EXPERIMENT AND NON-EXPERIMENTAL SCOPE OF WORK FORM, ANLHEP_644

Date of Submission _06/26/2008_ ☒ New ☐ Renewal ☐ Supplemental Change

Division:	HEP	**Dept./Section:**		**Div. Ref. #:**	
Project Title:	Test of Digital Hadron Calorimeter with Cosmic Rays				
Location (Building/Room, etc.)	Bldg 362, lab E-240				
Project dates:	**Start:**	07/2008	**End:**	Until tests are completed	
Designated Project Manager:	Jose Repond, Lei Xia				

The Project Manager / Principle Investigator must be familiar with the responsibilities and the requirements of the experiment safety review in the *ESH Manual*, Section 21.2.

Work may not be performed until procedures have been approved, and authorization is granted. This completed form, hazard analysis and all supporting documentation must be submitted to the division ES&H Coordinator. Appropriate personnel for ES&H issues associated with the proposed work will review the information. The Project Manager must resolve outstanding issues before the work begins; no work may begin until Approval and Authorization is granted.

Jose Repond ______________________ 8/28/08 ________

Project Manager Approval **Date**

______________________ ________

Review Approval **Date**

ES&H authorization pending, the following requirements must be completed before operation start-up.
1) All operators must complete Pressure System orientation training
2) Schematic diagrams indicating pressure gauges, check valves, component mixing and mixture percentages during operation, and the steps to follow in the case of an emergency should be posted at the gas distribution station
3) The entire experiment must be properly grounded. It is inappropriate practice in electronic/electrical applications to substitute paper clips for adequate current return path connections
4) The relay rack, which the HV electronic modules are mounted, should be connected to the earth grounding bus bar inside the lab
5) All electrical equipment used in the experiment, including the job made line cord used to power the relay rack, must comply with ANL standards requiring that they be UL listed or otherwise approved for use by division electrical equipment inspector, DEEI

ES&H Authorization Date 09/09/2008

H. Weerts

Division Authorization Date 8/28/08

SCOPE OF WORK (ISM STEP 1)

General Description

Provide a general overview description of the experiment (or non-experimental work project). Describe specific equipment for tasks within the project, concentrate on operations that focus on the work, and summarize the hazards that you expect to encounter. Attach designs, drawings, or other useful descriptive material.

This project involves the operation of a digital hadron calorimeter stack and the collection of cosmic ray data. The stack consists of up to 20 Resistive Plate Chambers (RPCs) with two possible sizes: 20cm x 20cm or 32cm x 96cm. Details on RPCs as particle detectors can be found in attachment 1 (F. Sauli, Gas Detectors: achievements and trends, CERN-EP/2000-080) and the references therein. Operating the RPCs requires a constant gas flow with a specific non-flammable mixture and a high voltage of up to ~6kV. To collect cosmic ray data, the experiment also operates a trigger and an electronic readout system. Brief introductions to these systems are given below. More details can be found in the attachments:

1. Gas distribution system.

   The RPC operation requires a specific gas mixture (R-134a : Iso-Butane : SF_6 = 94.5 : 5.0 : 0.5) of tetrafluoroethane (R-134a), iso-butane, and sulfur hexafluoride (SF_6). These three gases do not react chemically when mixed. The MSDS of the individual gases can be found in attachment 2,3,4. The iso-butane by itself is flammable, but the mixture is not flammable, due to the small percentage of iso-butane. The mixed gas will be provided by a dedicated mixing rack, which will be reviewed separately. The mixture will be delivered in small gas tanks (~11gal capacity) at ~50psi pressure.

   The gas distribution system takes the gas from the tank, uses a regulator to reduce the pressure to ~5psi (above atmospheric pressure) and distributes the gas to each RPC individually. The pressure of the system and the flow rate to each RPC are monitored by gauges and meters. A detailed schematic drawing of the gas distribution system, its operating procedure, and calculations on gas safety (gas released into the lab space under normal operation condition and in case of a catastrophic leakage) can be found in attachment 5.

