CHEMETRON Fire Systems™

CARDOX

CO_2

Application Bulletin

CHEMETRON Fire Systems™

A World of Protection

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Carbon Dioxide Fire Suppression and Inerting —

Coal Silos & Bunkers

Supplement A —

System Design, Operation & Use

Carbon dioxide (CO_2) vapor is used for the protection of coal silos by preventing or controlling fires caused by the spontaneous ignition of coal. The CO_2 is applied to create an inert atmosphere in the void space above the coal and is injected into the coal to control a smoldering fire buried in the silo or bunker.

A proper system is engineered so as to meet reasonable performance criteria, but creating the system design parameters presents some challenges. For inerting the void space in the silo, it is unknown how full the silo will be (i.e. how big the void space will be). Similarly, to effect control over a smoldering coal fire by injecting CO_2 into the coal, (A) it is unknown which path the CO_2 flow will take from the injection points to the "hot spot" (i.e. how much coal is between the two), (B) it is unknown how much CO_2 will leak from the silo or bunker; and (C) it is unknown how much of the CO_2 will be adsorbed by the coal.

We can't really document answers to these questions, as there are no "standards" that apply. So we rely on experience.

When injected from a properly designed system into the void space and into the coal by a continuous discharge, experience shows that a CO_2 gas volume equal to one gross volume of the coal vessel (silo or bunker) will usually be enough for the CO_2 vapor to both inert the void space and penetrate the coal to reach the buried burning coal and start the fire suppression process.

Continual CO_2 application will reduce or eliminate oxygen at the point of the burning and cause the smoldering coal to cool and the fire to be extinguished over time.

So, assuming it takes one volume of CO_2 to star t the extinguishing process in the system design, how long should it take to discharge this one volume? Again we don't have any "Standard" to use. These fires develop slowly, so urgent application is usually not required. Chemetron's experience is that an 8 hour work shift is a good target figure to use in the design. Injecting the CO_2 too rapidly will result in an inefficient application, while injecting the CO_2 too slowly will unnecessarily slow the process.

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When starting the inerting procedure, Chemetron recommends that an inert (>65% CO_2) atmosphere be established above the coal as soon as possible. This calls for directing the CO_2 flow to the top of the silo first. The initial discharge of CO_2 vapor should be as gentle as practical to minimize formation of a coal dust cloud in the explosive range.

NOTE

THE CO_2 PIPING SHOULD HAVE A PROPER GROUND (EARTH) CONNECTION TO PREVENT A STATIC BUILDUP, WHICH WILL HELP MINIMIZE THE POTENTIAL OF A STATIC DISCHARGE BEING AN IGNITION SOURCE.

Monitoring CO_2 concentration in the void space can be done by portable or fixed instruments.

After the 65% CO_2 level is reached above the coal, the CO_2 flow to this area can be cut back, allowing CO_2 vapor injection into the coal to be accelerated. However, continued slow CO_2 flow into the void space is recommended to maintain the inert CO_2 "blanket" over the coal.

Burning coal will give off gases (primarily carbon monoxide with some methane), which can be used to detect a fire and to monitor the effectiveness of the CO_2 application. An increase in off-gassing indicates increased burning, while a decrease indicates the fire control process is under way.

The CO_2 vapor should be injected where spontaneous ignition is most likely to occur. This is usually at the transition point where the silo changes from cylindrical to conical, which is the point of slowest coal movement. With the injection point being near the bottom of the silo, the CO_2 will fill the vessel from the bottom up during the continuous discharge. (The CO_2 is 1.5 times heavier than air).

NOTE

IT IS IMPORTANT THAT THE OUTLET VALVE AT THE BOTTOM OF THE SILO BE SEALED AS TIGHTLY AS POSSIBLE.

Once the hot spot(s) is immersed in CO_2 vapor, “fire control” is established. The higher the CO_2 level (lower oxygen level) and the longer it is held, the more complete the control becomes, until the point of full extinguishment. With reduced oxidation of the coal, the new heat generated will be less than that lost by conduction, causing the burning coal to cool. The rate of cooling will depend on the size of the mass of the burning coal.

