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DOCUMENT ID:	**3310 Appendix T2 Operational Safety Procedure Form**	Click for OSP/TOSP Instructions

PHYSICS DIVISION #

Serial Number: PHY-10-036-OSP PHY-10-010-OSP

(Assigned by ESH&Q Document Control x7277)

[X] **OSP** [ ] **TOSP**

***Attach the Task Hazard Analysis (THA) related to this procedure**

Click For Word Doc

Issue Date:	08-11-2010 [Enter Issue Date]	**Expiration Date:**	08-11-2013 **[Enter Expiration Date]**
(No more than three years from Issue Date except TOSP which is three months from 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 *ESH&Q Manual Chapter 3210 Appendix T3 Risk Code Assignment*.)	**Without mitigation measures (3 or 4):**	2	
	With mitigation measures in place (0, 1, or 2):	0	
Document Owner(s):	Howard Fenker	**Date:**	July 15, 2010

Supplemental Technical Validations:

Hazard Reviewed (per ES&H Manual 2410-T1):	**Subject Matter Experts Signature:**	**Date:**
② Flammable Gas Storage & Use	STEVE CHRISTO	8/11/10
[Enter Hazards]		
[Enter Hazards]		

Approval Signatures:	**Print**	**Signature**	**Date:**
④ **Division Safety Officer:**	~~Bert Manzlak~~ / DENNIS SKOPIK		8/11/10
① **Department or Group Head:**	Steve Wood		8/10/2010
③ **Safety Warden of Area:**	Walter Kellner		8/10/2010
Other Approval(s):	[Enter Name]		

Document History:

Revision:	**Reason for revision or update:**	**Serial number of superseded document**
[Rev]	[Enter Reason]	[Previous Rev]

Distribution: Copies to: affected area, authors, Division Safety Officer, ESH&Q Document Control
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Serial Number: ____________________

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1. Purpose of the Procedure

See attached

2. Scope – include operations, people, and/or areas where procedure applies

See attached

3. Description of the Facility: (include floor plans and layout of a typical experiment or operation)

See attached

4. Authority and Responsibility:

4.1 Who has authority to implement/terminate

See attached

4.2 Who is responsible for key tasks

See attached

5. Who analyzes the special or unusual hazards (See ES&H Manual Chapter 3210 Appendix T1 Work Planning, Control, and Authorization Procedure)

N/A

6. Personal and environmental hazard controls including:

6.1 Shielding

N/A

6.2 Interlocks

See attached

6.3 Other

NA

7. Monitoring systems

See attached

8. Ventilation

See attached

Serial Number: ______________________

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9. List of safety equipment (i.e: personal protective equipment or special tools)
See attached
10. Associated administrative procedures
See attached
11. Operating guidelines
See attached
12. Notification of Affected Personnel (How and Who)
See attached
13. List of steps required to execute the procedure from start to finish.
See attached
14. Back out procedures, i.e., steps necessary to restore the equipment/area to a safe level.
See attached
15. Special environmental control requirements:
N/A
16. Environmental Impacts (See EMP-04 Project/Activity/Experiment Environmental Review
None
17. Abatement Steps – Secondary Containment, or Special Packaging requirements
N/A
18. Training requirements
See attached
19. Unusual/Emergency procedures e.g., Injury, Fire, Loss of power
See attached
20. Instrument calibration requirements, e.g., safety system/device recertification, RF probe calibration
See attached
21. Inspection schedules
See attached

Serial Number: ____________________

(Assigned by ESH&Q Document Control x 7277)

22. References/Associated Documentation
Hall-C Expert Howto: Drift Chamber Gas System Operation (attached)
23. List of Records Generated (Include Location / Review and Approved procedure)
N/A

Authorized/Trained Individuals

Print Name/Signature	Date
See Table 8 of SOP attached	

ISSUING AUTHORITY	APPENDIX AUTHOR	APPROVAL DATE	EFFECTIVE DATE	EXPIRATION DATE	REV.	Page 4 of 4
ESH&Q Division	Harry Fanning	10/05/09	01/01/10	10/05012	0	

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

H. Fenker

July 15, 2010

1 Purpose

The drift chambers in the base equipment of Hall-C (i.e., in the HMS and, eventually, the SHMS 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. 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 document applies to all operations related to storing, supplying, using, and exhausting argon-ethane mixed by the *Hall-C DriftChamber Gas Mixing System*. and used by the *Base Equipment* in Hall-C (the HMS and, eventually, the SHMS drift chambers). 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), and it does not apply to non-*Base Equipment* detectors that may use the gas mixed by this system (in particular, it does not apply to the Q_{weak} drift chambers which operate under their own TOSP).

Note that the SOS drift chambers have been removed and the gas supply line to this spectrometer is disconnected. This spectrometer will be dismantled and removed from the Hall during the life of this document. References to the SOS remain for completeness and will be replaced by appropriate references to the new SHMS as that spectrometer is constructed. The HMS detectors currently receive no gas and are not expected to be used again until 2013.

