CARBON DIOXIDE SYSTEMS

INTRODUCTION

National Fire Protection Association (NFPA) documents describe a level of fire protection agreed on by persons representing a variety of interests. The guidance in these documents does not reflect unique conditions or special considerations, such as system performance under adverse conditions. Nor does NFPA guidance reflect the increased system reliability that AXA XL Risk Consulting recommends for high valued properties.

This PRC Guideline takes a position on the provisions of NFPA 12 that AXA XL Risk Consulting believes require clarification or changes. To understand the position, this PRC Guideline must be read with a copy of NFPA 12. The provisions of the NFPA document are not repeated.

POSITION

General

Carbon dioxide extinguishes by displacing oxygen to the point where combustion cannot be supported. The resulting local oxygen concentration is well below that which supports life. Therefore, use caution when designing and testing such systems in occupied, enclosed areas. To a lesser degree carbon dioxide also extinguishes by physical and chemical cooling.

System designers must be knowledgeable and competent. One way to demonstrate competency is by certification. In the U.S. the National Institute for Certification of Engineering Technologies (NICET) provides such a service for extinguishing system designers.

Beginning with the 2005 edition of NFPA 12, new total flood systems have been prohibited from use in normally occupied enclosures. The standard does allow some specific exceptions to this prohibition, however it is the committee’s opinion that use of these exceptions should be very rare.

Existing total flood systems protecting normally occupied enclosures are permitted. The following equipment must be provided:

- System lockout valves
- Pneumatic predischarge alarms
- Pneumatic time delays

Many applications previously protected by halon can be protected by carbon dioxide; however, all aspects of personnel safety must be considered.

Carbon dioxide does not usually cause thermal shock unless the discharge is directed at objects close to the nozzle. Some specialized installations are designed to pass the carbon dioxide through a vaporizing unit to reduce it to a gaseous state and reduce the cooling effects of vaporization.

Because high concentrations of carbon dioxide are lethal, exercise utmost care in the design, review, and acceptance testing of carbon dioxide extinguishing systems. Pay special attention to low-lying areas or pits where access and egress may be a problem. Incorporate appropriate audible and visible pre-discharge alarms and delayed discharge features. Although discharge should occur as promptly as possible, design time delays long enough to evacuate areas of carbon dioxide accumulation during discharge. A time delay of 20 s – 30 s is adequate in many cases.

System Lockout

To ensure personnel safety, lockout isolation valves and key-operated switches listed for this purpose are permissible for confined space entry. Supervise lockout isolation valves and key-operated switches. Provide both audible and visual alarm indicators. Only trained loss prevention personnel should operate these devices. Ensure systems are promptly restored to service.

In normally unoccupied areas having the potential for fast developing fire, a supervised occupancy interlock may be desirable. The device allows for a longer time delay while personnel are in the protected enclosure. Such a delay could be interlocked with room lighting or door switches, or it could be push-button actuated. When the interlock is not activated, the system will discharge gas after a preset shorter time delay.

Plan And Installation Approval

Submit complete details of the proposed installation including plans, calculations, bill of materials, sequence of operations, etc. to the AXA XL Risk Consulting Plan Review Office for review. Confirm that the design drawings note how the potential for over-pressurization has been addressed. Follow the requirements of NFPA 12, this document and PRC.13.0.2.

Some designers of carbon dioxide systems include additional fittings and lengths of pipe in their calculations to account for field revisions or rerouting of piping. This practice is tolerable for total flooding systems, because all of the carbon dioxide discharges into the enclosure and negates any small imbalance at the nozzles. The system designer should note on the plan how many feet of piping or how many fittings have been added so the installer will know how much liberty can be taken without significantly affecting the system design. Extra equivalent piping lengths change the terminal pressure, which may affect the selection of nozzle orifice sizes. An incorrect nozzle size may result in an imbalance of protection and permit a reflash.

Proper design calculations are critical for local application systems. Each nozzle must be properly sized and placed. Total flooding systems discharge all of the agent into the enclosure. However, each nozzle of a local application system protects its own portion of the hazard. Failure to control and extinguish the fire at any nozzle will allow the fire to reflash or rekindle when the agent dissipates to the surroundings.

Calculation for local application systems must be on an "as built" basis.

