Ames Procedural Requirements

APR 8715.1

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COMPLIANCE IS MANDATORY

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Ames Health and Safety Manual

Chapter 58 – Alarm Systems for Detection of Hazardous Atmospheres in Facilities

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Change History

Change #	Date	Description
1	8/8/2016	Initial issue of this APR 8715 chapter
2		
3		

PREFACE

P.1 Purpose

This chapter establishes procedures and practices for determining the need for sensor and alarm systems to detect flammable gases and vapors, oxygen deficient and oxygen enriched atmosphere due to leakage from cryogen containers (such as dewars and DOT container) or compressed gas cylinders.

P.2 Applicability

a. This directive applies to all Ames employees, Ames contractors and grantees as specified in their contracts or grants; and to other organizations (i.e., commercial partners, other Federal agencies, international parties, and Ames tenants) as specified and described in written operating agreements.

b. In this chapter, all mandatory actions (i.e., requirements) are denoted by statements containing the term "shall." The terms: "may" or "can" denote discretionary privilege or permission, "should" denotes a good practice and is recommended, but not required, "will" denotes expected outcome, and "are/is" denotes descriptive material.

c. In this chapter, all document citations are assumed to be the latest version unless otherwise noted.

P.3 Authority

NPR 8715.1A, NASA Occupational Safety and Health Programs

P.4 Applicable Documents and Forms
None.

P.5 Measurement/Verification
Verification and measurement for compliance to this directive will be tracked through Agency triennial audit and Ames Safety Accountability Program (formerly Ames Annual Voluntary Protection Program (VPP) self-inspections).

P.6 Cancellation
None.

/s/

Eugene Tu
Center Director

58.1 Overview

This chapter establishes procedures and practices for determining the need for sensor and alarm systems to detect flammable gases and vapors, oxygen deficient and oxygen enriched atmosphere due to leakage from cryogen containers (such as dewars and DOT container) or compressed gas cylinders. It also addresses issues related to installation and maintenance requirements of gas sensor and alarm systems.

58.2 Responsibilities

58.2.1 Supervisors or Principal Investigators of the Facility or Laboratory shall:

a. Initiate the Need for a Detection System Evaluation Worksheet (Fill out part A of Appendix E) and forward it to the Occupational Safety, Health and Medical Services Division for review if the laboratory is not exempt. See paragraph 58.3.1.1. for exemption.
c. Secure/provide the funding for the detection system.
d. Discuss with Plant Engineering Branch (JCM) and the Occupational Safety, Health and Medical Services Division the requirements for the detection system.

e. When it is determined that an active sensor system is no longer needed the requestor shall initiate a deactivation process. Requestor can be supervisors, principal investigators or their representatives.
f. Ensure employees are aware the hazard and the procedure when the sensor alarm system is activated, e.g. evacuation procedure.
g. Provide on the job training for specific detection system operations and hazards that the sensor monitors. Maintain records of on the job employee/staff training.

58.2.2 The Occupational Safety, Health and Medical Services Division shall:

a. Fill out hazard assessment section of Evaluation Worksheet (Appendix E) to help determine if flammable-gas, oxygen and gas detection sensor(s)/alarm(s) is/are needed.
b. Recommend detector type, alarm settings, location of sensor(s)/alarm, warning signs and lights (Appendix F).
c. Advise emergency responders on (e.g. health effects, monitor concentration of the leaked gas or cryogen) during an alarm event if requested.
d. Check calibration dates of registered flammable-gas, oxygen detection sensor(s)/alarm(s) and evaluate their needs periodically.
e. Review and validate requests for sensor system deactivation.