2. The high voltage system provides the running voltage for all RPCs. We use either a NIM based high voltage system, or a stand alone LeCroy HV4032A supply. The NIM based

The tests of our prototype Digital Hadron Calorimeter (DHCal) stack (reviewed separately), built with Resistive Plate Chambers (RPCs), require continued gas supply. This project provides the gas needed for the DHCal tests.

The gas used in DHCal RPCs consists of the following three components: tetrafluoroethane (R-134a), iso-butane, and sulfur hexafluoride (SF_6) at a ratio of R-134a : Iso-Butane : SF_6 = 94.5 : 5.0 : 0.5. The three components do NOT react chemically when mixed, and the gas mixture at the above mentioned ratio is NOT flammable. The MSDS of these gas components can be found in attachments 1,2,3.

In order to get the specified gas mixture, we have purchased pure gas components in commercial gas cylinders from vendor. All three gases are in liquid states, with vapor pressures 78psi (R-134a), 34psi (Iso-Butane) and 330psi (SF_6) at room temperature. We installed a cylinder regulator on the SF_6 cylinder, which will bring the vapor pressure down to 20-40psi at its output.

We plan to re-use an existing gas mixing rack which can mix up to four component gases. The rack was build by Ivars Ambats, who was the gas and pressure system expert in the HEP division. The schematic of the system is shown in attachment 4. The rack has been pressure tested and can hold the maximum pressure from the cylinders (78psi for R-134a). The rack is equipped with two precise pressure gauges (1^{st}: 0 – 800mmHg, 5mmHg/div; 2^{nd}: 0 – 500psi, 1psi/div) which can measure the partial pressure of the gas components to the required accuracy. One of the two gauges can only work at air pressure or below. A dedicated valve is used to isolate this gauge before the rest of the rack goes beyond air pressure. A strict operating procedure (see below and attachment 4) has been developed to protect this gauge.

We plan to re-use two gas tanks as the containers for the mixed gas. Both tanks have ~11 gal capacity and have been pressure tested to > 125psi.

In order to safely use this system and guarantee the mixing ratio is as specified, we have established a step by step operating procedure (attachment 4) and require all operation personnel to follow the procedure exactly.

The potential hazards identified in this project are: pressure system, flammable component in a non-flammable gas mixture.

HAZARD ANALYSIS (ISM STEP 2)

Hazard List

Examples include but are not limited to the examples below. Graded approach will be applicable with the appropriate consultation.

Low Risk

- ☐ Delivery of items such as furniture, office supplies.
- ☐ Equipment (bench top set up) utilizing hand tools and that does not fall into another hazard classification

- ☐ Equipment repair, de-energized, utilizing hand tools, and that does not fall into another hazard classification
- ☐ Equipment calibration, de-energized, utilizing hand tools, and that does not fall into another hazard classification
- ☐ Computer set-up
- ☐ Installation of window blinds that requires no power tools or use of a ladder
- ☐ Performing office-type tasks
- ☐ Assembly of technical components with use of hand tools and no exposure to additional hazards of a greater risk

Moderate Risk

- ☐ Installation of furniture utilizing power tools, battery operated tools or hand tools
- ☐ Installation of office partitions—including repair and modification to existing partitions, shelving involving no hard wiring of electrical connections, plug type only
- ☐ Installations of carpet with or without utilizing consumer quantity of adhesive product
- ☐ Low voltage calibration/testing—below 50 volts
- ☐ Repair and/or window glass replacement, window cleaning below 6 ft.
- ☐ Repairs that do not require lockout/tagout or use of chemicals that are above a consumer commodity quantity
- ☐ Kitchen appliance repair with out any additional exposure to a high risk activity
- ☐ Activity that does not involve working with any type of energy source, working above 6 ft., or entry into a confined space
- ☐ Painting with latex paint
- ☐ Site survey work that is not within 6' of a roadway and does not include the use of lasers higher than class 2
- ☐ Tree and flower planting in pots or planters
- ☐ Use of class 2 lasers
- ☐ Assembly of technical components utilizing power tools, battery operated tools, or hand tools
- ☐ Assembly of purchased component utilizing power tools, battery operated tools, or hand tools
- ☐ Service of experimental mechanical devices utilizing power tools, battery operated tools, or hand tools
- ☐ Installation of wire cages utilizing power tools, battery operated tools, or hand tools

