Design validation and Performance of close loop gas recirculation system

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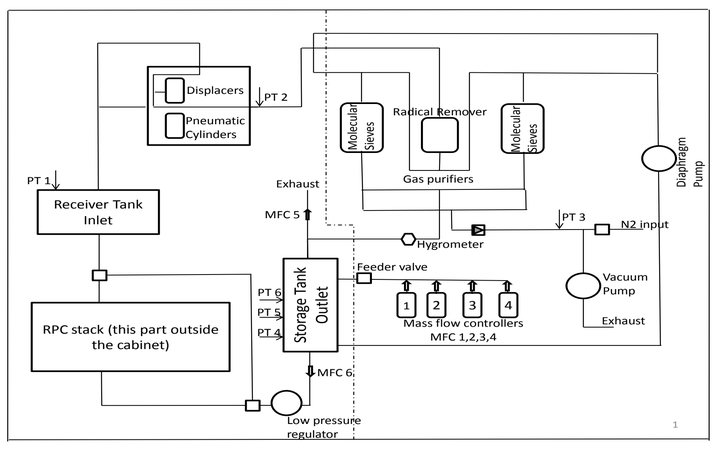
Introduction

- INO-ICAL experiment will use nearly 27000 Glass RPCs of size 2m x 2m each. Three detector stacks having a total internal volume of 250 cubic metres of gas mixture will operate with three independent close loop recirculation systems (Main Module).
- Scaled down Close loop gas recirculation for Engineering module having a single stack of 400 Glass RPC detectors is being designed to serve as a platform for generating specifications for Main Module.
- A Pilot Close loop Gas recirculation for stack of 12 Glass RPCs having 2m x 2m size has been commissioned in 2012 at INO lab TIFR. It is being continuously monitored for 4 years.
- Purpose of Pilot CLS is to study effect of extraneous and internal factors on safety and performance of Glass RPC detectors and to explore and evaluate design variables and parameters for Engineering and Main modules.

Considerations and Assumptions

- Pressure:
  - The pressure of gas mixture inside RPC can be held constant.
  - A narrow band of pressure is defined for operation to protect the RPC from over-pressurization
  - Pressure inside RPC should be more than atmospheric pressure to avoid entry of contamination into RPC in case of leakage.
- Gas flow rate :
  - It is controlled proportional to the deviation of pressure inside RPC from minimum and maximum allowable limit (Band of Pressure)
  - One volume change per day is sufficient to purge RPC of contamination. The equivalent gas flow rate is 6 SCCM through each RPC of 2m x 2m size.
  - Gas volume lost due to leakage is replaced (topped up) by preparing mixture through Mass Flow Controllers.
- Gas Concentration:
  - Transients in Mass flow controller operation will not interfere with concentration.
- Safety:
  - Harmful Radicals may form during passage of gas mixture through RPC, these need to be removed through chemical reaction.
  - Gas cylinders storage can be located outside Lab.

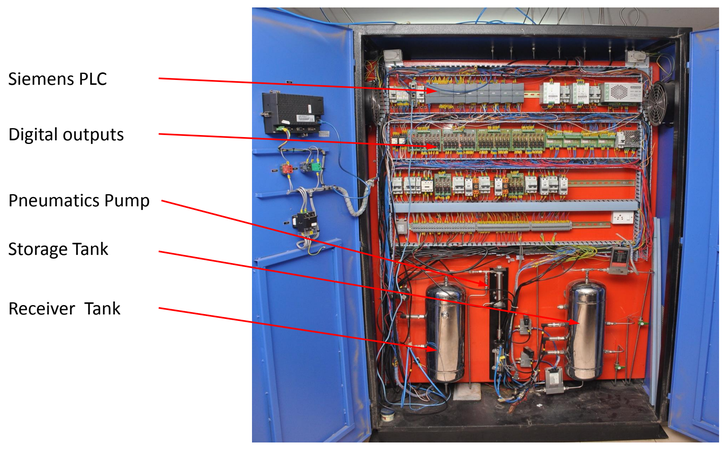
Schematic of Pilot Closed Loop Gas Recirculation System



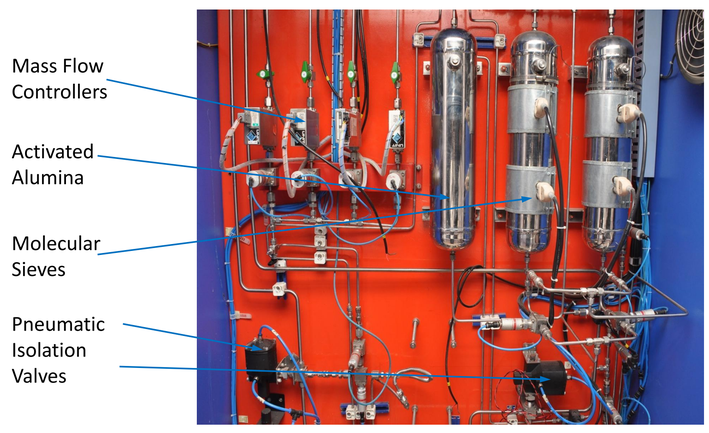
Close loop gas recirculation system

- The CLS supplies gas to12 RPCs of 2m x 2m size. A 1 stage pneumatically operated +ve displacement pump sucks gas mixture from receiver tank, connected to RPC outlets, at pressures between 1002 mBarA and 1005 mBarA and delivers to purifiers and to storage tank at 1650 mBarA.
- When Storage tank pressure drops below 1350 mBarA, Mass flow controllers, set at 95:4.5:0.5 ratio of R134a, Isobutane and SF6 respectively, start feeding gas mixture to storage tank till pressure is topped up to 1650 mBarA
- Residual Gas Analyzer (RGA) is connected at outlet of RPC exhaust.
- Solid State Pressure Transmitters monitor pressure of gas at 6 points. Atm. pressure is also measured.
- Siemens PLC with I/Os, actuators and SCADA interface control the flow and pressure throughout the loop. A Safety routine is built into the Logic. Data (14 parameters) is logged with time at different intervals.
- **Pilot CLS has achieved leak rate of 0.09 SCCM when connected to 4 RPCs of 2m x 2m size for 21 days.**

