THE USE OF CONTROLLED AIR TO INCREASE THE EFFECTIVENESS OF FUMIGATION OF STATIONARY GRAIN STORAGES

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ABSTRACT

Fumigant recirculation was first used in the early 1920's. Nearly all fumigants have been studied for their effectiveness when applied in this manner. These studies have shown that the less sorptive fumigants are the best to use with recirculation. Many techniques are used to move the air fumigant mixture through stationary grain but the most commonly used and effective one is the recirculation push method. Fan operation time and the number of air changes required varies with each chemical employed and is dependent on the release time of the fumigant. The low air flow fumigation method was developed and patented for use with aluminium or magnesium phosphide. This system results in even penetration and distribution of hydrogen phosphide (PH_3) in grain masses of any depth or configuration. There is no danger of ignition from pressure or build-up of high concentrations of PH_3 when the system is used properly.

INTRODUCTION

Recirculation, or the use of forced air to control and move fumigants through stationary bulk grain or a farinaceous mass, has been used for over fifty years. Moffett (1927) patented a recirculation method for use with hydrocyanic acid gas. During the 1930's DEGESCH, in Frankfurt, Germany, used recirculation for methyl bromide. Phillips (1955,1957) further developed the system so that it became commercially accepted, installed, and used in many areas of the Southern U.S. Shedd (1953) and others developed information on system design and on accurately measuring the air flows within the grain mass, so that the fumigant movement, behaviour, and distribution prior to the actual fumigation could be predicted.

The controlled air or recirculation technique has been used with nearly all fumigants, including hydrocyanic acid gas, chloropicrin, ethylene oxide and carbon dioxide, and with liquid fumigants containing ethylene dibromide, ethylene dichloride, carbon disulfide, carbon tetrachloride, methyl bromide, and Phostoxin^R (aluminum phosphide).

Flammable or ignitable chemicals must be avoided when this recirculation technique is employed. Highly sorptive fumigants, such as hydrocyanic acid, chloropicrin, ethylene dibromide, and ethylene dichloride are not suitable for this technique. Those chemicals with low sorptive characteristics, such as methyl bromide, the liquid fumigants containing carbon bisulfide and carbon tetrachloride, and aluminum or magnesium phosphide can be recirculated with a high degree of success. Equipment design and the method of application varies with each of these chemicals.

CONVENTIONAL TECHNIQUES FOR THE USE OF CONTROLLED AIR TO MOVE FUMIGANTS

The use of controlled air for fumigants is the vehicle of conveyance for the gas and can be moved or stopped at will. Techniques such as recirculation, forced distribution or single pass, whether pushed or pulled, are simply different means of moving a controlled amount of air through a mass of grain of any depth or configuration. The fumigant is introduced by various means into the moving air, resulting in the distribution of the air/gas mixture throughout the area to be treated. The air in any of these systems can be pulled from the top to the bottom of the bin or pushed from the bottom to the top. When pulling air down through the grain, the air will tend to bend away from the walls towards the aeration ducts and negative pressures are created around the bottom perimeter of the storage which will further dilute the gas concentration in that area. Pushing the air into the bottom and up tends to move the air radically away from the ducts to the opposite walls with better distribution in the bottom perimeter and between the ducts than when the air is pulled. The overhead becomes the weak point where the fumigant concentration can be easily controlled.

Single pass fumigations can be accomplished without the use of a return pipe, but the timing of the chemical release into the air stream tends to become complicated and erratic results may be expected. Pulling the air down through the bin has some advantages since the release of the chemical can be accomplished in a controlled manner.

Recirculation using the push method is the best choice in most cases. Changing the air/gas mixture within the load from one and a half to three times provides even distribution which is characteristic of recirculation systems. Irregular warehouse loading may cause the need for six air changes in some areas to attain a single change in others. Additional blower time beyond six air changes can result in high rates of sorption of the chemical and excessive gas leakage.

The air/gas distribution is totally determined by the aeration ducts installed in the bottom or sides of the storage bins. The return pipe from the top of the bin to the blower has little to do with distribution. Its dual purpose is to return the overhead gas concentration to the system which otherwise would be wasted to the outside atmosphere and to satisfy the blower requirements. Calculations and measuring the anticipated air change can be accomplished by several methods. These air changes are timed to the particular fumigant being used. As an example, using a 0.64cm o.d. polyethylene tube, a 90.7kg cylinder of methyl bromide will empty in about 30min. Thus, the o.025m^3/min./tonne standard is used which results in a 20min. air change.

THE LOW AIR FLOW FUMIGATION METHOD

Aluminium phosphide tablets have a peak-off or maximum release of hydrogen phosphide in 19 to 30h., depending on temperature and humidity of the grain bulk. Therefore, the very slow air flow of an air change in 8 to 24h. is effective and the need for a high horsepower fan, large diameter piping and duct system are drastically reduced. When compared with the system described above for use with methyl bromide the Degesch patented Low Air Flow Fumigation Method (COOK, 1980), originally developed for use with Phostoxin accomplishes circulation needs for the aluminium/magnesium phosphides. Two types of application methods which are referred to as the "J-System" and the "J-Probe" are used. The J-System indicates hydrogen phosphide usage with an air change in 8 to 12h. The return pipe and blower can be installed into an existing aeration system or mounted on the side wall and the bottom aeration ducts can be sized to the required lower air flow. The basic principles of aeration are adhered to by keeping velocities in the pipe to 610m/min. or less.

The J-Probe employs an air displacement within 24h. which has been tested on tall silos with side wall recirculation and in ship holds loaded with bulk grain. This method has been used successfully in 37m high silos and ships filled with grain to a 15m depth. The J-Probe violates the usual principle of proper aeration by using high air velocities in small pipes. This system is being improved so that this method of distribution becomes more efficient. Table 1 presents a comparison of equipment needed for conventional aeration and recirculation with equipment required for use with the J-System.