58.2.3 Plant Engineering Branch (JCM) shall:

a. Design the detection system. Any modifications to the requirements listed on the evaluation report shall require concurrence by the Occupational Safety, Health and Medical Services Division.
b. Manage the ordering and installation of the equipment.
c. Test the system to demonstrate that all of the detection system functional requirements have been met.
d. Inform the Occupational Safety, Health and Medical Services Division, Fire Department/Emergency Responders and the requester that the detection system has been installed.
e. Assemble a file on the installed detection system. The file will contain copies of the instruction manuals, the installation drawings, and the acceptance test results. It will be used for maintenance and calibration.
f. Maintain, repair and calibrate detection systems as required or recommended by the manufacturer or as directed by the Occupational Safety, Health and Medical Services Division.
g. Maintain an inventory of flammable-gas, oxygen detection sensors and toxic gas sensors at the Center and provide the inventory to the Fire Department, Environmental Services Division and the Occupational Safety, Health and Medical Services Division, annually

58.2.4 Environmental Management Division shall:

a. Update the building evacuation plans or similar plans to include the installed detection system.

58.3 General Guidance on Sensor/Alarm System

58.3.1 Determination of Need for Fixed Gas Detection System

58.3.1.1 Exemption from Detection and Alarm System Requirement

If the gas cylinders or cryogens are used inside a fume hood or stored in a ventilated gas cabinet, additional gas sensor/alarm system is not required in the room. See Appendix I, for quantities of compressed gas or cryogen used in the facility where the gas is use or stored and dimension of the facility, to see if the facility is exempt from sensor alarm.

58.3.1.2 Oxygen Displacement by Gas in a facility

If a cylinder of gas or a cryogen container in a facility such as a laboratory or a work center leaks, the oxygen in the room will be displaced. The overall concentration of oxygen in the laboratory will drop. Equation1 can be used to estimate the oxygen concentration. It assumes all the gas in a cylinder and all the cryogenic material in a container is released into the room at a release rate of R.
If there is a room with multiple gas cylinders, containers or system, it is assumed that the largest system, cylinder or container will release all its content into the room at a rate of release, R. For example, if a system is connect to two tanks. The two tanks are consider to be a system.

Equation 1: Oxygen Concentration (%) from a gas or cryogen leaks =

$$\left\{\frac{0.21}{(Q+R)}\right\}\left\{Q+R*exp\left[-(Q+R)/\left(\frac{t}{V}\right)\right]\right\}*100\%$$

V = Room volume (cubic feet)
T = Time from the start of the leak (minutes)
R= Release rate of the gas (cubic feet/minutes)
R =Release rate of cryogen * Its Expansion Ratio (ER)
Q= Effective air circulation rate (cubic feet/minutes)

$$Q=\frac{Q'}{K}$$

Q'= Actual or measured ventilation rate and K is a factor to allow for incomplete mixing

K = 1 for rooms with optimal mixing; K = 1.5 - 2 for rooms with good mixing; K = 2 - 5 for rooms with fair mixing; K = 5 - 10 for room with poor mixing. If a room or a laboratory has a fume hood that is running continuously, the flow rate of the fume hood will be accounted for as part of the actual measured ventilation rate of the room.

Release rate of the gas... If there is a regulator or a flow restrictor on the gas cylinder, the flow capacity, Cv, of the regulator or the flow restrictor (which ever provides a lower flow) and the pressure of cylinder the should be used to estimate the maximum leakage rate of the cylinder. Use the Cv and CGA E-4 to calculate gas flow leaving the gas cylinder.
The default release rate of a gas tank of 220 cubic feet is 44 cubic feet per minute.
The default release rate of a 65 gallon container is 134 cubic feet per minute. These values are the worst case value and are based on input from a manufacturer and a researcher.