Testing Of Systems

Conduct a full discharge test of all systems to verify the design and to ensure that all devices function properly. See PRC.13.0.5 and PRC.13.0.5.A. For total flooding systems, record concentration tests on a calibrated three-point, direct reading, recording-type meter. Field check the calibration of the meter just prior to performing the test. Provide enough carbon dioxide at the plant site to replace the agent immediately at the conclusion of the discharge test.

During the discharge testing of local application systems, confirm that flow from each nozzle is not obstructed.

Discharge tests for wet benches used at semiconductor facilities should be done at the factory on each type and size of bench, to verify proper distribution of carbon dioxide and adequate carbon dioxide for extinguishment. The test should incorporate the exhaust system running and protection extended to the ductwork. Acceptance test all equipment and features on site after installation is completed. This would include detectors, alarms, power interlocks, battery backup, valves actuate, etc. If there is concern about contamination from the carbon dioxide in the event of a false dump or system operation, medical grade carbon dioxide can be substituted. See PRC.17.11.1 for protection requirements.

Detection, Actuation And Control

Although NFPA 12 allows complete manual operation, automatic carbon dioxide system actuation with a manual means of release is preferred. A manual release that is entirely independent of the primary actuation system is a Mechanical Emergency Manual Release (MEMR). Provide a MEMR on all carbon dioxide systems.

A manual release that depends on the primary actuation system is a “normal” manual release. Locate both the normal manual releases and the MEMRs in readily accessible locations. In a local application system, locate the manual release devices a safe distance from the effects of the agent and the fire, but not far enough to cause confusion as to which hazard the release controls. Placing the release devices within 25 ft (8 m) of the hazards is usually adequate. In areas protected with total flooding systems, locate the manual release devices directly outside the enclosure at each exit so the system can be operated safely. Identify the hazard protected on a placard.

Both types of manual releases must actuate all devices necessary to release the agent into the enclosure from a single location, including system interlocks. An exception may be made for low-valued, noncritical operations where all equipment necessary to operate the system can easily be reached and manually operated.

Failsafe valves operate on loss of either power or pneumatic pressure. Although the valves that fail safe do not require a second pressure source, the remaining valves in the system do. Provide complete pneumatic supervision of all actuation piping and devices.

Some actuating devices used on carbon dioxide extinguishing systems use an explosive powder charge, called a “squib.” Powder explosives degrade with time. The useful life of squibs can generally be determined from Table 1; however, refer to the specific manufacturer’s literature for guidance. Usually the date of manufacture is on the squib.

TABLE 1
Useful Shelf Life Of Squibs

Maximum Ambient Temperature	Replace After
80°F	5 yr
100°F	3 yr
120°F	2 yr
140°F	1 yr

SI Units: °F = (°C × 1.8) + 32

To help assure circuit integrity during a fire, install the electrical detection, actuation and alarm circuits in steel conduit or tubing in accordance with Chapter 3 of the National Electric Code (NEC®), NFPA 70.

Fire alarm system wiring can be installed exposed. Installing the cable in conduit or tubing provides additional protection from physical damage and fire damage. The chance of damage by fire increases when the system uses a pre-discharge time delay.

Use mineral insulated metal sheathed cable, type MI, for electrical detection, actuation and alarm circuits in locations where the cable will be directly exposed by a fast developing, high rate of heat release fire. These types of fires usually involve flammable and combustible liquids. The cable does not have to be in conduit unless otherwise required by the NEC.®

Completely supervise the electrical or pneumatic detection, the primary actuation system, and the normal manual releases so any system failure actuates an audible and visible alarm.

Do not use fusible links, including frangible-bulb releases to actuate systems protecting high valued equipment because:

- Fusible links are not easily supervised.
- Only direct flame impingement ensures prompt operation.
- Fusible links do not warn of system operation.

Install appropriate detectors listed for the hazard and designed, installed and tested in accordance with NFPA 72 and PRC.11.1.1.0. Connect the detectors to control units specifically listed for release device service by a nationally recognized testing laboratory in accordance with NFPA 72. Locate the control panel in a safe, accessible area outside the area being protected. For detection systems used to release extinguishing agents, also follow the requirements of PRC.13.0.1.

Emergency Manual Control

Mechanical Emergency Manual Releases (MEMRs) serve two purposes. They allow delivery of carbon dioxide on the hazard in case any portion of the automatic system fails, and they can be used to inert the area in an emergency, prior to automatic actuation. Design the MEMR to be completely independent of the primary actuation system in accordance with the requirements in PRC.13.0.3.

