FUMIGATION TRAINING MANUAL

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PREFACE

The objective of fumigation is to ensure to protect agricultural products and human health of flora and fauna through effective standard. To minimize risk of introduction of pests and diseases, standard fumigation is one of the method of managing this risk.

Likewise, where effective fumigation is not available, consignments may only be fumigated on arrival.

Purpose of the manual

- Clearly outline and explain the minimum standards that apply to fumigation carried out to meet requirements of importing countries
- Give treatment provider, officers concern and stakeholder, the necessary information to understand fumigation requirement so they can effectively treat consignments for export and import

DEFINITIONS USED IN THIS DOCUMENT

Ambient temperature: temperature of the air immediately surrounding the fumigation enclosure (measured in the shade).

Container (also freight container): standardized transportation units, totally enclosed and weather proof, having a rigid roof, rigid side walls and a floor, having at least one wall equipped with doors and intended to be suitable for transporting a variety of cargo.

Hazard area: any area in proximity to a fumigation enclosure into which fumigant may escape in hazardous concentrations (determined by local legislation relevant to fumigation practice in the location in which the treatment is performed).

Dosage: the calculated amount of fumigant applied to a fumigation enclosure to treat a consignment. Usually expressed as weight of chemical per volume of treated space, e.g. g/m^3

Dunnage: materials used for supporting or protecting consignments during transportation

Fumigant: a chemical which at a particular temperature and pressure can exist in a gaseous state in sufficient concentration and for sufficient time to be lethal to insects or other pests

Fumigation: application of a fumigant to a fumigation enclosure to eradicate pests.

Fumigation certificate: documentation certifying that a fumigation treatment has been undertaken in compliance with importing country requirements.

Fumigation enclosure: any space or area designed to contain fumigant for the purposes of fumigation. Examples include containers, gas-proof sheets sealed to an impermeable floor with sandbags, and purpose built structures.

Normal Air Pressure (NAP): standard, natural atmospheric (air) pressure (10^5 Pa)

Pallet: a platform used to support cargo during shipment. Generally of standard dimensions to allow for easy stacking. Pallets used in shipping are generally made of timber, plywood, metal, plastic or moulded fiberboard.

Pest: any animal, plant or other organism that may pose a threat to the community or the natural environment.

Phytotoxic: poisonous to plants.

Quarantine pest: a pest of potential economic and / or environmental importance to an area where it is not yet present, or is present but not widely distributed and being officially controlled.

Skid: support placed under cargo to make it easier to maneuver. Generally consists of two pieces of timber placed under cargo to allow a forklift to raise or slide the cargo.

Sorption: the uptake of a fumigant by any material being treated with a fumigant. This may be reversible (unchanged fumigant may be released on airing) or irreversible (leading to residues of fumigant or breakdown of products in the commodity).

Timber: also known as lumber; term of commerce for wood, either in natural form as logs or in sawn units.

Threshold Limit Value (TLV): is the figure established for the maximum concentration of fumigant gases to which workers may be repeatedly exposed in the workplace without harmful effects. This figure is based on an 8-hours per day, 40-hour working week.

Half loss Time: is the time taken for one half of the original concentration of fumigant to be lost from a fumigation enclosure doe to leakage or sorption.

Leakage: is loss of fumigant gas from a fumigation enclosure.

Permeation: is loss of fumigant gas from a fumigation enclosure through gas-proof sheet, which are seldom completely impermeable.

Diffusion (Dispersion): is the process whereby a fumigant gas moves from an area of high concentration, ending with an equilibrium concentration.

Concentration: describe the amount of the fumigant in the air/atmosphere inside a fumigant enclosure during the exposure period, or in the workplace around fumigation enclosure, and is an expression of the weight or volume of fumigant gas in a given volume of air.

Equilibrium: occurs in well- sealed enclosure- after the dosage is applied- when the gas concentration remains stable and equal in all parts of the fumigation enclosure (within a specific range, e.g. plus or minus 15%) and remains above and established threshold for tolerant life stages of target pests)

Desorption: is the reverse of sorption. It is the release of sorbed fumigant gas from the product that was fumigated. Desorption generally occurs at the end of fumigation exposure, as the fumigant escapes or disperses out of the product during the aeration or ventilation state of a fumigation treatment.

GENERAL INFORMATION ON FUMIGATION TREATMENT

Requirements of effective fumigation:

Fumigation must not be considered unless all necessary resources are available, so that it can be done safely and successfully. If these resources are not available, then a fumigation must not be done.

Fumigation must not be attempted if:

- Trained fumigators are not available
- The enclosure in which the fumigation is to be carried out cannot be well sealed to the required standard of gas tightness, as will occur, for example, when there are drain under the stacks, and stacks built around pillar or columns
- Worker and other people cannot be reliably excluded from the enclosure and danger area
- The fumigant cannot be safely aired from the enclosure after the exposure is complete
- The commodity or product to be fumigated is likely to sorp excessive quantities of fumigant
- The temperature or moisture content of the commodity or product to be fumigate is below a threshold value.

For safety reasons, a fumigation should not be attempted in structures where:

- People have to work or live in the same building where a fumigation have to be done
- People may be exposed to the fumigant during the aeration period
- A building is closely surrounded by houses where people live.

Trained fumigation staff:

- Fumigation is complicated procedure that require careful planning and understanding of the processes involved. Fumigation must only be taken by trained and experienced people, who hold recognized, approved and current certification in the country where the fumigation is to be taken.
- Fumigation teams should be led by a fumigator in charge. A high level of supervision is required to be ensure.
- **“No licensed fumigator- no fumigation**”

Well-sealed enclosures:

Fumigations are carried out in an enclosure space. It must be possible to seal and make gastight the enclosures, in which the fumigation is to be undertaken. Fumigation enclosure must be well sealed, so that they can hold and effective concentration of fumigant over the whole of the exposure period.

Approve fumigant:

There must be enough fumigant available before the fumigation starts. The labels on the fumigant must be clear and give full instructions and warning notice in local language.

The fumigant of choice should be:

Registered for use in the country where the fumigation will be done, acceptable to the buyer, and market or end users of the commodity or product to be fumigated.

Choosing the correct fumigant for the treatment is important. Factors that can affect the choice of fumigant include:

- Market requirements for the commodity to be fumigated
- The time available to do the fumigation
- The temperature and moisture content of the commodity to be fumigated
- The sorptive capacity of the commodity to be fumigated

Material and equipment must include:

- Personal protection equipment (PPE) such as gloves, gas mask and appropriate canisters.
- Fumigant protection apparatus, available to monitor fumigant concentrations throughout whole of the exposure period.
- Gas sampling tubing and appropriate monitoring equipment.
- Appropriate fumigant release equipment.
    - For phosphine: tablet dispensing equipment, gloves. Cylinder gas dispensing equipment and phosphine gas generators.
    - For methyl bromide: gas cylinders, scales, heat exchanger gas distribution pipes, jets to vaporize the gas.
- A safe, lockable area must be available to store fumigant and fumigation equipment while the fumigation is being done. It should be at least 25 m from houses where people live and work.

PART A - METHYL BROMIDE FUMIGATION STANDARD

Methyl bromide fumigation has been a globally significant disinfestation treatment for many years. It has a reputation for effectiveness against a wide range of pests and has been used extensively.

1. Scope

This standard is for methyl bromide fumigation carried out for quarantine purposes. Some countries accept and encourage the use of other treatments for various commodities, the requirements for those treatments are not included in this standard.

2. Purpose

The purpose of this standard is to detail the procedure that fumigators must follow when performing methyl bromide fumigation for the purposes of meeting import and export requirements.

This document is based on “best fumigation practice/procedures” that will provide successful disinfestation treatments.

3. Methyl bromide as a quarantine treatment

Methyl bromide is the most widely used fumigant for quarantine purposes. It is favored in many countries for plant quarantine because of its reputation for having:

- good penetrating ability
- rapid action
- high toxicity to a broad spectrum of insects and similar pests.
- safe time

It is frequently used for treating timber, agricultural products, empty containers, foodstuffs, seeds and plants (with specific dosage) and wood packaging material.

3.1 Safety and methyl bromide formulations

Methyl bromide is an extremely toxic, odorless gas. Regulations in some countries (or states) may specify that methyl bromide used in fumigation treatments must contain a warning agent, typically 2% chloropicrin (tear gas). However, importers should be aware that methyl bromide with chloropicrin is phytotoxic to live plants, cut flowers, fresh fruit and vegetables and seeds. In many foodstuffs chloropicrin residues are not permitted in some countries such as Australia. Use 100% Methyl Bromide for plants for fresh fruit and flower.

NOTE: In some situations, the chloropicrin may condense and pool, adding to the health and safety hazards associated with the use of methyl bromide.

For the purposes of quarantine treatments, and where permitted, 100% methyl bromide should be used whenever possible. This is an extremely toxic substance. Its use should be subject to strict occupational health and safety standards to protect the people that are working with it as well as those who may be inadvertently exposed to it.

In countries where methyl bromide is only available either mixed with 2% chloropicrin or 2% carbon dioxide, fumigators must do the dosage calculations on the actual methyl bromide content only.

3.2 The commodity being fumigated

Some commodities are unsuited to methyl bromide treatment. Problems with taint or excessive sorption (causing safety hazards) may occur. The fumigated product may not be suitable for its intended use. If there is any concern that a commodity may be adversely affected by methyl bromide, importers, exporters and fumigators should seek expert advice regarding its effects or conduct tests on that commodity.

Methyl bromide is adsorbed by oils, fats and finely ground materials. In some cases, this may cause tainting, excessive bromide residues and phytotoxic.

The following table lists some commodities for which experts have found problems with methyl bromide fumigation. This list is not comprehensive and is provided for advice only.

Table 1: Goods for which problems can occur when fumigated with methyl bromide

<table>
<tr><td rowspan="2">1. Foodstuffs
a. Butter, lard and fats
b. Iodized salt stabilized with sodium hyposulphite
c. Full fat soybean flour, whole wheat flour, other high protein flours and baking powders
d. Nuts with high oil content</td><td>2. Leather Goods (Particularly kid or other leather goods tanned with sulfur processes.)</td></tr>
<tr><td>3. Woollens (Extreme caution should be used in the fumigation of Angora Woollens. Some adverse effects have been noted on woollen socks, sweaters, shawls and yarn.)</td></tr>
</table>

<table>
<tr><td rowspan="2">e. Certain baking sodas, cattle licks (i.e. salt blocks), or other foodstuffs containing reactive sulfur compounds
f. Bone meal

NOTE: Never exceed the recommended dosage or exposure periods for food or foodstuff commodities. Prior to repeated fumigation, have the food commodity analyzed for inorganic bromide residues.</td><td>4. Viscose rayon Those rayons processed or manufactured by a process in which carbon bisulfide is used.</td></tr>
<tr><td>5. Photographic chemicals
(Not camera film or X-ray film)</td></tr>
<tr><td rowspan="3">6. Paper
a. Silver polishing papers.
b. Certain writing and other papers cured by sulfide processes.
c. Photographic prints and blue-prints stored in quantity
d. "Carbonless" carbon paper.
e. Blueprint papers</td><td>7. Rubber Goods
a. Sponge rubber
b. Foam rubber, as in rug padding, pillows, cushions, mattresses, and some car seals
c. Rubber stamps and other similar forms of reclaimed rubber</td></tr>
<tr><td>8. Vinyl</td></tr>
<tr><td>9. Furs</td></tr>
<tr><td>10. Feathers (especially in feather pillows)</td><td>11. Rug Padding (Foam rubber, felts, etc.)</td></tr>
<tr><td>12. Charcoal, cinder blocks and activated carbon</td><td>13. Horsehair articles</td></tr>
<tr><td>14. Oil artworks</td><td>15. Sulfur-based paint</td></tr>
<tr><td>16. Cellophane</td><td>17. Polystyrene packaging, and containers</td></tr>
</table>

NOTE: Some living plant material (for example fresh fruit and vegetables, seed, bulbs and cut flowers) is fumigated with methyl bromide for quarantine purposes. Fumigation rates specified by countries are designed to minimize damage whilst addressing the quarantine risk.

4. Performing the fumigation

When performing a fumigation treatment for quarantine purposes it is the responsibility of the fumigator to comply with any relevant legislation or safety codes applicable to the state, country or area in which they are performing the treatment.

We will only consider methyl bromide fumigation valid for quarantine purposes if performed by a fumigation provider who employs competent fumigators. In some countries, competency is demonstrated by successful assessment against standard or equivalent. In other countries competency may be demonstrated against other standards.

4.1 Selection of good fumigation site

- The fumigation enclosure must be in a well-ventilated and sheltered area. The site must be protected from adverse weather conditions such as high winds and low temperatures. The site should not be a working area.
- High wind can be a major cause of fumigant loss.
- The use of ropes or belts may assist in holding fumigation sheets in place, preventing them from flapping loose.
- Water and electricity should be provided.

4.2 The fumigation enclosure

Fumigation treatments for quarantine purposes must be carried out in a tightly sealed enclosure.

Where it can be demonstrated that the fumigation enclosure is gastight (such as may be possible with a freight container or chamber) the use of sheeting is not necessary.

Where it cannot be demonstrated that the fumigation enclosure is gastight, fumigation sheets must be used. Gastight enclosure made up of good floor, standard sheet and sand snake.

4.2.1 The floor

The floor of any fumigation enclosure must be impervious to gas so that it is capable of maintaining the minimum fumigant concentrations for the duration of the treatment.

The floor of any site used for sheet fumigation must be:

- flat, horizontal and free of stones and other sharp objects so that a gastight seal can be made between the sheet and the floor with sand snake.
- free of cracks and drains or any other openings that will cause fumigant gas to leak out of the fumigation enclosure.
- Intact (well- sealed and good condition) concrete and asphalt are generally good floor surfaces for effective fumigation.

