UA and the LHC tunnel (both providing static pressure levels very similar at the supply points in the underground) make that in view of the surface of openings, the existing systems cannot guarantee the dynamic confinement between these areas.

To prevent backflow from the underground to the surface, an ECR was approved in 2008 to install ventilation doors in the ULs. These doors have proved very efficient and when closed provide sufficient confinement of the RA-UA assembly.

Other modification of importance is due to the collimators area at point 7. Following the calculations performed by the Safety Commission, it was decided that to increase the decay time before release to the outside, the ducts at the extraction point (Point 7) would be modified and the ducting from the underground to the surface removed. In doing this, the pressurized safe-area giving access to the lift had to be reduced (whereas previously the UJ76 and all the length of the TZ76 was part of the pressurized area, the present safe-area is reduced to the vestibule at the bottom of the shaft. The air extracted from sectors 6-7 and 8-7 is mixed in the TZ76 (where the ratio factor between the previous ducting and the gallery cross-section is at least 10), which becomes effectively a continuation of the LHC tunnel.

REFERENCE STANDARDS

There are many national and some international standards that cover the safety aspects linked to the ventilation of facilities similar to ours. However, most of these are limited to particular aspects (fire safety, radio-protection aspects and general safety aspects). Amongst those analyzed there are:

- National Fire Prevention Association (NFPA). This is a set of codes covering almost of aspects of fire prevention and fire safety in the USA. However does not cover radioprotection aspects. For those, one has to refer to the directives of the Department of Energy for their Federal Physics laboratories, in particular the "Nuclear Air Cleaning DOE Handbook" and the "Fire Protection Technical Report".
- French "Code du Travail" which, for the technical prescriptions regarding the ventilation of work places, in particular in regards to the risks of fire, refers to the Technical Instruction IT-246,
- ASME AG-1-2003, Nuclear Air and Gas Treatment.

But for the author, the most relevant referential applicable is the ISO 17873 (Nuclear Facilities – Criteria for the design and operation for ventilation systems nuclear installations other than nuclear reactors), in force since 2007. This standard mentions that the main purpose of the ventilation system is to improve the safety of the workers, the public and the environment by keeping them free of contamination. It defines a series of functions which are linked to safety:

- <u>Confinement</u> (dynamic) to counteract any defects in the static confinement and limit the egress of contaminants,
- <u>Purification</u> by conveying collected gases, dust, aerosols and volatiles towards collection points (filters, traps, etc.),
- <u>Monitoring</u> of the installation, by organising air flows to allow meaningful measurements and detect spread of activated components during normal and abnormal conditions,
- <u>Cleaning/purging</u> of the atmosphere by renewing the volumes of air (industrial hygiene),
- <u>Conditioning</u> of the atmosphere to obtain optimum functioning of machines,

And specifies that the HVAC system of a nuclear installation ensures that the safety functions be maintained in normal operation and maintenance conditions. The system may ensure some of these functions during abnormal or accidental situations, based upon a previous safety assessment of the installation.

In particular, in the case of fire, the HVAC system should:

- Inhibit the spreading of fire. To that end, the best prevention rule is to create fire compartments, which contains the fire to facilitate the extinguishing operation.
- If the event of fire, the associated HVAC system shall be designed to guarantee that the last level of filtration continues to operate efficiently throughout the duration of the fire (by dilution of gaseous effluents).
- Fire control philosophy will strongly depend on the design philosophy; one of the main objectives shall be the protection of the means of escape for safe evacuation and for fire fighters to gain access. Manual control of the ventilation system is recommended…

In its annual report, a well known Nuclear Power Facilities Operator indicates (Risques et Assurance) regarding the risk of fire in their installations that "in the hypothesis of a fire, the safety functionalities are protected by the confinement of the affected areas, thus limiting the propagation of the fire to a strict number of rooms, the use of non-combustible, self-extinguishing materials, the isolation of the ventilation and the installation of remotely controlled fire-extinguishing systems. Fire brigade intervention in foreseen in times compatible with the limitation of the spread of activated material. This concept may be difficult to apply to long tunnels where the first tens of minutes after the declaration of a fire may be necessary for the evacuation of personnel present in the facilities but the importance of confinement (static even more than dynamic) can be clearly seen in this text.

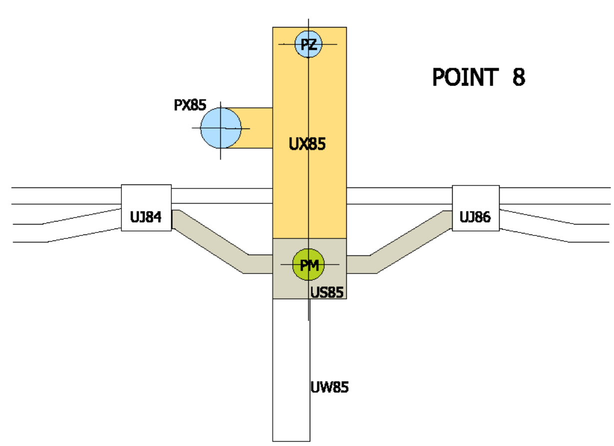
POSSIBLE IMPROVEMENTS TO THE LHC VENTILATION AND CONFINEMENT

Confinement

The case of the LHC presents a difficulty in the fact that the accelerator tunnel (in particular the RA area) and the technical UA gallery housing most of the power converters and other electronic equipment are part of the same volume. This is due to the existence of drilling for the passage of services from the UA to the RA which is not sealed for different reasons.

