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CO_2 SYSTEM OPERATION and MAINTENANCE

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14. ABSTRACT
This volume identifies Reclamation's standard operation and maintenance practices for carbon dioxide (CO_2) systems. Reclamation has used CO_2 fire suppression systems in its powerplants for many years to protect generators and large motors. Different operation and maintenance practices have evolved across the agency and new, low-pressure systems are supplanting the older, high-pressure systems in many locations. CO_2 poses risk to personnel who may be exposed to it, and adequate safety precautions must be in place. Consistency in practices is desirable to ensure effective fire suppression and to maximize safety for plant staff. This volume provides guidance in making those practices consistent.

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Volume 5-12

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1. Introduction

Many Bureau of Reclamation (Reclamation) powerplants are equipped with carbon dioxide (CO_2) systems for generator and large-motor fire protection.

Reclamation has phased out use of CO_2 in almost all locations except generator/motor air housings because of the risk to personnel and complexity of safety regulations.

CO_2 operation and maintenance (O&M) practices vary throughout the agency, yet standards dictate that minimum practices be developed, documented, and followed. This volume describes Reclamation minimum practices.

Various Reclamation CO_2-related documents have evolved over the years. This volume coordinates and references this information.

2. Scope

This volume addresses operation and maintenance practices for total flooding CO_2 systems at Reclamation facilities. Total flooding systems are those that apply CO_2 to an enclosed space to achieve a concentration sufficient to extinguish a fire.[1] Hand-held CO_2 fire extinguishers are not addressed

Although this volume points out many safety and health issues and recommended practices, it does not supersede *Reclamation Safety and Health Standards* (RSHS) or the safety office having jurisdiction at the facility.

3. Background

The National Fire Protection Association's NFPA 851, *Fire Protection for Hydroelectric Generating Plants*[2] recommends fire protection for generator windings.

Reclamation uses only CO_2 for automatic generator fire suppression. Halon systems—proposed as a safe alternative to CO_2 in the early 1970s—received limited use in Reclamation facilities before they were phased out due to concerns about ozone layer depletion. New, clean-agent gasses developed to replace Halon could be used for generator fire suppression but are prohibitively expensive compared to CO_2.

Most Reclamation generating units and pump-generating units—specifically all enclosed units larger than 10 MW—and several large motors are protected by automatic CO_2 fire extinguishing systems.[3] Smaller units are commonly air cooled and are not enclosed, which is necessary to make CO_2 effective. Although other utilities use other fire suppression media, Reclamation has had good experience with CO_2 extinguishing fires. CO_2 extinguishes the fire quickly, is harmless

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[1] NFPA 1_2 1-3.17.
[2] NFPA 851 5-3.1
[3] Bureau of Reclamation, *CO_2 Fire Protection Study for Hydrogenerators—Report of Findings*

to the machine's insulating system,[4] is easy to clean up (compared to other media), thus allowing quick return to service after an inadvertent release, and is relatively inexpensive. For a discussion of CO_2 in comparison to other suppression media, see the Reclamation *Hydrogenerator Design Manual*, section 8.15.1.

CO_2 is a colorless, odorless, electrically nonconductive gas that is a suitable medium for extinguishing fires. CO_2 extinguishes a fire by reducing the concentration of the oxygen in the air to the point where combustion stops.[5]

CO_2 is 1.5 times heavier than air and therefore tends to settle in lower levels of the plant. This can be life threatening due to oxygen displacement.

Materials used in generators and large motors are costly, and many are combustible. CO_2 is an effective way of limiting fire damage, since the extinguishing medium can be applied quickly, and the concentration can be maintained sufficiently to extinguish deep-seated fires. In many cases, windings can be repaired after a fire and the unit returned to service fairly quickly.

CO_2 does not damage other materials in the generator, is nonconducting, and results in very little cleanup work, since CO_2 does not produce any debris. Toxic fumes are minimized while CO_2 is suppressing a fire.

The cost of a CO_2 fire extinguishing system is well justified by the savings realized by reduced damage to the machine and rapid resumption of power delivery.

Reclamation CO_2 systems are designed to establish CO_2 concentrations of between 30 and 50 percent by volume. These concentrations are significantly above that deemed injurious to humans. Table 1 illustrates the risks.

With 30- to 50-percent concentrations of CO_2 in an air housing after a discharge, personnel are certainly at risk should they become exposed.

It is common belief that the only risk to people from CO_2 is that of asphyxiation. However, CO_2 is not a truly inert gas, is toxic, and causes injuries and death by interfering with the functions of the central nervous system.[6]

Discharge of CO_2 in concentrations used in Reclamation units causes serious hazards to personnel, including suffocation and reduced visibility during and after the discharge period.[7] There is also some risk of frostbite.

Most Reclamation facilities with CO_2 protection use high-pressure systems fed by banks of CO_2 storage cylinders through valves and piping and activated by electrical devices that rapidly discharge the cylinders. Some installations use, or are in the process of converting to,

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[4] Harmless from a contamination point of view. Thermal shock is possible as cold CO_2 interacts with hot windings. Nozzles should avoid directly striking the armature windings with the CO_2 stream.
[5] NFPA 1_2 1-5.1
[6] Wickham Associates, *Review of the Use of Carbon Dioxide Total Flooding Fire Extinguishing Systems*, section 6.3, August 8, 2003.
[7] NFPA 1_2 1-6.1.

Table 1.—Acute health effects of high concentrations of carbon dioxide [8]
(with increasing exposure levels of carbon dioxide)

Concentration (% carbon dioxide/air)	Time	Effects
2%	Several hours	Headache, dyspnea* upon mild exertion
3%	1 hour	Dilation of cerebral blood vessels, increased pulmonary ventilation, and increased oxygen delivery to the tissues.
4-5%	Within a few minutes	Mild headache, sweating and dyspnea at rest.
6%	1-2 minutes < 16 minutes Several hours	Hearing and visual disturbances Headache and dyspnea Tremors
7-10%	Few minutes 1.5 minutes – 1 hour	Unconsciousness or near unconsciousness. Headache, increased heart rate, shortness of breath, dizziness, sweating, rapid breathing.
10-15%	1+ minute	Dizziness, drowsiness, severe muscle twitching and unconsciousness.
17-30%	< 1 minute	Loss of controlled and purposeful activity, unconsciousness, convulsions, coma and death.

* Dyspnea: Difficult or labored respiration

refrigerated, low-pressure bulk storage systems, rather than cylinders, when a large quantity of gas is needed.

Toward the end of the twentieth century, it became more difficult to find replacement parts for Reclamation's aging high-pressure CO_2 systems. Firing squibs became almost impossible to find. Two solutions to this problem were used: (1) existing high-pressure systems could be retrofitted with modern components that actuate the high-pressure cylinders with pneumatic/electrical controls in lieu of firing squibs; this usually involved replacing the control panel, pilot and pressure operated cylinder discharge heads and valves, selector valves, and various connection components; or (2) replacing the high-pressure system with a modern low-pressure CO_2 system. This solution has the distinct advantage of eliminating the NFPA requirement to weigh the high pressure bottles every 6 months. To adopt this solution usually requires a storage tank, new control panel, selector valves, discharge nozzles, and various piping components.

[8] U.S. Environmental Protection Agency, *Carbon Dioxide as a Fire Suppressant: Examining the Risks*, Report EPA430-R-00-002, February 2000.

