International Cargo Cooperative Biosecurity Arrangement

Guide to Performing QPS Fumigations with Methyl Bromide.

Version1.0

Contents

I Purpose

This guide provides detailed information on and further explanation of, the various methods and techniques that can be used by fumigators to meet the requirements of the *Methyl Bromide Fumigation Methodology*.

II Scope

This document applies to treatment providers, commercial or government, performing QPS methyl bromide fumigation treatments on export consignments destined for countries who have adopted specific methyl bromide treatment schedules.

Even though the basic principles and requirements would be relevant this document is not intended to specifically cover fumigations of vessels, whether it is the vessel itself or its cargo, silos or other storage facilities, buildings or other fumigations not done in the types of enclosure described herein and not related to import or export.

III How to use this document

This document should be read in conjunction with the *Methyl Bromide Fumigation Methodology* which specifies the minimum requirements that must be met by fumigators when performing QPS methyl bromide fumigations.

This document covers the most commonly encountered fumigation situations and provides information on the methods that a fumigator may use to ensure a successful fumigation depending on the circumstances.

1 General Principles of Fumigation

1.1 Fumigants

A fumigant is a chemical which, at a required temperature and pressure, exists in the gaseous state in sufficient concentration to be lethal to a given pest organism.

A fundamental feature of fumigants is they exist in a gaseous state under normal treatment conditions so they diffuse as separate molecules enabling them to penetrate into the material being fumigated and to diffuse away afterwards. This is an important distinction from aerosols, which are particulate suspensions of liquids or solids dispersed in air, popularly referred to as smokes, fogs or mists. These are unable to penetrate even a short distance into materials because the particles are deposited on the outer surfaces only.

1.2 Fumigant Suitability

Fumigants vary greatly in their mode of action. Some kill rapidly while others kill slowly. In sub-lethal dosages, some fumigants may have a paralysing effect on the pest while others will not allow the pest to recover. Some fumigants have no effect on commodities while others are detrimental even at low concentrations. Commodities vary in their sorption of fumigants and in the effort required to aerate the commodities after fumigation.

There are a number of factors that will determine the suitability of a fumigant to treat a particular commodity and/or pest. These are:

- Toxicity
- Mode of action
- Potential to cause damage to the commodity and/or associated materials
- Ability to penetrate into the commodity being treated

1.3 Fumigant Properties

Each fumigant has different properties and characteristics that will affect how it should be applied to consistently achieve an effective fumigation.

1.3.1 Boiling Point

Some fumigants have a relatively high boiling point at normal atmospheric pressure, for example, methyl bromide boils at 3.6°C. Fumigants with relatively high boiling points can condense back into a liquid as it is being released into the enclosure. A build-up of back pressure in the supply system can result in liquid fumigant coming from the supply pipe with the potential to cause damage to the commodity.

The risk of releasing liquid fumigant can be reduced by heating the fumigant using a vaporiser (volatiliser) and by controlling the rate of gas flow through the supply system. The internal diameter of the pipes used in supply system should be the same or increase progressively from the fumigant supply towards the enclosure to minimise potential choke-points that could create sufficient back-pressure to condense the fumigant back to a liquid.

1.3.2 Rate of Diffusion

The rate at which a fumigant will diffuse throughout an enclosure is dependent on a number of factors. The heavier the gas the slower it will diffuse throughout an open space. The rate of diffusion is also directly related to temperature, so that a given gas will diffuse more quickly in hot air than in cold air.

If a gas is heavier than air it will have a tendency to settle to the bottom resulting in lower concentrations in the upper reaches of the enclosure. The use of fans or other means to force thorough mixing of the fumigant with the air will ensure uniform distribution throughout the enclosure.

When heavier than air fumigants are thoroughly mixed with the air any tendency to settle towards the base of the enclosure is of no practical importance during normal fumigation exposure periods.

1.3.3 Flammability

Some fumigants are highly flammable and can present a risk of explosion if suitable precautions are not taken. Dilution of the oxygen content in the enclosure by purging with an inert gas to non-combustible levels, sometimes combined with fumigation under vacuum, plus the removal of any potential source of ignition is commonly used to manage the risk associated with flammable fumigants. Methyl bromide is not flammable at fumigation concentrations so no special precautions are needed.

1.3.4 Sorption

Sorption removes fumigant gas from the atmosphere of the treated area. This could reduce the effective concentration of fumigant necessary for killing the target pests. The term 'sorption' covers three types of phenomena, (a) *absorption* which occurs when the gas is taken up by another substance forming a mixture, e.g. with oil and fat contents of a product, (b) *chemisorption* which is a process in which the fumigant reacts with the components of a commodity to form another compound and (c) *adsorption* which occurs when the gas molecules attach themselves by physical forces to the surface of the material. This last form of sorption is largely reversible and desorption occurs during ventilation after fumigation, usually increasing the time required for aeration. When the enclosure is ventilated to remove the fumigant from the space and the material, the fumigant slowly diffuses from the material and residual vapours are completely dissipated within reasonable periods, although the length of time varies considerably according to the gas used and the material treated.

The amount of fumigant used must be sufficient both to satisfy the total sorption during treatment and also to leave enough free gas to kill the pest organisms. Additional gas readings may be necessary to monitor concentration of gas to determine the rate of sorption.

1.4 Fumigant Concentration Levels

To achieve an effective fumigation the target of the fumigation must be exposed to a sufficient concentration of fumigant for a sufficient length of time to achieve a lethal dose. The dosage rate and any minimum retention rate, is set to effectively treat all life stages of the target pest.

Fumigation must be done in enclosures that are sufficiently gas-tight to maintain concentration levels above the minimum requirement over the duration of the exposure period. Typically, there will be a reduction of fumigant concentration in the enclosure over time due to penetration into or sorption by the commodity and leakage from the enclosure. To ensure that the target pest is subjected to a lethal concentration of fumigant over the entire exposure period a minimum final retention rate may be required. The minimum retention rate is a percentage of the dosage rate concentration which must be met or exceeded at the end of the fumigation exposure period.

1.4.1 Ct Product

The amount of fumigant required to achieve the lethal dose is referred to as the dosage rate and is expressed as a function of concentration and time, commonly referred to as the Ct product. It is an expression of the minimum total cumulative exposure to the fumigant needed to effectively treat the biosecurity risk associated with the consignment.

The starting dose is set to achieve the required Ct product taking into account gas loss during the exposure period from leakage and sorption. For example, timber is typically fumigated with methyl bromide at a dosage rate of 48g/m^3 for 24 hours giving a Ct product of 48 x 24 which is 1152 g/h/m^3, assuming no gas loss. In reality the actual Ct product, taking into account gas loss, is around 500 g/h/m^3 based on a retention rate of 30% after 24 hours.

1.4.2 The Effect of Temperature on the Dosage Rate

The most important environmental factor influencing the action of fumigants is temperature as the toxicity of a fumigant depends on the respiration rate of the target organism. Generally, the lower the temperature, the lower the respiration rate of the organism which tends to make it less susceptible. Fumigation at lower temperatures requires a higher concentration of fumigant than fumigation at higher temperatures.

Unless specified otherwise, the minimum expected ambient air temperature within the enclosure during the exposure period should be used to determine any adjustments to the dosage rate.

Some commodities, particularly perishables, require treatment at a specific temperature or within a specific temperature range to ensure the treatment is effective while minimising any adverse effects on the quality of the commodity that may result from increased temperatures. If the treatment requires measurement of the internal or pulp temperature of the commodity then suitable temperature probes must be used. Fumigations that require a specific temperature or temperature range must be performed in a facility capable of heating the commodity to the desired temperature and maintaining it for the duration of the fumigation exposure period.

The expected minimum ambient temperature for fumigations performed outside or in facilities without adequate temperature control should be obtained by checking the official forecast minimum temperature of the nearest locality to the fumigation site.

For practical purposes, it is increasingly difficult to kill insects with fumigants as the temperature is lowered to 10°C. In general, the effectiveness of fumigants can become unreliable below 10°C so, unless otherwise specified, fumigation is not normally permitted where the temperature is expected to fall below 10°C during the exposure period. If the ambient temperature is expected to fall below 10°C heaters can be used in the enclosure to increase the temperature and maintain it at a satisfactory level for the duration of the exposure period. There will be a gradient within the enclosure where the temperature will progressively decrease the greater the distance from the heat source. The temperature used to determine the dosage rate must be the ambient temperature expected in the coolest part of the enclosure.

Sufficient time must be allowed for the enclosure and the commodity to reach the desired temperature prior to starting the fumigation.

1.5 Safety

All fumigants are toxic gases which can be harmful to humans if not handled carefully. Appropriate precautions must be taken to avoid exposure to unsafe levels of fumigant by fumigation personnel as well as any other persons in the vicinity.

1.5.1 Risk area

A risk area must be established around the entire enclosure. It must be demarcated by a physical barrier, such as rope or tape hung on stands or bollards, held off the ground and so that someone has to deliberately step over the barrier to enter the risk area. Lines painted on the fumigation surface are ineffective and are not acceptable.

Outdoors a solid wall can be used for one or more of the sides if it is at least 2 metres high. Indoors, a wall can be used as part of the barrier if it extends from floor to ceiling.

Don't use other freight containers as part of the barrier unless you are certain that they will not be moved before the fumigation is finished.

Large, easily seen warning signs must be placed on all side of approach to the enclosure. For an enclosure that can be approached from all sides a minimum of four signs would be needed. They could either be placed on each of the corners of the risk area or on each side provided that they are visible from all angles of approach.

It is not advisable to use signs made from paper, cardboard or other material that could deteriorate by exposure to the elements.

1.5.2 Personal protective equipment (PPE)

Suitable respiratory protection must be worn at all times inside the risk area while it is in force. The respirator is the most important piece of equipment used for the protection of persons working with fumigants. When fumigation is carried out regularly, it is advisable for each of the operators to be supplied with their own respirator so that they themselves are responsible for its care and upkeep, for their own personal protection.

