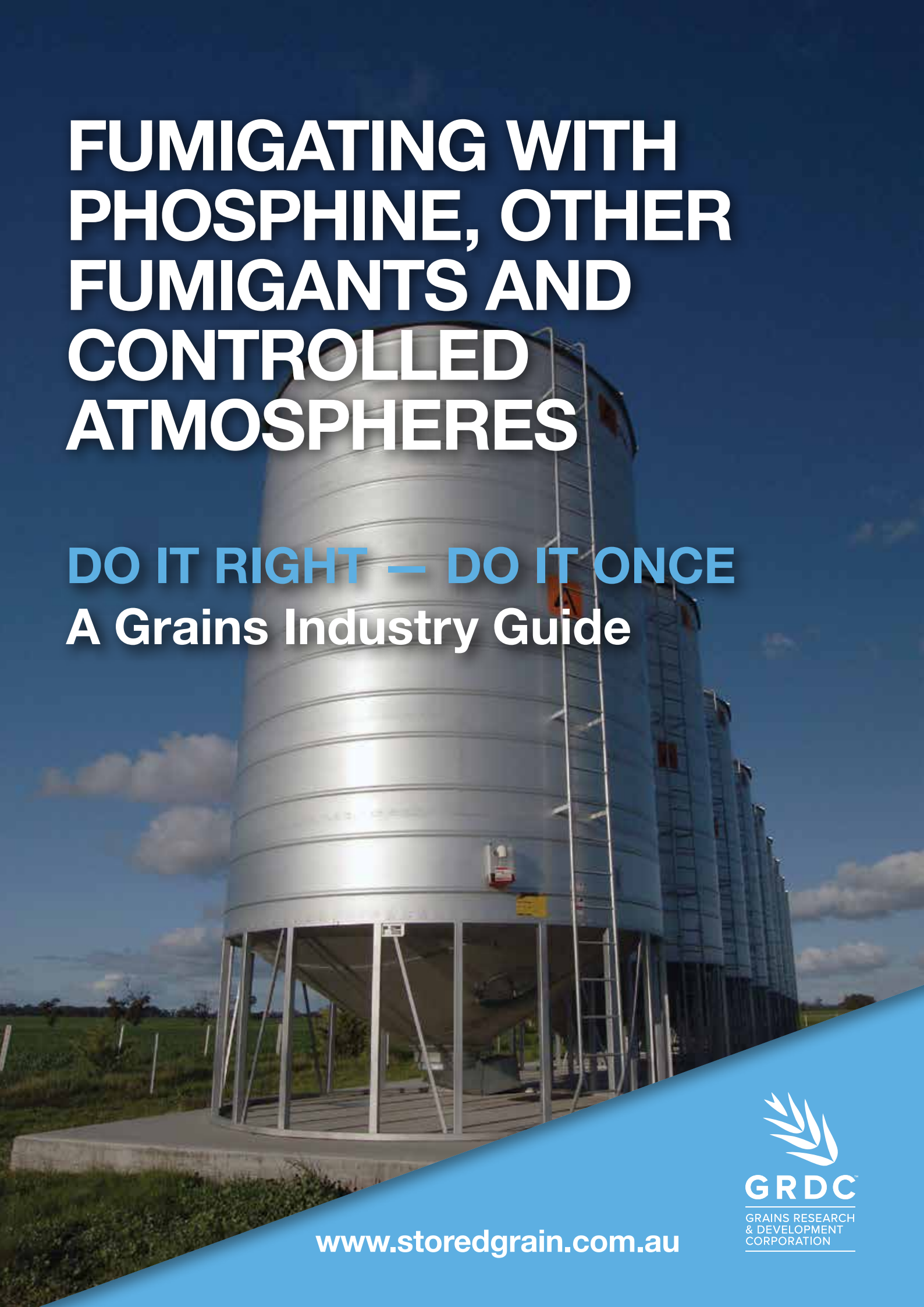
FUMIGATING WITH PHOSPHINE, OTHER FUMIGANTS AND CONTROLLED ATMOSPHERES

DO IT RIGHT — DO IT ONCE

A Grains Industry Guide



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Pressure testing a gas-tight, sealable silo – required for effective phosphine fumigation.

The Australian Standard (AS2628) states that sealable storage must perform a five-minute, half-life pressure test.

Start a pressure test with equal oil levels on the middle marker.

Pressurise silo to create a difference in oil levels of 25mm.

The time taken for the oil levels to drop from 25mm apart to 12mm apart must be no less than five minutes on new silos. For older silos, three minutes is acceptable.

Refer to page 4 for more information on performing a half-life pressure test.

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PUBLISHED **January 2011 (Reprinted July 2016)**
FUNDED BY THE **GRDC Grain Storage Extension Project, www.storedgrain.com.au**
PRODUCED BY **www.primarybusiness.com.au**
GRDC PROJECT CODE **PRB00001**

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AN INTRODUCTION TO PHOSPHINE

Phosphine remains the single-most relied upon fumigant to control stored grain pests in Australian grain-production systems, but continued misuse is resulting in poor insect control and developing resistance in key pest species (see Figure 1).

The Kondinin Group 2009 National Agricultural Survey (NAS) revealed that 85 per cent of respondents had used phosphine at least once during the previous five years and of those users, 37 per cent used phosphine every year for the past five years.

A Grains Research and Development Corporation (GRDC) survey carried out during 2010 revealed only 36 per cent of growers using phosphine applied it correctly — in a gas-tight, sealed silo.

This booklet explains how using phosphine incorrectly contributes to resistance problems and clarifies how to use it most effectively to achieve reliable results.

FIGURE 1 Phosphine resistance – National situation

- Sampling locations during the past 25 years.
- Weak resistance to phosphine has been found.
- Strong resistance to phosphine has been found.

SOURCE: DAFWA

Resistance

In the same way that repeated herbicide use of the same mode of action leads to resistant weeds, repeated phosphine use leads to resistant grain pests.

Glyphosate-resistant ryegrass is an example of the consequences of continuous use of a single mode of action chemical, which has led to resistance, with industry-wide ramifications.

Unlike herbicides, where resistance can be avoided by rotating chemical group from year to year, there are few alternative stored grain fumigation options other than phosphine. Alternative fumigants and controlled atmospheres* that are available for stored grain pests are in most cases more expensive.