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.

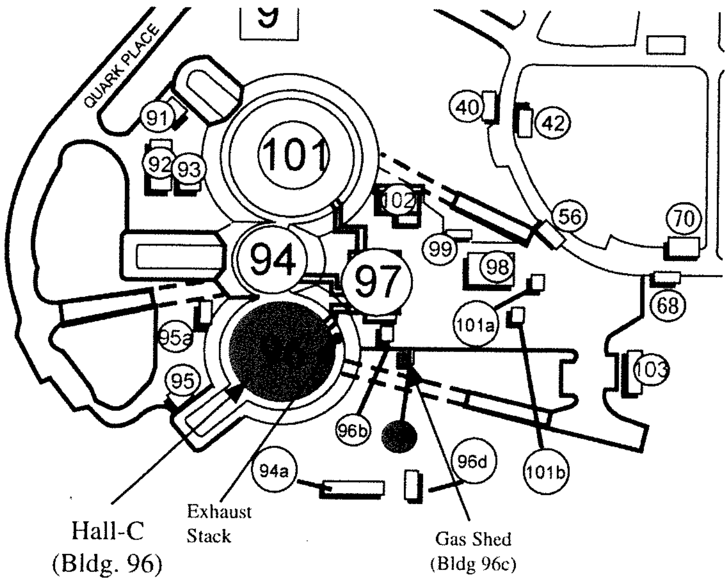

Figure 1: Area Site Map for the Hall-C Wire Chamber Gas System

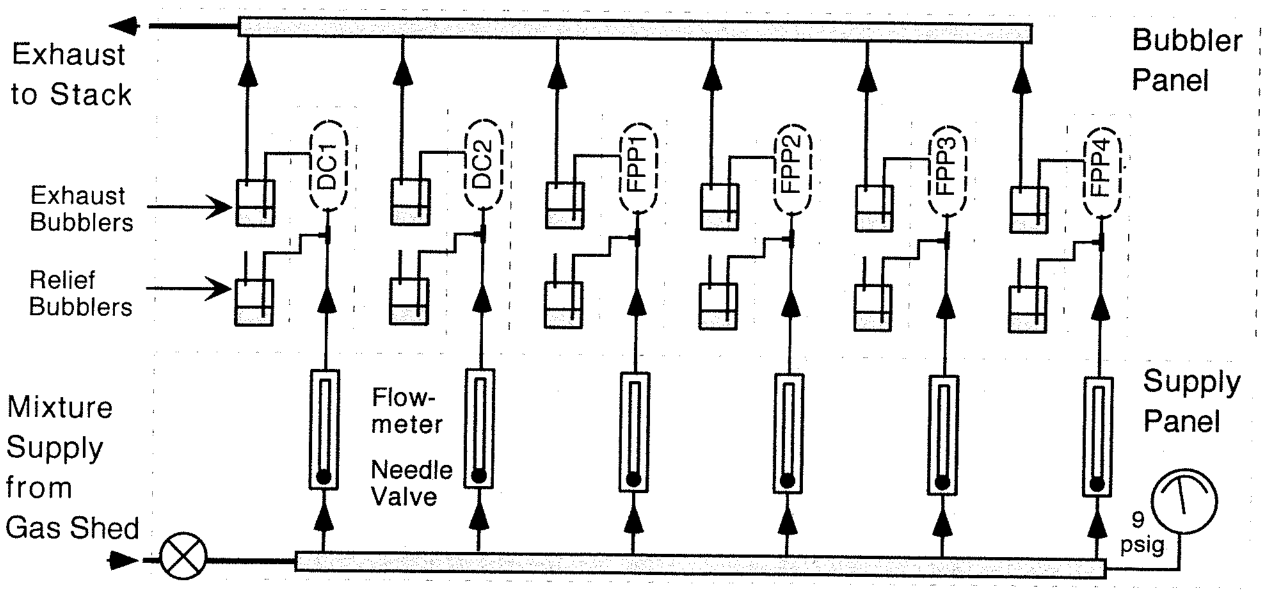

Figure 2: Flow and Valve Diagram for the HMS Shield House. A similar installation will service two drift chambers in the SHMS Shield House.