The two most common types of respirators used for QPS fumigations are ones that use a filter canister designed to remove contaminant gases from the air being breathed or self-contained breathing apparatus (SCBA). Whichever type of respirator is used the mask must cover the entire face, including the eyes.

1.5.3 Filter-type Respirators

For filter canister respirators it is strongly recommended that the fumigator read the manufacturer's instruction on the safe use for the brand of filter that they use. The canister provides protection only for a limited length of time which varies depending on the concentration of fumigant it is exposed to. The only practical way to determine if there has been exposure is to use a suitably sensitive electronic detector with an audible alarm set to signal if there are unsafe levels of fumigant present.

It is most important to check that the canister on the respirator is the right one for use with the specific gas or mixture of gases that will be used for that particular job. Cartridge-type respirators are small devices with one or two small chemical cartridges attached to the nosepiece. These are usually designed to give protection only against gases up to 0.1 percent by volume. They should not be used in any phase of fumigation work. Also, respirators designed as dust filters, or for use with insecticidal or fungicidal aerosols, afford no protection whatsoever against fumigants.

Detailed instructions for adjusting, putting on and checking respirators are supplied with each unit purchased. They should be carefully studied at the time of purchase and read over again before the respirator is used. Supervisors should give new operators detailed instructions on the proper use of the respirators.

When a canister is new its top and bottom are sealed. Manufacturers stamp an expiry date on the label in order to indicate when the canister must be discarded even if the seals have not been broken.

The supply of canisters should be stored in a cool, dry, well-ventilated place away from contamination by any gases.

1.5.4 Self-contained Breathing Apparatus (SCBA)

SCBA respirators provide breathable air from a portable cylinder carried by the wearer. These types of respirators are becoming more common as they have some significant advantages over the canister type respirators. They provide protection in environments with high concentrations and are effective against all toxic gasses. While the initial purchase price can be quite high compared to a filter type respirator the ongoing operating costs are much lower than the cost of replacing spent filter canisters. Operators need to be properly trained in their use and maintenance and they must only ever be re-filled by an authorised agent. The cylinder must never be refilled using normal air compressor as the air will be contaminated and cause severe injury or death.

1.5.5 Care and maintenance

Regular maintenance should be undertaken on the respirators to ensure that they continue to provide effective protection. After each use, particularly in hot conditions where the operator sweats profusely, the mask should be washed in mild soapy water otherwise the mask may become permanently tainted. The valves should be removed and checked regularly to ensure that they are clean and in good condition. Care should be taken to ensure that the valves are refitted correctly so that the respirator functions correctly. The seal around the face-plate should also be checked in case it has been damaged.

1.5.6 Threshold Limit Value Time (TLV)

The TLV is the maximum concentration of fumigant that the average person can be safely exposed to day after day over a working lifetime without adverse health effects. The TLV is an estimate based on the known toxicity in humans or animals of a given chemical substance. The limits specified are subject to change as new information emerges that may modify the risk assessment for a particular substance. Therefore it is strongly advised that any exposure to fumigants be minimised as much as possible unless proper respiratory protection is worn.

The TLV-TWA for fumigants are expressed as parts per million (ppm) or part parts per billion (ppb).

Three types of TLVs for chemical substances are defined:

1. Threshold limit value - Time weighted average (TLV-TWA): average exposure on the basis of an 8h/day, 40h/week work schedule. For methyl bromide the TLV-TWA is widely accepted as 5 ppm.
2. Threshold limit value - Short-term exposure limit (TLV-STEL): spot exposure for a duration of 15 minutes, that cannot be repeated more than 4 times per day with at least 60 minutes between exposure periods. For methyl bromide the TLV-STEL is widely accepted as 15 ppm.
3. Threshold limit value - Ceiling limit (TLV-C): absolute exposure limit that should not be exceeded at any time. There is currently no TLV-C defined for methyl bromide.

The TLV is different for each fumigant and may also vary from country to country.

2 Prior to Fumigation

Prior to performing the fumigation it is essential to undertake a proper evaluation of the consignment to determine if it is suitable and whether the treatment will be effective.

2.1 Target of the fumigation

The suitability of a particular consignment will depend on the nature of the risk.

The fumigator must know why the fumigation is being done and what the actual target of the fumigation is so they can determine if the fumigant will come into contact with and be able penetrate into the goods.

2.2 Consignment suitability

There are a number of factors that will affect the suitability of the consignment for fumigation. Some materials are adversely affected by methyl bromide which can cause damage to the commodity and thereby reduce its value. There are some commodities that are not suitable for fumigation with methyl bromide and others that may be affected in some circumstances.

The list in Appendix 1 of the Methodology provides a guide on some commodities where problems have been known to occur. Due to the variations in the composition of materials and other factors like temperature, humidity, length of exposure and concentration levels it is not necessarily straight forward to evaluate the suitability of a particular commodity. If there is some doubt as to the suitability of any particular material it may be necessary to conduct tests to determine if the outcome will be satisfactory.

The fumigator and the owner should also consider the potential for adverse effects on other materials in the consignment that are not necessarily the target of the fumigation that will also be exposed to the fumigant.

2.2.1 Free airspace

Good free airspace will allow the fumigant to readily circulate throughout the enclosure and greatly assist in achieving even gas distribution. The enclosure should be configured to ensure that there is adequate space above, below, at the sides and throughout commodity. Putting the commodity on pallets, creating space between the sheets and the commodity and stacking the commodity so there is space between items, will improve fumigant circulation.

If there is inadequate free airspace (usually only an issue for containerised commodities) then the consignment may need to be unpacked and fumigated as a stack. It is the responsibility of the owner/exporter of the goods to present the consignment in a way that is suitable for fumigation.

Load factors are important when treating some perishable items as the exposure periods can be very short and rapid distribution of gas throughout the enclosure and into the commodity is critical to achieve an effective treatment. Another reason to specify a load factor is to avoid an excessive concentration of methyl bromide which can damage the commodity in some instances. For example, if a load factor of 50% is specified then the quantity of the commodity and any associated packaging can occupy a maximum of half the volume of the available space inside the enclosure. This can also result in an effective doubling of the initial concentration of methyl bromide as half the air in the enclosure is displaced by the commodity.

2.2.2 Penetration into the Commodity

In many cases the fumigant must be able to penetrate into the commodity to effectively treat pests (for example, wood borers) that can exist inside the commodity itself. The fumigator should inspect the consignment to verify that it can be treated effectively prior to fumigation. If the consignment cannot be adequately inspected, the fumigator may need to rely on information from the manufacturer/exporter of the goods to ascertain whether there is anything that may prevent the fumigant from adequately penetrating into the commodity.

The degree of penetration into the commodity will depend on the fumigant used, the nature of the commodity and the exposure period. If there is a maximum depth which the fumigant can penetrate there will be restrictions on the size of that commodity which can be affectively treated with that fumigant. In general, the maximum thickness of a commodity that can be treated will be twice the penetration depth because the fumigant can penetrate from all sides. If, however, the commodity is partially coated with an impervious surface the maximum thickness from the uncoated surface will be the same as the penetration depth.

2.2.3 Maximum Timber Thickness

The effective penetration of methyl bromide into wood is 100 mm under normal fumigation conditions and exposure periods, therefore individual wooden planks, rounds and articles must have at least one physical dimension which is less than 200 mm.

2.2.4 Impervious wrappings, coatings and surfaces

If the target of the fumigation is wrapped in materials that are impervious to the fumigant the wrapping should be cut, slashed or removed prior to fumigation.

If the target of the fumigation has impervious surfaces that will prevent effective penetration of the fumigant then an alternative method of treatment must be used. Where practical, the commodity should be fumigated prior to any impervious surfaces being applied.

2.3 Site suitability

For fumigation performed in temporary enclosures, that is, anything other than a chamber, the fumigator must determine if the site is suitable to conduct a safe and effective fumigation. It is assumed that due safety considerations have been taken into account during the design of any permanent fumigation facility.

There must be sufficient space to create an exclusion zone around the enclosure to warn others that a fumigation underway. If the enclosure is adjacent to a high traffic area, either pedestrian or vehicular, it may be appropriate to extend the risk area out further if space permits. Where there is a prevailing wind it is also prudent to extend the risk area out further on the downwind side. Methyl bromide dissipates rapidly and the concentration will decrease exponentially as the distance increases from the source.

Ventilating the enclosure poses the greatest risk for un-protected personnel to be exposed to unsafe levels of methyl bromide. As part of the site suitability assessment the fumigator must determine if the enclosure can be ventilated safely before starting to fumigate. It is too late once the enclosure is under gas. As a general guide 50 metres downwind from the enclosure is safe in most circumstances. The section on ventilation provides more information on how the ventilation process can be safely managed in different situations.

The fumigation surface must be flat and even. For fumigations in un–sheeted shipping containers, uneven or sloping surfaces can cause the container to twist which may make it difficult to open and close the doors or result in greater leakage around the door seals.

The site should be well ventilated. This is particularly important when ventilating the enclosure to promote rapid dispersal of the fumigant.

Power must be available to run the fans and any other equipment that requires mains power. If mains power is not available then a generator will be needed.

Some concentration measuring instruments may be affected by fluctuations in the current so the more consistent and reliable the power source, the better.

Secure the fumigation enclosure from un-authorised access as much as practicable.

3 Safely Using Methyl Bromide

3.1 Toxicity of methyl bromide

Fumigants are, by definition, toxic gases and appropriate precautions must be taken to avoid exposure to un-safe concentrations. The effect of methyl bromide on humans and other mammals varies according to the intensity of exposure. The concentration and length of time determine the intensity of exposure and the resulting signs and symptoms can vary greatly.

Harmful effects from exposure to a toxic gas such as methyl bromide may fall into two general categories - acute and chronic.

