Ammonia Detection System
Codes and Design Specifications

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Ammonia Detection System Codes and Design Specifications

Following is a discussion of ammonia detection system design for facilities utilizing ammonia refrigeration systems. Regulations for the ammonia refrigeration industry have dramatically changed in the last 10 years.

Beginning with 2021 editions of the Uniform, International, NFPA, and ASHRAE codes and standards, you only need to consider recommendations from IIAR when you evaluate your ammonia detection system for compliance.

In addition to IIAR standards, you should always consider any local amendments or supplemental requirements of your local authority having jurisdiction (AHJ), recognized and generally accepted good engineering practices (RAGAGEP), and your insurance company. Many insurance carriers impose their own requirements to mitigate the risk of loss of life and product in a facility.

What follows is a system design that meets the requirements all of the above-mentioned influences. This document is updated periodically, and it is recommended that you check our website (www.ctiengineering.com) for the latest revision.

Table 1: Ammonia Detection System Overview

Location	Sensor	Actions
Compressor Room (minimum 2 sensors)	GG-NH3-250 (low range detector)	**25 ppm** - Alarm to monitored location **25 ppm** - Horn Strobe outside each entrance and inside engine room **150 ppm** - Emergency Ventilation
Compressor Room (minimum 1 sensor)	GG-NH3-2% (high range detector)	**10,000 ppm** - Redundant Emergency Ventilation* **20,000 ppm** - De-energize pumps, compressors, and normally closed valves
Vent Line*	GG-VL2-NH3	**1%** - Alarm to monitored location*
Refrigerated Areas	GG-NH3-100	**25 ppm** - Alarm to monitored location **25 ppm** - Horn Strobe* **35 ppm** - Close liquid and hot gas solenoid valves*
Packaged Systems		**See Table 1.2**
Enclosed Equipment	GG-NH3-2%	**20,000 ppm** - Disable ignition sources
Machinery under 100 HP and equipment Pits (not in machine rooms)	GG-NH3-100	**25 ppm** - Alarm to monitored location **25 ppm** - Close liquid and hot gas solenoid valves **25 ppm** - Horn Strobe inside room **25 ppm** - De-energize pumps, motors, and non-emergency fans **25 ppm** - Emergency Ventilation

**Not required by code*

Table 1.2: Packaged System Detection Overview

Location	Specification 1	Specification 2	Detection Level (See Appendix 3, page 8)
Indoor	Over 100 HP Inside a Compressor Room		Machinery Room Detection Level
	Under 100 HP Outside a Compressor Room	Potential of 40,000ppm? Yes	Level 3 Detection
		Potential of 40,000ppm? No	Level 1 Detection
Outdoor	Free Aperture? Yes	No detection required	
	Free Aperture? No	Under 100 HP	Level 1 Detection
		Over 100 HP	Machinery Room Detection Level

Compressor Room (0-250 ppm sensors)

Code requires audio-visual indication inside the compressor room and outside each entrance to the compressor room at 25 ppm. From the gas detection control panel or PLC, the warning outputs can be set at 25 ppm to activate a horn / strobe unit inside the engine room and outside each entrance. Entrance monitor display units can be located outside each doorway to warn personnel of ammonia concentrations prior to entry. Audio-visual alarms can automatically reset if the ammonia concentration drops below 25 ppm.

Code requires emergency ventilation at 150 ppm. The alarm setpoints should be set at 150 ppm and trigger the emergency ventilation fan starter. Emergency ventilation and visual alarms should be latched until manually reset by a switch located in the machinery room. Audible alarms shall continue to operate until they are manually reset by a switch located in the machinery room, or an area remote from the machinery room.

The compressor room is the highest risk location in most plants. It has the most potential leak sources, and the most ammonia available for disastrous concentrations. Using a minimum of two 0-250 ppm sensors is necessary for complete coverage and redundancy. Use two 0-250 ppm ammonia gas sensors in Engine Rooms 4,000 square feet or less. Install an additional sensor for each additional 2000 square feet. Locate sensors in the breathing zone ~ 5 feet off the floor. Locate one sensor below the ventilation fan so it samples airflow from throughout the room when the fan is on. Locate other sensor(s) evenly distributed throughout the room.