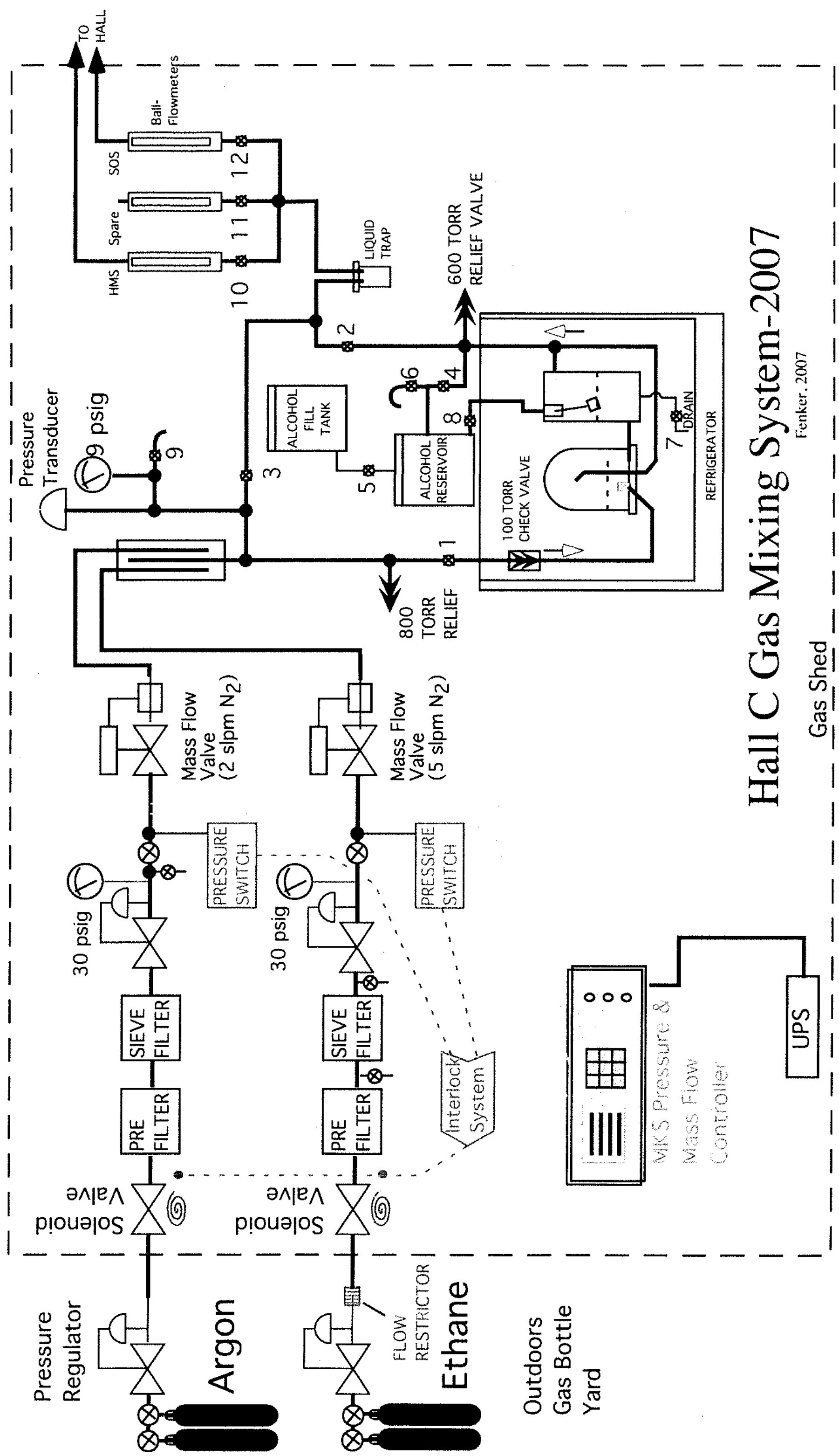

Figure 3: Flow and Valve Diagram for the Hall-C Wire Chamber Gas Mixing System.

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 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 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 $16,666ft^3$ (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 $50ft^3$ 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

Zoone 2: Hall-C Gas Shed	
System Component	**Volume (SCF)**
$\approx$ 50 feet of 1/4" OD Metal Tubing and Misc. plumbing at $<$ 45psig: $V < \pi r^2 l P = (\pi)(0.125^2)(50)((1/12 ft/in)^2)(4\, atm)$	0.07
Mixing bubbler and alcohol buffer tank (at 9 psig)	<1
$\approx$ 20 feet of 1/2" Plastic Tubing (at 9 psig) $V < \pi r^2 l P = (\pi)(0.25^2)(20)((1/12 ft/in)^2)(1.6\, atm)$	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 $V = 2 \times (300)(0.25^2)(\pi)((1/12 ft/in)^2)(1.6\, atm)$	1.3
2 each $\approx$ 300 feet 1" OD Exhaust Tube, 0 psig $V = 2 \times (300)(1^2)(\pi)((1/12 ft/in)^2)(1\, atm)$	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: $V < \pi r^2 l P = (\pi)(0.25^2)(60)((1/12 ft/in)^2)(1\, atm)$	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: $V < \pi r^2 l P = (\pi)(0.25^2)(180)((1/12 ft/in)^2)(1\, atm)$	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).
	Continued on next page

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		
Matt Lumanog		584-5811	358-8563	
Jerry Nines		584-7527	897-8848	
Charles Lassiter	7342	584-5471	596-5792	
Brad Sawatzky	5947	584-5947	874-0150	[signature]

Table 8: Personnel Authorized to Operate The Gas System

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.