Surfaces such as soil, sand, base rock, paving and plywood are not suitable as a fumigation enclosure floor. To achieve effective fumigation on these surfaces they must be covered by gastight ground sheets. When ground sheets are used, they should extend one more meter beyond the base of the stack built on them, to make sure a gas tight seal can be made with the fumigation sheets. The two sheets can be joined and seal by tightly rolling (one meter) of each together then weighting it down with sand snake. Gas tightness can be improved if the sheets are rolled narrow strips of wood or sand snakes and held together with clamps or weights (e.g. sand snakes).

4.2.2 Commodity stacking

Stack must be separated from each other to allow fumigant gas circulation. It should be far from the wall at least 1 meter of each side to allow fumigators work conveniently.

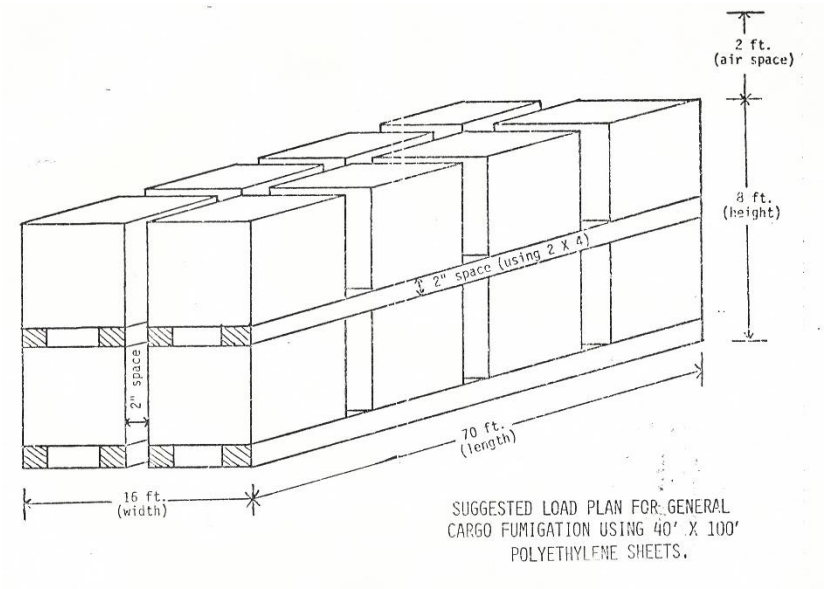
Make sure that the area of the stack is swept clean and so that a good floor seal can be achieved when the sheets are weighted down to the floor.

4.2.3 Rectangular stacks are preferred because:

- Fewer sheets are need to enclose them
- Less fumigant is need because they do not contain as much free air as irregularly shaped stack

4.2.4 Pallets

Stacks are often built on timber dunnage (pallets) if a floor sheet is used, it is essential to examine the underside of each piece of dunnage before it is place to the floor sheet. Any nails or other objects likely to damage the floor sheet must remove.



SUGGESTED LOAD PLAN FOR GENERAL CARGO FUMIGATION USING 40' X 100' POLYETHYLENE SHEETS.

4.3 Fumigation temperatures

The treatment dosages are based on the anticipated **minimum temperature of the enclosure is expected to experience during the fumigation period.**

This is important as the treatment dosages has outlined are based on the minimum temperature that will be experienced within the fumigation enclosure during the fumigation exposure period.

The minimum temperature for successful methyl bromide fumigation for quarantine purposes is 10°C. When temperatures are below 10°C within the fumigation enclosure some form of artificial heating must be used.

At temperatures below 10°C the fumigant has decreased effectiveness against pests, and increased sorption of the gas will occur. Excessive fumigant uptake can pose an increased safety risk, as the gas is very difficult to remove again from the commodity.

4.3.1 Overnight treatments

For fumigation treatments carried out overnight the fumigator must determine the average minimum ambient temperature expected within the fumigation enclosure for the duration of the treatment. This can be done using the estimated temperature for that region supplied by the local weather forecasting service.

The fumigation provider must record the temperature information on the Fumigation Certificate. For reviewing and examining by importing country.

4.4 Calculating the dosage of fumigant required

Fumigant dosage rates and the duration requirements of a fumigation treatment will differ according to the nature of the goods being fumigated. Dosage rates will be stated on the Permit to Import Quarantine Material or the Quarantine Direction relevant to that consignment. If the consignment is not accompanied by either of these it is the responsibility of the importer to obtain the correct dosage information from officer concerned.

Some of the more common standard dosage rates are listed in Table below.

Table 2: Common standard dosage rates for methyl bromide fumigation

PEST/COMMODITY	DOSAGE**
Giant African Snail rate	128g/m^3 at 21°C or above at Normal Air Pressure (NAP) for 24 hours
Khapra beetle rate	80g/m^3 for 48 hours at 21°C or above with a minimum concentration of 32g/m3 after 24 hours at NAP
Cosmopolitan stored product pest rate	32g/m^3 for 24 hours at 21°C or above at NAP
Timber rate	48g/m^3 for 24 hours at 21°C or above at NAP

** Generally, fumigation dosage rates are stated for 21°C or above

The fumigator must alter the dose by 8g/m^3 for every 5°C variation in temperature between 11°C and 21°C.

For each 5°C the temperature is expected to fall below 21°C the fumigator must add 8g/m^3. For example, the acceptable range would be:

32g/m^3 for 2 hours at 21°C and above (standard dosage)

40g/m^3 for 2 hours at 16°C-20°C

48g/m^3 for 2 hours at 11°C-15°C

56g/m^3 for 2 hours at 10°C.

For temperatures above 21°C no dosage compensation is allowed.

NOTE: Dilutents such as carbon dioxide (CO_2) are acceptable provided the fumigator calculates the dosage on the methyl bromide content only.

4.5 Calculation of fumigation enclosure volume

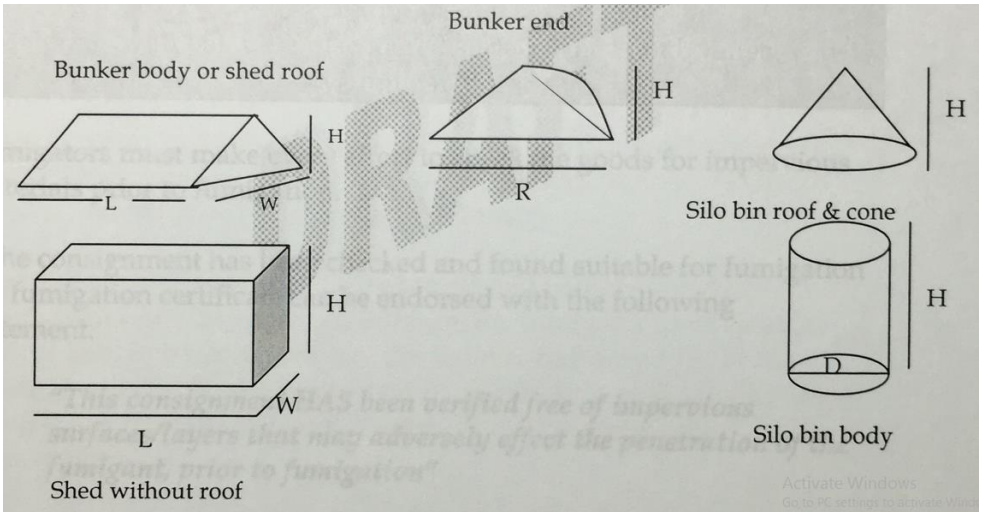
For the purposes of fumigation, the volume is the total space contained within the fumigation enclosure.

The volume of the enclosure is the height multiplied by the width by the length:

Volume = Height x Width x Length

Where an enclosed chamber is used for fumigation the volume of any gas circulation equipment external to the chamber must also be included in the calculation of the enclosure volume.

The following guidelines may be used to assist in calculating the volumes of different fumigation enclosures.



Measurements for calculating dosage only need be correct to the nearest meter.

The volume of a shed excluding the roof is	L x W x H
The volume of a shed roof, or the body of a bunker is	0.5 x L x W x H
The volume of a bunker end	0.53 x R x R x H
Silo bin body	3.2 X D/2 x D/2 x H
Silo bin roof or cone	1.6 x D/2 x D/2 x H

The internal volume of a storage can be calculated by adding up the volume of it parts.

L = Length W = Width H = Height

D = Diameter R = Radius

4.6 Impervious wrapping, surfaces and coatings

There are many factors to consider when fumigating various products. To ensure a product is not damaged during fumigation. It is advised that the client and the fumigator seek expert opinion on the best ways to prepare their goods for fumigation or conduct trials.

Unless specifically exempted by importing country, goods covered with or packaged in gas impervious materials (such as plastic wrapping or laminated plastic films, lacquered or painted surfaces, aluminium foil, tarred or waxed paper) must have the coverings or packaging opened, cut or removed, prior to fumigation. This must be sufficient to allow adequate gas penetration into the consignment and subsequent airing.

NOTE: Materials with painted or lacquered surfaces may not be effectively fumigated.

Fumigators must make every effort to check the goods for impervious materials prior to fumigation.

If the consignment has been checked and found suitable for fumigation the fumigation certificate can be endorsed with the following statement.

"This consignment HAS been verified free of impervious surfaces/layers that may adversely affect the penetration of the fumigant, prior to fumigation"

4.6.1 Fumigation of perishable commodities

Perishable commodities fall into several broad categories. They are live plants, cut flowers, fresh fruit and vegetables and some seeds.

The minimum acceptable temperature for fumigation of perishable commodities is 10°C, unless specifically exempted by importing country (e.g. the minimum temperature for treating New Zealand strawberries is 16°C).

When temperatures are below 10°C some form of artificial heating must be used such as temperature control room.

Unless otherwise specified by importing country, for fumigations with duration of two hours, at least 60% of the original fumigant must be retained at the end of the treatment. The faster in equilibrium made the better shelf life of the commodity.

NOTE ON POLYSTYRENE PACKAGE: It has been observed that methyl bromide concentrations decline below an effective level when used to treat grapes packed in polystyrene boxes.

4.6.1.1 Live plant fumigation

Some countries do not accept treatment of nursery stock by offshore treatment providers. It must be treated onshore. Export and fumigation provider should search this information from importing country before performing fumigation.

Living plants are likely to be damaged if fumigated at temperatures above 30°C.

4.6.1.2 Fresh fruit and vegetable fumigation

When fumigating fresh fruit and vegetables, the fumigator must use the fruit pulp temperature for dosage calculations, not the minimum ambient temperature as with other treatments.

The pulp temperature must be measured and included on the Fumigation Certificate. As a minimum, the fumigator must sample from at least one place in each of the bottom, center and top of the consignment. Each temperature probe should be placed into the center of a piece of fruit situated in the center of the carton (where appropriate).

4.6.2 Timber and timber products fumigation

Some countries will only accept fumigation of timber and timber products if:

- Individual planks, rounds or articles have at least one physical dimension which is less than 200mm (8 inches) thick
- The consignment is vertically separated every 200mm (8 inches)
- There is adequate physical distance (at least 50mm) between the timber and both the base and roof of the fumigation enclosure.

NOTE: There is no requirement for the separators to be a specific horizontal distance apart. However, they must maintain a continuous gap along the length of the timber.

This is because effective methyl bromide concentrations will only penetrate 100mm (4 inches) from the surface into the timber within the fumigation period. It also assists in getting adequate circulation on the fumigant around and throughout the consignment.

4.7 Using a vaporizer or volatilizer

For the performance of fumigation for quarantine purposes, a vaporizer or volatilizer MUST BE USED. Even in warm or hot climates fumigators cannot rely on ambient temperatures to adequately vaporize liquid methyl bromide during the gassing process.

Liquid methyl bromide has the potential to taint and damage certain products, such as seeds (loss of viability), aluminium (breakdown), foodstuff and other products (accumulation of residues). It may also change the processing quality of some products and in some cases react with materials present in the enclosure such as electronic goods.

The use of a vaporizer when introducing methyl bromide into the fumigation enclosure will ensure that the fumigant enters as a gas and is well distributed throughout the enclosure.

Complete fumigant vaporization ensures more effective distribution and penetration of the fumigant and reduces the possibility of product injury, pest survival and time of fumigation.

The only exception to this requirement is when methyl bromide is supplied from tins (or canisters) containing not more than 2.5 kg methyl bromide, when the temperature of the goods to be treated is at, or above, 15°C but not recommended to use.

Whenever methyl bromide is supplied from tins or canisters, the gas must be applied using commercially manufactured equipment to puncture the tins, with appropriate gas delivery lines / hoses leading to the goods inside the fumigation enclosure. This must be applied by skilled fumigator.

Figure 1: Vaporizer set

4.8 Fumigant distribution within the enclosure

An effective methyl bromide fumigation treatment requires a suitable system for distributing the fumigant within the fumigation enclosure because it heavier than air.

Where practical some form of forced distribution, such a fan, must be used to ensure adequate and rapid distribution of fumigant throughout the enclosure.

Fumigators can determine if the methyl bromide has been effectively distributed by monitoring gas concentrations at all monitoring points at set times after the introduction of the gas. If concentration levels cannot be achieved within more or less than 15%, the fumigant should be exhausted and the consignment should be re-gassed with the inclusion of a mixing device (fan).

For methyl bromide fumigation in small enclosures (such as shipping containers) at least one axial fan with a minimum of 70m^3/min (2500 CFM) should be used.

For fumigation of larger enclosures, at least two axial fans should be used. They should be run for 15 minutes after the introduction of the methyl bromide but some commodities can run the fan less than 15 minutes such as wooden pallets.

