

Carbon Dioxide Suppression System Design Changes

Draft White Paper for NRC and Industry Review
January 31, 2005

- Topic:** Options and Considerations for Making Changes to Carbon Dioxide (CO₂) Suppression Systems
- Purpose:** Provide technical design and regulatory considerations for plants considering changes in the status or their Carbon Dioxide (CO₂) Suppression Systems. Conversion from automatic to manual CO₂ systems or alternate forms of fire suppression will be addressed.
- Scope:** The scope of this white paper is limited to changes to carbon dioxide suppression systems. These considerations are not intended to be applied to changes or elimination of Halon or water based suppression systems. The focus on change in status for carbon dioxide suppression systems is based primarily on personnel safety considerations.
- Background:** Due to industry operating experience (some of which is documented in Information Notice 99-05), a number of plants that have automatic carbon dioxide (CO₂) fire suppression systems are considering either making these systems manually actuated or eliminating the systems in their entirety. Many of these CO₂ systems are installed in areas to meet specific regulatory requirements or as specific commitments made in fire protection licensing documents. These systems may also provide technical justification for exemption requests, deviation requests or Generic Letter (G.L.) 86-10 barrier evaluations. Therefore a change in the status of an existing automatic CO₂ system needs to be carefully considered.

CO₂ Systems That May Be Candidates for Change

CO₂ is effective as a fire extinguishing agent primarily because it reduces the oxygen content of the atmosphere by dilution to a point where the atmosphere will no longer support combustion.¹ A secondary attribute of CO₂ discharge is rapid cooling of the burning surface. Both of these extinguishing methods, while effective on fires, have potentially negative consequences in certain applications in a nuclear power plant, particularly as a personnel hazard.

CO₂ was a common choice as an extinguishing agent in both nuclear and fossil power plants for several reasons. Since CO₂ is used for purging hydrogen from the generator, most plants already had a CO₂ storage tank on site. CO₂ is inexpensive and is considered a clean agent (i.e., CO₂ will not leave a residue and is electrically nonconductive). Typical applications of CO₂ systems at nuclear power plants include: cable spreading rooms, electrical switchgear rooms, emergency diesel generator rooms, safety-related pump rooms, motor-generator set rooms, fuel and lube oil storage rooms, and turbine/generator bearings.

Personnel safety is the primary drawback to the use of CO₂. The same oxygen displacement property that makes it effective as an extinguishing agent also makes it deadly if personnel are exposed to a CO₂ discharge. There have been several significant incidents associated with CO₂

¹ Fire Protection Handbook, 16th Edition, Section 19 Chapter 1.

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discharges at commercial nuclear plants. National Fire Protection Association (NFPA) Standard 12 provides numerous safety considerations for the design and use of CO₂ systems, such as (1) the use of CO₂ systems should be limited to normally unoccupied areas, (2) pre-discharge alarms should be provided, and (3) lockout/tag-out procedures should be in place. However, at nuclear power plants, areas like cable spreading rooms, switchgear rooms, diesel generator rooms, and pump rooms, are often occupied by workers performing tests or maintenance.

Automatic CO₂ systems typically have a combination of electrical and pneumatic controls to discharge the systems. Industry experience provides clear documentation of a history of CO₂ systems inadvertently discharging for a variety of reasons. Virtually every nuclear power plant with a CO₂ system has had an event that resulted in an inadvertent discharge or an initiation of the discharge logic without discharge.

In addition to the personnel safety concerns associated with CO₂ systems, there are also potential equipment concerns associated with a CO₂ system discharge. The extreme temperature drop associated with a CO₂ discharge can effect equipment and can also result in condensation, which could create circuit pathways in electrical equipment.

Plant rooms and areas that may be candidates for change in the actuation method of the CO₂ system include the following:

- CO₂ protected rooms having considerable personnel occupancy. Examples include cable spreading rooms, switchgear rooms, pumps rooms and diesel generator rooms. Even CO₂ systems with discharge delays can be actuated in a manner that bypasses the discharge delay.
- CO₂ protected rooms containing equipment that could be directly affected by a CO₂ discharge. Examples include cable spreading rooms, switchgear rooms and diesel generator rooms (where engine combustion air is taken from the room).
- CO₂ protected rooms containing fire retardant cables as the primary combustible with little or no floor-based combustibles that could create an exposure fire to the cables (examples include cable spreading rooms).
- CO₂ protected rooms containing a single piece of equipment that is the only fire hazard in the room, and that would likely already be rendered inoperable by the event that caused the fire. (Examples include individual pump rooms, where a bearing failure that could cause a fire would likely have already rendered the pump inoperable.)