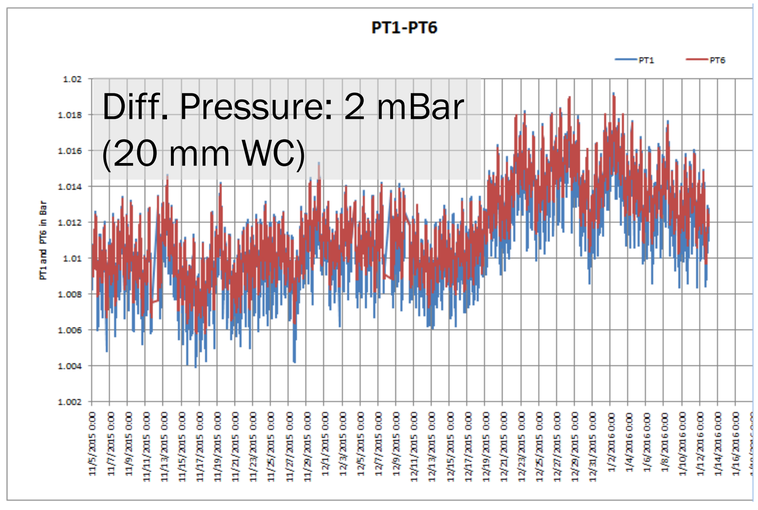
CLS Front view



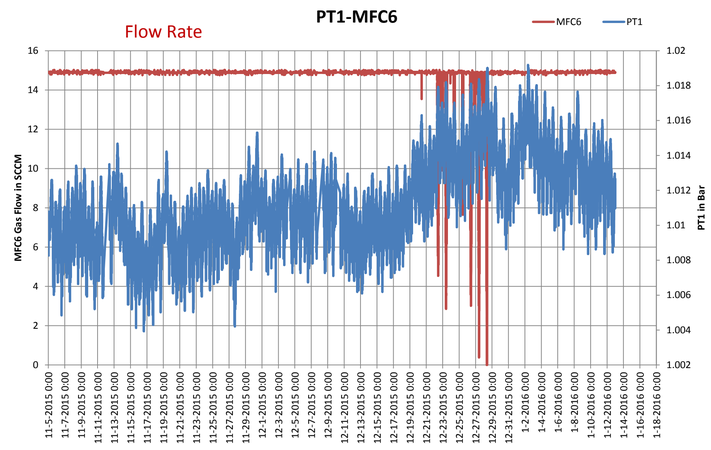
CLS Back view



Pressure variation over three months (Nov15-Jan16)



Pressure and flow through RPCs



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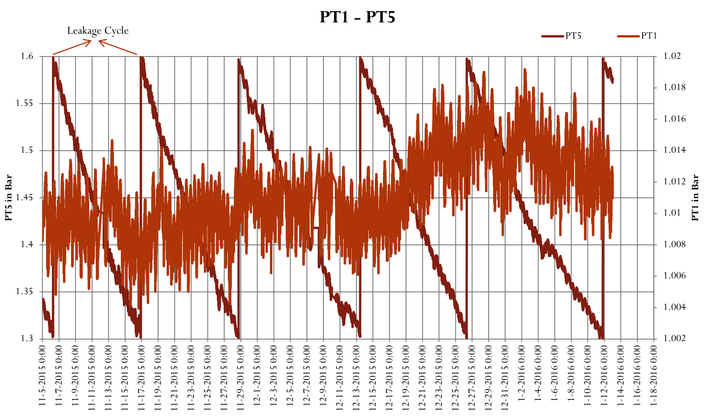

Results

- 2mBar (20 mm WC) pressure across RPC does not distort or damage it. At this pressure leak rate is low.
- During extreme weather turbulences, Atm. pressure may drop as much as 30 mBar within few hours.
- 6 SCCM flow is not enough if Atm. pressure drops faster than 1 mBar/Hour.
- RPC pressure should "follow" atmospheric with 2mBar Differential Pressure.
- 100% gas flow within pressure of 2 mBar is good.
- No evidence of Radicals was found by RGA Transient flow in MFC operation cause errors, MFC control valve must be electrically grounded.
- R134a heavier than Air, causes higher pressure in bottom RPCs.
- Liquid Isobutane is very corrosive .

Conclusion

- RPCs should be operated under negative differential pressure with respect to Atmospheric pressure
- A provision for 5 volume changes/day flow rate must be made for emergency Atmospheric pressure transients.
- Actual position of an RPC in the stack must be considered to calculate effective pressure inside.
- 2 mBar Differential pressure is safe for 2m x 2m RPC
- Mass flow controllers should be vented before and after back fill cycle. MFC control valve should be electrically grounded when not in use. The valves must be Normally Closed
- Under cosmic conditions Radicals are not produced from SF6 gas inside RPC.