Standard Operating Procedure (SOP)

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Issue Date:	8-16-07
Expiration Date:	**No more than three years from the Issue Date**
Title: Hall-C Base Equipment Gas Mixing System	
Location: Hall-C (Bldg. 96) and Hall-C Gas Shed (Bldg. 96c)	
Risk classification (See *EH&S Manual* Chapter 3210 *Hazard Identification and Characterization*.)	**Without mitigation measures (4, 3, or 2): 2**
	With specified measures implemented (1 or 0): 0
Author(s): Howard Fenker HC Fenker	**Date: August 15, 2007**

Supplemental technical validations:

Hazard reviewed:	**Reviewer signature:**	**Date:**
Flammable Gas Storage/Use	Jack Segal	8/15/07

Signatures:

		Date:
Division Safety Officer, recommendation:	Bert Manyak Jr.	8/16/07
Department manager, approval:	Stephen A Wood	8/15/07
Other approval(s):		

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Standard Operating Procedure for the Hall-C Base Equipment Gas Mixing System

H. Fenker

August 15, 2007

1 Purpose

The drift chambers in the base equipment of Hall-C (i.e., in the HMS and SOS spectrometers) operate on a 1:1 mixture of argon:ethane bubbled through isopropyl alcohol. Because these detectors must operate for long periods of time, it is an economic necessity to mix the components on-site as needed. While this mixture is never flammable, the use of a mixer requires that the system and procedures be analyzed for a worst-case failure (i.e. delivery of 100% ethane). Thus an approved ESH&Q Work Control Document (WCD) is required for the gas handling system. The *storage and use of flammable gasses* is a topic entirely covered by the JLab ESH&Q Manual. Therefore, this is **not** considered to be an unusual hazard and this Standard Operating Procedure (SOP) is the appropriate WCD.

2 Scope

This procedure applies to all operations related to storing, supplying, using, and exhausting argon-ethane mixed by the *Hall-C Drift Chamber Gas Mixing System.* It does not apply (and no WCD is required) during those times when this system may be temporarily or permanently supplanted by the use of premixed gas. It does not apply to other systems that may, from time to time, supply gas to other detectors in Hall-C (other detector systems must be covered by their own WCDs which include analysis of the *combined* gas inventory).

3 Description of the Facility

Fig. 1 identifies the locations of Hall-C, the Hall-C Gas Shed, and the system exhaust stack. A flow and valve diagram of the subject gas mixing system is shown in Fig. 3. A diagram for the installation in the HMS shield house is shown in Fig. 2.

Argon and ethane are each delivered at bottle pressure through two-bottle manifolds to pressure regulators on the outside wall of the Hall-C Gas Shed (building 96c). The output of the ethane manifold is fitted with an engineered flow orifice which limits the flow of ethane to less than 26.0 SLM (standard liters per minute) at 100 F (the flow is less at lower temperature), independent