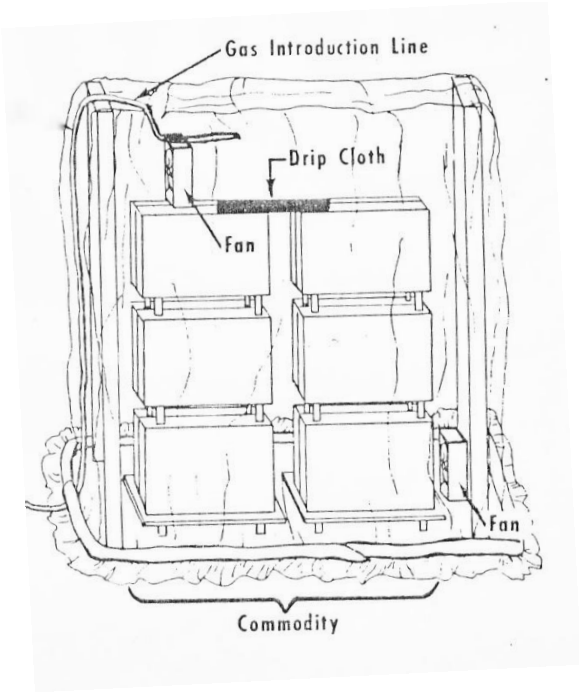
When two fans are used, one should be placed on the floor facing the center of the consignment. Under ideal conditions the other fan should be placed at the top of the opposite end, facing the consignment. Some standard place the first fan on the top of the consignment and the other fan placed at the bottom at the corner facing the consignment.

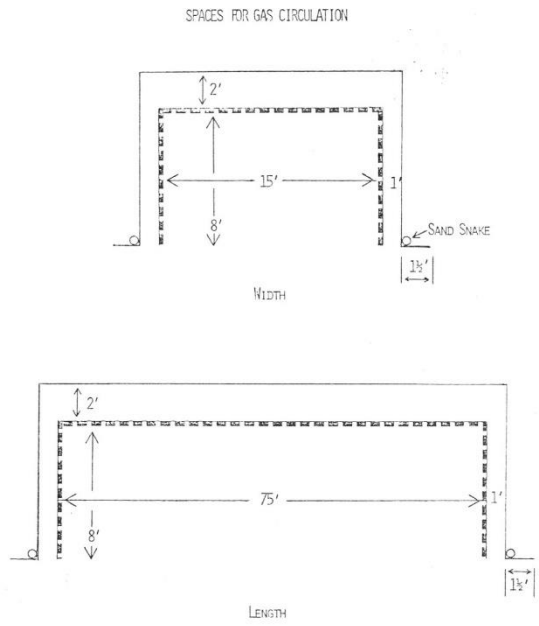
Additional fans should be used for consignments longer than 10m under fumigation.

NOTE: For fumigation of multiple containers under the same sheets each container requires its own fans to effectively distribute the fumigant.

Where high velocity and high volume fans are used they must not run for longer than for 15 minutes after the introduction of the gas. This is because they may force the fumigant out of the chamber.

Methyl Bromide





4.9 Fumigant supply lines & delivery of fumigant to the fumigation enclosure

Fumigators must position fumigant supply lines in a manner that allows for effective introduction and distribution of the methyl bromide into the fumigation enclosure. The fumigant must be introduced into the headspace above the consignment.

4.9.1 Multiple supply lines

Using multiple supply lines may assist in dispersing the fumigant for very large consignments under treatment.

Where multiple line systems are used the entire system must be balanced in order to achieve even distribution throughout the enclosure. Where the system is balanced it is possible to effectively deliver all of the fumigant through the entire system simultaneously.

Each arm of the system must contain fumigation supply lines that are equal in total length and diameter.

Where the fumigator cannot balance the system, they must dispense the right amount of fumigant though each supply line in turn until they have applied the total amount.

NOTE: Fumigators using methyl bromide formulations containing chloropicrin should be vigilant as some condensation and pooling of chloropicrin may occur.

4.9.2 Sealing supply lines

To prevent leakage from supply lines the fumigator must:

- make a gastight seal around every supply line exit point (from the enclosure)
- seal the exposed ends after the fumigant has been introduced into the enclosure.

4.9.3 Note on Methyl bromide formulations containing CO_2

Carbon dioxide (CO_2) is sometimes used to assist in the distribution of the fumigant. Methyl bromide is sometimes supplied in cylinders mixed with CO_2 to provide pressure to assist in dispensing the fumigant.

NOTE: High levels of CO_2 can give rise to incorrectly high methyl bromide readings on some commonly used monitors.

4.10 Fumigant sampling line specifications and placement

4.10.1 Fumigant sampling line specifications

In containers and other small fumigation enclosures the sampling lines should include internal tubes of crushproof (2mm ID hydraulic hose is effective).

For fumigation treatments requiring long sampling lines, fumigators may use other types of plastic hose. They should take care to ensure that:

- a free flow of gas/air mixtures can be maintained,
- the sampling lines are properly purged so the gas concentration INSIDE the fumigation enclosure is measured.

It is important for fumigators to make sure that no kinks or blockages are present in the hosing for this reason.

4.10.2 Placement of the sampling lines

Where practical and possible there should be at least three sampling lines within the fumigation enclosure; one line in each of the following positions:

- at the front base (mandatory)
- the top back
- in the center of the commodity being fumigated.

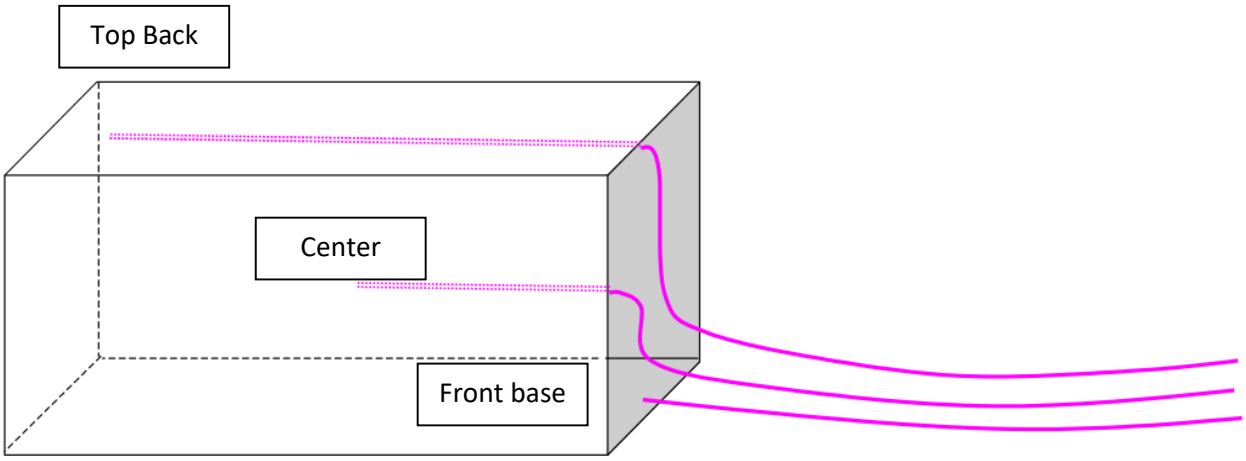


Figure: One container sampling line

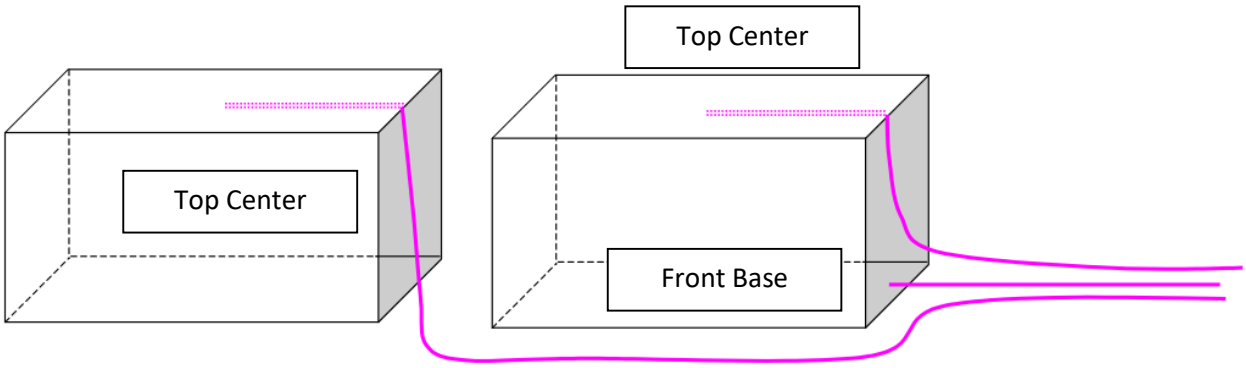


Figure 2: Two containers sampling line

NOTE: For multiple containers being fumigated in one stack, under the same sheets, each container must be treated as a separate enclosure - i.e. one sampling line should be used for each container.

Fumigators must:

- make the sampling lines identifiable from each other through the use of tags or individually colored tubes
- ensure that sampling line intakes are placed away from of the supply line outlets. Ideally, they will be equidistant from any outlet.

4.11 Sheet fumigation and sheet specifications

Prior to every treatment the fumigator must visually inspect all the fumigation sheets. The sheets must:

- be free from any defects (for example faulty seams/welds, tears or holes)
- have a permeability of less than 0.02 grams per day per square meter - expressed as g/m^3 for methyl bromide.

Tears, holes, and abrasions are a major contributing factor in significant gas loss.

Thinly coated, widely woven materials are unsuitable as fumigation sheets.

Pool liners or annealed polypropylene sheets are unsuitable as they transmit methyl bromide excessively.

4.11.1 Placement of fumigation sheets

The use of floor sheets is essential for sheet fumigation on porous surfaces.

for any sheet fumigation:

Figure 3: Cord, sampling line and gassing line are tightly sealed with wet sand before covering sheet

Figure 4: Sheeting container or stack and placing sandsnakes method

- a gastight seal must be made between the sheets and the floor using material such as loose heaped sand or sand or water snakes / flumes
- corners and areas where ropes, cords or sampling lines emerge from between or under the sheets must be tightly sealed by very wet sand.
- loose sheet on corners of stacks should be secured to prevent blowing out in the wind
- sheets must be weighed down and sealed to the floor using two rows of sand snakes sealed side by side like brickwork and laid flush against the consignment
- sheets must be positioned to avoid any sharp corners or objects that might damage them. This may require
- protection by covering problem areas with a suitable cushioning material
- sheets must be arranged so that there is at least 500mm of sheet extending beyond the limit of the seal.
- chains and timber are unsuitable for sealing sheets.

4.11.1.1 Sand and water snake specifications

Sand snakes must be filled only 65% - 75% with dry sand so that they lie flat on the floor.

If water snakes are used, the sheets must be weighed down and sealed using a single, continuous water snake laid flush against the consignment. Particular attention must be given to ensure a complete seal where the ends of the water snake meet.

4.12 Using gastight containers as fumigation enclosures

All containers must be fumigated under gas proof sheets unless it can be shown that they comply with pressure test standard for gas-tightness. This process must be undertaken every time before any container is fumigated.

The level of sealing required by DAFF must be measured using a pressure decay test. This corresponds to a pressure halving (or decay) time from 200-100 Pa of 10 seconds or more.

Containers that cannot be pressurized to 250 Pa (the starting pressure for the test) are deemed by DAFF to have failed the test and must be enclosed under gas proof sheets before being fumigated with methyl bromide.

4.12.1 Container selection

If it is possible to select a container before cargo is loaded into it the selection procedure below should be followed.

The containers should be positioned to allow easy access to all four sides and the roof. They should stand on a flat, horizontal surface to avoid twisting (or racking), which may prevent the doors from closing properly.

4.12.2 Procedure for pressure testing

The fumigator must determine the gas-tightness (pressure decay value) of the enclosure prior to the introduction of any fumigant. The result should be recorded on the Fumigation Certificate.

4.12.3 Inspect the container

All containers should be inspected before pressure testing. They should be structurally sound - with their sides and roofs free of significant holes, and free of obvious distortion. Containers that are obviously damaged, (for example where large holes and gaps are present in the roof and walls, or where the doors, door seals and locks do not fit and function properly), should not be pressure tested.

The container identification number should be recorded on the fumigation certificate.

4.12.4 Inspection procedure

The exterior of the container should be inspected to ensure it is structurally sound and in good condition - with no significant distortion. Its sides and roof must be sound and free of significant holes, tears or gaps.

Where rust is present the affected areas should be closely inspected and probed for holes.

Containers with holes, gaps or those that are badly rusted are not suitable for pressure testing.

The doors must make firm contact with each other, the door frame and floor sill so that their seals function effectively. The rubber seals around the doors should be unbroken, leaving no obvious gaps.

Containers with faulty doors and door seals are unsuitable for pressure testing.

The interior of the container should be inspected from inside, with the doors closed.

NOTE: For safety reasons, at least two people should be involved in the inspection - one person must remain outside the container at all time.

With the doors closed any gaps or holes should be visible as they will allow light to enter the container. Containers with any holes and gaps are unsuitable for pressure testing.

Containers with wet or damaged floors are unsuitable for pressure testing - the floor should be dry, in good condition and have no signs of extensive damage.

4.12.5 Close and seal the ventilators.

Make sure the area around each ventilator is dry and free from grease, then completely cover and seal all ventilators make them gastight.

4.12.6 Pressurize the container.

The pressure inside the closed container must be raised to 250 Pa using high pressure compressed air supplied from a portable compressor or gas cylinders.

4.12.7 Measure the pressure halving time

1) As the pressure inside the container reaches 250 Pa, turn off the compressed air supply.

2) Allow the pressure to decay to 200 Pa.

3) Start measuring the time (in seconds) when it reaches 200 Pa.

4) Stop measuring the time (in seconds) when it reaches 100 Pa.

5) Record the pressure decay time on the fumigation certificate / report.

NOTE: Containers that give a pressure halving time (from 200 to 100 Pascal) of 10 seconds, or more than 10 seconds, may be fumigated with methyl bromide without enclosing them under gas proof sheets.

It is considered that container with a pressure decay value, of 10 seconds or more than 10 seconds to be gastight.

If the pressure decay value does not meet this minimum requirement, the fumigator must choose another container (where appropriate) or perform sheet fumigation.

NOTE: Both container doors MUST be opened up against the sides of the container when containers are fumigated under gas tight sheets.