Compressor Room Shutdown (0-2% sensor)

In the compressor room, code also requires shutdown of compressors, pumps, and normally closed solenoid valves at a very high concentration (20,000 ppm is industry standard). The alarm output can be used to shut down at 2% (20,000 ppm). For redundancy at no cost, the warning output can be used to also trigger emergency ventilation at 1% (10,000 ppm). Use one 0-2% sensor located ~ 5 feet off the floor below the emergency ventilation fan so it samples airflow from throughout the room in an emergency condition. Note that a sensor in this range cannot be used to detect lower concentrations covered by the 0-250 ppm sensor.

Vent Line

Vent line sensors are used to provide an alarm to a monitored location in the event of a safety relief valve opening from an overpressure condition. This alerts operators to discharges of ammonia to atmosphere through the vent line so they can take action to mitigate the release. An alarm setpoint of 1.0% (10,000 ppm) is recommended for this application to minimize alarms due to “weeping” relief valves. Locate vent line sensors outdoors, 3 ft off the roof, utilizing the provided mounting kit with the tee test-port facing down.

Refrigerated Rooms

In refrigerated rooms, code requires alarming to a monitored location. Some insurance companies require shutdown of liquid feed and hot gas solenoids in the event of a leak (but the major codes currently do not). Use 0-100 ppm sensors in these rooms. This range gives the best accuracy at very low concentrations which is appropriate in these unrestricted areas. From the gas detection panel or PLC, the warning output can alarm to a monitored location at 25 ppm. Additionally, the alarm output can be used to shut down the liquid feed and hot gas solenoids at 35 ppm to mitigate the leak.

Locate sensors in the breathing zone ~ 5 feet off of the floor. The quantity of sensors should be determined by locating at least one sensor within 30 horizontal feet of each potential leak source (one sensor located between 2 evaporators could cover them both if they are 60 feet apart). In large, open cold storage warehouse rooms where this results in more than 3 sensors in a room, distances can reasonably be relaxed to 50 horizontal feet from a potential leak source, with a minimum of 3 sensors.

Machinery under 100 HP not in Machine Rooms, and Equipment Pits

Where an ammonia refrigeration system or equipment is installed outside of a machinery room, the area containing the system or equipment shall comply with the following. At 25 ppm, alarm to a monitored location, close liquid feed and hot gas solenoid valves, activate audio/visual devices inside the area, activate emergency exhaust and de-energize all pumps, motors and non-emergency fans.

Use 0-100 ppm sensors in these rooms. This range gives the best accuracy at very low concentrations which is appropriate in these areas. Locate sensor(s) in the breathing zone ~ 5 feet off of the floor.

Packaged Systems

Packaged systems and equipment shall comply with the following. At 25 ppm, alarm to a monitored location and activate audio/visual devices inside the area.

Use 0-100 ppm sensors in these areas. This range gives the best accuracy at very low concentrations which is appropriate in these areas. Locate sensor(s) in the breathing zone ~ 5 feet off of the floor.

Enclosed equipment with a potential to reach 40,000 ppm that has either open flame or hot surfaces, or has unclassified equipment shall comply with the following. Use one 0-2% detector to disable the ignition sources at 2% (20,000 ppm). Note that a sensor in this range cannot be used to detect lower concentrations covered by the 0-250 ppm sensor.

Installation Design Requirements

General

Detectors shall use supervised wire runs such that any faults in the wiring are reported to a monitored location. Loss of communication between the detector and the control system(s) that enables response shall be reported to a monitored location. Detectors shall actively monitor primary sensing elements and report any trouble signal to a monitored location. Audible alarms should provide an SPL of 15 decibels (dBA) above the average ambient sound level, and 5 dBA above the maximum sound level of the area in which it is installed.All ammonia detectors shall be designed and tested in accordance with UL-61010-1 or ANSI/ISA 92.0.01.

Sensor Mounting Height

There is much confusion in the industry concerning the best height to mount ammonia sensors. This is because there are valid reasons for different heights. Codes simply say “locate sensor where it is expected to be the most effective, and can be accessed for maintenance and testing ”. Ammonia vapor is lighter than air so vapor leaks will rise to the ceiling in normal conditions. A liquid leak will drop to the floor and if large enough can cool down a room so quickly that high concentrations are found on the floor with very low concentrations at the ceiling. In refrigerated areas there is normally enough air flow from evaporator fans to mix the refrigerant fairly well in the room. In all locations, 25 ppm is the first alarm point and this is intended for personnel protection. To best protect personnel, the sample should be representative of what they are breathing ~ 5 feet off of the floor. Most importantly, the sensor needs to be easily accessible for the required 6-month calibration and output testing. An untested safety system only takes a few years to become a nonworking safety system. The breathing zone is the best height to satisfy all of the above concerns.