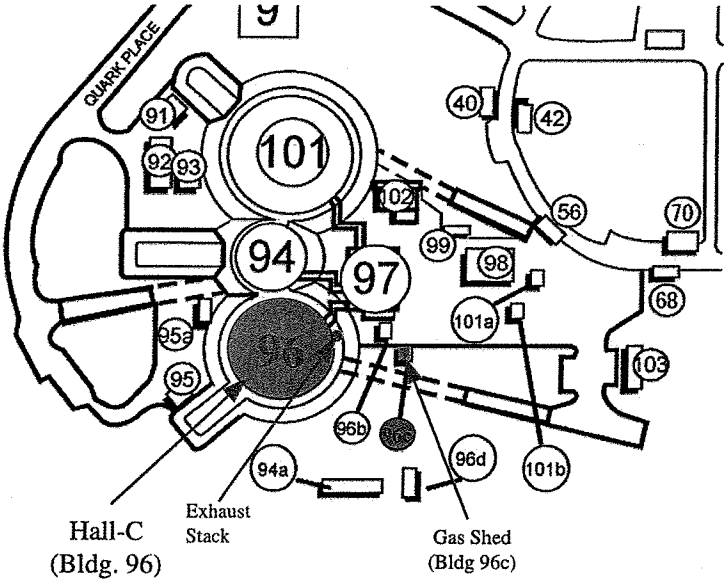

Figure 1: Area Site Map for the Hall-C Wire Chamber Gas System

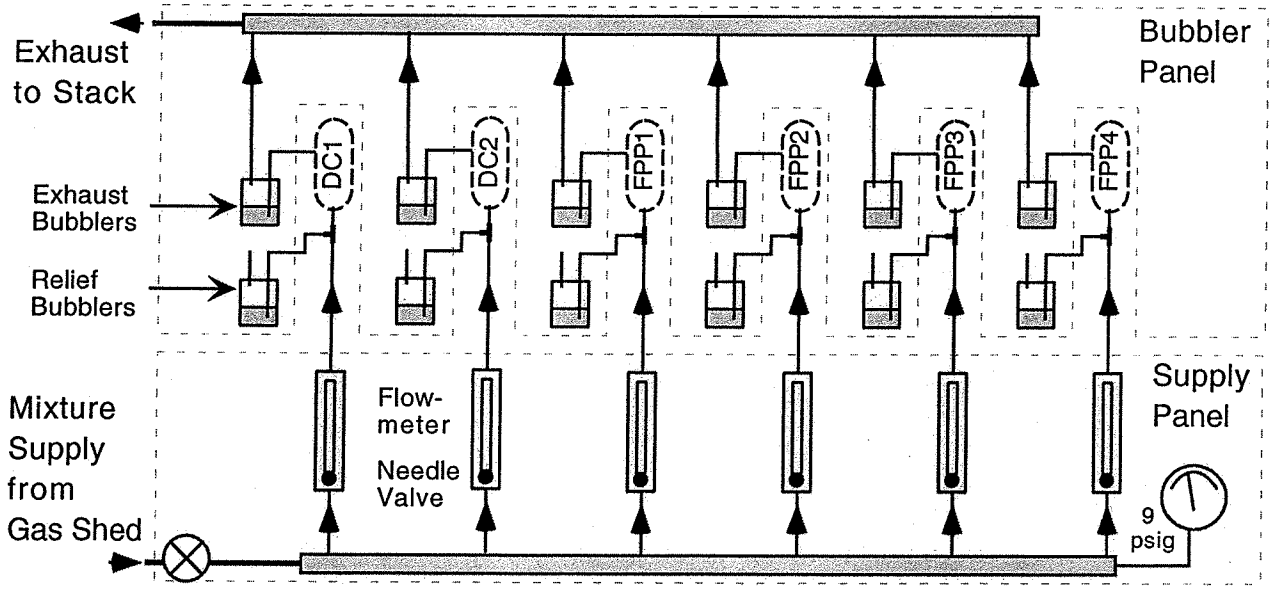

Figure 2: Flow and Valve Diagram for the HMS Shield House. A similar installation services two drift chambers in the SOS Shield House.

of any regulator or valve setting. The two pressure-regulated gas lines then enter the shed and feed an additional pair of pressure regulators as well as filters and normally-closed electrically-operated valves. These secondary regulators provide gas at 30 psig. to the mixing valves.

The mixing valves are manufactured by MKS Industries and are controlled by an MKS model 647C controller. The full-scale range for the argon valve is 2.78 SLM (2000 sccm N2) and for the ethane valve it is 2.5 SLM (5000 sccm N2). The controller is capable of setting these valves to

