CO2 Gas Detection System
Codes and Design Specifications

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CO2 Gas Detection System Codes and Design Specifications

In the last decade, carbon dioxide refrigerant has become a more viable alternative in commercial and industrial refrigeration systems. IIAR has just recently released its first-ever safety standard for carbon dioxide (IIAR CO2). In addition to closed-circuit CO2 refrigeration systems, CO2 is used in many other applications.

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.ctigas.com) for the latest revision.

Regulatory concentrations of interest for CO2:

OSHA PEL(Occupational Safety and Health Administration - Permissible Exposure Limit)
- 5,000 ppm (0.5%) TWA (8 Hour Time-Weighted Average).

NIOSH REL (National Institute for Occupational Safety and Health - Recommended Exposure Limit)
- 5,000 ppm (0.5%) TWA
- 30,000 ppm (3.0%) STEL (Short Term Exposure Limit = 15 min time-weighted average)
- 40,000 ppm (4.0%) IDLH (Immediately Dangerous to Life and Health)

ACGIH TLV (American Conference of Governmental Industrial Hygienists - Threshold Limit Value)
- 5,000 ppm (0.5%) TWA
- 30,000 ppm (3.0%) STEL

Following is a discussion of CO2 gas detection system design for both leak detection and when used in a process.

CO_2 Gas Detection - *Refrigerant Leak Detection*

(when CO_2 is used as refrigerant)

The typical CO_2 Gas Sensor for refrigerant leak detection should be ranged 0-3% CO_2, with instantaneous warning setpoints at 0.5%, alarm1 setpoints at 1.0%, and alarm2 setpoints at 3.0% CO_2.

With the above low and high alarm setpoints, the recommended actions would be to investigate a potential CO_2 leak at 0.5%, shut down solenoid valves to the evaporator at 1.0%, and evacuate the room at 3.0%. A 3.0% evacuation is recommended rather than the 4.0% IDLH, because it is a point measurement and CO_2 concentrations can be higher elsewhere in the room.

One issue to keep in mind is that unlike ammonia, CO_2 is always present in air, and concentrations can build up to these levels in a facility from sources other than a leak in the CO_2 refrigeration system. Common examples of CO_2 presence are from dry ice usage, and normal personnel respiration in a non-ventilated room. Field experience indicates that a Carbon Dioxide alarm at 0.5% is high enough that background CO_2 levels will not reach that level in most cases; therefore 0.5% CO_2 can be reliably used as a leak indicating set-point.

Table 1: CO_2 Refrigerant Leak Detection Overview (when used as a refrigerant)

Location	Sensor	Actions
Compressor Room	GG-CO2-3%	**0.5% (5,000 ppm)** - Horn/strobe in engine room and outside each entrance **0.5% (5,000 ppm)** - Alarm to monitored location **0.5% (5,000 ppm)** - Emergency ventilation **3.0% (10,000 ppm)** - Evacuate*
Refrigerated Areas	GG-CO2-3%	**0.5% (5,000 ppm)** - Horn/strobe **0.5% (5,000 ppm)** - Alarm to monitored location* **1.0% (10,000 ppm)** - Close liquid and hot gas solenoid valves* **3.0% (10,000 ppm)** - Evacuate*
Outdoor Tank Monitoring* (2 sensors recommended)	GG-CO2-2500	**600 ppm** - Alarm to monitored location*

**Not required by IIAR CO2 standard but recommended by CTI.*

There are a few exceptions to this rule, including: Poultry processing plants, dry ice plants, and bottling plants. In these plants, trying to warn lower than 0.5% will usually result in frustrating “false alarms” due to CO_2 from sources other than a refrigeration system leak. – See Part 2: Process Leak Detection for more information.

Selecting your CO_2 Sensor range:

To select the proper CO_2 sensor range, two primary concerns must be balanced:

1. You want a range low enough to give you good resolution and accuracy at the 0.5% and 1.0% set-point levels.
2. You want the range to be high enough to give a real indication of truly dangerous situations.

If a 0-1% sensor is chosen and found in a leak situation at 1.0% CO_2, more information is necessary to make the proper response decision. It is very important to know if the STEL of 3.0% has been exceeded. If a level of 3.0% CO_2 has been exceeded, investigation and response must be executed with great caution. Choosing a 0-5% sensor range does not give the desired resolution at the 0.5% warning level. A 0-5% CO_2 sensor can be desirable if paired with a 0-1% sensor, or if you are monitoring for catastrophic leaks only.