TABLE 1

COMPARATIVE EQUIPMENT FOR A LARGE STORAGE BIN *

	PIPE ** DIAMETER (cm)	BLOWER H.P. (K.W.)	STATIC PRESSURE (PASCAL)	AIR CHANGE TIME
AERATION AND CONDITIONING	152	32 (24)	872	2.5min
RECIRCULATION METHYL BROMIDE	71	4.8 (3.6)	374	20min
J-SYSTEM PHOSTOXIN	15	0.33 (0.25)	62	8 to 12 hours

** Air velocity in the pipe restricted to 610m/min.
* Typical 3,000 to 5,000T./bin.

When deep grain depths are fumigated with aluminium phosphide by probing or broadcasting with or without plastic covering over the surface, 2000 to 4000 ppm of hydrogen phosphide (PH_3) can occur at the application or generation points. With PH_3 penetrating these grain depths at approximately 3m./day, in 3 to 5 days only 50ppm or less will be recorded at the furthest point of penetration. With the Low Air Flow Method very even distribution will occur throughout the grain mass at any depth. PH_3 Concentrations of 400 to a maximum of 1000ppm will be recorded at the point of generation and not less than 300 to 800ppm will be detected throughout the bin within 8 to 24h. after application. Table 2 presents results of the effectiveness of the J-System when compared to the conventional method of applying PH_3 in a grain bulk.

TABLE 2

COMPARATIVE RESULTS USING PHOSTOXIN TABLETS (6.6g PH_3/tonne) FUMIGATION IN GRAIN DEPTHS OF 9 to 15m.

METHOD OF APPLICATION	TIME OF EFFECTIVE PENETRATION	TOTAL EXPOSURE	RECORDED PH_3 CONCENTRATION (ppm)		
			OVERHEAD	MIDWAY	BOTTOM
1.5m Probe or Broadcast	3 to 5 days	8 to 12 days	2500	300	30
J-System	8 to 12 hours	3 to 5 days	340	330	310

If Phostoxin is properly applied, ignition from the high concentration of 1.79% (17,900 ppm) PH_3 cannot be attained. Since the J-System rarely creates more than 5 to 10cm total static pressure, measured as water, and the J-Probe

23 to 28cm, explosions from high negative pressures of 457cm cannot occur. In field studies where no standing water or condensation were present, we have found it difficult to develop PH_3 concentrations of more than 4000 to 6000 ppm.

PROCEDURES FOR USING THE LOW AIR FLOW METHOD

With a properly designed system there are no problems with application and gas distribution. The Low Air Flow Method is no panacea and it is most important to realize its capabilities and limitations. After the storage facility is sealed for fumigation and the blowers, recirculation pipe, and other equipment, are checked for proper performance, the following procedures are followed:

1. Phostoxin, preferably 3g tablets, are broadcast over the grain surface at the proper labelled dosage for the amount of grain to be treated. We do not probe the tablets into the grain nor do we cover the surface with film except for special applications.
2. Within several hours after application as determined by the temperature and humidity of the grain the blowers are activated. The air/gas mixture will be drawn from the overhead, through the return pipe down to the fan and up into the grain mass via the aeration system.
3. The gas concentration moving up through the grain mass will be slightly less than that recorded in the overhead. Since the upward air flow exceeds the ability of the gas to penetrate downwards, the last portion of the grain mass treated will be in the upper areas of the bin.
4. Distribution will be attained in 8 to 24h. After 24 to 36h. most of the aluminium phosphide tablets reduced to ash, the fans are turned off and usually no further distribution will be needed for the remaining 3 to 5 day exposure.
5. High PH_3 readings may be recorded throughout the bin within 8h. and the fans could be turned off. These readings can be misleading as the concentration will drop very rapidly within 12 to 18h. and the proper PH_3 concentrations will not be attained and maintained in the bottom two-thirds of the storage facility.
6. In very tight welded steel or concrete storages PH_3 concentrations of 30 to 50ppm may still be recorded well beyond the exposure period of 5 days. If there are no storage problems, personnel hazards, or a need to move the grain, we recommend not aerating the grain or moving it for as long as practical.
7. After the desired exposure period the treated grain can be aerated with the use of the existing system or by the same method used for other fumigants. Do not re-enter the area until it is determined by gas analyses that it is safe.

8. Distribution of the gas is not adversely affected by lower temperatures, but there will be a slower PH_3 release from the formulation.
9. The piping from the fan exhaust through and to the aeration system must be tight since the blowers must be run 24 to 30h. while the PH_3 is being released. Excessive leakage will result in loss of gas causing a possible fumigation failure and hazard to personnel.
10. Tight, welded steel or concrete storage facilities lend themselves best to these methods of fumigation with resultant reduced dosages and costs. Even so, we have installed hundreds of these systems in the less tightly sealed corrugated sheet metal buildings. However, if the storage cannot be sealed properly or where excess leakage is anticipated in the exterior aerating system, the Low Air Flow Method should not be considered.
11. In general, dosages are set to customer standards as requirements vary from country to country. The needs and requirements in the United States range from a knock down control for a quick load out to long-time storage requirements which result in almost nil infestation.
12. The normal systems which have been developed for Phostoxin application cannot be used with methyl bromide since this fumigant requires higher air flows than are produced by the J-System.

CONCLUSIONS

The Low Air Flow Method is a technique for attaining and maintaining an even distribution of an insecticidal concentration of PH_3 in a grain mass in a minimum of time. It has been proven effective in all types of storages such as country elevators, terminal elevators and in ships holds and in both vertical and horizontal structures and shows promise for the effective application of PH_3 in storages for insect control.

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