The best way to prevent resistance is to use phosphine correctly — in a gas-tight, sealed silo.

Control of all life stages

In order to kill grain pests at all stages of their life cycle (egg, larva, pupa, adult), including pests with strong resistance, phosphine gas concentration levels need to reach and be maintained at 300 parts per million (ppm) for seven days (when grain is above 25°C) or 200ppm for 10 days (between 15–25°C).

Footnote *Controlled atmospheres involve replacing oxygen in a gas-tight storage with nitrogen or applying carbon dioxide. (See page 12 for more information)

Fumigation trials in silos with small leaks demonstrate that phosphine levels can reach as low as 3ppm close to the leaks. The rest of the silo also suffers from reduced gas levels, making it impossible to kill insects at all life stages.

Figure 2 illustrates the concentration levels achievable in a gas-tight sealed silo that performs a 3.5 minute half-life, pressure test. The required 300ppm is reached at the top and middle of the silo within the first day and is reached at the bottom by mid-way through the second day. The gas concentration then remains well above 300ppm for the required seven days.

Figure 3 shows that in a silo with minor leaks (not gas-tight) phosphine gas concentrations do not reach the required concentration level, for the necessary period, to kill pests at all life stages.

Concentration levels at the top of the silo in Figure 3 do go above the required 300ppm but only for four days, not the required seven days. At the middle of the silo gas concentration levels don't even reach 300ppm and at the bottom of the silo gas concentrations are so low (zero to 3ppm) they are barely detectable.

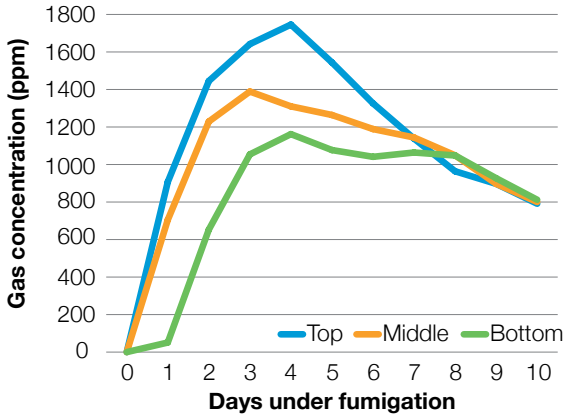
The poor gas concentration levels in the silo in Figure 3 are a result of gas leaking out through two minor gaps, one in the top and the other at the bottom of the silo. This silo is not gas-tight.

Poor fumigations may appear successful when some dead adults are found but many of the eggs, pupae and larvae are likely to survive and will continue to develop and reinfest the grain.

These partial kills are often worse than no kill at all because the surviving insects, (adults, pupae, larvae and eggs) are likely to be those that carry increased phosphine resistance genes as a consequence. Under-dosing risks increasing the number of insect populations carrying the genes for phosphine resistance and this has serious consequences for the industry.

FIGURE 2 Gas concentration in a gas-tight silo

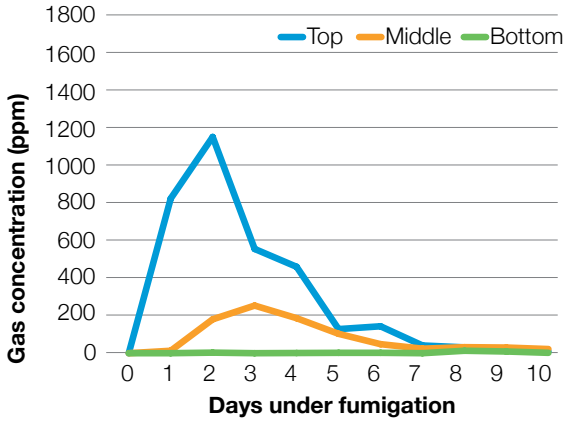
(3.5 minute half-life pressure test)



SOURCE: DEEDI, QLD

FIGURE 3 Gas concentration in a non-gas-tight silo

(8 second half-life pressure test)



SOURCE: DEEDI, QLD

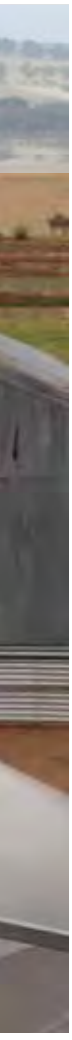


PHOTO: DAFWA

PHOTO: CHRIS WARRICK, KONDININ GROUP

PRESSURE TESTING PROVES PARAMOUNT

Pressure testing sealable silos — why

As mentioned previously, fumigating an unsealed silo with phosphine does not kill pests at all stages of their life cycle.

Repeat fumigations in unsealed silos allow resistant insects to survive and increase the likelihood of high levels of resistance developing.

From a safety aspect, phosphine labels also include a statement saying, 'DO NOT fumigate work situations where there is a risk that phosphine gas could leak from fumigation enclosures into working areas'. This means the silo acting as the fumigation chamber must be gas-tight to prevent phosphine from leaking and potentially harming workers around the site.

A pressure test is a measure of how well a silo will contain fumigant to ensure it holds gas concentrations at a high enough level for a sufficient time to kill insects at all life stages without leaking.

Busting the myth

To some people a sealed silo may be one that keeps rain out or one that is sold labelled as a sealed silo — but this is not the case.

Technically, a silo is only truly sealed if it passes a five-minute half-life pressure test according to the new Australian Standard AS2628.

Even if a silo is sold as 'sealed' it is not sealed until it is proven gas-tight with a pressure test. Buying a silo that is gas-tight will enable fumigation. Aeration cooling also enables proactive pest prevention as well as enabling a shorter ventilation period.

Pressure testing sealable silos — when

If silos are properly maintained, pressure testing is a quick-and-easy process that is ideally carried out at three distinct times:

PHOTOS: CHRIS WARRICK, KONDININ GROUP

1. Choose the right time to pressure test

Consider the ambient conditions of the day before pressure testing.

Air inside a silo heats and expands as the daily temperature rises and the sun warms the silo walls.

When a silo is sealed this expansion of air can give false readings during a pressure test indicating a silo seals better than it actually does. The best time to pressure test silos is in the morning within an hour of sunrise or on a cool, overcast day — when the ambient temperature is stable and the sun is not heating the silo.

