Update on RPC Gas System Status

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on behalf of the CERN Gas Team
A work-package agreement was prepared last year to define all upgrades of CMS RPC gas system: https://edms.cern.ch/document/2068585/3

RE1+ and RE1- gas mixture distribution top/bottom splitting  
- Modification for the RE1 distribution modules to align RE1 to the same top and bottom separation as the rest of the RPC system  
  - Mixture distribution in RE1 was divided in outer and inner rings  

RE3.1 and 4.1 upgrade  
- Modification for the RE3 distribution modules to include mixture distribution to the new stations RPC RE3.1 and 4.1  

Dummy chambers  
- Installation of dummy chambers that simulate the RPC chambers for a reliable measurement of pressure  

Pre-distribution upgrade  
- Addition of automated regulation valves in pre-distribution to automate the chamber pressure regulation
**Dummy chambers**

The chamber pressure for the pressure regulation should be measured at the return of the highest chamber of each sector. Pressure sensors are installed but often they cannot be used due to the presence of leaks at the detector level.

This upgrade consists in the installation of volumes that simulate the chambers allowing to have a reliable measurement of the pressure in a safe place.

- The pressure regulation of each set of chambers will be done by using dummy chamber as reference
- With this upgrade we will have a reliable measurement of the pressure in the highest point of each circuit.
- It will therefore allow to minimize the overpressure at the detector level and, consequently, the risk of developing new leaks at the detector level.
Dummy chambers: status

- All dummy chambers ready for the installation since last year
  - 28 prepared and tested in lab
  - 18 installed in CMS but only for 9 pipes and cables are installed
  - 9 connected and operational

- Waiting for CMS to finish installation of remaining dummy chambers (10) and installation of pipes and cables

- Installed dummy chambers already visible in gas system control panel and used for chamber regulation test
  - Racks 70 (YB-1), 83 (YE+1)
Regulation valves

Nowadays pressure regulation is done automatically for group of racks and only manually for each distribution rack.

The goal is to install new automated regulation valves on the return of each distribution rack to minimize any pressure changes and therefore decreasing the risk of developing new leaks at the detector level.

- The new regulation valves will allow to reduce chamber pressure variations and equalize pressure between different zones of RPC system.
  - They will allow to follow any change in the gas mixture density.
  - This is crucial in particular during gas refill procedure after YETS or LS.
  - They will help also in all situations where different modules need different regulations.
Regulation valves: search

Requirements

- Regulation in the range of few tens of mbar
- Compact (no space available in existing racks)
- Silicon free
- Cheap (<1000 CHF)

- Search on the market for new regulation valves
  - In the market valves with our requirements do not exist
  - ~ 20 regulation valves were tested
    - Many of them designed for higher pressure applications → difficult regulation in low pressure ranges

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<th>VALVE</th>
<th>TYPE/description</th>
<th>FEEDBACK</th>
<th>COST [CHF]</th>
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<td>RESOLUTIONAIR PINCH VALVE</td>
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<td>VON ROHR ELECTROPNEUMATIC</td>
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Regulation valves: test in laboratory

- Set-up in laboratory
  - Possible to test the gas flows of both BARREL and ENDCAP racks (~500 l/h and ~250 l/h)
  - Use of N₂ and R134a
- ~20 regulation valves were tested
  - 4 valves selected for the test in gas system

reference: manual valve

Looking for similar or better behaviours
Regulation valves: test in CMS

- Integration of 4 regulation valves in pre-distribution modules
  - Racks 69 (YB-2 BOT), 70 (YB-1 BOT), 74 (YB-2 TOP) 83 (YE+1)
- Several types of test performed
  - Change of flows, pressure, PID, etc.
- Only two regulation valves gave good results
  - ECONEX and GULEX motor

Valve selected: ECONEX

- But…
  still not sure about final installation
- ECONEX behaviour different in endcap and barrel racks
- Test on-going to find the good valve’s seat and settings
  - Different flows in ENDCAP and BARREL
  - Transition N₂ <-> R134a
  - etc
Regulation valves: magnetic field