Table 1: Expansion ration (ER) of common encountered cryogen at Ames are listed below

Cryogen	Carbon Dioxide	Nitrogen	Helium	Argon	Neon
ER	450	696	757	847	1438

Equation 2: The lowest attainable fraction of oxygen (%) for a given leak rate at t = ∞, and is equal to

$$\left[\frac{0.21\,Q}{(Q+R)}\right] * 100\%$$

58.3.1.3   Flammable Gas in a Laboratory

When flammable gas such as hydrogen or acetylene is stored in a facility such as a laboratory, calculation is needed to be made to see if there is a hazardous atmosphere. In making this calculation, it is assumed that the entire content of the flammable gas is leaked into the room at a rate of R. The room has an effective ventilation rate of Q. If there is multiple flammable gas cylinders in the room, the biggest system is the one that is assumed to leak. If the calculated flammable gas concentration in the room is more than 10% of the flammable gas’s lower explosive limit, the laboratory is considered to have a hazardous atmosphere, and the installation of a permanent gas sensor/alarm system for the flammable gas is required. Equation 3 can be used to calculate the concentration of the flammable gas.
Equation 3: Flammable Gas Concentration (ppm)

$$\{\frac{R}{Q}\left[1 - exp\left(-\frac{Qt}{V}\right)\right]\} * 10^6\,ppm$$

Acetylene and hydrogen are examples of flammable gases that can be found in Ames.

Equation 4: $$\text{Percent LEL }(\%) = \frac{Flammable\ Gas\ Concenteration\ (ppm)}{Lower\ Explosive\ Limit\ (ppm)} * 100\%$$

If the calculated flammable gas concentration is greater than 10% of the lower explosive limit, a sensor/alarm system is required.

58.3.1.4 Regulated Compressed Gas

When a tank of compressed gas leaks in a facility such as a laboratory, its concentration can be estimated using Equation 5.

Equation 5: Gas concentration (%) build up in the facility can be estimated using the following equation.

$$\{\frac{R}{Q}\left[1 - exp\left(-\frac{Qt}{V}\right)\right]\} * 10^6\, ppm$$

If the concentration of the gas in the facility is calculated to be greater than its immediate danger to life and health value, Threshold Limit Value ceiling, Permissible Exposure Limit Ceiling or NIOSH Recommended Exposure Limit Ceiling Limit or the 15-minute short-term exposure limit, the facility is required to have a chemical sensor. Example of regulated compressed gas that can be found in Ames include carbon dioxide.

58.2.1.5 Oxygen Enriched Atmosphere in a facility

If compressed gas oxygen is stored and used in a facility, such as a laboratory or a work center, calculation is needed to determine the maximum oxygen concentration in the facility if there is a leakage from the gas cylinder.

Equation 6: Oxygen Concentration (%)

$$\left\{0.2095 + \frac{R}{Q'}\left[1 - exp\left(-\frac{Qt}{V}\right)\right]\right\} * 100\%$$

If the calculated oxygen concentration in the laboratory is more than 23.5%, it is considered to be an oxygen enriched atmosphere. An oxygen alarm is required for an oxygen enriched environment.

58.2.1.6 Alarm for Refrigerant

As required by paragraph 8.11.2.1 of ANSI/ASHRAE Standard 15-2013, Safety Standard for Refrigerating Systems, each refrigerating machinery room shall contain a detector, located in an area where refrigerant from a leak will concentrate, that actuates an alarm and mechanical ventilation at a value not greater than the corresponding TLV-TWA (or toxicity measure consistent therewith). The alarm shall annunciate visual and audible alarms inside the refrigerating machinery room and outside each entrance to the refrigerating machinery room. The alarms required in this section shall be of the manual reset type with the reset located inside the refrigerating machinery room. Alarms set at other levels (such as IDLH) and automatic reset alarms are permitted in addition to those required by this section. The meaning of each alarm shall be clearly marked by signage near the annunciators. Detectors are not required when only systems using R-718 (water) are located in the refrigerating machinery room.

58.3.2 Alarm Settings

Alarm settings shall be determined on the basis of the evaluation, the detection system manufacturer's recommendations, and applicable codes and standards. Typical settings is listed in Table 2.