4.12.8 Materials and equipment for pressure testing containers

4.12.8.1 Closing the ventilators

The most effective way to close ventilators is to completely cover them with plastic sheeting (polyethylene or PVC) attached to the container using masking tape. Ventilators may also be sealed directly with masking tape, or plastic duct tape.

NOTE: Because plastic tapes stretch when they are unrolled, care should be taken to allow them to contract before attaching them to the container walls otherwise a good seal will not be achieved.

It is important to open all ventilators at the end of the exposure period - and always before the container is loaded onto any form of transport (trucks, ships etc.).

4.12.9 Pressurizing the container.

This should be done without drilling holes through the walls of the container. A purpose built 'finger manifold' would be appropriate for this purpose.

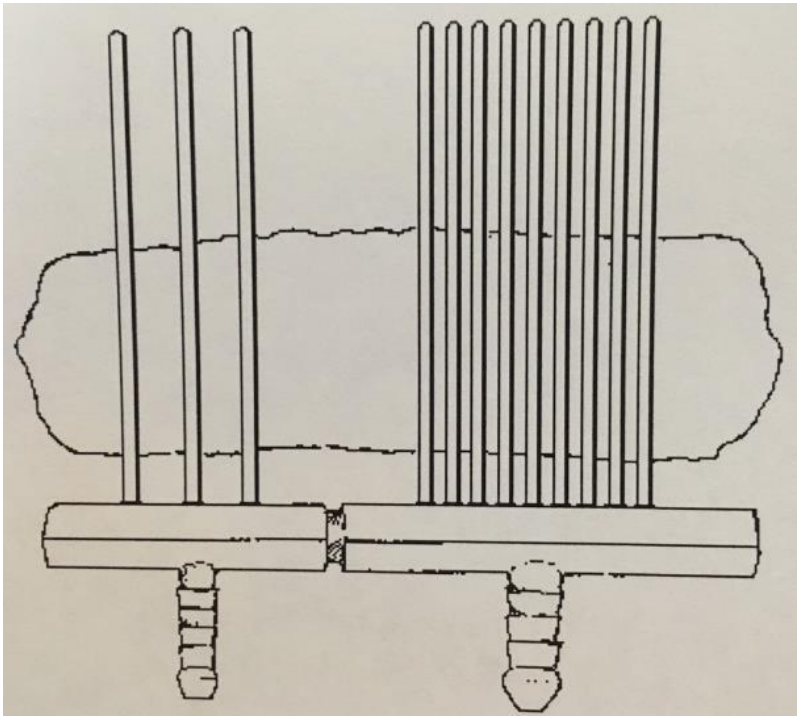


Figure 5: Example of a finger manifold designed for delivering compressed air into a container and then measuring the internal pressure of the container

The ‘finger manifold’ is design to deliver compressed air into a container, pressurizes it and allow the pressure decay to be measured. The manifold (illustrated above) has twelve ’fingers’, nine of which deliver compressed air into the container while three measure the pressure within it. The ‘fingers’ are made of soft copper tubing that can be bent to shape as necessary.

In use the manifold is bent to fit over the front of the sill so that it can be sealed between the right hand door and the sill and removed after the pressure test has been completed. See Figure below.

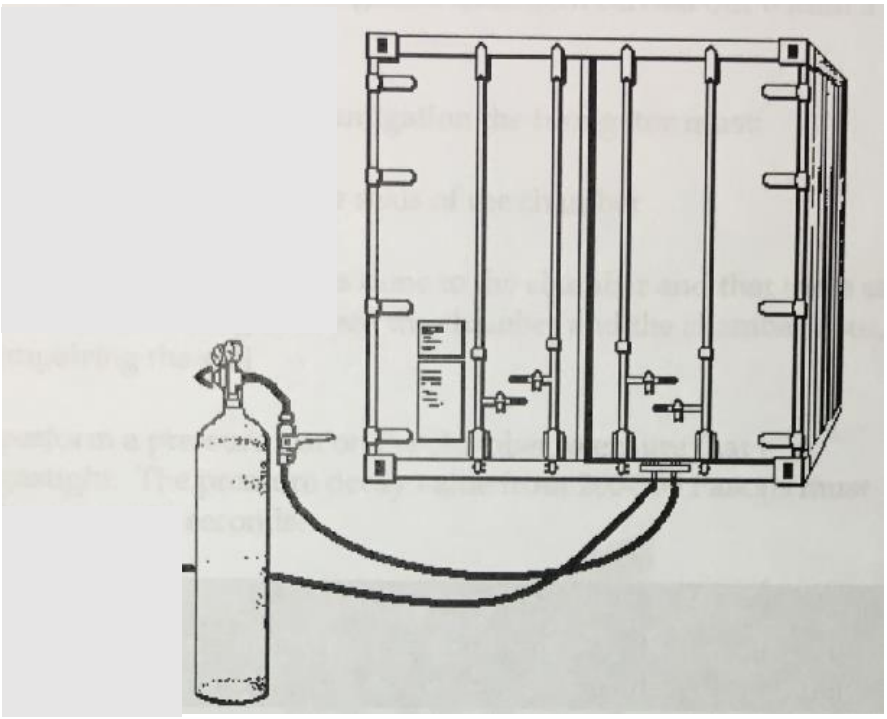


Figure 6: A finger manifold in use on a shipping container. The copper tubes can be bent over the door seal so that the door seals tightly around it.

4.12.10 Measuring the pressure halving time

The pressure inside the container may be measured using a variety of instruments. The equipment required ranges from relatively simple to proprietary instruments, including:

- a simple U tube manometer or an inclined manometer with a manually operated stop watch
- any sensitive pressure gauge with a manually operated stop watch
- a purpose made instrument, the CONTESTOR, that combines a pressure sensor with a timer that cuts in when the required pressures have been achieved.

The CONTESTOR includes a sensitive pressure gauge, digital timer and allows gas tightness to be measured by relatively unskilled operators and allows pressure tests to be undertaken rapidly when large numbers of containers have to be tested.

4.12.11 Un-sheeted container fumigation

Shipping can be used as fumigation enclosure without the need to cover them under a gas proof sheet. Any container used as a fumigation enclosure without sheet, is to be set up and managed as a separate fumigation, even if each container is part of the same consignment. For this reason, in some circumstances, it may be more efficient to fumigate multiple containers under a single fumigation sheet.

Container inspection

Before preparing the container for fumigation, the fumigator must:

- Check that there is space to position and operate the fan inside with the door closed
- Inspect the container for any visible holes or damage that would make it unsuitable
- Check the door seals are intact and in good condition
- Seal the air vents from the outside using impervious tape that will remain in place throughout the exposure period.

Container preparation

- Install sampling tube and fan in accordance with the requirements
- Arrange the tube and leads so they all exit the container where the doors meet at the base of the container. There is more space between the door at this point making them easier to close and less likely to compress or kink the sampling tubes. Tape or other suitable method of sealing can then be used to reduce leakage further.
- Injection the fumigant into the container should be done by inserting the supply hose through the door seals at the top of the container where the doors meet.
- A risk that could cause a problem is excessive leakage through the container floor.
- These leak may not be able to be detected and, even if they are, it is not practical to fixed them if the container is on the ground. If there are significant leak through the floor the rate of gas lost will be exacerbated by any wind passing under the container. This can be minimized by creating a barrier around the enclosure to reduce the airflow. One of the simplest method to create this barrier is to use sand snakes to cover any folk-lift holes or gaps. This doesn't intend to stop any leak only to slow down the effects of the wind.
- Monitoring at the start of the fumigation is advisable to give an indication of the rate of gas loss and if it is acceptable. If the monitoring shows a trend that may lead to fumigation failure, a possible solution may be to enclose the fumigation, as is, under a gas-proof sheet provided the fumigation surface is acceptable

4.12.12 Chamber fumigation

Chamber fumigation refers to fumigation treatment carried out within a specifically designed chamber.

Figure 7: Fumigation Chamber

Before performing any chamber fumigation, the fumigator must:

- Visually inspect the door seals of the chamber
- Ensure that no damage is done to the chamber and that there are no objects coming between the chamber and the chamber door, impairing the seal
- Perform a pressure test on the chamber to ensure that it is gastight. The pressure decay value from 200-100 Pascal must be at least 10 seconds.

NOTE: The pressure decay values for DAFF standards are for effectiveness only - occupational health and safety issues should be considered separately.

4.13 Measuring and monitoring equipment

There is a variety of equipment available for measuring methyl bromide concentrations. The equipment used should be suitable for the monitoring of fumigant concentrations and leaks.

Fumiscope (Monitoring Equipment)

Halide Detector Lamp

4.13.1 Specifications for monitoring equipment

Monitoring equipment should be capable of measuring methyl bromide concentrations within the fumigation enclosure of between 2-100 g/m^3.

The equipment used for measuring methyl bromide concentrations in **hazard areas** and post treatment clearance of the enclosure should be capable of detecting concentrations of between 2-100ppm v/v.

4.13.2 Maintenance of monitoring equipment

Monitoring equipment requires regular calibration and maintenance to ensure that it is operating effectively. It is particularly important to maintain the CO2 and moisture absorbers fitted to the instruments (if applicable).

Monitoring equipment must be maintained and calibrated according to the manufacturer's specifications.

Temperature probes used to determine fruit pulp temperatures should also be regularly calibrated using ice-slurry.

5. Measuring and monitoring fumigant levels

5.1 Options for ensuring maintenance of correct fumigant concentrations

Table 3: Options for ensuring maintenance of correct fumigant concentrations

Fumigation duration	Option 1	Option 2	Option 3
Less than 12 hours	Pressure testing and correct dosage application	Initial and endpoint monitoring – with top-up option at the end	
Greater than 12 hours	Pressure testing and correct dosage application	Initial and endpoint monitoring – with top-up option at the end	Continuous monitoring with top-up options

5.1.1 Option 1 - Pressure testing and correct dosage application

No monitoring is required after the fumigation has begun, provided:

- the fumigator performs a pressure test on the enclosure
- the pressure decay value is within the standards
- the correct amount of fumigant is introduced into the chamber.

NOTE: All of these details must be recorded and included on the Fumigation Certificate.

5.1.2 Option 2 - Initial and endpoint monitoring with top-up option at the end

The person monitoring the treatment must measure the methyl bromide concentrations within the fumigation enclosure at two specific times during the fumigation period. See table below.

Table 4: Monitoring times

Treatment length	Initial monitoring time	Final monitoring time
Up to 6 hours	20-30 minutes after start	End of treatment
Greater than 6 hours	30-60 minutes after start	End of treatment

NOTE: In the case of fumigation treatments of 48-hour duration, an additional measurement must be taken 24 hours into the treatment. This allows for the implementation of remedial action if required.

Measurements from all sampling lines should be within 1- 15% of each other at the set monitoring times. Where this is not reached at the initial monitoring time, the period must be extended or other action taken to resolve the problem

5.1.2.1 Problems with methyl bromide concentrations and sampling lines

If measurements from the sampling lines are not within more or less than 15% of each other at the set monitoring time, there may be a problem with:

- inadequate fumigant distribution throughout the enclosure, compromising the effectiveness of the treatment
- blockages in the sampling lines
- other sampling problems
- monitoring equipment
- gas-tightness
- fumigation sheets
- enclosure seals
- adequate circulation (fans etc.).

If the fumigator can determine the cause and subsequently rectify it without compromising the fumigation enclosure, the fumigation can continue as normal. If a top-up is required, it must be performed as per Option 3. Fumigators should keep a record of the problem and solution.

Where the fumigator cannot readily identify the cause (particularly in smaller fumigation enclosures, such as containers) they should stop treatment and vent the fumigant from the enclosure.

Once the area is safe (free of fumigant levels hazardous to humans) the fumigator should inspect the consignment and enclosure for possible causes.

If the cause can be identified and rectified, the fumigator and client should discuss their options for re-treatment.

5.1.2.2 Minimum fumigant concentrations for initial and endpoint monitoring

Unless otherwise prescribed by DAFF, the percentage concentration of methyl bromide in the enclosure at the end of the treatment must fall within the values in table below.

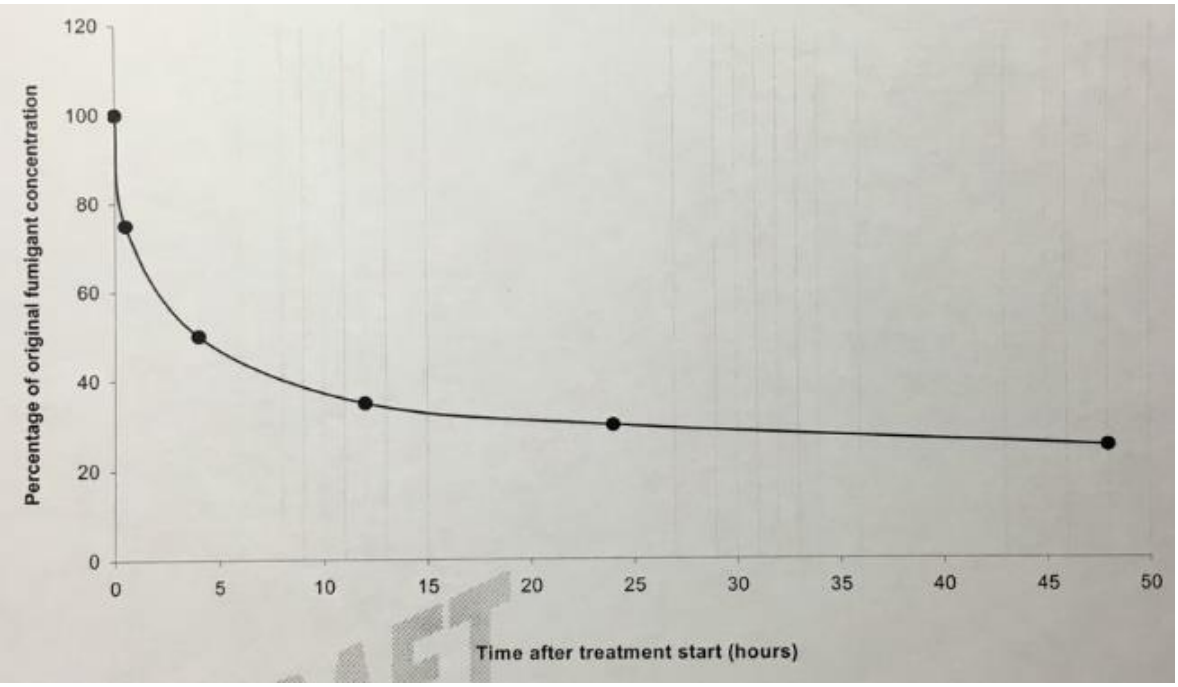
Table 5: Standard concentrations required at times.