4. Standards and References

Several standards and references apply to CO_2 systems and their use in Reclamation facilities:

- NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*, 2000
- NFPA 70E, *Standard for Electrical Safety in the Workplace*, 2004
- NFPA 72, *National Fire Alarm Code*, 1996
- NFPA 851, *Fire Protection for Hydroelectric Generating Plants*
- NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*
- 29 CFR Part 1910.146, *Permit-Required Confined Spaces*
- 29 CFR Part 1910.147, *The Control of Hazardous Energy (Lockout/Tagout)*
- 29 CFR Part 1910.160 thru 163, *Fixed Extinguishing Systems*
- 29 CFR Part 1910.164, *Fire Detection Systems*
- 29 CFR Part 1910.165, *Employee Alarm Systems*
- 29 CFR Part 1910.269, *Electric Power Generation, Transmission, and Distribution*
- ISO Standard 6183, 1990, *Fire Protection Equipment, Carbon Dioxide Systems for Use on Premises, Design and Installation*
- *Reclamation Safety and Health Standards*, Bureau of Reclamation, 2001
- *Carbon Dioxide as a Fire Suppressant: Examining the Risks*, Report EPA430-R-00-002, Environmental Protection Agency, February 2000
- *Review of the Use of Carbon Dioxide Total Flooding Fire Extinguishing Systems*, Wickham Associates, August 8, 2003
- FIST Vol. 1-1, *Hazardous Energy Control Program*, Bureau of Reclamation, March 2002
- FIST Vol. 4-1B, Maintenance *Scheduling for Electrical Equipment*, Bureau of Reclamation, April 2001
- FIST Vol. 5-12, *Personnel Safety with CO_2 Discharge*, 1992
- *Hydrogenerator Design Manual*, Bureau of Reclamation, 1992

- Design Standard No. 4, Chapter 2, *Electrical Rotating Machinery*, Bureau of Reclamation, 1984

- Design Standard No. 4, Chapter 6, *Power Plant Control and Station-Service Equipment*, Bureau of Reclamation, 1950

- *CO_2 Fire Protection Study for Hydrogenerators—Report of Findings*, Bureau of Reclamation, 1984

5. Confined Space

5.1. Air Housings

According to *Reclamation Health and Safety Standards*, Section 14.2, and 29 CFR 1910.146, a confined space is defined as:

> "A space large enough for an employee to enter, but with limited means of entry and egress, and which is not designed for continuous occupancy."

Generator/large-motor air housings fit this definition. Furthermore, RSHS and 29 CFR 1910.146 define a permit-required confined space as:

> "A confined space in which one or more of the following potential hazards or existing conditions: (a) the space contains, or may contain, an atmospheric hazard; (b) the space contains a potential engulfment hazard (i.e., water or other flowable material which may engulf an entrant); (c) the space has a configuration which may trap or asphyxiate and entrant; (d) the space has any other serious safety or health hazard. A serious safety or health hazard for purposes of this standard means a hazard that may render an entrant incapable of self-rescue."

From these definitions, most if not all generator and large-motor air housings are clearly permit-required confined spaces, as long as the instantaneous CO_2 system ("atmospheric hazard") is armed. RSHS Section 14, *Confined Spaces*, and 29 CFR 1910.146 describe requirements for permit required confined space, which must be applied to the air housing.

At no time should any person enter a space protected by an instantaneous, armed CO_2 system, even under permit-required confined space procedures. An exception to this may be made if the unit is not energized and a self-contained breathing apparatus (SCBA) is used. In the case of the unit being energized, NFPA 70E (RSHS Section 8.5.8) arc flash protection clothing and personal protective equipment considerations must also apply. Because permit-required confined space and arc flash provisions are so onerous, it is recommended that personnel be prevented from entering the air housing any time the unit is energized or protected by CO_2.

When entrance to the air housing is required, it will be necessary to temporarily reclassify (declassify) the space as a nonpermit-required confined space per RSHS Section 14.4.l. In part, this requires the removal of all hazards, including CO_2, and any new hazards that may be introduced while in the space. For CO_2, this requires that a clearance be applied that ensures the CO_2 system cannot operate (usually defeating the control system and mechanically blocking discharge via lockout-tagout). A clearance is only one step in eliminating the atmospheric hazard. Other requirements defined by RSHS and the local safety office also must be met to reclassify the space as nonpermit required.

The qualified confined space supervisor must approve any such reclassification (declassification) on a Certificate of Declassification that identifies the space, the actions taken to eliminate the hazards, and the time for which the declassification is valid. The certificate must be posted at the point of entry for the period of time of validity, which will not exceed one shift, and filed in the confined space program files at expiration. A new certificate is required for each shift.[9] Reclamation does not have an official form for this purpose; one must be developed based upon the aforementioned information.

All affected personnel, and those potentially affected, must be notified of reclassification. Any additional documents required by other standards, such as switching procedures, clearances, hazardous energy control documents, or hot work permits related to the work in the confined space, must be attached to the confined space permit or Declassification of a Space certificate.

The protected space must be reclassified as permit-required confined space when the CO_2 system clearance is released. Doors to air housings must be kept locked at all times when the CO_2 system is armed.

Note that CO_2 is not the only atmospheric hazard; ozone produced by the generator can be at dangerous levels and must be considered before any air housing entry. Arc-flash hazards must also be addressed in locations with energized equipment in accordance with NFPA 70E.

Reclamation Safety and Health Standards and the safety office having jurisdiction should be consulted for permit-required confined space and reclassification procedures and requirements. For more information, contact Safety and Health Services, D-1430.

5.2. CO_2 Storage Rooms

At some facilities, CO_2 cylinders (active and/or spares) are located in storage rooms that may meet the confined space criteria discussed above. In normal operation, these rooms do not pose the same kind of "atmospheric hazard" risk as the air housing, since the room is not protected by an armed CO_2 system. However, during times of maintenance when cylinders are being weighed or changed, valves are being replaced, etc., a risk to personnel does exist, since an accident could discharge sufficient CO_2 to be hazardous. Caution should be used when working on or around pressurized CO_2 cylinders and associated safe handling requirements followed.

[9] Where work in the air housing is of such magnitude (e.g., rewind) that the CO_2 system is dismantled, the safety office having jurisdiction should be consulted for alternative measures.

Permit-required confined space classification and procedures may be appropriate for maintenance work in these storage rooms. In these cases, the confined space requirements described in the previous section apply.

5.3. Entering Enclosures After CO_2 Discharge

The powerplant should be evacuated upon CO_2 discharge according to the plant Emergency Evacuation Plan. Only qualified, trained, and properly equipped personnel should re-enter the plant after discharge.

Staff entering a protected space after a CO_2 discharge must be very cautious of the hazards involved. CO_2 concentrations are likely to be at lethal levels until the gas is ventilated. A written procedure must be developed and followed when allowing staff to enter the space:

- Enough time should be allowed for the CO_2 application to extinguish the fire.
- Proper clearances and confined space entry permits must be issued.
- Self-contained breathing apparatus (SCBA) must be worn.[10]
- Verification should be made that the fire is extinguished before entering.
- Doors and vents should be opened and fans used to evacuate CO_2 and smoke.
- Atmospheric tests for toxic gas and adequate oxygen must continue until it is safe to reclassify the space as nonpermit-required confined space and allow other qualified personnel to enter.

6. Plant Locations

Originally, total flooding CO_2 systems were installed in generator and large-motor air housings, in some oil storage/processing rooms, and in at least one transformer vault.

Reclamation's current practice is to remove CO_2 systems from all locations except generator/motor air housings (see appendix A). CO_2 is justified for generators, since access to the air housing can be controlled, and repairs often can be accomplished, and the unit returned to service, after a quickly extinguished fire. Other equipment, such as transformers, are usually unsalvageable if involved in a fire, and therefore CO_2 is not justified.

CO_2 should be removed in frequently visited locations, such as oil storage rooms because of the risk to personnel. It is very difficult to enforce the access control necessary to keep personnel safe, when using a frequently visited area, such as an oil storage room protected by CO_2. A

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[10] NFPA 1_2 A1-6.1.1

deluge water system, which lowers the temperature of burning oil below the flash point, is now the recommended type of fire suppression for oil storage rooms.