Identify and locate MEMRs as close to the hazard as reasonably possible to enable fast emergency operation. Usually the MEMR is a mechanical device located on the discharge mechanism, but sometimes cable pull mechanisms are used on high-pressure systems. The MEMR on low-pressure carbon dioxide systems is usually a remote pneumatic device, pilot cabinet, or a manually operated valve. On a low-pressure carbon dioxide system, design the system so that the selector and master valves are both operable from an accessible single location near the hazard.

Pilot cabinets are metal enclosures used to house electric and pneumatic actuation devices on low-pressure carbon dioxide systems. Pilot cabinets are not necessary if the following conditions are met:

- The selector valve is readily and safely accessible from floor level. Do not allow piping obstructions or slippery floors in the pathway to the master valve. A permanently attached platform to access the selector and master valves is a less desirable option.
- Two independent sources of operating pressure are provided; or if one source is provided, and the master valve can be remotely operated by operation of the selector valve.
- All actuation piping is pneumatically supervised and arranged so the master valve opens when the selector valve operates.

Operation of the manual pneumatic release should open the proper selector valve on multiple hazard systems and should be arranged to **either** manually operate the cylinder releases of two pilot cylinders on high-pressure systems **or** open the master valve on low-pressure systems.

Many low-pressure systems using electrically operated automatic detection systems depend on pneumatic lines to actuate the systems. Any manual release that depends on the same run of pneumatic piping as the automatic system is the normal manual release. Close-couple the MEMR to the discharge valve assembly, or pipe it independently of the normal manual release.

During an emergency, an operator might attempt to operate every protective device within reach. For that reason, do not group MEMR devices from different hazards together. Use distinct labeling.

The designer should investigate the need for installing a time delay with an MEMR.

Power Sources And Interlocks

Design the controller to automatically shut down fuel input, power supplies to the hazard and auxiliary equipment, such as conveyor systems upon system actuation. Use manual reset devices.

In computer and electronic occupancies, the system should normally shut off the computer electric power when the carbon dioxide discharges. However, power shutdown procedures should be reviewed with the supervisor of computer operations before an emergency occurs to prevent difficulties with “real-time” computing applications. If power must be left on, consideration should be given to installing an Emergency Power Off (EPO) switch outside of the protected space to allow for remote shutdown of all electrical power.

System Aborts

Although lockouts for safety purposes are acceptable, **abort switches are not permitted**. The nature of the hazard is usually such that a delay for investigation or improper use of an abort switch could bring about excessive damage prior to the attempt at extinguishment.

Supervision And Lockout Valves

Supervise all portions of the automatic detection, the automatic and the normal manual means of actuation, the valves, the alarms, and the power supplies on all **new or upgraded** systems. MEMRs need not be supervised.

Although supervision of the interconnecting pipe or tubing between cylinders is preferred, it need not be provided if the following conditions are met:

- Cylinders are in a manufacturer’s bracket assembly, immediately adjacent to and almost touching each other.
- Interconnection piping or tubing is in a direct run between two adjacent cylinders and is of minimal length.
- Piping, if used, is Schedule 80 with malleable fittings and flexible connectors listed for use with the system installed.

Evaluate existing systems on the basis of potential loss if the piping system should fail. If the potential damage to property or the interruption to the process is substantial, recommend upgrading.

In low-pressure systems provide the required high/low-pressure supervisory alarms. Lock the manual tank shut-off valve and the vapor supply line valve open. Supervise the valves. The vapor supply line provides the necessary pressure to operate the master and selector valves.

Alarms And Indicators

Pre-discharge and discharge alarms must be distinguishable. Pre-discharge alarms, discharge alarms, and trouble signals should be audible and visual. Some systems use carbon dioxide discharge whistles.

Extend carbon dioxide system alarms and supervision to any existing central station or other protective signaling equipment in service at the protected facility. In addition, extend the existing service to all carbon dioxide control valves needed to operate the system.

Predischarge Alarm And Time Delay

Use time delay devices with pre-discharge alarms to allow personnel time to evacuate congested or enclosed areas. Pneumatic time delays should be used for total flood designs of normally occupied spaces occupiable spaces or for local application designs that present an exposure to occupants.