Choosing the 0-3% range is best for balancing concerns in industrial CO_2 detection. The 0-3% range provides accuracy and resolution at the 0.5% and 1.0% levels, and gives operators the crucial information for calculating the seriousness of the situation. In terms of danger, there is a big difference between 1.0% and 3.0% CO_2 and your fixed CO_2 gas detector should provide this information accurately and in a timely manner.

CO2 Gas Detection - *Process Monitoring*

(when CO2 is used in a process)

CO2 monitoring when CO2 is used in a process (rather than as a refrigerant) differs a bit in philosophy. These applications include:

Dry Ice Plants, CO2 plants, Poultry Processing Plants, Bottling Plants, and any plant with CO2 freeze hoods.

The main issues of concern in process leak detection are:

1. Warning and ventilation are key output functions with evacuation beginning at 3.0% instead of 1.0%.
2. Time-weighted averaging alarms (rather than instantaneous) is a very beneficial function in most CO2 process applications.
3. Sensors need to be located where people frequent, not necessarily close to the CO2 source. A sensor near a CO2 source can result in unusually high readings.

Choosing Alarm set points and actions for CO2:

The typical CO2 Gas Sensor for process leak detection should be ranged of 0-3% CO2, with a low alarm set-point at 0.5% (8 Hour TWA allowable exposure) and alarm set-points at 3.0% (15 minute STEL) CO2.

With the above warning and alarm set-points, the recommended actions would be to initiate ventilation at 0.5%, and set off alarms for evacuation at a level of 3.0% CO2 has been reached.

Table 2: CO2 Process Gas Detection Overview (when used in a process)

Location	Sensor	Actions
CO2 Process Areas	GG-CO2-3%	**0.5% (5,000 ppm) TWA** - Initiate ventilation **0.5% (5,000 ppm) TWA** - Low alarm horn/strobes in immediate area **0.5% (5,000 ppm) TWA** - Alarm to monitored location **3.0% (30,000 ppm) STEL** - High alarm horn/strobes in immediate area **3.0% (30,000 ppm) STEL** - Initiate high-speed ventilation if applicable **3.0% (30,000 ppm) STEL** - Evacuate

Selecting your CO2 Sensor Range:

For CO2 process leak detection, you must consider the following issues:

1. The ability to initiate ventilation at 0.5%.
2. The ability to initiate evacuation at 3.0%.

A 0-1% sensor is out of the question unless directly paired with a higher range sensor. The accuracy on the low end is beneficial, but the inability to detect past the range of 1.0% renders this sensor inadequate for process leak detection.

A 0-5% sensor is not accurate enough on the low end of the scale to trip precisely at 0.5% to initiate ventilation. This sensor will only be beneficial if paired with a low range detector.

The 0-3% range provides accuracy and resolution at the 0.5% and 1.0% levels for ventilation and warning necessary at your plant. It will also trip relays set at 3.0% CO2 for Evacuation. The ability to handle the ventilation and evacuation set points, and everything in between, make the 0-3% CO2 sensor the best sensor for process leak detection.

Time-weighted averaging (TWA):

Having a gas detection controller with a time-weighted average feature is useful in situations where the time of exposure to CO2 or the concentration of that CO2 varies. For example, if a worker is exposed to different levels of CO2 for different amounts of time, a TWA calculation can help safely determine the average level of exposure.

Time-weighted average values are calculated as the sum of exposure during a workday to a particular hazardous substance in ppm-hours and dividing it by an 8-hour period. For fixed (stationary) CO2 monitoring, calculating true exposure values becomes flawed if/when personnel regularly leave the area (i.e. lunch breaks, entering/exiting the area throughout the work day).

Compressor Room

Code requires audio-visual indication inside the compressor room and outside each entrance to the compressor room at 0.5%. From the gas detection control panel or PLC, the warning outputs can be set at 0.5% 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 CO2 gas concentrations prior to entry. Audio-visual alarms can automatically reset if the ammonia concentration drops below 0.5%.

Code requires emergency ventilation at 0.5%. The alarm setpoints should be set at 0.5% 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. Evacuate the space at 3.0% CO2.

The compressor room is the highest risk location in most plants. It has the most potential leak sources, and the most CO2 available for disastrous concentrations. Use two or more 0-3% CO2 gas sensors in compressor rooms if the distance from potential leak sources is greater than 30 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.

