c.c. Gary Leonard
done 5-2-08

Department of Energy
Fermi Site Office
Post Office Box 2000
Batavia, Illinois 60510

APR 30 2008

DIRECTOR'S OFFICE
MAY 1 2008

Dr. Bruce L. Chrisman
Chief Operating Officer
Fermilab
P.O. Box 500
Batavia, IL 60510

Dear Dr. Chrisman:

SUBJECT: MODIFICATION OF FERMILAB WORK SMART STANDARDS SET – FESHM CHAPTER 6020.3

Reference: Letter, B. Chrisman to J. Livengood, dated March 13, 2008, Subject: Modification of Work Smart Standards

The Fermi Site Office has reviewed the revised Fermilab ES&H Manual (FESHM) Chapter 6020.3, *Storage and Use of Flammable Gases*, March 2008. Our conclusion is that the changes made during this revision of FESHM 6020.3 will not negatively impact the Fermilab safety program. For this reason, the Fermi Site Office concurs in your request to replace the previous version of FESHM 6020.3 in the Fermilab Work Smart Standards set.

If you have any questions regarding this correspondence, please contact Jon Cooper or Ed Bucki, of my staff, at extension 4288 or 4891, respectively. Thank you.

Sincerely,

Dr. Joanna M. Livengood
Site Manager

cc: P. Oddone
Y.-K. Kim
W. Griffing

Fermilab

Bruce Chrisman
Director's Office
Directorate
630.840.2359 (phone)
630.840.8752 (fax)
chrisman@fnal.gov

March 13, 2008

Dr. Joanna Livengood
Site Manager
Fermi Site Office
U.S. Department of Energy
P. O. Box 2000
Batavia, Illinois 60510

Dear Dr. Livengood:

SUBJECT: Modification of Work Smart Standards

The following Fermilab ES&H manual chapter has been revised. Since this chapter is in the Worksmart Set of Standards, we are required to obtain your concurrence.

FESHM chapter 6020.3, STORAGE AND USE OF FLAMMABLE GASES
This FESHM chapter has been revised to reflect current operations.

Sincerely,

Bruce Chrisman
Chief Operating Officer

Encl.

cc:

B. Grant, w/encl.
B. Griffing, w/o encl.
Y.-K. Kim, w/o encl
P. Oddone, w/o encl.

DOE/FRMI Group Concurrence Date

ES&H File: Work Smart Standards

Fermilab

Section Office
ES&H Section
630.840.8069 (phone)
630.840.3390 (fax)

Memorandum

March 4, 2008

To: Bruce Chrisman

From: William Griffing

Subject: Revised FESHM Chapter 6020.3 – Storage and Use of Flammable Gases

FESHM chapter 6020.3, "STORAGE AND USE OF FLAMMABLE GASES" has been revised to reflect current operations. It was posted for review and comments were addressed.

After final approval, please return this approval page to Elizabeth Bancroft at MS119 for posting on the web.

Encl.

Recommended for Approval:

Bruce Chrisman — Date: 3/5/08

Approved:

Piermaria Oddone — Date: 3/11/08

STORAGE AND USE OF FLAMMABLE GASES

INTRODUCTION

The use of flammable gases in physics experiments presents a unique type of installation, requiring special considerations. In many cases, mixing of gases is involved. Large volumes of gases may be present; thus even small leaks or ruptures of thin windows may cause incursions into the flammable concentration region with a large inventory to support fire. Some flammable gases may be stored in the liquid state, increasing the inventory. Electrical equipment is an integral part of such installations and can thus provide an ignition source if such a system is improperly designed, fabricated, or operated. The purpose of this chapter is to mitigate the hazards associated with storage and use of flammable gases.

SCOPE

This chapter is intended to apply to activities using flammable gases, whether part of approved experiments taking beam or in testing labs and shops located across Fermilab chapters. This chapter excludes gasses used as fuels, gasses used for welding, burning and brazing procedures and transportation of compressed gasses addressed by other chapters. It also excludes liquid hydrogen targets and the area immediately around them, but does not exclude hydrogen storage or piping outside the tent or immediate vicinity of the target if there is no tent.

Compliance of all flammable gas system components with other relevant mandatory Fermilab ES&H Standards is required. If the amount of flammable gas stored at any single location exceeds 10,000 pounds the requirements of OSHA part 1910.119, Process Safety Management of Highly Hazardous Chemicals, shall be followed.

RESPONSIBILITIES

Division/Section (D/S) Heads are responsible for

- Assuring that the requirements of this chapter are met.

- Assuring that any flammable gas used in an experiment is reviewed and approved for its use, the experiment set up, and the effect on other experiments and the building.