Tailor the delay time to the hazard. Generally, delays of 20 s – 30 s have been adequate for most circumstances. Arrange the time delay to operate with either the automatic or the manual means of actuation. Bypass the time delay on the second shot, because the time delay will have already alerted personnel, and further delay could prevent extinguishment.

Power Sources

When calculating secondary power capacity, consider the power requirements of detectors, control panels, multiple audible and visual alarms, the actuation circuit, and electrical interlocks. A standby automatic electrical generator or standby batteries are acceptable secondary power sources.

Quantities

In high-pressure systems, activating the proper number of cylinders provides the correct amount of carbon dioxide. See the interpretation regarding acceptable cylinder sizes for high-pressure systems.

On low-pressure systems the tank capacity is designed to contain enough agent for the largest group of interconnected hazards plus an extra amount for possible carbon dioxide hose connection usage. Provide enough carbon dioxide for at least two complete discharges plus 10% more for allowable losses before refilling. An improperly sized tank could jeopardize protection.

Connected Reserve

In high-pressure systems, provide a second set of charged cylinders to the system's discharge manifold. This reserve supply is actuated by manually operating the main/reserve switch on either electrically operated or pneumatically operated systems.

Design high-pressure systems to operate identically in either position of the main/reserve switch.

In some cases utilizing high pressure systems, a connected reserve may be omitted provided:

- There are multiple small hazards of similar design utilizing a single cylinder.
- A fire in an individual hazard would cause minimal property damage and business interruption.
- The facility maintains a supply of replacement cylinders for quick restoration of the system.
- Plant personnel are aware that this arrangement does not offer the full redundant protection that a permanent connected reserve supply can provide.

In low-pressure systems, the designer takes care of the reserve supply by providing a storage tank of sufficient capacity.

- A connected reserve is desirable for four reasons:
- To protect if reflash occurs.
- To provide reliability if the main bank malfunctions.
- To protect when main tanks are impaired during replacement.
- To protect other hazards when multiple hazards are protected by the same set of cylinders.

Replenishment

Maintain a **third** complement of fully charged unconnected spare cylinders on the premises for emergency use if a full complement of charged cylinders cannot be obtained, or if the empty cylinders cannot be recharged, delivered and reinstalled in 24 h. Spare cylinders need not be provided if the hazard is protected adequately by automatic sprinklers.

Storage Containers

Carbon dioxide for extinguishing applications can be stored either at room temperature in high-pressure cylinders or in temperature controlled tanks maintained at 0°F (–18°C). Either type of system can provide equivalent protection, so the decision is a matter of economics. Since most of the carbon dioxide system's cost is in hardware, the larger the system the more suitable a single low-pressure storage arrangement becomes. The capacity of the smallest low-pressure storage tank is ¾ ton (680 kg). A low-pressure system is capable of multiple discharges, because discharge is timed and only part of the contents of the tank is discharged.

Cylinder Size

The smallest recommended high-pressure cylinder used for protection is a nominal 50 lb (30 kg). Common sizes in the US are 50 lb, 75 lb, 100 lb and 120 lb (only 30 and 50 kg sizes are used Outside the US).

NFPA 12 requires that multiple containers protecting the same hazard be the same size. A facility with multiple carbon dioxide systems might consider standardizing on one cylinder size so that all spare full cylinders would be interchangeable.

Storage Temperature

External heating or cooling of high-pressure cylinders is not recommended. Locate cylinders in a properly controlled environment. If extreme temperature changes affect system effectiveness, provide temperature supervision.

Low-Pressure Supply

The following guidance pertains to the actuation piping for low-pressure systems:

- Use pipe that conforms to 4.7.
- Use malleable fittings.
- Properly support piping to prevent damage.
- Pneumatically supervise piping to ensure integrity.
- Protect piping against mechanical damage.

Inspection

Once a system has been installed, acceptance tested, and placed in service, arrange to have competent personnel inspect the system as part of the regular Fire Protection Equipment Inspection program as described in Section 12 of *OVERVIEW* and PRC.1.12.0.

System Impairment

Impairment of vital special extinguishing systems constitutes a severe condition requiring that affected production equipment be shut down until protection is resumed. Follow the impairment handling instructions found in Section 1 of *OVERVIEW* and PRC.1.1.0.