Gas Detection Panel (or PLC)

The gas detection system should be powered with a dedicated branch circuit from an emergency generator backup system that can operate the system in the event of a power outage. An uninterruptable power supply (UPS) that can run the system for a few minutes during the transition to emergency generator power should be utilized. All wire runs should be supervised with the controller indicating a fault if communication with a sensor is lost. Loss of power to the system should send a fault indication to a monitored location.

Any alarm condition should send a signal to a monitored location. This can be in the facility such as a control room or guard shack. It can also be a building monitoring company, an auto-dialer, or other notification system that notifies responsible personnel 24/7.

All output functions should be configured to latch, so even if ammonia concentrations fall below the setpoint, a manual reset is required under the supervision of a qualified operator. This is necessary to protect against repeating a leak scenario that has been successfully detected and mitigated.

CO2 Cascade systems

For CO2 cascade systems, ammonia and CO2 detection are both required in the compressor room which contains the ammonia system and the cascade heat exchanger. CO2 detection is required instead of ammonia detection in refrigerated and process areas. Detection system design and output functions are similar with the difference being the CO2 sensor selected, warning setpoints at 0.5% (5,000 ppm) (OSHA 8 hour TWA) and alarm setpoints at 1.0%.

One controller can support a combination of ammonia and CO2 sensors. One caveat to keep in mind is that unlike ammonia, CO2 is always present in air, and concentrations can build up to these levels in a facility from sources other than a leak in the refrigeration system. Common examples are dry ice usage and normal personnel respiration in a non-ventilated room. CO2 sensors should be mounted in the breathing zone ~ 5 feet off of the floor.

Specifications:

Table 2: Equipment table

Part Number	Description	Application
GasMark M255	Modbus controller	Monitor gas detection system
EM2	Entrance monitor	Outside compressor room doorways
MB-3R-1A	Remote relay module, 3 relays	Remote relay outputs
UPS-2000VA-LCD	Uninterruptible power supply	Backup Power for M255 controller
SB-SR1	Remote silence/rest switch	Inside compressor room
SHA-24-BLUE	Strobe/Horn assembly 24vdc	Audio Visual
SHA-PAX-120-Blue	Strobe/Horn assembly 120vac	Audio Visual, 110 dB
MM420-LR	4-20mA to RS-485 Modbus converter	For 4-20 mA detectors on Modbus channels
GG-NH3-100	0/100 ppm electrochemical sensor	Refrigerated Area
GG-NH3-250	0/250 ppm electrochemical sensor	Compressor Room
GG-NH3-2%	0/2% catalytic bead sensor	Compressor Room shutdown
GG-VL2-NH3	0/1% vent line sensor	HP relief header, above roofline
GG-CO2-3%	0/3% infrared sensor	CO2 refrigeration systems
PS-24-6500	Auxiliary 24Vdc power supply	Additional power for Modbus devices

Table 3: Warning and Alarm Setpoints table

Room	Warning / Alarm setpoints
Refrigerated areas	25 ppm / 35 ppm
Compressor Room (0-250 ppm)	25 ppm / 150 ppm
Compressor Room Shutdown (0-2%)	1% / 2%
Vent Line	1.0%
Carbon Dioxide refrigerated area	0.5% / 1.0%