The ESH Section is responsible for providing consultative support as chair of the Fire Safety Subcommittee

The Fire Safety Subcommittee (FHS) is responsible for

- Reviewing and recommending approval of risk classification to the D/S Head
- Reviewing and recommending approval of equivalent methods

PROGRAM DESCRIPTION

Flammability

Flammable gases may be diluted with inert gas to the point where the mixture is not flammable. This standard does not apply to facilities using only non-flammable mixtures. The flammability of a mixture can be determined by referencing Bureau of Mines Bulletins 503 and 627. Contact the Particle Physics Division Mechanical Support Department for these bulletins.

Gas Storage And Usage Facilities Risk Classification

1. A risk analysis shall be conducted using the chart shown in Figure 1. The analysis is based on the energy in the gas available for a fire. The chart in Figure 1 utilizes the limits on quantities of hydrogen gas. These quantities must be adjusted for other gases using the heat of combustion as described in Appendix 4. The results of the analysis indicate the Risk Class as described in Table 1.

Table 1 - Risk Classes

Risk Class 0	Risk of a small local flash fire
Risk Class I	Risk of a local fire
Risk Class II	Risk of a general fire

Examples of Risk Class analyses are given in Appendix 1.

2. The upper limit for a Risk Class 0 is the combustion energy in 0.6 kg of hydrogen. The equivalent quantities of some typical flammable gases are given in Table 2. This equivalence is scaled according to the heat of combustion of the gas.

Table 2
Maximum Quantities of Flammable Gases Meeting Criterion for Risk Class 0

	Mass (kg)	Mass (SCF)
Hydrogen	0.6	250
Deuterium	1.2	250
Methane	1.5	80
Ethane	1.7	50
Propane	1.7	30
Isobutane	1.8	25
Dimethyl Ether	2.7	30

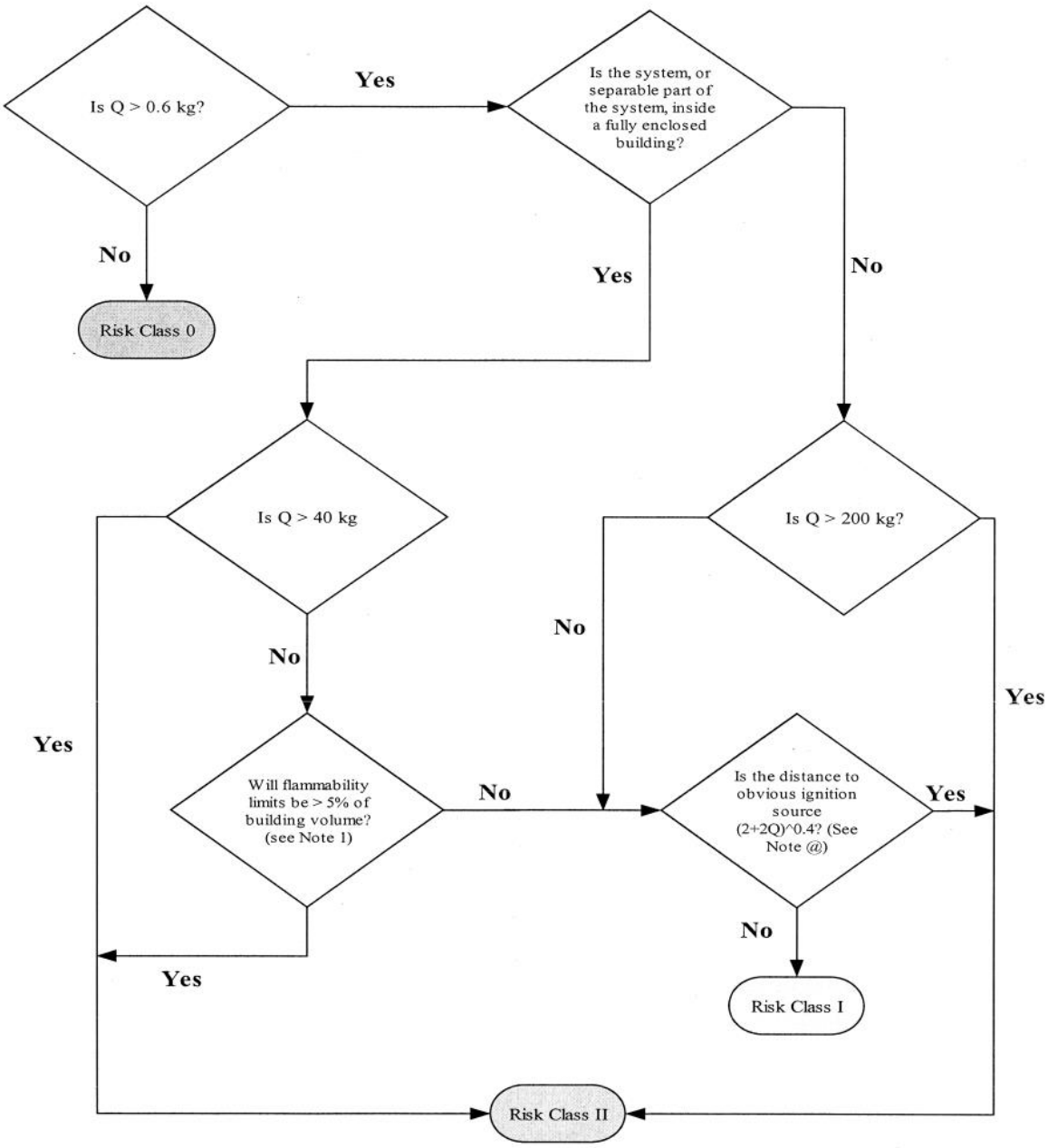
3. Installations may be subdivided into separable parts if restrictions exist to keep the gas flow from one part to another from exceeding ten times the normal flow rate. Normally, the separable parts will be in physically separate rooms. The Risk Class shall be determined for each installation or separable part thereof using Figure 1.