The risk and consequences of fire inside the plant are recognized, and fire suppression—generally in the form of a water-type system—should be seriously considered for high risk equipment/locations. A significant amount of damage can be done to plant structures and other equipment (not to mention forced outages) when equipment burns inside a plant. Fire protection system designers should be consulted if fire suppression is desired for equipment in the plant, other than generators/large motors.

7. CO_2 System Configuration

7.1. General

This volume is not a design standard, and experienced designers should be consulted for site-specific designs and applicable codes. For more design information, contact the Mechanical Equipment Group (D-8410) and the Electrical Systems Group (D-8440).

Both high- and low-pressure CO_2 systems are used in Reclamation. Both rely on a system of piping and valves to route the CO_2 to the faulted generator. When CO_2 is released into the air housing, it is distributed throughout the machine by action of the rotor as it is slowing down. CO_2 concentration must be maintained at effective levels by keeping the air housing as airtight as possible and by discharging additional CO_2, in some cases.

In Reclamation units, the initial release of CO_2 will achieve a concentration of 50 percent within 7 minutes, but the rate of application cannot be less than that to achieve a concentration of less than 30 percent within 2 minutes. Time-delayed or extended discharge of CO_2 is typically required to maintain a 30-percent concentration for at least 30 minutes to overcome any leakage.

The sudden release of a large quantity of CO_2 into a well-sealed air housing will cause an increase in atmospheric pressure in the air housing. This may cause the air housing to distort or may cause bearing oil surfaces to distort sufficiently to expose the bearings. Therefore, pressure relief doors are often installed to control the increase in pressure.

Figure 1 shows a typical low-pressure CO_2 extinguishing system for a hydroelectric unit. This example shows two sets of piping, valves, and nozzles for distribution of the initial and delayed discharges.

For the high-pressure system, a similar arrangement of piping, valves, and nozzles is also required. Figure 2 shows a typical high-pressure cylinder arrangement.

Figure 1. Low Pressure CO_2 Extinguishing System

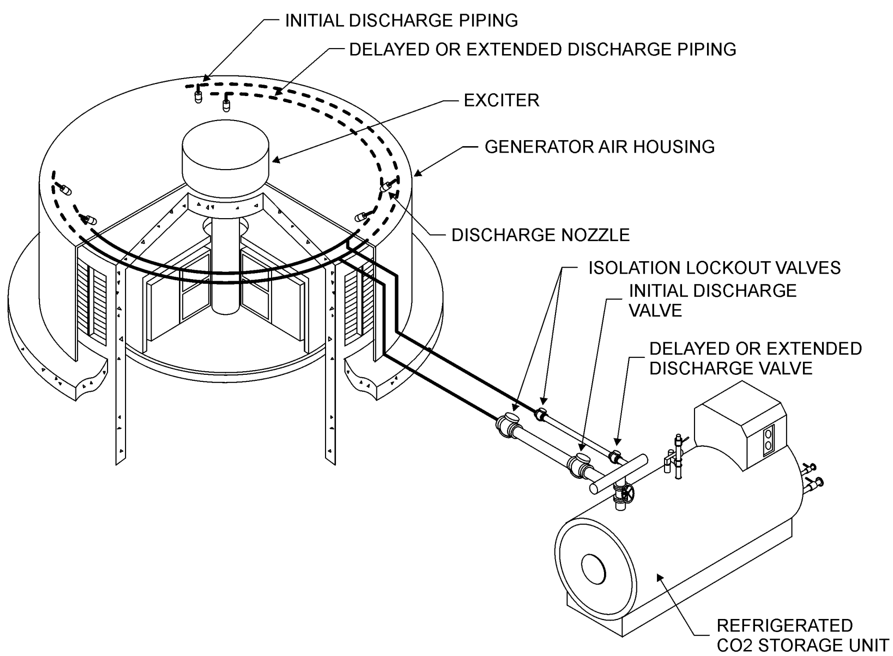
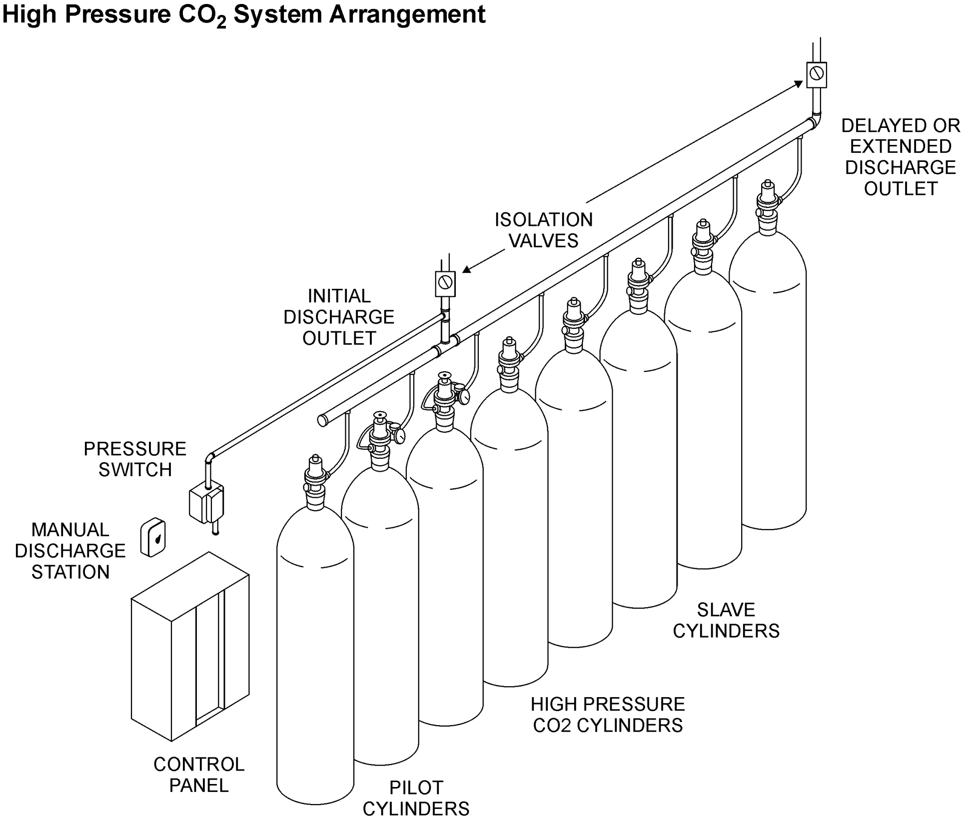


Figure 2. High Pressure CO_2 System Arrangement



7.2. High-Pressure Systems

Most Reclamation CO_2 systems are high-pressure type, operating at 750 lb/in^2 at about 55 °F. Since CO_2 pressure depends on its temperature, as temperature increases, pressure also increases. At a temperature of 88 °F, the pressure of CO_2 within a high-pressure cylinder is approximately 1000 lb/in^2.

Originally, high-pressure systems came equipped with “squibs” that explosively ruptured discs to release gas from the pilot cylinders. High-pressure gas released into the header from the pilot cylinders caused discs on the slave cylinders to rupture to discharge the remaining gas. This process was used for both the initial and delayed portions of the CO_2 system.

In recent years, squibs have become obsolete, since they are no longer manufactured. Squibs are being replaced by pneumatic/electrical discharge devices that perform the function of discharging the pilot cylinders, after which operation of the system is the same as before. For this modification, equipment that typically needs to be replaced are the fire control panel, pilot and pressure operated cylinder discharge heads and valves, selector valve, and various connection components.

High-pressure systems require that the content of the CO_2 in the cylinders be verified every 6 months to ensure availability of sufficient CO_2. CO_2 cylinders must also be hydrostatically tested every 12 years. High-pressure cylinders must also be replaced or refilled after a discharge, a time-consuming, labor-intensive, and potentially risky chore.

In order to eliminate the numerous high-pressure cylinders and associated maintenance tasks, high-pressure systems on large generating units are being converted to low-pressure systems in some cases, depending on design and cost considerations.