Maintenance

Properly maintain and test the carbon dioxide system in-house, or obtain a maintenance service contract from a reputable contractor. Although annual testing may be suitable for a low valued dip tank, more frequent testing is necessary as loss potential increases. All equipment associated with the system, including the valve actuators, can be tested without discharging the containers. See PRC.13.0.4.

During normal testing, a review of the enclosure for penetrations should be made. Penetrations should be sealed immediately. If numerous penetrations to the enclosure have been made since the previous review of the enclosure, a discharge test may be warranted to ensure the enclosure integrity can be maintained.

Unclosable Openings

Limit unclosable openings. Automatically close large openings before discharge occurs, **or** provide additional compensating gas in the system design. As with all installations, evaluate system performance, including the extended discharge by conducting a full discharge test.

Soak Time For Deep-Seated Fires

Although NFPA 12 requires maintaining concentration a suitable holding time for deep-seated fires, the standard does not specify a specific time. An extended discharge system may be used to maintain the concentration throughout the holding period.

Liquids And Gases

If residues could result in deep-seated combustion, increase the design concentration and soak time. Establish specific design criteria if no data is available upon which to establish protection requirements. Base the design criteria on fire tests arranged by the submitting contractor. The carbon dioxide equipment manufacturer may conduct these tests.

Volume Determination

The volume of the enclosure may be reduced for permanent **impermeable** structures. Concrete block enclosures and cinder block enclosures in particular are permeable unless the internal surface is sealed with a material such as paint.

Interconnected Volumes

Isolated interconnected volumes can be considered as separate areas when selecting suitable volume factors. However, design the system to discharge to all volumes simultaneously if fire propagation between the volumes is possible. This will ensure protection if the isolation means fails between the interconnected volumes.

Soak Time - Surface Fires

During the acceptance test, confirm that an extinguishing concentration can be held in the enclosure long enough to completely extinguish the fire. Extend the soak period to allow sufficient time for fire-fighting personnel to arrive. Although no guidance is presently given in NFPA 12, a minimum 3 min soak time is appropriate for most surface fire applications; however, some total flooding application surface fires with residues might not be extinguished by the end of the discharge period.

Concentration losses are affected by such variables as temperature, ventilation, and the size and location of unclosable openings. A change in any one of these variables will greatly affect the final concentration, especially with smaller volumes.

Deep-Seated Fires

NFPA 12 requires a minimum soak period of at least 20 min for some deep-seated fires. For record storage areas, the confined carbon dioxide should normally be permitted to soak or penetrate into the hazard for at least of 30 min. For fur vaults and anechoic chambers, however, allow at least 60 min. For rotating electrical units, determine extended discharge on the basis NFPA 12.

Design Concentration For Specific Hazards

A minimum nominal cylinder size of 50 lb still applies to hazards up to 500 ft^3 (30 kg for hazards up to 19 m^3). While this table is located in the deep seated fire section of the standard, some of the hazards in this table could actually be a surface fire. For example, the protection for the interior of ductwork with a light oil residue (no thick accumulations) should be designed for a 65%. A fire in this ductwork would be expected to burn like a surface fire, so the discharge time and soak times for surface fires should be used.

Extended Discharge

Although carbon dioxide may be applied at a reduced rate during extended discharge, the rate must be sufficient to maintain the design concentration for an adequate soak period. Once the leakage rate has been established, an extended discharge design using separate piping and nozzles is recommended.

Rotating Electrical Equipment

Do not protect bearings on rotating equipment on a local application basis unless the system is designed to deliver carbon dioxide throughout the deceleration period. Automatic water spray is the preferred protection.

Exhaust Ducts

Provide pressure-operated dampers, preferably near the roofline. Protect exhaust stacks with automatic, carbon dioxide discharge. Provide a discharge nozzle both upstream and downstream of the damper. Design for a flooding factor of 8 ft^3/lb (0.5 m^3/kg) of carbon dioxide. Shut down ventilation fans upon carbon dioxide system operation.

Exposing Hazards

Generally, hazards less than 25 ft (8 m) apart expose each other and are protected on the basis of a single hazard. Conversely, if such hazards are 25 ft (8 m) or more apart, they may be considered separate hazards. Consider other factors in the protection design. For example, two small tanks containing high-flashpoint liquids need not be considered a single hazard if the tanks are located 25 ft (8 m) apart. By contrast, two large tanks containing low-flashpoint liquids located in a poorly ventilated area might well be considered a single hazard even though the distance between them exceeds 25 ft (8 m).

