Fermi National Accelerator Laboratory

FERMILAB-TM-1989

Fixed Target Flammable Gas Upgrades

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Fermilab Technical Memo TM-1989

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Introduction

Summary

In the past, fixed target flammable gas systems were not supported in an organized fashion. The Research Division, Mechanical Support Department began to support these gas systems for the 1995 run. This technical memo describes the new approach being used to supply chamber gasses to fixed target experiments at Fermilab. It describes the engineering design features, system safety, system documentation and performance results.

General Description

Gas mixtures provide the medium for electron detection in proportional and drift chambers. Usually a mixture of a noble gas and a polyatomic quenching gas is used. Sometimes a small amount of electronegative gas is added as well. The mixture required is a function of the specific chamber design, including: working voltage, gain requirements, high rate capability, aging and others. For the 1995 fixed target run all the experiments requested once through gas systems.

Operating Problems

We obtained a summary of problems from the 1990 fixed target run and made a summary of the operations logbook entries from the 1991 run. These summaries primarily include problems involving flammable gas alarms, but also include incidents where Operations was involved or informed. Usually contamination issues were dealt with by the experimenters. The summaries are attached.

We discussed past operational issues with the experimenters involved. There were numerous incidents of drift chamber failure where contaminated gas was suspect. However analyses of the gas at the time usually did not show any particular problems. This could have been because the analysis did not look for the troublesome component, the contaminant was concentrated in the gas over the liquid and vented before the sample was taken, or that contaminants were drawn into the chambers directly through leaks or sub-atmospheric pressures. After some study we were unable to determine specific causes of past contamination problems, although in argon-ethane systems the problems were due to the ethane only.

Design Features

Buying in bulk

Past practice was to use portable cylinders. Since these cylinders were frequently changed, there was always a chance to contaminate the systems with air or vent gas into the room. Since the cylinders arrived at different times, sometimes from different suppliers, they can have different contaminants. At the least this could cause the chamber gain to vary as different cylinders were put in use.

We decided to purchase gas in bulk. This allows one batch to serve for a long time, even the entire run in most cases. The gas can be analyzed carefully then before being used. For ethane service, tube trailers were overhauled and DOT certified. The trailers were evacuated and filled with argon gas here before filling by the gas supplier. A gas specification was written and competitive bids requested for the ethane supply. Buying gas in bulk is less expensive and less work during operations.

Gas Contaminants

We studied papers by Sauli, Brown and Atac to learn what contaminant gasses were most troublesome to drift chamber operation.

An ethane specification was written based on the CDF specifications and discussions with Atac and others. It is included in the appendix. The gas was analyzed both at the supplier and after arrival here. We found a commercial analysis lab that we have had check gas samples from these trailers. Past complaints included oil and moisture contamination. Filters and adsorbers were installed to remove them to acceptable levels.

Mixing

We looked at past mixing systems and their operating history. We decided to standardize, using modern mass flow meters and automatic controls. A Fisher and Porter controller is used to maintain the mixing tank pressure and the mix ratio for two or three components. It also includes alarms and interlocks that shut down the mixer if the mix ratio is out of tolerance. A typical controller configuration is attached. In case the mixing system should stop for any reason, cylinders of premixed gas are kept connected and ready to supply gas automatically. The controls were installed with UPS(uninteruptable power supplies) in most cases.

We made cost estimates for mixing gasses versus buying premixed gasses for each experiment. Unless the quantity used is very small, mixing is less expensive.

Detail Engineering

Some common past trip problems were reduced by attention to installation details. For example, crash buttons were relocated or installed with covers to prevent accidental use. Better electrical installation reduced fuse blowing incidents. Pressure regulator failures are reduced by proper selection, maintenance and installation.

Safety Requirements

Fermilab ES&H chapter 6020.3 covers flammable gas systems. The general precepts have been accepted for years. They include determination of risk classification by amount of stored combustion energy and progressive requirements as the risk classification increases.

Tiger Team Task 1409 was to revise and modify chapter 6020.3. The finding was that the chapter does not provide clear instructions to experimenters. There is no industrial standard that is directly applicable to the flammable gas systems as we use them.

The changes were made with three objectives: To clarify the standard, to update it with other relevant standards and to add or remove requirements to make it an achievable document resulting in consistent application. To achieve this the entire chapter was revised. Numerous details were changed while adhering to the general precepts mentioned above. Redundancies were eliminated and the chapter was reorganized to be easier to follow. Impractical or vague requirements were changed and new requirements were added. The approval process was clearly described.

Comments from interested parties were included and the Fire Hazard Subcommittee has gone over the standard thoroughly.

We obtained copies of Bureau of Mines 627 and 503 to help define whether a mixture is flammable or not since this has been an open issue in the past.

The old requirement for chamber leakage was difficult to measure and depended on the skill of the operator. It also required that the chamber be filled with flammable gas. We designed and built portable instruments to measure total chamber leakage at normal operating pressure, using any gas.

The specific changes are listed in the May 30, 1995 revision summary.

Electrical Safety

One of the past inconsistencies was electrical safety. Gas houses held a mixture of NEC Class 1, Div. 1 and general purpose devices. This showed a poor understanding of the NEC(a.k.a. NFPA 70) requirements for classified areas. Training in Electrical Safety In Hazardous Locations was taken. Copies of relevant documents were obtained including ANSI/ISA S12.12, API RP500, ISA RP12.6, NFPA 325M, NFPA 497A, NFPA 497M. Using these documents as guides standard classifications were defined. For example the gas houses were generally NEC Class 1, Group D, Division 2. This is much less costly than the Division 1 installations often used previously. It must be pointed out that NEC classification is often a matter of judgment.

NEC chapter 500 was abridged as pertinent to the gas systems and a copy of these guidelines was appended to the ES&H chapter. The intent was not to reproduce the NEC, but to make routine installations consistent and easier to design.

Flammable Gas Alarms

During past runs, there have been too many flammable gas alarms. We found that calibration was inconsistent, since hard to reach sensors were infrequently calibrated. Some sensors were installed in magnetic fields or other unsuitable locations.

We placed sensors in appropriate locations where they can be calibrated without undue difficulty. They are not in magnetic fields that render them useless and they are installed near the floor for heavy gasses. We instituted a plan of regular calibrations. Since past studies had found that calibration is needed quarterly, we have recalibrated every three months. As of now the sensor accuracy is generally within a few percent after this period and we are considering increasing the calibration interval.

Documentation

Past documentation was usually sketchy when it existed at all. We have documented the new gas systems thoroughly, modeling the safety reports after the RD Cryogenic system documentation. There is a standard table of contents, and a typical one is attached. These documentation packages are distributed to the safety panel and copies are kept locally and in a specially designated bookcase in the department office.

All piping and instrument drawings are now drawn on IDEAS. They are drawn using standard symbols per ISA S5.1.

Results

The mixing systems have been running very reliably. The E815 system was the first to be installed in March 1995. It has been running for twenty-one months. It has had five operational problems in the first year and one in the last nine months. The first year's operation is summarized in MSD-EN-TSG-023. Since March 1996 there has been only one incident, involving improper controller settings. The controller configuration was modified to prevent this in the future. We have applied lessons learned from these projects to all the others as applicable, and the results so far are very encouraging.