Refrigerated Rooms

In refrigerated rooms, code requires activation of a horn/strobe in the area of the leak at 0.5%. 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 0-3% ppm sensors in these rooms. This range gives the good accuracy at the 0.5% action level, and provides crucial information up to the STEL level. From the gas detection panel or PLC, the warning output can alarm to a monitored location at 0.5% . Additionally, the alarm output can be used to shut down the liquid feed and hot gas solenoids at 1.0% to mitigate the leak. Evacuate the space at 3.0% CO2.

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.

Vent Line

Caution: Safety relief valves should always be located at the very end of the header to atmosphere. In the event of a release, an ice plug can form after the valve and completely impede the CO2 from venting to atmosphere.
If a CO2 detector is required, contact CTI for proper installation details.
Vent line sensors are used to provide an alarm to a monitored location in the event of a SRV opening from an overpressure condition. Locate vent line sensors outdoors at the discharge to atmosphere, but not in the header. Use 0-5% range sensors.

CO2 Process Areas

Unlike CO2 refrigerant leak detection, CO2 process applications can have continuous levels of CO2 gas present. This can present a challenge due to regulatory exposure limits and ventilation limitations. Use 0-3% ppm sensors in these rooms. This range gives the good accuracy at the 0.5% and 3.0% action levels. From the gas detection panel or PLC, the warning output can trigger audio-visual alarms and ventilation at the 0.5% TWA level. Additionally, the alarm output can be used evacuate the room at the 3.0% STEL level.

Locate sensors in the breathing zone ~ 5 feet off of the floor. Mount sensor in an area with personnel in mind but not too close to the CO2 source to prevent unusually high readings. One sensor can typically cover 4,000 square feet with good air circulation in the room.

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 CO2 detectors shall be designed and tested in accordance with UL-61010-1 or ANSI/ISA 92.0.01.

Sensor Mounting Height

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 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.

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-visual alarms are allowed to reset automatically for both CO2 leak detection and CO2 process areas.

For CO2 leak detection, emergency ventilation must continue to operate until they are manually reset by a switch located inside the machinery room

Specifications:

Table 3: Equipment table

Part Number	Description	Application
GG-6	Six channel controller	Monitor gas detection system
GG-XM	Eight channel expansion module	Additional monitoring capability
GG-RD1	Remote display for GG-6	Remote monitoring of gas detection system
EM2	Entrance monitor	Outside compressor room doorways
UPS-1000VA-LCD	Uninterruptible power supply	Backup Power for GG-6
SHA-24-(*lens color*)	Strobe/Horn assembly 24vdc	Audio Visual
GG-CO2-3%	0/3% infrared sensor	CO2 refrigeration systems or process areas
GG-VL2-CO2	0/5% infrared vent line sensor	HP relief header

Table 4: Warning and Alarm Setpoints table

Room	Warning / Alarm1 / Alarm2 setpoints
Compressor Room (0-3%)	0.5% / 1.0% / 3.0%
Refrigerated Room (0-3%)	0.5% / 1.0% / 3.0%
Process Area (0-3%)	0.5% TWA / 3.0% STEL
Vent Line (0-5%)	5.0%

