Daya Bay Near Experiment Hall

RPC Gas System

Procedure for operation of the RPC gas system

(1/31/2011)

DocDB #6076-V3

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1. Purpose

The Daya Bay RPC gas system provides predefined gas mixture to the RPC modules. Each experimental hall has its own RPC gas system. The gas system is designed to be robust and well protected from fault operation. However if the operator does not follow the operating instruction, it may interrupt the normal operation of entire RPC system. Resuming the nominal gas mixture may take hours or even days. Although the routine maintenance and system debug are the tasks for gas experts, the gas cylinder replacement and the system daily check-up are supposed to be the routine tasks for the trained personnel, the basic operation concept of the gas system is also important information for the shifter in case of emergency they will know what action they need to take immediately. This procedure provides the basic information of the gas system and the daily operation of the RPC gas system. Shift taker should read through this procedure carefully. Since the RPC gas mixture has flammable gas - isobutane in it, extra precaution must be taken when you are operating the system.

2. Scope

This document covers the basic information about the RPC gas system.

3. Policy

Princeton University has provided the RPC gas system, is responsible for the safely running this system, however the Daya Bay experiment needs a team to operate and maintain the normal operation of this system. The procedure mentioned in this document should be the routine tasks for this team.

4. References

The RPC gas system user's manual (DocDB #5441 http://dayabay.ihep.ac.cn/DocDB/0054/005441/001/DayaBayGasSystemUserManual.pdf) is the most comprehensive resource for those who want to know the details of the RPC gas system. This document is just a short version of the user's manual.

5. Definitions

6. Precautions and Limitations

This procedure intends to provide the basic information for the operation of the RPC gas system. The execution of this procedure is the task of the Daya Bay RPC gas team only, not for every shift taker. During the experiment if there is any warning message appeared on the DCS screen, the shift taker can obtain detail description of the warning from this document or the RPC gas system user's manual. In emergency case please be advised that contact gas expert (Changguo Lu, Tel. 1-609-258-1288, Jilei Xu, Tel.13426305618) to get immediate advice before taking any action.

7. Parts and Equipment

8. Procedure

8.1 Introduction of the Daya Bay RPC gas system and its operation procedure

The gas system building blocks are shown in figure 1.

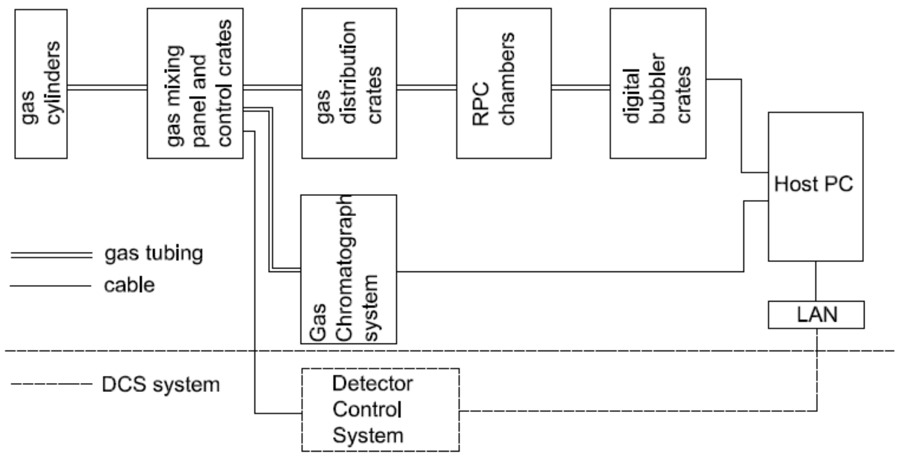


Fig. 1. Daya Bay RPC gas system building blocks.

8.2 Description and operation of the RPC gas system

8.2.1 Gas cylinders and cylinder switchover panel

Four gases are used for Daya Bay RPC gas mixture: Argon 65.5%, R134A 30%, Isobutane 4% and SF6 0.5%. To eliminate the down time when the depleted gas cylinder is being replaced, for each gas line a gas switchover panel is equipped. For the argon gas an automatic gas switchover panel is used, it is shown in figure 2 and 3. For the other three gases the manual switchover panel is employed, shown in figure 4.

8.2.1.1. Automatic switchover panel

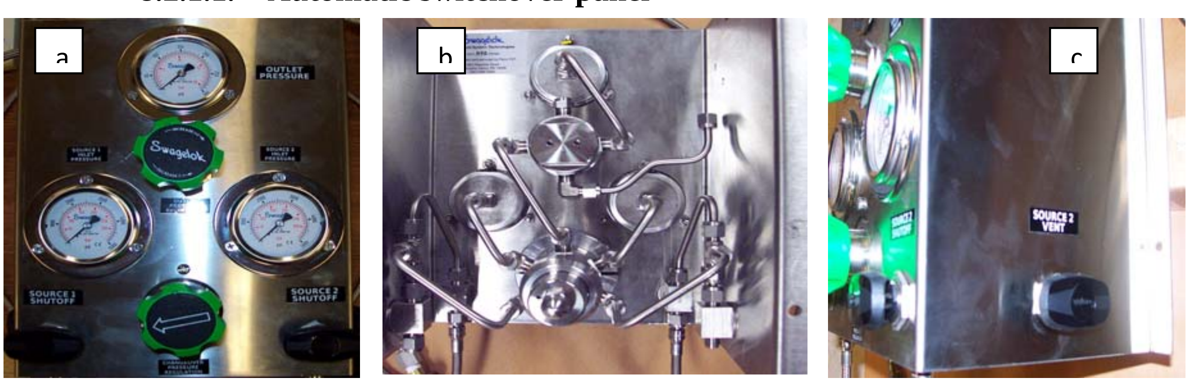


Fig. 2. Argon cylinder automatic switchover panel. (a) Front; (b) Rear; (c) Side.

Operation procedure of this panel is as follows:

The illustration of various parts and the mechanical sketch of this switchover panel is sketched in figure 3.