Avoid sunny days if there are clouds in the sky, which intermittently break the sun's radiance on the silo, constantly changing its temperature and therefore pressure.

2. Check seals

Before performing a pressure test, check seals around the lid, access hatch, hopper or boot and make sure the aeration fan seal is in a sound condition. Make sure all latches on lids and seal plates are locked down firmly.

3. If there is no aeration fan; install an air valve

If the silo doesn't have an aeration fan, install a tubeless tyre valve to pressurise the silo with an air compressor. Unscrew the centre of the valve to get higher air-flow into the silo. Alternatively for larger silos or if the air compressor is too small, install a PVC male fitting that can connect to a venturi gun (Blovac) that fits on the end of the air line.

4. Check oil levels

Oil relief valves are primarily fitted to protect the silo structure from damage due to air expansion and contraction when the silo is sealed during fumigation.

However, the relief valve can also be used to test how well the silo holds a positive pressure. In other words; check for leaks in a sealable silo.

If a silo does not have an oil relief valve, it is unlikely to be gas-tight and it will take a considerable amount of work to make it gas-tight.

Oil relief valves can be bought separately and fitted to silos where they are absent, damaged or up high on the silo and not easily visible.

On silos with an oil relief valve not easily visible for performing a pressure test, a piece of clear, U-shaped hose half full of water can be connected to an air valve in the silo to act as a temporary manometer for the half-life, pressure test.

Before pressurising the silo, check the oil levels are equal on both sides of the gauge and are at the middle indicator mark as shown in the photo above.

Some older oil relief valves may not have a gauge on them — use a marker pen to show start and finish of oil levels.

PHOTOS: CHRIS WARRICK, KONDININ GROUP

1. When a new silo is erected on farm, carry out a pressure test at a suitable time of day (see following testing guide) to make sure it's gas-tight before filling with grain.
2. Importantly, a silo also needs to be pressure tested when full, before fumigating grain. If the silo has a slide plate outlet that has been tested empty, retest when full to make sure the weight of the grain doesn't compromise the seal. The weight of grain can break the seal on a slide-plate outlet that is not well supported by cam-locks or bolts etc. For older, poorly-designed silos, gentle pressure from a jack may assist the seal on a slide-plate outlet.
3. Pressure testing silos needs to be part of the annual silo maintenance routine. It is much easier to replace seals and carry out repairs on slide plates and bottom access holes when silos are empty.

5. Pressurise the silo

If fitted with an aeration fan, pressurise the silo by turning the fan on for a few seconds until the oil levels are more than 25mm apart. Then quickly turn the fan off and seal the fan inlet. This job is easier with two people — one to operate the fan and the other to watch the oil gauge.

Be careful — there is potential for damage if fans are left running for extended periods while the silo is sealed or with the fan inlet blocked.

If the silo doesn't have an aeration fan, use the tyre valve and an air compressor to pressurise the silo. A venturi gun (Blovac), with connection fittings to the silo can also be used.

6. Time the HALF-LIFE

If oil levels are further apart than 25mm, wait until the pressure drops and the oil levels reach a distance of 25mm. The time taken for the oil to drop from 25mm to 12mm apart must be no less than five minutes on new silos. For older silos three minutes is acceptable.

This is known as the half-life pressure test.

THE AUSTRALIAN STANDARD

During March 2010 standards body SAI Global published an Australian Standard (AS2628) for gas-tight sealed silos in response to industry concerns that phosphine fumigation in improperly sealed storages was not killing insects at all life stages.

The standard is based on a new silo meeting a five-minute half-life pressure test. When a pressure test is undertaken, oil levels in the pressure relief valve must take a minimum of five minutes to fall from 25mm to a 12.5mm difference if the silo is sufficiently gas-tight.

The standard allows growers to refer to an industry benchmark when buying a gas-tight, sealable silo and be confident they are investing in a silo that will perform in the way it's intended.

This means it will work as a gas-tight chamber and hold a lethal concentration of gas for the time specified on the label, to control insects at all life stages.

It is important to then ensure gas-tight, sealable silos are maintained and pressure tested before fumigating to ensure they remain gas-tight and continue to perform as an effective fumigation chamber.

7. Looking for leaks

If the half-life pressure test is less than five minutes on a new silo, or three minutes on an old silo, there is a leak. To find leaks, pressurise the silo again and use soapy water in a spray bottle to check for air leaks around seals.

Common places for leaks include; bottom outlet, aeration intake seal, damaged top fill point rim or lids (caused by the auger when lining it up to fill the silo), seals on external seal plates, the wall to cone and wall to roof joints. Common causes for leaks at these points are latches on lids not applying enough pressure on rubber seals, damaged rubber seal or an old rubber seal with lapsed memory.

Bottom outlets with a slide plate can be sealed by adding a small amount of pressure to the bottom of the slide plate with a jack. Older silos may require more extensive maintenance to achieve a gas-tight seal.

After you believe the leak has been fixed, pressurise the silo again and repeat the half-life test — steps five and six.

Pressure testing sealable silos — how

If regular silo maintenance is undertaken to keep seals in working order, pressure testing is fast by following these seven simple steps:

Little leaks cause big problems

Gas-tight, sealable silos are like any other piece of machinery in that they require regular maintenance. With time, silos that were gas-tight on erection will deteriorate and develop small leaks as inlet and outlets wear and rubber seals perish or become damaged.

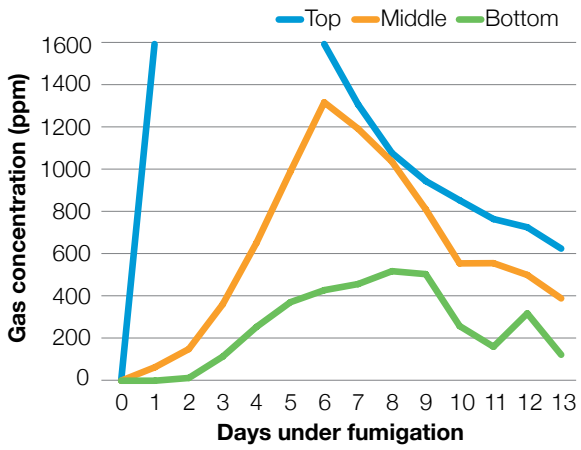
A trial was carried out by DEEDI QLD to determine the effect on fumigation in a silo that was gas-tight, but compromised with a small leak at the bottom outlet. For the trial, a gas-tight silo had the bottom outlet clamps loosened just a fraction, resulting in a 45 second half-life when pressure tested rather than the required three-minute half-life for non-new silos.