4. Gas in cylinders connected to a piping system is included in the quantity calculation. Nearby stored gas may be excluded from the quantity calculations if the stored quantity is less than the amounts listed in Table 2 for risk class zero.

5. If the Risk Class is not determined by a written analysis, then a default assignment of Risk Class II will be chosen.

6. Before using the flowchart in Figure 1, evaluate the total gas inventory in terms of the hydrogen equivalence Q using the heat of combustion as a scaling parameter. The system may be separated into parts each with its own risk classification. For storage facilities, the value of Q is determined in all containers including detectors, piping, and manifolds by the total gas present. For systems in which the gas is not in storage, the inventory is the sum of the mass

Table 1 - Risk Classification Flow Chart



Note 1: Ventilation should be considered for accidental venting of gas, including "worst case" scenarios such as the rupture of one or more detectors with discharge of their inventory. See text for consideration of "steady state" leaks. For storage facilities, this should consider the worst case such as the dumping of one full gas container. In some systems a credible accident may have to include the dumping of several cylinders manifolded together.

Note 2: Ignition sources include arcing devices, electrical equipment not rated Class 1 Division 2 locations per NEC article 500, welding, grinding, open flames, etc. For storage facilities, consider the worst case such as the dumping of one full gas container.

Procedures For Approval

1. Risk Class 0
   The risk analysis shall be reviewed by the Fire Hazard Subcommittee (FHS) or by an independent reviewer appointed by the Division/Section head. A copy of the independent review shall be sent to the FHS. Approval by the Division/Section head is required before the introduction of flammable gas into a system.

2. Risk Classes I and II
   The risk analysis and the installed system shall be reviewed by the FHS or by an independent reviewer appointed by the Division/Section head. A copy of the independent review shall be sent to the FHS for concurrence that the requirements of this chapter have been met. Approval by the Division/ Section head is required before the introduction of flammable gas into a system.

3. Nothing in this Chapter is intended to prevent the use of methods or materials of equivalent or superior quality to those prescribed below. The Fire Hazard Subcommittee will review documented requests for equivalency.

Flammable Gas Installation Requirements

Risk Class 0 Installations:

1. The area shall be posted "Danger-Flammable Gases, No Ignition Sources" using standard signs available from the Fermilab ESH Section. A list of responsible persons with their phone numbers shall also be posted.

2. Combustibles and ignition sources shall be minimized within three meters of gas handling equipment, piping or apparatus.

3. A pressure regulator appropriate for the gas and its environment shall be used.

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.

5. All gas cylinders shall be secured. Cylinders not in use shall be capped. Empty cylinders shall be promptly removed.

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.

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. If the aggregate leak rate is constant individual detectors do not need to be checked. Leakage exceeding 20% of the lower explosive limit at a distance over two inches from an identified "point" leak shall be repaired.

8. Ventilation above one air change per hour shall be maintained in areas using or storing flammable gas. This may be accomplished by mechanical or natural ventilation. For natural ventilation, a room vent with a minimum of 1/2 square foot free area shall be provided per 1000 cubic feet of room volume.

9. Welding burning, brazing, and grinding permits shall not be issued for areas within ten meters of the equipment containing flammable gas unless approved in advance by the responsible D/S Head or designee.

10. Oxidizers shall be stored separately from flammable gas containers or combustible materials. Either a distance of 20 ft (6.1 m) or a noncombustible barrier at least 5 ft (1.5 m) high having a fire resistance rating of at least ½ hour is a minimum separation requirement.