In several cases the experimenters have adjusted the mixture ratio to obtain the best detector gain. Gas ratio adjustments are easy to make with these mixing systems.

Cost is minimized with these mixing systems. Buying gas in bulk is less expensive than in small cylinders, and buying pure gasses is much less expensive than buying premixed. Generally pure gasses cost about half as much as premix. The additional cost of mixing valves and controls is small compared to the gas savings.

Referenced papers

F. Sauli, Principles of Operation of Multiwire, Proportional and Drift Chambers, 1977

S. Brown, Basic Data of Plasma Physics

M. Atac, Breakdown Processes in Wire Chambers and Prevention, 1982

Bureau of Mines 503, Limits of Flammability of Gases and Vapors, 1952

Bureau of Mines 627, Flammability Characteristics of Combustible Gases and Vapors, 1964

NEC, National Electrical Code, NFPA 70, 1992

ANSI/ISA S12.12, Electrical Eqpmt. for Use in Class 1 Division 2 Hazardous Locations, 1986

API RP500, Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities

ISA RP 12.6, Wiring Practices for Hazardous Locations, Instrumentation Part 1, Intrinsic Safety, 1995

NFPA 325M, Fire Hazard Properties of Flammable Liquids, Gases and Volatile Solids, 1984

NFPA 497A, Classification of Class 1 Hazardous Locations for Electrical Installations in Chemical Process Areas, 1992

MFPA 497M, Manual for Classification of Gases, Vapors and Dusts for Electrical Equipment in Hazardous Locations, 1986

ISA S5.1, Instrument Symbols and Identification, 1984

Appendix

A 1990 fixed target flammable gas problem summary
B 1991 fixed target flammable gas problems summary
C ethane specification
D mixing control diagram
E MSD-EN-TSG-023
F Fermilab ES&H 6020.3 Revision Summary
G Flammable Gas Safety Report contents
H E781 description
I E799/E832 description
J E815 description
K E831 description
L E866 description
M E871 description
N E872 description

Flammable Gas Alarms Logged by Ops Center:

Jan 1, 1990 to Jul 16, 1990

›ate	Time	Site	Problem
Jan 23	13:03	MP9	Unspecified false alarm.
Feb 6	08:52	NMS	Changing head.
13	10:52	NMS	Power surge (Experimentors working on mixer)
13	16:48	MW9	Bad DC110
14	17:02	NMS	Bad DC110
14	21:33	NMS	Bad SC100
17	16:16	MB7	Bottle connection leak.
Mar 4	00:36	MW9	Power supply blown fuse.
6	23:26	WBL	Chasis not working
13	00:29	MW9	Bottle change.
13	02:13	MW9	Blown fuse.
16	15:48	PC4	Accidental bumping Crash Button.
20	22:34	PC4	Solenoid malfunction.
21	23:12	MP9	Accidental bumping Crash Button.
22		MP9	SC100 failure
25	19:00	MP9	Gas regulator failure
26	01:32	MP9	Gas regulator failure
Apr 1	23:47	MW9	Power supply fuse blown
5	19:12	WBL	Accidental bumping Crash Button.
14	03:41	WBL	Bottle change.
May10	10:11	WBL	Gas purge.
11	07:53	WBL	Gas purge.
Jun16	04:51	PC4	Battery for permit chasis dead.(Power off for several hours)
26	13:58	ME	Gas head change
Jul 2	10:28	MT6	Accidental bumping Crash Button.
12	08:56	PC4	Accidental bumping Crash Button.
13	07:59	PC4	Bottle change.

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OF THE 27 ALARMS SINCE JAN. 1 , 11 HAVE BEEN DUE TO HUMAN ERROR AND 15 HAVE BEEN MECHANICAL IN NATURE. ONE WAS NOT SPECIFIED IN THE OPS CENTER LOG BOOK.

Problems by type:

Accidental bumping of Crash button	5
Bottle changes involving gas release	3
Blown fuses	3
R~gulator failure	2
› purge	1
Gas head change with gas release	2
Dead battery (power out several hours)	1

Solenoid malfunction	1
Chasis malfunction	1
SC100 malfunction	2
Bottle leak	2
DC110 malfunction	2
Power surge (experimentors error)	1
Unspecified	1
	27

****

Problems by site location;

PC	5
MT	1
ME	1
WBL	5
MW	5
MP	5
MB	1
NMS	3
	27

Problems With the Flammable Gas Alarms

Power Supply/Blown Fuse-8

1. Jan. 2, 1991 16:58
2. Jan. 5, 1991 2:31
3. Feb. 26, 1991 7:54
4. Apr. 16, 1991 15:25
5. Apr. 22, 1991 17:49
6. Sep. 7, 1991 1:22
7. Sep. 20, 1991 6:33
8. Dec. 13, 1991 :41

Chassis Malfunction-3

1. Jan. 2, 1991 17:08
2. Apr. 18, 1991 15:13
3. May. 22, 1991 10:33

Gas Purge-17

1. Jan. 3, 1991 4:46 - Out of Nitrogen
2. Mar. 4, 1991 9:15 - Photo Neon gas tube
3. Mar. 4, 1991 15:08 - Smell of swamp gas
4. Mar. 16, 1991 :32 - Improper Argon gas mixture
5. Mar. 16, 1991 7:26 - No Argon gas flow
6. Mar. 16, 1991 14:56 - No Argon gas flow
7. Apr. 25, 1991 6:46 - Chamber gas system alarm sounding
8. May 2, 1991 23:24 - N2 phototube gas flow alarm
9, June 4, 1991 20:12 - No Argon supply pressure
10. Aug. 25, 1991 2:40 - Proton helium flow
11. Sep. 20, 1991 21:39 - Low CO2 supply
12. Nov. 17, 1991 16:09 - Low CO2 supply
13. Dec. 27, 1991 22:19 - E-687 changing dewars
14. Jan. 1, 1992 12:41 - Argon switching dewars
15. Jan. 15, 1992 11:47 - N2 photo tubes gas flow alarm
16. Jan. 27, 1992 14:40 - N2 photo tubes gas flow alarm
17. Jan. 31, 1992 14:56 - N2 photo tubes gas flow alarm

Accidental Bumping of Crash Button-4

1. Feb. 8, 1991 9:14
2. Feb. 11, 1991 14:54
3. Apr. 29, 1991 15:12
4. Aug. 14, 1991 15:56

Unspecified Alarm-3

1. Jan. 28, 1991 14:01
2. Jul. 14, 1991 18:50
3. Dec. 12, 1991 17:36

Regulator Failure/Malfunction-10

1. Jan. 28, 1991 14:40 - Malfunction in makeup of alarm
2. Mar. 18, 1991 8:59 - Regulator valve adjusted
3. Apr. 18, 1991
4. May 29, 1991 17;04 - Problems with electronic gas mixer
5. Jul. 7, 1991 20:54 - An improperly set gas regulator
6. Jul. 10, 1991 - Argon dewars empty
7. Jul. 29, 1991 22:52 - A gas regulator failure
8. Oct. 28, 1991 15:44 - Malfunction in chambers
9. Oct. 28, 1991 15:50 - Malfunction in gas system
10. Dec. 30, 1991 19:33 - Closed valve system