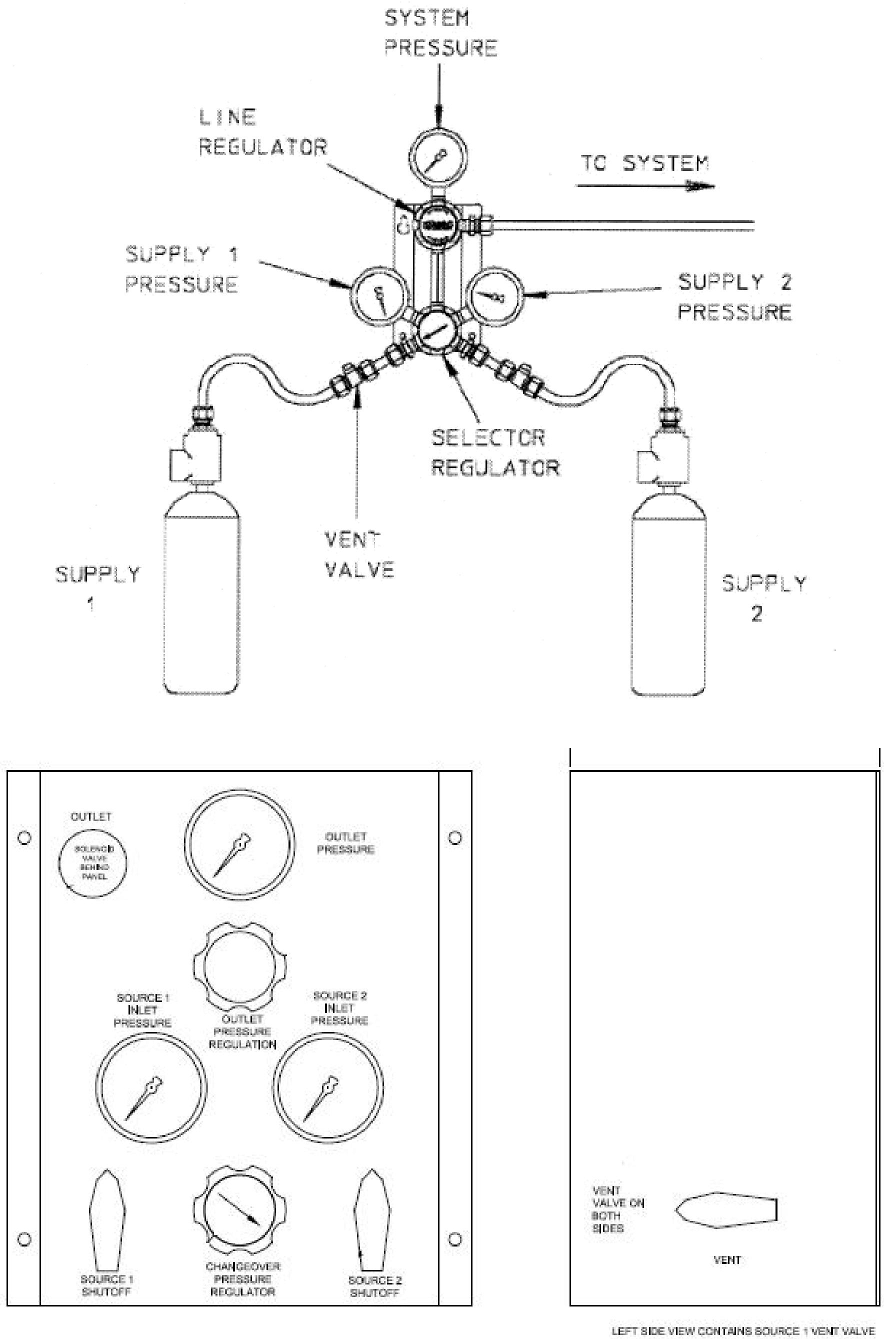


Fig. 3. Illustration of various parts and mechanical sketch of argon automatic switchover panel.

When the supply side pressure drops below 100 psig, the selector regulator is then internally switched to the other side of the gas supply. The respective inlet pressure gauges show two sides gas pressures, therefore the operator will know which side is depleted, and can replace the bottles.

To change the depleted bottles please refer to the "Procedure for replacement of the argon cylinder", DocDB #xxxx-Vx.

8.2.1.2 Manual switchover panel

Two types of manual switchover panel are used, one with the solenoid valve at the outlet as shown in figure 4, is used for Isobutane gas; the other one w/o solenoid valve is used for both R134a and SF6.

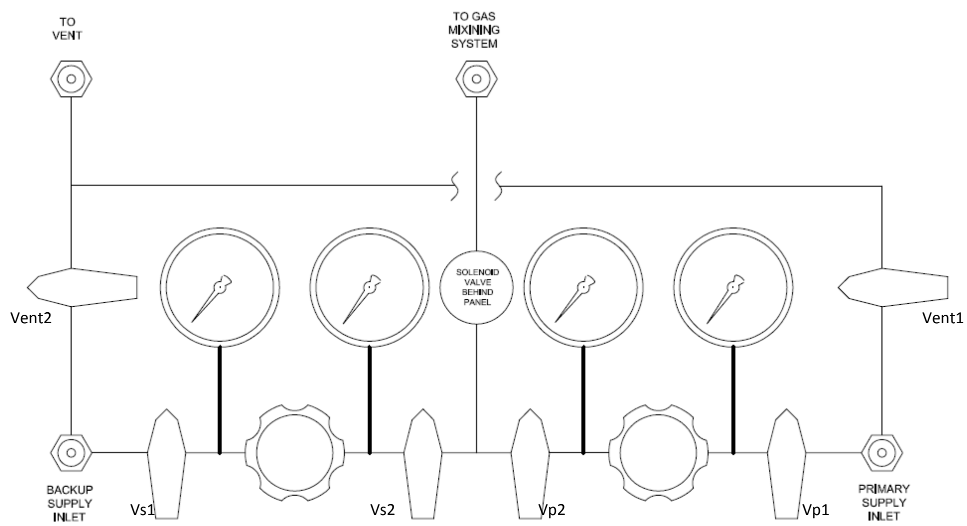


Fig. 2. Manual gas switchover panel used for isobutane.

The isobutane gas switchover panel is installed inside the gas cabinet, its photo is shown in figure 5.