11. Inert chamber systems prior to introducing flammable gas. Require sufficient chamber purging prior to allowing high voltage to the chambers.

Risk Class I Installations

Risk Class I installations are subject to the Risk Class 0 requirements, as well as the following requirements:

1. The system, including vessels, chambers, supply and vent piping, and exhaust points shall be labeled "flammable gas".

2. 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.

3. Joints shall be made by brazing, pipe thread, or commercial fittings appropriately installed. Custom-made fittings required by detector design shall provide secure connections.

4. 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 per Chapter 5034 of the Fermilab ES&H Manual.

5. Bubblers, flow meters and other instruments shall be securely mounted and protected from possible breakage.

6. 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.

7. 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 shall not be used if equipment overpressure could result due to built up back pressure.

8. 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 three meters of an air intake. Vents shall be protected from clogging by debris, snow or ice.

9. Flammable gas detectors shall be installed near equipment installations, mixing stations, and in storage sheds:

   a. A high level alarm shall be installed and set no higher than 20% of the lower explosive limit (LEL) to summon the Fire Department through the

FIRUS system. (Local alarms at a lower percentage of LEL may be used to initiate corrective action.)

b. A high level alarm shall automatically shut off the supply of flammable gas and turn off power to potential ignition sources within three meters of operative gas usage apparatus.

c. "Crash buttons" shall be provided to accomplish the shutdowns described in b. These devices shall be conveniently located, and one shall be adjacent to the fire alarm panel, if present. Crash buttons shall be labeled "Gas System and Experiment Power Shutdown". They shall be shown on the Building Hazard 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.

10. 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 displayed at the locations of these warning lights.

11. Possible Oxygen Deficiency Hazards shall be addressed according to FESHM Chapter 5064. The hazard shall be considered for each building or room using or storing flammable or inert gas.

12. The following documentation shall be provided to the FSH, and all applicable Division /Section safety subpanels if convened, and a copy kept at the system site.

a. A general description of the system, 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.

e. Procedures for normal and abnormal operations including purging, startup, 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.

13. The Fire Department shall be notified of actual gas startup and system shutdown.

14. The chemist in the Fermilab ES&H section shall be notified before using any types of gas not found in the stockroom.

Risk Class II Installations

Risk Class II installations are subject to the Risk Class 0 and I requirements, as well as the following requirements:

1. Storage and processing enclosures shall be constructed, where practical, to comply with the guidelines of Chapter 7 of NFPA-58 (Appendix 2). While this document is specifically applicable only to LP gas storage facilities, it is a useful guide. Exceptions may be made with the approval of the Fire Hazard Subcommittee.

2. In addition:

   a. All storage enclosures shall be maintained free of standing water and/or ice to prevent falls of personnel handling gas system components.

   b. Adequate hardware for securing all cylinders used or stored shall be available.

c. Windows in gas sheds shall be wire glass set in metal frames with a fixed sash.

d. Enclosures near areas of vehicle access shall be protected with bumper posts.

e. The use of gas system enclosures to store oxidizers or gases used as fuels shall be prohibited. These enclosures shall not be used to store items not relevant to the gas system.

f. Electrical installation shall comply with NEC Article 500, Hazardous (Classified) Locations. The classification guidelines are shown in Appendices 5 and 6.

g. There shall be provisions for the ventilation of such enclosures per NFPA-58 (Appendix 2). Mechanical ventilation failure shall be alarmed.

28. The use of line-regulators downstream of cylinder regulators is strongly encouraged.

29. Fire sprinklers shall be installed in accordance with NFPA 13 to protect any adjoining or enclosing buildings from a fire in the gas storage facility. Sprinklers shall not be installed within the gas storage facility itself since it is not desirable to quench a gas fire with the leak still present.

APPENDIX 1
EXAMPLES OF RISK CLASS DETERMINATION

This appendix provides examples of Risk Class determination using Figure 1 and requirements of this chapter. The first step in such an analysis is to determine the inventory in terms of hydrogen content and then to follow the Figure 1 flowchart to determine the Risk Class. In many cases, the presence of flow and/or pressure restrictions may permit the facility to be separated into constituent parts which may be assigned different Risk Classes.

SUBDIVISION OF A SYSTEM

Figure 1A below is an illustration of a typical facility amenable to such separability. The storage area is an attached building separated from a processing area which is, in turn, separated from the experimental area. The processing area could, for example, contain mixing apparatus or temperature regulation equipment. One could, of course, have the processing area included within either the storage area or in the experimental hall. Each installation will differ, however generally solid walls with appropriate ventilation controls are required along with the limitations on the gas flow to render areas separable.