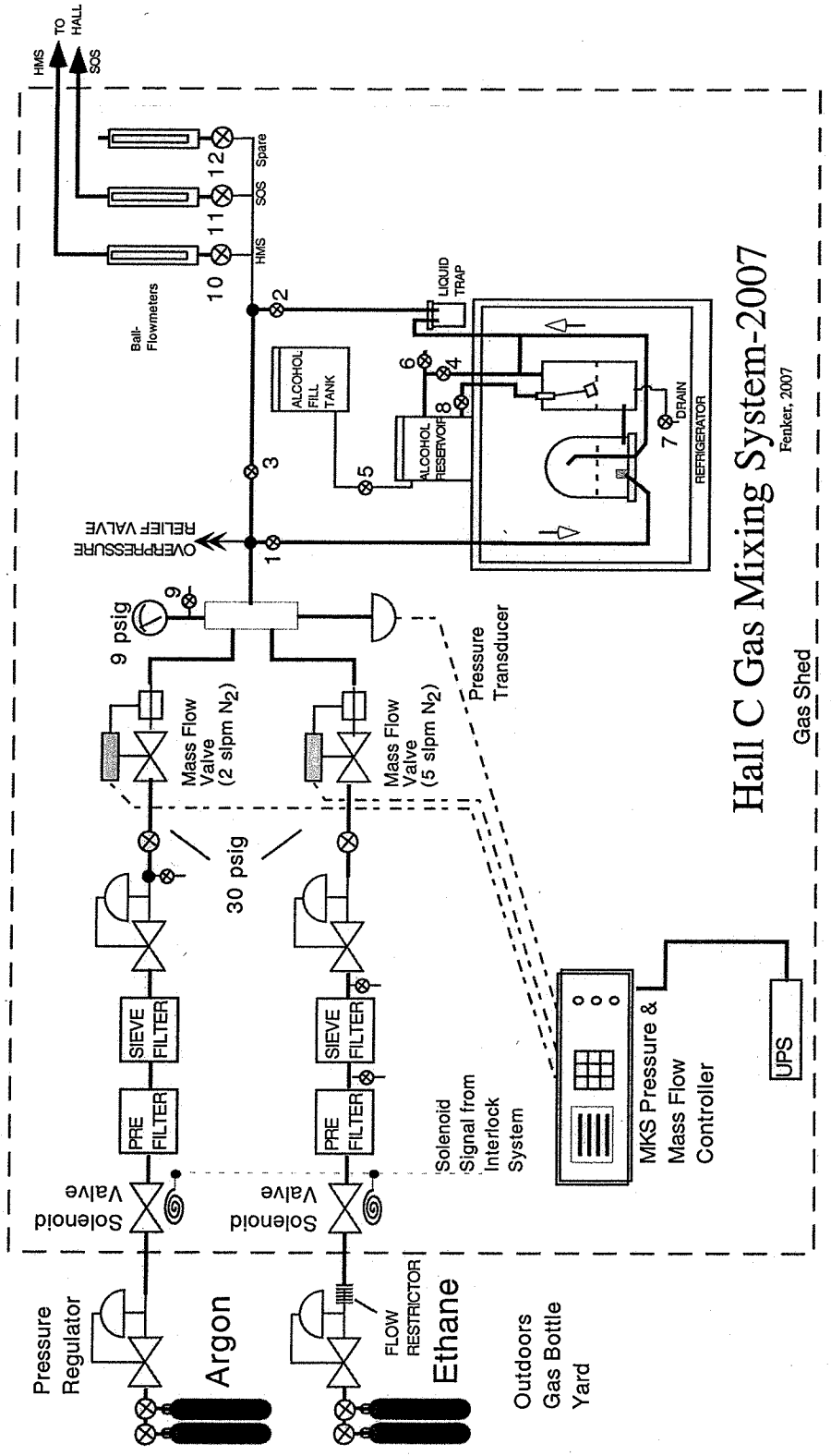

Figure 3: Flow and Valve Diagram for the Hall-C Wire Chamber Gas Mixing System.

110% of full scale. The outputs of the two valves are connected to a small ($\approx$1 liter) mixing tank. The pressure in the tank is measured by an MKS pressure transducer. The resulting pressure signal is fed back to the 647C which uses it as the input to a PID controller which adjusts the mixing valves in order to obtain the desired pressure under varying conditions of flow demand and inlet pressure. The set-point for this system is 500 Torr (about 9 psi) above atmospheric pressure.

The mixed gas is passed through an alcohol bubbler inside the refrigerator. The alcohol temperature is maintained at a set point between 0 C and 5 C. Alcohol is drawn from a warm reservoir outside the refrigerator, under control of a float valve, into a cold reservoir and the bubbler vessel inside the refrigerator. A liquid trap on the gas outlet line assures that no liquid alcohol enters the lines leading to the hall.

Fully mixed gas at 9 psig is delivered into Hall-C through two 1/2-inch diameter nylon tubes which are enclosed within flexible duct for mechanical protection. One tube supplies detectors in the SOS (or, in the future, the SHMS), and the other tube supplies detectors in the HMS.