False Alarm-3

1. Feb. 20, 1991 3:08
2. Apr. 17, 1991 10:50
3. Sep. 20, 1991 4:06

Gas Leak/Spill-5

1. Feb. 23, 1991 13:56
2. Feb. 23, 1991 15:47
3. Feb. 26, 1991 :01
4. Jun. 26, 1991 11:10
5. Oct. 6, 1991 13:05

Bottle Changes Involving Gas Release-3

1. Apr. 10, 1991 10:33
2. Mar. 7, 1991 16:33
3. Jun. 29, 1991 10:06

Bumping of Gas Detector Head-1

1. Aug. 26, 1991 11:27

BLANKET ORDER **7/7/95**

SECTION I - TERM, PRODUCT, AND QUANTITIES (1 YEAR ESTIMATE)

1. This order will have a term of three years. It will begin on August 12, 1995 and will end on August 11, 1998.

2. Ethane delivered in Fermilab furnished tube trailers will be delivered to the Lab B yard. Each tube trailer shall be filled so as to reach 5,000 lb.. of ethane, the maximum as specified in Bureau of Explosives, Tariff Number BOE-6000-1. This corresponds to approximately a pressure of 545 PSIG, at a maximum quality of 3.7% at 70°F for a 261 CF tube trailer. The ethane shall have a minimum purity of 99.0% with the following upper limits on contaminants:

Carbon Dioxide	CO_2	0.1%
Ethylene	C_2H_4	20 PPM
Hydrogen	H_2	10 PPM
Hydrogen Sulfide	H_2S	10 PPM
Methane	CH_4	0.5%
Nitrogen	N_2	0.1%
Oxygen	O_2	10 PPM
Propane	C_3H_8	1%
Total Halogens		10 PPM
Water	H_2O	10 PPM
Carbon Monoxide	CO	0.1%

(Total impurities not to exceed 1%)

3. It is anticipated that the annual usage of ethane will amount to approximately 110,000 SCF. This quantity is an estimate only. Actual requirements will be purchased which may exceed or fall below the annual estimate. Fermilab, however, will purchase a minimum one tube trailer (5,000 lb.. or 59,100 SCF).

SECTION II - DELIVERY PROCEDURES AND REPORTING REQUIREMENTS

1. Delivery of Ethane shall be made in accord with programmatic needs. The actual date and time of each delivery shall be negotiated between the vendor and Bruce Squires of the Research Division's Mechanical Support Department or his designated alternate. The vendor is expected to deliver ethane within 120 hours after notification by Fermilab.

2. Each tube trailer delivered shall be certified as to its impurities in the ethane. As a minimum, the impurities listed in Section I shall be provided in the analysis. The ethane tested shall be from the tube trailer after it has been filled.

3. Upon the initial request for delivery, the vendor shall fill a trailer to its maximum load certifying the amount of ethane provided and listing the impurities present in the ethane.

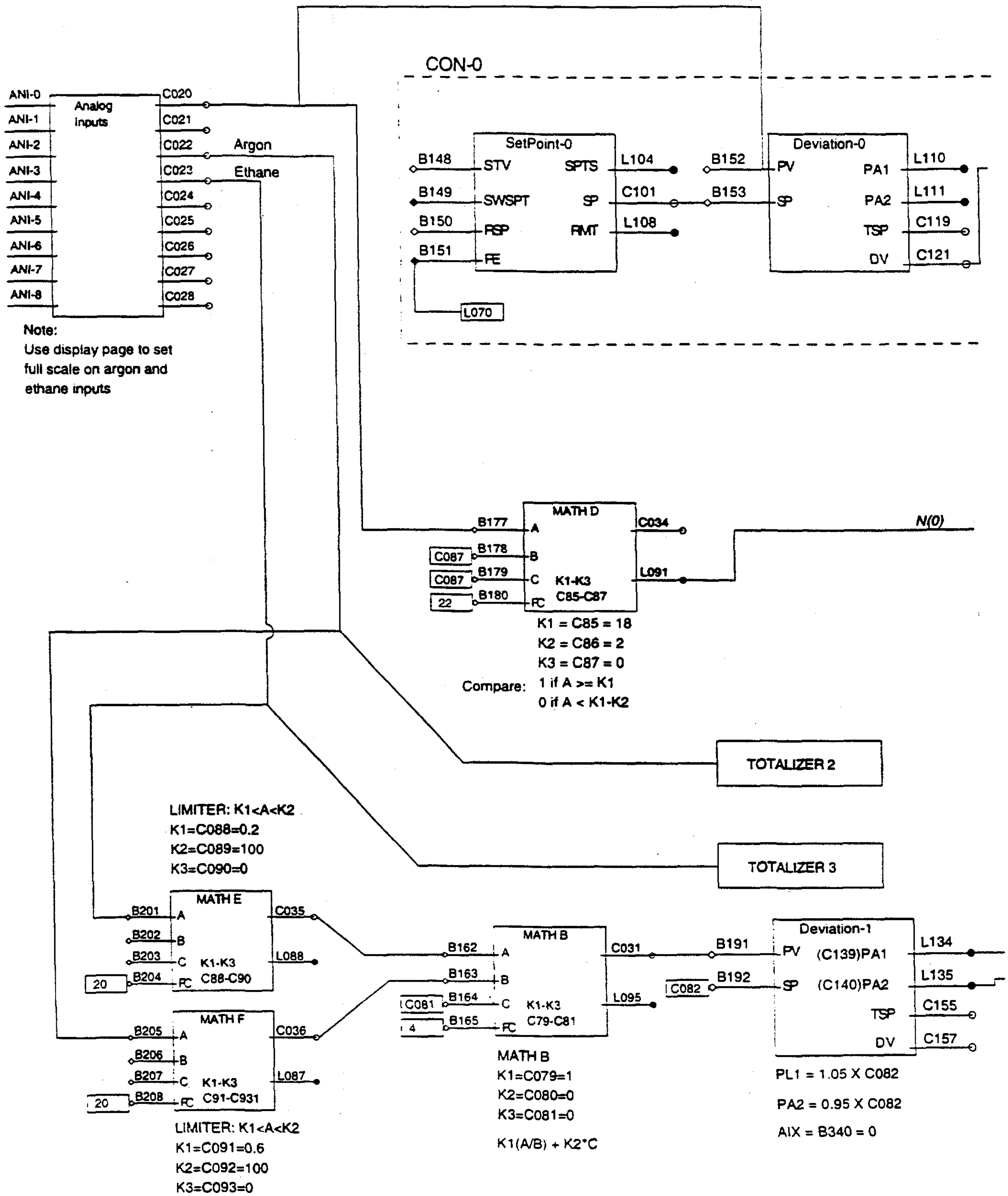
4. At Fermilab, the vendor's driver shall weigh in the tube trailer separately at Fermilab's scale house in order to verify the amount of ethane being delivered. Weight tickets and delivery tickets are to be deposited in the box provided inside the scale house. After weigh-in, the ethane trailer shall be delivered to the Lab B yard at the north end of Lab E.