In this figure a system is shown in which two different gases (designated by different cross-hatching) are used to supply various detectors. Important details such as bubblers, check valves, orifices, shutoff valves, and gas detectors are not shown. Note that the storage area contains several cylinders in "off-line" storage. After passage through the detectors, the gases are vented to the outdoors at the right of the figure. The precautions of this policy are dependent upon the nature and size of the entire complex including all flammable gases present, even if there are independent systems supplying different detectors, or even different experiments in the same building.

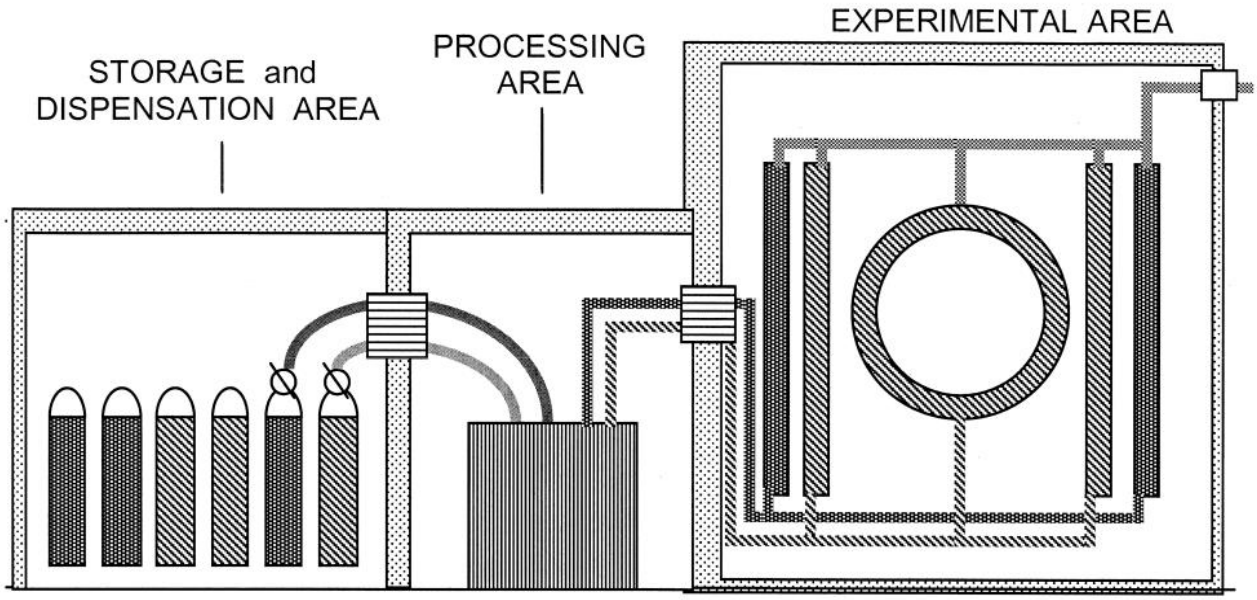


Figure 1A Typical Flammable Gas Installation

EXAMPLES OF RISK ASSESSMENT

Example 1

Two 81 SCF cylinders of a 50-50 mixture (by volume) of argon-ethane (Fermilab stock catalog number 1980-1095) will be used in a room whose volume is 9*15*20 ft^3 (2700 ft^3). This room, inside a larger building, contains no obvious fire hazards such as welding operations. The gas is to be supplied to drift chambers.

First, to determine Q, it is recognized that only 40.5 SCF of a given cylinder is ethane. Thus, from Appendix 3 and Appendix 4;

$$Q = 2*40.5\ ft^3 *0.028(m^3/ft^3)*1.26(kg/m^3)*0.36(H_2 \text{ equivalence factor})$$

$$Q = 1.03 \text{ kg hydrogen equivalent inventory}$$

Thus by box 1 in the flowchart, we exceed the limit for Risk Class 0 and must go to box 2. Continuing to box 2, we find the answer to be yes but the answer to the question in box 3 is negative. Doing the calculation prescribed in box 4 we find that 5% of 2700 ft^3 is 135 ft^3. Dividing 81/135 finds a maximum concentration of 60 %, which exceeds the

flammability upper limit. Thus, any concentration below this limit is reachable with the available inventory, since no inventory controls have been specified. Therefore the answer to this question is affirmative and the Risk Class is II. If only a single cylinder was needed, the Ø.5 kg hydrogen equivalence would have rendered a Risk Class 0 determination.