In each detector shield house the gas is distributed to individual detectors through a manifold feeding a set of needle-valve / ball-flowmeter units. Each needle-valve is adjusted so that an appropriate flow of gas is supplied to each detector.

Adjacent to the flowmeter panel is a set of mineral-oil bubblers. One of these bubblers is teed into the gas circuit at the inlet of each detector. These serve to prevent overpressure in the detector, protecting the thin detector windows from rupture. Any gas flowing through these relief bubblers is immediately apparent to the system operator and is exhausted to the room air directly behind the bubbler panel.

Gas exhausted from each detector is passed through another bubbler to prevent back-streaming and to provide visual confirmation of gas flow through the detector. The flow from these output bubblers is collected in a manifold and plumbed into a 1-inch diameter common exhaust tube (also enclosed within flexible duct). This exhaust line takes the gas out of the hall and releases it to the atmosphere through an inverted-J stack whose location is indicated in Fig. 1. This stack is screened to prevent the intrusion of insects, etc.

4 Authority and Responsibility

This SOP is authorized by and may be terminated by the following:

- Administrative
  - Physics Division Safety Officer
  - Physics Division ESH&Q Staff
  - Hall-C Group Leader
  - Hall-C Safety Warden
- Technical
  - Howard Fenker (*System Owner*)
  - Andy Kenyon (primary operator)

Operation of the system is restricted to those individuals listed in Table 8.

5 Analysis of Special or Unusual Hazards

The only hazard associated with this system that might be considered special is the storage and use of flammable gas, although this is a topic completely addressed in the ESH&Q Manual.

Flammable gas system hazard classification at JLab is based upon the hydrogen equivalent combustion energy contained in the gas present within each separable part of the system. For ethane, the threshold volume that would promote a system to Hazard Class-1 is 50 standard cubic feet.

In the Hall-C system there are five geographical zones. The volume of gas contained in each one is calculated in Tabs. 1, 2, 3, 4, and 5. Note that, in keeping with the worst-case scenario analysis, the volumes shown are *total* volumes for each device. That is, they represent the maximum amount of ethane potentially present in the event that a multi-component failure allowed the system to deliver 100% ethane for a long period of time. Normally, and in the event of any *reasonably-foreseeable* failure mode, only a fraction of the gas volume would be ethane.

- **Zone 1:** This is an outdoor area isolated from any obvious ignition sources, and the volume of ethane present is well below $16,666 ft^3$ (the ethane volume threshold for outdoors Class-2). Therefore, this area is classified as an **Outdoors Class-1** installation.
- **Zones 2,3,4,5:** The volume of ethane in zones 2, 3, 4, and 5, taken either separately or together, is below the $50 ft^3$ threshold, thus these zones are all **Class-0** installations.

Zone 1: Outdoors Gas Bottle Rack and Manifold	
System Component	**Volume (SCF)**
Two industry-standard 410 cubic foot ethane bottles	820
Misc. tubing, valves, regulators (max)	0.5
Total	**820.5 ft^3**

Table 1: Outdoors Gas Volume Calculation

Zone 2: Hall-C Gas Shed	
System Component	**Volume (SCF)**
$\approx$ 50 feet of 1/4" OD Metal Tubing and Misc. plumbing at $<$ 45psig: $V < \pi r^2 lP = (\pi)(0.125^2)(50)((1/12 ft/in)^2)(4\ atm)$	0.07
Mixing bubbler and alcohol buffer tank (at 9 psig)	<1
$\approx$ 20 feet of 1/2" Plastic Tubing (at 9 psig) $V < \pi r^2 lP = (\pi)(0.25^2)(20)((1/12 ft/in)^2)(1.6\ atm)$	0.04
Total	**$<$ 1.2 ft^3**

Table 2: Hall-C Gas Shed Volume Calculation

Zone 3: Experimental Hall C not including the shield houses	
System Component	**Volume (SCF)**
2 each, $\approx$ 300 feet 1/2" OD Supply Tube, 9 psig $V = 2 \times (300)(0.25^2)(\pi)((1/12ft/in)^2)(1.6\ atm)$	1.3
2 each $\approx$ 300 feet 1" OD Exhaust Tube, 0 psig $V = 2 \times (300)(1^2)(\pi)((1/12ft/in)^2)(1\ atm)$	3.3
Total	**4.6 ft^3**