7.3. Low-Pressure Systems

Low-pressure CO_2 systems operating at 300 lb/in^2 have a refrigerated bulk storage tank with a liquid level indicator situated in one central plant location to serve multiple units. These systems have the distinct advantage of eliminating NFPA requirements to periodically perform content and hydrostatic tests required for high-pressure cylinders. In addition, spare CO_2 can be provided in the storage tank, so that in the event of a discharge into a unit, the other units in the plant would still be protected.

Low-pressure systems use electrically or pneumatically operated solenoids or valves to release the CO_2 from bulk storage tanks.

While low-pressure systems are an appropriate replacement for high-pressure systems in many cases, each installation should be evaluated individually for total cost and design considerations. Replacement may mean higher initial cost and low-pressure systems have additional maintenance requirements for the refrigeration system. Long-term cost and maintenance considerations make low-pressure systems attractive in many installations.

To convert a high-pressure system to a low-pressure system, the equipment that typically needs to be furnished are the storage tank, control panel, selector valves, discharge nozzles, and various connection components.

8. Control and Protection

Figure 3 shows a typical CO_2 control system overview.

Generator/motor electrical control and protection systems activate CO_2 systems. Design of such systems varies according to the specifics of the CO_2 system and machine being protected. For more information regarding CO_2 control and protection system design, contact the Electrical Systems Group, D-8440.

The unit differential protection system (differential and ground relays) will disconnect the generator/motor from the power system upon a fault, initiate stopping unit rotation, and trigger CO_2 discharge, as well as associated alarms and indication. Likewise, discharge of CO_2 should initiate unit shutdown. Manual CO_2 discharge should also be provided.

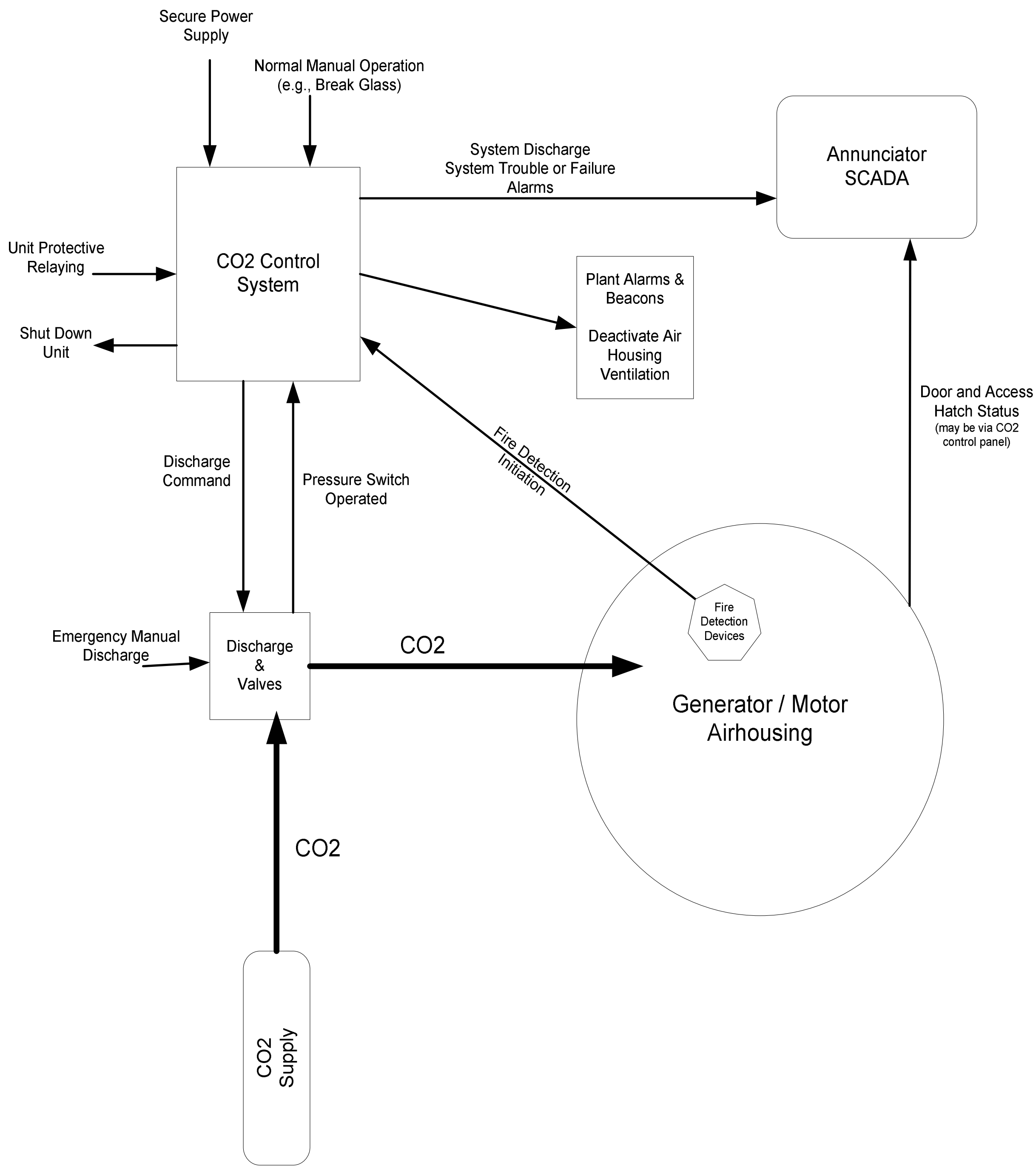
With either high- or low-pressure systems, modern programmable addressable fire control panels have the distinct advantage of being able to electrically supervise CO_2 system components for trouble and activation.

8.1. Initiating Devices

The Reclamation *Hydrogenerator Design Manual* (section 8.15.2) identifies the following devices as possible CO_2 initiating devices:

- Unit differential relays
- Split-phase differential relays
- Thermal links
- Ionization detectors
- Smoke detectors
- Stator ground relays
- Infrared detectors (heat sensors)
- Ultraviolet detectors (arc sensors)
- Optical detectors (flame or flicker detectors)
- Heat sensing wire resistor systems
- Pressurized tubing systems
- RTDs (resistance-temperature detectors)
- RF (radio-frequency) detectors
- Rate-of-rise thermal detectors

Figure 3 - CO2 Control System Overview
October 26, 2004



Also, manual break-glass stations should initiate discharge. Care must be used in applying any of these devices. For example, it may be desirable to require two devices (e.g., smoke detector plus infrared) to both operate before triggering CO_2 to prevent nuisance trips. On the other hand, thermal links, ionization detectors, and protective relays, such as differential, split phase differential, and stator ground should not be supervised by another device.

The stator ground relay (64G) should be used in accordance with recommendations made in Reclamation's *CO_2 Fire Protection Study for Hydrogenerators*, which states that the stator ground relay should not initiate CO_2 discharge when units are bused together at terminal voltage, because the relay cannot distinguish which unit the fault is on. Where units have dedicated transformers (not bused together, and the stator ground relay can identify which unit is faulted) only the portion of the stator ground relay that detects faults in the upper (higher voltage) portion of the winding should trip CO_2. Faults in the lower portion of the winding near the neutral are less likely to provide sufficient energy to start a fire, and relay action in this region is less reliable, potentially causing unwarranted trips of CO_2. This portion of the relay is usually connected to an alarm but should not be connected to trip CO_2.

Experienced designers should be consulted when designing or revising a CO_2 control and protection scheme.

8.2. Control Considerations

The "Application Guidelines" section in the *CO_2 Fire Protection Study for Hydrogenerators—Report of Findings* (http://intranet.usbr.gov/~hydrores/) provides the following guidance, updated here:

- Ionization detectors should be considered "first-line" protection and not supervised in the control scheme.

- Normal manual discharge of CO_2 (i.e., break-glass stations) should be provided, preferably at the CO_2 control panel near the machine air housing access door. Other normal manual means of discharge may also be appropriate (NFPA 12, section 1-8.1(b)).