Figure 4 below shows gas concentration levels at the top and middle of the silo were still adequate, but the gas concentration level at the bottom of the silo did not maintain the required 300ppm for seven days or 200ppm for 10 days. A small compromise in the bottom outlet seal means gas concentration levels at the bottom of the silo aren't high enough to kill grain pests at all life stages.

This trial concludes that gas-tight silos must be maintained and must perform a three-minute (five minutes on new silos) pressure test before fumigation to ensure they are gas-tight.

FIGURE 4 **Gas concentration in an unmaintained gas-tight silo**

(45 second half-life pressure test)



SOURCE: DEEDI, QLD

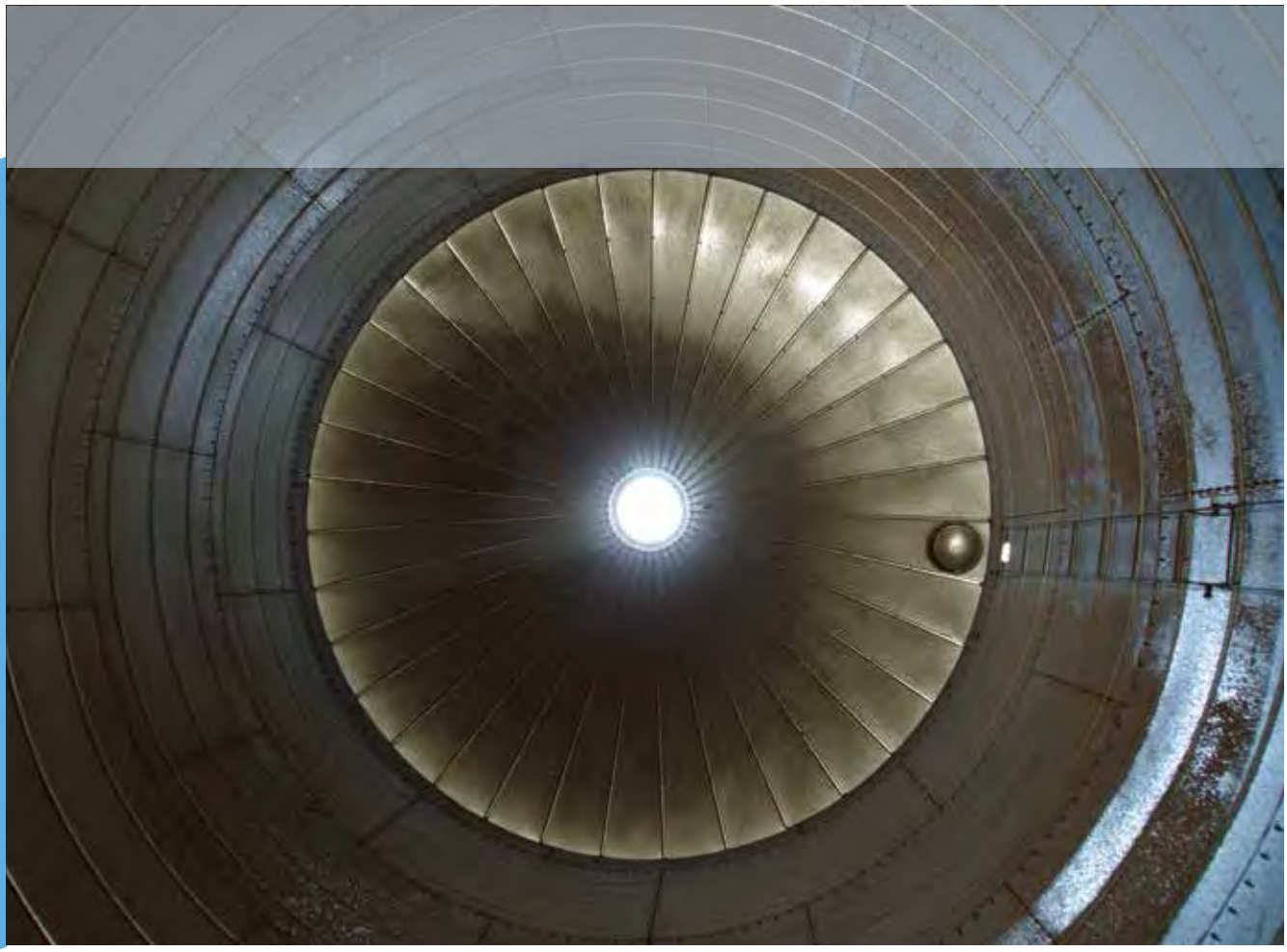


PHOTO: CHRIS WARRICK, KONDININ GROUP

SILO SAFETY

Personal safety

After a silo has been pressure tested and satisfied the half-life pressure test of five minutes for a new silo or three minutes for an older silo, it can then be used as a fumigation chamber for phosphine.

Phosphine is highly toxic and must be handled with care while wearing appropriate personal protective equipment (PPE).

Phosphine is classed as a schedule seven poison, which is indicated on the label — DANGEROUS POISON.

As a minimum requirement, the label directs the use of cotton overalls buttoned to the neck and wrist, eye protection, elbow-length PVC gloves and a breathing respirator with combined dust and gas cartridge.

Working with phosphine in an open, well-ventilated area with the wind coming from the side will reduce the amount of gas blown into the operator's face.

Avoiding explosion

Only open phosphine containers outdoors. When opening containers take care and point container lids away from the face and body. Under certain conditions possible build-up of gas inside the container can result in flash flame upon exposure to air.

When opened, use the entire contents or carefully dispose of excess chemical — do not reseal left-over tablets. The reason for this is that after a container has been opened and exposed to ambient air carrying moisture, the phosphine tablet starts evolving into gas as it reacts with moisture in the air. If the lid is replaced, gas inside the tin continues to be released and can reach flammability levels if it builds up to 17,900ppm.