1. Equipment
    a. Equipment notes
        i. All controllers and sensors shall be manufactured by CTI - phone number 866-394-5861.
        ii. See Equipment table for part numbers and function descriptions.
        iii. See Warning and Alarm setpoints table for recommended setpoints.
    b. Controller
        i. Provide a M255 controller to monitor all fixed sensors. The controller shall be equipped with programmable alarm relays to activate external horn/strobes, exhaust fans, monitoring systems, and shut down equipment.
        ii. The controller shall provide three alarm setpoints per channel.
        iii. The controller shall provide TWA and STEL alarm setpoints.
        iv. The controller shall provide Modbus communication to sensors along with 4/20 mA signal inputs.
        v. The controller shall provide +24 Vdc to power connected sensors.
        vi. The controller shall provide an touchscreen operator interface for simple menu-driven programming.
        vii. The controller shall provide remote silence/reset functionality to remotely reset machine room ventilation and silence horns.
        viii. The controller shall provide data logging and trending for all connected sensors.
        ix. The controller shall provide an alarm log to record and store all events.
        x. The controller shall provide a calibration mode which locks relay outputs for sensor maintenance and calibration.
        xi. Controller shall supervise wire runs and indicate a fault if communication with sensors is lost.
        xii. Power controller with dedicated branch circuit using uninterruptable power supply (UPS) backed up by emergency generator to provide 24 hour operation in the event of a power outage.

c. Entrance Monitors
    i. Provide an EM2 entrance monitor outside each compressor room entrance.
    ii. Entrance monitor shall terminate 4-20 mA signal from sensor and retransmit same to controller.
    iii. Entrance monitor to provide a digital display to warn operators of ammonia concentration present prior to entering compressor room.
    iv. Entrance monitor shall have on-board 8 amp relay.
    v. Entrance monitor shall have potted electronics to protect circuit board and components from & corrosion.
    vi. Entrance monitor shall have a polycarbonate enclosure to prevent corrosion.
    vii. Entrance monitor shall have a linear 4-20 mA output signal.
d. Horn/strobes
    i. Provide (1) or more SHA-24-Blue or SHA-PAX horn/strobes inside the compressor room and one at each outside entrance of the compressor room
    ii. Horn/strobe shall be labeled “Ammonia” for easy at-a-glance interpretation of the alarm.
    iii. Horn/strobe shall be rated for outdoor use to prevent corrosion.
    iv. The sound level shall be at least 15 dBA above the average ambient sound level and 5 dBA above the maximum sound level of the area.
e. Reset Switch
    i. Provide (1) SB-R1 reset switch inside the compressor room.
    ii. The switch shall be wired to discrete input terminals of the M255 controller.
f. Silence Switch
    i. Provide (1) SB-S1 reset switch inside the compressor room.
    ii. The switch shall be wired to discrete input terminals of the M255 controller.
g. Modbus Module
    i. Provide MM420-LR Modbus modules to convert any industry-standard 4-20 mA analog device to RS-485 Modbus communication to the M255 controller.
    ii. The Modbus module shall have potted electronics to protect circuit board and components.
    iii. The Modbus module shall be field-addressable via dip switches.
h. Remote Relay Module
    i. Provide MB-3R-1A remote relay modules for remote control of horn/strobes, stacklights, solenoid valves, and ventilation fans.
    ii. The remote relay module shall also provide an 4-20 mA analog output for use with VFD fans.
i. Auxiliary Power Supply
    i. Provide PS-24-6500 power supplies for sensors when power consumption is a factor.
    ii. The power supply shall supply 24Vdc, 6.5A.
j. Uninterruptable Power Supply (UPS)
    i. Provide (1) UPS-2000VA-LCD UPS for battery backup of the M255 controller.
    ii. The UPS shall provide 2000 volt/amps during loss of power.

2. Sensors
a. Compressor Room 0-250 ppm
    i. Provide (2) GG-NH3-250 ammonia gas sensors in Compressor Rooms 4000 square feet or less. Install an additional sensor for each 2000 square feet.
    ii. Locate sensors in the breathing zone – 5 feet off the floor.
    iii. Locate one sensor below the continuous ventilation fan so it samples airflow from throughout the room.
    iv. Locate other sensor(s) evenly distributed throughout the room.
    v. The sensor shall have potted electronics to protect circuit board and components.
    vi. The sensor shall have a polycarbonate enclosure to prevent corrosion.
    vii. The sensor shall provide a temperature controlled enclosure for use in any area for improved cell life.
    viii. The sensor shall have Modbus communications and a linear 4-20 mA output signal.
b. Compressor Room Shutdown 0-2%
    i. Provide (1) GG-NH3-2% ammonia gas sensor for each Compressor Room.
    ii. Locate sensor 5 feet off the floor below the emergency ventilation fan so it samples airflow from throughout the room.
    iii. The sensor shall have potted electronics to protect circuit board and components.
    iv. The sensor shall have a polycarbonate enclosure to prevent corrosion.
    v. The sensor shall provide a temperature controlled enclosure for use in any area for improved cell life.
    vi. The sensor shall have Modbus communications and a linear 4-20 mA output signal.
c. Vent Lines
    i. Provide (1) GG-VL2-NH3 ammonia vent line sensor for each high-pressure relief line discharge to atmosphere.