5. During subsequent deliveries, the vendor shall deliver a full trailer and pick up the empty trailer.

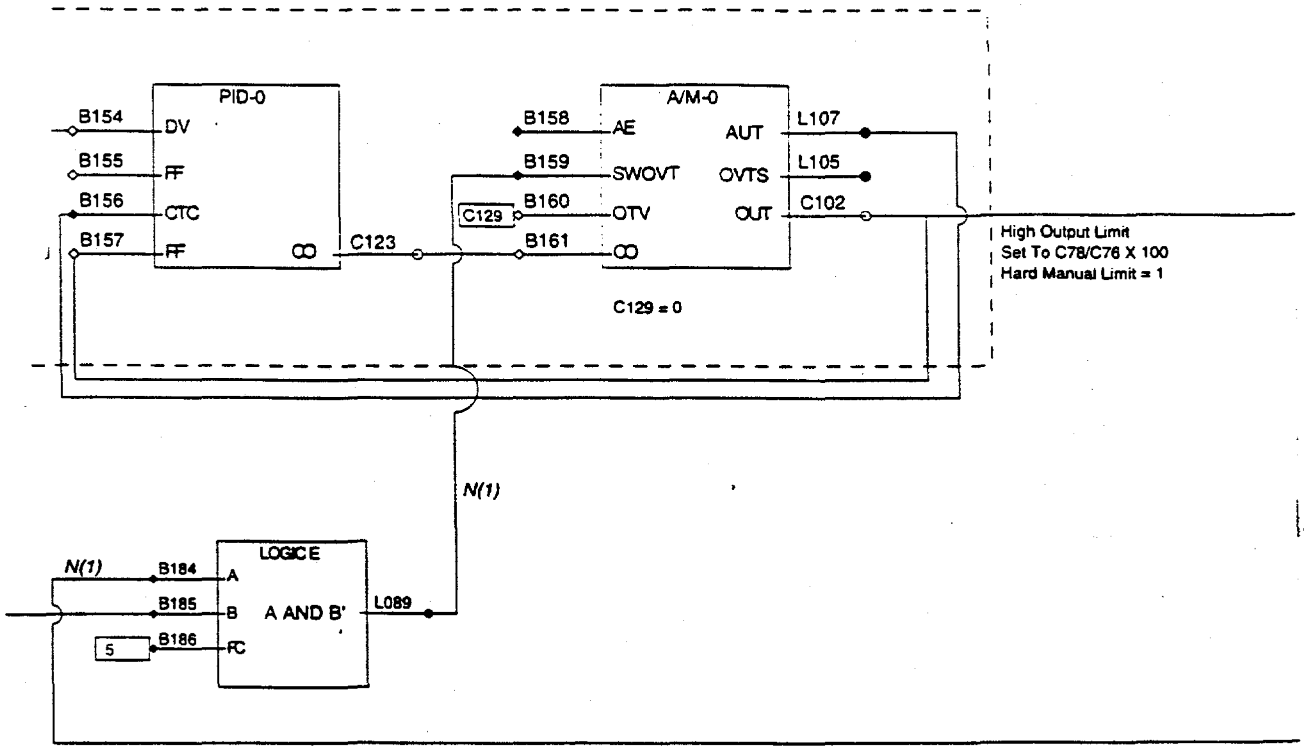
   IMPORTANT: With respect to delivery, Fermilab will reserve the right to purchase ethane elsewhere if in its judgment the vendor cannot deliver on time or deliver the quantity needed.

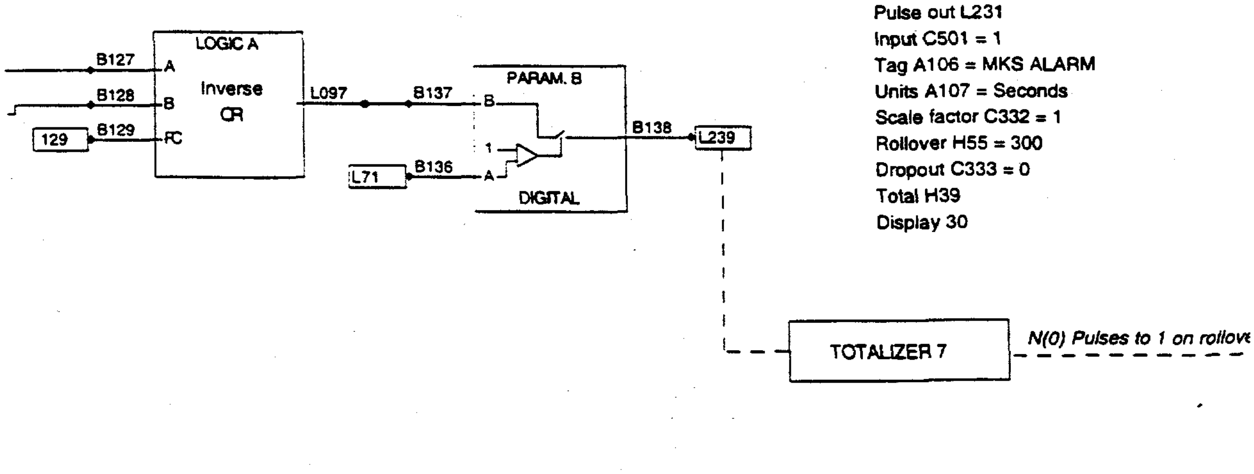
6. COST ESTIMATE : $0.42/SCF

   COST ESTIMATE FOR 1 YEAR (2 TRAILERS): $50,000.00


CON-0
ANI-0
ANI-1
ANI-2
ANI-3
ANI-4
ANI-5
ANI-6
ANI-7
ANI-8
Analog Inputs
C020
C021
C022
C023
C024
C025
C026
C027
C028
Argon
Ethane
Note:
Use display page to set full scale on argon and ethane inputs
SetPoint-0
B148
B149
B150
B151
STV
SWSPT
RSP
FE
SPTS
SP
RMT
L104
C101
L108
L070
Deviation-0
B152
B153
PV
SP
PA1
PA2
TSP
DV
L110
L111
C119
C121
MATH D
B177
B178
B179
B180
C087
C087
22
A
B
C
FC
K1-K3
C85-C87
C034
L091
N(0)
K1 = C85 = 18
K2 = C86 = 2
K3 = C87 = 0
Compare:
1 if A >= K1
0 if A < K1-K2
TOTALIZER 2
TOTALIZER 3
LIMITER: K1<A<K2
K1=C088=0.2
K2=C089=100
K3=C090=0
MATH E
B201
B202
B203
B204
20
K1-K3
C88-C90
C035
L088
MATH F
B205
B206
B207
B208
20
K1-K3
C91-C931
C036
L087
LIMITER: K1<A<K2
K1=C091=0.6
K2=C092=100
K3=C093=0
MATH B
B162
B163
B164
B165
C081
4
K1-K3
C79-C81
C031
L095
MATH B
K1=C079=1
K2=C080=0
K3=C081=0
K1(A/B) + K2*C
Deviation-1
B191
B192
C082
PV
SP
(C139)PA1
(C140)PA2
TSP
DV
L134
L135
C155
C157
PL1 = 1.05 X C082
PA2 = 0.95 X C082
AIX = B340 = 0