Personal exposure limits

The National Occupational Health and Safety Commission (NOHSC) has set limits for exposure standards for phosphine, for the safety of users and people who come in contact with the grain post fumigation.

The label states TLV (TWA) 0.3ppm — but what does that really mean?

The Threshold Limit Value (TLV) for a Time-Weighted Average (TWA) — an eight-hour working day and a 40-hour working week— in which a worker may be repeatedly exposed without adverse health effects is 0.3ppm.

The MSDS also states STEL 1ppm — what does this mean?

The Short-Term Exposure Limit (STEL) or maximum concentration for a continuous exposure limit of 15 minutes (with a maximum of four such periods per day with at least 60 minutes between exposure periods) is 1ppm.

In summary, workers must not be exposed more than four times per day to more than 1ppm for longer than 15 minutes with at least one hour between each exposure. And workers must not be exposed to more than 0.3ppm for more than eight hours per day or 40 hours per week.

The odour threshold of phosphine (for those that can smell it) is 2ppm, which is higher than both of these TLVs. This means by the time workers can smell phosphine the gas concentration level is already exceeding the safe exposure limit.

Never rely on the odour of phosphine to determine if the atmosphere is safe.

Always read the product label and Material Safety Data Sheet (MSDS) for safety information and required PPE.

Electrical equipment

Phosphine will corrode copper-based materials so seal or remove any sensitive electrical and electronic equipment (switchers or meters) inside the silo before fumigating.

PHOTO: BEN WHITE, KONDININ GROUP

Life saver: *Personal phosphine monitors sound an alarm if harmful concentration levels are detected.*

Personal monitors

Personal phosphine monitors are available and easy to use. The monitors simply clip onto the operator's collar or top pocket (close to their nose and mouth) and will sound an alarm if more than 0.3ppm is detected and sound another alarm if more than 0.6ppm is detected.

Price may deter growers who only use phosphine occasionally, but these handy devices can potentially save a life, so are worth serious consideration.

PHOTO: CHRIS WARRICK, KONDININ GROUP

Breathe with ease: *A full-face breathing respirator is required for handling phosphine. The respirator must be fitted with a combined dust and gas cartridge (canister) with an international code that includes the letter 'B', which stands for inorganic gas. The number in the code refers to the capacity of the cartridge, for example an ABE1 has a shorter life span than an ABE2.*

APPLICATION

Forms of phosphine

Phosphine is available in two different forms for on-farm use (bag chains and tablets) and there are various ways to apply each option effectively in a gas-tight, sealed silo.

Bag chains are the safest form and the best way to guarantee no residue is spilt on the grain or will harm the operator.

The other form is the traditional and most recognised — tablets — which can be bought in tins of 100.

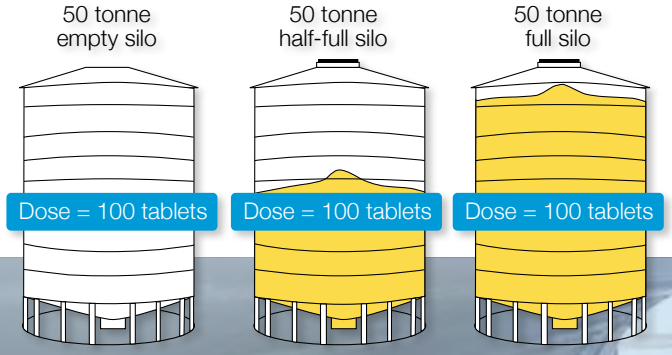
A third form — phosphine blankets — is available, but is designed for bulk storages larger than 600 tonnes.

Phosphine application rates are based on the internal volume of the gas-tight, sealable silo to be fumigated. Regardless of how much grain is in the silo whether it is full or empty, the rate is the same — based on the volume of the silo (see Figure 5).

Using bag chains

The application rate for fumigating with a standard bag chain is one bag chain per 75m^3 or 60t of wheat storage capacity. Always refer to the label.

FIGURE 5 Treat the silo volume not the grain



SOURCE: CBH

Do not cut a bag chain to save extra phosphine for use at a later date.

The phosphine will start evolving as soon as it is exposed to air, so will be less effective if it's stored for use at a later date.

Storing phosphine after it has already been opened also poses a danger when re-opened, as the gas has been dissipating in a confined space, potentially reaching explosive levels.

For larger bulk storage silos, phosphine can be obtained in blanket form. Like bag chains, blankets must not be cut or separated so the minimum size storage for fumigation using a single blanket is 750m^3 or 600t of wheat storage capacity.

Using tablets

The application rate for phosphine is 1.5 grams per cubic metre, which in tablet form equates to three tablets per 2m^3.

Considering the typical bulk density of wheat is 1.3m^3/t the application rate is two tablets (2g of phosphine) per tonne of storage capacity (see Table 1).

TABLE 1 Application rates for phosphine tablets in storage

STORAGE CAPACITY		NUMBER OF TABLETS REQUIRED
TONNES WHEAT	CUBIC METRES	
1	1.3	2
50	65	100 (1 tin)
100	130	200 (2 tins)
200	260	400 (4 tins)
300	400	600 (6 tins)

SOURCE: NUFARM

WARNING SIGN

During fumigation, never attempt to enter the silo until after it has been ventilated as required. Place a warning sign on the silo to tell others to stay away. The sign must contain the words DANGER — POISONOUS GAS, KEEP AWAY.

A sample warning sign has been included on page 13.

Hung up: *Spreading phosphine tablets out across two trays is better than in one tray. Aim to hang the trays as level as possible to avoid heaping to one side.*

PHOTO: CHRIS WARRICK, KONDININ GROUP

In the bag: Phosphine in bag chains removes the risk of residue being spilt, but at least 1% of residue will not evolve until it comes into contact with moisture so a respirator and PPE are also required to remove it from the silo.

Fumigation from below: Some silos are built with a chamber and passive (thermo-siphon) sealed recirculation system for applying phosphine from the bottom.

Active recirculation: Phosphine is placed in the fumigation box and recirculated through the gas-tight silo.

Always read the product label to confirm recommended application rates.

Phosphine distribution

In a gas-tight, sealed silo phosphine gas density (1.17) is so similar to air (1.0) that it will disperse evenly through grain from either the top or the bottom of the silo.

