A PROCESS FOR TREATING BULK COMMODITIES WITH PHOSPHINE

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Abstract

A new process was developed to treat bulk commodities - especially grain - infested by pests while in storage in closed spaces such as bulk containers, silo bins, shipholds and storage bunkers. The phosphine-releasing preparation, in the form of bags, bag blankets, or pellets on trays is placed on the surface of the bulk commodity and a closed-loop gas flow can be operated through the grain by means of a ventilator. The gas flow is continued only for the limited time which is necessary to change at least once the interstitial gas volume of the commodity. After a preselected period of time, the gas flow is repeated. The number of circulation pulses can be set at between 2 and 12 per day, and the duration of each pulse between 15 and 45 minutes. The gas circulation is completed when the phosphine liberation is about 90 % complete. The phosphine concentrations are always far below the explosion limit.

Several years ago it became necessary to fumigate huge quantities of bulk grain by application of the phosphide preparation to the grain surface. In many cases application technique was by means of bag blankets which were unrolled over the surface of the grain; a fumigation process which is easy and quick and is used in bulk storages, shipholds, big silos and so-called storage bunkers. It was found that the penetration of phosphine is sufficient to reach depths of up to 30 metres but that up to ten days were required for phosphine to reach the bottom of the bulk commodity.

Therefore, under such conditions long exposure times are necessary to achieve a hundred percent kill and differences in phosphine concentrations between grain surface and bottom are considerable. Under unfavourable conditions the lower explosion limit of the gas may be reached or even exceeded near the source of phosphine liberation, especially if the air space above the "bag blankets" is small. Furthermore, in regions of high concentration a so-called "narcosis effect" on certain pests may also occur. Tests have shown that the above drawbacks can be avoided and that exposure times of 3 to 6 days are in most cases sufficient if in a closed space of the bulk commodity the gas/air mixture is circulated by means of a ventilator. It was found that it is not necessary to circulate continuously until the end of the exposure time. The circulation can be carried out in pulses. For each pulse it is preferable that the interstitial gas volume of the bulk commodity, especially grain, be changed once. If this is not possible because the mass of the bulk grain is too big, at least a reasonable part of this volume should be moved by circulation.

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The duration of each pulse can be between 15 and 45 minutes and in very big storages some hours. The number of circulation pulses should be between 2 and 12 per day, depending on temperature. Gas circulation may be stopped when 90 % of the phosphine is liberated, because no noticeable increase in concentration will be observed after that. Therefore, the total number of pulses will be between 6 and 30.

By this procedure, phosphine concentrations in all parts of the circulation system are always below the lower explosion limit and possible ignition is therefore avoided. Suitable phosphine gas concentrations for pest control purposes are in the range of 500 ppm to 2,000 ppm. Since the circulated air always contains enough humidity, liberation of phosphine will be satisfactory even at relatively low temperatures. The efficacy of the gas can be enhanced by the addition of carbon dioxide to the system, allowing effective fumigation at relatively low phosphine levels.

In all cases the metal phosphide composition should be applied to the top of the commodity but not in direct contact with it. The metal phosphide composition may, for example, be contained in, or be spread onto a gas-pervious but substantially dust-proof wrapping or sheet. More preferably, the metal phosphide is applied in the form of bags or "bag blankets" which are unrolled on top of the commodity. Alternatively the preparation can be held suspended in the headspace of the bulk commodity. Such a process is, for example, suitable for application in silos: the phosphine preparation is applied in bag blankets suspended from the region of a manhole or the like at the top of the silo bin. After the exposure time, the spent preparation can be easily removed from the surface of the commodity.

The process may be carried out in an apparatus consisting of a storage space to contain a bulk commodity, means for inducing a gas flow through the commodity and return flow along a separate duct at a rate sufficient to comply with the requirements as defined for the above mentioned process, and a timing device programmed to switch the gas flow on and off in a manner and according to a time pattern as described above. The programme may be adapted to be set automatically or manually as a function of time, for example coupled to a temperature sensing or concentration sensing probe or probes contained in the gas space or in other regions of the apparatus. The temperature is relevant because it determines the rate of phosphine release for a given metal phosphide preparation and for a given humidity. It also determines the safe upper concentration limit before auto-ignition and possible explosions occur. The temperature moreover controls the metabolism of insect pests and therefore the optimum phosphine concentration for insect control.