Example 2

This example is the same as that explored in example one except that these two cylinders are used to test a drift chamber in an open experimental hall 60*200*30 = 360,000 ft^3. The nearest ignition source is a temporary brazing operation at a distance of 40 ft (12.2 m). Following the flow chart, the same path is found until box 4 is reached. Five percent of this much larger room volume is 18,000 ft^3. Thus the maximum concentration in this volume would be 1.5 %, so that this question is answered negatively. At box number 6, we determine that objects or operations presenting an ignition hazard (the brazing operation) are more distant than the 2.0 m required by the formula based on the hydrogen equivalent quantity. Thus the Risk Class is I.

Example 3

A large system having an inventory of 15 cylinders such as used in the first two examples is stored in a separate "gas room" and is connected to a drift chamber system in the same experimental hall as in example 2. The same brazing operation is continuing. There is no processing area, only a storage area and the experimental hall. The inventory of the storage area is 15*0.5 kg/cylinder = 7.5 kg hydrogen equivalent. For the storage area a "yes" is encountered at box 2 while a "no" is encountered at box 3. The volume of the storage room is only 6*10*8 = 480 ft^3(13 m^3), however the gas inventory corresponds to a volume of 608 ft^3. Thus, without considering ventilation, the storage area will be Risk Class II after the query of box 4. Continuing on to the experimental hall the interconnection is considered. If appropriate flow restrictions exist, one may only have to consider Q to be the volume of detectors plus piping in the hall. Thus it may be appropriate to declare the experimental hall to be Risk Class I, if the condition on the distance from obvious ignition sources is met at box 6. If the detector volumes are large, then box 4 may indicate Risk Class II.

APPENDIX 2

CHAPTER 7 of NFPA-58

Standard for the Storage and Handling of Liquefied Petroleum Gases

(Copyright 1992, National Fire Protection Association, Quincy, MA 02269)

7-1 Scope

7-1.1 Application

7-1.1.1 This chapter includes the construction, ventilation and heating of structures housing certain types of LP-Gas systems as referenced in this standard. Such structures may be separate buildings used exclusively for the purpose (or for other purposes having similar hazards), or they may be rooms attached to, or located within, buildings used for other purposes.

7-1.1.2 The provisions of this chapter apply only to buildings constructed or converted after December 31, 1972, except for those previously constructed under the provisions of 5-3.3. Also, see 1-2.4.1.

7-2 Separate Structures or Buildings

7-2.1 Construction of Structures or Buildings

7-2.1.1 Separate buildings or structures shall be one story in height and shall have walls, floors, ceilings and roofs constructed of noncombustible materials. Exterior walls, ceilings and roofs shall be constructed as follows:

(a) Of lightweight material designed for explosion venting, or

(b) If of heavy construction, such as solid brick masonry, concrete block or reinforced concrete construction, explosion venting windows or panels in walls or roofs shall be provided having an explosion venting area of at least 1 sq. ft (0.1 m^2) for each 50 cu ft (1.4 m^3) of the enclosed volume.

7-2.1.2 The floor of such structures shall not be below ground level. Any space beneath the floor shall preferably be of solid fill. If not so filled, the perimeter of the space shall be left entirely unenclosed.

7-2.2 Structure or Building Ventilation

7-2.2.1 The structure shall be ventilated utilizing air inlets and outlets arranged to provide air movement across the floor as uniformly as practical and in accordance with 7-2.2.1(a) or (b). The bottom of such openings shall not be more than 6 in. (152 mm) above the floor.

(a) When mechanical ventilation is used, air circulation shall be at least at the rate of one cu ft per minute per sq ft (0.4 $m^3/s/m^2$) of floor area. Outlets shall discharge at least five ft. (1.5 m) away from any opening into the structure or any other structure.

(b) When natural ventilation is used, outlet and inlet openings shall be provided, each having a total free area of at least one sq in. (645 mm^2) for each sq ft (0.1 m^2) of floor area.

7-2.3 Structure or Building Heating

Heating shall be by steam or hot water radiation or other heating transfer medium with the heat source located outside of the building or structure (see Section 3-8, Ignition Source Control), or by electrical appliances installed in the building, if they are listed for Class 1, Group D, Division 2 locations, in accordance with NFPA 70, National Electrical Code (see Table 3-8.2.2).

7-3 Attached Structures or Rooms within Structures

7-3.1 Construction of Attached Structures

Attached structures shall comply with 7-2.1 (attachment shall be limited to 50 percent of the perimeter of the space enclosed; otherwise such space shall be considered as a room within a structure - see 7-3.2), and with the following:

(a) Common walls at points at which structures are to be attached shall:

(1) Have, as erected, a fire resistance rating of at least one hour. NOTE: For information on fire resistance of building materials, see NFPA 251, *Standard Methods of Fire Tests of Building Construction and Materials.*

(2) Have no openings. Common walls for attached structures used only for storage of LP-Gas are permitted to have doorways which shall be equipped with 1 1/2 hour (B) fire doors. NOTE: For information on fire doors, see NFPA 80, *Standard for Fire Doors and Windows.*

(3) Be designed to withstand a static pressure of at least 100 lb (0.7 MPa) per sq ft (0.1 m2).