High Risk

- ☐ Electrical or other energy sources requiring lockout/tagout for any installation or modification
- ☐ Working with or having an exposure to hazardous materials (e.g., toxins, carcinogens, asbestos, lead, beryllium, etc.)
- ☐ Excavations of any type or depth that requires a Dig Permit
- ☐ Confined spaces
- ☐ Noise levels above 85 dB
- ☐ Ionizing radiation (per entry posting)
- ☐ Non-ionizing radiation (per entry posting)
- ☐ Working on energized equipment of greater than 50 volts
- ☐ Installation of office partitions containing electrical hard wire electrical connections

- ☐ Activity requiring lockout/tagout of energy source
- ☐ Work on transformers
- ☐ Working with the potential for a fall from a height greater than 6 ft
- ☐ Pole work of any nature
- ☐ Communication tower work including erecting, painting, or inspection
- ☐ Elevator repair/maintenance/inspection
- ☐ Overhead crane inspections or repair
- ☐ Equipment alignment of energized equipment
- ☐ Sprinkler repairs or modifications
- ☐ Utility line work on gas line, electrical, water, steam, air, or communication
- ☐ Mechanical work that may include welding, cutting, burning, or any open flame work, metal grinding, or saw cutting
- ☐ Concrete boring/cutting/grinding/jack hammering
- ☐ Hoisting, rigging, or lifting
- ☐ Parking lot paving and striping
- ☐ Tree and stump removal, grass burning, or chemical treatments
- ☐ Laser repair and installation
- ☐ Painting with epoxy paint
- ☐ Chiller or refrigerant repair/recovery or replacement
- ☒ Chemical use (use of flammable products, asbestos abatement, work on lead painted surfaces)
- ☐ Potential releases to environmental media (air, land, surface water, and/or groundwater)
- ☐ Equipment use (cranes, fork lift, scissor lift, boom lift, scaffolds, back hoes, bobcats)
- ☐ Other high risk situations as determined by line management or the division ES&H coordinator

Is this job performed in a location or environment having a special designation where specific precautions are to be observed? ☒ Yes ☐ No

Examples:

(Check those applicable)

- ☐ Nuclear facility
- ☐ Nonnuclear radiological facility
- ☐ Radiological controlled area
- ☐ Outdoor—NEPA review
- ☒ Indoor—laboratory, service area, common area
- ☐ Floor loading limitations
- ☐ Noise posted area
- ☐ Laser controlled area
- ☐ Biohazard area
- ☐ Magnetic field
- ☐ Ultraviolet (UV)
- ☐ Microware
- ☐ High heat/cryogenics
- ☐ Hazardous/flammable/reactive chemicals
- ☒ Energized systems—electrical, pressure
- ☐ Confined space
- ☐ Elevated 6 feet or more above working level
- ☐ Asbestos, lead, mercury, beryllium in area or could be disturbed
- ☐ Clean room
- ☐ Other specifically defined locations or environments?

Is this job a complex activity? ☒ Yes ☐ No

Examples:

(Check those applicable)

☐ More than one work group necessary to complete the job.
☒ Steps of a task or tasks of a job must be completed in an exact sequence.
☐ Shutdowns of various systems and lockout/tagouts of various energy sources must be completed.
☐ Life safety features/egress routes altered.
☐ Additional specific training/skills/knowledge/fitness required for those performing task.
☐ Materials handling issues — heavy, bulky, hazardous materials handled individually, with manually operated equipment, with powered equipment such as forklifts, cranes, etc.
☐ Other specific complex activities?

HAZARD CONTROLS (ISM STEP 3)

ENGINEERING CONTROLS

Describe the engineering controls applied to control the hazards. Engineering controls include enclosures and barriers that cannot be removed without the use of tools, interlocks, ventilation, software controls, etc.