Such an apparatus may comprise gas circulation ducts to provide the separate pathways for gas flow including a gas blower or equivalent and valves in the ducts designed to interrupt the closed loop flow and instead to draw in atmospheric air and to return the air through a vent to the atmosphere after having passed through the commodity. It may optionally include means for phosphine absorption or decomposition connected to the vent adapted to remove phosphine from the return air. These features are useful for the rapid removal of poisionous phosphine gas after having completed the treatment of the bulk commodity. The storage space may be the interior of a bin, a silo, a shiphold or a storage bunker.

In the following, the process will be explained further by way of examples with reference to the accompanying figures.

Fig. 1 represents a grain silo incorporating the features required for the fumigation process. The silo (1) is filled with grain (2) up to a level (3) above which there is an air space (4). The silo is adapted to be filled through a hatch (5) in the top of the silo which can be sealed in a gastight manner. A gas circulating device is provided comprising a suction fan (6) a withdrawal pipe (7) leading from the upper gas space down to the fan and a discharge pipe (8) leading to the bottom of the bulk grain equipped with an adequate number of gas discharge apertures along its length in the region (9). For improved gas distribution, section 9 may take the form of an annular pipe loop which is illustrated only diagrammatically. The inlet pipe of the fan also comprises a valve-controlled inlet pipe (10) leading directly to the atmosphere. The operation of the fan is designed to be controlled by a relay box which in turn is operated by a time switch device and an automatic monitoring apparatus. The monitoring apparatus receives and processes signals from measuring probes A and B, probe A leading into the upper gas space whilst probe B extends into the central region of the grain. Preferably, there are additional probes, for example in the immediate vicinity of the gas generation region to be described further below. The probes include temperature measuring gauges and/or automatic phosphine measuring probes.

Optionally, an automatic recorder may be connected to the control apparatus which keeps a record of the parameters measured by the monitoring apparatus, of the progress of the fumigation operation and in particular of the times of switching on and off of the fan.

The apparatus in Fig. 1 can be operated and controlled in a variety of manners, according to requirements.

In a particularly simple operating mode, the time switch is manually set to a predetermined operating cycle which may optionally be modified as the fumigation proceeds in accordance with data recorded on the automatic recorder, such as temperature variations and phosphine concentrations at different locations in the system. However, usually it is possible on the basis of the known volume and contents of the silo, the known or expected average temperature, the previously measured humidity inside the silo and the calculated dosage of phosphine releasing composition, to predetermine the operating cycles for the whole duration of the fumigation with sufficient accuracy.

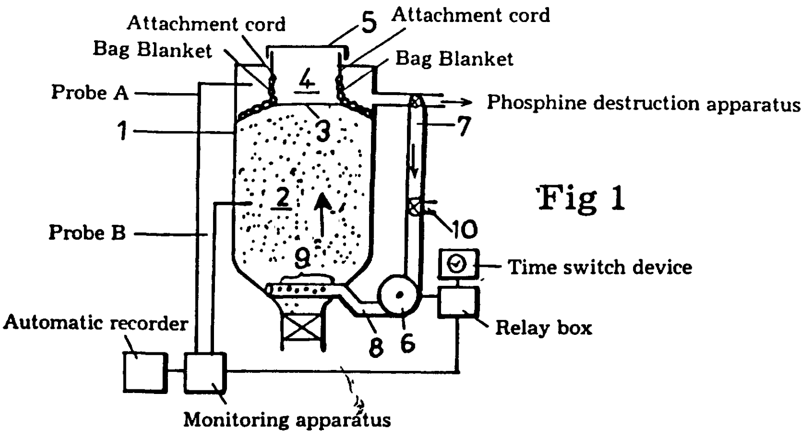
Alternatively, the monitoring box comprises or is connected to a computer which is programmed to preset and, optionally, adjust from time to time a built-in time switch device on the basis of the data signals supplied by the various probes. As a further alternative, the control and monitoring apparatus may be designed to merely operate the fan in response to gas concentrations reaching certain predetermined levels as monitored by the probes A and B (Fig. 1). The apparatus may also be programmed to switch on the gas circulation as soon as the PH_3 concentration at probe A exceeds that at probe B by a predetermined absolute or relative amount, for example by 20 percent, and to switch off the circulation as soon as the concentrations at the two localities have attained a different predetermined relationship, for example equality.