ii. Install vent line sensor utilizing supplied mounting kit. Locate outdoors, 3 feet off of the roof. Install utilizing supplied mounting kit with tee test port pointed down.
iii. The sensor shall have potted electronics to protect circuit board and components from moisture and corrosion.
iv. The sensor shall have a stainless-steel enclosure to prevent corrosion.
v. The sensor shall have Modbus communications and a linear 4-20 mA output signal.

d. Ammonia refrigerated areas
i. Provide GG-NH3-100 ammonia gas sensors near evaporators, valve groups, and other equipment with sensors installed no further than 30 horizontal feet from the potential leak source (50 feet if more than 3 sensors in a room).
ii. Locate sensors in the breathing zone – 5 feet off of the floor.
iii. The sensor shall have potted electronics to protect circuit board and components from moisture and corrosion.
iv. The sensor shall have a polycarbonate enclosure to prevent corrosion.
v. Sensor shall provide a temperature controlled enclosure for use in any environment for improved cell life.
vi. The sensor shall have Modbus communications and a linear 4-20 mA output signal.

e. Carbon Dioxide refrigerated areas
i. Provide GG-CO2-3% carbon dioxide gas sensors near evaporators, valve groups, and other equipment with sensors installed no further than 30 feet from the potential leak source (50 feet if more than 3 sensors in a room).
ii. Locate sensors in the breathing zone – 5 feet off of the floor.
iii. The sensor shall have potted electronics to protect circuit board and components from moisture and corrosion.
iv. The sensor shall have a polycarbonate enclosure to prevent corrosion.
v. Sensor shall provide a temperature controlled enclosure for use in any environment for improved cell life.
vi. The sensor shall have Modbus communications and a linear 4-20 mA output signal.

Explanatory Material

Back in 2012, there were six different U.S. model codes and standards written by different agencies regulating ammonia refrigeration, including ANSI/IIAR 2-2014, ASHRAE 15, NFPA-1, UMC, IFC, and IMC. Gradually, these agencies have started to adopt IIAR-2 standards, rather than continue to write their own. As of 2021, the IIAR-2 standards have become the generally accepted industry standard to which most other organizations now defer.

Appendix 1: Summary of Ammonia Detection Code Requirements

ANSI/IIAR 2-2021	ASHRAE 15-2019	NFPA 1-2021	UMC-2021	IFC-2021	IMC-2021
	Comply with IIAR 2	Comply with IIAR 2	Comply with IIAR 2	Comply with IIAR 2	Comply with IIAR 2

Appendix 2: IIAR 2-2021 Standards

Location	Description/Details			Detection Level
Machinery Room				Machinery Room Detection
Area containing refrigeration equipment located outside of a machinery room	Less than 100 HP	Potential of 40,000 ppm? Yes		Level 3 Detection
		Potential of 40,000 ppm? No		Level 1 Detection
Equipment Pits				Level 3 Detection
Refrigerated Spaces				Level 1 Detection
Packaged Systems	Indoor	Over 100 HP Inside a machinery room		Machinery Room Detection
		Under 100 HP Outside of machinery room	Potential of 40,000 ppm? Yes	Level 3 Detection
			Potential of 40,000 ppm? No	Level 1 Detection
	Outdoor	Free Aperture*? Yes		No detection needed
		Free Aperture*? No	Under 100 HP	Level 1
			Over 100 HP	Machinery Room Detection