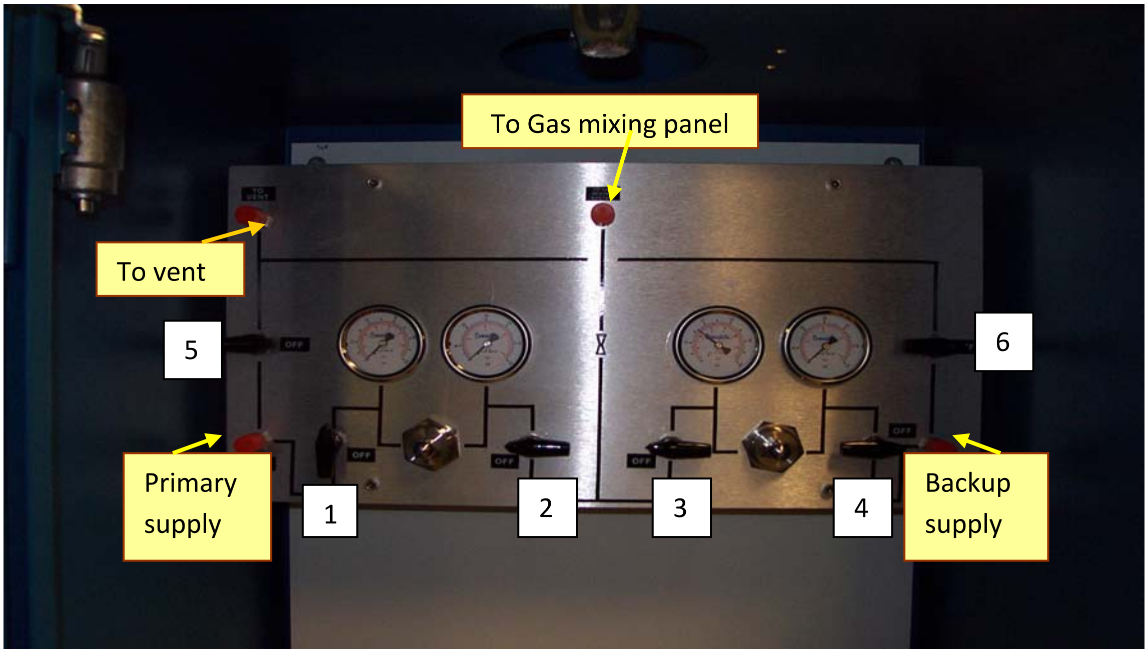


Fig. 3. Isobutane gas switchover panel mounted inside of the gas cabinet.

The solenoid valve controls the isobutane gas outlet. In emergency the gas control system will automatically shut off the power of this valve, therefore no isobutane gas will flow into the gas mixing panel. To replace the depleted Isobutane cylinder please refer to the "Procedure for replacement of the isobutane cylinder", DocDB #6071-V3.

The manual switchover panel for SF6/R134A is similar to Isobutane panel, only difference is without the solenoid valve before the outlet port. To replace the depleted SF6/R134A cylinder please refer to the "Procedure for replacement of the SF6 and R134A cylinder", DocDB #6072-V3.

8.2.2 Gas mixing and control system

The outlets of the switchover panels for four gases are connected to the inlets on the gas mixing panel via ¼" Swagelok fittings. This system consists of gas mixing panel and four crates: flowmeter crate, pressure crate, power supply crate and gas status crate.

8.2.2.1 Gas mixing system

8.2.2.1.1 Gas mixing panel

The picture of the gas mixing panel is shown in figure 6. Figure 7 shows the schematic of the mixing panel.

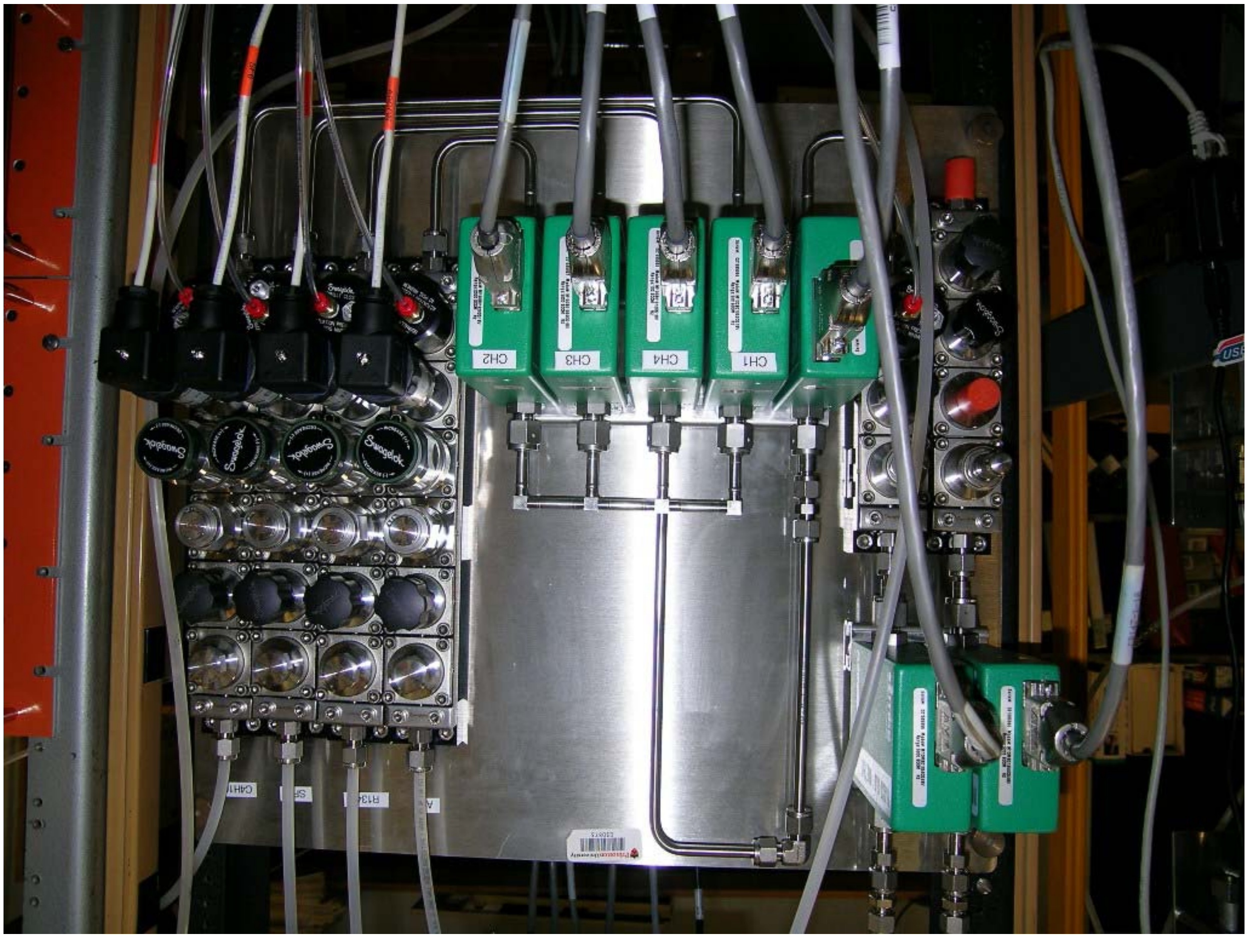


Fig. 6. Gas mixing panel (Penn Fluid System, ASY-550).