Hall C Expert Howto

Drift Chamber Gas System Operation

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July 21, 2010

Abstract

This document provides detailed setup information for the drift chamber gas mixing system, as well as the correct procedure for refilling the alcohol supply and changing gas bottles. This information is intended for use by **gas system experts only.** For day-to-day shift worker instructions, refer to the corresponding *user* howto document.

1 Overview

The drift chamber gas is composed of 50% Argon and 50% Ethane (by volume), bubbled through isopropanol maintained at a temperature such that the gas mixture contains approximately 1% alcohol vapor. The mixing system that produces this gas is housed in the Hall-C gas shed (Bldg. 96c). The bottles supplying the gas to the mixing system are attached to two two-bottle manifolds outside the gas shed, within the fenced-in gas bottle yard.

A single mixing system provides the gas for the HMS and, eventually, the SHMS detectors. During the Q_{weak} run (2010-2012) it provides the gas mixture for the Q_{weak} drift chambers. Gas is delivered to the hall at a pressure of about 9 psi (500 Torr) above atmospheric pressure. Each detector's flow is controlled by its own individual needle-valve with flowmeter, located in the appropriate shield house, near the detector. The job of the mixing system is to simultaneously maintain the delivery pressure and mixing ratio by providing whatever total flow rate of gas (between zero and 5.28 standard liters per minute [SLM]) is demanded by the detectors. This is accomplished by controlling two flow valves (argon and ethane) so that they each flow the same volume of gas while keeping the output pressure nearly constant. The mixing system flow diagram is shown in Fig. 1.

2 Gas Interlock System

The flow of gas from the supply bottles may be automatically shut off by normally-closed solenoid valves installed in the primary argon and ethane manifolds. Several conditions such as over-temperature, fan failure, gas leak, and fire alarm must all be in the non-alarm state before these valves will open. Alarm conditions are indicated on the gas system alarm panel on the lower-left side of the center counting-house console.

When any of the required conditions is not satisfied the sounder on the panel in the counting room will make an annoying noise and both solenoid valves will close. The audible alarm may be silenced by a toggle switch on the panel. Be certain to return it to the "on" position as soon as the fault is cleared.

The most confusing, but most common alarm condition is "Low Pressure". The solenoid valves will not remain open unless there is already ample pressure on the output side of both valves. This prevents, for example, the flow of pure ethane to the drift chambers when the argon bottle is empty. The way to clear this condition is to make sure there are no other faults and that both argon and ethane manifolds are properly pressurized and fitted with non-empty bottles; then press and hold the "override" button on the alarm panel for several minutes. This button forces the solenoid valves to open even if there are fault conditions present. If all is well, gas will flow through the valves and clear the "low pressure" condition so that the button may be released.

3 Operating the Mass Flow Controller.

The gas flow is controlled by a MKS 647 controller and mass flow control valves. Delivery pressure is sensed at the mixer output by a *Baratron* pressure transducer. The 647 is menu driven from a display on the front panel using a keypad with numeric and cursor controls for input. It features a non-volatile memory so that most of its settings are retained even if the unit is unpowered. The pressure-regulation

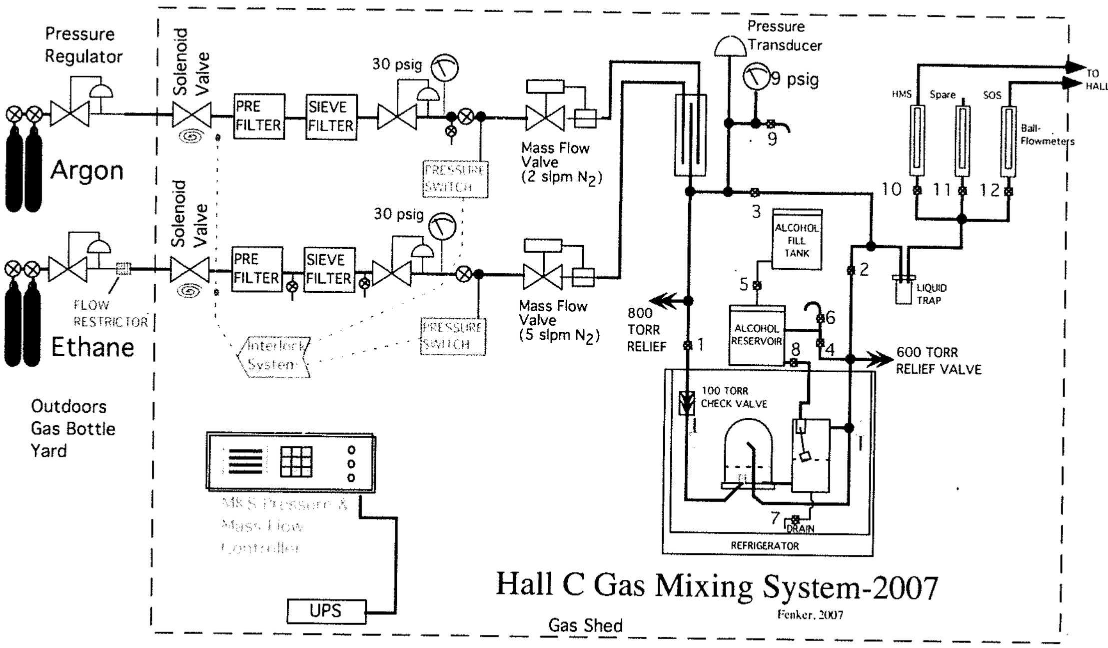

Figure 1: Diagram of Hall C Gas Mixing System

parameters do need to be reset if power is lost, however, so the controller is powered through an uninterruptible power supply (UPS).