Acute effects can result from a single exposure to high levels methyl bromide. At concentrations not immediately fatal, it produces neurological symptoms. High concentrations may bring about death through pulmonary injury and associated circulatory failure. The onset of toxic symptoms is delayed and may vary between 30 minutes to 48 hours, according to the intensity of the exposure and the personal reaction of the individual. The most common signs and symptoms of acute exposure include central nervous system depression, nausea, fever, dizziness, confusion, delirium, staggering, visual disturbances, abdominal pain, mania, tremors, pulmonary oedema, convulsions and coma.

Contact of the skin with the liquid or strong concentrations of the gas may cause severe local blistering.

Chronic effects may result from an overdose on a single exposure or from repeated long-term exposure to relatively low concentrations. In some cases the effects are cumulative and may not become apparent for some time, therefore they may not be easily associated with long term low level exposure to methyl bromide.

Experiments with animals and records of accidents to human beings seem to indicate that daily exposure to concentrations of 20 to 100 ppm of methyl bromide can quickly result in serious neurological symptoms. Exposure for only a few hours to concentrations of 100 to 200 ppm may cause severe illness or death.

Persons should not be exposed continuously to concentrations of this gas in excess of 5 ppm. This concentration is the most broadly accepted threshold limit for an 8-hour daily exposure. Some countries already have or, are moving towards, a lower value. The fumigator must fully comply with the local requirements whenever they are more stringent.

3.2 Risk assessment

As part of the site suitability assessment the fumigator must evaluate the site from a safety perspective. Is the fumigation able to be carried out safely and, to the extent necessary, any potential risks be satisfactorily managed?

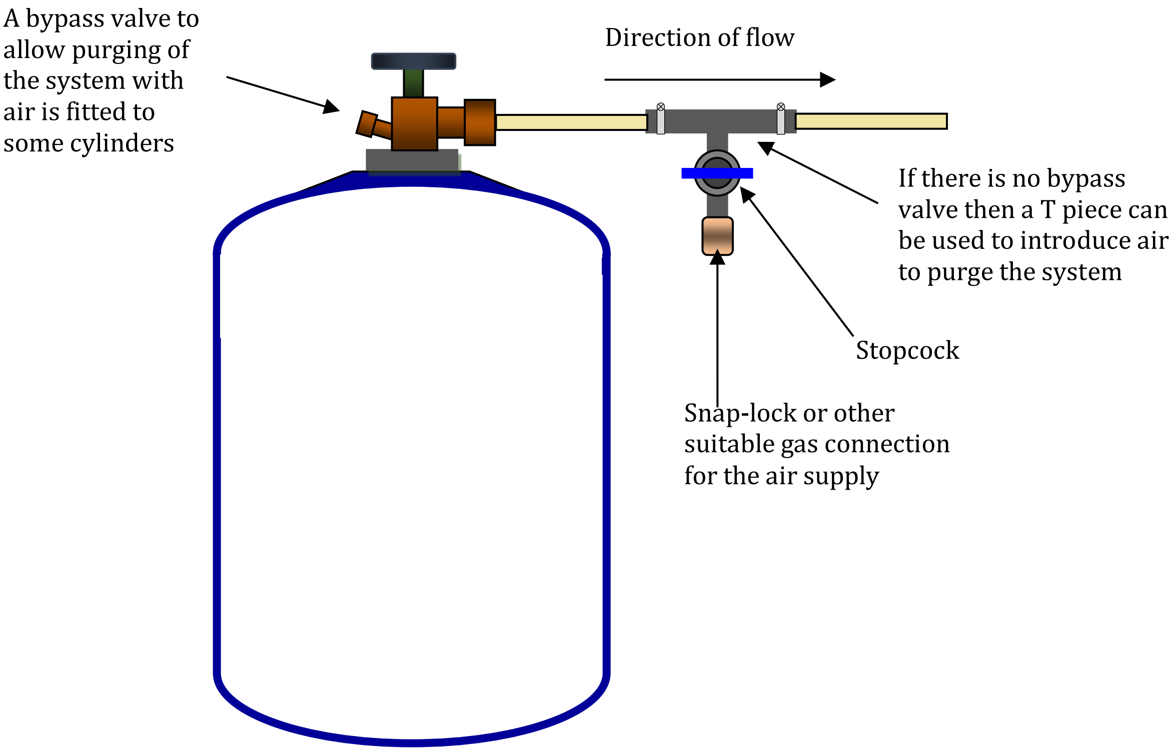
There are three phases during the fumigation which present different types and degrees of risk.

The first phase is the gas injection phase. If proper preparation is done and adequate care exercised then this process should be low risk. The main concern is accidental leakage from the supply system. The fumigator should pre-determine a safe and accessible route to follow away from the fumigation area, either as a result of the fumigation or some other occurrence that represents a danger. In the event of an accidental leak the supply cylinder should be shut off immediately and both fumigators should leave the area together walking in the direction of their pre-determined exit route. Once sufficient time has passed for the methyl bromide to dissipate the fumigators can return to the fumigation and rectify any problems before resuming the fumigation. If canisters are used to supply the methyl bromide a bucket of water should be close by. If there is a leak from the applicator the canister can be dropped into the water bucket. This will slow down the rate of release from the canister and allow the fumigators to exit the area until it is safe to return.

Using good quality supply hose and secure connections will significantly reduce the potential for problems. Avoid any sharp angles or bends in the supply pipe as the gas will be very hot and under high pressure so there is the possibility of the hose bursting.

No-one other than the fumigators directly involved in the injection of the gas should be in the risk area. The methyl bromide supply and the vaporiser must be inside the risk area during injection and un-protected personnel kept well away even if they are outside the risk area.

When the required amount of methyl bromide has been measured out close the methyl bromide cylinder securely, this is not applicable for cans as the entire contents must be fully discharged into the enclosure. The supply system will now contain pure methyl bromide which should be purged before dismantling the supply system. This can be readily done by forcing air through the system from the methyl bromide supply to the enclosure. Some methyl bromide cylinders have an additional valve for this purpose, if it doesn't then a simple T piece with a valve connected in-line with the supply pipe close to the cylinder outlet is effective. Purging the methyl bromide from the supply system not only prevents the diffusion of methyl bromide out of the system which may accumulate in un-safe levels, particularly in enclosed spaces, but will ensure that the entire dose is in the enclosure. This can be a significant proportion of the dose depending on the volume of the system in relation to the enclosure.



An alternative is to disconnect the supply pipe from the cylinder and force air down the pipe until all the methyl bromide has been forced into the enclosure.

The second phase is the exposure period. There is minimal risk of exposure during this phase providing that the enclosure has been carefully checked to find and fix any significant leaks. Un–sheeted containers should be locked to prevent the inadvertent opening of the container while it is under gas.

By their nature fumigation under sheets cannot be secured to prevent someone from inadvertently, or otherwise, lifting the sheet and gaining access to the goods. Despite the establishment of a risk area with good warning signs it not unheard of for someone to try and access the sheeted enclosure while it is under gas to steal the goods.

The final phase is ventilation. The fumigator must plan for the safe ventilation of the enclosure before it is put under gas, it is too late afterwards. The fumigator must consider the proximity of occupied buildings, other site personnel in the vicinity and the likelihood of passing traffic, either pedestrian or vehicular.

3.3 Filter Canister for methyl bromide

For methyl bromide the correct filter canister designation is AX, which is designed for Volatile Organic Compounds (VOC) with a boiling point below 65° C. Do not use A2 filters as they are specifically designed for VOCs with a boiling point above 65° C and are much less effective.

3.4 Fumigation personnel

Fumigators should not work alone as toxic gases are being used and serious consequences may ensue if a fumigator becomes sick or faint and is unable to maintain control of the operation endangering themselves or others so it is recommended that at least one other person is present in case of emergency.

It is difficult to communicate verbally while wearing a respirator so it is advisable for the fumigation team to establish visual signals to indicate if there is a problem and what action should be taken. For example, one of the fumigators may notice a leak from the supply system. The first action should be to shut off the gas supply at the cylinder, then they can assess the situation and, if the leak was significant enough to warrant them to temporarily leave the area, get their colleagues attention by tapping on their shoulder and indicate that they must leave the area until it is safe to return.

4 Preparing the fumigation enclosure

A safe and effective fumigation requires good preparation.

4.1 Concentration sampling tubes

Concentration sampling tubes must be placed at representative points within the enclosure to allow measurement of the fumigant to check if it is evenly distributed and that concentration levels are at or above any specified minimum amount.

Enclosure smaller than $30m^3$ only require at least one sampling tube, therefore, equilibrium is not necessary. The sampling tube should be placed at the top-centre of the commodity.

Enclosures larger than $30m^3$ must have at least 3 sampling tubes. They should be placed towards the top-back of the enclosure, somewhere around the middle and at the front base. Fumigation of multiple shipping containers under a fumigation sheet requires at least three sampling tubes in the enclosure with at least one in each container. If two containers are being fumigated under a sheet a sampling tube must be placed at the top-centre of the commodity in each container with the third sampling tube placed at the front-base of either container. Three or more containers fumigated as stack sheet require at least one sampling tube in each container placed at the top-centre of the commodity. Therefore, five containers being fumigated under a single fumigation sheet would need five sampling tubes, one placed at the top centre of the commodity in each container.

The reason for positioning the sampling tubes as recommended is to check that the fumigant is evenly distributed throughout the enclosure.

Positioning the tubes in a loaded container can present a problem especially for the two tubes away from the door. Fixing the tubes to rigid poles long enough to extend into the container can solve this problem, bamboo poles or plastic electrical conduit is commonly used for this purpose. If the configuration of the commodity in the enclosure makes placement of the sampling tubes at the recommended locations impractical, they can be re-positioned to more accessible locations provided the even distribution of fumigant throughout the enclosure can still be adequately determined. The tubes should be labelled according to their location within the enclosure.

The internal diameter of the sampling tubes should be suitable for the inlet of the concentration measuring instrument used. The connection must be gas-tight no fresh air is drawn in contaminating the sample. The usual range of internal diameter is from 2mm – 6mm.

The sampling tubes should be long enough to extend outside the risk area to allow readings to be taken without the need to wear respirators.