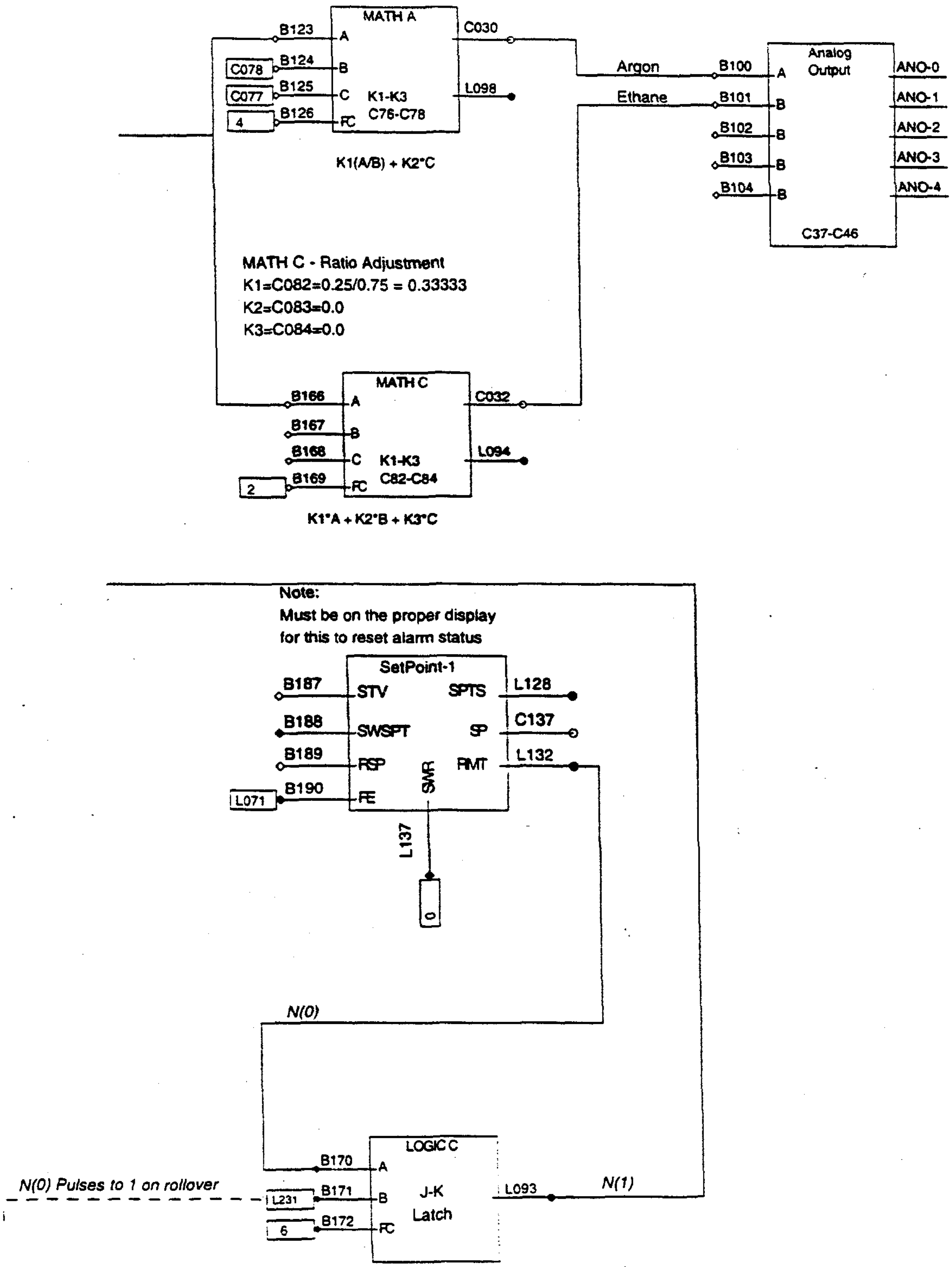
E831 Argon Ethane Mixing Control Program





TOTALIZER 7
Reset L239
Pulse out L231
Input C501 = 1
Tag A106 = MKS ALARM
Units A107 = Seconds
Scale factor C332 = 1
Rollover H55 = 300
Dropout C333 = 0
Total H39
Display 30

MATH A - FS Flowmeter Adjustment
K1=C076=FS Ethane (2.75338 LPM)
K2=C077=0
K3=C078=FS Argon (7.99302 LPM)



MECHANICAL SUPPORT DEPARTMENT
ENGINEERING NOTE

NUMBER: MSD EN-TSG-023 DATE: March 27, 1996

TITLE: E-815 Mixing System
Summary After One Year of Operation

AUTHOR: Bruce Squires

REVIEWER: Ted Gasteyer

KEY WORDS: E-815, argon, ethane, mixing system

ABSTRACT/SUMMARY:

E-815 uses a mixing system for the 50/50 argon/ethane mixture used in the drift chambers. After one year of operation, the mixing system has proven reliable. We have experienced five problems with the system. The table below summarizes these problems. System checks have caught most of the problems before any major effect was noted.

Problem	Description	Gas Interruption	Resolution
Power Supply Failure	The Power Supply for a Mass Flow Controller Shorted Out Internally and Blew Out the Fuse	Yes	Replaced Power Supply and Fuse then Tested Identical Supplies
Low Argon Pressure	Dewar Pressure Building Loop Supply Installed on the Wrong Supply Pipe	No	Changed Piping on Pressure Building Loop
Blank Controller Display	The Operator Interface (Faceplate) on the Main Controller Failed	Yes/Indirectly	Replaced Faceplate and Sent Out for Repair
Blown Ethane Heater Fuse	The Fuse on the Ethane Heater Blew Out and the Cause has Not Been Determined	No	Investigated Cause and Replaced Fuse
Low Ethane Pressure	Sticky Ethane Trailer Regulator Due to Oil and Water	No	Cleaned Regulator and Installing Coalescer Between Heater and Regulator

The first tube trailer of ethane was delivered on March 13, 1995. The mixing system was brought on-line that same day. On September 29, 1995, the second tube trailer was placed on-line. The third trailer was placed on-line on March 16, 1996. On that date, over 100,000 SCF of ethane had been mixed with argon at E-815.

We have had five problems with the gas system since operation began. Of these problems, only one directly effected the mixing system. Another one was misinterpreted and a resulting change in the system configuration caused the mixing system to shut down. System checks have caught most of the problems before any major effect was noted. There are plans to run signals into EPICURE that may be used to alarm the experiment if problems occur.

The first problem occurred in April 1995. One of the power supplies for the mass flow controllers failed. We investigated the probable causes for the failure including testing four supplies at 100%, 125%, 150% and 200% of the rated current for one month without a single failure. In normal operation, the mass flow controller pull less than 100%. During warm-up, it may pull a little more than 100% but tests indicate that this higher current only lasts a couple of seconds. We believe the failure was a faulty supply.