- Emergency manual discharge of CO_2 should be provided through manual operation of the valves requiring no electrical power (NFPA 12, section 1-8.1(c)). However, in the case of a fire, evacuation of personnel should take precedence over manually discharging CO_2.

- The electrical CO_2 discharge control circuit should remain active even after machine shutdown and only deactivated through an intentional, separate action by the powerplant operator. This provides automatic protection if the latent heat should ignite a fire during or immediately after shutdown.

- For personnel safety, a CO_2 discharge warning bell located near the machine air housing access door, or other suitable alarm, should activate to warn that the CO_2 has been discharged.

- Because reliable operation of the CO_2 discharge system is critical, the electrical control circuit should be monitored for power failure.

- The fire suppression capability is proportional to the level of CO_2 concentration in the air. Therefore, the position of access doors, hatches, and pressure or explosion relief doors should be detected by limit switches and monitored by the annunciator and supervisory control and data acquisition (SCADA) system to ensure that all access doors and hatches will be closed during machine operation.

- Ventilation systems that exhaust from the protected space (e.g., ozone exhaust) should be deactivated upon CO_2 discharge to ensure proper concentration of CO_2.

- CO_2 control systems should always be powered from a reliable source, such as the plant battery system (NFPA 12, section 1-8.6).

9. System Testing

9.1. Concentration Test

After initial installation, rewind, uprate, or major modification of the unit or CO_2 system, a concentration test should be performed to demonstrate the ability of the air housing and machine to maintain the needed CO_2 concentration. This test verifies:

- Operation of air housing pressure relief devices
- Bearing pressure equalization features
- CO_2 concentration achieved
- Time duration that CO_2 concentration is maintained after initial and delayed releases

9.2. Functional Tests

After initial installation, rewind, or uprate of the unit, or major modification of the unit or CO_2 system, a CO_2 system functional test should be performed simulating an actual fire using smoke bombs, local heaters, or other methods to test operation of the detectors and sensors. This test should be repeated every 5 years. Although discharge of CO_2 is not required during this test, operation of the discharge valve or pneumatic/electrical discharge devices should be verified.

Annually, a functional test of the control/protection circuits should be performed. This test should include verification that the unit differential relay would initiate CO_2 discharge. Although discharge of CO_2 is not required during this test, operation of the discharge valve or pneumatic/ electrical discharge devices should be verified.

10. Alarms and Beacons

Provisions should be made to alert plant staff that CO_2 has been discharged. CO_2 gas should be odorized with wintergreen so that staff can smell it if a discharge takes place. The powerplant should be evacuated upon CO_2 discharge.

CO_2 discharge should alarm throughout the plant, and personnel should evacuate. The CO_2 alarm should be distinct from other plant alarms, such as annunciators, but may be the same as the plant fire alarm that initiates plant evacuation.[11]

CO_2 detectors should be considered for lower levels of the plant where CO_2 might accumulate from system leakage.

Staff should be alerted through annunciation and SCADA, if the fire detection system is malfunctioning or the power supply is lost.

Since personnel are not allowed in spaces protected by active CO_2 systems, predischarge alarms are not necessary.

In accordance with Power Equipment Bulletin No. 3 (appendix B) and NFPA 72 6-3.1.2, visual warning beacons or strobes should be installed in turbine pits and other high-noise areas to alert staff that a CO_2 discharge has taken place and that evacuation is required. These may be the same visual strobes as the plant fire alarm strobes that initiate plant evacuation.

11. Signage

To advise personnel of the risk of CO_2 systems in the vicinity, appropriate warning signs must be affixed in conspicuous locations. See NFPA 12, sections 1-6.1.2.1 and 1-6.1.2.2 for typical warning sign wording

12. High-Pressure Cylinders

12.1. Changing and Filling

Cylinder outlets should be fitted with safety covers or antirecoil devices, whenever the cylinder is not connected to the system piping.[12]

CO_2 quality must meet NFPA 12, section 1-9.3, which specifies the following minimum properties:

- The vapor phase shall not be less than 99.5 percent carbon dioxide with no detectable off-taste or odor (introduced wintergreen odor excepted).

[11] NFPA 12 A-1-8.5.2
[12] NFPA 12 A-1-6.1.8

- The water content of the liquid phase shall comply with the Compressed Gas Association's G6.2, *Commodity Specifications for Carbon Dioxide*.

- Oil content shall be not more than 10 ppm by weight.

12.2. Weighing

Per NFPA 12, Section 1-11.3.5 and FIST Vol. 4-1B, Section 12.2, high-pressure CO_2 cylinders must be weighed semiannually to verify that the proper volume of gas is available. Containers showing a loss in net content of more than 10 percent must be refilled or replaced.

While weighing cylinders is a sure way to determine CO_2 content, it has drawbacks: it is potentially dangerous as cylinders are moved; it is time consuming and therefore costly; and it may require an outage on a generator that would otherwise be left unprotected. Alternate methods for determining the amount of CO_2 in the cylinders have been identified and are thoroughly discussed in Power Equipment Bulletin No. 20 (appendix C).

12.3. Testing

Per NFPA 12, Section 1-9.5.1 and FIST Vol. 4-1B, Section 12.2, high-pressure CO_2 cylinders must not be recharged without a hydrostatic test (and remarking) if more than 5 years have elapsed from the date of the last test. Cylinders continuously in service (or spares) without discharging may be permitted to be retained in service for a maximum of 12 years from the date of the last hydrostatic test. At the end of 12 years, they must be discharged and retested before being returned to service.

12.4. Transporting

Safe handling procedures must be followed when transporting CO_2 system high-pressure cylinders.[13]

High-pressure cylinders should be constructed, tested, and marked in accordance with U.S. Department of Transportation (DOT) specifications, and shipment may be illegal where the cylinder has been damaged or exposed to fire. Federal and local regulations should be consulted.[14]

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[13] NFPA 12 1-6.1.8
[14] NFPA 12 A-1-9.5.1

13. Operation

CO_2 system operation is defined in the powerplant Standing Operating Procedure (SOP), which should be kept up to date and for which personnel should be trained.

As described above, CO_2 protected areas are considered permit-required confined spaces until the hazard has been removed and the space reclassified as nonpermit-required confined space. Therefore, doors to CO_2 protected spaces must be kept locked at all times when the CO_2 system is in service and proper lockout-tagout procedures followed.

In some cases, a CO_2 system is shared between units. Thus, when CO_2 is discharged into one unit, protection is not available for the other shared units until the CO_2 supply is replenished. It is recommended that unprotected units not be operated when unprotected by CO_2. However, if the CO_2 supply is replenished quickly, the risk of running an unprotected unit for a short period of time is small, and the facility manager may determine, with management's concurrence, that the risk is worth taking. The local policy for running or not running units unprotected by CO_2 should be documented in the SOP.

14. Training and Drills

Staff must be trained annually in the proper operation and maintenance of the CO_2 system. Drills should be conducted on emergency manual release of CO_2 and evacuation procedures.

All personnel should also be informed of the effects of CO_2 discharge on humans, including:

- Risk of asphyxiation
- Eye and ear injury
- Loss of balance due to impingement of high velocity discharging gas
- Frostbite to exposed skin

15. Summary of Testing, Maintenance, Training, and Drills

Before proceeding with testing CO_2 systems or alarms, personnel in the plant must be notified to prevent unnecessary response or evacuation. Returning the system to normal service must also be announced to personnel, so that personnel can respond normally to an actual CO_2 discharge.

Per NFPA 12 A-1-11.1, a CO_2 inspection is a quick check to give reasonable assurance that the extinguishing system is fully charged and operable, done by seeing that the system is in place, that it has not been activated or tampered with, and that there is no obvious physical damage or condition to prevent operation. As a minimum, the inspection should determine that:

- High-pressure cylinders are in place and properly secured.