The tubes should not be able to be compressed easily or susceptible to kinking which may restrict air flow and adversely affect the accuracy of the readings.

4.1.1 Perishable fumigations

In addition to the general sampling tube quantity and positioning requirements perishable fumigations must have sampling tubes placed in the commodity (within cartons, bags, protective sleeves etc.) to demonstrate that the fumigant has penetrated in sufficient concentrations to achieve an effective treatment.

4.2 Fumigant supply pipes

Aluminium tubing should not be used for any part of the system used for the application of methyl bromide as it can react violently on contact with liquid methyl bromide.

For temporary enclosures the method used to inject the methyl bromide depends on whether the enclosure is created using a fumigation sheet or is done in an un-sheeted shipping container.

If the fumigation is done in an un-sheeted container then the gas can be injected using a rigid tube fitted to the end of the supply pipe and pushed through the door seals, usually at the top where the doors meet. Once injection is complete the tube is withdrawn and the door seal can be checked for leaks. If additional fumigant needs to be added to the enclosure simply re-insert the supply tube through the seal.

For sheeted enclosures the pipes should be disconnected from the vaporiser after injection is complete, sealed to prevent leakage and left in position for the duration of the exposure period in case additional fumigant needs to be added. The supply pipes should be positioned so the fumigant is directed into the free airspace to aid circulation and secured in place to prevent it from moving around due to the force of the gas exiting the hose. The outlet should be positioned away from the sampling tubes. If the supply pipes are not purged of methyl bromide after injection is complete they will contain pure methyl bromide which will slowly diffuse out of the pipe and may create a localised pocket of higher concentration near the outlet and any nearby sampling tube. One to two metres should be sufficient.

Using more than one supply pipe in larger enclosures will help to achieve even fumigant distribution more quickly. Fumigations of multiple containers in a single sheeted enclosure must have at least one supply pipe placed in each container.

Where more than one supply pipe is used the fumigant can released into the enclosure through the pipes simultaneously if the pipes are balanced. A balanced system is where the supply pipes are of equal internal diameter and equal length so an equal amount of fumigant will flow through each pipe. Using multiple supply pipes that are balanced can significantly shorten the time taken to achieve equilibrium. If the multi-pipe supply system is not balanced and equal proportion of fumigant should be released through each pipe in turn.

4.3 Fans

Since MB is more than three times heavier than air, it diffuses outward and downward readily, but requires fans to ensure upward movement and equal gas distribution. Fan circulation also enhances penetration of MB into the commodity. Once the gas is evenly distributed, it maintains that condition for the duration of the treatment unless an outside event such as excessive leakage occurs.

One or more fans must be used in each enclosure to force the fumigant to mix thoroughly with the air and circulate throughout the entire enclosure until even gas distribution is achieved.

Fumigations in shipping containers, whether it is a single container or multiple containers in a stack, must have at least one fan placed in each container. The fans should be positioned so that an air flow will be created to rapidly disperse the fumigant evenly throughout the enclosure. The capacity and/or number of fans used should be proportional to the volume of the enclosure. The total combined air flow capacity of the fans in each enclosure should be sufficient to move the equivalent of the enclosure volume of air every one to two minutes.

It is very important to check that the fans are working when they are installed. After testing the fan make sure that the power switch on the fan itself is left on and turn it off by unplugging the lead from the power source on the outside of the enclosure. Once the enclosure is sealed and under gas the fans can't be operated if the power switch inside the enclosure is off.

Fans should be turned on 10 – 15 minutes before releasing any fumigant into the enclosure and continue to run until equilibrium is reached. The time it takes to achieve equilibrium will vary depending on factors such as, how tightly packed the commodity is, the size of the enclosure, the capacity of the fans and the number of supply pipes used to introduce the fumigant. It is a matter of experience to judge how long to run the fans before taking the first readings.

Fans must be turned off prior to taking any concentration readings. Once even gas distribution has been achieved there is no practical benefit in continuing to run the fans so they can be switched off until ventilation unless there is a need to add additional fumigant during the exposure period.

5 Fumigation enclosures

5.1 Gas–tightness

All enclosures will leak to some degree, particularly temporary ones such as sheeted enclosures and shipping containers. The fumigator must take all reasonable steps to minimise fumigant loss from the enclosure during the exposure period to;

- ensure the treatment is effective
- prevent unsafe levels of fumigant accumulating in the immediate vicinity
- reduce methyl bromide usage by minimising the need to use additional fumigant

5.2 Sheeted enclosures

Temporary fumigation enclosures are often created using a sheet or sheets to surround the consignment and retain fumigant in contact with the contents of the enclosure. The space enclosed by the gas–proof sheets is, irrespective of the size of the enclosure, a single fumigation for concentration monitoring and documentation purposes. There are three main causes of gas loss from sheeted enclosures:

- The fumigation surface is not impervious
- The fumigation sheet is not made of a suitably impervious material or it is in poor condition
- Leakage from between the sheet and the floor.

The first two of these are covered in the sections on site selection and fumigation sheets respectively.

The sheet must be held flat against the fumigation surface to prevent excessive leakage. This is most easily done by the use of sand snakes, flexible tubes filled with sand around 100mm in diameter and from 0.5 – 1.5 metres long. Sand snakes should only be filled to 65 – 75% with clean dry sand so they remain flexible enough to bend around corners and lie flat on the ground. A minimum of two rows of sand snakes should be used around the entire enclosure. They should be laid end to end with the second row offset to overlap the joins of the first row in a brick-work like pattern.

Water snakes can also be used. A single continuous water snake should be laid flush against the stack and filled 75 – 85% full. Care should be taken to ensure a complete seal where the ends of the snake meet. The water snake should not start or end on a corner. If water is used to create snakes similar to sand snakes they should be laid in the same way as sand snakes.

Loose sand or soil can also be used to seal the sheet to the floor. Sufficient sand or soil must be used to create a continuous seal around the entire enclosure.

Fumigation sheets should extend at least 500mm from the base of the stack to allow more sand snakes, water snakes or the like to be added to improve the seal between the sheet and the fumigation surface if a leak is detected. The additional snakes should be placed alongside the existing rows rather than on top.

The sheet at the corners of the stack should be folded so the sheet will lay flat against the surface making it easier to get a good seal. Once folded the corners should be secured with clamps or tape to prevent the wind from pulling the sheet apart.

Strong winds can cause the fumigation sheet to billow resulting in excessive loss of methyl bromide with the potential to cause the fumigation to fail. In circumstances where high winds are unavoidable (for example, an open site at a port) ropes should be used around the enclosure to hold the sheet in place.

5.2.1 Fumigation Sheets

Fumigation sheets must be impervious to the fumigant being used. They must be able to easily retain sufficient fumigant concentrations for the entire exposure period without the need to add additional fumigant. The ability of the sheets to retain fumigant will deteriorate with use and they should be carefully monitored to ensure their condition is good enough to reliably meet the gas retention requirements.

The sheets must be inspected for any damage before each use. Any tears or holes can be temporarily repaired using suitable tape capable of adhering to the sheet material. Permanent repairs should be made to sheets at the first opportunity by heat welding or gluing patches over the damaged area. Patches must not be sewn on as the needle holes will still allow too much gas to escape.

A variety of different materials are suitable for use as fumigations sheets. They range from relatively thin plastic sheets that last for only a few uses to heavier, more durable sheets that will last for many years if handled with care. Most of the materials used in the manufacture of fumigation sheets are not completely gas-tight because such materials are all permeable to some degree to fumigants. The rate at which diffusion through the sheet takes place depends upon the type of material, its thickness and the ambient temperature. Diffusion through the sheet will reduce the concentration of fumigant to which insects are exposed in the stack. If a sheet is highly permeable to methyl bromide there may be uneven distribution of fumigant within the stack to such an extent that in some localities the concentration is insufficient to kill all the insects present. As the ratio of sheet area to stack volume is greater in small compared to large stacks, losses by diffusion would be expected to be proportionally greater in small stacks.

Woven tarpaulins that are not coated or only thinly coated allow too much gas to be lost and are unsuitable for use as fumigations sheets.

When purchasing fumigation sheets consideration should be given to the following:

- permeability
- durability of the material
- flexibility
- weight
- size
- ease with which any holes, tears or abrasions can be permanently and effectively repaired

Many fumigators prefer to use lightweight sheets regardless of other properties, because such sheets require less labour and are easier to handle. However, this may be dangerous and there must be a proper compromise between durability, permeability and ease of handling. Removal of debris such as stones from the fumigation floor, carrying rather than dragging the sheet and padding any sharp corners can protect the sheet and they can last for many years.

The sheets should be large enough to completely cover the enclosure being fumigated with a minimum 500 mm of sheet extended out from the base of the enclosure on all sides. As a guide the following size sheets would be sufficient for shipping containers:

20 ft = 12.5m wide x 16m long

40 ft = 12.5m wide x 22m long

Sheets can be joined to create larger enclosure if necessary but care should be taken to ensure that the joins are gas-tight.

They can be joined by tightly rolling a 400 mm to 500 mm overlapped join, which should be secured by tight gripping welding style clips or other suitable means. Often a better join can be created by wrapping the sheets around something rigid like lengths of wood. Roll the sheets at least three to four full turns around the battens and hold together with tight gripping clips or other suitable method.

Any clamps or clips with sharp edges should not be used or the sharp edges covered in some way to prevent damaging the sheet.

Joins should be made and positioned so they are supported by a solid surface e.g. a container roof.

5.2.2 Sand Snakes

Sheeted enclosures require some method of creating a gas tight seal between the sheet and the fumigation floor.

Sand snakes are the most common method used for sealing sheets to the floor of the enclosure. They are preferred because they are:

- heavy enough to hold down the sheet flat to the fumigation floor to create a good seal
- light enough to be easily handled
- flexible so they can be bent around corners
- soft, so they do not damage fumigation sheets
- easy to make
- reusable, if made from durable material
- versatile, they can also be used to pad sharp corners, hold down supply pipe and sampling tubes etc

The snakes should be partially filled with clean dry sand to no more than 65-75%. To check how full a sand snake is, hold it up lengthwise and shake the sand down. For example a correctly filled snake 1 metre long should have sand up to between 65 - 75cm.