A similar problem difficulty exists in the Insertion areas of the experimental caverns and the accelerator tunnels, where sealing may be difficult.

It is however of the maximum importance for the confinement of the different risks (helium release, smoke, radioprotection issues) to the area of its origin that sufficient sealing be provided in different ventilation areas.



The standard ISO10648-2 ("Containment enclosures: classification according to leak tightness and associated checking methods") determines a classification of confinement according to the activation/contamination to be expected in these areas. These values are clearly not attainable in the LHC tunnels and Experimental caverns but efforts to improve the sealing of different adjacent areas must continue to provide the highest reasonably achievable confinement, which in the view of the author should be above the value of 20 Pa required by the IT-246 for staircases (or air velocity above 0.5 m/s through openings).

Confinement of the accelerator tunnels with respect to the US caverns and the access areas in the PM shafts has been achieved by means of the installation of additional ventilation doors in the UL galleries, which did not exist in LEP times. The flow of air from the LHC towards the surface buildings has been reduced in this fashion to virtually zero. These doors also play an important role in ensuring the correct ventilation of the machine sectors, by preventing the by-pass of air to the outside. It is recommended that these doors be installed with automatic closers and possibly alarmed in the future, in view of the heavy traffic through these doors for access to the LHC tunnels during shutdown.

Confinement in the fire-proof access modules in the PMs, PXs and PZ shafts has been measured prior to the first run of the LHC in 2008 and found satisfactory. The measured overpressure was in the range or above the 20 Pascals minimum overpressure required by IT-246. The same campaign of measurements focused in the underground accessible areas of the LHC. The results in this case were encouraging but indicated that further improvement was possible and necessary. In general it is not unusual to find spots (insertion areas, drilling for the passage of services or access or service galleries) where numerous openings of different size exist.

Availability of the HVAC installations

A certain degree of redundancy of HVAC equipment exists. The accelerator tunnels air handling units were designed with enough capacity to provide ventilation to both sectors they serve in the event of breakdown and stop of one of them, in a degraded, low-flow-rate, mode.

However, there are many elements in the LEP-era design of the LHC ventilation system that do not coincide with the requirements of a safety-related equipment. In particular the powering of the LHC HVAC system is cut by emergency stops, which makes it particularly sensitive in case of fire.

The pressurization of the access modules is nonetheless one of the few systems that are supplied from a no-break supply and will continue to operate in the event of a general emergency stop, to help in the safe evacuation of people.

Filtration

The existing LHC extraction units have not been fitted with High Efficiency Particulate Filters (HEPA), although it is possible to do so during a shutdown period and could be done if considered necessary for radio-protection reasons. An issue worth studying in case HEPA filters were installed is the need for fire detection inside the air handling units to ensure the integrity of the filtration barrier in the event of a fire in the underground. Most of the contamination spread incidents in nuclear facilities have originated when these extremely effective filters caught fire and were destroyed without being detected or having a possibility of confinement.

The existing system also features manually operated "cold-smoke" extraction units, which the fire-brigade can activate after the extinction of a fire. These units are not fitted with any filters (nor it is possible to) so use of this system should be previously authorized by the Safety Commission's RP service.

The matter of the filtration of the smoke and the use of the unfiltered cold-smoke extraction units brings to light the question on the policy to be applied in case of fire in the underground. There are LEP documents for the Fire-Brigade on the general operation of the HVAC system but these do not provide guidelines on the actions to be taken.

The author believes that, although leaving of course all the freedom to the fire chief on how to act in case of emergency, a general policy should be defined together with guidelines on how best operate the HVAC system in case of emergency and what precautions are necessary to ensure the integrity of the filtration barriers. One additional aspect to be studied is the importance of the atmospheric conditions in the event of unfiltered extraction (wind speed and direction for dissemination studies, rain that may fix and deposit some of the contaminants being extracted, etc.).

Monitoring

The HVAC systems are controlled and monitored by industrial PLCs and supervision systems. Operational parameters should be made available in 2009 via DIP (Data Interchange Protocol) to the CCC and the Experiments. There have been however losses of communication and data. In order to make the availability of important, safety-related, data more reliable independent alarms for the pressurization of the access modules to the underground accessible areas have been wired (via MMD) to TI in CERN's control room. These alarms are independent of the HVAC control system in order to provide monitoring of the functionality even in the event of a control system crash.

There is no monitoring of the velocity of the air in the sectors but indirect methods of monitoring can be achieved if the UL ventilation doors are equipped with closure contacts together with the monitoring of the correct operation of the tunnel supply and extraction units.

CONCLUSIONS

The previously existing LEP ventilation system, which largely constitutes the LHC system, is because of its design difficult to upgrade to conform to recent standards. Full adherence to the latest standards requires serious consideration to ensure their practicality and cost effectiveness.

However, inexpensive improvements of the system can be proposed in hardware, static confinement and operational procedures, although it will require the collaboration of different actors at CERN.