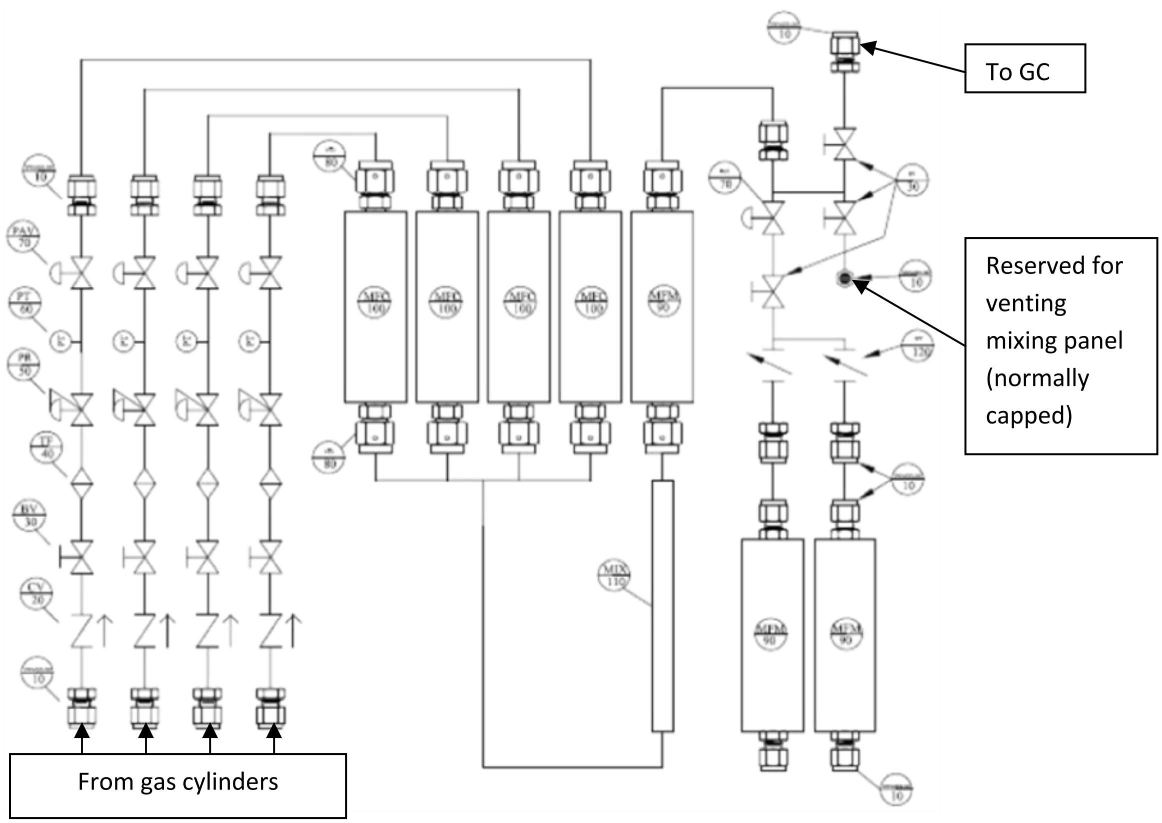


Fig. 7. Schematic of the gas mixing panel.

Table 1. Gas flow controller's parameters.

Channel #	Gas	Full range for N_2 (sccm)	Gauge factor	Gas Correction Factor	Calculated Scaling Control Factor (SCF)	Set the rear Scaling Control Pot	Calibrated at flow rate (sccm)
1	Isobutane	500	50	0.273	13.65	152	150
2	Ar	2000	200	1.4119	300	035	1000,250
3	R134A	5000	50	0.3115	16.8	175	500
4	SF_6	100	100	0.2502	26.99	035	20

This mixing panel can mix 4 gases, including 0.5% of SF_6. There are two additional outlet ports on the top-right corner in figure 7. One port is connected to a GC system to check the gas mixing ratio once every two hours. The other port is reserved for venting the gas mixing system in certain circumstance. Four mass flow controllers are controlled by MKS 247D, see figure 8.

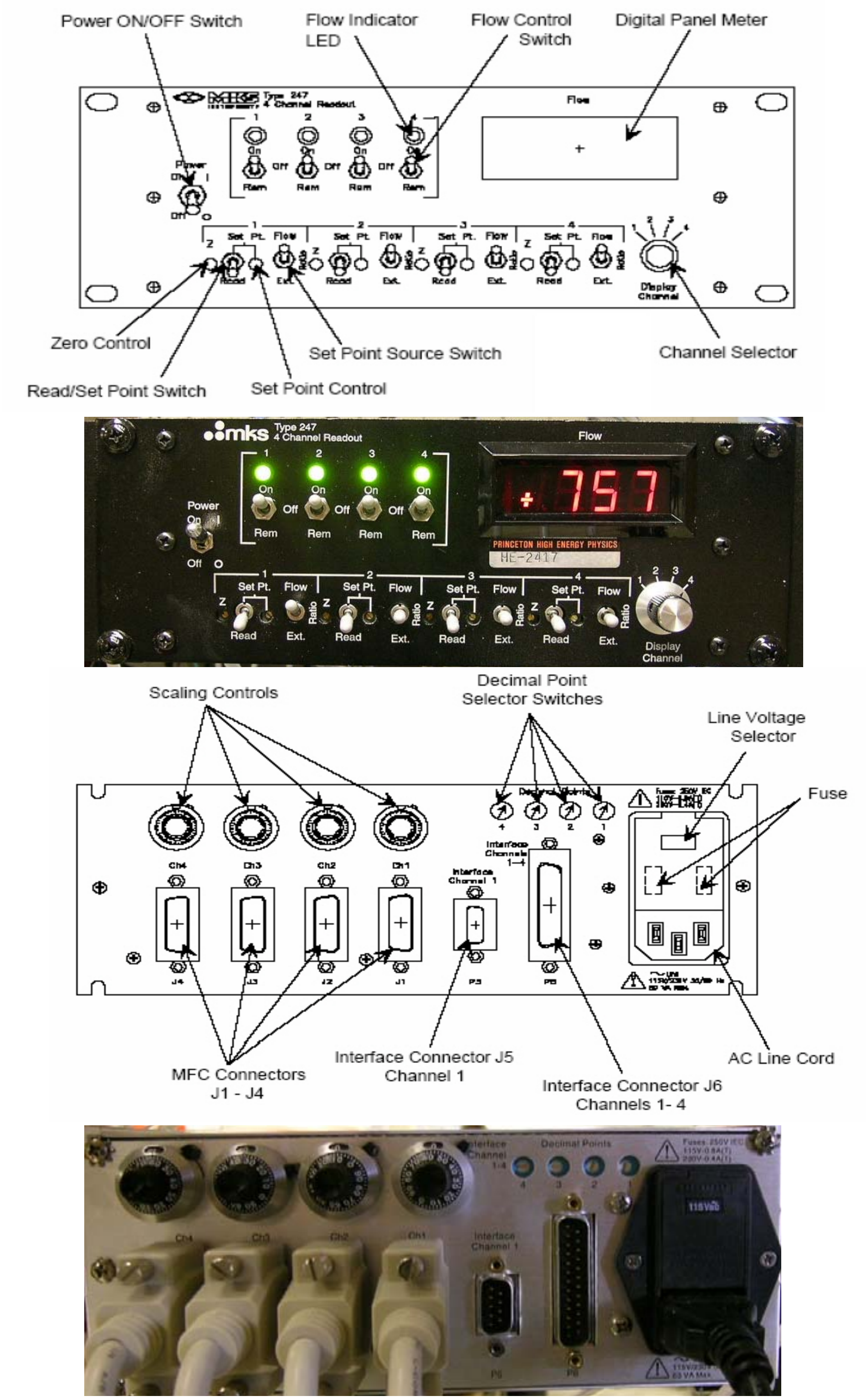


Fig.8. MKS 247D four-channel readout box, (Top) front panel, (Bottom) rear panel.