The temperature of the control system must be maintained within the operating range of the MKS 647 (15° C - 40° C), the pressure transducer (0° C - 50° C), and the mass-flow meters and valves (0° C - 50° C). Therefore, the heating and cooling systems in the gas shed must be maintained in working order. The temperature is indicated by the red LED display labeled *Controller Temperature*, located in the right-hand rack of the gas shed.

3.1 Settings for Normal Operation

A summary of all of the settings required to make the controller function properly is given in Table 1. The table also shows which screen contains each parameter. Instructions for setting parameters are given below. Detailed instructions for configuring and operating the MKS 647 can be found in the manufacturer's instruction manual, a copy of which is posted at *http://hallcweb.jlab.org/document/vendor_manuals/*.

Parameter	Set To	*Controller Screen*/Comments
Manual Valves		Valves are labeled
Valves 1, 2, 4, 8	OPEN	
Valves 3, 5, 6, 7	CLOSED	
Pressure PID Loop Settings		*Pressure Control* (Fig. 6)
Pressure	500 Torr	
PID Mode	AUTO	
PID GAIN	4.0	
PID INTEG	10.0	
PID LEAD	0.000	
Mixture	1	*User* (Fig. 4)/ Lower-right corner
Gas Composition for Mixture 1		*Gas Composition* (Fig. 7)
Channel 1	1.000	(Argon)
Channel 2	1.000	(Ethane)
Channel 3	0.000	
Channel 4	0.000	
MFC Valve Size / Gas		*Range Selection* (Fig. 8) *Gas Selection* (Fig. 9)
Channel 1	2.0 SLM / Ar	provides 2.78 SLM Argon
Channel 2	5.0 SLM / C_2H_6	provides 2.50 SLM Ethane
Channel 3	*unused*	
Channel 4	*unused*	
Channels ON/OFF Settings		*Extended Display* (Fig. 5)
Channel 1	ON	Press "ON 1" *(Argon)*
Channel 2	ON	Press "ON 2" *(Ethane)*
Channel 3	OFF	Press "OFF 3" *(not in use)*
Channel 4	OFF	Press "OFF 4" *(not in use)*
Pressure Transducer		*Pressure Setup*
Controller	STD	
Range F.S.	1000 Torr	
MFC Valve Controls		*Mode Selection* (Fig. 10)
Channel 1	PID	
Channel 2	SLAVE / 1	
Channel 3	INDEP	
Channel 4	INDEP	
Alcohol Temp.	2° C	Electronic Temperature Control Box

Table 1: Normal Valve and Parameter Settings for the Gas Mixing System.

3.2 General Operation of the Mass Flow Controller

If the controller screen is dark, press **ESC** to awaken the display. Many screens merely provide a menu of other screens you may access: simply press the item number you desire. To go up one level in the menu hierarchy, press **ESC**. The *Menu Tree* for the 647C controller is shown in Fig. 2.

In general, to change a parameter displayed on the controller screen use the **left/right** arrow keys to move the cursor to the item you wish to change. Then either use the number keys to enter the value desired for that item (numeric parameter) or use the **ENTER** or **up/down** keys to cycle a parameter through its available settings (configuration parameter). Numeric parameters may be incrementally modified by using the **up/down** arrow keys. To make certain that a new parameter becomes active, move the cursor off of the parameter after you have entered the new value.

The initial menu upon startup is the **Main Menu** (Fig. 3). For normal operation use the **User Display** menu (Fig. 4). It shows the amount of each gas currently flowing, the total gas flow, and the current delivery pressure. This display also shows which of several possible pre-defined gas mixtures is selected. These mixtures are configured on the **Gas Composition** screen, Fig. 7. For normal operation, we use only mixture **#1**, (number shown on the lower-right of the display). **Only on this screen can this parameter be changed.** Mixture **#2** is usually configured to provide 100% argon for purging flammable gas out of the chambers.

The **Extended Display** menu (Fig. 5) shows actual flow, flow set point, units, valve full-scale range, gas calibration factor, whether that channel is enabled, and whether each channel is operating in master, slave, PID, or independent mode. This display is most useful to a system expert wishing to verify the system parameter settings. Most parameters cannot be modified from this screen, however.

Delivery pressure set-point and pressure *PID-loop* control parameters may be configured from the **Pressure Control** screen (Fig. 6).