NOTE

AS MENTIONED ABOVE, IT IS COMMON PRACTICE TO MONITOR FOR CARBON MONOXIDE IN THE ATMOSPHERE IN A SILO TO DETECT WHEN THERE IS A FIRE IN THE COAL AND TO MONITOR HOW WELL THE CO_2 IS WORKING. THE CO_2 SYSTEM IS DESIGNED SO THAT AN OPERATOR CAN INCREASE CO_2 FLOW TO SPEED UP CONTROL OR DECREASE FLOW TO CONSERVE CO_2, AS INDICATED BY MONITORING THE SILO ATMOSPHERE

System Actuation

The CO_2 is stored as liquid in the system storage unit. When the inerting is started, the master valve at the storage unit is opened by operation of the "system start" electrical control or plant PLC. This operates a 3-way solenoid pilot control valve, which in turn, using CO_2 vapor pressure, opens the pressure operated master valve. The use of the inerting system is annunciated in the Control Room.

Opening the master valve allows CO_2 liquid to flow to the vaporizer, which changes it from liquid to vapor. CO_2 vapor must be used in the coal injection because liquid CO_2, when released to atmospheric pressure, creates “dry ice,” which will block injection points.

The vaporizer is a "direct to process" type that operates on demand, so it can be switched on and left on. As the "cold" CO_2 liquid enters the vaporizer, thermostatically operated heater elements (platens) are turned on to provide the heat of vaporization to change the liquid CO_2 to vapor.

NOTE

THE RATING OF THE VAPORIZER IS BASED ON CHANGING STATE (LIQUID TO VAPOR) ONLY. DOWN-RATING THE FLOW CAPACITY OF THE UNIT CAN BE USED TO PROVIDE SUPERHEAT TO WARM THE CO_2 , IF NECESSARY.

For instance, when the coal is wet, the introduction of cold vapor can freeze the water in the coal, resulting in ice blocking the CO_2 vapor injection.

To ensure that liquid CO_2 is not discharged from the vaporizer when flow exceeds the vaporizing capacity, a thermostatic control will shut off flow if the CO_2 outlet temperature drops to 5°F (-15°C). When the flow is stopped and the vaporizer has heated the CO_2 above 5°F, this valve will open again.

Downstream of the vaporizer, the CO_2 vapor piping leading to the equipment to be inerted is pressurized when the master valve opens. At each silo there is a sectionalizing (selector) valve that can be used by the operator to direct the CO_2 to the specific silo to be inerted.

Located at the silo is a flow control scheme (which consists of a throttling valve with a downstream pressure gauge) in the pipe feeding nozzles at the CO_2 injection points.

When the system is activated by opening the master valve at the CO_2 supply, the branch piping up to the throttling valve is pressurized. When the throttling valve is opened, the downstream piping is also pressurized up to the flow constricting orifice union nozzle(s), which constrict the flow at points of CO_2 injection. As a result, the CO_2 flow rate can be controlled through the nozzle(s) to the coal injection points and out into the void space above the coal. The pressure downstream of the throttling valve is shown on the pressure gauge. The orifice is fixed at a calculated size so that increasing the pressure increases the CO_2 flow, while throttling back reduces the flow. Thus, flow is controlled by increasing pressure (opening the throttling valve) or decreasing pressure (closing the throttling valve). The pressure, as read on the gauge, is used to calibrate flow rate.

NOTE

THE PIPING FROM THE VAPORIZER TO THE THROTTLING VALVE IS SIZED LARGE ENOUGH SO THAT THERE WILL BE NO APPRECIABLE PRESSURE CHANGE AT THE THROTTLING VALVE INLET OVER THE RANGE OF FLOW FOR WHICH THE SYSTEM IS DESIGNED.

Monitoring the CO_2 Flow

Chemetron designs to pressure downstream of the throttling valve in the range (0-200) psi (0-1379 kpa). We generally consider a midpoint design of 90 psi (620 kpa) with a fixed orifice nozzle designed to specific job requirements, which gives a midpoint flow rate in the range needed. A job specific chart is provided that shows flow rates above and below that midpoint for varying pressures. Total flow rate is the sum of the flow through all nozzles.