(b) The provisions of 7-3.1(a) may be waived if the building to which the structure is attached is occupied by operations or processes having a similar hazard.

(c) Ventilation and heating shall comply with 7-2.2.1 and 7-2.3.1.

7-3.2 Construction of Rooms within Structures

7-3.2.1 Rooms within structures shall be located in the first story and shall have at least one exterior wall with unobstructed free vents for freely relieving explosion pressures. NOTE: For information on explosion venting, see NFPA 68, Guide for Venting of Deflagrations.

(a) Walls, floors, ceilings or roofs of such rooms shall be constructed of noncombustible materials. Exterior walls and ceilings shall either be of lightweight material designed for explosion venting, or, if of heavy construction (such as solid brick masonry, concrete block or reinforced concrete construction), shall be provided with explosion venting windows or panels in the walls or roofs having an explosion venting area of at least 1 sq ft (0.1 m^2) for each 50 cu ft (1.4 m^3) of the enclosed volume.

(b) Walls and ceilings common to the room and to the building within which it is located shall:

(1) Have, as erected, a fire resistance rating of at least one hour. For information on fire resistance of building materials, see NFPA 251, *Standard Methods of Fire Tests of Building Construction and* Materials.

(2) Not have openings. Common walls for rooms used only for storage of LP-Gas are permitted to have doorways which shall be equipped with 1 1/2-hour (B) fire doors. See NFPA 80, *Standard for Fire Doors and Windows.*

(3) Be designed to withstand a static pressure of at least 100 lb (0.7 MPa) per sq ft (0.1 m^2). Exception: The provisions of 7-3.2.1(b) shall be permitted to be waived if the building within which the room is located is occupied by operations or processes having a similar hazard.

(c) Ventilation and heating shall comply with 7-2.2.1 and 7-2.3.1.

APPENDIX 3
FLAMMABILITY LIMITS

Data from NFPA 325M-1984

Fire Hazard Properties of Flammable Liquids, Gases and Volatile Solids

Gas	Density at NTP (kg/m^3)	Flammability Limits (percentage volume in air at NTP)		
Hydrogen*	0.0824	4.0	-	75.0
Deuterium*	0.180	5.0	-	75.0
Methane	0.668	5.0	-	15.0
Acetylene*	1.174	2.5	-	100
Ethane	1.26	3.0	-	12.5
Propane	1.87	2.1	-	9.5
Isobutane	2.49	1.8	-	8.4
Dimethyl Ether	1.95	3.4	-	27.0

*Not expected to be routinely used in detectors because of its large flammability range, included for reference only.

Cylinders are generally specified as containing a given number of standard cubic feet (SCF). The inventory may be estimated by using the above densities of the gas phase with the conversion 0.028 m^3/ft^3.

APPENDIX 4
HEATS OF COMBUSTION

Hydrogen equivalent, Q

The heat of combustion for other gases is used to determine the hydrogen equivalent mass, Q, for use in Figure 1 in the main text. For example the table indicates that ethane has 0.36 times the heat of combustion of hydrogen per unit mass. Therefore 1.7 kg of ethane is equivalent to 0.6 kg of hydrogen in determining Risk Class.

Heats of Combustion

The following table of heats of combustion may be useful for calculating hydrogen equivalents. The heats of combustion can be found in, for example, *The Handbook of Chemistry and Physics.*

Gas	Molecular Weight	Gross Heat of Combustion (kj/g)	Relative to That of Hydrogen
Hydrogen-H_2	2	143	1.00
Deuterium-D_2	4	72	0.50
Methane-CH_4	16	55	0.39
Acetylene-C_2H_2	26	50	0.35
Ethane-C_2H_6	30	51	0.36
Propane-C_3H_8	44	50	0.35
Isobutane-C_4H_{10}	58	49	0.34
Dimethyl ether-$(CH_3)_2O$	46	32	0.22

-

Appendix 5
ELECTRICAL CLASSIFICATION GUIDELINES

These guidelines are based on common gas system installations at Fermilab. The classification shall be determined for each specific installation. All areas are assumed to be NEC Class 1, Group D.

1. Enclosed gas storage and mixing sheds are Division 2. This is based on adequate ventilation, this standard, and that a flammable mixture is likely to be present in the atmosphere less than ten hours per year.

2. A sphere with a diameter of 1.5 meters around outdoor vents is Division 1. A sphere with a diameter of 3 meters is Division 2. Generally there would be no electrical equipment in this area.