TABLE 2—ALARM SETTINGS

Type of detection system	Low	High
Flammable gas	10-percent of the lower Flammable limit	25-percent of the lower explosive limit
Oxygen	19.5 percent	23.5 percent
Regulated Compressed Gas	TLV, PEL or REL whichever is lower	IDLH, STEL whichever is higher

58.3.3 Alarm Response

Employees shall evacuate the building and notify the central dispatch (911) when the alarm signal is activated. Subsequent response actions will be determined by the Fire Department Emergency Response Incident Commander.

58.3.4 Sensor, Alarm, and Warning Light Location

The Occupational Safety, Health and Medical Services Division will recommend the number and location of the sensors. In general, the sensors should be placed close to the potential hazard source. The height at which the sensor is placed is typically based on the manufacturer's recommendation. The placement of the sensor will depend on the density of the gas of interest. If it is lighter than air, and it is flammable, the sensor should be placed at the highest point in the room. Breathing zone is between 4.5 feet to 6 feet. For gases that are heavier than air, the gas sensor is recommended to be placed between 4 to 5 feet. In general, audible alarms are placed inside the room or area, and a warning light is placed outside at each entrance of the room.

58.3.4 Warning Signs and Barricades

Warning signs are required near each warning light or audible alarm to provide sufficient information regarding the hazard. At least one inside and one at the room entrance. Please see appendix H for example of warning signs.

58.4 Detection System

58.4.1 Design of the Detection System

Plant Engineering Branch shall design the detection system in conformance to applicable building codes and NASA design specifications.

58.4.2 Installation of the Detection System

Once the need for a detection system has been determined, the design has been completed, Plant Engineering Branch will oversee the ordering and installing of the equipment. After the equipment is installed, tests shall be conducted to demonstrate that all of the detection system functional requirements have been met.
Plant Engineering Branch shall inform the Occupational Safety, Health and Medical Services Division, and the requester that the detection system has been installed.
The Environmental Management Division shall update the building evacuation plan to include the installed detection system. Plant Engineering Branch will assemble a file on the installed detection system. The file will contain copies of the instruction manuals, the installation drawings, and the acceptance test results. It will be used for maintenance and calibration. All gas sensor alarms systems shall be wired to the dispatch/centralized system.

58.4.3 Changes to a Detection System

To have changes made to the design and/or installation of an existing detection system, the requester should submit a work request to Plant Engineering Branch. A change to the installed detection system could be as minor as the addition or deletion of a single component, such as a detector or a strobe/siren, or as major as a large expansion or complete deactivation of the detection system.

58.4.4 Calibration and Maintenance of the Detection System

Once a system has been activated, Plant Engineering Branch will automatically implement a program of periodic calibration and preventive maintenance, as recommended by the manufacturer.

58.4.5 Detection System Deactivation

For sensor system deactivation the requester shall submit a request to the Occupational Safety, Health and Medical Services Division to evaluate the process and validate that deactivation is a safe course of action. Once validated, the requester shall submit a work request to Plant Engineering Branch, with supporting documentation, to have the system deactivated.

58.4.6 Use of Portable Oxygen or Chemical Sensors

Portable sensors are allowed for short duration projects if approved by the Occupational Safety, Health and Medical Services Division. Please contact the Occupational Safety, Health and Medical Services Division for approval prior obtaining any portable sensing system.

Appendix A: Definitions

Flammable gas.—A gas that burns—this includes fuel gases, hydrocarbons, hydrogen, and carbon monoxide.

Detection system.—A device or collection of devices designed and installed to produce an alarm signal in the presence of a predetermined level of a specific hazardous material or condition.

Hazardous material.—A material that is a physical hazard or a health hazard. This includes materials that are carcinogenic, toxic, irritating, corrosive, flammable, or reactive.

Immediately Dangerous to Life or Health—It is defined by the US National Institute for Occupational Safety and Health (NIOSH) as exposure to airborne contaminants that is likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from such an environment.

Low-oxygen (or oxygen-deficient) atmosphere.—An oxygen concentration of less than 19.5 percent by volume.

