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# Closed Loop Fumigation of a Small Rural Concrete Elevator in a Growing Urban Setting

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**Abstract**: As urban areas spread to adjacent rural countryside, small rural elevator managers are faced with increased safety challenges. While fumigation practices are closely monitored and documented, every effort must be made to contain gases within the structure and make the most efficient use with the least amount of chemical possible. This research project installed and tested a closed loop fumigation (CLF) system in a small concrete elevator in a growing downtown center. One half of the facility was included in the closed loop system while the remaining half was treated as conventional fumigated silo storage. Phosphine treatment rates were set by the elevator manager using his normal dosage rate for non – CLF treated bins. Phosphine levels were monitored at three locations in each silo: bottom, middle and headspace. Gas levels in the closed-loop bins were compared to a silo under standard fumigation. The closed-loop system maintained phosphine concentration levels as much as ten times higher than the standard gravity fumigated silo. An economic comparison between closed loop fumigation and traditional gravity methods is presented in this research. Economics strongly favor closed loop fumigation. This research concludes that closed loop fumigation in a concrete elevator provides better containment of gases which provides a safer environment through better control of fumigant, and a more economical method of achieving improved concentration over the required time to control all life stages of stored product insects. CLF will provide opportunity to greatly reduce dosage and manpower, greatly increase efficacy, and fumigate on short notice, compared to conventional silo fumigation. Better safety conditions for elevator personnel conducting the fumigation using a closed loop system are documented.

**Key words**: closed loop fumigation, CLF, concrete silos, phosphine, fumigation, efficacy

## Introduction

Population growth has caused the urbanization of land area surrounding grain storage facilities located in areas that were previously considered rural. Elevator managers are more cognizant than ever of the need to pay strict attention to safety measures not only for their employees but also for the environment and the inhabitants surrounding the storage facilities. Conventional fumigation application techniques known as "probe", "probe and tarp", automatic dispenser, or gravity fumigation offer increased risk of exposure to fumigant during insertion of the fumigant into the grain and because of the time it takes to place a tarp over the grain[1]. In concrete silos, automatic pellet dispensers place fumigant pellets or tablets into the grain stream via bucket elevators or conveyor belts, requiring the grain to be turned or moved. Some of the pellets spill out of elevator cups and fall into the leg boot. This releases gas into the basement. A stalled leg, belt or drag conveyor can also increase fumigant concentration levels to the point that workers should be wearing self-contained breathing apparatus (SCBA) to work within the facility. In the above application methods, fumigant is left to travel throughout the storage facility without adequate control. The escape of the fumigant is dependent on structure sealing, weather, temperature, and humidity conditions.

Methyl bromide fumigation has been accomplished using closed loop fumigation (CLF) practices for many years. James Cook patented a recirculation process called The J-System® in 1980[2]. CLF is an example of the J-System. A typical CLF system consists of a low-pressure, low-volume centrifugal blower that moves a fumigant-air mixture through pipes from the headspace of grain bins and silos, and re-circulates the gas-air mixture into the base of the storage structure. Pressurized base ducts force the gas mixture to move upward through

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the grain bulk in a loop-like pattern (thus the name "closed loop") providing better gas distribution through the grain. Thus, the chance of fumigation failure is reduced due to better distribution of the gas in partially sealed structures, compared to conventional fumigation in unsealed storage. By providing suction from the storage headspace, fumigant leakage is minimized by the slight vacuum on the storage headspace. Storage base openings are easier to seal than roofs and silo roof decks, vents, man-entry doors and downspouts from legs or conveyors.

Without CLF in sealed or partially sealed storages, the gas fumigant in unsealed storage will escape into other areas of the structure and out to the environment through openings and leaks in the bin. In the case of phosphine fumigants, the weight of the gas is close to that of air. The fumigant will move in and out of the bin anywhere air is allowed to move or leak from the structure. The use of a CLF system necessitates better sealing of grain bins and provides better control of the fumigant's travel through the grain bulk. Fumigant pellets and/or tablets are normally placed on the top surface of the grain or, in some cases, can be inserted from outside the storage facility, thus reducing the exposure time for employees. Turning of grain in a conventional fumigant application increases the opportunity for grain dust explosion and also causes an economic loss due to the product shrinkage that occurs during the handling of the grain.

CLF does not require extra turning operations, thus reducing explosion risk, grain dust loss shrinkage, and labor costs. Grouping several concrete silos within a facility as a "closed loop unit" can reduce the amount of labor and the amount of exposure workers encounter to the gases and grain dust during fumigation. While the fumigant is eventually purged to the atmosphere outside the structure after fumigation, this purging can be scheduled when conditions are favorable for the least hazard potential.

Because CLF in sealed storages requires a much lower dosage, there is much less gas released to atmosphere during ventilation of the storage. If grain does not need to be moved after fumigation, the structures can be left sealed, allowing the gas to slowly dissipate for days or weeks, providing extended insect protection from the residual gas and sealed openings. This is legalas long as the "Danger" warning placards are left in place to warn people that the storage is still under fumigation.