Monitoring times	Concentration of the original fumigant required
0.5 hours	75% or more
2 hours	60% or more
4 hours	50% or more
12 hours	35% or more
24 hours	30% or more
48 hours	25% or more

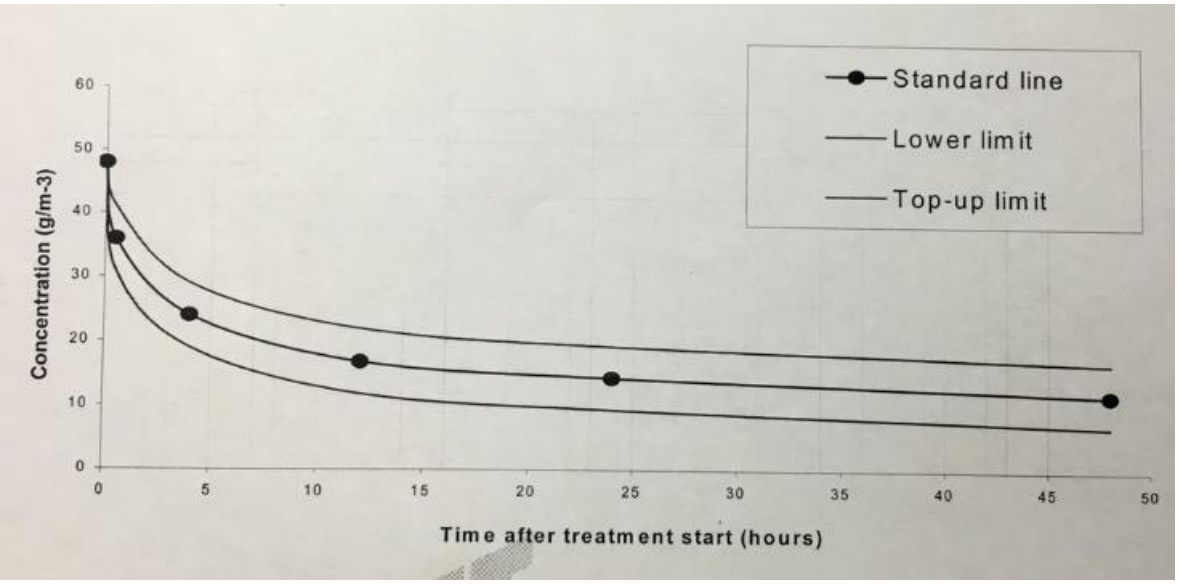
The fumigator must record all monitored concentrations on the fumigation certificate.

NOTE: Table 4 shows only standard retention rates - some retention rates may differ for specific commodities. If you have any doubts about the commodity you are treating contact plant quarantine officer directly.

Graph 1: Percentage of original dosage required vs time for 48g/m^3



Graph 2: Concentration vs time (48g/m^3 initial dosage fumigation)

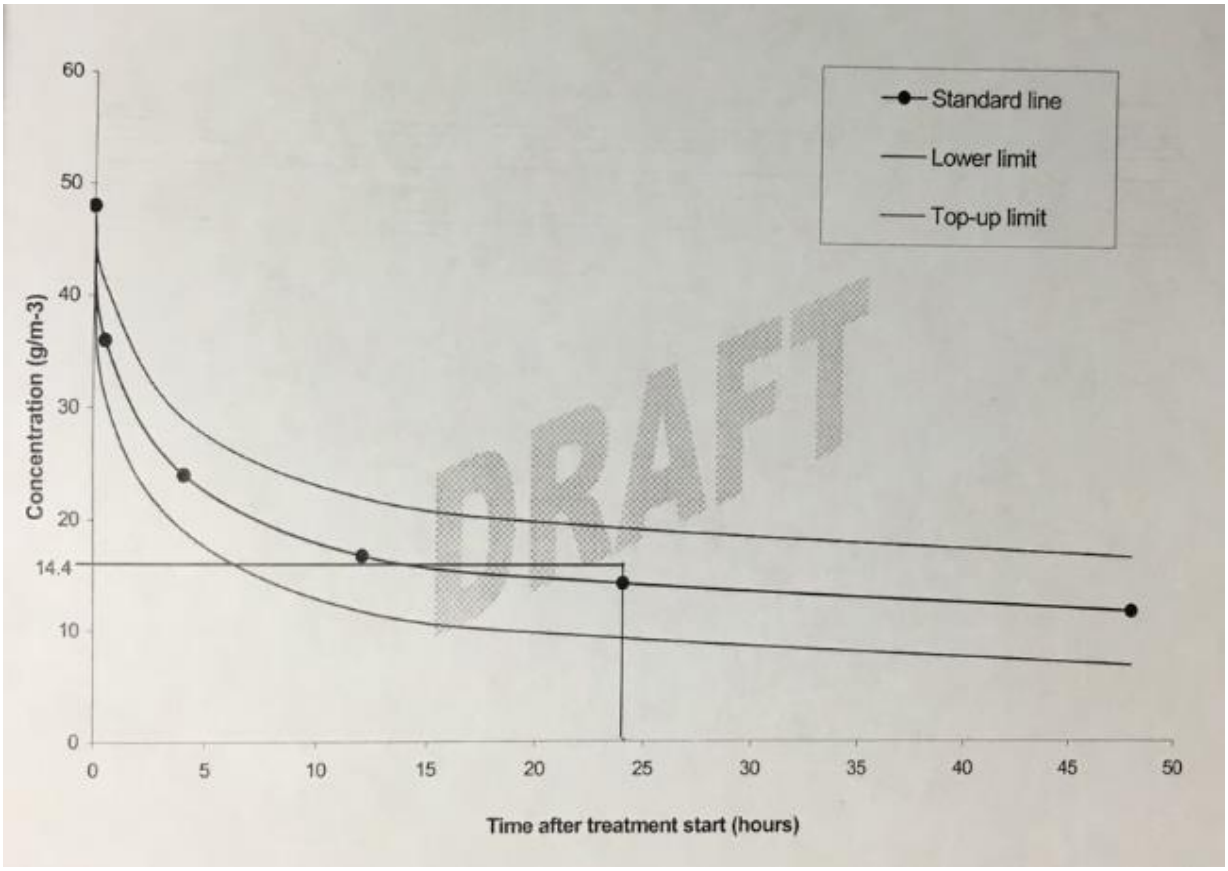


5.1.2.3 Final monitoring above the standard line

If the concentration of fumigant remaining at the final reading is on or above the standard, it will consider the fumigation to have been completed successfully.

For example, for a fumigation with an initial dosage of 48g/m^3 and for 24 hours' duration the minimum concentration required at the end of the 24 hours would be 14.4g/m^3 (see graph 3).

Graph 3: 24 hours reading of concentration vs time (48 g/m^3) initial dosage fumigation



5.1.2.4 Final monitoring between the standard and the lower limit

If the final reading falls between the standard and the lower limit the fumigator has the option of topping up the fumigant level. The fumigant can only be topped up to the corresponding value on the top-up limit line and no more.

The fumigation period must also be extended for a further 4 hours duration.

NOTE: For fumigations less than 12 hours in duration top-up is not an option.

For example, on graph 4 (below) point A represents the final reading, say 13g/m^3, in a 24-hour treatment with an initial dosage of 48 g/m^3. This is below the standard line but is still above the lower limit line. Top-up should be performed.

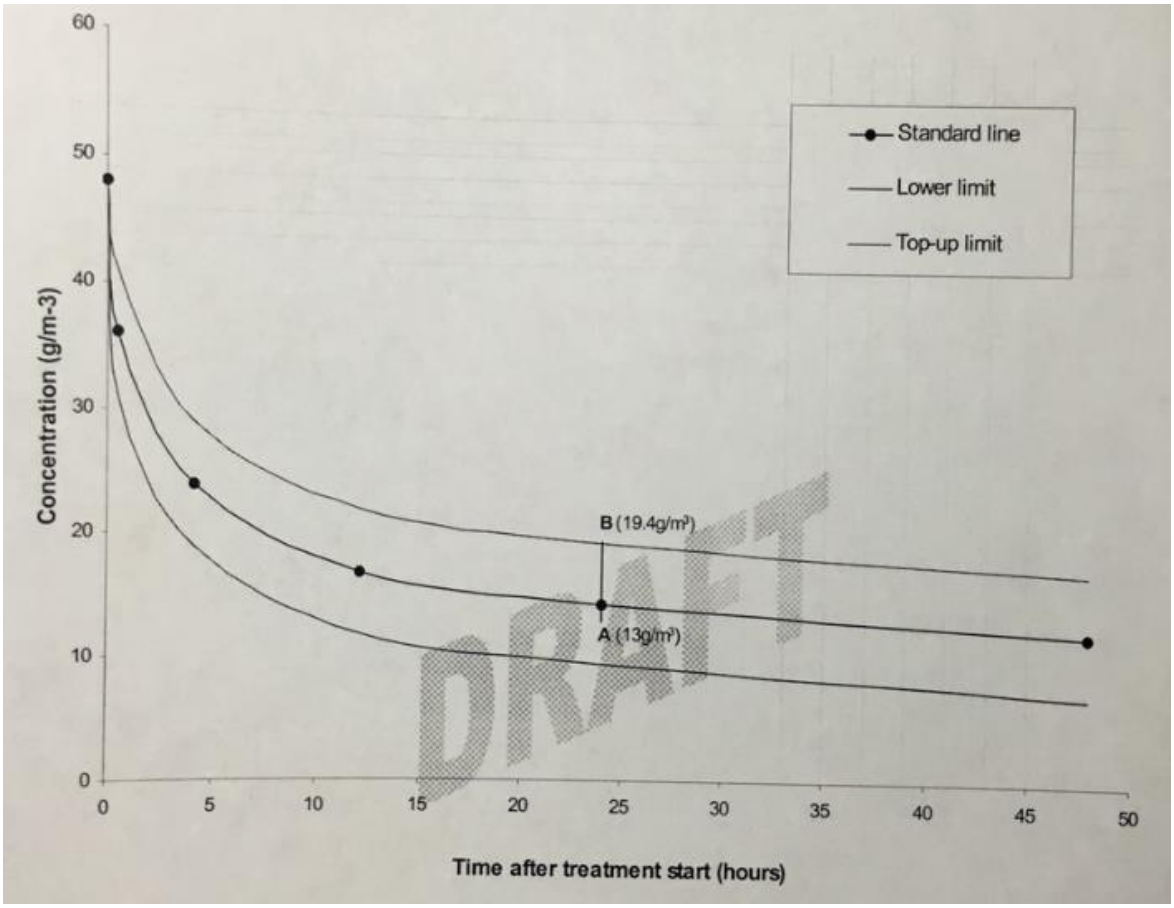
NOTE: The lower limit and the top-up limit are 5g/m^3 below and above the standard line respectively. For initial dosages above 60g/m^3 they are 8g/m^3 above and below the standard line respectively.

The amount of fumigant the fumigator can add is the amount required to make it up to the standard line plus 5g/m^3 (8g/m^3 for fumigations above 6Og/m^3).

For example, at point A is 13 g/m^3 and the standard concentration required is 14.4 g/m^3. The maximum top-up point is at point B (19.4g/m^3)

So the amount you could add would be 1.4g/m^3 (top-up to standard line) + 5g/ m (to reach point B). The amount of fumigant for the top-up would be 6.4g/m^3 in total (i.e. 19.4 - 13 = 6.4)

Graph 4: Concentration vs time (24-hour top-up)



5.1.2.5 Final monitoring below the lower limit line

If the final reading is below the lower limit (i.e. more than 5g/m^3 below the standard line or for fumigations with dosage rates greater than 6Og/m^3, 8g/m^3). It will be considered the fumigation to have failed.

The fumigator should vent off all of the remaining fumigant. Once they can ensure the area is free from hazardous levels of fumigant they can then inspect the fumigation enclosure for the possible cause. When the cause is rectified the fumigator may then re-fumigate the consignment (if appropriate) at the required concentration in accordance with standards.

5.1.3 Option 3 - Continuous monitoring with top-up options

Fumigators must measure the fumigant concentrations at intervals during the treatment. Monitoring at the set times as for option 2 must still be done. However, fumigators may elect to monitor at intervals not greater than 6 hours apart throughout the fumigation if they suspect that the relevant final concentration will not be achieved. For example, where large fumigation enclosures are being used and some leakage is expected, or under circumstances where there are highly sorptive commodities, it may be necessary to add additional fumigant to ensure the desired treatment concentrations can be maintained.