Table 2.—Summary of CO_2 system testing, maintenance, training, and drills

Component	Test or maintenance	Frequency	Reference
High-pressure cylinders	Volume by weight	Semiannually	NFPA 12 1-11.3.5 and FIST vol. 4-1b, section 12.2
	Hydrostatic testing	Every 12 years or before refilling if not hydrostatic tested in last 5 years	NFPA 12 1-9.5.1 and FIST vol. 4-1b, section 12.2
Low-pressure system - liquid level gauge or IR camera - pressure gauge - high/low-pressure supv. alarm	Calibration	Annually	Reclamation practice
Low-pressure system - liquid level gauge	Observe for losses	Weekly	NFPA 12 1-11.3.6
Routing valves	Manually operate	Annually and after painting	Reclamation practice
Initiating devices (see section 8.1)	Inspection and test	After any modification to the alarm/beacon system and per NFPA 72	NFPA 72 7-3.1 NFPA 72 7-3.2
Control system	Functional test	Annually	NFPA 12 1-11.3.2
Discharge alarm and beacon	Inspections and test	After any modification to the alarm/beacon system and per NFPA 72	NFPA 72 7-3.1 NFPA 72 7-3.2
System hose including flexible connectors	Pressure testing	5 years	NFPA 12 1-11.2
CO_2 system	Inspection (see below)	Monthly	NFPA 12 1-11.1
	Functional test	Every 5 years or after rewind, uprate, or major CO_2 system modification	Reclamation practice
	Concentration test	After initial installation, rewind, uprate or major modification of the CO_2 system	NFPA 12 1-7.4 (b)
	Manufacturer's recommended maintenance	Per manufacturer's recommendation	Manufacturer's instruction books
Training	O&M, effects of CO_2 on personnel	Annually	Reclamation practice
Drills	Emergency manual discharge and evacuation	Annually	Reclamation practice

- For low-pressure storage units, the pressure gauge shows normal pressure, that the tank shutoff valve is open, and that the pilot pressure supply valve is open. Liquid level gauge should be observed. If at any time a container shows a loss of more than 10 percent, it should be refilled unless the minimum gas requirements are still provided.
- Carbon dioxide storage is connected to discharge piping and actuators.
- All manual actuators are in place and tamper seals are intact.
- Nozzles are connected, properly aligned, and free from obstructions and foreign matter.
- Detectors are in place and free from foreign matter and obstructions.
- The system control panel is connected and showing the “normal-ready” condition.

16. Appendices

Appendix A

Memorandum dated December 30, 1997, CO_2 Systems—Continued Maintenance and Replacement Options, including Attachment A (*CO_2 System Spare Parts Source*) and Attachment B (*Carbon Dioxide Fire Extinguisher Systems*) by John Grass

December 30, 1997

Memo

To: Power Facility Managers
Area Office Power O&M Managers & Engineers
Regional Power Contacts

From: Gary Osburn and Roger Cline, Hydroelectric Research and Technical Services Group (D-8450)
John Grass, Mechanical Equipment Group (D-8410)

Subject: CO_2 Systems—Continued Maintenance and Replacement Options

In recent months, personnel at several facilities have raised questions about the continued availability of critical components for Reclamation high-pressure CO_2 systems. Generally, project staff have had difficulty finding firing squibs and rupture discs and have asked for references and for recommendations on keeping these CO_2 systems functional.

Even though these items are no longer being manufactured on a regular basis, it is possible for Reclamation offices to acquire a limited number of additional squibs and discs from the source listed in Attachment A.

Although buying these spare parts will solve the immediate problem of keeping CO_2 systems functional, this should be considered only as a short-term solution. **The appropriate long-term solution is to convert to modern high-pressure or low-pressure systems.** Attachment B describes the advantages of conversion in addition to providing general CO_2 system information. We highly recommend that every office make the conversion as soon as possible to ensure reliable operation of these systems as well as to reduce maintenance.

Please contact John Grass, Mechanical Equipment Group, 303-236-8410 X266 (now 303-445-2862) for more information.

cc: D-8440, D-8430, D-8420, D-8410, D-8400

ATTACHMENT A

CO_2 SYSTEM SPARE PARTS SOURCE

As of December 23, 1997, CO_2 system spare parts are available from:

Mr. Harvey Van Zandt
C-O-Two, Inc.
55 Skyline Dr.
Morristown, NJ 07960
Phone: 973-539-6492
FAX: 973-292-0844

Mr. Van Zandt is a retired employee of the now-defunct C-O-Two Fire Equipment Co. of Newark, New Jersey.

<u>Discharge Plugs ("Squibs")</u>
- 115 in stock (1/3/97)
- Part Number: 9388520
- $149.50 each (not including shipping - explosives require special shipping)
- These have a 5-year lifespan

<u>Rupture Discs</u>
- About 100 in stock (1/3/97)
- Part Number: 50112
- $21.00 each

ATTACHMENT B

CARBON DIOXIDE FIRE EXTINGUISHING SYSTEMS

John Grass, Technical Service Center

HISTORY:

Many Bureau pumping and powerplants have had CO_2 fire extinguishing systems installed in them to protect the flammable components inside their motors or generators. Most of these systems are high pressure CO_2 systems which store the required quantity of CO_2 in bottles to be released automatically to extinguish fires in the motor and generator housings.

DESIGN PHILOSOPHY:

CO_2 fire extinguishing systems are normally provided for enclosed motors and generating units that are 10MW and larger. This is because units smaller than 10MW are commonly air cooled and are not of an enclosed design. The materials used in the manufacture of a large generating unit or motor are costly and many of them are flammable. CO_2 is an effective way of controlling fire damage since the extinguishing medium can be applied quickly with very little cleanup work required since CO_2 does not produce debris. Since the CO_2 is applied rapidly the source of ignition is extinguished quickly with very little subsequent damage to other materials that would result from a fire that was allowed to propagate. Rapid oxidation of a fire can cause significant damage in a generator or motor in addition to producing toxic fumes, and the cost of revenue loss in addition to the cost of machine repair or replacement justifies the installation of a CO_2 fire extinguishing system.

The design and installation of carbon dioxide fire extinguishing systems is governed by the National Fire Protection Association (NFPA) Standard No. 12. This NFPA standard states that the rate of volume method be applied to situations where three dimensional irregular objects such as an electrical generator or motor are protected. The total discharge rate of the system is based on the volume of the enclosure surrounding the hazard. The standard states that for every 12 ft^3 of air housing volume, 1 pound of CO_2 shall be provided for initial discharge. (This requirement has changed over the years, many of our facilities are designed for 1 pound of CO_2 for every 16 ft^3 of volume.)

A delayed or extended discharge of CO_2 is also required for the unit air housing to maintain the required concentration when leakage occurs. The amount of delayed or extended CO_2 required is based on the shutdown deceleration time and amount of leakage of the unit. For deep seated fires such as we have with enclosed rotating electrical equipment, a CO_2 design concentration of 50 percent shall be achieved within the air housing in 7 minutes, but the rate of application shall not be less than that required to develop a concentration of 30 percent in minutes.

PROBLEMS:

Since CO_2 fire extinguishing systems have been installed in Bureau facilities since the early part of this century, problems have developed in maintaining these systems to keep them operational. Many of these systems contain components of an older design which are no longer commercially available. These obsolete components such as firing squibs are no longer used in modern CO_2 fire extinguishing systems. The majority of these systems where replacement parts have been difficult to obtain were designed and installed by the now-defunct C-O-Two Fire Equipment Co. of Newark, New Jersey.

SOLUTIONS:

Since firing squibs and other obsolete CO_2 equipment components appear to be no longer available, existing high pressure CO_2 systems can be retrofitted two ways:

1. An existing high pressure CO_2 fire extinguishing system can be retrofitted with modern components that actuate the high pressure cylinders with pneumatic/electrical controls in lieu of firing squibs. The equipment that typically needs to be replaced would be the control panel, pilot and pressure operated cylinder discharge heads and valves, selector valves and various connection components. The high pressure CO_2 system operates at approximately 750 psi at room temperature.