Permissible Exposure Limit-A chemical exposure limit established by OSHA

Recommended Exposure Limit (**REL**) is an occupational exposure limit that has been recommended by the United States National Institute for Occupational Safety and Health to the Occupational Safety and Health Administration (OSHA) for adoption as a permissible exposure limit. The REL is a level that NIOSH believes would be protective of worker safety and health over a working lifetime if used in combination with engineering and work practice controls, exposure and medical monitoring, posting and labeling of hazards, worker training and personal protective equipment.

Safety Data Sheet (SDS) —A fact sheet containing characteristics and hazards of a specific hazardous material. SDSs provide precautionary information on the safe handling of the material as well as emergency and first-aid procedures.

Requester—As used in this chapter, the requester is the project manager, research engineer, operations engineer, or person who requests the detection system.

Short-term exposure limit.—This is a 15-min time-weighted average exposure that should not be exceeded at any time during a workday. Exposures above the time-weighted average up to the short-term exposure limit should not be longer than 15

minute and should not occur more than 4 times per day. In addition, there should be at least 60 minutes between successive exposures in this range.
Threshold limiting value—The time-weighted-average concentration for a normal 8-hour workday and a 40-hour workweek; this is the amount to which nearly all workers may be repeatedly exposed, day after day, without adverse health effects.

Appendix B: Acronyms

APR	Ames Procedural Requirement
ARC	Ames Research Center
ER	Expansion Ratio
CFR	Code of Federal Regulations
NASA	National Aeronautics and Space Administration
NFPA	National Fire Protection Agency
NPR	NASA Procedural Requirement
OSHA	Occupational Safety and Health Administration
PPE	Personal Protective Equipment
PPM	Parts Per Million
REL	Recommended Exposure Limit
STEL	Short Term Exposure Limit
TLV	Threshold Limit Value
PEL	Permissible Exposure Limit

Appendix C: References

NPR 1800.1 NASA Procedural Requirement, NASA Occupational Health Program Procedures

ANSI/ASHRAE Standard 15-2013, Safety Standard for Refrigeration Systems

ANSI/ASHRAE Standard 34-2013, Designation and Safety Classification of Refrigerants

NFPA 69 Standard on Explosion Prevention Systems (2013 ed.). Quincy, MA: National Fire Protection Association.

NFPA 72 National Fire Protection Association. National Fire Alarm Code, 2016.

29 CFR 1910, Sec. 146 Occupational Safety and Health Standards. Permit-Required Confined Spaces.

29 CFR 1910, Sec. 134 Respiratory Protection Standard

ODH, Oxygen Deficiency hazard Cryogenic Analysis, Superconducting Super Collider Laboratory, 13 Jul 1993.

The limiting oxygen concentration and flammability limits of gases and gas mixtures, Isaac A. Zlochower, Pittsburgh Research Laboratory, National Institute for Occupational Safety and Health, Pittsburgh, PA 15236, USA

Industrial Ventilation, A Manual of Recommended Practice for Design, 28th Edition, ACGIH