When it's time to ventilate or purge the gas from the structure, by operating the CLF fan, purging can be accomplished quicker than by using natural air flow and gravity venting. Because gas fumigant is contained and re-circulated, better control of the fumigant is achieved and less fumigant is used.

Objective of Research

The objective of this research was to compare aluminum phosphide fumigation using a CLF system to traditional fumigation within the same concrete elevator under the same conditions.

## Materials and Method

A CLF system was installed in a portion of a small, rural elevator that is now located in a growing urban downtown area in the eastern part of the state of Oklahoma, USA. One half of the facility was included in the closed loop system (Figure 1). This portion included six bins with approximately 8660 MT (120 000 bushel) capacity. The facility stores primarily oats and barley. The CLF system consisted of a 249 W (1/3 HP) blower which discharged the air/gas mixture at approximately 0.15 $m^3/s$ (320 cfm) into the bottom of the bins and pulled air and gas out of the headspace above the grain. The bin structure was partially sealed using closed-cell expanding foam insulation to close the air vents at the top of the silos and the interior vents between CLF bins and adjacent bins not included in the CLF system, thus forming a composite storage unit of six silos that can be fumigated as one unit.

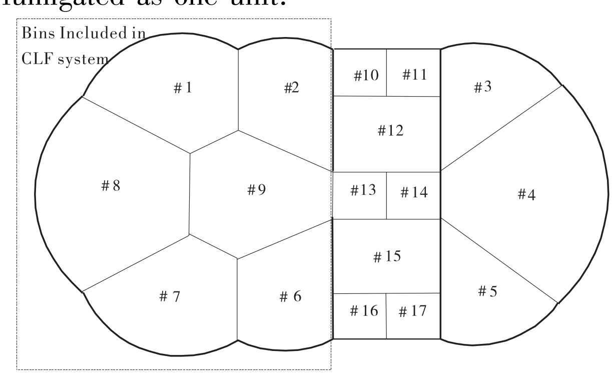


**Fig. 1 Bin layout diagram for elevator fumigation. Left side was included in a closed loop fumigation system. Right side was treated with conventional fumigation methods**

Duct tape and plastic sheeting (6 mm thickness) were used to seal covers at the top and bottom of each bin included in the CLF system. Polyvinylchloride (PVC) and flexible plastic piping with ball valves from each bin bottom was connected into a manifold so that individual bins could be monitored or excluded from fumigation. Flexible hose and plastic pipe running vertically through the man-lift (elevator) shaft carried discharge air and fumigant to the manifold from the blower. The blower was mounted outside on top of one of the bins adjacent to the head house. The inlet of the blower was connected to a suction port opening in the steel man-entry door cover on one of the silos. After piping installation and sealing of the bins, the system was pressure checked for leaks and blockages.

The elevator manager recommended the dosage rate of phosphine fumigant according to the rate that he would normally use for the silos under conventional fumigation. The chosen rate was 17 pellets/$m^3$ (475 pellets/1000 $ft^3$). This suggested rate was used to treat the CLF part of the elevator. The same rate was applied at the same time by dropping the pellets into the non – CLF side while grain was being loaded into the bins. Both sides of the elevator were treated at the same time. The CLF bins were treated by placing pellets on the top surface of the grain in each of the bins. Care was taken not to stack or pile the pellets, thus decreasing possibility of explosion or fire. After dosage, all bin covers were secured and sealed with plastic sheeting and duct tape. The blower was switched on. Electronic gas detection meters were used to record gas concentration levels in each of the bins, both conventional and CLF, every 4 hours for the first 32 hours and then every 10 hours for the next 88 hours. Gas samples were taken from the headspace, the bottom of thebins and the midpoint of the bin through pre-installed gas sampling tubes. Readings in adjacent work areas and bins were recorded to identify escaping gas and to document safe working conditions. When gas concentration levels were sufficiently uniform throughout the grain bulk, the blower was turned off. When gas levels dropped significantly, the blower was turned on again for a few minutes to re-distribute gas from the CLF silos to the headspace of all six silos. At the end of the fumigation, the blower discharge piping was disconnected and the blower was used to evacuate the fumigant from the CLF side of the elevator by drawing gas from the base and exhausting it into the air above the silo roof deck, about 35 meters above ground level, where rapid dilution of the gas will take place, especially with the wind that is normally present on top of concrete elevators in the U. S. This gas purge evacuation was scheduled for the night time when area residents and elevator employees were least likely to be in the vicinity of the storage facility.