Detailed information on using this box can be found from “MKS Type 247D Four-Channel Readout Instruction Manual”. Here we just give a brief description of this control box.

The operation of MKS 247D is set in the ratio mode, the channel #1 (Isobutane) is the master channel; the other three channels are slaves. On the front panel the Set Point Source Switch is set at “Ratio” position for channel #2, 3, 4, and at “Flow” position for channel #1. If you need to change the total flow rate and maintain the mixing ratio unchanged, you only need to change the flow rate of the first channel by adjusting its potentiometer “Set point” on front panel of 247D.

The Varian 430 GC system is used to verify the mixing ratio.

8.2.2.1.2 Water bubbler

The water bubbler is used to add ~4000ppm water vapor into the gas mixture. The gas mixture is split into two branches: one branch of the gas will be bubbling through water. The water vapor saturated gas mixture is then mixed with the dry gas mixture from the other branch. By adjusting the flow rate in two branches we can easily change the water content in the gas. Figure 9 shows a picture of this system.

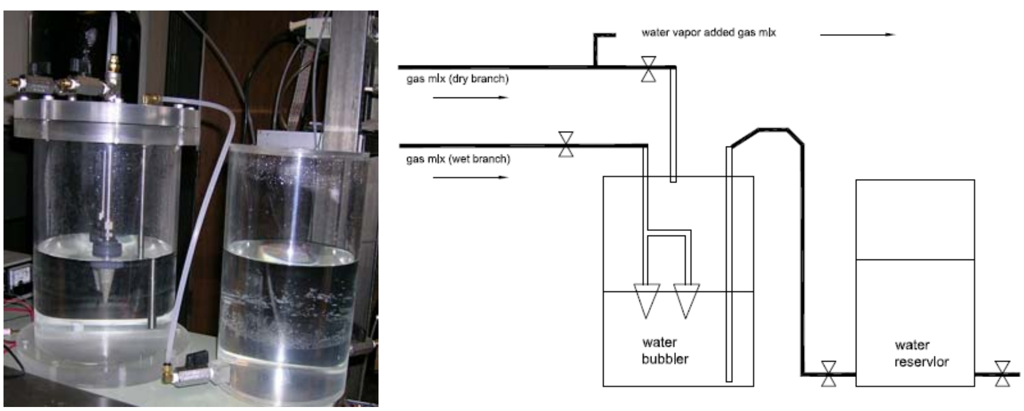


Fig. 9. Water bubbler.

The left tank is the water bubbler, gas mixture is flowing through a sintered metallic bubbler head and entering the water, getting saturated water vapor in it before flowing out the tank. The right tank is used as a water reservoir. There is a tube connecting two tanks through a valve. There are marks on each tank to indicate the required water level, the water level in the reservoir always higher than the level in the water bubbler. Anytime if we need to add water into the bubbler, we only need to open the valve and let the water flows from reservoir to bubbler. If the water ceased flowing, lift the water reservoir will help the water flow. Be advised that use the distilled water to fill the tanks only.

8.2.2.2 Gas control system

The gas control system includes four crates, they are: Gas Flowmeter crate; Gas Pressure crate; Power crate and Gas System Status crate.

8.2.2.2.1 Gas flowmeter crate

The gas flowmeter crate is used to display the gas flow rate from four mass flow controllers and three flow meters. The later are for the water vapor control branches: total, dry branch and water vapor added branch. A normal flow rate band is defined for each of seven flow meters, if the flow rate is out of this preset band, the build-in relay of the Simpson controller will be acting accordingly. This signal will be sent to gas pressure crate, which will control the solenoid valve. The abnormal flow rate/pressure signal will shut off the solenoid valve, which in turn will close all gas inlets to the mixing panel. In reality the gas flow rate/pressure fluctuation due to power supply glitch and/or atmospheric pressure sudden change is possible during certain season. To eliminate this type of interfere there is a "BYPASS" timer push button, push this button can bypass the status check logic for 5 minutes (meanwhile a buzzer will be actuated to remind you that the bypass is acting), keep the solenoid valves open for such time duration. Usually within this period the environmental fluctuation would calm down and return to normal, therefore the gas system will continually operate w/o interrupt. When you see all flow rates and pressures show normal value, the Simpsons show no warning signs on the right side bar, you should push the RESET/START button, and the "Flow Interlock OK" green light should be back on. This "BYPASS" button is also very useful during the cylinder replacement operation. Push this button before the cylinder replacement can temporarily disable the interlock mechanism, thus avoid the unwanted system interlock that may be caused by the cylinder replacement.

There is a RESET/START button on the front panel. When the entire gas system is just powered up, push and hold this button down until all seven flow rates displayed on the Simpson meters reach normal value (no warning sign on any of the meters), then release the button. By doing this the system will lock itself in a normal operation mode until the next abnormal state occurs. After you push this button, the green light labeled as "Flow Interlock OK" should be on. Also the water branches green light should be on, red light should be off.

The water branches are used for adding water vapor into the gas mixture. There are three Simpson meters to display the flow rate for branch #1, #2 and the total. Branch #1 gas mixture will be bubbling through water, then combine with the dry gas mixture from branch #2. The metering valves on branch #1 and #2 can adjust the flow ratio between them, thus adjust the water vapor content in the mixture.

Figure 10 shows the picture of the front and rear panels of the flowmeter crate.

A B

Fig. 10. Gas flowmeter crate, A. Front; B. Rear.

8.2.2.2.2 Gas pressure crate

The gas pressure crate is used for displaying the gas pressure at the upper stream of the flow controller for each gas. The ambient pressure will read as 0 psi. When any gas shows lower than preset pressure limit, this crate will generate warning signal, shut off the solenoid valve that will in turn shut off all gas inlet ports on the gas mixing panel.

The pressure can be adjusted by four gas regulators on the gas mixing panel (you are NOT permitted to adjust the regulators!). All gas pressures are maintained around 20 psi, at higher pressure isobutane might be liquefied at lower temperature, the orifice of mass flow controller for the Isobutane might be clogged to cause it malfunctioning. If it happens call gas expert immediately and get guidance.