If the filling does not move freely then it is likely that the filling is not clean sand. This can affect the ability of the snake to lay flat against the floor reducing its effectiveness to create a gas tight seal. A correctly filled sand snake can be turned around a right angle corner with an even distribution of sand along the full length of the sand-snake.

5.2.3 Water Snakes

Water snakes are much less common than sand snakes. While they can be very effective in creating a gas tight seal they have a number of disadvantages over sand snakes such as:

- water for filling is required on-site
- they are very heavy and can be difficult to move or adjust once filled
- easily punctured
- can make the ventilation procedure more difficult

Water snakes must be filled to the point where they are still flexible enough to bend at right angles around the corners of the enclosure, lay flat against the fumigation surface and be heavy enough to give a good seal. Particular care should be taken around the corners if they are not folded and flattened as the water will flow to the lowest points reducing the weight and hence their effectiveness. This can also be a problem on uneven surfaces.

5.2.4 Maintaining gas-tightness

The success of the fumigation depends on maintaining the required gas concentrations for the entire exposure period. Some simple and easily performed preparations can assist greatly in improving gas retention on sheeted enclosures. Folding and securing sheet at the corners so the sheet lays flat against the floor improves the effectiveness of the seal. Putting a rope around the enclosure between a third and half way will also help to reduce sheet movement in windy conditions which may result in the sheet working loose and releasing fumigant.

5.3 Un-sheeted shipping containers

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

5.3.1 Container inspection

Before preparing the container the fumigator, in addition to general consignment suitability considerations, must also:

- Check that there is enough space to position and operate the fan inside with the doors 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.

5.3.2 Container preparation

Once the fumigator is satisfied the container is suitable they can now install sampling tubes and fan (and/or heaters) in accordance with the requirements.

Arrange the tubes and leads so they all exit the container where the doors meet at the base of the container. There is more space between the doors at this point making them easier 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 of 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. Remove the supply hose after injection. A rigid tube may need to be fitted to the end of the supply hose to make it easier to insert through the door seals.

A potential risk that could a problem is excessive leakage through the container floor. These leaks may not be able to be detected and, even if they are, it is not practical to fix them if the container is on the ground. If there are significant leaks through the floor the rate of gas loss will be exacerbated by any wind passing under the container. This can be minimised by creating a barrier around the enclosure to reduce the airflow. One of the simplest methods to create this barrier is to use some sand snakes to cover any fork-lift holes or gaps. This is not intended to stop any leaks only to slow down the effects of the wind.

Sometimes, despite careful preparation and set-up, a container may still leak gas too quickly to be able to maintain the required concentration throughout the exposure period. If the fumigator is concerned about this then careful monitoring at the start of the fumigation is advisable to give an indication of the rate of gas loss and if it is sustainable. If the monitoring shows a trend that may lead to fumigation failure a possible solution in some circumstances may be to enclose the fumigation, as is, under a gas-proof sheet provided the fumigation surface was acceptable.

A false door can fitted to create the gas-tight seal. This is normally done if the extraction of the gas needs to be carefully controlled because of maximum concentration limits or for recapture. The supply pipe, sampling tubes and power leads must pass through the false door and there must be a re-sealable opening to allow fresh air into the container to replace the extracted gases. The door needs to be leak checked and any leaks detected sealed using tape.

The tape used for any sealing should be impervious and able to withstand wet weather if there is a possibility of rain.

5.4 Fumigation chambers

Most chambers are either converted shipping containers or a structure designed and built specifically for fumigation. The door seals on converted shipping containers need to be inspected regularly for wear.

5.5 Pressure testing

5.5.1 Procedure for performing a pressure test

Check the monitor tubes, supply pipes and exhaust system valves are closed.

The pressure inside the closed chamber must be raised to 250 Pa. This can be done using high-pressure compressed air supplied from a portable compressor or gas cylinders attached to the supply pipe or, in some designs, by reversing the flow of the extraction fans.

Attach a suitable pressure measuring instrument to one of the sampling tubes.

1) When the pressure inside the chamber 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.

5.5.2 Instruments for measuring the pressure decay time

The pressure inside the chamber can 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, using a manually operated stop watch;

Any sensitive pressure gauge, using a manually operated stop watch;

A purpose made instrument, the CONTESTOR, which combines a pressure sensor with a timer that cuts in when the required pressures have been achieved.

6 Calculating the dose

6.1 Dose rate

The dose rate specifies the concentration of fumigant that must be initially applied to the enclosure and the period of exposure required.

6.2 Dose rate compensation for temperatures below 21 °C

The most important environmental factor influencing the action of fumigants is temperature as the toxicity of a fumigant depends on the respiration rate of the target organism. Generally, the lower the temperature, the lower the respiration rate of the organism which tends to make it less susceptible to the mode of action of the fumigant. To compensate for this effect, fumigation at lower temperatures requires a higher concentration of fumigant than fumigation at higher temperatures.

For practical purposes, it is increasingly difficult to kill insects with fumigants when the temperature is 10°C or less. In general, the effectiveness of fumigants becomes unreliable below 10°C so fumigation is not normally permitted where the temperature is expected to fall below 10°C during the exposure period. It should be noted though, that some countries do permit fumigations to be performed at temperatures below 10 °C. In these cases the fumigator should be aware that the sorption of methyl bromide increases as the temperature lowers, which is another reason the concentration needs to be increased. In some circumstances, particularly at higher concentrations, the methyl bromide may condense on the surfaces inside the enclosure at these lower temperatures potentially causing damage to some commodities.

The expected minimum ambient temperature must be used to determine any adjustments to the dosage rate for fumigations performed outside or in facilities without adequate temperature control. The temperature can be obtained by checking the official forecast minimum temperature of the nearest locality to the fumigation site.

A typical adjustment schedule for temperatures below 21 °C is:

21 °C and above	no adjustment allowed
16 – 20 °C	add 8 g/m^3 to the prescribed dose rate
11 – 15 °C	add 16 g/m^3 to the prescribed dose rate
10 °C	add 24 g/m3 to the prescribed dose rate

If the ambient temperature is expected to fall below 10°C heaters can be used to increase the temperature and maintain it at a satisfactory level for the duration of the exposure period. There will be a gradient within the enclosure where the temperature will progressively decrease the greater the distance from the heat source. Using fan heaters can improve the heat distribution in the enclosure but they may also contribute to an increased loss of methyl bromide from the enclosure, for this reason, the enclosure needs to be as gas-tight as practical.

The use of a min/max thermometer within the enclosure to measure the minimum temperature is recommended. Where possible it should be placed at the point farthest away from the heat source. By recording the actual minimum temperature in this way the fumigator can improve the accuracy of their estimates when using heaters in fumigation enclosures.

Sufficient time must be allowed for the enclosure and the commodity to reach the desired temperature prior to starting the fumigation.

Position the heaters within the enclosure so they will not present a fire risk or cause damage to any goods.

If there is a need for heaters it is advisable to set up the fumigation at the warmest time of the day if possible. It is more efficient and effective for the heaters to try and maintain a steady temperature rather than try to re-heat a cold enclosure.

6.2.1 Temperature probes for fruit and vegetables

Some commodities, particularly perishables, require treatment at a specific temperature or within a specific temperature range to ensure the treatment is effective while minimising any adverse effects on the quality of the commodity that may result from increased temperatures. If the treatment requires measurement of the internal or pulp temperature of the commodity then suitable temperature probes must be used. Fumigations that require a specific temperature or temperature range must be performed in a facility capable of heating the commodity to the desired temperature and maintaining it for the duration of the fumigation exposure period.

The temperature must be measured by placing the temperature probe into the centre of a piece of fruit located in the middle of a carton. At least three temperature readings must be taken from fruit in three different cartons/pallets and from different varieties within the consignment:

- From one carton at the top of the pallet;
- From one carton in the middle of the pallet;
- From one carton at the bottom of the pallet

6.2.2 Calibration of temperature probes used for fruit and vegetables

Temperature probes must be maintained to an accuracy of at least plus or minus (±) 1 °C. A suitably qualified technician, manufacturer or distributor will be able to calibrate the probes at least once a year. You can also calibrate the probes using the following method.

Ice Water Slurry

- Crush several pieces of ice (about 50-100g) and place in a small container such as a drinking glass.
- Add enough cold water to produce a slurry but not so much that the ice floats.
- Stir the ice slurry vigorously and let stand for approximately 5 minutes.
- Insert the probe into the slurry and wait at least one to two minutes for the reading to stabilise.
- Record the temperature.
- Take three further readings at least one minute apart.

If consecutive readings are not within 0.5°C replace or service the probe.

If the temperature readings are higher than +1°C or lower than -1°C attach a label to the probe showing the date the calibration check was made and the variation from 0°C. Alternatively purchase a new probe.

The complete measuring system (sensor probe, cable, data logger, etc.) has to be checked and calibrated, not only the sensor.

The date and result of the calibration of each thermometer must be recorded.

6.3 Enclosure Volume

The volume of the enclosure must be calculated from the measured dimensions. When fumigating sheeted enclosures the measured external dimensions should be used. The dimensions of sheeted enclosure should be measured each time because significant variations in volume can occur depending the set-up of the enclosure.

If the enclosure is an un-sheeted container or a chamber the known internal volume of the enclosure can be used. The volume of any gas circulation equipment external to the chamber must be included in the calculation of the enclosure volume.

No reduction in the volume and therefore, the dosage, is allowed to account for any displacement of air in the enclosure by the commodity.

6.4 Chloropicrin

Some fumigants can be supplied mixed with other gases so the fumigant is diluted to less than 100%. For example, methyl bromide is commonly supplied with a mixture of 2 % chloropicrin. Methyl bromide is colourless and odourless at concentrations normally encountered during fumigation so the chloropicrin is added as warning agent.