When the CO_2 is released into the piping by opening the sectionalizing valve with the throttling valve closed, the piping is closed-ended and will be quickly pressurized to a constant pressure. When the throttling valve is opened the flow rate will be determined by the pressure applied to the downstream nozzle orifice and the size of that orifice. Increasing the pressure by opening the valve will increase the flow, while flow is reduced by throttling back.

The vapor flows needed are usually low enough so that the size and configuration of the feed pipe from the CO_2 storage can be eliminated as a factor in determining flow rate. Good system design ensures this.

The feed pipe must be big enough to allow enough CO_2 to flow so that the pressure at the throttling valve is adequate for the design. Since the vapor flow in the feed pipe is low, there is not much pressure drop. (Piping, except at the valves and nozzles, should be at least 1".)

It is important to understand that the rate of vapor application can be virtually anything you want to make it and that the rate is controlled by the vaporizer capacity, the throttling valve, gauge and orifice nozzle - not by the feed pipe. Determining the size of the feed pipe necessitates a number of assumptions - which should be conservative enough to ensure that this pipe cannot be a factor in restricting flow.

It is important to be able to estimate the flow to monitor CO_2 storage quantities. Stubborn fires have occurred due to air entry into the bottom of the silo with associated excessive CO_2 loss (leakage at the outlet valve or through cracks in concrete silos are examples of conditions causing same). Prolonged CO_2 applications will be needed in these cases.

Since the CO_2 storage unit can be refilled while the system is in use, it is appropriate to estimate (based on flow rate being used at that time) how many hours of supply you have left during an incident so provision can be made for storage unit refill, if needed.

System Shutdown

It is recommended that burning coal in a silo not be moved (NFPA No. 850).

NOTE

NFPA STANDARD NO. 8503, PULVERIZED FUEL SYSTEMS, PROHIBITS INTRODUCING BURNING COAL INTO A COAL PULVERIZER.

Therefore, when there is evidence that the fire is extinguished, the coal can be cleared from the silo by normal means. However, it is recommended that CO_2 vapor (maximum flow) be directed into the top of the silo while the coal is being cleared from the silo.

When the silo is clearedand/or filled with fresh coal, the CO_2 can be shut off.

Fire Prevention

With reactive coal such as Powder River Basin coal, when an unscheduled shutdown of the fuel system occurs, stopping the movement of coal through the silo, many plants have used CO_2 to prevent a fire from starting by inerting the silos at this time. The operation of the system in this case is essentially the same, but with emphasis on getting CO_2 into the coal itself, where spontaneous ignition would be expected to start.

Inerting System Design Considerations

When CO_2 vapor is being used to inert portions of a coal grinding, processing and storage system, the design parameters are not well defined.

The vapor can be introduced into various pieces of equipment individually or in a variety of combinations. At the same time the required rate of application is not fixed for any individual piece of equipment. No Standard exists that spells out rates of application as there are for CO_2 fire suppression systems in NFPA Standard #12. Therefore, the system designer attempts to develop a system that can function properly at minimum flow rates when little inerting is required, while at the same time be able to deal with the guesstimated maximum flow situation.

Since the system involves a single fixed piping system with a single flow restricting orifice scheme, and the pressures on these orifices will vary with flow rate, we use an approach that allows the plant operator to manage the flow.