Task	Engineering Controls

ADMINISTRATIVE CONTROLS

List all work procedures, permits and checklists necessary to mitigate hazards. The Project Manager must describe where skill of the researcher/craft/work is being relied upon for hazard mitigation and control.

Task	Administrative Controls
Gas mixing operation	All operating personnel are required to take "Pressure Safety Orientation" (ESH119) as part of the training
Gas mixing operation	All operating personnel are required to follow the operation procedure

PERSONAL PROTECTIVE EQUIPMENT

Specify personal protective equipment (PPE) to be worn. For gloves, be specific as to the type appropriate for the task and which steps in the activity the PPE is required.

Task	PPE

WORKING WITHIN CONTROLS (ISM STEP 4)

All work must be performed within the controls for all the identified hazards.

It is the Project Manager responsibility to verify that this document is kept up to date and determine if changes are significant enough to require a new review/document.

FEEDBACK (ISM STEP 5)

Identify types of records and the reporting method that is useful for improvement on the tasks within this project. This could include lab notebooks, datasheets, computer data, instrument logs, images, etc.

Task/Situation	Record
Emergency	Call 911, take appropriate immediate action (e.g., evacuate space) notify supervisor, building manager, division management, ESH coordinator

Was a graded approach applied to this scope of work? For example, work or experiments involving a few hazards of low severity may not require extensive review. Appropriate review for such may be to have a knowledgeable colleague who will neither supervise nor perform the experiment examine the setup, and ISM implementation then document his or her conclusions in accordance with division policy for work approval and authorization . ☒ Yes ☐ No

If yes, describe the graded approach taken.

This project involves a few potential hazards with very low severity. The following precautions will be used in order to avoid these hazards:

1. require all operating personnel to take proper training classes, including "Pressure System Orientation" (ESH119)
2. establish step by step operating procedure, and require all operating personnel to follow the procedure exactly

<Project Manager last name> Project No. <xxx>

EXPERIMENT AND NON-EXPERIMENTAL SCOPE OF WORK FORM, ANLHEP_644

Date of Submission 08/22/2008 ☒ New ☐ Renewal ☐ Supplemental Change

Division:	HEP	**Dept./Section:**		**Div. Ref. #:**	
Project Title:	Gas Mixing Operation in support of DHCal Test Experiment				
Location (Building/Room, etc.)		Bldg 362, lab F-216			
Project dates:	**Start:**	08/2008	**End:**	Till tests done	
Designated Project Manager:		Jose Repond, Lei Xia			

The Project Manager / Principle Investigator must be familiar with the responsibilities and the requirements of the experiment safety review in the *ESH Manual*, Section 21.2.

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Jose Repond 8/28/08

Project Manager Approval **Date**

Review Approval **Date**

ES&H authorization pending, the following requirements must be completed before operations start-up.
1) All operators must complete Pressure System orientation training
2) Schematic diagrams indicating pressure gauges, check valves, component mixing and mixture percentages during operation, and in the case of an emergency the steps to follow should be posted at the gas distribution station
3) The gas mixing procedure and precautions must be clearly posted

ES&H Authorization — 09/09/2008 **Date**

H. Weerts — 8/28/08

Division Authorization — **Date**

SCOPE OF WORK (ISM STEP 1)

General Description

Provide a general overview description of the experiment (or non-experimental work project). Describe specific equipment for tasks within the project, concentrate on operations that focus on the work, and summarize the hazards that you expect to encounter. Attach designs, drawings, or other useful descriptive material.

The potential hazards of the experiment are the high voltage, the pressurized gas (50psi) and the pressurized distribution system (mostly at ~5psi, except the input is at up to 50psi).

HAZARD ANALYSIS (ISM STEP 2)

Hazard List

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Examples:

(Check those applicable)

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☐ Nonnuclear radiological facility
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☐ Elevated 6 feet or more above working level
☐ Asbestos, lead, mercury, beryllium in area or could be disturbed
☐ Clean room
☐ Other specifically defined locations or environments?

Is this job a complex activity? ☒ Yes ☐ No

Examples:

(Check those applicable)

☐ More than one work group necessary to complete the job.
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☐ Other specific complex activities?