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CO₂ System Change Options

There are three basic options available for making changes to an automatic CO₂ system: The selection of the appropriate option should be based on the fire hazard in the room/area, the impact of a fire (on the ability to achieve and maintain safe shutdown) in the room/area being protected by the system, and the ability of the fire brigade to manually extinguish the fire.

1. Convert the automatic system to a manual system
2. Install another type of fire suppression system
3. Completely eliminate the CO₂ system.

Attachment 1 provides guidance in selecting the appropriate option, considering the hazard conditions along with the fire protection options. A summary of each of these fire protection options is provided below.

1. Conversion of automatic CO₂ system to manual: Plant modifications should be undertaken to assure that personnel safety will not remain an issue. If the manual system can inadvertently actuate, additional safety precautions may still be required. To provide the fire brigade more time to respond to a fire while still in an incipient condition, additional smoke or incipient detection should be provided if heat detectors were originally used to actuate the system.
2. Alternate Fire Suppression Systems. The installation of a sprinkler system (wet-pipe or pre-action) should always be considered as an alternative to an automatic CO₂ system. For every plant that has an automatic CO₂ system in a specific type of room, there is another plant that has a sprinkler system being used in a similar application. Considerations for sprinkler systems are floor drain capability, ceiling access (there are some cable spreading rooms that simply do not have accessible ceilings) and hanger supports. There may be a high cost associated with the installation of an alternative suppression system. Smoke detection should also be considered for rooms with sprinkler protection to provide early warning of a fire condition.

Alternate Clean Agent Systems. NFPA 2001 addresses clean agent systems. While these systems were originally intended as a replacement for Halon systems, they share similar clean agent attributes with CO₂ and will provide an alternative to CO₂ if appropriate for the intended hazard. For example, in a cable spreading room, it should be determined whether the alternate agent is acceptable for use on deep-seated fires.

3. No suppression. This option has limited application as an alternative to an automatic CO₂ system. This option would likely have to be paired with the installation of additional smoke detection (such as incipient detection). This option would be limited to very specific applications, would require a detailed evaluation, and should be supported by risk analyses.

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Interim and Long Term Compensatory Measures

Compensatory measures may be appropriate in the event an automatic CO₂ system is converted to manual operation prior to NRC approval or prior to an evaluation that justifies a change. Some of these compensatory measures may become permanent actions as part of the justification for converting the system to manual operation. These compensatory measures are in addition to any that may be mandated by a plant's Technical Requirements Manual or similar fire protection administrative control program, and may include:

- Specific instructions for discharging the CO₂ system manually in the pre-fire strategy plans. In addition to the instructions for physically discharging the system, criteria to be used in determining when to discharge the system should be provided.
- Additional fire protection. Specifically, additional smoke detection or incipient detection may be warranted to ensure response to the fire while still in an incipient stage. Additional standpipes and hose stations may be a consideration.
- Additional fire fighting equipment. This may include additional fire extinguishers, special nozzles to get water up to cable tray stacks (e.g., cellar nozzles or navy applicator nozzles), ladders to access trays and possibly a thermal imaging camera.
- Restrictions on activities within the room. This may include strict limits on transient combustibles, limitations on hot work, limiting access, etc.

Risk Considerations

Every plant should have a fire risk analysis as part of the IPEEE performed for Generic Letter 88-20 Supplement 4, and some plants may have more current fire PRAs. A change to the CO₂ system actuation method should be considered against the risk analysis. For plants that have maintained their Fire PRA this may not be difficult. For plants that used a screening methodology, it is possible that the room may have screened out (i.e., Δ risk below 1 E-6) without consideration of the fire suppression system. Using a fire model to help determine the impact of a manual vs. an automatic CO₂ system may be effective in determining the Δ risk.

Regulatory Considerations

Any consideration of a change from an automatic to a manually actuated CO₂ system must address the regulatory implications of such a change. Two reviews should be performed:

- Consideration of the plant licensing basis
- Determination of whether prior NRC approval of the change is required

Licensing Basis

Consideration of the licensing basis should address the following questions:

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- Is an automatic CO₂ [suppression] system needed for Appendix R compliance? For example, does the area have one hour rated cable wrap or 20 feet free of intervening combustibles? If so, plant modifications may be necessary or an exemption request may be required.
- Was an automatic CO₂ system used to support an exemption/deviation request? Was the automatic system CO₂ system used to support an exemption request and did the NRC included the system as part of their justification in the Safety Evaluation Report approving the exemption? If so, an amendment to the exemption or deviation request may need to be submitted.
- Is an automatic CO₂ system needed to support a G.L. 86-10 evaluation? Was the automatic CO₂ system part of the technical justification for a fire barrier evaluation or other fire protection engineering evaluation? If so, a revision to the G.L. 86-10 evaluation will be necessary.
- Does the Fire Protection Safety Evaluation Report (FPSE) contain specific commitments for the CO₂ system? The information contained in the FPSE typically forms the basis for fire protection program that is either referenced by, or included in the UFSAR. If so, a change to the fire protection program should be processed (using the plant change process consistent with NEI 96-07).