If the fumigant is mixed with another gas the dosage must be adjusted to compensate for the dilution. The dosage is divided by the percentage of the active fumigant in the mixture to give the total amount of fumigant mix that needs to be released into the enclosure to achieve the specified dosage rate concentration.

6.5 Rounding

Whichever method is used to measure the amount of methyl bromide to be used it is not possible to do it precisely so there will always be some degree of error. For this reason the calculated dose should be rounded up to the nearest reliably measurable increment.

7 Injecting the dose into the enclosure

7.1 Measuring the dose

The three methods for measuring the dose are by;

- volume
- weight
- can – 1 pound (454 g) and 1 ½ pound (680 g)

If cans are used the fumigator must round the dose up to the next full can, calculate using a combination of 1 and 1 ½ pound cans (454g and 680g respectively) to get the optimal combination. Partial use of a can is not permitted so the dose in this case must comprise one or more full cans.

Due to the inaccuracy inherent with measuring the dose by weight or volume the actual amount of methyl bromide injected into the enclosure will vary slightly to what was intended. The actual amount used, as far as can be practically determined, must be recorded on the Record of Fumigation.

7.2 Vaporising the methyl bromide

7.2.1 The purpose of vaporisation

The main reason the methyl bromide must be completely vaporised is to prevent liquid methyl bromide from being released into the enclosure. If liquid methyl bromide comes into contact with the commodity it can cause cold 'burns' as it continues to try and draw the heat from the environment it needs to evaporate. Not only can this cause damage to the commodity, it is potentially dangerous as liquid methyl bromide reacts explosively on contact with aluminium, magnesium and zinc (gaseous methyl bromide does not do this).

It is poor fumigation practice to not ensure that the methyl bromide is fully vaporised and the fumigator may be held responsible if the value of the product is adversely affected as a result.

In addition, vaporising the methyl bromide has the added benefit of energising the methyl bromide molecules improving the speed of dispersal throughout the enclosure and encouraging more rapid penetration into the product if it is porous.

7.2.2 Vaporiser design

There are two related factors that affect the vaporisation of methyl bromide, the first is temperature and the second is pressure. The higher the temperature i.e. the more heat available, the greater the tendency there is to become a gas. Conversely, the higher the pressure the greater the tendency there is to stay as, or turn back into, a liquid. Both these factors need to be taken into account to ensure that the methyl bromide is fully vaporised before it reaches the enclosure.

Methyl bromide is supplied as a liquid under pressure in cylinders or cans. As the methyl bromide is released it changes from a liquid to gas, this process requires energy in the form of heat which it draws from the immediate surroundings. When it vaporises the methyl bromide increases 275 times in volume and this expansion increases the pressure in the supply hose. If this pressure gets too great and there is not enough heat available the methyl bromide will turn back into a liquid. As more methyl bromide passes through the supply system there is progressively less and less heat available so the liquid methyl bromide will travel further towards the outlet without vaporising until it exits into the enclosure.

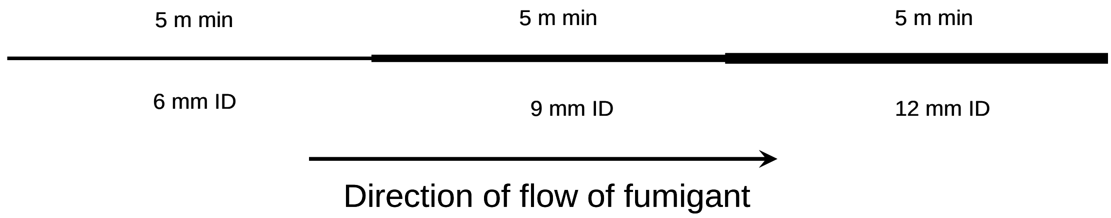
The vaporiser is a heat exchanger that uses a metal coil immersed in a container of hot water to provide the energy needed to ensure that the methyl bromide is fully vaporised and remains in a gaseous state. There is a direct relationship between the amount methyl bromide passing through the system and the energy available to turn it into a gas. If there is insufficient heat available the pressure build-up in the supply system can turn the methyl bromide back into a liquid.

Following is a simple design for a versatile and portable vaporiser suitable for most fumigation situations that would be covered by the Methyl Bromide Fumigation Methodology.

7.2.3 The Heat Transfer Coil

The coil should be made from copper tubing because it is a good conductor of heat. The coil can be made from one continuous length that should be at least 12 metres long and with an internal diameter (ID) no greater than 12 mm. Internal diameters larger than 12 mm proportionally decreases the ratio of surface area to volume (assuming equivalent flow rates) making the vaporisation process less efficient as the internal diameter increases. This, in combination with allowing the methyl bromide to pass more quickly through the system, increases the chances of liquid methyl bromide exiting the supply pipe unless the flow rate is carefully monitored and controlled.

Another design option for the coil is to construct it from three five metre lengths of copper tubing of progressively increasing from 6 mm ID to 9 mm ID and finally 12 mm ID. This smaller ID at the start of the coil restricts the flow rate of methyl bromide from the supply cylinder and the subsequent increasing size improves the flow of the gas in the direction of the by avoiding excessive back-pressure which can re-liquefy the Methyl bromide.



The lengths of tubing must be carefully joined in a manner that is completely gas-tight. The joins should be checked regularly as they can be susceptible to leaks, particularly if the vaporiser is moved around frequently.

Whichever coil design is used, suitable connectors should be used to join the coil to inlet and outlet of the vaporiser.

7.2.4 The Water Container

The water capacity of the vaporiser should be proportional to the length of the heat transfer coil. A water volume between 20 to 25 litres would be adequate for the coil specifications described above.

The container should be constructed of a material suitable for the heating method used. Stainless steel is a good option.

It is advisable for the vaporiser to have handles so that it can be moved if needed while it is full of water.

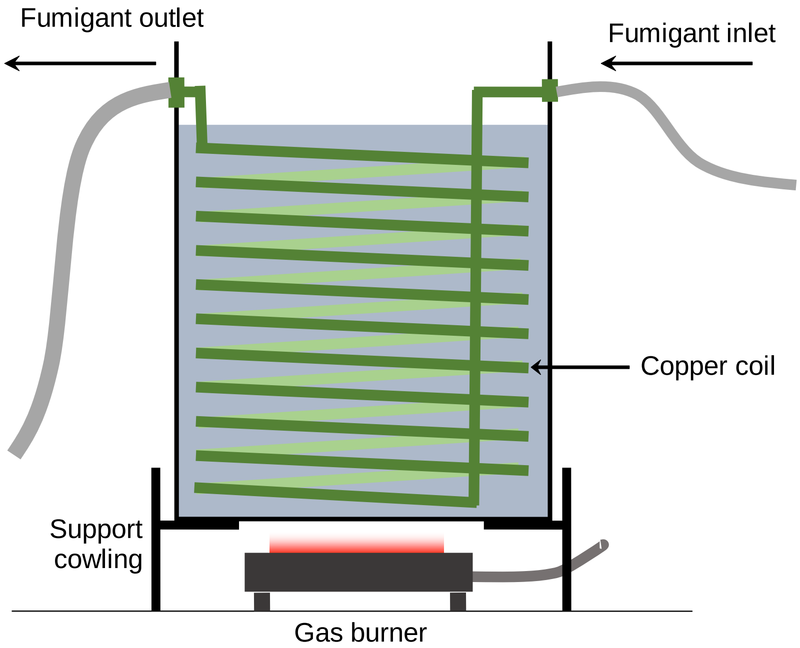
A lid that can be easily removed once the water is hot to make it easier to monitor the water temperature during injection. Alternatively a thermometer or steam whistle could be used.

7.2.5 Heating the Water

The heating method used should be able to heat the water to boiling in around 20 – 30 minutes, this is about the time it would normally take an experienced fumigation team to prepare the enclosure for fumigation.

The method of heating must also be able to maintain the water temperature above 65° C while the fumigant is being injected. The vaporisation process will draw heat from the water as the Methyl bromide passes through the coil so the heat source must continue operating during injection to replace the lost heat.

It is strongly recommended that good capacity gas burners are used. A cowling should be included to support the container above the gas burner and to protect the burner from the wind. Electrical heating elements are acceptable but they are generally less effective than gas slowing down the rate at which the gas can be injected.



7.2.6 Fittings and connections

The choice of fittings for both inlet and outlet will depend on the individual and the equipment used. However it is strongly recommended that good quality, gas rated fittings are used. Threaded fittings on all gas piping is recommended, rather than relying on hose clamps to hold piping in place on bare copper tubing. It is never a good idea to use tape to join any part of the supply system.

7.2.7 Using the vaporiser

Prior to use the vaporiser should be inspected for damage and that the connections and fittings are in good order.

Set up the vaporiser up inside the risk area and start heating the water so that it will be ready to use as soon as the enclosure has been prepared. Do not connect the vaporiser to the cylinder until just before you are ready to inject the gas.

Check the vaporiser for leaks by releasing a small amount of Methyl bromide from the cylinder and test all the connections along the supply system with a suitable leak detector. Fix any leaks before starting to inject the dose into the enclosure. Be careful to open the supply valve slowly to avoid rapid pressurisation of the system which could result in weak or poor connections coming apart releasing methyl bromide into the area. Suitable respiratory protection must be worn while releasing the methyl bromide.

While the required minimum water temperature is 65° C it is recommend that the water be kept on the boil prior to and during the injection process as this allows the operator to easily check that the temperature is above the mandatory requirement. If the water is not boiling or the operator cannot see if it is, then a simple method to test the temperature is Ok is to hold the outlet hose about a metre from the vaporiser with bare hands. If it is almost too hot to hold firmly then the water temperature should be sufficient.

The operator must regulate the flow rate of the methyl bromide so that the temperature of the water is maintained and there is not excessive build up of pressure in the system. Some vaporisers are fitted with thermometers or pressure gauges to assist with managing the rate of release. If the water temperature drops too low slow or stop the methyl bromide until the water has time to recover and recommence at a slower rate.