Table 3: Hall-C General Area Volume Calculation

Zone 4: SOS Shield House	
System Component	**Volume (SCF)**
$\approx$ 60 feet of 1/2" Plastic Supply, Return, and Relief Tubing at $\approx$ 0psig: $V < \pi r^2 lP = (\pi)(0.25^2)(60)((1/12ft/in)^2)(1\ atm)$	0.08
SOS Drift Chambers: 2 each at $(0.7m \times 0.50m \times 0.12m)$ $(1\ atm)$	3.0
Total	**3.1 ft^3**

Table 4: Hall-C SOS Shield House Volume Calculation

Zone 5: HMS Shield House	
System Component	**Volume (SCF)**
$\approx$ 180 feet of 1/2" Plastic Supply, Return, and Relief Tubing at $\approx$ 0 psig: $V < \pi r^2 lP = (\pi)(0.25^2)(180)((1/12ft/in)^2)(1\ atm)$	0.25
HMS Drift Chambers: 2 each at $(0.56m \times 1.37m \times 0.15m)$ $(1\ atm)$	8.2
FPP Chambers: 4 each at $(1.34m \times 1.66m \times 0.07m)$ $(1\ atm)$	22
Total	**30.5 ft^3**

Table 5: Hall-C HMS Shield House Volume Calculation

6 Environmental Review

During normal operation the gas system exhausts argon, ethane, and isopropyl alchol to the atmosphere. In the worst case, a catastrophic component failure could release the entire connected inventory of one or more of these substances. The releases were reviewed by the JLab Environmental Engineer who determined that "the complete release of any or all would not meet any regulatory threshold so no special environmental protection attention is needed". (Bert Manzlak will record any Environmental Aspects for this process.)

7 Hazard Controls

The requirements of the JLab ESH&Q manual and this system's methods of implementation are described in the following tables. Table 6 applies to all five zones.

Table 6: Class-0 Requirements and Mitigation in Hall-C

Requirements for Flammable Gas Installations A. Class 0 Installations:	**Hall-C Mitigation**
1. The area shall be posted "Danger-Flammable Gases, No Ignition Sources" using standard signs available from the Jefferson Lab Safety Lab (in Building 35 or by contacting the Physics Division ESH&Q Staff). A list of responsible persons with their phone numbers shall also be posted.	Already posted on old equipment. New signs have been posted on new equipment.
2.Combustibles and ignition sources shall be minimized within 10 feet or three meters of gas handling equipment, piping or apparatus.	Procedures in place, as before.
3.A pressure regulator appropriate for the gas and its environment shall be used.	In place, as before.
4.An orifice, excess flow valve or other fixed means of limiting the flow to no higher than ten times the maximum operational flow rate shall be installed.	Passive flow restrictor on outlet of ethane manifold limits ethane flow to < 26 *SLM*. Maximum operational ethane flow is 2.75 *SLM*. $26 < 10 \times 2.75$
5.All gas cylinders shall be secured. Cylinders not in use shall be capped. Empty cylinders shall be removed at the earliest convenient date or on a predetermined, regular schedule coordinated with vendor delivery of new cylinders. See also Chapter 6150 Compressed Gases.	Procedures in place, as before.
6.Enclosed volumes containing piping or equipment shall be incapable of becoming pressurized. For example, chest freezers shall not have latching doors. Electrical devices enclosing or enclosed within these volumes shall be listed for use in Class 1, Division 2 locations per NEC Article 500 or otherwise be documented and approved as non-sparking devices.	Magnetic seal on refrigerator door. No electrical switches inside refrigerator.
	Continued on next page