HAZARD CONTROLS (ISM STEP 3)

ENGINEERING CONTROLS

Describe the engineering controls applied to control the hazards. Engineering controls include enclosures and barriers that cannot be removed without the use of tools, interlocks, ventilation, software controls, etc.

Task	Engineering Controls
Use of high voltage devices	Use warning signs in area with potential HV exposure Use appropriately rated HV cables and connectors. Use trip mechanisms with proper current limit settings, as provided by the HV power supplies.

Use of low voltage devices	Properly fuse all low voltage power lines
Use of gas distribution system	Use properly rated parts for the pressure in the system

ADMINISTRATIVE CONTROLS

List all work procedures, permits and checklists necessary to mitigate hazards. The Project Manager must describe where skill of the researcher/craft/work is being relied upon for hazard mitigation and control.

Task	Administrative Controls
Gas distribution	Use well established procedure to ensure not to overpressure the rack and ensure proper operation of the distribution system
Gas distribution	All operating personnel need to enroll in "Pressure Safety Orientation" (ESH119) classes

PERSONAL PROTECTIVE EQUIPMENT

Specify personal protective equipment (PPE) to be worn. For gloves, be specific as to the type appropriate for the task and which steps in the activity the PPE is required.

Task	PPE

WORKING WITHIN CONTROLS (ISM STEP 4)

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Task/Situation	Record
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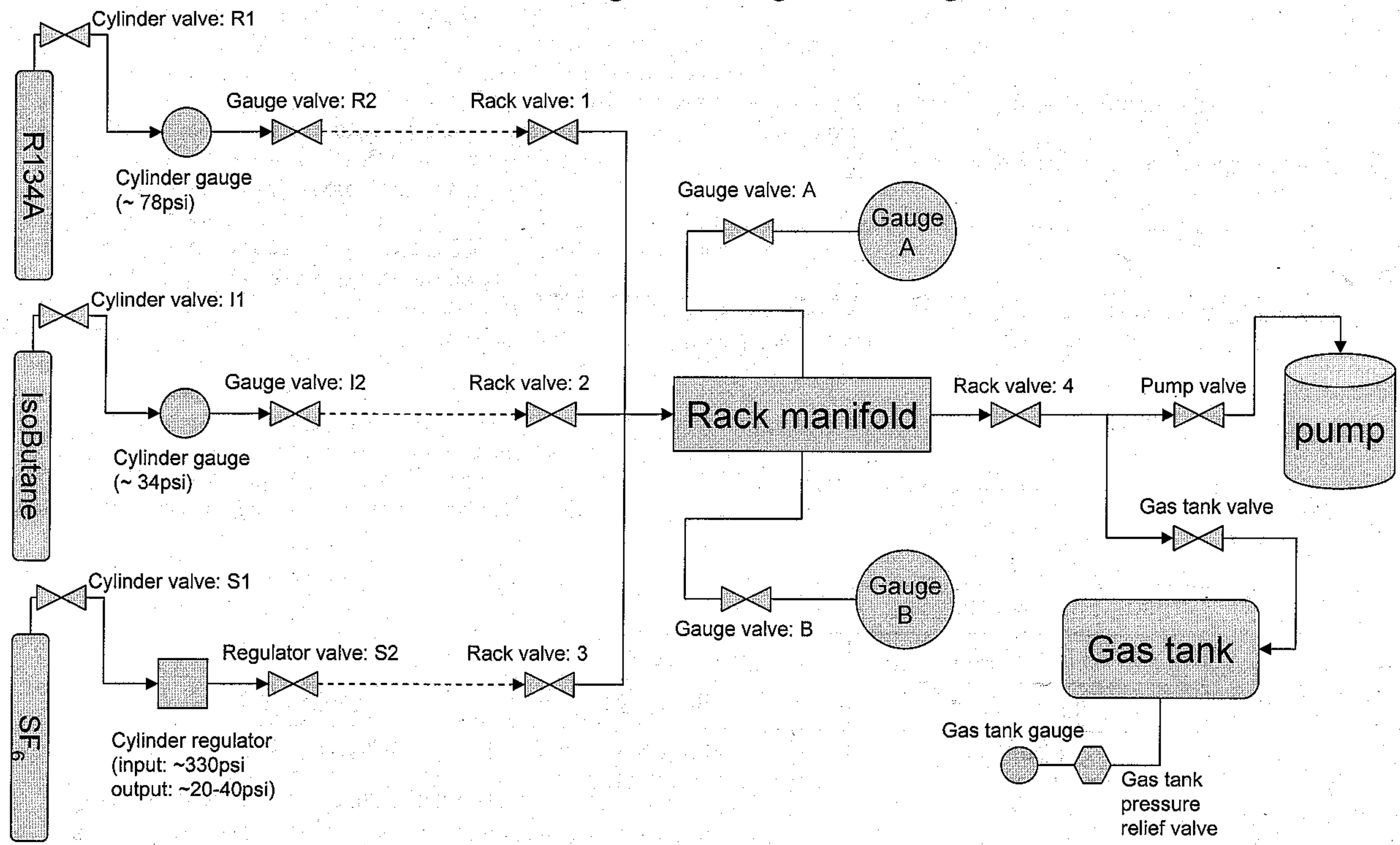
If yes, describe the graded approach taken.