Application from the top

Hang bag chains in the head space or roll out flat in the top of a gas-tight, sealed silo so air can freely pass around them as the gas dissipates.

Always spread out phosphine tablets evenly on trays, before hanging them in the head space or placing them level on the grain surface inside a gas-tight, sealed silo. The aim is to place the tablets where as much surface area as possible is exposed to air so the gas can disperse freely.

Prevent trays from sitting on an angle to avoid tablets piling up to one side and creating more than one layer in the tray.

PHOTO: CHRIS WARRICK, KONDININ GROUP

Application from the bottom

Some silos are fitted with purpose-built facilities for applying phosphine from the bottom. This method of application carries a safety advantage as the operator doesn't have to leave the ground to apply the phosphine.

However, ensuring top lids or vent openings on silos are in sound condition and correctly sealed before fumigation, will usually require a climb to the top.

Bottom-application facilities must have a passive or active air circulation system to carry the phosphine gas out of the confined space as it evolves. Without air movement, phosphine can reach explosive levels if it's left to evolve in a confined space.

Active recirculation

On large (greater than 150t) gas-tight silos a fan-forced recirculation system will assist phosphine gas distribution throughout the storage. The suction side of the fan connects to a large hose that is sealed into the top of the silo and the outlet side of the fumigation box connects with another large hose to the in-floor aeration ducting.

Fan-forced recirculation can improve the speed of gas distribution so the whole silo reaches the required 300ppm gas concentration for the required period as quick as possible.

Phosphine application through a fan-forced recirculation system still requires a gas-tight, sealed silo. If the silo and recirculation system is not gas-tight the phosphine will not kill insects at all life stages and a reinfestation will be inevitable, while also increasing the risk of selecting for resistance.

The most important thing to remember with any form of recirculation system is if the recirculation stops for any reason, gas concentration levels inside the chamber or box can reach explosive levels. If the fan stops, for example from a power outage, open the fumigation chamber or box with caution and while wearing the appropriate PPE, let the gas disperse into the ambient air and start the fumigation again with fresh phosphine after the power is restored.

Wetting is worse

There is a myth that wetting phosphine makes it release gas quicker but this is not only dangerous, it's less effective against grain pests.

Adding water to phosphine causes uncontrolled release of phosphine gas, greatly increasing the likelihood of it reaching flash flammability point or explosive concentration levels.

Releasing phosphine gas uncontrollably by wetting it, does not eliminate the need for a gas-tight sealed storage nor does it reduce the fumigation period. It is dangerous and less effective against grain pests.

Fumigation period

A gas-tight, sealed silo (one that satisfies a half-life pressure test) must remain sealed for the full 7–10 days to achieve a successful fumigation using phosphine tablets or bag-chains.

In a gas-tight, sealed silo the required fumigation period is seven days if the grain temperature is above 25°C or 10 days if the grain temperature is between 15–25°C. If the temperature inside the silo is below 15°C, insect pests will not be active and phosphine is not reliably effective — avoid its use (see Figure 6).

Opening the silo during fumigation is potentially harmful to the operator if they are not wearing the appropriate PPE, but also compromises the fumigation as gas concentration levels will quickly fall below the lethal level required to kill insect pests.

Phosphine label recommendations have been developed as a result of thorough industry testing so using phosphine as the label specifies will achieve the best result.

Phosphine monitoring devices

While grain is under fumigation, phosphine monitors can determine the gas concentration levels inside the silo. This is the only way to know if the required 300ppm is reached for seven days or 200ppm for 10 days.

A less expensive, although less accurate, method of detecting the success of phosphine fumigation is to put a piece of copper wire in the storage at the opposite end to where the phosphine was placed. At the end of the fumigation period the copper wire will change colour as a result of a reaction with the phosphine gas.

Keeping a lid on it

Grain stored in sealed silos can, in some circumstances, be left sealed to create a physical barrier to pests entering the storage, but there are risks involved and the grain still requires regular monitoring.

Grain left in a sealed silo is at risk from condensation of water vapour inside the silo due to day and night temperature changes, so it must still be checked fortnightly during summer and monthly during winter. Don't attempt to leave grain that is 12 per cent or higher moisture content sealed for any longer than the required fumigation period, as it is at much higher risk of moisture condensation and mould growth.

If aeration cooling is available, it's better to return the grain storage to an aeration cooling cycle following fumigation. Storing grain below 23°C during summer and below 15°C during winter with aeration creates an uninviting environment for pests and maintains seed quality and viability for longer.

Extended fumigation

During summer when grain temperature is high, monitor grain fortnightly. This means the fumigation period cannot be extended because the silo must be ventilated according to the label before re-entry to check the grain.

During winter monitor grain at least monthly. This means the fumigation period can be extended for a week or two

Copper indicator: *In a successful fumigation copper wire will turn black after 7–10 days exposure.*

PHOTO: CHRIS WARRICK, KONDININ GROUP

On the level: *Phosphine meters draw a small amount of air from inside the silo through a small tube and measure the phosphine gas concentration level in parts per million (ppm).*

to create a physical barrier to insect reinfestation, but allow enough time to ventilate the silo according to the label before re-entry for the monthly grain check.

Remember to wear appropriate PPE when working around silos that are, or have been, under fumigation until the required ventilation period is complete.

If aeration is available, return the silo to aeration cooling rather than extending the fumigation period beyond label recommendations.

Ventilation period

Following fumigation, ventilate silos to allow phosphine gas to escape into the atmosphere, so grain can be delivered free of harmful gas residues.

When a silo is first opened after a successful fumigation the gas concentration levels are extremely harmful.

The same PPE required for applying the phosphine is required again to open the silo and remove the phosphine residue.

Working with your side to the wind can significantly reduce the amount of phosphine gas blown past your face.

A personal phosphine meter is a good way to monitor phosphine levels around your face to help avoid excess exposure.

With tablet residue or bag chains removed, leave open a silo without aeration fans fitted to ventilate for no less than five days.

Silos with aeration fans fitted must be opened to ventilate with fans operating for no less than one day (see Figure 6).

Disposal

Phosphine residue and used bag chains can still have some active phosphine not released during fumigation. Disposing of these residues incorrectly creates the risk of explosion or flame-over if left in a confined space. Phosphine residue also can injure someone exposed to the remaining gas as it continues to dissipate.