3.3 Gas Flow Rates

The flow rates are adjusted automatically by the controller in order to maintain a constant delivery pressure at the output. Only the flow *ratios* should be set by

- MAIN MENU (Fig. 3)
  - 1 USER DISPLAY (Fig.4)
  - 2 EXTENDED DISPLAY (Fig. 5)
  - 3 PRESSURE CONTROL (Fig. 6)
  - 4 DIAGNOSTICS
    - 4.1 ERROR LISTING
    - 4.2 SIGNALS
  - 5 INSTRUMENT SETUP
    - 5.1 RANGE SELECTION (Fig. 8)
    - 5.2 GAS SELECTION (Fig. 9)
    - 5.3 MODE SELECTION (Fig. 10)
    - 5.4 ZERO ADJUST
    - 5.5 TRIP LIMITS
    - 5.6 GAS COMPOSITION (Fig. 7)
  - 6 SYSTEM SETUP
  - 7 PRESSURE SETUP
  - 9 INFORMATION
  - 0 POWER OFF

Figure 2: Command Tree for the MKS-647C Control Panel

the operator. We use a 1:1 ratio, set on the **Gas Composition** screen (Fig. 7), as indicated in Table 1.

The average total flow should equal the sum of the flows to all of the detectors in the shield house. (Note that the ball-type flowmeters in the shield house are calibrated for nitrogen. The approximate multiplier to convert these readings for 50/50 Argon-Ethane is 0.9 .)

System configuration parameters specifying the full-scale flow capacity (for nitrogen) of each valve, the types of gases actually flowing through each valve, and the mode of control for the valves are set in the screens pictured in Figs. 8, 9, and 10. These figures show the nominal settings for the Hall-C system.

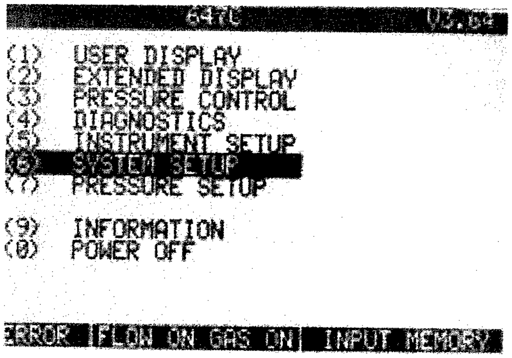

Figure 3: MKS 647 Main Menu

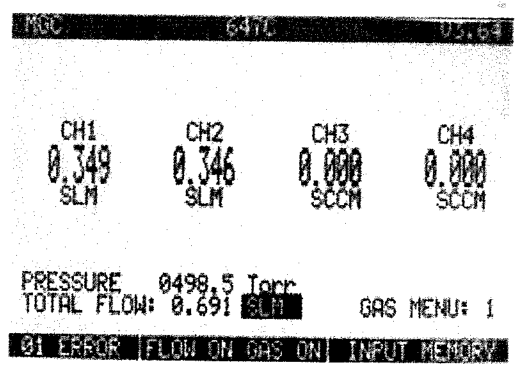

Figure 4: MKS 647 User Display

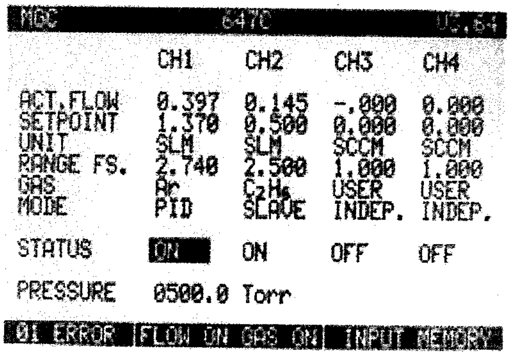

Figure 5: Extended Display Screen

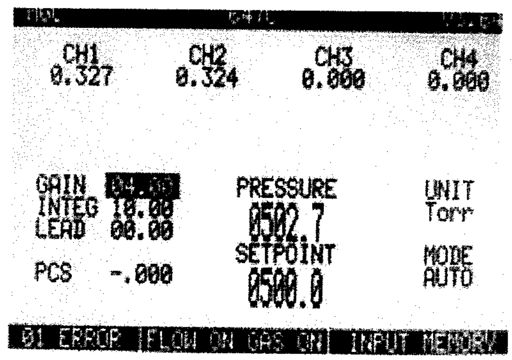

Figure 6: Pressure Control Screen

3.4 To set the Delivery Pressure:

Navigate to the **Pressure Control** menu. The pressure set-point (in Torr) is indicated at the bottom-center of the screen. This value should be se to 500.0. Note that the system can not respond instantly to a change in requested gas pressure: it has no way to release excess pressure and must wait for the detector systems to consume it [1]; it cannot build up pressure any faster than the flow-control valves can supply it. It may take thirty minutes or so for the pressure regulation system to stabilize at a new set-point or stabilize in response to a change in total gas consumption. However, you should be able to observe a change in the gas flow within a few seconds (possibly up to a minute) after a set-point change.