Appendix 3: Detection Levels Defined

	IIAR 2-2021 Minimum Standard		CTI Recommendation	
Machinery Room Detection	At least 2 detectors with identical sensing ranges		At least 2 detectors with identical sensing ranges *Plus 1 high range detector*	
	25 ppm	Notify a monitored location Activate audio alarms and visual indicators	25 ppm	Notify a monitored location Activate audio alarms and visual indicators
	150 ppm	Activate emergency ventilation	150 ppm	Activate emergency ventilation
	40,000 ppm	De-energize refrigerant compressors, pumps, and normally closed valves	20,000 ppm	De-energize refrigerant compressors, pumps, and normally closed valves
Level 1 Detection	At least 1 detector		At least 1 detector within 30 feet of potential leak sources	
	25 ppm	Notify a monitored location	25 ppm	Notify a monitored location *Activate audio and visual indicators*
Level 3 Detection	At least 1 detector		At least 1 detector	
	25 ppm	Notify a monitored location Activate Audio alarms and visual indicators Close valves feeding liquid and hot gas De-energize pumps, fans, and motors that are part of the refrigeration system Activate emergency exhaust systems	25 ppm	Notify a monitored location Activate audio alarms and visual indicators Close valves feeding liquid and hot gas De-energize pumps, fans, and motors that are part of the refrigeration system Activate emergency exhaust systems

Additional Audio-Visual Requirements

Audible alarms shall provide a sound pressure level of 15 dBA above the average ambient sound level and 5 dBA above the maximum sound level of the area in which it is installed.

Alarms shall be identified by signage adjacent to visual and audible alarm devices.

Audible alarms, visual indicators and emergency exhaust systems that are activated at 25 ppm can by automatically reset when concentration drops below 25 ppm.

Visual indicators and emergency exhaust systems that are activated at 150 ppm or higher must continue to operate until they are manually reset by a switch located inside the machinery room. Audio alarms that are activated at 150 ppm or higher can be reset remotely.

Definitions

Packaged System: A stand-alone, complete, plug-and-play refrigeration system that is built off-site, mounted on a steel base or skid and delivered as a single unit to an end-user facility. A packaged system can be designed for indoor or outdoor installation and can be enclosed or unenclosed.

Enclosure: An area that is surrounded by walls or a fence. IIAR 5.15.1 states that enclosures for ammonia equipment shall be suitable for the installation location and shall be provided with protection from physical and environmental damage as required for the installed location.

Free Aperture: Free aperture refers to the amount of natural, passive ventilation of an enclosed or partially enclosed area. Packaged systems that are located outdoors and do not have sufficient free aperture must have ammonia detection. To calculate the free aperture of an enclosure, use the formula listed in IIAR 7.3.2 as follows:

> The free-aperture cross-section for natural ventilation shall not be less than:
>
> $F = G^{0.5}\ (I\text{-}P)$ *(using ft^2 and lbs of NH3)*
> $F = 0.138G^{0.5}\ (SI)$ *(using m^2 and kgs of NH3)*
>
> where:
>
> F= the free opening of the area, ft^2 (m^2)
> G= the mass of ammonia in the largest independent circuit, any part of which is located within the enclosure or structure, lbs. (kg)

Level 2 Ammonia Detection and Alarm. The normative parts of this standard currently require only level 1 and level 3 ammonia detection and alarm levels. Information regarding level 2 is retained here for reference. Designers or end users may wish to use level 2 in lieu of level 1. If level 2 ammonia detection and alarm are implemented, it would have the following features:

1. At least one ammonia detector would be provided in the room or area.
2. The detector would activate an alarm that reports to a monitored location so that corrective action can be taken at an indicated concentration of 25 ppm or higher.
3. Audible and visual alarms would be provided inside the room to warn that when the alarm has activated access to the room is restricted to authorized personnel and emergency responders.

Exceptions

1. In machinery rooms, the use of a single detector is permitted if the failure or maintenance of the detector that causes the detection system to become inoperable, starts emergency ventilation system that shall continue to operate until the detection system is restored.
2. Unoccupied areas with continuous piping that has been joined by welding and does not include valves, valve assemblies, equipment, or equipment connections do not require level 1 detection and alarm.
3. Where not prohibited by the AHJ, rooms or areas in industrial occupancies that are normally occupied 24 hours/day and are regularly patrolled when the rooms' functions are idled for scheduled downtime and are provided with an alternative to fixed detection and alarm equipment do not require level 1 detection and alarm. A means for emergency notification and initiation of alarm response shall be provided.
4. Where not prohibited by the AHJ, alternatives to fixed ammonia leak detectors shall be permitted for areas with high humidity or other harsh environmental conditions that are incompatible with detection devices. A means for emergency notification and initiation of alarm response shall be provided.

Ammonia Detection System Layout Example