The front and rear panels for the pressure crate is shown in figure 11.

A B

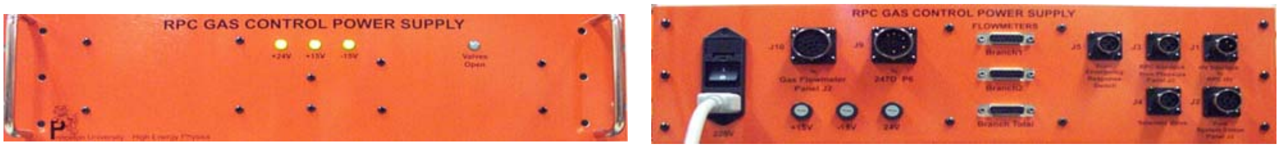
Fig. 11. Gas pressure crate, A. Front; B. Rear.

8.2.2.2.3 Gas system power supply crate

The power supply crate provides the DC power to all flow meters, solenoid valves.

There are four lights on the front panel: +15V, -15V, +24V, (solenoid) Valves open. In normal case all of them should be on.

Figure 12 shows the front and rear panels of the power supply crate.



A B

Fig. 12. Gas power supply crate, A. Front; B. Rear.

8.2.2.2.4 Gas status crate

Fig. 13 shows the gas status crate.

The front panel of the gas status crate is divided into two regions: the right region displays RPC gas system status and the left region is fire safety system status.

Gas system status region shows: 1, Actual weights of isobutane, R134A and SF6 gas cylinders and their Weight Low Warning LEDs. Any of these three gas cylinders hits its preset low weight limit, this warning red LED will light up to indicate it is the time for replacing the depleted gas cylinder. 2, Relative humidity of the fresh gas mixture (flowing into the RPC module) and the return gas mixture (flowing out the RPC module). Two gas sub-branches are monitored. By rotating the Gas Humidity switch the % of relative humidity for channel #1 or channel #2 will be displayed on the Simpson controllers.

Fire safety system region displays % of LEL measured by HAD #1 and #2, gas cabinet air ventilation velocity. HAD sensor #1 is installed at lower section inside the gas cabinet, HAD sensor #2 is mounted outside the gas cabinet. They have been calibrated by 0.9% of isobutane in air, which is 50% of isobutane LEL. When the measured level reaches 10% LEL, the warning LED will turn on. If the level reaches 25% LEL, the solenoid valve that controls the opening of all four pneumatic valves in front of each gas inlet will shut off, thus all gas inlet ports on the gas mixing panel will shut off. The gas cabinet air ventilation is monitored by a Pitot tube and a Digihelic differential pressure meter, which measures air velocity. We set the ventilation warning limit at 0.005” water.

A B

Fig. 13. Gas status crate, A. Front; B. Rear.

8.2.2.3 Emergency shutoff system

There are two emergency response mechanisms constructed in the gas system: hardware push button and software clickable button on the detector control gas system monitoring page.

Hardware solution: There is an emergency shutoff switch installed on the outside wall of the gas room as shown in Fig. 14. This switch is enclosed under a spring loaded Plexiglas cover. In an emergency case people can lift the cover and push the button, it will shut off the entire RPC gas system immediately. All gas inlets on the gas mixing panel will be closed, the solenoid valve in the Isobutane gas cabinet will also close, therefore no more Isobutane gas flows out the gas cabinet. At the same time RPC interlock will be activated, HV will be automatically reduced to a safe value to protect RPC modules. The remaining gas mixture upstream of RPC modules will continue flow into the modules until the gas pressure of the mixture reaches the ambient atmospheric pressure. The RPC modules are still protected by the output gas bubblers, which keeps the RPC modules' gas pressure about 3cm W.C. higher than the ambient pressure.

Software solution: On the slow control gas system monitoring page, there is a clickable emergency button, when this button being clicked, a popup window will ask for your confirmation for shutting down the gas system, if it is conformed, then it will function just like what the hardware push button does.

Fig. 14. Emergency shut off switch. To use the switch lift the cover and push the button.

8.2.3 Gas distribution/digital bubbler system

The Daya Bay near hall gas distribution/digital bubbler system consists of seven panel-branches. A schematic of this system is shown in figure 15.

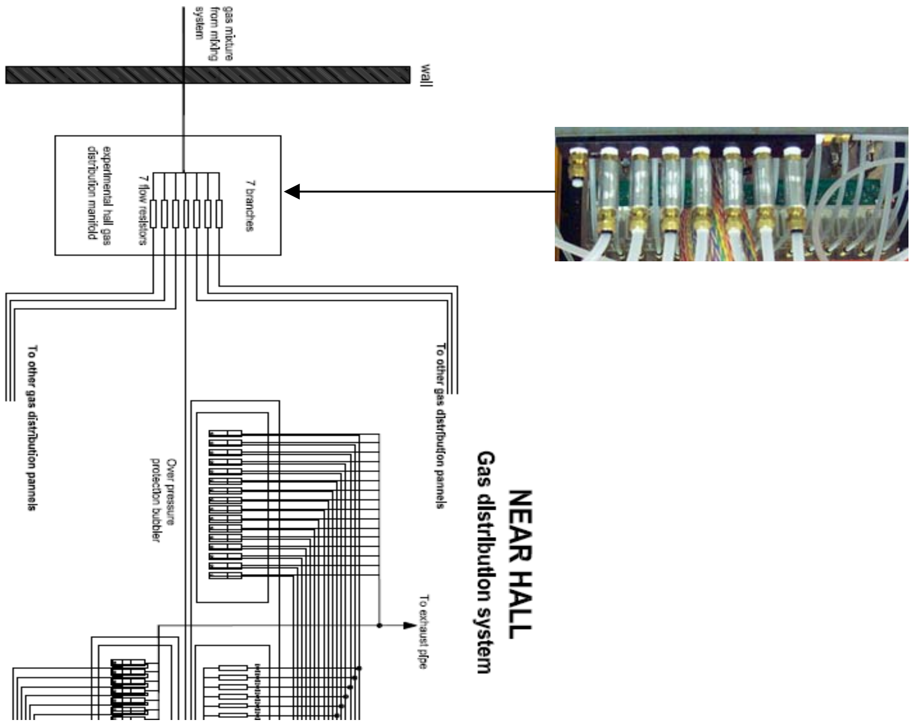


Fig. 15. Daya Bay near hall RPC gas distribution system (part).

The schematic diagram of one panel-branch of gas distribution/digital bubbler system is shown in Fig. 16(A), its photo is in Fig. 16(B).