Given the differences that exist among fire protection licensing bases within the industry, each site must carefully consider those regulatory requirements and commitments that are associated with their fire protection program.

Determining Need for Prior NRC Approval

The standard Fire Protection Licensing Condition as contained in G.L. 86-10 states the following, "The licensee may make changes to the approved fire protection program without prior approval of the Commission only if those changes would not adversely affect the ability to achieve and maintain safe shutdown in the event of a fire." For plants with this license condition statement, an evaluation should be performed utilizing NEI 02-03 that determines whether the change in the CO₂ system would not adversely impact the ability to achieve and maintain post-fire safe shutdown (FSSD).

If the change in the CO₂ system actuation method is deemed to require prior NRC approval through an exemption/deviation request or revision to a previously approved exemption, the process for NRC approval is clear. If a licensee determines that the change in the CO₂ system could adversely impact the ability to achieve and maintain FSSD (and still wants to make the change), then a License Amendment Request would be indicated.

The more difficult scenario is one in which the conclusion is that there is no adverse impact on the ability to achieve and maintain FSSD, but there is a specific commitment to an automatic fire suppression system (that matches the guidance in Appendix A to BTP APCS 9.5-1, or commitments to BTP CMEB 9.5-1, or requirements contained in Appendix R) for the room being

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protected. Some plants have determined that this condition requires prior NRC approval and have submitted a License Amendment Request. Other plants have determined that a submittal was not required, based on the standard License Condition that their site had adopted. In this case the licensee should make the determination based on his specific licensing basis and in consideration of the factors described in this paper.

If the NEI 02-03 analysis indicates no adverse impact on safe shutdown and no specific commitment to an automatic suppression system, the licensee should be able to effect the design change without prior NRC approval.

Insurance Considerations

Any change in the status of the method of actuation of a CO₂ system will require notification of the Insurance Company. NEIL typically has "should" requirements for automatic suppression systems in plant areas. NEIL should be notified of this change regardless of the impact the ability to achieve and maintain FSSD. The change of an automatic CO₂ system to a manual system will likely involve a "should" recommendation and potentially a rate penalty. This rate penalty is site specific. It is recommended that the Insurance Company be notified well in advance of making the change.

Summary

The process to change the status of CO₂ system from automatic to manual or provide an alternate fire suppression system is a multidisciplinary effort. Support from the following groups is recommended: fire protection engineering, fire safe shutdown engineering, operations, licensing (regulatory), PSA, and procurement as a minimum. Support from senior management is essential throughout the process. It is likely that the process will be closely reviewed by third parties so documentation of each technical and regulatory decision made during this process is essential, with any documentation retained for future reference and review. Benchmarking with plants that have had experience in this process may provide additional insights.

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Attachment 1

Consideration of Fire Protection Alternatives to Automatic CO₂ Based on the Hazards or Considerations Within the Room/Area

Fire Protection Approach (Note 2)	Significant quantity of Class B hazard present	Fire retardant cables present (Note 3)	Non-fire retardant cables present (Note 3)	Room/Area readily accessible by fire brigade	Room/Area not readily accessible by fire brigade	Room contains cable wrap rated less than 3 hours	Room contains more than one train of safe shutdown equipment	Complete loss of room will not affect FSSD ability	No floor drainage in room	High voltage electrical equipment present?
Manual CO ₂ system	No	Yes	No	Yes	No	No	No	Yes	Yes	Yes
Pre-action Sprinkler	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Wet Pipe Sprinklers	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Automatic Alternate Clean Agent System	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Eliminate CO ₂ system and install incipient detection	No	Yes	No	Yes	No	No	No	Yes	Yes	No

Note 1 – A “Yes” indicates that the indicated alternative to an automatic CO₂ system (for example, “Pre-action sprinkler”) is appropriate for the indicated plant condition (for example, “Fire Retardant Cables Present”). A “No” indicates that it is not appropriate.

Note 2 – Assumes room/area had fire detection capability as part of automatic CO₂ system. However, consideration must always be given to the type and adequacy of the existing detection in light of the change. Smoke detection or incipient detection should be considered to replace heat detection to provide earlier notification of a fire condition.

Note 3 – Fire retardant cables are those that meet IEEE 383 or equivalent. Non-fire retardant cables are those cables that are not qualified to IEEE-383 or equivalent. Assumes that cables installed in the area will primarily be of one type or the other.