3. A sphere with a diameter of one meter is Division 1 around indoor vents. A sphere with a diameter of two meters is Division 2.

Appendix 6
ELECTRICAL INSTALLATION GUIDELINES

Class 1, Division 2 requirements as applied to gas systems, based on the National Electric Code, NFPA 70, Article 501.

This note is a summary of Article 501 as it pertains to Fermilab flammable gas systems. It is written as a simplified, general guide and meant to cover most, but not every conceivable situation. The NEC article covers both Divisions 1 and 2. The general plan for the gas systems is that electrical devices will be kept out of Division 1 areas when possible and that the gas sheds will be Division 2. Division 2 is applicable when a flammable mixture is likely to be present less than ten hours per year.

Ignition temperatures per NFPA 325M-1991:

Ethane	472 C
Methane	537 C
Isobutane	460 C
Isopropyl Alcohol	399 C
Ethyl Alcohol	363 C

Meters, Instruments, Relays, Signals and Alarms, 501-3(b) and 501-14(b)

1. Contacts shall be either:
   a. Approved for Class 1, Division 1
   b. Immersed in oil,
   c. Enclosed within a hermetically sealed chamber
   d. In circuits that do not release enough energy to ignite a flammable mixture

2. Electronics shall be either:
   a. Approved for Class 1, Division 1
   b. Immersed in oil,
   c. Without contacts and below 80% of the ignition temperature

3. Equipment without contacts like solenoids must be enclosed.

4. Fuses may be used in general purpose enclosures if preceded by a switch.

5. Plug and cord connections may be used if:

a. The receptacle is de-energized with a suitable switch.
b. The current does not exceed 3 amps at 120 VAC.
c. The power cord does not exceed 3 feet length.
d. The cord is extra hard usage or protected hard usage per NEC 400-4.
e. The plug and receptacle are locking and grounding type.
f. Only necessary receptacles are provided.
g. The receptacle has a warning against unplugging under load.

Wiring Methods, 501-4(b)

Wiring shall be either type PLTC, MI, MC, TC, or SNM.

Any of the following may be used:

a. threaded rigid metal conduit,
b. threaded steel intermediate metal conduit,
c. enclosed gasketed busways,
d. enclosed gasketed wireways,
e. Cable tray systems.

For flexibility, one of the following shall be used:

a. flexible metal fittings,
b. flexible metal conduit with approved fittings,
c. armored cable with approved fittings,
d. liquid tight flexible metal conduit with approved fittings,
e. liquid tight flexible nonmetallic conduit with approved fittings,
f. extra hard use cord with approved bushed fittings

Sealing and Drainage 501-5

Positive means to prevent gas from traveling through conduits or cable insulation from classified to unclassified areas must be used. Unbroken conduit can pass through a classified area without seals.

Conduit seals 501-5(b)

Seals shall be used for:

a. connections to Division 1 locations.
b. conduits between Division 2 and unclassified locations unless the conduit ends in an open raceway in the unclassified location.

Seal requirements. 501-5(c)

a. Fittings and compound shall be approved by a recognized testing lab..
b. Compound thickness shall be the minimum of conduit size or 5/8 inch thick.
c. No wire splicing in seal fittings.

Cable seals 501-5(e) and (f)

a. Cables entering enclosures with a gas tight sheath shall have the sheath removed and individual conductors sealed.
b. Cables which transmit below 198 CC/hour do not require sheath removal.
c. Cables that can transmit gasses shall be sealed at the Division 2 boundary.
d. Process instruments shall have two seals to prevent gas from entering the conduit system. Leakage of the primary seal should be obvious. The secondary seal must be designed for the conditions it will see if the first seal fails.

Switches, breakers and fuses, 501-6(b)

Switches, breakers and motor starters shall either:

a. be suitable for use in Division 1 areas,
b. be in a general purpose enclosure with hermetically sealed contacts,
c. have contacts that are oil immersed,
d. have the current interruption occurring in an approved chamber.

Fuses may be used if:

a. they are within suitable enclosures, or
b. the element is hermetically sealed.

Motors 501-8(b)

Use totally enclosed or general purpose squirrel cage motors.

Lighting 501-9(b)

Light fixtures shall be protected from damage. Surface temperatures must not exceed 80% of the ignition temperature.

Heaters 501-10

Heater surfaces shall not exceed 80% of the ignition temperature.

Flexible cords 501-11

Cords for portable equipment shall be:

a. the extra hard usage type,
b. equipped with a grounding conductor,
c. securely connected to the terminals,
d. supported so there is no stress on terminal connections,
e. sealed when entering explosion proof enclosures.

Live parts 501-15

There shall be no exposed live parts.

Grounding 501-16

All wiring and equipment shall be grounded and bonded.