To ensure neither risk occurs, dispose of phosphine residue and used bag chains as the label instructs, which means deactivating any remaining residue before disposing of it, or the container.

Deactivating phosphine can be done by swamping it with dilute acid or soapy water in open air until bubbling stops. Use long-handled tools where possible to keep a distance between the reacting phosphine and your body.

Bury the deactivated residue deeper than 500mm in an approved disposal pit, specifically marked and set up for this purpose, clear of waterways, desirable vegetation and tree roots.

Triple rinse all empty phosphine containers with soapy water to ensure any residual phosphine is deactivated. Destroy rinsed containers by breaking, crushing or puncturing before depositing them in the local authority landfill or burying deeper than 500mm in an approved disposal pit.

Do not burn empty containers or product and always follow the label instructions.

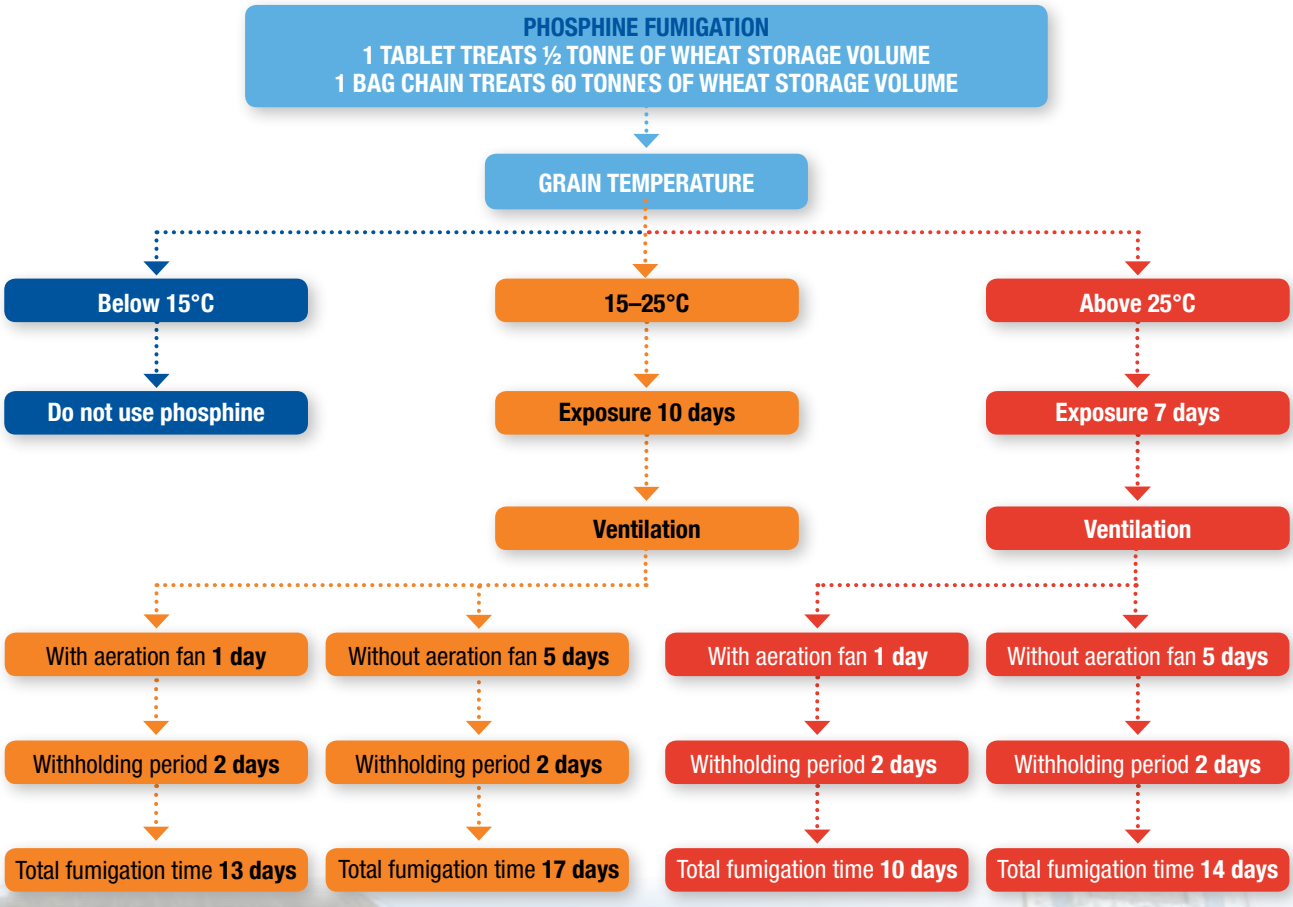
Withholding period

After fumigating with phosphine, hold grain for a further two days after ventilation before delivering or using for human consumption or animal feed. This is a legal requirement as instructed by the label.

The total time required for fumigation ranges from 10–17 days accounting for the minimum exposure period, ventilation and withholding period.

Figure 6 demonstrates the minimum periods for each stage of the fumigation process, depending on the temperature and the ventilation period, to give a total fumigation time required. This highlights the importance of monitoring grain regularly and at least 17 days before out-loading to allow sufficient time for the fumigation process when required.

FIGURE 6 **Phosphine fumigation period**



SOURCE: KONDININ GROUP

PHOTO: BEN WHITE, KONDININ GROUP

OTHER FUMIGANTS AND CONTROLLED ATMOSPHERES

Although phosphine is still the most commonly-used gas fumigant for controlling pests in stored grain, there are other options.

Each of the alternatives still requires a gas-tight, sealable silo and are currently more expensive than using phosphine, but they offer an alternative for resistant pest species.

Nitrogen and CO_2 carry the advantage of being non-chemical control alternatives.

Both nitrogen and CO_2 methods of control are sometimes referred to as controlled atmosphere (CA) because they change the balance of natural atmospheric gases to produce a toxic atmosphere.

Carbon dioxide

Treatment with CO_2 involves displacing the air inside a gas-tight silo with a concentration level of CO_2 high enough to be toxic to grain pests.

This requires a gas-tight seal, measured by a half-life pressure-test of no less than five minutes.

To achieve a complete kill of all the main grain pests at all life stages CO_2 must be retained at a minimum concentration of 35 per cent for 15 days.