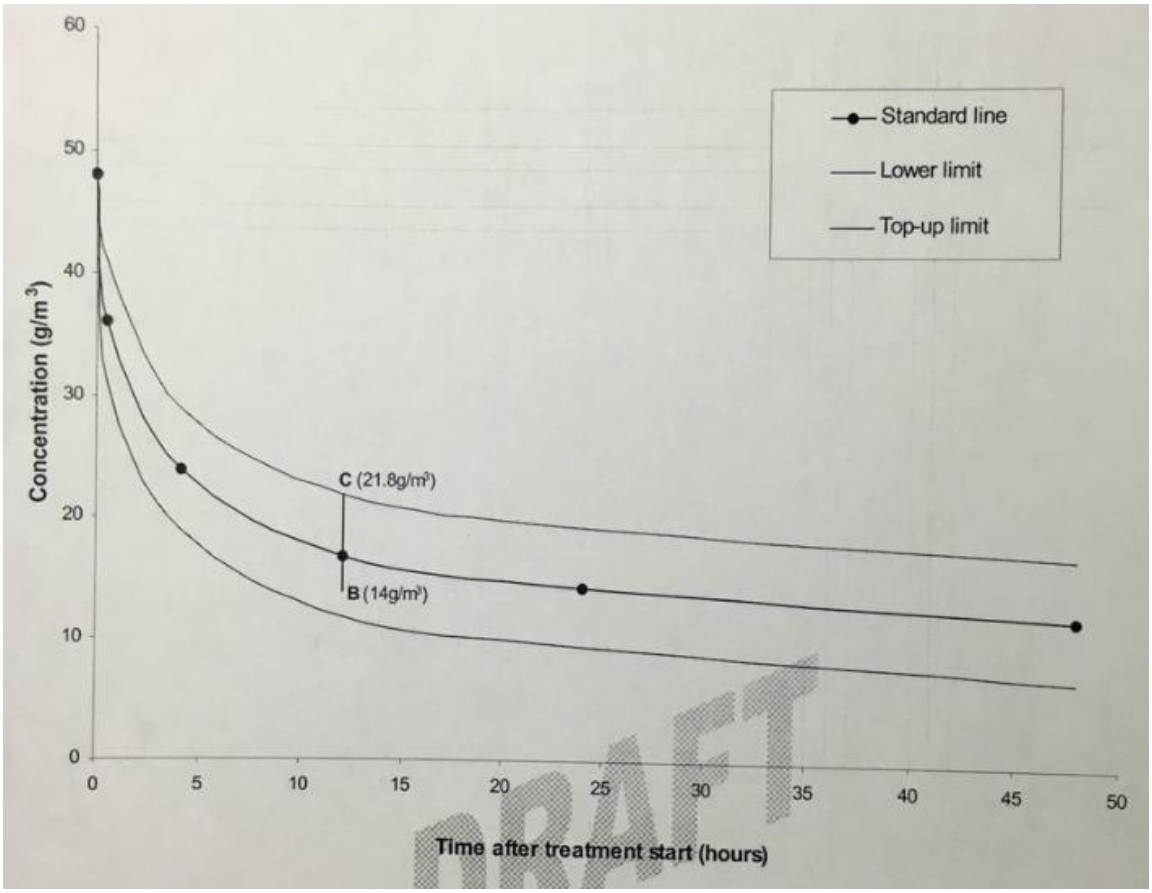
Australian will only allow for one top-up during any given fumigation treatment.

Where fumigant level checks indicate that the fumigant concentration has dropped or is likely to drop below the standard and provided it is still above the lower limit the fumigator can top-up the fumigant. The fumigator should first inspect the fumigation enclosure for possible causes of fumigant loss. After they have identified and rectified the problem they can then top-up the fumigant level. Top-ups must be performed the same way as for Option 2.

Graph 5 (below) is an example for fumigant top-up at the 12-hour point in 24 or 48-hour fumigation.

For example, if the concentration at point B is 14g/m^3 and the standard required is 16.8g/m^3 then the maximum amount the fumigator could add would be 2.8g /m^3 (the difference) + 5 = 7.8g/m^3. Therefore, point C will be at 21.8g/m^3.

Graph 5: Concentration vs time (12-hour top up)



5.2 Airing

On completion of any fumigation treatment the fumigator must vent the fumigant from the fumigation enclosure to below 5ppm v/v (the current Threshold Limit Value (TLV) for methyl bromide). They can do this through either natural airing or forced ventilation.

Before anyone is allowed access to the fumigation enclosure the fumigator has the responsibility to take precautions to ensure that the area is free from hazardous levels of fumigant.

Inadequately aerated goods threaten the health of workers involved in their unpacking and inspection. Where there is no documentation showing that an enclosure or container has been vented, handlers should treat it as still 'under gas until a qualified fumigator has cleared it as safe.

5.3 Certification and release

Fumigation providers must issue a certificate to indicate that the fumigation was successful and conformed to standards.

6. Selected References and Further Reading

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APPENDIX A1: METHYL BROMIDE AS AN OZONE DEPLETING GAS

At a meeting in November 1992 of signatories to the Montreal Protocol methyl bromide was listed as a category I ozone depletant. This decision was made due to concern that its continued use would threaten the integrity of the ozone layer. The depletion of the ozone layer allows greater amounts of ultra violet (UV) radiation to reach the surface of the Earth. Subsequently, developed countries have agreed to progressively phase out the general use of methyl bromide by the year 2005 and developing countries by 2015.

Recognition that methyl bromide is an important tool in quarantine, without alternatives in many cases, has seen an international exemption on phase out for quarantine purposes for the time being. However, it is likely that as the phase-out takes effect the costs of producing methyl bromide will increase substantially, and the commodity will become increasingly difficult to obtain. As a result, and despite the current exemption, it is likely that methyl bromide has only a limited future for quarantine purposes.

Lao PDR recognizes the ozone depleting properties of methyl bromide and is actively seeking to reduce methyl bromide use and emissions where possible within the constraints of quarantine protection.

Suppliers and users of methyl bromide need to be aware that the import of this gas in Lao is prohibited under the law.

Monitoring Ready Reckoner for Methyl Bromide

PETER MEADOWS Consulting Pty Limited
www.petermeadows.com.au

Adapted from the AQIS Methyl Bromide Fumigation Standard

Dosing Phase	Initial Dosage	24g/m³	32g/m³	40g/m³	48g/m³	56g/m³	64g/m³	72g/m³	80g/m³	128g/m³
Gas Distribution Phase Before Start Point	< 1 hr after gas introduction (75% or more of initial dosage)	24 / 18	32 / 24	40 / 30	48 / 36	56 / 42	64 / 48	72 / 54	80 / 60	128 / 96
	≥ 1 hr after gas introduction (70% or more of initial dosage)	24 / 16.8	32 / 22.4	40 / 28	48 / 33.6	56 / 39.2	64 / 44.8	72 / 50.4	80 / 56	128 / 89.6
Fumigation Phase Methyl Bromide Concentrations after Start Point	2 hrs after start point (60% or more of initial dosage)	19.4 / 14.4 / 9.4	24.2 / 19.2 / 14.2	29 / 24 / 19	33.8 / 28.8 / 23.8	38.6 / 33.6 / 28.6	46.4 / 38.4 / 30.4	51.2 / 43.2 / 35.2	56 / 48 / 40	84.8 / 76.8 / 68.8
	4 hrs after start point (50% or more of initial dosage)	17 / 12 / 7	21 / 16 / 11	25 / 20 / 15	29 / 24 / 19	33 / 28 / 23	40 / 32 / 24	44 / 36 / 28	48 / 40 / 32	72 / 64 / 56
	12 hrs after start point (35% or more of initial dosage)	13.4 / 8.4 / 3.4	16.2 / 11.2 / 6.2	19 / 14 / 9	21.8 / 16.8 / 11.8	24.6 / 19.6 / 14.6	30.4 / 22.4 / 14.4	33.2 / 25.2 / 17.2	36 / 28 / 20	52.8 / 44.8 / 36.8
	24 hrs after start point (30% or more of initial dosage)	12.2 / 7.2 / 3**	14.6 / 9.6 / 4.6	17 / 12 / 7	19.4 / 14.4 / 9.4	21.8 / 16.8 / 11.8	27.2 / 19.2 / 11.2	29.6 / 21.6 / 13.6	32 / 24 / 16	46.4 / 38.4 / 30.4
	48 hrs after start point (25% or more of initial dosage)	11 / 6 / 3**	13 / 8 / 3	15 / 10 / 5	17 / 12 / 7	19 / 14 / 9	24 / 16 / 8	26 / 18 / 10	28 / 20 / 12	40 / 32 / 24

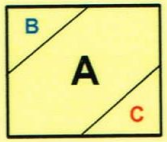
Dosing is complete once ALL the required amount of gas has been introduced into the enclosure

Start Point is achieved when ALL monitor point readings are at or above the standard AND within 15% of the lowest reading (Equilibrium)

During this phase, if the concentrations fall below Standard because of sorption or leakage, if redistribution will not be effective and if the cause can be identified and rectified without releasing the remaining fumigant, fumigant may be added, up to the initial dosage, and fumigation re-commenced.

The exposure period commences only when Start Point has been reached.

For example, if a 24 hr fumigation reaches Start Point 1 hours after dosing, fumigation is considered complete 25 hours after dosing if all concentrations are at or above the standard concentration (A) at 24 hours



A = Standard concentration
B = Maximum concentration for top-up
C = Minimum concentration to allow top-up

** Methyl Bromide Concentrations less than 3g/m³ are below the threshold for effectiveness

Methyl Bromide Concentrations (g/m³) required to meet the AQIS Fumigation Standard

APPENDIX A2: METHYL BROMIDE FUMIGATION READY RECKONER

APPENDIX A3: EXAMPLE OF A FUMIGATION CERTIFICATE

COMPANY LETTER HEAD

Certificate Number: **DOA number:**

This is to certify that the following regulated article has been fumigated according to the appropriate to conform to the current phytosanitary requirements of the importing country:

ARTICLE DETAILS

Description of goods: ……

Quantity declared: …… Distinguished marks: ……

Consignment Link: ……

Country of origin: …… Port of loading: ……

Country of destination: …… Declared point of entry: ……

Name and address of consignor/exporter/shipper: ……

……

Declared name address of consignee/buyer/notified party: ……

……

TREATMENT DETAILS

Name of fumigant: …… Date of fumigation: ……

Place of fumigation: ……

Dosage: …… Exposure period: ……

Minimum air temperature: …… Fruit temperature: ……

Fumigation carried out under gas tight enclosure/ sheet: ☐ yes ☐ no ☐ n/a

Fumigation performed in a container: ☐ yes ☐ no ☐ n/a

Container meets pressure test requirements: ☐ yes ☐ no ☐ n/a

Container has free air space in accordance with the fumigation standard: ☐ yes ☐ no ☐ n/a

Container has been ventilated to below TLV: ☐ yes ☐ no ☐ n/a

WRAPPING AND TIMBER

Has the commodity been fumigated prior to lacquering vanishing painting or wrapping? ☐ yes ☐ no ☐ n/a

Has plastic wrapping been used in the consignment? ☐ yes ☐ no ☐ n/a

- If yes, has the consignment been fumigated prior to plastic wrapping? ☐ yes ☐ no ☐ n/a
- Or has the plastic wrapping been slashed, opened or perforated in accordance with Lao standard? ☐ yes ☐ no ☐ n/a

Is the timber in this consignment less than 200 mm thick in one dimension and correctly spaced every 200 mm in height? ☐ yes ☐ no ☐ n/a

---

ADDITIONAL DECLARATIONS

……

……

……

I declare that these details are true and correct and the fumigation has been carried out in accordance with the Lao standard.

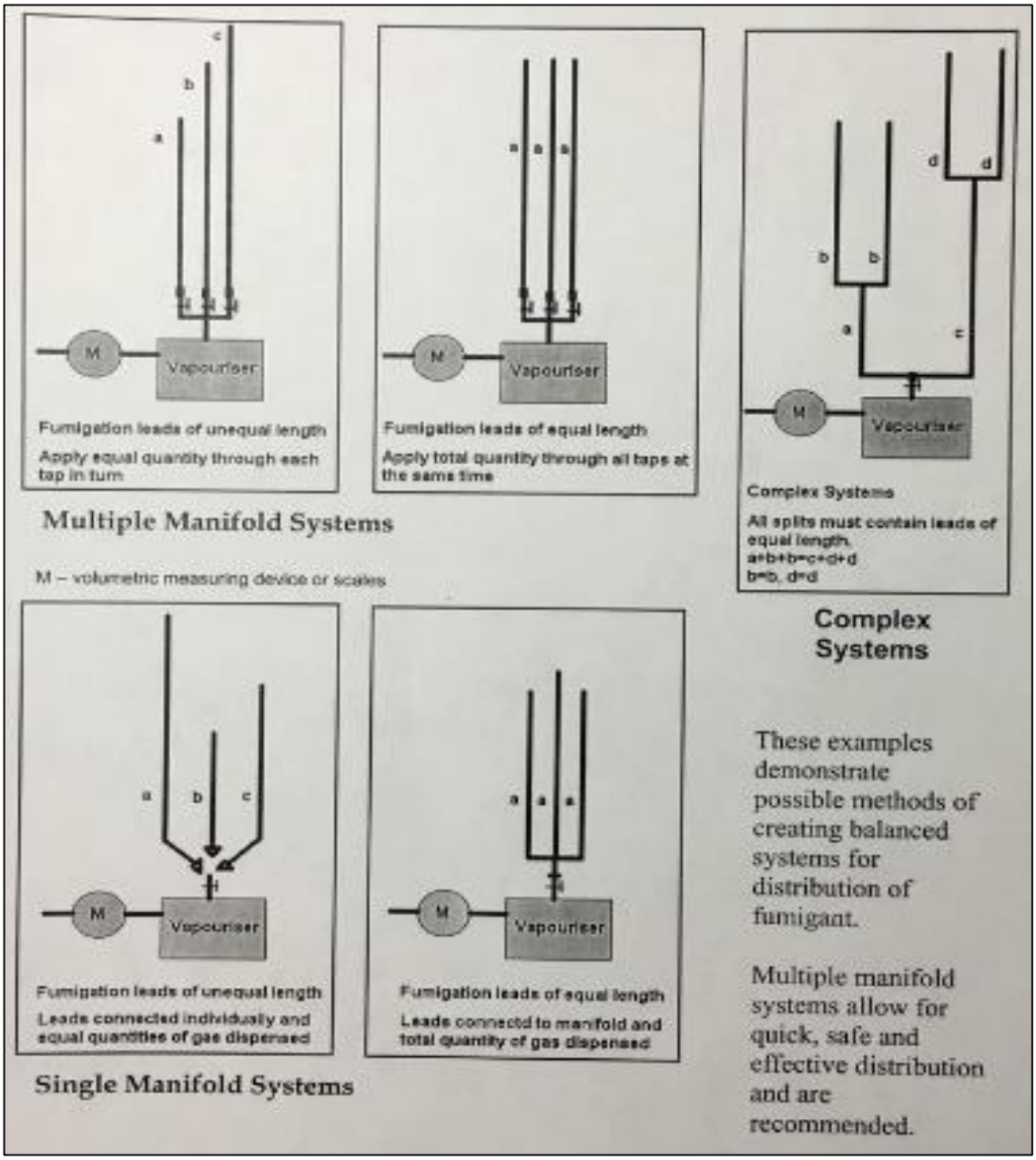
Place and Date

Company stamp

Signature and Name of Accredited Fumigator

APPENDIX A4: FUMIGATION SUPPLY LINE SYSTEMS

Arrangements of fumigation leads for single and multiple manifold systems to ensure balanced distribution of fumigant into the fumigation area.