This project involves a few potential hazards with very low severity. The following precautions will be used in order to avoid these hazards:

1. use of properly rated cables and connections when using high voltage.
2. use of the trip-off mechanism on the high voltage supplies with properly set current limits
3. use of signs to label area with potential high voltage exposure
4. use of properly fused low voltage supply
5. use of properly rated parts for the pressures we are dealing with
6. properly train personnel for operating the gas distribution system
7. use strict procedures to operate the gas distribution system

Schematic diagram for gas mixing rack



Note:

1. Max. pressure seen by the system is ~78psi (R134a vapor pressure), except regulator on SF6 cylinder (input at ~330psi)
2. The only component in the system that doesn't take 78psi or higher is the gauge A (max. pressure 15psi), which is needed to measure partial pressure for SF6 and Iso-butane
3. Strict operation procedure is established to avoid subjecting gauge A to pressures higher than 15psi (see next page)

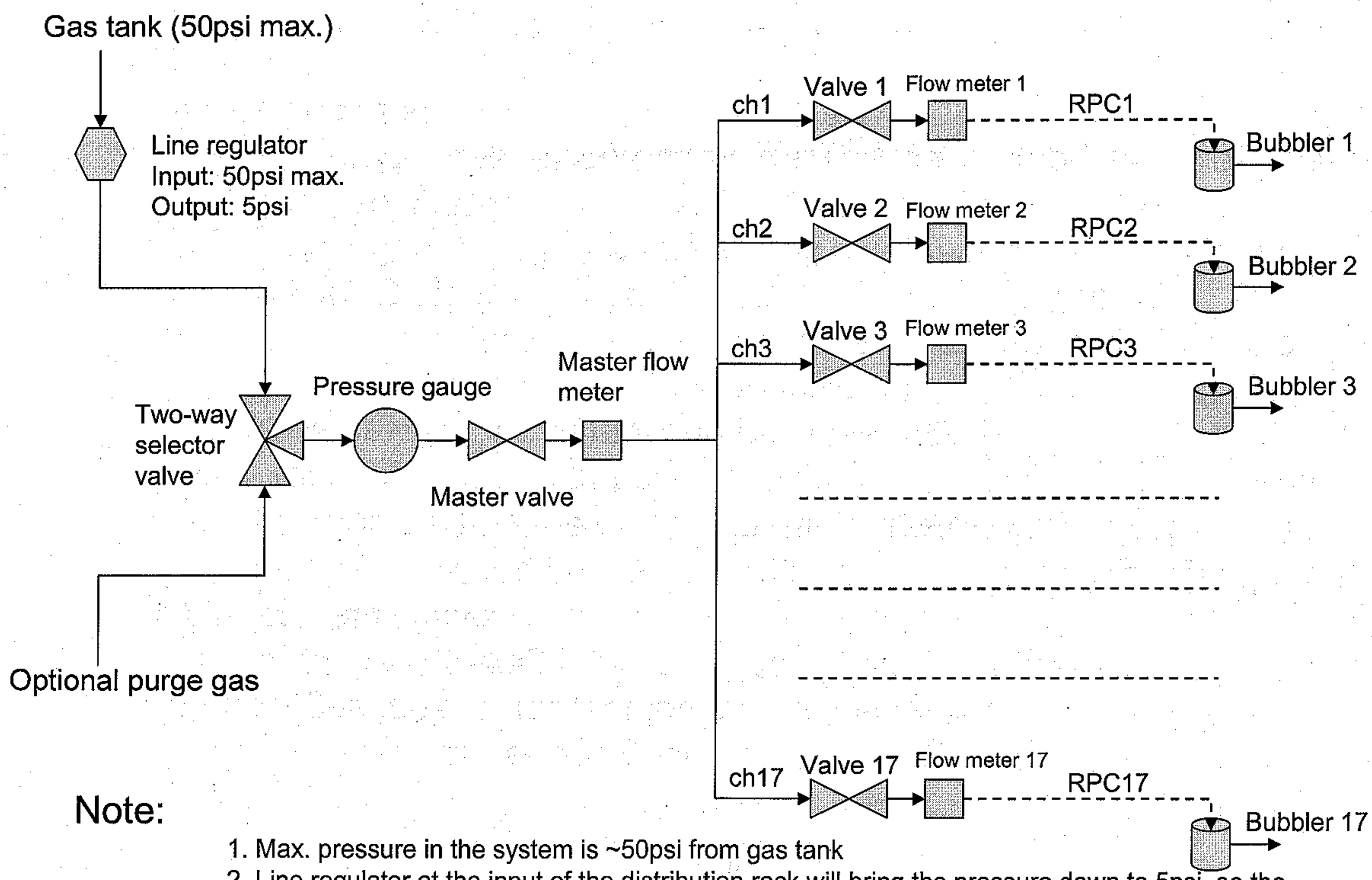
Gas mixing procedure

Target pressure: 50psi above air pressure (14.7psi)
Target mixture: SF_6:Iso-butane:R-134a = 0.5%:5.0%:94.5%
Partial pressure and filling pressure:

Gas (fraction)	Partial P	Filling P
SF6 (0.5%)	16.7mmHg	16.7mmHg
Iso-butane (5%)	167.2mmHg	184.0mmHg