The amount of CO_2 required to reach 35 per cent concentration for 15 days is one 30 kilogram (size G) cylinder per 15t of storage capacity, plus one extra cylinder.

CO_2 is a non-flammable, colourless, odourless gas that is approximately 1.5 times heavier than air. Food grade CO_2 comes as a liquid in pressurized cylinders and changes to a gas when released from the cylinder.

The basic process is to open the storage's top lid to let oxygen out as CO_2 is introduced. Regulate the CO_2 gas into the bottom of the silo via a high pressure tube ideally 1 metre long (no longer than 2m). One kilogram of liquid CO_2 will produce approximately half a cubic metre of gas.

Each cylinder could take three hours to dispense. In cooler conditions this process will take longer as the gas will tend to freeze if released from the bottle too quickly. This method of fumigation is not recommended when temperatures are below 15°C. Once the concentration at the top of the storage reaches 80 per cent, stop adding CO_2 and seal the top lid.

Even in a silo that meets the five-minute, half-life pressure test, an initial CO_2 concentration of 80 per cent or more is required to retain an atmosphere of 35 per cent for the full 15 days, because the CO_2 is absorbed by the grain, reducing the atmospheric concentration over time. If the storage does leak, CO_2 can be added periodically over the 15 days if required. The key is to maintain the CO_2 concentration above 35% for 15 consecutive days, which will require suitable electronic instruments or a gas tube detector kit for monitoring.

At temperatures below 20°C carbon dioxide is less effective because insects are less active so the concentration must be maintained for an extended period.

Seek more information from the *Insect control* section of www.storedgrain.com.au

Nitrogen

Grain stored under nitrogen provides insect control and quality preservation without chemicals. It is safe to use, environmentally acceptable and the main operating cost is electricity. It also produces no residues so grains can be traded at any time, unlike chemical fumigants that have withholding periods.

Insect control with nitrogen involves a process using Pressure Swinging Adsorption (PSA) technology, modifying the atmosphere within the grain storage to remove everything except nitrogen, starving the pests of oxygen.

The application technique is to purge the silo by blowing nitrogen-rich air into the base of the silo, forcing the existing, oxygen-rich atmosphere out the top. PSA takes several hours of operation to generate 99.5 per cent pure nitrogen and before the exhaust air has a reduced concentration of two per cent oxygen.

At two per cent oxygen adult insects cannot survive, providing this concentration is maintained for 21 days with a grain temperature above 25°C. Anything less will not control all life stages — eggs, larvae and pupae. For grain below 25°C this period is extended to 28 days. The silo must be checked the day after fumigation and may need further purging to remove oxygen that has diffused from the grain.

Nitrogen storage will also maintain the quality of canola and pulses by inhibiting the respiration process that causes oxidation, which leads to seed deterioration, increased free fatty acids and loss of colour.

For further information on controlled atmosphere fumigation with CO_2 or nitrogen, contact the commercial suppliers of appropriate gas and equipment; BOC Gases Australia Ltd, on 13 12 62 or visit www.boc.com.au

ProFume®

Only licensed fumigators trained under Dow AgroSciences' Precision Fumigation program can use ProFume (active ingredient — sulfuryl fluoride).

However it is helpful to understand the basics to determine its suitability for the situation.

Where grain is stored for human consumption, ProFume is only registered for use in cereal. Where grain is stored for seed or uses other than human consumption ProFume can be used on grains other than cereals. It is always safer to check with the grain buyer before using any chemical treatments or fumigants.

ProFume is said to be effective on most of the common pests found in Australian on-farm storages including Rust-red flour beetle, Lesser grain borer, Saw-toothed grain beetle, Flat grain beetle, Rice weevil and Indian meal moth.

Before the licenced fumigator applies ProFume, they should use the ProFume Fumiguide computer program to calculate the required dosage needed for each specific situation. The maximum concentration rate is 128 grams

per cubic metre. Following fumigation with Profume, the storage must be ventilated and confirmed that the concentration level is less than 3 parts per million before re-entering. Grain must be withheld for at least 24 hours before consumption.

For more information on ProFume contact Dow Agrosciences Australia Ltd on 1800 700 096 or visit www.dowagro.com/au

VaporMate®

VaporMate consists of 16.7 per cent ethyl formate by weight with the balance being CO_2. It is registered for use in cereal grains and oilseeds for control of Lesser grain borer, Four beetle, Psocids, Storage months, Saw-toothed grain beetle and Flat grain beetle at all life stages as well as the Rice weevil in egg, larvae and adult life stages.

VaporMate is supplied by BOC Gases Australia Ltd as a liquefied gas under pressure and is applied in a gas-tight, sealed storage at a rate of 420g/m^3 held for 24 hours or 660g/m^3 held for three hours. Following fumigation, ventilation requires ehyl formate to be less than 100ppm and CO_2 to be less than 5000ppm, at which point there is no withholding period there after. An additional point to be aware of is that ethyl formate is readily absorbed by grain. This can make it difficult to reach the required consecration in the centre of a large storage and ventilation will also take longer in a large storage.

For more information on VaporMate contact BOC Gases Australia Ltd, on 13 12 62 or visit www.boc.com.au

This warning sign template can also be downloaded from **www.storedgrain.com.au**

SOURCE: PHA

FURTHER READING

Grain storage pest control guide (GRDC Fact sheet)

Stored grain pests – identification (GRDC Fact sheet)

www.storedgrain.com.au

GRAIN BIOSECURITY CONTACTS

Plant Health Australia
02 6215 7700
biosecurity@phau.com.au
www.planthealthaustralia.com.au

GRAIN STORAGE SPECIALISTS

National hotline
1800 weevil (1800 933 845)

QLD and northern NSW, Philip Burrill
philip.burrill@daf.qld.gov.au

Southern NSW, VIC, SA and TAS, Peter Botta
pbotta@bigpond.com

WA, Ben White
ben@storedgrain.com.au

USEFUL RESOURCES

GRDC Grain storage extension project
www.storedgrain.com.au

Grain Trade Australia
02 9235 2155
www.graintrade.org.au

Poisons Information Centre (Australia)
13 11 26

Plant Health Australia
02 6215 7700
biosecurity@phau.com.au
www.planthealthaustralia.com.au

www.storedgrain.com.au

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