Table 6 – continued from previous page

Requirements for Flammable Gas Installations A. Class 0 Installations:	**Hall-C Mitigation**
7.Leaks from experimental devices such as drift chambers shall be measured and documented prior to initial operation (with nonflammable gas, if possible). Leakage above seven liters/hour from any one chamber shall be mitigated. Recheck for leaks after major repairs or modifications, and at least every twelve months. Leakage exceeding 20% of the lower explosive limit at a distance over five centimeters from an identified "point" leak shall be repaired.	SOS chambers (2 of) total ethane leak rate: 6 l/h. HMS chambers leak effectively all gas supplied (18 l/h ethane). Leak rates measured 4/12/07. Leaks are distributed (not 'point'). By nature of construction, chamber leaks cannot be reduced further. Mitigation: both shield houses have forced airflow. Both have flammable gas sensors. Detection of > 25% LEL sounds alarm in Counting Room and disables gas supply.
8.Ventilation above one air change per hour shall be maintained in areas using or storing flammable gas if normal operational flow rates are less than 5 Standard Cubic Liters Per Minute (SCLM). This ventilation may be accomplished by mechanical or natural ventilation. For natural ventilation a room vent with a minimum of 1/2 square foot of free area shall be provided per 1000 cubic feet of room volume. If normal operational flow rates are greater than or equal to 5 SCLM, supervised mechanical ventilation in accordance with Section 7-2.2.1 (a) of NFPA 58 Liquefied Petroleum Gas Code, 2004 edition shall be provided (not applicable to outdoor Jefferson Lab storage).	Gas shed and HMS Shield House have powered exhaust fans. Both HMS and SOS shield houses are ventilated by forced-air systems. Total flow (2.75 SLM ethane max) is less than 5 SLM ■ no supervision of ventilation required.
9.Welding permits (Fire Hazard Work Permit) Reference Appendix 6122-T1 Use of Fire Hazard Work Permits shall not be issued for areas within 35 feet or ten meters of the equipment containing flammable gas unless approved in advance by the responsible Division/Section head or designee.	Procedures in place, as before.

In addition to the items in Table 6, the outdoor Class-1 gas-bottle manifold is subject to the requirements and mitigations listed in Table 7.

Table 7: Class-1 Requirements and Mitigation in Hall-C

Requirements for Flammable Gas Installations A. Class 1 Installations:	**Hall-C Mitigation**
10.The system, including vessels, chambers, supply and vent piping, and exhaust points shall be labeled "flammable gas."	Done.
11.Piping requirements: Exceptions to this paragraph are permitted adjacent to experimental apparatus where needed for flexibility, electrical isolation, repairs or because of congestion. This exception is limited to within five meters of the normal operating position. a.Piping and fittings shall be protected from mechanical damage. b.Piping shall be rated for the expected temperature and pressure. c.Supply piping shall be metallic. d.Piping shall be supported in a substantial and workmanlike manner. e.Piping shall not be installed inside cable trays with electrical conductors.	Done.
12.Joints shall be made by welding, brazing, pipe thread, or commercial fittings appropriately installed. Custom-made fittings required by detector design shall provide secure connections.	Done.
13.The entire piping system shall be pneumatically tested for leaks at approximately 0.9 times the relief pressure before operating the system. Any piping with relief valve settings above 150 PSIG shall be tested at 1.25 times the relief pressure.	Done.
14.Bubblers, flow meters, and other instruments shall be securely mounted and protected from possible breakage.	Done.
15.Provisions shall be made to purge the entire system with an inert gas. If vacuum pumps are used for this, they shall be listed for flammable gas service.	Purge from Ar bottle using CGA350/580 adapter.
16.Pressure relief devices shall be provided to limit the pressure to the maximum working pressure in various parts of the system. In the case of low pressure equipment, dedicated bubblers may be used as relief devices. Common exhaust piping (where the flammable gas vent is shared with exhaust vents for other systems) shall not be used if equipment overpressure from any combination of devices sharing the exhaust could result due to built up back pressure.	Commercial manifold equipment ■ rated to contain full bottle pressure.
17.Relief devices in flammable gas service with a capacity over two standard liters per minute shall be vented outdoors. The exhaust locations shall be chosen to minimize fire hazards and shall not be within 10 feet or three meters of an air intake. Vents shall be protected from clogging by debris, snow, or ice.	Installation is outdoors already.
	Continued on next page