Location Of Hazard

Carbon dioxide is an inappropriate choice for outdoor protection. Do not consider using it unless the hazard area is suitably shielded and air movement losses are contemplated in the design.

Cooling Of Hot Surfaces

Although NFPA 12 recommends increasing the discharge time to adequately cool heated surfaces, the standard does not provide any guidance. Surfaces, which heat quickly, will also cool quickly when applying carbon dioxide. A one-minute discharge time is reasonable for cooling normally heated surfaces of containers containing liquids with auto-ignition temperatures above their boiling point. Heated vessels with combustible or flammable contents may be more difficult to cool.

Another concern is with quenching oil tanks. When the quenching cycle is interrupted while a tank is quenching massive items, portions of an item may extend above the surface of the liquid and may not be cooled sufficiently during the normal discharge period. A properly designed system will avoid this problem.

Coated Surfaces

Since minimal controls exist for drippage on a drain surface, use the rate-by-volume method to protect coated surfaces. Another concern is heavy residue buildup. Residues that have deep-seated tendencies cannot be protected by local application.

Partial Enclosures

The following formula represents the interpretation of this section for determining the discharge rate for local application rate-by-area, when enclosure walls do not provide complete isolation:

$$(0.75)\,\frac{a - b}{a} + 0.25$$

where:

a = the assumed perimeter

b = the actual perimeter

The limiting factor is the actual wall must extend at least 2 ft (0.6 m) above the hazard.

Hose Lines

Provide hose lines where appropriate after thoroughly reviewing the loss potential of the hazard. Properly locating and using hand hose lines during an emergency can greatly reduce damage.

In low-pressure systems, feed hose reels by a separate master valve **or** by a selector valve that does not control the automatic protection for the specific hazard.

Restaurant Hazards Example

Placing a damper at the top of the hood duct is preferred. Shut down the ventilation fan upon discharge. Add a suitable amount of carbon dioxide to the system for agent loss during fan coast-down and damper closure.

Printing Hazards Example

Protect printing presses using highly flammable inks by installing total room flooding systems or by using local application directly on the rolls, fonts, reservoirs, etc. Provide complete sprinkler protection for the entire area. Also see PRC.17.18.1.

In a local application system protecting press rows or lines 6 ft (1.8 m) or more apart, a selector valve system may be used for each row or line provided as shown in Figure 1:

- The total gas supply equals four times the amount required for a single shot on the largest press row or line.
- Automatic resetting selector valves are used.