The second problem occurred on November 27, 1995. The argon dewar was filled by the vendor. He blew down the dewar lower than the normal operating pressure. The dewar was unable to build the pressure back up. The mixing system automatically adjusted for this problem. It was discovered that the supply for the vaporizer was connected to the vapor space of the dewar instead of the liquid portion. A temporary fix was put in place shortly afterward. A permanent fix was performed within a week.

The third problem was with the controller that is used to set the flow rates for the mass flow controllers. The controller face plate had failed, however the controller was still operating. This became obvious after reading a logbook entry by one of the experimenters. The entry stated that they shut off the ethane flow to allow only argon to go into the chambers. Five minutes later, the argon flow was shut down by the controller. This indicates that the controller was working properly because it is programmed to shut off the argon and ethane supplies if the mixing ratio is out of tolerance for more than five minutes at any one time. An investigation of the ethane and argon rotameters would have shown that the flow controller was still operating. The face plate was replaced and sent back for repair.

The fourth problem was a blown fuse on the heater for the ethane tube trailer regulator on January 29, 1996. This did not effect the mixing system. The temperature of the ethane heater block was noted to be low during routine system checks by the experimenters. The cause for the blown fuse remains a mystery. The fuse has been replaced and it has been running ever since without any problems.

The fifth problem was with the regulator on the ethane tube trailer. On March 18, 1996, it was noted that the supply pressure was at 47 psig while the daily checklist was being performed. This is the ethane backup pressure. Since the backup cylinders were on-line, the mixing system was not effected. Upon investigation of the problem, it became obvious that the regulator could not keep up with the ethane demand. Attempts at getting the regulator to work properly indicated that the regulator was operating in a sticky fashion. We removed the regulator and put in a temporary one. It appears there is water and oil in the regulator. We are installing an oil coalescer between the ethane heater and the regulator. This should prevent this from occurring again. We will drain the coalescer when installing a new tube trailer.

ES&H Chapter 6020.3 Revision Summary May 30, 1995 RLS

Tiger Team task 1409 was revise and modify chapter 6020. The finding was that the chapter does not provide clear instructions to experimenters. There is no industrial standard that is directly applicable to the flammable gas systems as we use them.

The changes were made with three objectives: To clarify the standard, to update it with other relevant standards and to add or remove requirements to make it an achievable document resulting in consistent application.

Comments from interested parties were included and the FHS has gone over the standard thoroughly resulting in sixteen revisions to the proposed standard.

Clarity
Redundancies were deleted. Most of the primary standard was also in the technical appendix. Sentences with no clear purpose were removed or rewritten. Vague requirements including the phrase "when practical" were deleted. Double spacing between words was eliminated, making reading easier.

Revisions
The general approach, that the hazard is a function of the amount of gas used, is unchanged. Also many of the requirements are unchanged. Some specific changes follow:

Introduction
This is a combination of the two present introductions. The section about Director's exception is deleted since it goes without saying.

Scope
Most of it comes from the TA introduction about exclusions. The definition of physics experiments as it pertains to this standard is added. Also the sentence about 1910.119 is added.

Flammability
This section is added to exclude non-flammable mixtures, which have occasionally been treated as flammable.

Classification
Deleted risk class III since neither mixing or pressures above fifteen PSIG are not specially hazardous. Also the existing requirements for class III are not substantially more that class II. Under separated systems, changed a few to ten times the normal flow rate. Generally the normal flow rates are very low. Few is indefinite and ten times allows reasonable sizing of flow limiting devices.
Added a definition of ignition sources.
Revised the table adding standard units.

Procedures for Approval
The procedures for approval are gathered together in one section instead of being scattered.
Added review of class zero calculations to make sure they were done correctly.
Added paragraph three to define the time period needed to come into compliance.
Added paragraph four to allow equivalency.

Requirements for flammable gas installations:
1 Combined TA and main standard. Added the sentence about standard signs.

2 Added dimensions since near was not specific enough. Removed sentence about compatible materials. Moved welding limitation to another paragraph.

3,4 Deleted check valve and flash arrestor, add flow limiting device. The flash arrestor serves no useful purpose and does not limit the flow rate. The intent now is to limit the flow into buildings in the event of a severed line, open vent, etc. The limit of ten times was chosen because purge rates are normally low and to avoid operational difficulty.

5 Added requirement that unused cylinders be capped.

6 Added definition to 'non-sparking'.

7,8 Add specifics on leak test schedule, allowable leak rates, broke out ventilation as a separate paragraph. Deleted sentence about spot checks.

9 Welding permit requirement moved to here.

10 This is a combination of the TA and the main standard.

11,12 Changed to cover all situations. Unnecessary specifics deleted.

13 Addressed the main issues of piping leakage and deleted pipe pressure testing for low pressure systems.

14 Added other instruments.

15 Changed explosion proof to pumps designed for pumping flammable gas. This affects the internal design, not the electrical classification. Move the ODH requirements to their own paragraph since it is important and not limited to purging considerations.

16 Required relief devices such as dedicated bubblers, dropped exception since chamber should always be protected.

17 Allowed small relief's to vent indoors. Deleted metallic piping requirement for vent lines.

18b Removed "if possible" from turning off ignition sources and defined the distance to be included.

18c Added labeling requirement to crash buttons.

18d Changed division head review to follow local emergency procedures to be more in line with sensible common practice.

19 Visual indication moved here.

20 Moved ODH requirements here from above. Added that it be considered for each building or room.

21 Documentation section has quite a bit added. Some is moved here from other locations in the standard. The existing documentation is very weak, and that inhibits a consistent review or easy understanding by others.

22 Added fire department notification so they would know when systems are commissioned and decommissioned.

23 Chemist notification is added since there is the possibility of toxic gasses or byproducts being used.

24 Where practical left in since it is defined. Deleted last phrase "where possible" to eliminate grand fathering.

25f Added comment about the guideline in the appendix. The goal is to classify areas per the NEC then follow the rules. Presently gas sheds are mixtures of general purpose and explosion proof equipment. Explosion proof is very expensive and is of little value if not installed correctly.

25g Added alarm requirement. Which is needed for larger systems. Fan reliability should not be taken for granted, and ventilation is the key means to avoid flammable mixtures.

Appendix 2
This is updated to the 1992 revision.

Appendix 3
Moved here from the text and updated per NFPA.

Appendix 4
Moved here from the text and updated.

Appendix 5
This guideline is to help provide consistency in classifying installations. Electrical classification per NEC is not well defined. Over-classification is very expensive, and not effective if installed improperly. These guidelines are based on NFPA reference documents, the NEC, and typical gas installations at the Lab. They are guidelines only and care must be taken to classify each area properly.

Appendix 6
The NEC is written for general use. Inapplicable requirements make using it on gas systems difficult. This appendix, like appendix 5, was written to promote consistent application of the code.