The overlying principle is that a balanced system will distribute the same volume of gas through each arm of the system in the same time. If it is not possible to achieve a balanced system, then balanced application must be achieved by distributing measured amounts of fumigant through each arm of the system.

PART B: PHOSPHINE FUMIGATION STANDARD

1. Introduction of Phosphine Fumigation

Fumigation with phosphine is generally consider to be much easier than fumigation with methyl bromide because phosphine is generated from solid metal phosphide preparation (pellets, tablets, plates, sachets, chains blankets etc.). The extra demand of phosphine fumigation arises because the dosages used with phosphine kill the larval and adult life stages of insects. These are called the susceptible life stages. The eggs and pupae are not killed. These are called the tolerant life stages. Increasing the dosage will not kill these life stage. These life stages are killed by allowing them to grow and develop into the next susceptible life stage- egg to larvae, and pupae to adults- while they are inside the enclosure. This is why long exposure period extending up to 7-8 days (sometimes longer) are required when fumigation treatment is done with phosphine.

In fumigation practice this mean that:

- The concentration of phosphine inside the enclosure must be held at a poisonous level long enough to allow eggs and pupae to develop through larvae and adults
- Enclosure made with fumigation sheets must be sufficiency gastight to allow phosphine to be held up to this concentration for up to 7-8 days
- Fumigation treatments where most gas is lost by about the fifth day will fail.

2. Hydrogen Phosphide or Phosphine (PH_3)

Phosphine can be used to treat grain stored in various structure. It is qualities effective fumigant which

- Highly toxic to all life stages of insects if proceed proper fumigation standard.
- It is cheap, readily available and economical to use.
- It can be used for treating seed without adverse to seed germination.

2.1 Metal Phosphide (PH_3)

- Aluminium phosphide $Al_2(PH_3)_3$
- Magnesium phosphide $Mg_3(PH_3)_2$
- Inert ingredient
    - Ammonium carbonate
    - Ammonium bicarbonate
    - Urea and paraffin
    - Calcium (impurity)
    - Sodium (impurity)
    - Heavy metal (impurity)

- These materials are used for regulating releasing of the gas and suppress flammability.

All Aluminium Phosphide Formulations are not equal depend on

- Purity and quality of raw materials.
- Degassing and spent residue in flasks / sachets.
- Quick release of gas during application.
- Temperature attained during gas release, ignition temperature should never occur during fabric.
- Hardness of the formulations (tablets and pellets).
- Sachets with appropriate fabric.
- Use of red phosphorus, not yellow or white, to produce a greyish color product.

2.2 Properties of Phosphine

Formula	PH_3
Molecular weight	34
Boiling point	-87.4 °C
Specific gravity (air = 1)	1.17
Vapor pressure	42
Flammability limits in air (v/v)	1.79 %
Solubility in water (v/v)	26 %

Flammable and explosive with high concentration

React with Gold, Silver and Copper

High toxic with insect and mammal

No residue

Threshold limit value (TLV)	0.3 ppm

Pure phosphine concentration lower than 220 ppm is odorless

2.3 Type of phosphine in commercial used

There are two types of PH_3 used in commercial in fumigation for stored grain. They are Aluminium phosphide and Magnesium phosphide with purity of PH_3 approximately 50-60 %. Mostly in pellet product especially for Mg_3P_2. Aluminium phosphide is produce in various types such as table, pellet, sachet, plate and strip

Tablet contain pure PH_3 1 gram (a.i.) in 3 gms of tablet

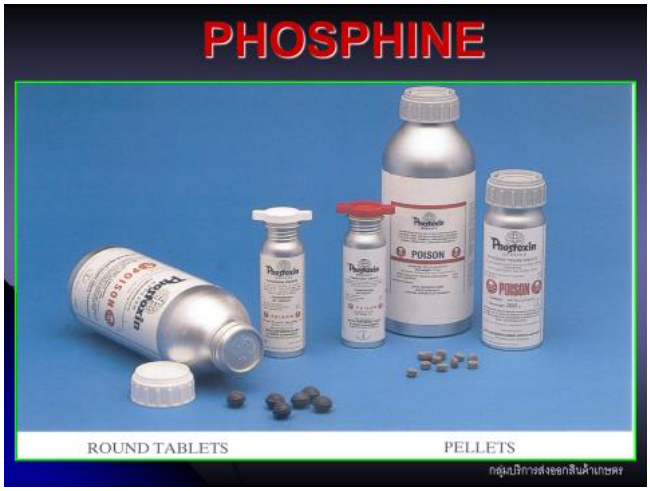
Pellet contain pure PH_3 0.2 gram (a.i.) in 0.6 gms of pellet

One unit of AIP or Mg_3P_2 contain 1/3 of pure PH_3

Magnesium phosphine formulation as: Tablets or pallets

Flat plates: The formulation is embedded in plastic matrix that regulate access of moisture and control release of the gas.

Residue consists of aluminium and magnesium hydroxide.



2.4 Gas release

Phosphine gas is release from the product by the influence of temperature and moisture. Reaction time for gas release will vary depending on the moisture and temperature. It starts slowly gradually accelerates are then tapers of

- Aluminium

  $AIP + 3H_2O \rightarrow Al(OH)_3 + PH_3$

- Magnesium

  $Mg_3P_2 + 6H_2O \rightarrow 3Mg(OH)_2 + 2PH_3$

Magnesium release gas faster than Aluminium when dosage rate;

- 2 gms/cu.m or 2-3 tablets for 1 MT of grain
- Exposure period 5-7 days
- Cannot increase dosage rate and reduce exposure time

2.5 Toxicity

- 2,000 ppm in air lethal to human in a very short time
- Threshold Limit Value(TLV) at 0.3 ppm. for a 40 hrs. work week.
- Toxic to store product insects but decline as the temperature fall to 5 c
- Require long exposure time normally 4 or more days
- Exposure time cannot be shortening by increasing the dosage.
- Exposure time can reduce by adding carbon-dioxide
- Egg and pupae are usually hardest to kill, so 10 days of fumigation may reach the susceptible state of insect.

2.6 Insect resistance

The effectiveness of phosphine can be reduced considerably by development of resistance in insect particularly where inadequate technique of fumigation was employed.

2.7 Effect on plant life

Seeds

Under normal condition phosphine does not affect the seed germination. The growth and yield of plants grown from seed suggested to repeat fumigation with phosphine may be significantly reduced

Living plants

There is little information on the tolerance of growing plant to the vapor of phosphine.

2.8 Effect on plant products

To date there has been no report of appreciable adverse effects from recommended treatment.

Test on fresh fruit and vegetable show that insect such as fruit flies can be controlled using gas generated from magnesium phosphide preparation without injury to the produce.

2.9 Residues in foodstuffs

- There are 3 types of residues result from the use of phosphine fumigant
  i. Reaction of the products of formulation
  ii. Unchanged phosphine absorbed incommodity
  iii. Products formed by chemical combination
- Aluminium and magnesium phosphide leave mainly and inert of metallic hydroxide. Unreacted material may also remain
- Some precaution should be taken to avoid hazards
- Residual should be collected and disposed

2.10 PH_3 decomposition in the atmosphere

Hydrogen phosphide $\xrightarrow[O_2]{\text{OH radical}}$ Phosphoric acid (H_3PO_4) $\xrightarrow{\text{rain}}$ Phosphate (PO_4)

The eventual oxidation result of phosphine will be phosphorous oxy-acids and inorganic phosphate which will be deposited and contributed to the nutritive environment of soil and surface water.

2.11 Recommended Tolerances

- Phosphine arates rapidly from foodstuff
- For cereals in international trade a tolerance of 0.1 mg/kg is recommended

2.12 Formulation

- Aluminium and magnesium phosphide powder is compressed into hard round or flat tablets, permeable paper bags or sachets.
- Additional materials: paraffin, ammonium carbonate or ammonium bicarbonate
- Every formulation of aluminium and magnesium phosphide weight 3 gms will release PH_3 1 gm

3. Commodities which can be treated with Phosphine

- Raw agricultural commodities
    - All kinds of cereals
    - All kinds of nuts
    - Pulses
    - Seeds
    - Coffee and cocoa bean
- Processed foods
    - Cereal products
    - Dried or dehydrated vegetables and fruits
    - Dried or dehydrated dairy products
    - Cheese
    - Cured, dried and processed meat and fish products
    - Processed coffee and tea
    - Processed herbs, spices and condiments
    - Chocolate
- Non-food items
    - Tobacco leaf
    - Animal products
    - Animal feed
    - Natural fibres

- Clothes
- Paper and paper products
- Wood/timber, rattan, bamboo

Frequent pests attacking stored products

- *Acanthoscelides obtectus* (Say)
- *Araecarus fasciculatus* (D.)
- *Cryedon serratus* (Olive.)
- *Cryptolestes ferrugineus* (Steph.)
- *Dermestes lardarius* (L.)
- *Lasioderma serricorne* (F.)
- *Oryzaephilus surinamensis* (L.)
- *Rhizopertha dominica* (F.)
- *Sitophilus granaries* (L.)
- *Sitophilus oryzae* (L.)
- *Sitophilus zeamais* (Motsch.)
- *Tribolium castaneum* (Herbst)
- *Tribolium confusum* (J. du V.)
- *Trogoderma granarium* (Everts)
- *Ephestia elutella* (Hbn.)
- *Ephestia kuehniella* (Zell.)
- Plodia interpunctella (Hbn.)
- Sitotroga cerealella (Oliv.)

- Bean weevil
- Coffee Bean Weevil
- Groundnut Seed Beetle
- Rust-red Grain Beetle
- Larder Beetle
- Cigarette Beetle
- Saw-Toothed Grain Beetles
- Lesser Grain Borer
- Granary Weevil
- Rice Weevil
- Maize Weevil
- Red Flour Beetle
- Confused Flour Beetle
- Khapra Beetle
- Tobacco Moth
- Mediterranean Flour Moth
- Indian Meal Moth
- Angoumois Grain Moth

NOT ONLY insects but also other stored product pests, such as rats and mice cannot survive a fumigation

Insects of stored products can be separated into four groups according to their feeding habits:

- **Internal feeders:** rice weevil, granary weevil, Angoumois grain moth
  - Larvae feed entirely within the kernel of whole grain
- **External feeders:** lesser grain borer, drugstore beetle, cadelle, khapra beetle, tobacco beetle
  - Insects feed on the outside of the grain. They may also chew through the outer coat and devour the inside
- **Scavengers:** confused flour beetle, saw-toothed grain beetle
  - Feed on grain only after the seed coat has been broken either mechanically or by other insects
- **Secondary pests:** yellow mealworm, some grain mites
  - Feed only on materials which are deteriorating, damp, and have some mold growth present some of them feed on mold rather than on the food product

Occasional exceptions to these feeding habits may be found; however, as a general rule each of these insects will feed as indicated.

A knowledge of these feeding habits, plus some knowledge of their biology and behavior and the ability to identify the pest, are invaluable to the pest management professional.

4. Dosage and exposure guidelines

Type of commodity	Phosphine dosage
Loosely pilled grain	2-5 g / ton or cbm
Silo bins	2-5 g / ton or cbm
Bagged commodities, packed/processed food, animal feed	2-3 g / cbm
Tobacco	1-3 g / cbm
Space fumigation	1-3 g / cbm

5. Recommended exposure times (at approx. 60% rel. humidity)

Temp.	Tablets AlP	Pellets AlP	
Under 5 °C	No fumigation	No fumigation	No fumigation
5 - 10 °C	10 days	8 days	14 days
11 – 15 °C	5 days	4 days	7 days
16 – 15 °C	4 days	3 days	4 days
Over 25 °C	3 days	3 days	3 days
Temp.	**Tablets MgP**	**Pellets MgP**	**Plate/Strip, Forte Bag MgP**
Under 5 °C	Up to 15 days	Up to 15 days	Up to 15 days
5 - 12 °C	10 days	8 days	14 days
12 – 20 °C	5 days	4 days	7 days
Over 20 °C	3 days	3 days	3 days

*Some standard recommend exposure time not less than 7 days at 15 or above

International Standards for Residues of Phosphine in Food

- **Phosphine 0.1 mg/kg (0.1 ppm):** Cereal Grains
- **Phosphine 0.01 mg/kg (0.01 ppm):** Cereal food, flour, pasta, coffee, tea, herbs, tobacco, dairy products, etc.