## Results and Discussion

The CLF bins were compared to similar bins in the traditional side of the elevator. The gas concentration sampling data for two of those bins are presented in Figure 2. These results are typical of the data taken for the remaining bins. Research entomologists report that in order to kill all life stages of insects, fumigant concentrations of 200 ppm must be held for at least 100 hours[3]. The conventional side of the elevator never reached the needed concentration of 200 ppm for insect kill. The CLF side easily reached and exceeded the necessary concentration by almost ten fold. Areas adjacent the conventional bins encountered external gas concentration levels exceeding 20 ppm. Fumigation personnel were required to wear protective gear to monitor these areas for extended periods beyond the allotted fumigation time period until conditions allowed the gas to dissipate. The elevator manager reported low gas amounts leaked

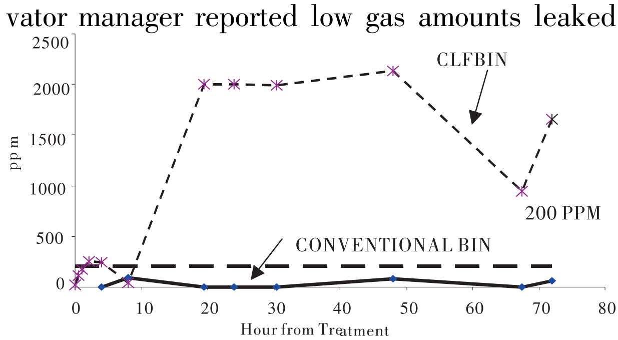


**Fig. 2 Comparison of gas concentrations in closed loop fumigations versus conventional fumigation. Data points represent averages of three sampling points in each of two of the six silos.**

from the sealed and piped CLF bins. The use of CLF can reduce cost by reducing the amount of fumigant required, the cost of turning the grain, grain dust weight losses, labor expense, health costs, and insurance costs. Table 1 shows general differences in the expense and benefits of CLF vs. conventional fumigation. The greatest economics savings in CLF is the lack of turning costs and the resulting shrinkage. The amount of savings depends greatly on the market price of the grain. Figures 3 and 4 show comparisons of the different cost factors for conventional fumigation and CLF. Figure 3 considers the price of wheat to be 55USD/MT ( $ 4/bu) while Figure 4 assumes 110 USD/MT ( $ 8/bu). While CLF has a higher installation cost, the higher turning cost resulting in shrinkage, more fumigant required to try to achieve adequate efficacy, and the higher labor costs involved with conventional fumigation methods give CLF a major economic advantage. In the case of the elevator used for this research, the installation costs total approximately 0.18USD/MT ( $ 0.013/bushel), primarily for plumbing and sealing, materials, and special equipment. This installation cost is a one-time expense while the turning and shrinkage costs in conventional fumigation occur each time the facility is fumigated.

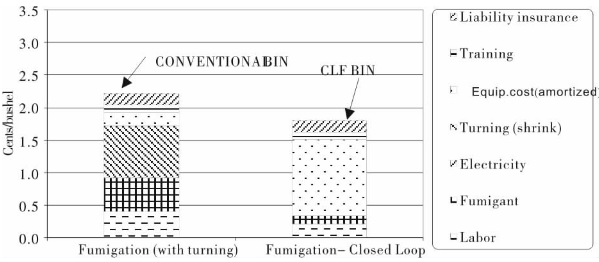


**Fig. 3 Comparison of conventional and closed loop fumigation cost at 55 USD/MT ( $4/bu wheat price).**

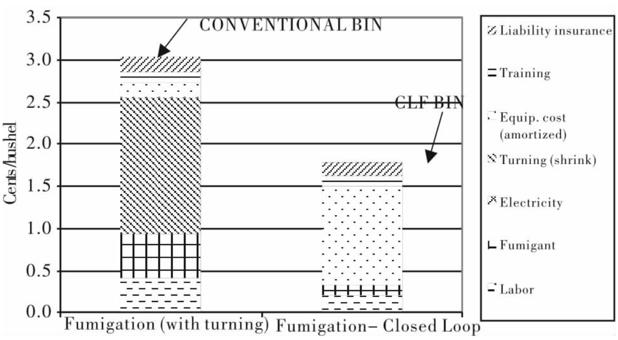


**Fig. 4 Comparison of conventional and closed loop fumigation cost at 110 USD/MT ( $ 8/bu wheat price) 1 bushel is equivalent to 0.07216 metric ton.**

The results of this study indicate that not only was the fumigation more successful due to the much higher concentrations of fumigant sustained over the required period of time but it is much less risky for workers and the residents and businesses around this once – rural elevator. The CLF system will allow this facility to apply fumigant at minimum labeled dosage rates instead of the much higher rates this manager has traditionally used. Operating costs will be reduced due to approximately 75% savings in fumigant cost and larger savings in shrinkage costs as the price of grain continues to increase. Further research in this facility will validate this data and will also extend the CLF system to the entire elevator.

**Table 1. Comparison of Closed Loop Fumigation general expense categories to Conventional Fumigation Methods**

| Closed Loop Fumigation | Conventional Fumigation |
|---|---|
| · Installation costs | · Turning costs and product shrinkage |
| · Less fumigant (20 – 35% Conv.). | · More fumigant – residual dust in grain |
| · High Efficacy | · Low efficacy – phosphine resistance |
| · Minimal labor (1 – 2 workers) | · More labor (4 – 10 workers) |
| · Less worker exposure, injury | · More bin entry required of workers, |
| · Lower insurance/health costs | · High health risk, higher insurance rates |
| · Precise timing (1 – 2 hours) | |

1 bushel is equivalent to 0.072155 metric ton.

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