E-815 Flammable Gas Safety Report

General Description : E-781 Detector Gas System

Experiment 781 is located in the PC4 area. It contains a large gas distribution system for supplying both flammable and non flammable gasses to various detectors. The experiment has 17 detectors that require gas supplies. Ten of these have flammable gas flowing through them. The table below lists all the detectors which are being supplied with gas.

Detector	Chambers	Gas	Volume	Flow Rate
			(liters)	(liters/hour)
BTRD	1	Xe/CH4 (70/30)	0.11	0.30
TRSSD	1	Nitrogen	1	0.3
LASD1	1	Nitrogen	20	10
M1 PWC	3	Magic Gas 2	900	75
M1 DC	2	Ar/Ethane (50/50)	1418	71
LASD2	1	Nitrogen	10	5
DSSD	1	Nitrogen	10	5
DPWC1	3	Magic Gas1	82.3	7
DPWC2	4	Magic Gas1	184	15
ETRD	1	Xe/CH4 (70/30)	63	2.6
ETRD	1	Carbon Dioxide	71	2.7
VEEA	3	Ar/Ethane (50/50)	519	65
VEEA	3	Nitrogen	150	31
VEEB	3	Ar/Ethane (50/50)	519	65
VEEB	3	Nitrogen	150	31
VEEC	3	Ar/Ethane (50/50)	519	65
VEEC	3	Nitrogen	150	31
LPWC	3	Magic Gas1	200	45
NCAL PWC	17	Ar/CO2 (80/20)	85	14
Photon 1	1	Nitrogen	5000	1000
Photon 2	1	Nitrogen	5000	1000
Photon 3	1	Nitrogen	5000	1000

All the flammable gasses are bubbled through isopropyl alcohol except for the Xe/Methane. Ethane and nitrogen gas are supplied from a tube trailer and dewar respectively located at PS4. Argon is supplied by 160 liter dewars outside the gas house. Xenon gas is supplied from a Russian gas bottle located in the PC4 experimental hall. The remaining gasses are supplied through bottles in the gas house. There are two mixing stations which supply the argon ethane and magic gasses located in the gas house. The detector gasses then flow into the experiment hall though four multitube bundles to four gas distribution racks located along the beam line. One of the distribution racks contains the xenon methane mixing station which supplies gas to the TRD's. From the distribution racks the gas flows into the chambers. The chamber outlet gas flows through a bubbler and into an exhaust manifold to the outside.

KTeV Flammable Gas System

The gas system provides 50/50 argon/ethane to the drift chambers with a cumulative volume of about 850 liters. The normal system flow rate is about 1.2 lpm. The argon/ethane is supplied by premixed cylinders located in the gas room. A flow restriction orifice is located in the gas line in the event of a ruptured line downstream of the gas room. The gas passes through a bubbler containing 0°C isopropanol. The gas from the bubbler is then distributed to the chambers. Nitrogen is provided to purge the chambers. Argon/CO2 is also provided for situations where argon/ethane is not desirable and may also be used for purging the chambers.

The vent for the chambers goes to the south wall (east side) of the experimental hall where the gas vents under the intake of ventilation taking the gas outdoors. This ventilation has two centrifugal fans in series. The second fan is included in the event of a failure of the first fan. Both fans are alarmed. In the event of both fans failing, the chamber flow is stopped by closing both the supply and vent solenoid valves.

The flow to the chambers is controlled by flow meters located in the gas room. The pressure in the chambers is set by a valve on the exhaust of each chamber. The pressure in the chambers are monitored by a PLC. If the pressure in a chamber goes high, the inlet solenoid valve will close. If the pressure goes low, the vent solenoid valve will close.

This analysis shows that only the gas room requires an alarm system, however, crash buttons, gas status signs and gas heads will be installed in the experimental hall. The alarm system is connected to FIRUS and a crash button is located at the fire panel. The gas room has both a crash button and a gas status sign located outside.

In the event of a power outage, a UPS has been installed to operate the gas system with the exception of the chiller for the alcohol bubbler. When the UPS has run down, the gas system will shut down in a fail-safe mode. All of the flammable gas system solenoid valves are normally closed and are energized during normal operation.

E-815 Flammable Gas System

This experiment is a continuation of E-770 which last ran in the 1986-7 fixed target run. Most of the chambers are located in Lab E. There are three small chambers that will be operated in NKC and two small chambers in NEB.

The gas system provides 50/50 argon/ethane to 78 drift chambers in Lab E with a cumulative volume of about 700 SCF. The normal system flow rate is about 30 SCFH. The argon/ethane is mixed in the gas house with two flow controllers. The flow rate of the controllers is determined by a pressure controller on a 50 gallon buffer tank. This controller maintains the pressure in the buffer at 15 PSIG. If the flow rate drops below a set minimum, the pressure controller will maintain the pressure between 16 and 18 PSIG. A pressure regulator downstream of the buffer tank reduces the pressure to about 0.5 inches of water column. At this point, the supply line is protected by a relief bubbler located in the gas house and is set at about 0.7 inches of water column. Mineral oil is used in this bubbler. The gas then passes through the alleyway to Lab E where the gas is distributed to the chambers. The gas from the chambers enter the vent header which passes through the alleyway then into the gas house and then up to about 10 feet above the Lab E roof. This vent line contains an oil bubbler in the gas house to prevent air from entering the system if the flow stops. This bubbler contains mineral oil.

Gas from the buffer tank is also sent to the Lab F loft, Lab F and the NKC and NEB enclosures. The volume of each of the Lab F chambers is about 9.3 cu. ft. and that of the NEB and NKC chambers is less than two cubic feet. An orifice in the gas line in the gas house restricts the flow for these areas. In the enclosures, the argon/ethane pressure is reduced to about 3 PSIG and then bubbles through alcohol at about 0°C. The gas from these chambers are vented outdoors through 1/2" tubing.

The gas house equipment has been completely redone. A ventilation fan has been added in order to provide adequate ventilation. The mixing system has been replaced and upgraded to include ethane filtering to remove oil, H_2S, and H_2O. The gas cylinders in the gas house are only used for backup to the main gas supplies. The gases provided are ethane, argon, argon/ethane premix and nitrogen. The main supply for ethane is a tube trailer located at the northeast corner of Lab E. Argon is supplied from the dewar west of the gas house. Nitrogen can also be supplied from this dewar when argon is not needed for extended periods. Provisions have been made so that 160 liter dewars can be used to supply argon or nitrogen.

The chambers are checked for leaks about every 12 months and leaks are repaired as necessary. The gas system in Lab E remains essentially unchanged. One exception is that the relief bubblers on the chamber inlets were removed. The chambers are now protected by the relief bubbler in the gas house on the supply line for the chambers. The piping in the alleyway has only had a couple small changes. Three valves have been removed and the vent bubblers have been reduced to only one bubbler which is now in the gas house. The vent stack is also new.

General Description : Focus (E831) Detector Gas System

The Focus experiment is located in wide band lab. It contains a gas distribution system for supplying both flammable and non flammable gasses to various detectors. The experiment has 7 detectors that require gas supplies. Three of these have flammable gas flowing through them. The table below lists all the detectors which are being supplied with gas.