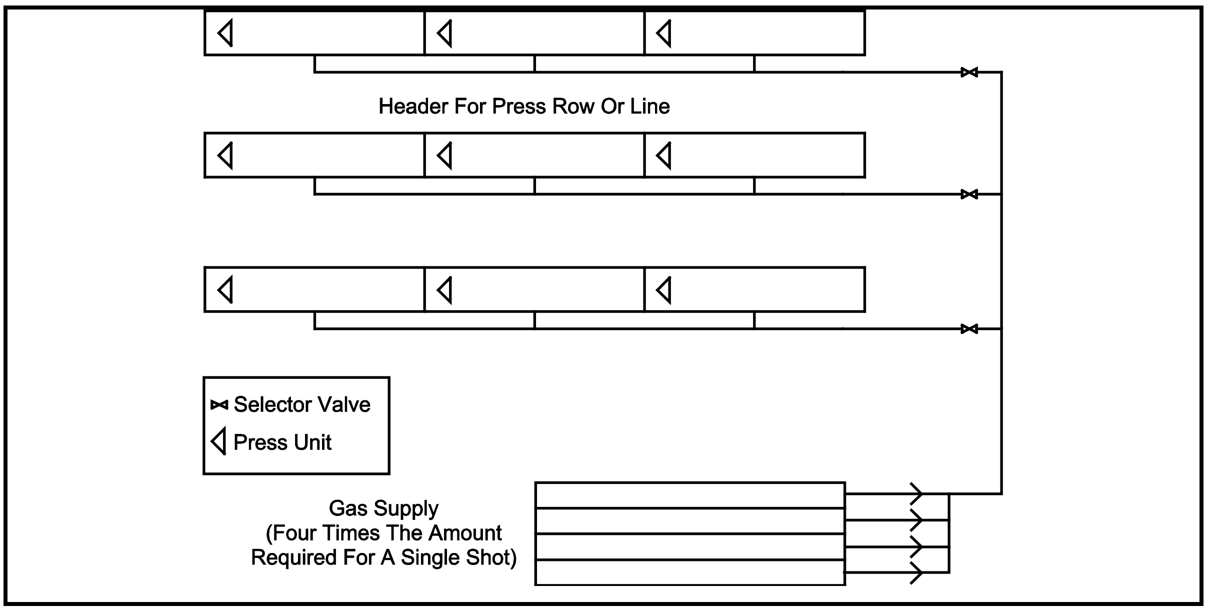


Figure 1. Single Selector Valve For Each System.

A selector valve system may also be used if separate systems are supplied for each press row. A reserve bank of carbon dioxide is arranged to discharge to any one of the systems through one manual (reserve) release as shown in Figure 2.

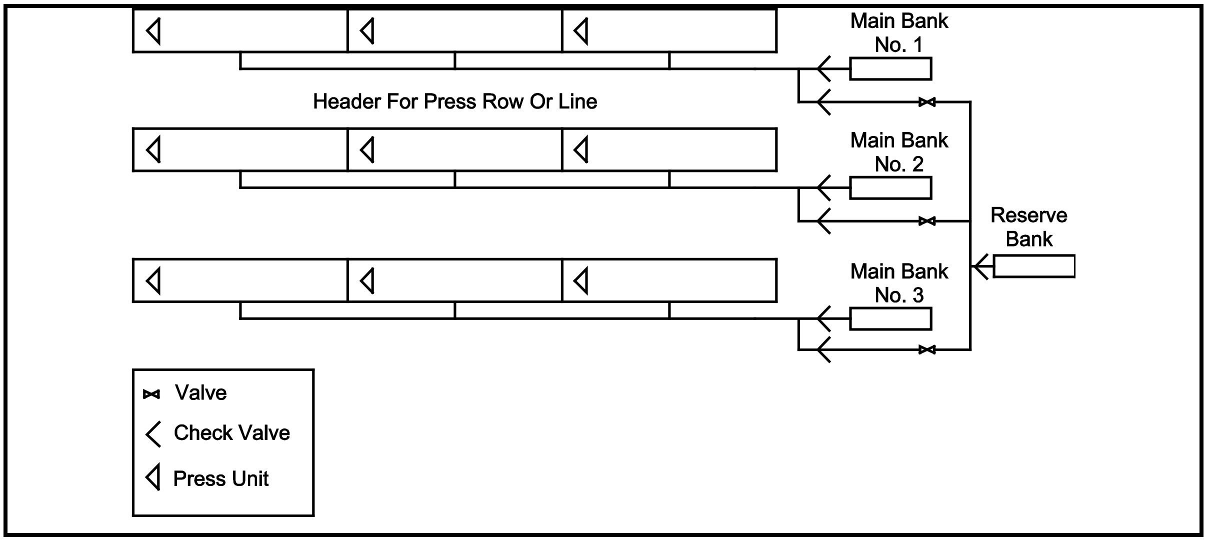
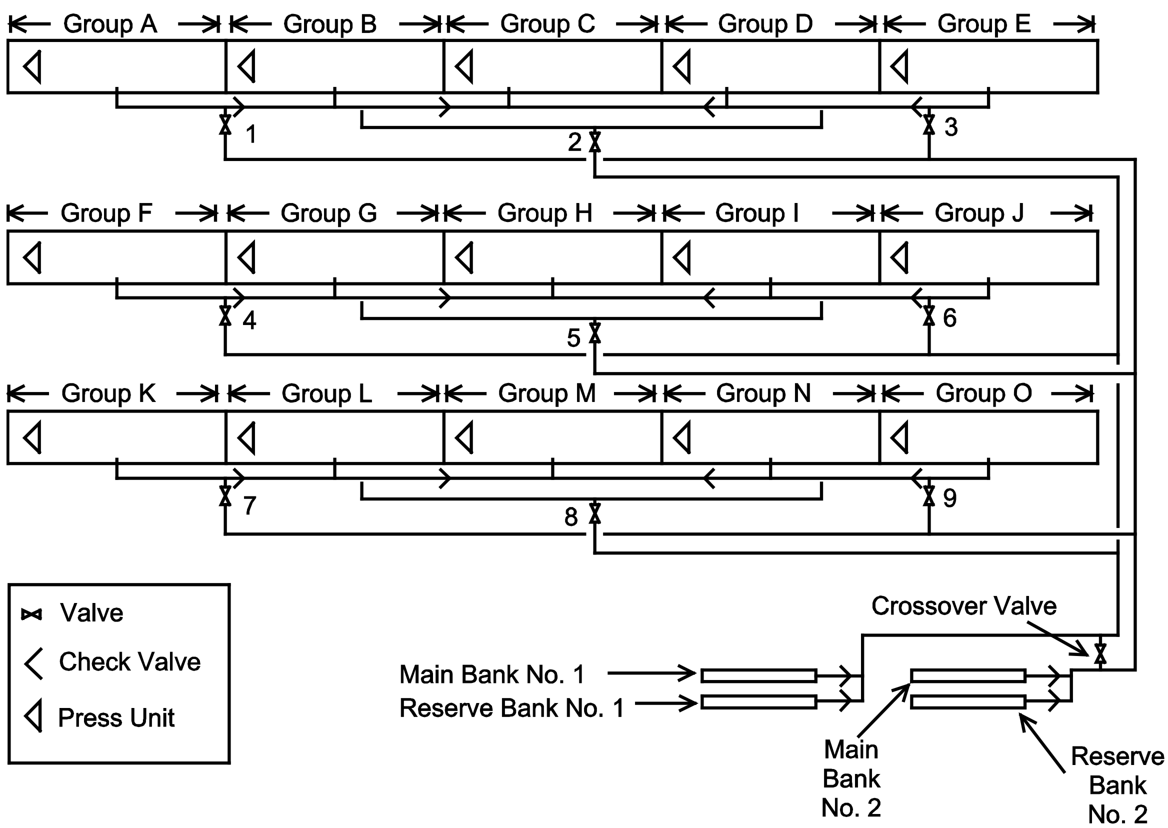