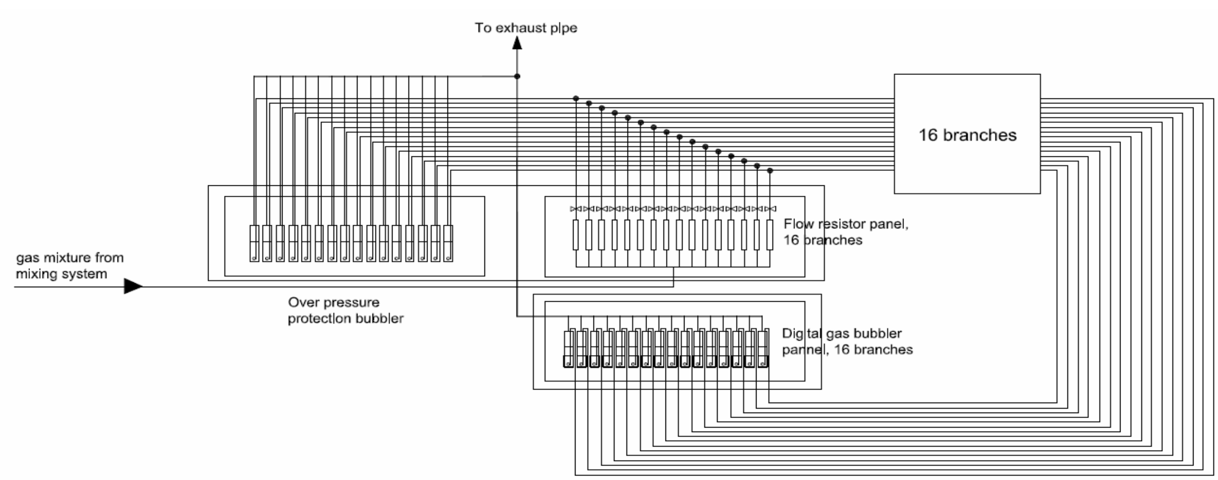


Fig. 16(A). One panel-branch of gas distribution/digital bubbler system

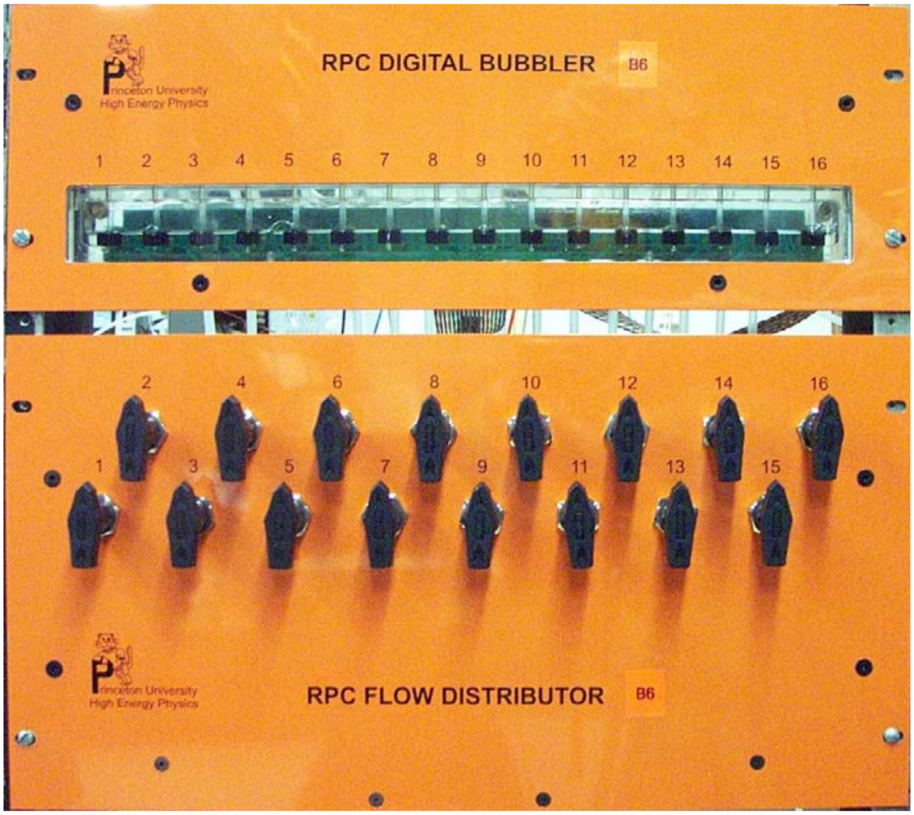


Fig. 16(B) Gas distribution (bottom) and digital bubbler (top) panels.

For a gas detector system the oil bubblers are always used at the outlets of the chambers to isolate the gas chamber from air. Besides this basic function the digital gas bubbler can provide additional quick on-line diagnosis of gas flow. In this system the bubblers are instrumented with photogates. Its working principle is illustrated in figure 17. Without gas bubble the light reaches the photogate through oil without interruption. When a bubble passes, it will reflect partial light, and the light intensity at that moment would be reduced, thus generates a pulse signal to the photogate PC board.

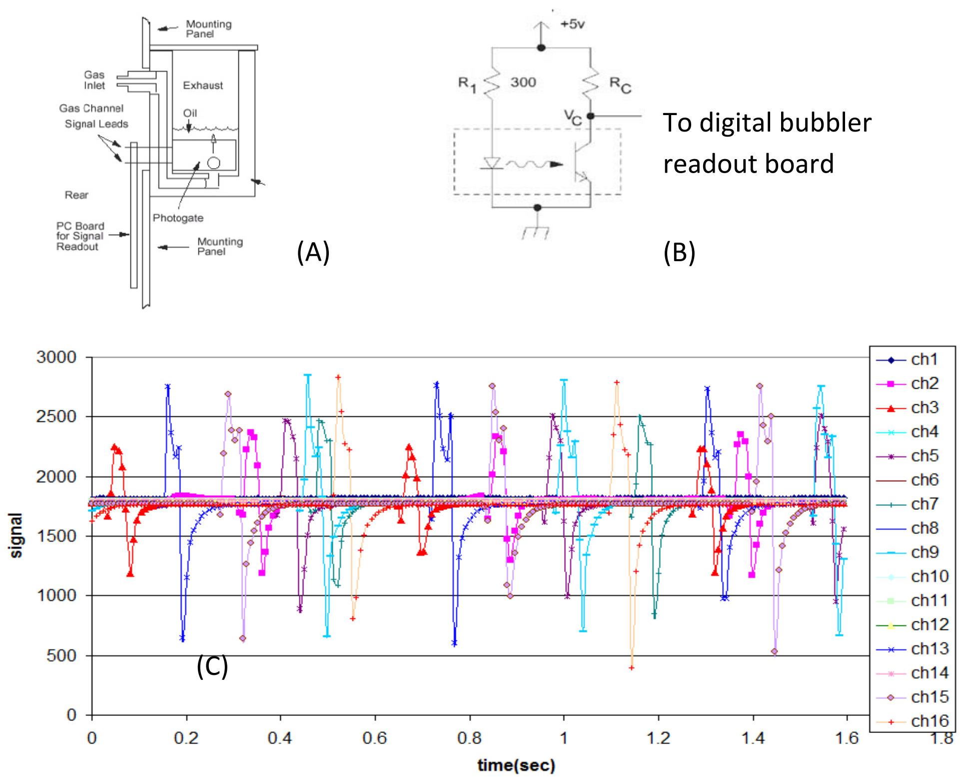


Figure 17. Digital gas bubbler. (A) Mechanical structure of the bubbler (for illustration purpose only, not the same as used in our gas system); (B) Working principle of the photogate; (C) The digital bubbler output signal recorded by microcontroller.