[1] An *over-pressure relief valve* releases gas through a small oil bubbler in the gas shed if the pressure exceeds about 600 Torr.

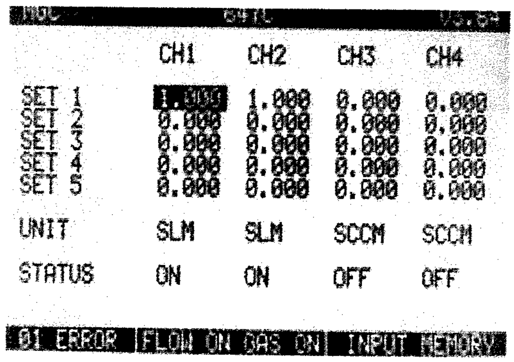

Figure 7: Gas Composition Screen

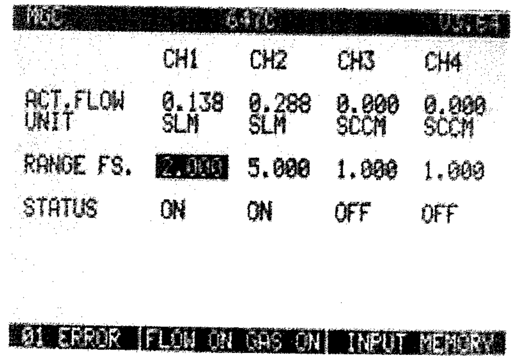

Figure 8: Range Selection Screen

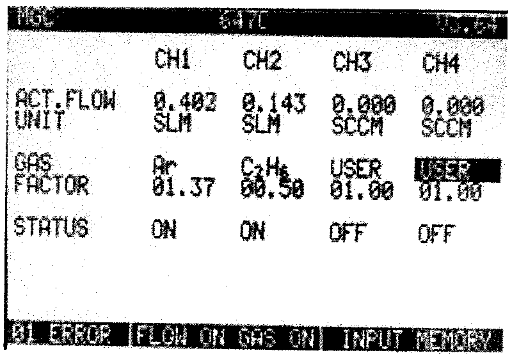

Figure 9: Gas Selection Screen

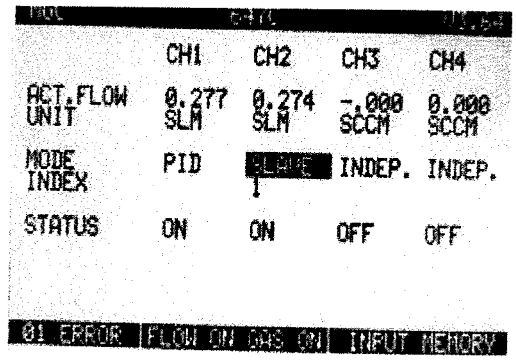

Figure 10: Mode Selection Screen

3.5 To turn gas flow on or off:

The gas flow can be turned on or off while in any menu. In the Extended Display menu the bottom line displays "ON" or "OFF", by channel, to show which mass flow valves are enabled. "ON" must be displayed in the bottom row of the Extended Display menu for gas to be flowing in a particular channel.

For gas to flow, two conditions must be met:

1. Each channel (1 and 2) must be enabled by pressing "ON" and then the desired channel number.

2. The entire system must be enabled by pressing "ON" and then "ALL" from the keypad.

Thus, each valve can be controlled individually using "ON/OFF - *Channel Number*", or all flow can be controlled using "ON/OFF - ALL". If the system is enabled, the status line at the bottom of every screen will indicate "FLOW ON GAS ON". **Note:** because Valve-2 (ethane) is normally slaved to Valve-1 (argon), when Valve-1 is disabled there will be no flow through Valve-2.

4 To Change a Gas Bottle

The argon and ethane supply bottles should be replaced by new (full) bottles when the bottle content drops below about 10% of its capacity. For argon, the bottle content is directly indicated by the bottle pressure: a new bottle usually contains 2000 to 3000 psig. Argon bottles should be changed whenever the bottle pressure is found to be below about 200 psig.

Ethane bottles, on the other hand, contain liquefied ethane. Thus the bottle pressure is just the vapor pressure of ethane at whatever the current temperature happens to be. At 70° F this is about 544 psig. The pressure gauge will not tell you how much ethane is left in the bottle until it reads zero! Instead, we measure the ethane content by observing the weight of the bottle and comparing it to the weight when the bottle was full. A standard B-size cylinder contains about 32 pounds of ethane. The ethane cylinders on the manifold sit on scales which have been pre-set to indicate the net weight of ethane in the bottle. Numbers in the green portion of the dial indicate ethane remaining. If the indicator points to the red portion of the dial, the bottle is empty.

Handling and connecting bottles of compressed gas require special knowledge. The high pressure gas stored in the cylinders (bottles) constitutes significant stored energy. Mishandling of a gas bottle can pose a lethal hazard! Refer to the JLab ESH&Q Manual [1] for safe handling practices. If you do not already know how to safely manipulate compressed gas hardware, have a knowledgeable person train you.