Figure 2. Single Reserve Supply With Cross-Over Valves.

On a multiple-group press line, initial discharge need not cover the entire press line if it is arranged as shown in Figure 3:

- The initial discharge covers one full group (including folder) on each side of the group in which the fire started.
- Alternate groups are fed from one of two main banks.
- Automatic resetting selector valves are used.

If the presses have aisles spaced less than 6 ft (1.8 m) apart, design the system for simultaneous discharge of press units across the aisle from the group in which the fire started.



If fire occurs in group:	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Mail bank tripped:	2	2	1	2	2	1	1	2	1	1	2	2	1	2	2
Selector valve opened:	1	1	2	3	3	4	4	5	6	6	7	7	8	9	9
CO_2 discharge to groups:	ABC		BCD	CDE		FGH		GHI	HIJ		KLM		LMN	MNO	

Figure 3. Multi-Valve Programmed Operation.

Partially Enclosed Tanks

Provide local application systems to protect quench tanks with bolted covers that extend over most of the tank surfaces. Exclude the conveyor and elevator openings. Arrange nozzles as if the covers were not in place.

Design the protection for quench tanks as a combination of total flooding and local application. Protect quench tanks with welded covers that extend over most of the tank surface by providing total flooding in the space below the covers. Calculate the amount of gas used in the tanks as if the tanks are empty. Use local applications to apply carbon dioxide to the enclosure openings, conveyors and the elevator openings. Protect pits, roll conveyors, exhaust duct systems, etc. with the same carbon dioxide system.

Do not discharge carbon dioxide inside the internal quench tank enclosure. However, protect oily residue in hoods and ducts on a total flooding basis and protect roll conveyors by local application.

Spray Booths

If desired, protect flammable liquids spray booths with carbon dioxide. However, provide automatic sprinklers to the booth, plenum, and exhaust ducts. Apply carbon dioxide on a rate-by-volume basis to all wetted surfaces. Aim nozzles at the wetted surfaces for better cooling. Provide interlocks to shut down the entire paint system, including the exhaust fans. Protect the plenum and exhaust ducts on a total flooding basis. Extinguishment may not be possible for heavy residues unless extended discharge is used.