Detector	Chambers	Gas	Total Flow Rate
			(liters/hour)
PWC	5	Ar/Ethane (75/25)	178.50
Straw Tubes	3	Ar/Ethane (50/50)	9.5
RPC	1	Ar/Isobutane/CO2/Freon	7
Ion Chambers	3	Argon/CO2	3
Cherenkov 1	1	He/Nitrogen	566
Cherenkov 2	1	Nitrous Oxide	566
Cherenkov 3	1	Helium	1416

The chamber gasses except for nitrous oxide for cherenkov 2 are supplied from the south gas house. The nitrous oxide comes from a bottle manifold in the north gas house. The PWC gas is bubbled through isopropyl alcohol. This bubbler is in the south gas house. Ethane and nitrogen gas are supplied from the tube trailer and dewar respectively located at wide band. The remaining gasses are supplied through bottles in the south gas house. There is a mixing station located in the gas house which supplies the argon ethane for the PWC's. The detector gasses then flow into the experiment hall though the multitube bundles to the gas distribution rack located along the beam line. Some of the gasses flow first into the counting room where they are split up for each chamber then they return to the gas house and continue down to the experimental hall. From the distribution rack in the experimental hall the gas flows into the chambers. The chamber outlet gas flows back to the distribution rack and through a bubbler into the exhaust manifold to the outside.

E-866 Flammable Gas System

The chambers are in 4 locations (stations) along the detector. Each station contains 3 chambers. Station 2 through 4 chambers are operated on 50/50 Argon/Ethane with about 0.7% ethanol. The station 1 chambers are operated on 50/50 Argon/Ethane with about 1% ethanol. The total chamber gas volume is about 484 ft^3. The typical chamber pressure is 0.2 inches H_2O.

This gas system has been used in previous fixed target experiments (E-772, E-789). Gas is supplied to the chambers via a mixing system. Two ethane cylinders with a combined capacity of 800 SCF supply ethane to the mixing system. A 160 liter liquid argon dewar with a capacity of about 4690 SCF and two back-up argon cylinders, each with a capacity of 285 SCF, supply argon to the mixing system. The total argon capacity is 5260 SCF. The maximum mixing system ethane flow is about 22 SCFH.

Two stage regulators are used to reduce the ethane cylinder pressures to 37 psig. A line regulator is used to lower this pressure to 26 psig before it reaches the mixing system. Flow meters are used to control the mixing ratio. Orifices at the flow meter inputs are used to reduce the maximum flow rate to 22 SCFH. Gas flow to the tubes is switched on or off with solenoid valves. The mixing tube is followed by a back pressure regulator which is used to provide better control of the mixing ratio. The output of this regulator goes to a buffer tank with a volume of 4 ft^3. The buffer tank pressure is nominally 15 psig, although the pressure varies from 14 to 17 psig during the mixing cycle.

The output of the storage tank is reduced to 10 psig with a pressure reducing regulator. Two back-up cylinders of 50/50 Argon/Ethane and regulators set at 6 psig tee into the system at this point. The total ethane volume of the two cylinder is 81 SCF. The gas is bubbled through ethanol and then piped to gas distribution racks. Pressure regulators in each rack reduce the pressure to 3 psig. Needle valves and flow meters are used to control the flow of Argon/Ethane/Ethanol to each chamber from this source.

The total amount of ethane in the supply system is 885 SCF. The chambers contain an additional 242 SCF. The total ethane in the experiment is about 1127 SCF. The flammable gas detectors are placed at each of the station 1 to 3 locations, each station 4 chamber, each gas distribution rack, the freezer and the gas house for a total of 10 gas detectors. At 20% LEL, these gas detectors shut off the ethane and Argon/Ethane gas supplies as well as the high voltage supplies for the chambers while sending a signal to FIRUS to alert emergency personnel. Inerting gas is not supplied to the chambers when there is an alarm.

E-871 Flammable Gas System
General Description

This experiment is located in MC7. There are five large proportional chambers and four smaller proportional chambers located in the experimental hall. These chambers and their gas system will be installed close to the 1996 fixed target run.

The proportional chambers have a gas volume totaling approximately 9 SCF. This gas system provides a 50/50 concentration of Isobutane/Halocarbon-14 to the chambers. The normal total gas system flow rate out of the mixing system is approximately 2 SCFH.

The Isobutane/CF_4 is mixed in the gas house using two MKS flow controllers. The flow rate of the controllers is determined by a pressure controller on a 50 gallon buffer tank. This Fischer & Porter controller maintains the pressure in the buffer at 5 psig. If the flow rate drops below a set minimum, the pressure controller will maintain the pressure between 3 and 5 psig At this point, the supply line is protected by a relief bubbler located in the gas house and is set at about 5 psig. Mineral oil is used in this bubbler. The gas is then distributed to the chambers via a bundled tube of copper lines, from the gas shed, through MBOTTOM into a distribution rack in MC7 and finally into the nine proportional chambers. The gas exiting the chambers is vented into the atmosphere. This chamber exit line contains an oil bubbler to prevent air from entering the system if the flow stops.

The gas house equipment has been completely redone. A ventilation fan has been added in order to provide adequate ventilation. The mixing system has been replaced and upgraded to include ethane filtering to remove oil, H_2S, and H_2O. The gases provided are Isobutane, Halocarbon-14, Isobutane/ CF_4 premix, Argon/CO2 and Nitrogen. The main supply for Isobutane and CF4 are cylinders located in the MC gas house. Liquid Nitrogen is supplied from a 160 liter dewar into a heating coil into the gas house.

E-872 Flammable Gas System

There are three large chambers and one smaller chamber. The four chambers are located in PW8. These four chambers and their gas system will be installed close to the 1996 fixed target run.

This gas system provides 50/50 argon/ethane to four drift chambers with a gas volume totaling approximately 190 SCF. The normal total system gas flow rate is 5 0 SCFH.

The argon/ethane is mixed in the gas house using two MKS flow controllers. The flow rate of the controllers is determined by a pressure controller on a 50 gallon buffer tank. This controller maintains the pressure in the buffer at 15 psig. If the flow rate drops below a set minimum, the pressure controller will maintain the pressure between 14 and 17 psig. A pressure regulator downstream of the buffer tank reduces the pressure to about 3 psig. At this point, the supply line is protected by a relief bubbler located in the gas house and is set at about 5 psig. Mineral oil is used in this bubbler. The gas is then distributed to the chambers. The gas from the chambers enter the vent header which passes through the pit and then up to about 30 feet, then through the roof. This vent line contains an oil bubbler to prevent air from entering the system if the flow stops.

The gas house equipment has been completely redone. A ventilation fan has been added in order to provide adequate ventilation. The mixing system has been replaced and upgraded to include ethane filtering to remove oil, H_2S, and H_2O. The gas cylinders in the gas house are only used for backup to the main gas supplies. The gases provided are ethane, argon, argon/ethane premix and nitrogen. The main supply for ethane is a tube trailer located northeast of HIL and the berm. Argon is supplied from 160 liter dewars outside the gas house. Nitrogen is supplied from cylinders, inside the gas house.