Table 7 – continued from previous page

Requirements for Flammable Gas Installations A. Class 1 Installations:	**Hall-C Mitigation**
18.Flammable gas detectors shall be installed near equipment installations, mixing stations, and in storage sheds (the measures in this requirement are not necessary for outdoor storage applications): a.A low level alarm no higher than 10% of the lower explosive limit (LEL) shall sound a local alarm and be used to initiate corrective action according to a plan included in the documentation of system operating procedures. b.A high level alarm no higher than 25% of the lower explosive limit (LEL) shall summon the Newport News Fire Department through the Jefferson Lab fire alarm network. This high level alarm shall also automatically shut off the supply of flammable gas and turn off power to potential ignition sources within 10 feet or three meters of operative gas usage apparatus. c."Crash buttons" shall be provided to accomplish the shutdowns described above. These devices shall be conveniently located, and one shall be adjacent to the fire alarm panel, if present. Crash buttons should shut off all flammable gas sources which could conceivably be confused by unfamiliar person in a state of panic. Crash buttons shall be labeled "Gas System and Experiment Power Shutdown." They shall be located on the Building Evacuation Plan Maps. d.Automatic restart of flammable gas systems and power sources shall not be allowed after a high level alarm. This restriction is intended to require a safety assessment of the situation. In case of an alarm follow the local emergency plan.	Does not apply (outdoors storage application).
19.Visual indication of the actual use of flammable gas shall be provided at both the storage location and at the experimental apparatus. Such lights shall be controlled automatically and shall indicate actual "gas on" and "gas off" status in real time. Flammable gas alarm status shall be also be displayed at the locations of these warning lights.	The Class-1 installation involves no experimental apparatus. Indication of 'gas-on' is the pressure reading on the pressure regulator.
20.Possible Oxygen Deficiency Hazards shall be addressed according to Chapter 6500 Cryogenic and ODH Safety. The hazard shall be considered for each building or room using or storing flammable or inert gas.	Does not apply (outdoor application).

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Table 7 – continued from previous page

Requirements for Flammable Gas Installations A. Class 1 Installations:	**Hall-C Mitigation**
21.The following documentation shall be provided to the Experimental Equipment Review Committee (E2RC) and a copy kept at the system site. a.A general description including the types of gases to be used. b.An accurate piping and instrument diagram with symbols per ISA S5.1 (Instrument Society of America), including the normal set point of regulators. c.An instrument and valve summary. d.A plan view of the installation including the locations of flammable gas detector heads with their elevations marked. e.Procedures for normal and abnormal operations including purging, start-up, gas bottle changes, mixing, leak detection, tests, alarms, shutdown, emergency situations, and ventilation. f.Documentation and/or test results demonstrating the adequacy of the pressure-relief system. g.A call list, including home telephone numbers and available pagers, of personnel familiar with the operation of the system. h.A summary of leak-test measurements.	a,b,c: This document. d: Does not apply: no gas detectors in use. e,g: Operating Manual ■ attached. Also see personnel list below. f: Does not apply: no reliefs in the Class-1 system. h: Regularly tested with Snoop. Long-term static pressure test after assembly. No detectable leaks.
22.The Physics Division ESH&Q group shall be notified of actual gas start-up and system shutdown.	Procedures in place, as before. ESH&Q can be reached at x7556, x7608, or x7740.
23.The Physics Division ESH&Q group shall be notified before using any types of gas not found in the stockroom, and a copy of the MSDS for the new gas shall be provided to both the Physics Division ESH&Q group and to the Jefferson Lab MSDS Coordinator. Reference Chapter 6610 Chemical Hygiene and Appendix 6610-T1 Material Safety Data Sheets.	Does not apply (standard gases).
Note: Items 24 - 27 in the ESH&Q manual are applicable only to Class-2 installations, and are therefore omitted from this table.	N/A
28.Outdoor installations shall meet all applicable sections of NFPA 55 Standard for the Storage, Use, and Handling of Compressed Gases and Cryogenic Fluids in Portable and Stationary Containers, Cylinders, and Tanks, 2003 Edition and 58 for outdoor storage, use, and handling of liquefied gasses. In particular, designers of outdoor installations are cautioned to pay attention to the requirements of these standards for issues such as perimeter construction, roof construction, protection of stored gas from vehicle damage, weather protection, site terrain, etc., and to design the installation in a manner that separates adjacent storage tanks by at least the minimum allowed value based on the size of the tanks	No changes to storage yard since construction in 1994. It is believed to satisfy all requirements.