6. Application

- If moisture content and temperature are high, all of the gas in aluminium phosphide formulations is evolved in 3 days

- For the treatment of bagged grains and other raw commodities in transport facilities, pellets or tablets may be spread out evenly over the load or place in moisture permeable envelope
- When fumigate packaged commodities under gas proof sheets, the tablets or pellets can be spread out on trays to lay under the sheet before it is secured
- Be aware of laying tray under the sheet, otherwise the tablets will not release PH_3 gas eventually or unreacted material may also remain.
- In warehouse, after the structure is adequate seal, the tablets or pellets are spread out on trays or sheets of kraft so that material can be easily collected at the end of treatment

6.1 Application procedure

- Fumigation management plan
- Stack fumigation
- Space fumigation
- Silo bin fumigation
- Ship fumigation (J- system)

6.2 Fumigation management plan

Fumigation management plan is an organized description of the steps involved to help ensure a safe, effective fumigation. By following a step-by-step procedure, yet allowing for flexibility, safe and effective fumigation can be performed.

Before any fumigation begin, carefully read and review the label and all the technical information/manuals the registrants provide. Give this information to the appropriate company officials (supervisors, foreman, safety offer, etc.) in charge of the site.

Organization is the key to any successful operation.

6.3 Preliminary planning and preparation

1. Determine the purpose of the fumigation

- Elimination of insect infestation
- Preventive sanitation
- Elimination of rodent infestation

2. What is the type of fumigation?

- Space
- Mill
- Food plant
- Container

- Stack
- Vehicle
    - Rail car
    - Grain car
    - Box car
- Commodity
    - Raw agriculture
    - Processed food
- Grain
    - Flat storage
    - Vertical silo
    - Farm storage
- Vessel
    - Ship
    - Barge

3. Become fully acquainted with the site and commodity to be fumigated, including:

- Review history of fumigation of structure
- Assure the applicator is properly licensed
- The general layout of the structure, connecting structures and escape routes, above and below ground. Draw or have a sketch of structure to be fumigated
- The number and identification of persons who routinely enter the area to be fumigated, and the proximity of other persons and animals
- The specific commodity, it's mode of storage, and its condition
- The previous treatment history of the commodity, if available
- Establish method of communication
- Current emergency telephone numbers of local Health, Fire, Police, Hospital and Physician
- Name and phone number of appropriate company officials
- Check, mark and prepare the points of application if the job involves entry into the structure to be fumigated
- Exposure time considerations
    - Down time available
    - Aeration requirements
    - Clean-up requirements
- Determination of dosage
    - Cubic meters/tons or gram per cubic meter
    - Structure sealing capability
    - Label recommendations
    - Temperature, humidity, wind
    - Commodity

7. Personnel – protection and equipment

- Confirm that all personnel in and around the area to be fumigated have been notified
- Instruct all fumigation personnel about the hazards that may be encountered; and about the selection of personal protection devices, including detection equipment
- Confirm that all personnel are aware of and know how to proceed in case of an emergency situation
- Instruct all personnel on how to report any accidents and/or incidents related to fumigant exposure
- To protect the fumigators and other people at risk from inhaling excessive quantities of phosphine must be provided with either a full-face canister respirator or an open-circuit SCBA with full face mask.

Figure 8: Full face gas mask fitting tested by closing the inlet

7.1 Monitoring

1. Monitoring should be conducted to determine concentrations and prevent possible exposure

2. Monitor gas concentration after 6, 12, 24, 48, 72 hours and so on

3. Keep a log or manual of monitoring records of each fumigation site

4.Minimum require concentration and time to achieve a high level of kill all stored product beetles exclude *Trogoderma sp*. Are as follow:

10,000 ppm for 1.5 days

1,200 ppm for 2 days

1,000 ppm for 8 days

200 ppm for 10 days

35 ppm for 20 days

10 ppm for 30 days

8. Application procedures: actual fumigation

8.1 Phosphine fumigation equipment

- Tarpaulin sheet 200-micron thickness
- Sand snake
- Tablet dispenser
- Gloves
- Monitoring equipment (Detector tube) or electronic monitoring equipment
- Gas mask with appropriate canister
- Ladder
- Fumigant
- Masking tape
- Monitoring tube and pump
- Calculator
- Self-contained breathing apparatus (SCBA)
- Warning sign and barrier tape

8.2 Introducing phosphine into an enclosure

- Apply all fumigants in accordance with the registered label recommendations
- When entering into the area to be fumigated always work with two or more properly trained people
- Be sure that fumigation area is vacated and all persons are accounted for before the release of fumigant is performed
- Have safety equipment:
    - One full face gas mask per person
    - Two phosphine filters per person
- Secure structure so that there is only one entrance:
- Plan how the phosphine generating preparation will be distributed inside the enclosure
- Take action to protect any materials and equipment (electrical apparatus, computers. machines. etc.) containing copper that may be damaged by expose to phosphine gas during the exposure period, and ventilation process.
- Measure the stack to be fumigated, work out the volume, then calculate the dosage base on its volume (which is more effective than dosage base on weight of commodity.
- When tablets or pellets are used, these must be placed in cardboard or plastic trays so that the commodity is nor contaminated by spent residues (the dust left after phosphine has been released). The spent residues can be collected and disposed of safely.
- Trays containing tablets or pellets should be distributed evenly around the base of the stack.
- Where the stack is built on pallets, they can be place under the pallets.
- Where no pallets are used, they may be place along the side of the stack.

- When placing tablets or pellets in tray, it is important to make sure they are evenly spread out on the tray, in single layer. This is because when they are piled or heap up
    - The phosphine may ignite when concentration of gas that exceed the lower limit Flammability are generated.
    - The tablets or pellets at the bottom of the heap are prevented from decomposing fully, because they are covered by spent residues from the tablets or pellets on the surface of the heap

8.3 Notification

- Confirm all local authorities (fire departments, police departments, etc.) have been notified as per label instructions and obtain any necessary permits
- Release fumigant in direction to entrance door
- Take into consideration prevailing wind and other weather factors
- Make certain that fumigators have left structure before close the entrance
- Seal this door too
- Monitor gas concentration after 6, 12, 24, 36, 48, 72 hours and so on
- Check surrounding areas for leaks

8.4 Stack fumigation

- Goods stored in sacks and bales are frequently fumigated under tarpaulins or fumigation sheets
- Use of tested gastight fumigation sheets or tarpaulins is one of the easiest and least expensive means for providing gastight fumigation enclosures which are well suited for fumigation
- It does not matter whether the commodity is in storerooms or outdoors – important is only that the stacks are well covered and stacking for good circulation.
- The sheets must be sealed to the floor with 2 row over-lapping sand snake, sheet at the corner is rolled and clamped together to provide gastight enclosure.
- If the flooring upon which the commodity rests is of wood or other porous material, it should be repositioned onto a gastight tarpaulin prior to covering the entire stack for fumigation

8.5 Fumigation procedure

- Cover the stack with a gastight tarpaulin sheet which should have a rim of approx. 50 cm resting on the ground
- Roll up tarpaulin and fix to enable easy release
- Place PHOSPHINE Plates in an upright position leaning them on the stack
- Place PHOSTOXIN tablets/pellets onto suitable bases, such like cardboard or plastic, and push these under the stack in different places

Figure 9: Sheet sealed to the floor with sand snakes, 2-row overlapping

Preparation of stack fumigation using simulate wooden structure instead of container showing a sheet which has been folded for easy deployment. Corner are padded to protect the sheet from tears. Sand snakes are two-row overlapped and are heavy enough to seal the sheet to the ground. Corners should be rolled, not enveloped to avoid being pulled out by wind.

The sheet is pulled tightly to reduce flapping and to minimize the volume of the enclosure the loose sheet on the fumigation floor should be arranged to ensure that it is as flat as possible with no ridges which may provide channel for gas escape.

Figure 10: Placing sand snake to seal the sheet to the floor

Figure 11: Gastight enclosure ready for fumigation

8.6 Fumigation procedure of store room

- Determine the dosage of fumigant to be applied based on the following parameters:
    - Volume of the structure
    - Air and/or commodity temperature
    - General tightness of the structure
- Seal all openings except for the door being used to enter and leave. Pay particular attention to openings to connecting ad adjacent structures
- Stripes are placed in zick-zack on the floor, but with very high storerooms, a second level of Strips should be placed in a certain height.
- If placement of fumigant on the floor is not convenient (e.g. during rainy season), then Strips may be hung up
- When fumigating multiple store buildings, each floor is considered as separate enclosure. Application should begin with the top floor and end with the ground floor
- The door used to leave must be well sealed after application

Figure 12: Storeroom fumigation

NOTE:

- Small storerooms such like containers are easily and economically fumigation with Plate
- Flat storage: when fumigation grain in flat storage or bulk stores Al/ Mg phosphide tablets are distributed evenly into commodity with a probe
- Vertical silo: Al/Mg phosphide tablets or pellets are used worldwide for silo-cell fumigations. The fumigants may be applied by hand (gloves) either onto the conveyor belt or directly into the feeder opening. More economical and safer for the applicator is the use of Automatic Dispenser, suitable both for Round Tablets and Pellets.

Figure 13: Phosphine automatic dispenser for silo bin

8.7 J-System (Ship fumigation)

The J-System is a recirculation system, which controls a precise and even air change within the grain mass of any storage facility regardless of its size and shape.

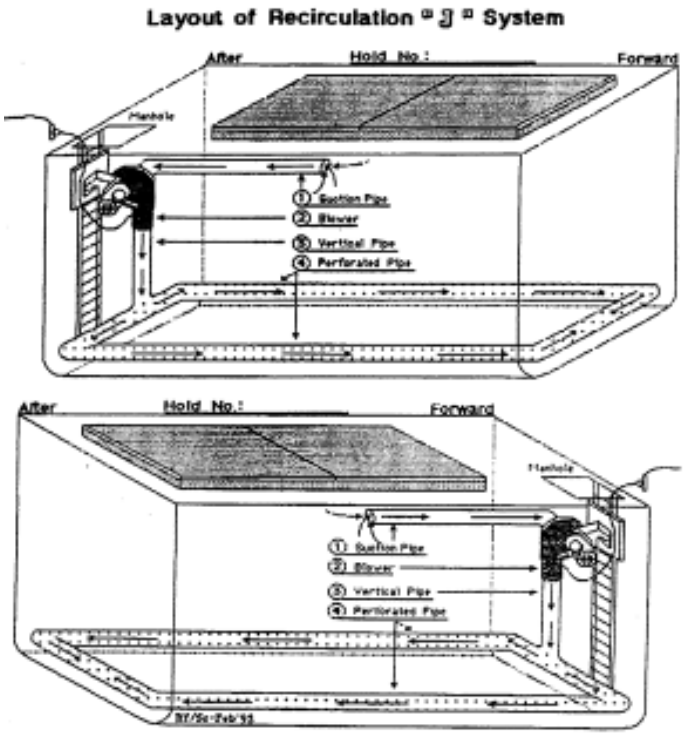


Figure 14: J-system model

Advantages:

- Safety
  - Reduces workers exposure to PH_3
  - Eliminates unforeseen hazards
  - Reduces headspace loss of phosphine
- Efficiency
  - Quicker and more even distribution of PH3
  - Insects are exposed to lethal concentrations earlier
- Economy
  - Eliminates costs of a turning operation
  - Dosages may be reduced to a certain extent, provided the bin is gastight

8.8 Post fumigation procedure (degassing)

- Put your face mask with filter on
- Aerate building / structure by opening doors, windows, switching ventilators on
- Monitor gas concentration to make certain phosphine is evacuated:
    - Continue aeration until gas concentration is equal or less to 0, 1 ppm
    - Put your gas mask off
- Dispose of degassed fumigant (p.e. Plates) or fumigant residues (p.e. Pellets):
    - Apply dry or wet method to deactivate degassed fumigants and powdery residues
- Notify authorities that fumigation is over and structure is safe for re-entry:
    - Plant personnel, police, fire brigade and others
- Take down warning signs

9. Storage of Phosphine products

- Respect local regulations
- Tins, flasks and drums should be stored in a day, cool, well ventilated area under lock and key
- Do not store in buildings where human beings or domestic animal reside
- Do not contaminate water, food or feed by storing pesticides in the same areas used to store these commodities
- Keep out of reach of children
- Shelf-life of the products is virtually unlimited as long as the containers have not been opened and are tightly sealed and stored according to the recommendations
- Tablets/Pellets: 5 years; Plate / Strip: 2 Years

10. Disposal of phosphine residues

- Ensure that no powdery residues are inhaled
- Use full face gas mask with phosphine filter
- Under no circumstance should the residual powder be put in closed containers
- Both methods should be done outdoors
- There are 2 methods;
    - **Wet method**
        - Tablets, Pellets
            - Collect powdery residues on plastic tray or paper sheets
            - Attention: formulations containing aluminium/magnesium phosphide react vigorously with water
            - Use full face mask plus filter
            - Fill 2/3 of a drum with water, add detergent to reduce surface tension

- Slowly mix the powder into the water by stirring as the dust is added
- When bubbles no longer rise, the liquid can be emptied on rubbish dump

▪ Plate/Strip

- Collect degassed Plate/Strip in wire basket
- Attention: formulations containing aluminium/magnesium phosphide react vigorously with water
- Use full face mask plus filter
- Fill 2/3 of a drum with water
- Submerge Plate/Strip for approx. 36 hours, keep them submerged with a suitable weight (don't let them float)
- When bubbles no longer rise, Plate/Strip can be taken out, buried or burned following local regulations

○ **Dry method**

▪ Tablets, Pellets

- Collect powdery residues on plastic tray or paper sheets
- Fold the paper sheets into small packets
- Burn the packets in an appropriate incinerator or dispose them in recommended dump sites

▪ Plate/Strip

- Collect degassed fumigants in wire baskets
- Burn them in an appropriate incinerator or dispose them in an appropriate landfill
- Respect local regulations

11. Conclusion

- Phosphine has been the choice fumigant for more than 50 years.
- It is an economic fumigant of choice for treating commodities.
- Flexibility in application to various commodity.
- Meet worldwide requirements for delivering commodities free of insecticide residues.
- Follow good product stewardship and pest management programs to keep phosphine for future.

12. Selected References and Further Reading

Joachim F. Jeltsch (2005) Safe practice in handling and application of Phosphine, Manual of Fumigation Training Course, DETIA DEGESCH GmbH Germany.

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