R-134a (94.5)	3161.1mmHg	3345.1mmHg (64.7psi)

1. Check all valves are in 'Closed' position
2. Release any residual pressure in gas tank and mixing rack by opening pressure relief valve
3. Pump out residual gas, open the following valves in sequence:
   pump valve, gas tank valve, rack valve 4, gauge valve B, gauge valve A
3. Pump system for a minimum of 5 hrs
4. Close pump valve, turn off pump, record zero off-set on gauge A (X mmHg)
5. Open valve S1, check regulator input pressure (~330psi) and output pressure (20-40psi), open valve S2
6. Slowly open rack valve 3, monitor gauge A reading, close rack valve 3 when gauge A reading reaches 16.7+X mmHg
7. Close valve S1, valve S2, record gauge A reading
8. Open valve I1, check cylinder pressure gauge (~34psi), open valve I2
9. Slowly open rack valve 2, monitor gauge A reading, close rack valve 2 when gauge A reading reaches 184.0+X mmHg
10. Close valve I1, I2, record gauge A reading
11. Close gauge valve A (gauge A should NOT be subjected to pressure higher than air pressure, or gauge will be damaged)
12. Open valve R1, check cylinder pressure gauge (~78psi), open valve R2
13. Slowly open rack valve 1, monitor gauge B reading, close rack valve 1 when gauge A reading reaches 64.7psi
14. Close valve R1, R2, gauge valve B, record gauge B reading
15. Close gas tank valve, disconnect gas tank and pump from mixing rack
16. Check all valves are securely closed