A host PC is supervising the microcontroller readout board through RS232 port. Figure 18 is a photo of this system.

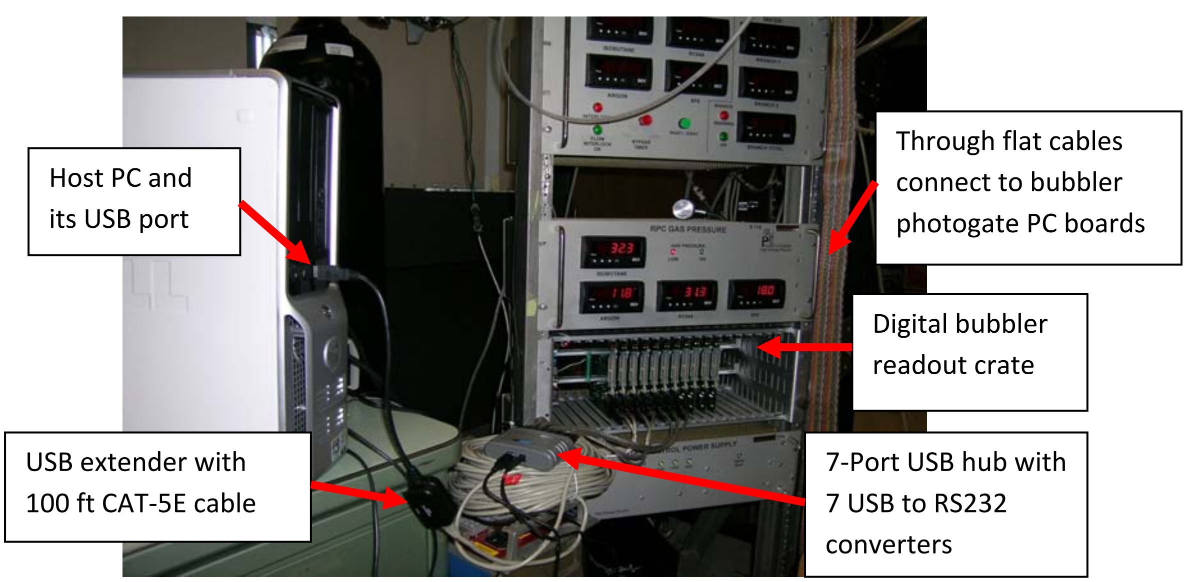


Fig. 18. Digital bubbler readout crate and its host PC with USB extender/100ft long CAT-5E cable. (In the photo the flat cables are disconnected from the digital bubbler readout boards.)

The cable interconnection of the digital bubbler system is shown in figure 19.

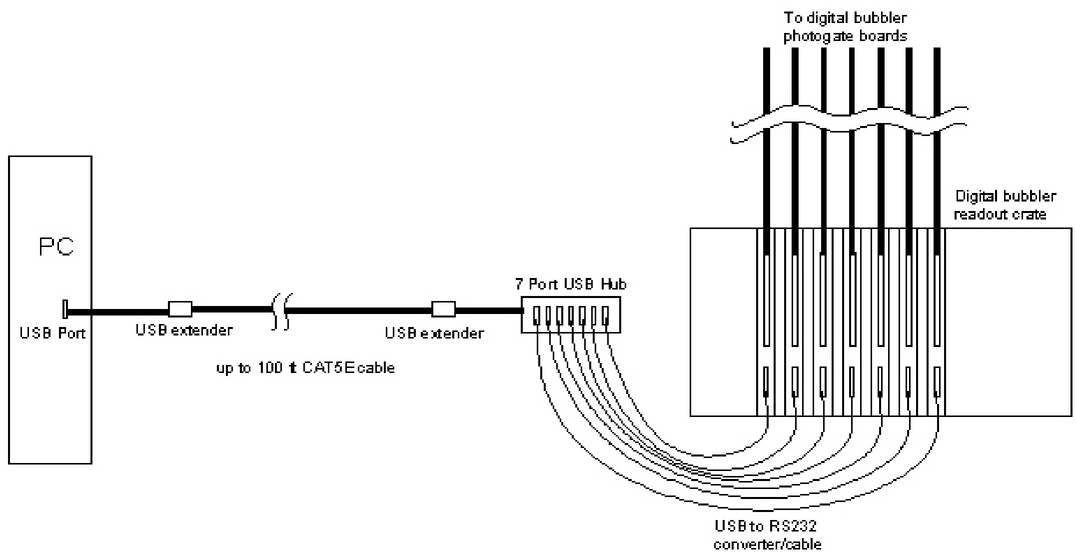


Fig. 19 Interconnection of the digital bubbler system.

The host PC will be in the gas room, the digital bubbler hardware and readout crate will be located on the RPC module supporting platform, the distance between two locations is around 20m. Use a pair of USB extenders and a 100 ft CAT5E cable to link them together. The interconnection of the digital bubbler system is shown in Fig. 19.

8.3 Troubleshooting

This section is evolving with the running experience; your feedback is most welcome.

Symptoms	Possible cause	Remedy
All gas flow meters show zero flow rates.	1, The solenoid valve doesn't open, all pneumatic valves are closed. 2, Nitrogen gas cylinder does not have enough gas pressure (< 5 atm).	1, Check if all four gases' pressures are higher than low limits or their flow rates are higher than preset lower flow limit (check 247D). 2, Replace a full N2 cylinder.

Buzzer activated.	Bypass button has been pushed unintentionally.	After 5' it will turn off automatically.
Bubbling rate histograms show all zero	COM port lost connection.	Check COM port communication: Start|Control Panel|System|Hardware| Device Manage, click Ports(COM & LPT) to see if all required COM ports are there and in correct Order. Sometimes the electric interference, such as plug a new device into the same power strip, it may disturb the COM port communication. Unplug the USB cable, then plug in, it may solve the problem.
Solenoid Valve Open LED not on, no any other warning light on, but there is no gas flow in all 4 channels.	Check with Detector Control System to make sure they are not activating the emergency shut off state and the wall mounted fire emergency push button is not on.	