After attaching a new gas bottle to the supply manifold, check the connection for leaks using *Snoop* or a similar leak detector.

5 The Alcohol Bubbler

To reduce the rate of aging of the wire chambers, the operating gas contains a small quantity of alcohol vapor. The vapor is added by bubbling the argon/ethane mixture through liquid alcohol. The temperature of the alcohol controls the alcohol vapor pressure, which determines the amount of vapor added to the gas. The alcohol content also affects the electron drift velocity in the wire chambers, so it must be held approximately constant.

Gas is bubbled through the liquid alcohol inside the glass dome vessel in the refrigerator. The dome is covered by a perforated steel cylinder as a precaution against breakage. The alcohol level is controlled by a float valve inside the metal cold reservoir, which is also inside the refrigerator. As long as there is alcohol in the warm reservoir (sitting on top of the refrigerator), the liquid levels inside the refrigerator will remain constant. A drain valve (#7) inside the refrigerator is available for emptying all liquid from the system. It is for use by experts only and should remain closed during normal operation.

The reservoir should be refilled before it becomes empty to maintain a head of liquid over the float valve. This will prevent air from entering the system.

5.1 To by-pass the alcohol system

Open valve **3**, then promptly close valves **1 & 2**, in that order!
To restore flow through the bubbler, open valves **1 & 2** then close valve **3**.

5.2 Alcohol Temperature Control

To keep the alcohol temperature (and thus the vapor pressure) constant, the alcohol bubbler is housed in a refrigerator which is controlled by an electronic temperature regulator having 1 C° sensitivity. The controller is located on a shelf in the right-hand rack of the gas mixing system. Normally, the actual temperature in the refrigerator is indicated on the front panel of the controller. The controller should be set to maintain a temperature of 2° C.

5.3 Step-by-Step Instructions for Refilling the Alcohol Bubbler

These 13 steps must be individually completed in the order listed! Refer to Fig. 1.

1. Remove the three screws securing the cover on the alcohol fill-tank (the top-most metal tank at the rear of the mixer rack. Carefully remove the lid without allowing dust or dirt to fall into the tank.
2. Fill this tank to about 75% full from a bottle of 2-propanol.
3. Replace the lid and retaining screws.
4. Remove the small brass cap which seals the port on the lid.
5. Isolate the warm reservoir by **closing valves 4 and 8.**
6. Release pressure in the warm reservoir by **slowly opening valve 6 fully.**
7. **Open valve 5 fully** to begin the flow of alcohol from the fill-tank to the warm reservoir.
8. **Monitor the level** of alcohol in the warm reservoir sight-tube.
9. When the level is 2 cm from the top of the sight-tube, **close valve 5.**
10. Replace the brass cap on the lid of the fill-tank.
11. **Close valve 6,** *then* **slowly open valve 4.**
12. **Open valve 8.**
13. Record what you did in both the gas logbook and the electronic logbook.

6 Gas Filters Maintenance

There are gas filters on the argon and ethane supply lines just inside the gas shed. These filters should be replaced on a regular schedule. See Howard Fenker for details.

7 Secure Pressure Regulators

The gas mixing system is protected from failure or mis-setting of the primary pressure regulators (the ones mounted on the manifolds on the exterior of the gas shed – near the bottles) by *hidden* regulators mounted just inside the gas shed. It is these regulators which actually set the maximum supply pressure to the mixing valves. These regulators should *never* be adjusted by other than a gas system expert! The nominal secondary pressure supplied by both the argon and ethane secure regulators is 30 psig.

8 Ethane Flow Restrictor

A calibrated flow-restricting orifice is installed at the outlet of the main ethane high-pressure manifold outside the gas shed. This orifice passively limits the flow rate of ethane into the gas shed even if there is a catastrophic failure of the flow and pressure-controlling devices inside the shed. It is model `IC-DM4-9-SS` manufactured by *O'Keefe Controls Co.*, Trumbull, CT, USA. While it may look like simply a stainless-steel union fitting, it is in fact a precision part, and a necessary component of the gas safety system. It limits the flow of ethane to less than 26.5 SLM, which is a little less than ten times the maximum capacity of the flow-control system.

9 Related *Howtos*

- MKS 647 Mass Flow Controller Manual [2]
- Base Equipment Shift Checklist Items [3]

References

[1] Jefferson lab environment, health, & safety manual. Jefferson Laboratory. `http://www.jlab.org/ehs/manual/EHSbook.html`.

[2] MKS Instruments. *Multi Channel Flow Ratio/Pressure Controller Type 647C Instruction Manual*, May 2004. `http://hallcweb.jlab.org/document/vendor_manuals/647C_EN_0504A1.pdf`.

[3] H. Fenker. Hall-c base equipment checklist. `http://hallcweb.jlab.org/document/howtos/base_equip_checklist/`. Hall C User Howto.