2. An existing high pressure fire extinguishing system can be converted to a modern low pressure CO_2 fire extinguishing system. This solution has the distinct advantage of eliminating the NFPA requirement of weighing the high pressure bottles every six months. This type of system typically has a bulk storage tank with an liquid level indicator that is situated in one central plant location. The equipment that would need to be furnished to convert from a high pressure to a low pressure system would be the storage tank, control panel, selector valves, discharge nozzles and various piping components. The bulk storage tank operates at 300 psi since the bulk storage tank unit is refrigerated.

With either a high or low pressure CO_2 system, modern programmable addressable fire control panels are provided which can electrically supervise the CO_2 system components.

MANUFACTURERS:

Some current manufacturers of *modern* high and low pressure CO_2 fire extinguishing systems are:

Ansul Preferred CO_2
9800 Harwood Court
Fairfield, Ohio 45014
Phone: 1-800-887-5774

Chemetron Fire Systems
4801 Southwick Drive
Matteson, Illinois 60443
Phone: 708-748-1503

Kidde-Fenwal Protection Systems
400 Main Street
Ashland, MA 01721
Phone: 508-881-2000

OIL STORAGE ROOM CO_2 SYSTEMS

In the distant past, CO_2 systems were also used in Reclamation plants to protect oil storage rooms. However, this practice was abandoned many years ago for personnel safety reasons and existing oil storage room CO_2 systems have been replaced by water deluge systems. ***Any remaining oil storage room CO_2 systems should be deactivated immediately.***

CONTACT PERSON:

John Grass of the Mechanical Equipment Group, D-8410, of the Technical Service Center in Denver can assist with the development of cost estimates or specifications paragraphs to convert existing archaic high pressure systems to either a modern high pressure or low pressure CO_2 fire extinguishing system. He can be contacted at (303) 445-2862.

Appendix B

Power Equipment Bulletin No. 3, *Recommended Installation of CO_2 Beacons in Turbine Pits of Hydroelectric Generators*

Power Equipment Bulletin No 3.
May 25, 2000

RECOMMENDED INSTALLATION OF CO_2
BEACONS IN TURBINE PITS OF HYDROELECTRIC GENERATORS

The purpose of this bulletin is to recommend the installation of beacons in turbine pits to warn anyone present that carbon dioxide (CO_2) gas has been released into the generator air housing and that the area should be evacuated immediately.

EXECUTIVE SUMMARY

Safety must be considered in all aspects of powerplant operation and maintenance, including situations where workers are present in the turbine pit of a hydroelectric generator. The environment in the turbine pit is very noisy and somewhat isolated from the rest of plant. Voice communication and audible warning systems are often ineffective. A visual means such as the use of warning beacons is recommended to inform workers of the presence of CO_2, released to extinguish a fire in the generator, while they are in the area of the turbine pit.

CO_2 gas is heavier than air and, if present in sufficient concentrations, can deprive a person of oxygen. It is possible for released CO_2 gas to escape from the generator air housing and quickly collect in the turbine pit below, overcoming anyone in the area. This bulletin recommends the installation of beacons that flash when CO_2 is released to prevent harm or death due to CO_2 release.

DANGER ASSOCIATED WITH THE PRESENCE OF CO_2 IN TURBINE PITS

Compressed CO_2 gas is provided at most Reclamation powerplants to extinguish any fires that may occur in the air housings of generators. CO_2 is a colorless, odorless gas, that cannot be detected by one's senses alone. The gas is stored in high pressure bottles that are connected to manifolds and pipes to deliver the gas into the air housing when needed. When CO_2 is released into the air housing of a generator, it is intended that the gas will suffocate the fire by displacing most of the air through any holes in the air housing and through spring- or weight-loaded pressure relief doors. In the release process, some of the gas escapes into the surrounding air. Significant quantities of the CO_2 can migrate down into the turbine pit.

Turbine pits are located directly below hydrogenerator air housings. Often, the pits are deep enough to trap any gasses, such as CO_2, that are heavier than air. Some turbine pits are enclosed by doors or other sound damping systems which can inhibit diffusion and convection of the gas from the pit. If a person remained in a turbine pit when CO_2 is released, it is possible that the person could be overcome by the CO_2 and, within a few minutes, die of suffocation.

BEACON WARNING SYSTEMS

It is recommended a beacon or system of beacons, that would flash when CO_2 gas has been released or detected in the turbine pit be installed to warn anyone present of the danger and indicate that evacuation is necessary. The system may also be configured to alarm when CO_2 is released into a nearby unit. FIST Volume 5-12 provides further details of CO_2 safety procedures and warning systems.

It is also recommended that CO_2 be purchased with an oderant, such as wintergreen, so that when released it can be detected and the area evacuated. This method should not be considered the sole means of notification of the presence of CO_2 gas because persons with impaired sense of smell or those with head colds might not detect the odor.

Please consider installation of CO_2 warning beacons in the turbine pits of any generator units in your facility that are protected by CO_2 systems and pass this bulletin on to your maintenance staff. Should you have questions or need assistance with identification, purchase, or installation of this safety device, please contact D-8450.

CONCLUSION

The hazard due to the presence of CO_2 gas should be reduced with the installation of flashing beacons in the turbine pits of hydrogenerators.

Appendix C

Power Equipment Bulletin No. 20, *Alternate Methods of Measuring Liquid Levels in CO_2 Bottles*

Power Equipment Bulletin No. 20

Alternate Methods of Measuring Liquid Levels in CO_2 Bottles

March 15, 2004
Revised April 8, 2004

The purpose of this document is to inform Reclamation power O&M staff about procedures for alternate methods of measuring liquid levels in CO_2 bottles in lieu of weighing each bottle. These alternate methods will reduce the amount of labor when performing required preventative maintenance and eliminate potential injuries associated with physically moving and lifting CO_2 bottles.

EXECUTIVE SUMMARY

Reclamation standards require measuring the amount of CO_2 in fire suppression bottles by weighing the bottles semi-annually. This is a requirement of NFPA 12-2000, *"Standard on Carbon Dioxide Extinguishing System,"* and FIST Volumes 4-1B, "*Maintenance Scheduling for Electrical Equipment,"* and 5-2, "*Firefighting and Fire Prevention."* NFPA 12-2000 states in Appendix A, "Check the contents for weights by acceptable methods for each cylinder or low-pressure tank (if the contents are more than 10 percent below the normal capacity, refilling is required)."

BACKGROUND

Weighing the bottles is a very dependable method of determining any loss of CO_2 from a bottle. Regardless of the temperature of the bottle, the CO_2 will weigh the same. While weighing the bottles is a sure way of determining the amount of CO_2 in a bottle, it does have several drawbacks. First, each bottle must be loosened from its mounts and lifted onto a scale. This is a potentially dangerous procedure, as bottles often weigh more than 100 pounds. Second, this work can be time consuming and therefore costly to the maintenance program. Third, the CO_2 system must be disabled during this work, temporarily leaving a running generator without CO_2 protection. In some plants, this last concern mandates a unit outage, resulting in lost power generation revenue. An alternate method of measuring CO_2 could eliminate these problems.

ALTERNATE METHODS

Our research found three alternate methods of measuring the level in CO_2 bottles. In England, the level is measured with ultrasonic instruments and with heat-activated liquid level strips. The United States Coast Guard allows liquid level measurement by ultrasonic means for CO_2 and Halon bottles.