CGA E4-201, Standard for Gas Pressure Regulators

Matheson Guide to Regulator

CGA SB-2—2014, Oxygen-Deficient Atmospheres

APPENDIX D—DETECTION SYSTEM PROCESS

- Activity involves the use of or operation of a material listed in Section 58.1. See section 58.3 and contact the Occupational Safety, Health and Medical Services Division if there is any questions.
- Requester completes evaluation worksheet–Determine the need for a detection system (see Appendix E) and forwards it to The Occupational Safety, Health and Medical Services Division.
- The Occupational Safety, Health and Medical Services Division reviews the evaluation of need for a detection system worksheet (Appendix E).
- The Occupational Safety, Health and Medical Services Division completes evaluation worksheet (see Appendix F) --> Copies sent to requester
- If detection system is needed, The Occupational Safety, Health and Medical Services Division instructs requester to initiate a work request with Plant Engineering Branch.
- Requester initiates a work request with Plant Engineering Branch.
- Requester, The Occupational Safety, Health and Medical Services Division and Plant Engineering Branch meet to discuss scope of effort.
- Requestor generates a Statement of Work, attaches it to work request, and obtains a cost estimate
- Plant Engineering Branch notifies requester of cost
- Requester provides funding
- Plant Engineering Branch oversees the procurement and installation of the detection system
- Plant Engineering Branch tests system with The Occupational Safety, Health and Medical Services Division and requester present
- Plant Engineering Branch maintains configuration control drawings of the detection system.
- Environmental Management Division updates building evacuation plan.
- Plant Engineering Branch calibrates and maintains the detection system per manufacturer’s recommendations.
- Change or deactivation of the detection system must be implemented via a work request that goes through the same process.

APPENDIX E—EVALUATION WORKSHEET TO DETERMINE THE NEED FOR A DETECTION SYSTEM

PART A

Building: __________ Room/Area: ___________ Date: ______________

Name of Supervisor/PI: _____________________________ Phone:_______________

Description of system (include preliminary design drawings or sketches):

Operational procedures:

Materials to be used or stored and the quantity of each (attach Safety Data Sheets):

Name of gas/cryogen	Size of Cylinder/size of Container	Quantity	Regulator (model, manufacturer)

Approximate dimensions of the room or area where the chemicals will be used or stored:
Height:___________Width:__________Length:__________

PART B: Hazard Assessment * To be filled out by the Safety Office

Name of evaluator (QH): ______________________________ Date:______________

Measured air flow rate or ventilation rate of the room (e.g. return air), Q':____________

Is there fume hood(s) in the room: Yes or No. If yes, what is/are the ventilation flow rate?_____________

Mix factor: ______ see Fig 2-1 of Industrial Ventilation Manual for examples
K = 1 for rooms with optimal mixing; K = 1.5 - 2 for rooms with good mixing; K = 2 - 5 for rooms with fair mixing; K = 5 - 10 for room with poor mixing.

Release rate of the gas or cryogen:______________ (What is the flow capacity, Cv, of the regulator. Use the Cv and CGA E-4 to calculate gas flow leaving the gas cylinder. If no other information is available the default release rate of gas is 44 cubic feet/minute for gas cylinder or 65 gallon cryogen in 45 minutes.)

Circle the appropriate equation being used.

Equation 1: Oxygen Concentration from a gas or cryogen leak =

$$\left\{\frac{0.21}{(Q+R)}\right\}\left\{Q + R * exp\left[-(Q+R)/\left(\frac{t}{V}\right)\right]\right\} * 100\%$$

Equation 2: The lowest attainable fraction of oxygen for a given leak rate at t = ∞ ,

$$\left[\frac{0.21\,Q}{(Q+R)}\right] * 100\%$$

Equation 3: Flammable Gas Concentration $\{[\frac{R}{Q}\left[1 - exp\left(-\frac{Qt}{V}\right)\right]\} * 10^6\, ppm$

Equation 4: Percent LEL $= \dfrac{Flammable\ Gas\ Concenteration}{Lower\ Explosive\ Limit}$

Equation 5: Regulated gas concentration build up in the laboratory can be calculated using the following equation. $\{[\frac{R}{Q}\left[1 - exp\left(-\frac{Qt}{V}\right)\right]\} * 10^6\, ppm$

Equation 6: Oxygen Concentration $\left\{0.2095 + \frac{R}{Q}\left[1 - exp\left(-\frac{Qt}{V}\right)\right]\right\} * 100\%$
Worst case calculated atmosphere condition in the room (e.g. oxygen concentration greater than 23.5, carbon dioxide concentration greater its IDLH value):_________________