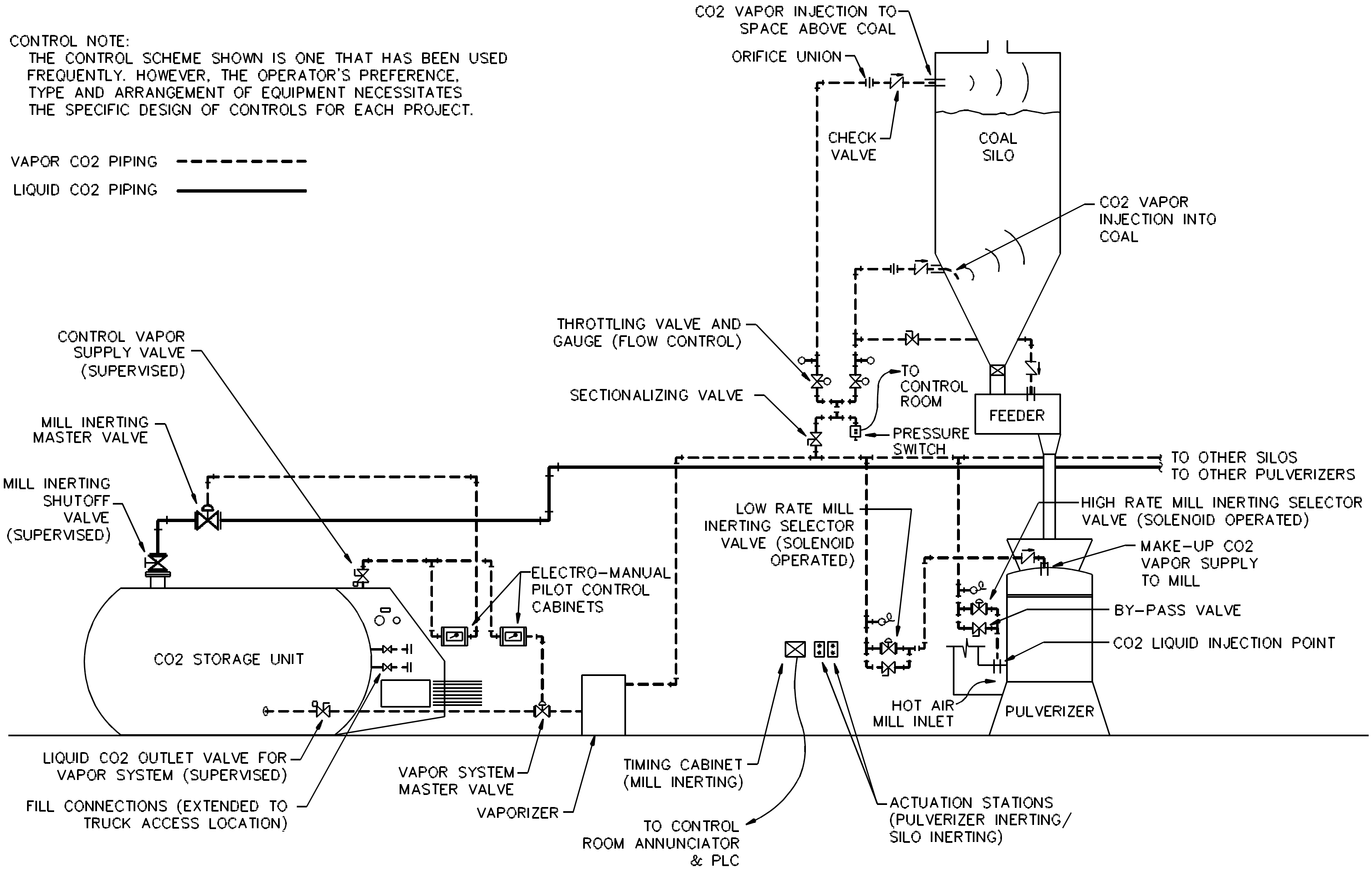
Experience is used to estimate a reasonable amount of time in which to apply the inerting CO_2 vapor needed. This establishes a base rate. Orifices are sized for flow at this rate.

The exactness of this CO_2 flow rate is not critical. If an actual application flow rate higher or lower than that which is used in the design occurs, no Standard is violated. The system performance is not compromised – there is no pass/fail criteria.

It should be understood that compromises in the system design process are necessary. The vaporization equipment has a rated output capacity at certain stated conditions. Using that maximum capacity as a basis for all phases of the system design of piping and nozzles can present undesirable conditions for minimum flow. Therefore, the designer seeks a middle ground and, using throttling valves, he gives the operator the ability to control the flow to a desirable level for the inerting needed at the time.

Monitoring of flow quantities by the installation of a flow meter in the outlet line is not necessary; even if the flow varies slightly from that expected, the variation will not effect the system performance as long as the required CO_2 level is reached in a reasonable time period.

CONTROL NOTE:
THE CONTROL SCHEME SHOWN IS ONE THAT HAS BEEN USED FREQUENTLY. HOWEVER, THE OPERATOR'S PREFERENCE, TYPE AND ARRANGEMENT OF EQUIPMENT NECESSITATES THE SPECIFIC DESIGN OF CONTROLS FOR EACH PROJECT.



Schematic Arrangement - CO_2 Coal Silo and Pulverizer Inerting System

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