7.3 Checking for leaks

Excessive leakage from the enclosure may allow the fumigant concentrations to fall below acceptable levels resulting in an ineffective fumigation.

Carefully check the enclosure for leaks. For stacks check where the sheet meets the fumigation surface around the entire enclosure paying particular attention to the corners, where the monitoring tubes and leads exit the enclosure, any cracks or expansion joints in the floor and any temporary repairs made to the sheet. Check around the door seals of containers used as enclosures without sheeting.

The leak detection equipment must be sufficiently sensitive to detect fumigant concentrations low enough to find a leak that warrants attention. As a general guide the leak detector should be capable of detecting concentrations down to 30 ppm.

The leak detection equipment must be fit for purpose and properly maintained in accordance with the manufacturer's instructions.

7.3.1 Halide leak detection lamp

A halide lamp works on the principle that a flame in contact with a clean piece of copper will burn with a green to blue flame if vapour of an organic halide is present in the surrounding air. The copper ring must be kept clean and replaced regularly to ensure proper functioning. These instruments can be used to detect methyl bromide in the air for the purpose of detecting serious leaks which can then be rectified to prevent excessive loss of fumigant and thereby reduce the likelihood of fumigation failure.

At increasing concentrations of the halide gas, the colour changes from green to greenish-blue or blue.

Determining Methyl Bromide Concentrations with the Halide Detector:

Concentrations in air - Parts per million	Reaction of Flame
0	No reaction
10	Very faint green tinge at edge of flame
20	Light green edge to flame
30	Light green flame
100	Moderate green
200	Intense green, blue et edge
500	Blue green
1 000	Intense blue

Note: Owing to variations in response of individual lamps, readings below 30 ppm are unreliable

Halide detection lamps cannot be relied upon for accurate quantitative measurements. They are useful for indicating the presence of immediately dangerous concentrations, for preliminary checking the effectiveness of aeration and for finding leaks during treatment. They are not suitable for checking threshold limits for continuous daily exposure to methyl bromide; for this purpose some more accurate method of must be used for final determination of gas clearance after ventilation.

Changes in the colour of the flame can be difficult to identify, particularly in direct sunlight or brightly lit areas. Halide lamps cannot be used by colour blind people.

7.3.2 Electronic gas detection

There is a range of electronic methyl bromide gas detection equipment available and they are more sensitive and easier to use then a halide lamp. There are two types of electronic leak detectors, ones that only detect the presence of methyl bromide and those that give an actual value for the concentration detected. Leak detectors that provide quantitative reading of the concentration are also suitable for checking TLV if they can detect concentrations below 5ppm.

Leak detectors used for refrigerant gases are not suitable for use with methyl bromide and are not acceptable.

7.4 Circulating the fumigant

The methyl bromide must be evenly distributed throughout the enclosure to ensure that the entire space has fumigant concentrations sufficient to administer a lethal dose to the target pests.

Methyl bromide is considerably heavier than air (3.27 times) and could be described as a 'lazy' gas so, if it is allowed to disperse naturally, there will likely be areas of high concentration near the outlet and lower concentrations further away. Also, smaller spaces between and air pockets within the stack of goods are particularly susceptible to lower concentrations as the natural movement of air has less effect in dispersing the methyl bromide into these areas.

Mechanical agitation of the air is required to force rapid dispersal of the fumigant throughout the enclosure and into the spaces between and within the commodity. It is most common to use an electric fan for this purpose.

There is no specified minimum capacity as the suitability of a particular fan will depend on the size of the enclosure, how the consignment is configured and the amount of free airspace. However, the fan will have a direct effect on how quickly equilibrium is reached and therefore when start-time is achieved.

A fan with a capacity of at least 30 cubic metres per minute would be reasonable for an enclosure around 30 m^3 in volume (equivalent to a 20ft shipping container)—a 40 cm domestic fan will normally be capable of meeting this requirement.

For larger enclosures it is advisable to use a higher capacity fan and, for large stacks over 100 m3, multiple fans would further assist in achieving equilibrium.

Turn the fan/s on 5 to 10 minutes prior to injecting the gas to get the air moving. As the methyl bromide is injected this will encourage the methyl bromide to mix with the air and be transported throughout the enclosure. Even though methyl bromide is heavier than air the tendency for it to accumulate in higher concentrations lower down in the enclosure is minimal during normal fumigation exposure periods if it has been thoroughly mixed with the air from the beginning.

The fans must be running during the injection phase and for as long as necessary to achieve equilibrium. The fans must be turned off prior to taking the concentration readings to allow the air in the enclosure to settle. This helps to get more accurate and stable readings.

It is not necessary run the fans again once equilibrium is achieved unless additional methyl bromide is added to the enclosure.

8 Monitoring fumigant concentration levels

The principal objective of fumigation is to maintain an adequate concentration of the fumigant vapour within the treated area for a sufficient length of time for all pests, including different stages of their life cycle, to receive a lethal dose. The only way to determine if the minimum concentration levels have been met is to take concentration readings at the start of the fumigation and again at the end. If both these readings are at or above the minimum level specified for the time they were taken, then the concentrations have met the minimum requirements throughout the entire exposure period.

Every concentration reading must also show the time at which it was taken. When taking readings from more than one sampling tube the time should after the final reading was taken and this is used as the time for all the readings in that set.

8.1 Concentration measuring instruments

There are a number of suitable monitors that can be used. While price is always a significant factor in choosing any equipment careful consideration should also be given to the reliability and ease of use. Some of the brands on offer can be more difficult to use in the field then it would first appear. It would be prudent to carefully research what brand and model would represent the best choice to suit each fumigator's individual circumstances. When deciding on a fumigation monitoring instrument you should consider the following:

- Accuracy
- Detection range
- Durability
- Reliability
- Sensitivity to other factors such as CO2 and moisture
- Cycle time between readings
- Ease of use
- Portability if required
- Calibration and maintenance requirements
- After sales service
- Purchase price and ongoing costs for maintenance and repair

The detection range should be between 2 – 200 g/m^3 ($1 g/m^3$ = 250 ppm)

Below are 3 of the most widely used instruments for monitoring methyl bromide fumigations.

Fumiscope version 5.0 and 5.1

range = 0 – 2999 g/m^3

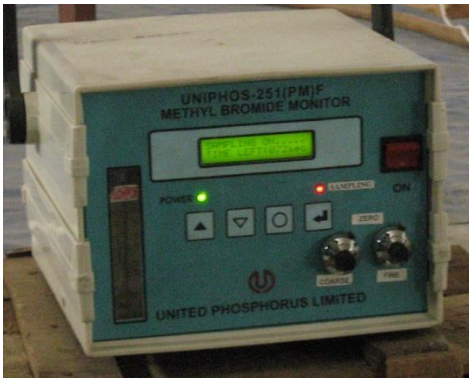
The operator's manual can be found at:
http://www.fumiscope.com/pdf/51englishlanguagefumiscopemanual.pdf

Riken FI-21

range = 0 – 200 g/m^3

The operator's manual can be found at:
http://www.rkiinstruments.com/pdf/mFI-21.pdf

Uniphos 251PM-F



range = 0 – 200 g/m^3

Some perishable commodities (e.g. garlic, onions, mangoes) release high amounts of carbon dioxide and this affects gas measurements of some instruments. It is particularly important to maintain the carbon dioxide and moisture absorbers fitted to instruments.

It is not uncommon to see experienced fumigators using their equipment incorrectly so it is important for all fumigators to read and understand the user's manual for their instrument even if they are trained by a colleague.

Maintenance and calibration records must be kept for all monitors.

8.2 Monitoring frequency

There may times when it is sensible for the fumigator to take concentration readings in addition to the mandatory readings. If the fumigator is concerned that fumigant levels may fall below the required concentration for whatever reason then the fumigator should carefully monitor the fumigant levels and take preventative measures if needed.

The minimum gas retention rates assume that there will be a certain amount of gas loss during the fumigation due to leakage, sorption and, in some cases, chemical reaction. The rate of gas loss tends to be highest at the start of the fumigation and then stabilises. If there are any leaks then the enclosure will be losing gas until the leaks are found and fixed. Any sorption will happen early in the exposure period until the product becomes saturated.

Another important factor is the degree of penetration into the commodity. The goods will occupy an amount of volume making less air space available for the fumigant so the initial concentrations measured will be somewhat higher as the dose is calculated assuming an empty enclosure. If the goods are porous, timber for example, then the methyl bromide will progressively penetrate into it reducing the methyl bromide in the surrounding space. The rate and extent of penetration depends on number of factors and will vary considerably depending on the nature of the goods.

To account for these factors the minimum concentration levels allow for a 50% loss of gas in the first 4 hours If the rate of loss is greater than this it is almost certain that the concentration levels are going to fall below the minimum levels and the fumigation will fail unless the problem is addressed.

8.3 Start time of the fumigation

It is a common mistake for fumigators to start the exposure period as soon as they get equilibrium and overlook the need for the concentration to be above the required level. Whenever any concentration readings are taken the fumigator must first check if they are at or above the required level for the time at which they were taken.

9 Topping–up to compensate for low concentrations

If any of the readings show concentration level has fallen below the standard concentration specified for the time the reading was taken then, technically, the fumigation has failed. Rather than automatically require the fumigation to be done again it is permitted, in some circumstances, to add additional methyl bromide to the enclosure to get the concentration levels back to a satisfactory level and continue the fumigation.

9.1 Topping-up before reaching start point

If the concentration falls below the standard concentration before even gas distribution has been achieved there is probably excessive leakage from the enclosure. For sheeted enclosures it is most likely due to fumigations sheets that are not suitable or in poor condition, a porous fumigation surface or proper care was not taken to create a good seal between the sheet and the surface.

Before adding any additional methyl bromide the fumigator must find and fix the cause of the problem otherwise there is no possibility that they will be able to achieve a successful fumigation. Once the problem has been fixed the fumigator needs to take another set of readings to determine how much fumigant remains in the enclosure as the fumigant would have continued to leak until the problem was fixed. Use the lowest of these readings to calculate the amount of additional methyl bromide to add by subtracting the low reading from the initial dose concentration to give a value in g/m^3. Use this value, plus an extra 5- 8 g/m^3 as a buffer, to calculate the amount as you would normally.