V = Room volume (cubic feet)
T = Time from the start of the leak (minutes)
R= Release rate of the gas (cubic feet/minutes)
R =Release rate of cryogen * Its Expansion Ratio (ER)
Q= Effective air circulation rate (cubic feet/minutes)

$$Q = \frac{Q'}{K}$$

Q'= Actual or measured ventilation rate and K is a factor to allow for incomplete mixing
K = 1 for rooms with optimal mixing; K = 1.5 - 2 for rooms with good mixing; K = 2 - 5 for rooms with fair mixing; K = 5 - 10 for room with poor mixing. If a room or a laboratory has a fume hood that is running continuously, the flow rate of the fume hood will be accounted for as part of the actual measured ventilation rate of the room.
Release rate of the gas (R)... If there is a regulator or a flow restrictor on the gas cylinder, the flow capacity, Cv, of the regulator or the flow restrictor (which ever provides a lower flow) and the pressure of cylinder the should be used to estimate the maximum leakage rate of the cylinder. Use the Cv and CGA E-4 to calculate gas flow leaving the gas cylinder.

Alarm is required because (please check any of the reason that applies)

__ Calculated oxygen concentration is less than 19.5%...Due to displacement of oxygen by a gas—Oxygen alarm is required

__ Calculated concentration of the compressed gas in the room is greater than the IDLH, TLV or PEL—Chemical alarm is required

__ Refrigerant is used in the room- an oxygen sensor or a chemical sensor is required

__ A explosive gas sensor/alarm is required because the calculated concentration of the flammable gas is greater than 10% of the lower flammable limit of the gas.

__ An oxygen gas alarm/sensor is required because oxygen is stored in the room and the calculated concentration of oxygen is greater than 23.5%

APPENDIX F—REQUEST FOR A DETECTION SYSTEM

Work Request no.: ______________________________

Building: __________ Room/Area: ___________

Requestor: ______________________________

Signature of Requestor:____________________________ Date: _________________

The Occupational Safety, Health and Medical Services Division
Representative:_____________________________

Detection system needed: ___Yes ____No

Worst-case concentration: _________________

Allowable concentration: __________________

Recommended engineering controls:

Type of detection system:

Alarm setting(s): Low ________ High ________

Whenever possible, alarm should set to average gas measurements over 1 minute to provide a more stable/representative reading.

Number of sensors required: ___________

Sensor(s) location(s):

Alarm indicating device(s) location(s):

Number of warning signs required: _______

Wording:

Location:
Evacuation procedures:

Building evacuation plan updated: ____Yes ____No
Conditions of operation (to be included on the safety permit):
Barricades required:

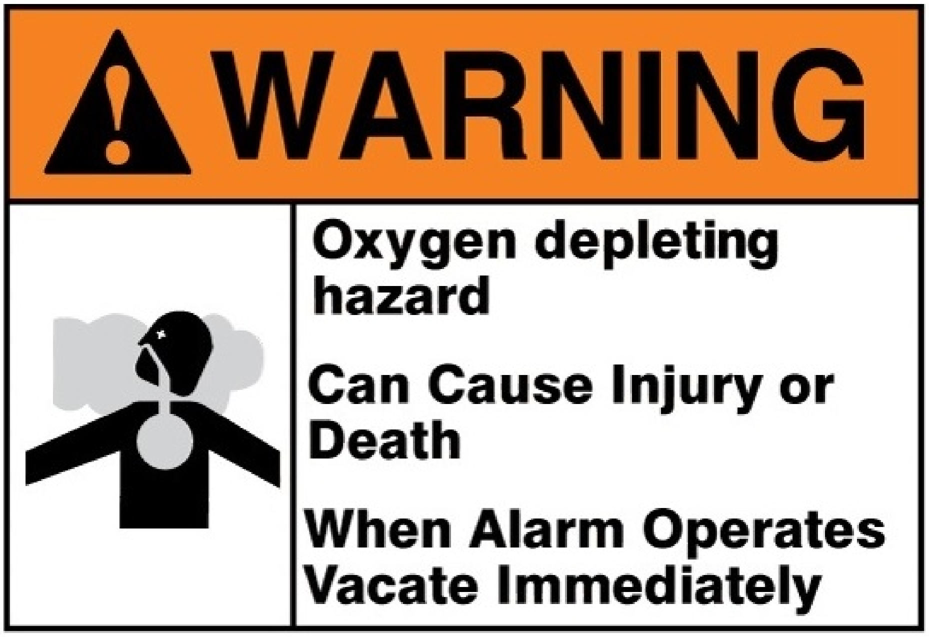
Additional comments:

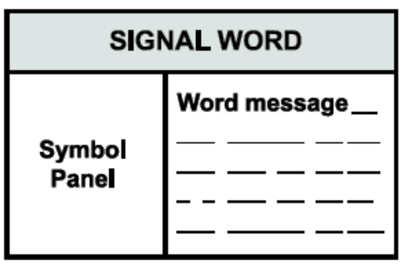
Appendix G. **Health Effects of Different Oxygen Concentration** Hazard Category of the Alarm Based on Health Effects Associated with Different Oxygen Concentration.

Oxygen %	Health Effects[1]/Comments
Greater than 23.5	Considered an “Oxygen Enriched Atmosphere” consider to be danger to human life because increase in risk of fire and explosion. **Oxygen content greater than 23.5%...Oxygen sensor required to be wired to the dispatch/centralized system**
20.9	Normal Oxygen Content in the atmosphere
19.5	Safety Limit according to OSHA Respiratory regulation, 29 CFR 1910. 134
17	First signs of hypoxia. Some increase in breathing volume and accelerated heart rate.
16	Impaired Judgment
14	Impaired concentration and coordination
12.5	IDLH-Immediately Dangerous to Life or Health
10	Very faulty judgment and muscular coordination. Intermittent breathing.
6	Spasmodic breathing, convulsive movements, death in minutes.

Adapted from ASSE Safety 2004 Proceedings, “Confined Space Hazards”, R. Craig Schroll, CSP, CUSA

APPENDIX H: EXAMPLES OF HAZARD WARNING SIGNS





DANGER indicates a hazardous situation which, if not avoided, will result in death or serious injury

WARNING indicates a hazardous situation which, if not avoided, could result in death or serious injury

CAUTION indicates a hazardous situation which, if not avoided, could result in minor or moderate injury

NOTICE is used to address practices not related to physical injury

Safety instruction (or equivalent) signs indicate specific safety-related instructions or procedures

APPENDIX I: Exemption Look-up Table

If volume of the room is less than the value in the table below, please fill out part A of Appendix E and have the Safety Office evaluate with an oxygen sensor is required (part B of Appendix E).

TABLE 3- Oxygen Sensor Requirement Look-Up Table for Commonly Encountered Cryogens in Ames Research Center

Volume of Cryogen in Liter	Volume of Room (cubic feet)				
	Carbon Dioxide ER= 450	Nitrogen ER= 696	Helium ER=757	Argon ER=847	Neon ER=1438
4 liter	374.603	579	630	705	1197
6 liter	561.9045	869	945	1058	1796
8 liter	749	1158	1260	1410	2394
30 liter	2809	4345	4726	5288	8977
160 liter	12000	12000	12000	12000	12000
230 liter	12000	12000	12000	12000	12000
240 liter	12000	12000	12000	12000	12000

TABLE 4- Sensor Requirement Look-Up Table for Regulated Compressed Gases

Name of the Gas Full size 1 A cylinder (9” diameter X 51” height/220 cubic feet of compressed gas	Number of cylinder	Chemical Sensor required if the room volume is less than the value below, based on IDLH value of the chemical	Oxygen Sensor is required if the room volume is less than the value below, based on 19.5% of oxygen requirement
Carbon Dioxide (IDLH= 40,000 ppm)	1	5,500 cubic feet	3,531 cubic feet
Nitrogen	1	NA	3,531 cubic feet

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