Gas distribution rack schematic



Note:

1. Max. pressure in the system is ~50psi from gas tank
2. Line regulator at the input of the distribution rack will bring the pressure down to 5psi, so the rest of the system will see 5psi max.
3. The whole gas distribution rack has been tested to 45psi at Fermilab.
4. The RPC gas volume pressure is determined by mineral oil depth in the bubblers (~2mm), due to the very small flow rate

Gas distribution rack operating procedure

1. Check all valves are securely closed
2. Connect gas tank to gas distribution rack input line
3. Make sure the two-way selector valve is pointing to gas B
4. Open gas tank valve
5. Check rack regulator input pressure gauge and gas tank gauge, the two readings should be the same (within gauge uncertainty ~5psi)
6. Check rack regulator output pressure gauge, reading should be ~5psi
7. Open master valve, open master flow meter valve
8. One by one, slowly open flow meter valve on each gas channel that is going to be used. Monitor the flow meter reading and output bubbler while adjusting the flow meter valve to set desired flow rate
9. Iterate procedure 8 until flow rates in all channels are stable and set to the desired flow rates
10. Check flow rate, gas tank pressure daily, replace empty ($P<10$psi) gas tanks as needed

Lab volume measurement

Length = 350 in = 8.89 m
Width = 235 in = 5.97 m
Height = 113 in = 2.87 m

Total volume = 8.89 x 5.96 x 2.87 = 152.3 m^3

Calculation on gas usage under normal operation condition/flow rate

1. Maximum detector configuration (planned):
   10 small RPC (gas volume 20cm x 20cm x 0.1cm = 40cc)
   10 large RPC (gas volume 32cm x 96cm x 0.1cm = 307.2cc)
   total detector gas volume V = 10 x (40cc+307.2cc) = 3.5 liters
   (current configuration: 10 small RPC, total V = 0.4 liter)

2. Maximum flow rate in any test: 2 volume exchange/hr, or 48 exchange/day
   (normal flow rate: 4 – 6 exchange/day)

3. Maximum daily gas usage (max. configuration + max. flow rate)
   V = 48 x 3.5 liter = 168 liters
   (max. configuration + normal flow rate: V’ = 6 x 3.5 liter = 21 liters)
   (curr. configuration + normal flow rate: V” = 6 x 0.4 liter = 2.4 liters)
   Long term daily gas usage is (expected to be) between V’ and V”

4. Daily gas usage as a fraction of lab air volume (page 5)
   Max. configuration + max. flow rate: F = 0.168 / 152.3 = 0.11%
   Max. configuration + normal flow rate: F’ = 0.021 / 152.3 = 0.014%
   Curr. configuration + normal flow rate: F” = 0.0024 / 152.3 = 0.0016%

Conclusion: daily gas release into the lab, even under the maximum usage is only 0.11% of the total lab air volume. This will not create any hazardous condition

Calculation on gas release under catastrophic leaking condition

Assumption: this calculation is to show the gas release as a fraction of the total lab air volume, under a sudden catastrophic leakage of the gas distribution system (even though this condition is extremely unlikely to occur).

Condition 1: using gas tank from planned on-site gas mixing

a. Gas tank volume: 11 gallons = 11 x 3.79 = 41.7 liters
b. Gas tank pressure: 50 psi = 50 / 14.7 = 3.40 atm
c. Total gas release: V1 = 3.40 x 41.7 = 141.8 liters @ 1 atm
d. Fraction of total lab volume: F1 = 0.1418 / 152.3 = 0.093 %

Condition 2: using pre-mixed gas from vendor

a. Total usable gas ("350" cylinder): V2 = ~ 450 liters @ 1 atm
b. Fraction of total lab volume: F2 = 0.450 / 152.3 = 0.30 %

Conclusion:

1. **Under all conditions, a sudden catastrophic leakage of the gas distribution system will not create hazardous condition in the lab (total gas release < ~ 0.30 % of the lab air volume)**
2. **Using gas tank from planned on-site gas mixing is safer than using pre-mixed cylinder (gas release 0.093% vs. 0.30%)**