In addition, the monitoring box and the time switch device may be preset to stop all further circulation once a predetermined phosphine concentration level has been attained throughout the apparatus and/or after a predetermined time, more specifically the time at which under the prevailing conditions of temperature and humidity the metal phosphide preparation is known to have released substantially all its available phosphine gas, e. g. at least 90 percent of the available phosphine.

In the present example, it is assumed that so-called "bag blankets" are used to introduce and retain the metal phosphide composition. Their immediate surroundings, namely within 10 cm of the surface, we considered the phosphine generating region for present purposes. These "bag blankets" in the form of long strips are each introduced through the hatch at the beginning of the operation and suspended from their individual attachment cords. This may be done so that the "bag blankets" hang freely in the headspace or so that the lower part of the "bag blanket" rests on the upper surface (3) of the grain. At the end of the fumigation period, the hatch is opened, the spent "bag blankets" are withdrawn through the hatch and disposed of.

The direction of gas flow through the pipe system and through the commodity is indicated by arrows. After the fumigation period has been completed, the apparatus can be used to aerate the commodity in order to remove the residual phosphine gas. For this purpose, the hatch is opened and a three-way valve is so operated that atmospheric air enters the fan through the inlet port and is blown through the commodity in the direction of the arrow and out through the hatch.

If there are objections to releasing the residual phosphine gas to the atmosphere, the hatch may be kept closed and a further three-way valve may be operated to release the gas from space (4) through a further pipe connection leading into a phosphine absorption or decomposition device not shown in the figures.



In Fig. 2, the arrangements are similar in principle to those in Fig. 1, except that the silo is replaced by a shiphold (1) which is again filled with a bulk commodity such as grain (2). The numbers in Fig. 2 have the same meaning as those in Fig. 1. The instrumentation described with reference to Fig. 2 is also the same as in Fig. 1 but is not shown. The fan in this case delivers the gas withdrawn from the upper gas space (4) through a down pipe (8) into a pipe manifold system with discharge apertures (9).

Fig 2

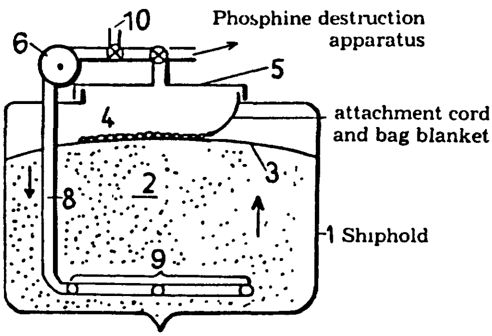


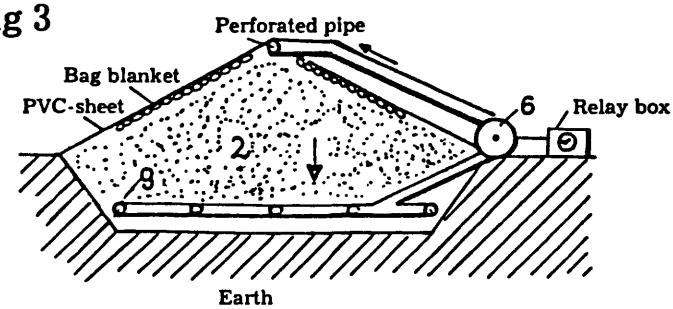
Fig. 3 shows the process applied to the fumigation of a PVC-lined and PVC-covered earth storage bunker for grain which consists of a large trench comprising an earth floor flanked on either side by earth banks. The trench is filled with grain heaped to a level well above the ground. The trench is lined with PVC sheeting and coverd with PVC sheeting. In order to introduce the fumigant, "bag blankets" are introduced with a suitable rod or pole through slits in the sheet cover, to come to lie between the top of the grain and the PVC sheet. The introduction holes are subsequently resealed.