- New valves will be installed in USC where there is a B-field of few tens of mT
- Test of ECONEX valve in magnetic field necessary to validate its operation
  - Test performed at 100 mT
- No change of behaviour during movements of the valve and stable operation in B-field in a long run
Regulation valves: few more problems to solve

In addition to find the good valve’s settings...
(probably few more months of tests)

Integration
- Impossible to install the valves inside the gas racks
  - Very very crowded inside
- Impossible to build new racks
  - Missing manpower and money (~50 kCHF per rack)
- Only solution: installation of valves on top of the racks
  - But also here very crowded...
  - Engineering integration study on-going

Purchase
- ECONEX company doesn’t accept CERN rules for purchasing
- Discussion on-going with purchase office and ILO
- If we don’t find a solution, price could be twice or more…
R134a Recuperation System

New R&D to develop the first \( \text{C}_2\text{H}_2\text{F}_4 \) recuperation system

Initial idea was to separate the gas mixture components in 2 phases with cold traps and then extract the R134a.
R134a Recuperation System: status

- First prototype tested in ATLAS at the end of Run 2 gave very good results
  - Pure R134a recuperated with good efficiency
- R134a recuperation prototype installed in CMS in December 2019
  - System under test since January 2020
  - Stop during Covid19 period
  - Activities resumed in mid-May

On-going tests:
- Difficult to reproduce ATLAS results
  - It looks like very small variations in pressures and temperatures can make a big difference in separation and efficiency
- Tests in finding the best parameters configuration
  - A lot of variables to take into account
- Modification and test of new/different mechanical parts of the setup to improve the performance
We discovered that **R134a and iC4H10 form a so called azeotrope:** a mixture of liquids whose proportions cannot be altered or changed by simple distillation.

Results obtained in ATLAS (and now reproduced at CMS) were due to lucky coincidences: we managed to get in perfect conditions for gas separation at the first attempt mainly because of a faulty valve.
R134a Recuperation System: few results

Present status:
- Input flow: 100 l/h
- Good separation achieved in the last two weeks
- Tests performed in a temperature range between -32.5 C and -34.5 C
- Efficiency under study: it seems good at -34.5 C but further tests are needed to confirm
**R134a Recuperation System: plans**

- Fine tuning of temperatures (below -34.5 C)
  - 1-2 weeks
- Improve theoretical understanding of the process (role of the warm buffer and what should be its temperature)
  - In parallel and in collaboration with Department of Chemistry, Pavia
- Repeat detailed measurements of the R134a/iC\textsubscript{4}H\textsubscript{10} azeotrope curve
  - 1-2 weeks
- Increase total gas mixture flow up to 1000 l/h (max expected rate from RPC exhaust)
  - 1-2 weeks to see limit of current system
- Integration of the compressor unit (more difficult with the azeotrope)
  - Several hardware modifications needed
  - 3-4 weeks
- Re-use of recuperated C\textsubscript{2}H\textsubscript{2}F\textsubscript{4} in mixer
  - If previous steps successful
Conclusions

- Change of PLC and software upgrade done last year
  - But standard maintenance has to be done as soon as we can stop the gas system

- Modification of RE1+, RE1- and RE3 distribution modules done
  - Very difficult work because distribution racks were very crowded

- Installation of dummy chambers on-going
  - Gas Team ready, waiting for cables and pipes

- Regulation valve selected but several tests are needed to find the good parameters
  - The valve selected is the best between the 20 valves tested but it is not perfect
  - Probably different valves are needed for Barrel and Endcap
  - Only if we’ll obtain positive results, we’ll go ahead with the installation fo the valves
  - The installation of the valves will require the stop of the gas system for several weeks

- R134a recuperation tests on-going
  - A lot of work has been done to reproduce results obtained in ATLAS
  - Several tests on-going to better understand the process of recuperation of gases
  - Integration of the compressor unit will be done in a second stage