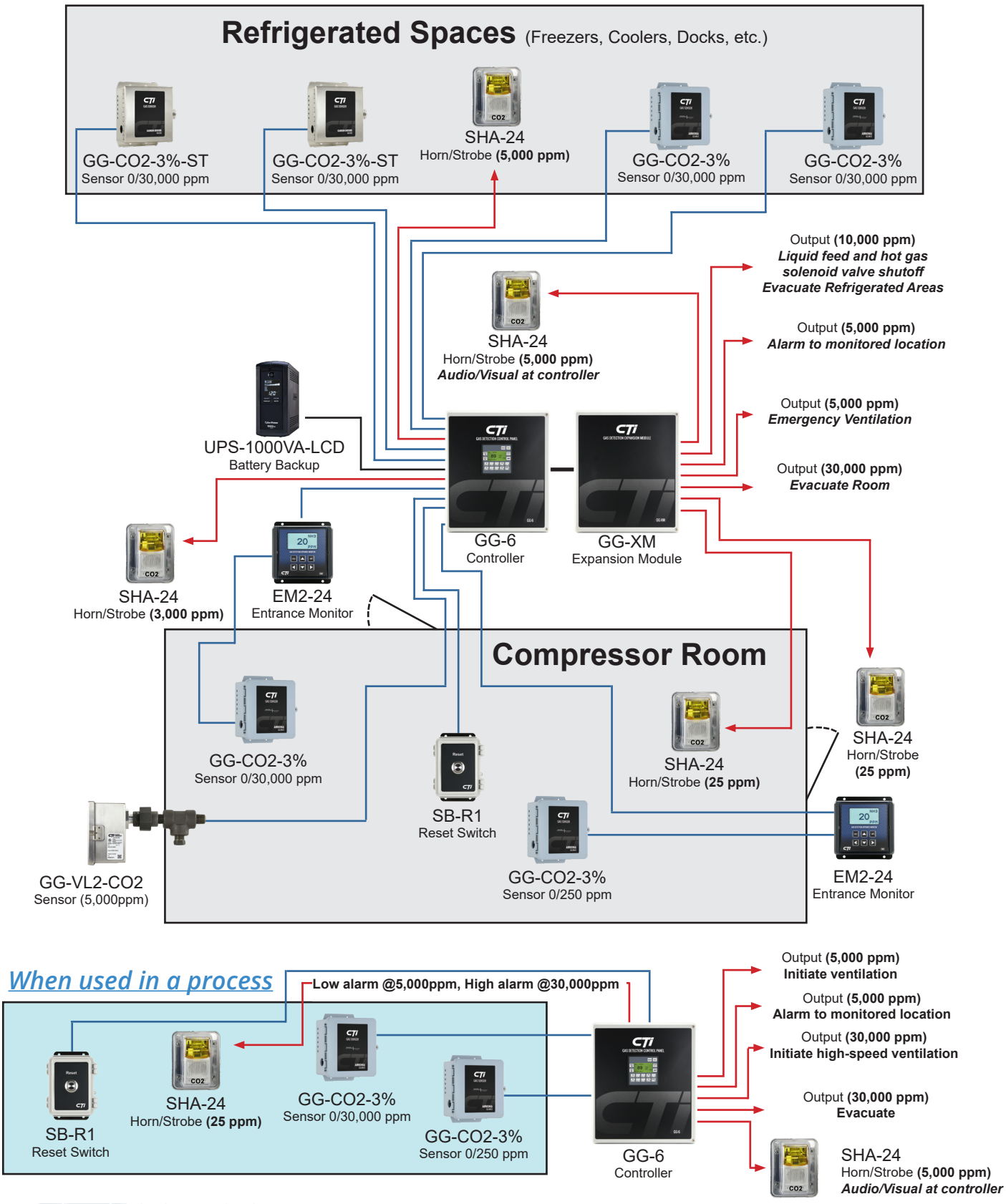
1. Equipment
    a. Equipment notes
        i. All controllers and sensors shall be manufactured by CTI - phone number 866-394-5861.
        ii. See Equipment table for part numbers and function descriptions.
        iii. See Warning and Alarm setpoints table for recommended setpoints.
    b. Controller
        i. Provide a GG-6 controller and necessary Expansion Modules 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 and expansion modules shall provide 4-20 mA signal inputs.
        iv. The controller and expansion modules shall provide +24 Vdc to power all connected sensors.
        v. The controller shall provide an LCD operator interface for simple menu-driven programming.
        vi. The controller shall provide a watertight enclosure to protect electronics and allow for outdoor installations where necessary.
        vii. The controller shall provide a horn relay which is silenceable from front panel silence key.
        viii. The controller shall provide an alarm log to record and store all events.
        ix. The controller shall provide a calibration mode which locks relay outputs for sensor maintenance and calibration.
        x. Controller shall supervise wire runs and indicate a fault if communication with sensors is lost.
        xi. 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 CO2 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-(*lens color*) horn/strobes inside the compressor room and one at each outside entrance of the compressor room
    ii. Horn/strobe shall be labeled “CO2” 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.

2. Sensors
    a. Compressor Room 0-3% (30,000 ppm)
        i. Provide (1) GG-CO2-3% carbon dioxide 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 a linear 4-20 mA output signal.
    b. 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 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 a linear 4-20 mA output signal.
    c. Vent Lines
        i. Provide (1) GG-VL2-CO2 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 a linear 4-20 mA output signal.
    d. Process areas
        i. Provide GG-CO2-3% carbon dioxide gas sensors in CO2 process areas where personnel frequent but not too close to CO2 gas sources.
        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 a linear 4-20 mA output signal.

Carbon Dioxide (CO_2) Detection System Layout Example

When used as a refrigerant



When used in a process