International Organization for Standardization (ISO) standard 6183, "*Fire protection equipment – Carbon dioxide extinguishing systems for use on premises – Design and installation, for CO_2 fire suppression systems,*" is a similar standard to NFPA 12. It calls for checking the level of the CO_2 but does not specify how this is to be done. Link Instruments of the United Kingdom provides both ultrasonic measuring devices and inexpensive heat-activated liquid level strips. The liquid level strips are attached to the bottles and then heated with a heat gun. As the strip is heated, it will turn from black to yellow and then back to black as it cools down. When the metal of the bottle near the strip is heated sufficiently, the strip will stay yellow above the liquid level for a few seconds and will turn back to black very quickly below the liquid level. The level can easily be detected and marked with a permanent marker. The strips are reusable.

The level indicator strips were recently tested at Canyon Ferry Powerplant. The strips were applied to six bottles. The level in all of the bottles except one was found to be within an inch of each other. The level in three of the bottles was approximately 31 inches measured from the bottom of the bottle. Based on the 10 percent allowance, the level could have been 3.1 inches below that and been acceptable. The sixth bottle was found to have a level more than a foot below the others. This bottle was removed, weighed, and found to have lost approximately 20 pounds from its 50-pound full load of CO_2.

For more information on the Link Instruments Liquid Level Strips, check their web site www.linkinst.com . The 18-inch strips cost approximately $6.00 each. The actual cost depends on the number of strips ordered and the exchange rate the day the order is placed. Their telephone number from the United States is 011 44 1730 26 96 09, and their fax number is 011 44 1730 23 11 84.

Another method of visually measuring the CO_2 levels is to use an infrared camera to view the bottles after heating them with a heavy-duty heat gun. This method was successfully tested at Flatiron Powerplant. Two bottles were heated using the heat gun. The gun was moved up and down the bottle and the bottles viewed by the infrared camera. The liquid level can be distinctly seen as shown in an attached picture. As with the strips, the level can be marked with a permanent marker or a strip of black electrical tape. The black electrical tape will show up on the infrared camera as a warm area on the tank. However, it is important to pass over the tape with the heat gun. The tape should be placed in a location where the heat from the heat gun will directly pass over it and where the infrared camera can pick up the black electrical tape. This method was also tested at the Technical Service Center in Denver using an ABC fire extinguisher and two strips of black electrical tape and is shown in an attached picture.

One problem with measuring CO_2 levels, rather than weighing the cylinder, is the fact that the CO_2 liquid level will rise and fall with a change in temperature. If the CO_2 bottles are measured at different ambient temperatures, different levels will be found. To overcome this, when measuring a bank of bottles, one bottle from the bank should be weighed to verify it is full and its liquid level determined with the temperature strips or infrared camera. This level can be measured from the bottom of the bottle, and the rest of the bottles should be within 10 percent of that level. It should be noted that at a temperature of above 87.8 ˚F, CO_2 can only exist as a gas and, consequently, a liquid/vapor interface cannot be detected. Liquid level measurement of CO_2 should not be done at temperatures above 87.8 ˚F.

PROCEDURES

Recommended Procedure for Using Link Instruments Liquid Level Strips

Measure ambient temperature and record. If temperature is above 87.8 ˚F, all of the bottles will have to be weighed.

If the ambient temperature is below 87.8 °F, weigh one bottle to verify it is full.

Place a level indicator strip on the known full bottle. Place the top of the strip approximately 6 inches above the center of the bottle.
Heat the level indicator strip with the heat gun, moving the gun up and down the length of the strip. (Note: Heat gun must have the capability to reach 1100 ˚F.)
When an area is noticeably staying black longer, concentrate the heat gun in that area (i.e., 3 inches above and 3 inches below).
The top of the dark area indicates the level of the CO_2. Mark the level with a permanent marker or black electrical tape.
Measure from the bottom of the bottle to this mark.
Place level indicator strips on the remaining bottles so that the top of the strips are approximately 3 inches higher than the measured level of the first bottle.
Use the heat gun to check the remaining bottles. The level on these bottles should not be more than 10 percent lower than the measured level of the first bottle.
Document, schedule, and record in MAXIMO.

Recommended Procedure for Measuring CO_2 Level Using an Infrared Camera
Measure ambient temperature and record. If temperature is above 87.8 ˚F, all of the bottles will have to be weighed.
If the ambient temperature is below 87.8 ˚F, weigh one bottle to verify it is full.
Heat the bottle with the heat gun, moving the gun up and down the length of the bottle.
View the bottle with the infrared camera. The portion of the bottle with liquid CO_2 will be cooler than the portion with gas.
Mark the level with a permanent marker or black electrical tape.
Measure from the bottom of the bottle to this mark.
Use the heat gun and infrared camera to check the remaining bottles. The level on these bottles should not be more than 10 percent lower than the measured level of the first bottle.
Document, schedule, and record in MAXIMO.

The intent of NFPA 12 is to ensure CO_2 systems are properly maintained so they will operate as intended when required. NFPA 12-1-2.1 states, "…Nothing in this standard is intended to restrict new technologies or alternate arrangements, provided the level of safety prescribed by the standard is not lowered." The Authority Having Jurisdiction (AHJ) may accept alternatives to the code. NFPA is not the AHJ, as it has no authority to enforce the standard. As Reclamation is a government entity, we are our own AHJ and can decide to adopt the standard or accept alternative methods to the NFPA code as long as an equal or greater level of safety is maintained. When properly utilized, the liquid level strips and infrared camera procedures provide the same level of safety as weighing the bottles. These new methods of determining the level in CO_2 bottles will be included in future revisions of FIST Volume 4-1B, "*Maintenance Scheduling for Electrical Equipment,*" and 5-2, "*Firefighting and Fire Prevention,*" as acceptable equivalent alternatives to weighing each individual bottle.

For assistance or additional information, please contact Bill McStraw at (303) 445-2293.

Figure 1. - Heating Liquid Level Strip

Figure 2. - Liquid Level Strip, showing level of CO_2

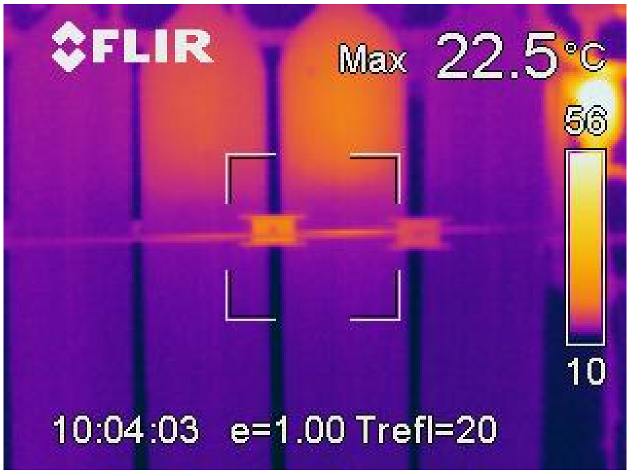

Figure 3. - Infrared picture of CO_2 bottles after heating with heat gun

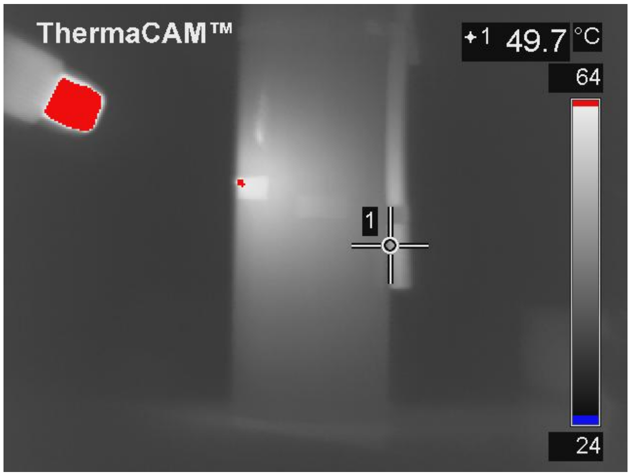

Figure 4. - Infrared picture of an ABC fire extinguisher while being heated with a heat gun. The white square areas on the extinguisher are black electrical tape.

MISSION STATEMENTS

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.