8 Procedure

Written procedures (the *Howto*) for operators of the system are attached to this document.

9 Special Environmental Controls

As indicated in Section 6, no special environmental protection attention is needed.

10 Training Requirements

The formal training requirement for operators of this system are to read and understand this SOP and the accompanying *Howto* operating instructions, and to participate in a system *Walk-Through* performed by a previously-trained operator.

11 Unusual/Emergency Procedures

- **Power Failure:** Gas flow will automatically be halted by the normally-closed electrically-operated valves at the point where gas enters the gas shed. Note that the mixture-controller will continue receiving power from its UPS.
- **Fire Alarm in an Area Serviced by the Gas System:** Gas flow should be turned off either by manually closing the valves on the cylinders outside the gas shed, or by interrupting electrical power to the gas shed.
- **Program Interruption** (long unattended period, weather emergency, long accelerator- down): System should be purged with argon or nitrogen for several hours to remove flammable content. After purging, a low flow of argon or nitrogen should be maintained to keep the detectors dry (preferred), or the gas system should be shut down completely.

12 Instrument Calibration Requirements

The gas mixture has a direct impact on the quality of data obtained from the detectors being supplied. Thus, monitoring of the data is the normal method of assuring that the mixer controller calibration is correct. After a long downtime, the mixing valve calibration can be approximately verified by cross-checking the mixer readbacks with the readings obtained on the installed ball-type flowmeters. The valve manufacturer is available for servicing and recalibrating valves to factory specs.

Flammable-gas sensors are to have their calibrations checked annually using a standard calibration gas. A written record of the calibration is maintained by the *System Owner.*

13 Inspection Schedules

- Connections to gas bottles are to be checked with a leak-detector liquid each time a bottle is replaced.
- System interlocks (automatic closing of the electrically-operated valves) are to be verified annually or prior to resuming operation after a long downtime.

- Flammable-gas sensors in the shield houses are to have their calibrations checked annually using a standard calibration gas. A written record of the calibration is maintained by the *System Owner.*

14 References/Associated Documentation

- *The MKS-647 Operator's Manual* (vendor manual) available at *http://hallcweb.jlab.org/document/vendor_manuals/*
- *The Hall-C Drift-Chamber Gas System Expert's Manual.* Attached and posted at *http://hallcweb.jlab.org/document/howtos/drift_gas_system*

15 Authorized Personnel

FOR HELP WITH THE HALL-C WIRE CHAMBER GAS SYSTEM CONTACT ONE OF THE PEOPLE ON THE LIST BELOW. FOR THE CURRENT ON-CALL PERSON, CONSULT THE WHITE BOARD IN THE HALL-C COUNTING ROOM OR TELEPHONE EXTENSION 6666.

After reading and understanding this document and the supporting documents, the persons whose signatures appear in Table 8 are the authorized operators of this gas system. The gatekeeper for this list is the first person listed.

Name	Lab Ext.	Pager	Home Phone	Signature
Howard Fenker	7431	584-7431	890-9512	
Andy Kenyon	7555	584-7555	544-4752	
Joe Beaufait	7131	584-7131		
Bill Vulcan	6271	584-6271		
Matt Lumanog	—	584-5811	358-8563	
Jerry Nines	7342	584-7527	897-8848	
Charles Lassiter	7342	584-5471	596-5792	
FRANK VESSELLA	5566		826 2020	
Jessica Cavucci	7342	584-7449	872-0909	
[redacted]		[redacted]		
[redacted]	[redacted]			
Walter Kellner	5512		592-1527	
BRAD SAWATZKY	5947		874-0150	

Table 8: Personnel Authorized to Operate The Gas System

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16 Conclusion

This document and the attached Operating Manual ("Howto") describe the design and operation of the Hall-C base-equipment gas mixing and delivery system, and present a hazard classification analysis of the system. The included tables provide a checklist or description of actions taken to mitigate the identified hazards and satisfy the requirements enumerated in the JLab ESH&Q Manual. All of the requirements are met. The system should be given an operating permit upon completion of a review.