Prior to the introduction of the grain, a set of pipes, having a series of outlet apertures is laid along the floor of the trench and is interconnected by a manifold pipe, leading to another pipe which passes to the delivery fan the operation of which is controlled by a time switch device. From the fan a pipe leads to a perforated pipe laid along the length of the apex of the grain heap.

Optionally, measuring probes may be provided in appropriate positions as in Fig. 1. However, these are not illustrated in Fig. 3.

Storage bunkers of the type to which Fig. 3 refers have been used successfully, particularly in Australia.

Fig 3



The following examples may demonstrate how the fumigation process works.

EXAMPLES

Example 1

A small silo cell similar so that illustrated in Fig. 1 having a volume of 188 m^3 is filled with 133 tons of wheat. The interstitial volume amounts to about 70 m^3. The fan has a capacity of 360 m^3 per hour. It is switched on at two hourly intervals for 15 minutes for three days. Accordingly, each switch-on cycle of 15 minutes amounts to an interstitial gas exchange of about 120 % if the volume of the space is also taken into account. The dosage of aluminium phosphide composition was 1 sachet per 2 m^3 of total cell volume (the sachets being incorportated in bag blankets and each sachet containing 23 g of technical aluminium phosphide).

After one and a half days the desired maximum concentration of 1 500 ppm had been attained. After three days the gas circulation was stopped. After one week the silo was opened and aerated. In a test run conducted at 9 to 10° C (a low temperature for fumigation with aluminium phosphide) the disinfestation was nevertheless complete, all insect pests at all developmental stages having been killed. In this test run the phosphine gas concentration was not observed to exceed even the relatively moderate level of 2 500 ppm at any time or in any part of the apparatus, not even in the immediate vicinity of the bag blankets.

However, in comparative tests using the same kind of silo bin at more frequently encountered higher temperatures, without gas circulation, concentrations of 15 000 ppm were reached before the experiments were stopped to avoid exceeding the lower explosion limit of phosphine. In one case the gas concentration reached 20 000 ppm.

Example 2

Example 1 was repeated with a different silo cell of similar design but having a capacity of 723 m^3 suitable for holding 550 tons of wheat. The procedure and results were substantially the same as in example 1, except that the maximum concentration of PH_3 with uniform gas distribution throughout the cell was 1 200 ppm. Again pest eradication was complete.

Example 3

Using the same apparatus as in example 2, the time switch is set to switch on the fan for the first time, four hours after the introduction of the bag blankets, and for a duration of two hours, and thereafter once daily for two hours. Each two hour cycle of the fan amounts to about two complete interstitial gas exchanges. Although in this example higher maximum concentrations of phosphine gas are reached in the immediate vicinity of the bag blankets and in the gas space, the concentrations do not at any stage reach dangerous or disadvantageous levels. After the second fan operation cycle there already exists a substantially uniform and lethal concentration of phosphine gas throughout the silo and after the third cycle the entire silo has reached maximum phosphine concentration, whereafter no further recycling takes place.

Example 4

A large silo containing 3 600 tons maize was fumigated as described in example 1 at 25° C. The fumigant was applied in the form of "bag blankets", in an amount of 1 sachet per 5 tons of maize. The interstitial volume was about 50 % of the bulk volume of the grain, and the empty head space constituted about 10 % of the silo volume. The first circulation pulse was applied after 8 hours at which stage the concentration in the head space was 1 600 ppm. The pulse duration was 2 hours during which period about 60 % of the interstitial volume was displaced. The gas concentration in the head space dropped to about 200 ppm. The circulation was repeated once every 12 hours and was stopped altogether after the 6th pulse. After 2 1/2 days a maximum PH_3 concentration of 700 ppm had been attained throughout the silo. After 1 week pest eradication was found to be complete.

Conclusions:

The advantage of the above described fumigation process is that already after some initial pulses a lethal concentration is obtained in all parts of the bulk storage, and after the termination of circulation, the distribution of phosphine is almost uniform in the whole system. Since the time of circulation is minimized, the possible loss of gas by means of leakages is small.

Due to this process, the dosage can be kept smaller in comparison with a surface application without circulation, since even at the bottom of the bulk the phosphine concentration will achieve its highest possible level. Also, at relatively low temperatures the liberation of phosphine is sufficiently rapid since fresh air containing sufficient humidity always passes over the phosphide preparation.