The fumigation now effectively starts again and all the requirements for injecting, even gas distribution and start time apply.

If start point can be achieved then the fumigation can proceed but it would be sensible to take some additional readings an hour or so after the start to check that the concentration levels can be maintained.

9.2 Topping-up during the exposure period

The need to top-up during the exposure period could be a result of sorption, leakage or a combination of both. The process of sorption occurs mostly at the start of the fumigation and then tapers off as the material becomes saturated so then need to top-up due to sorption stops after a couple of hours. If the need to top-up is because of leakage then this will continue unless the leak is found and fixed.

If the enclosure has been carefully leak checked and there is a need to top-up more than once during the exposure period then it would indicate that the fumigation sheet is not suitable and is unable to retain the methyl bromide for the required time. If the sheets are not made of a suitable material the gas will pass through the sheet. The cumulative effect over a large surface area can be significant and lead to excessive gas even if it can't be directly detected. If this is the case, the fumigation sheet needs to be replaced before doing another fumigation with one that it is suitable.

9.3 Topping –up at the end of the exposure period

If a top-up is necessary at the end the only difference to topping up during the exposure period is the need to extend the exposure period by 4 hours. If this is a regular occurrence it is indicative or poor gas retention and that problem needs to be addressed.

10 Ventilating the enclosure

At the end of the exposure period the enclosure must be safely vented to remove the fumigant and aerate the consignment by exposure to fresh air until the concentration of fumigant is below unsafe levels.

Good free airspace and turning the fans on will help to ventilate the enclosure more quickly. The time taken to ventilate depends on number of factors such as the size of the enclosure, how tightly packed the commodity is, whether there is sorptive materials in the enclosure and the degree of penetration into the goods.

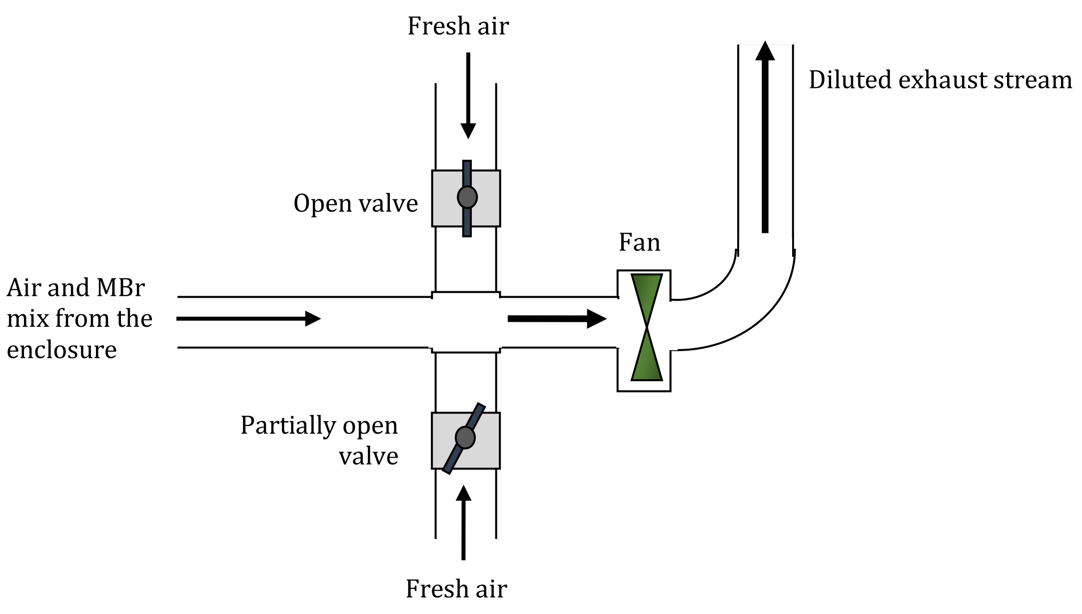
The methyl bromide in the air around the commodity will dissipate rapidly once the enclosure has been opened. If, however, the methyl bromide has penetrated into the commodity, for example timber or cardboard boxes, then it will take considerably longer for the gas to diffuse out of the goods and dissipate. This process could take 24 hours or more depending on the nature and configuration of the commodity and the fumigator needs to plan for this prior to starting the fumigation.

10.1 Safety during ventilation

Releasing the fumigant from the enclosure is the only time a fumigator knowingly exposes themselves and possibly others to methyl bromide. The fumigator needs to actively manage the risk to themselves and anyone in the vicinity. The fumigator should control the rate of release by progressively opening up the enclosure so the fumigant is not released as a large plume which can travel further and in higher concentrations than it would otherwise do.

If electronic leak detection equipment is available these should be used to verify that the buffer zone around the enclosure is sufficient and when and by how much it can be decreased as the ventilation proceeds.

If there are local regulations that set a maximum concentration that can be released from the enclosure the fumigator must dilute the exhaust stream to restrict the concentration under the level specified. This normally done by drawing the air from the enclosure through a duct which is attached to a chimney many metres tall so the gas is released high above ground level. The exhaust stream is diluted by valves along the duct that controls the amount of fresh air from the surround area to be drawn into the flow from the enclosure.



10.2 Releasing the fumigant from the enclosure

10.2.1 Procedure for ventilating a stack

Remove all the sand snakes except a few down both sides of the enclosure. Lift the sheet on both corners to no more than waist height and secure, use the belly rope if there is one. Do this first on the downwind direction so the wind doesn't get under the sheet and lift it off before you are ready. Repeat this procedure at the upwind end then pull the sheets out at the sides. The few sand snakes that were left down the sides will hold sheets in place creating a sort of wind tunnel effect. Wait for 5 to 10 minutes until most of the fumigant has dissipated then remove the sheet entirely.

10.2.2 Procedure for ventilating an un-sheeted shipping container

Remove the tape from the vents then open the right-hand door slightly and leave ajar. In windy conditions a rope or chain can be used to prevent it from blowing open and a block of wood or similar can be inserted to prevent the door from closing. After 10 or so minutes both doors can be open fully and the container left until ventilation is complete.

10.3 Checking the TLV–TWA

Ventilation of the enclosure and aeration of the commodity must continue until concentration levels in the enclosure are at or below the TLV-TWA. Attach the TLV measuring instrument to the monitoring tubes positioned in the centre or back of containers can be used to check if TLV has been reached at all points with the container.

The concentration levels in the free airspace will fall relatively quickly compared to the rate of fumigant diffusion back out of the commodity. It is particularly important that the consignment is fully aerated if it is fumigated in a shipping container. Once the container is closed concentrations levels can increase again to unsafe levels as fumigant continues to diffuse out of the commodity. This has the potential for unprotected personnel to be exposed to unsafe levels of fumigant when the container is opened at its destination.

The equipment used to test for TLV must be sensitive enough to accurately and reliably detect concentrations in ppm below the TLV.

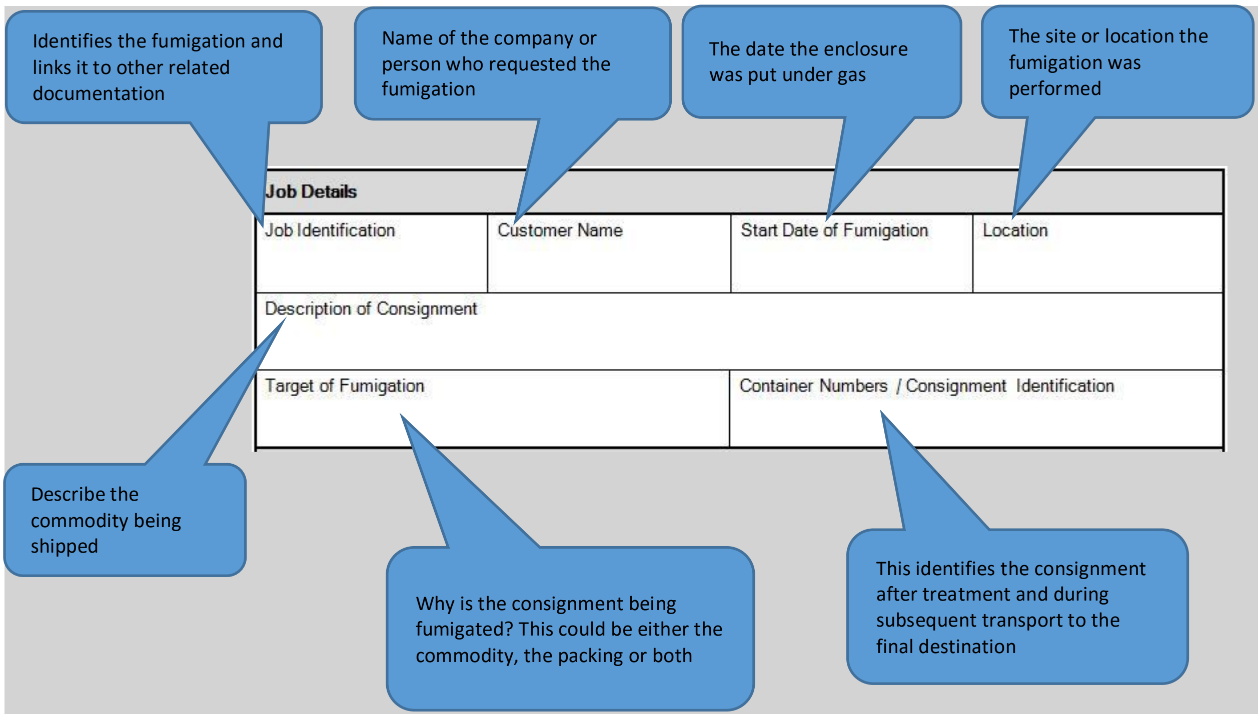
10.4 Releasing the consignment from the fumigator's control

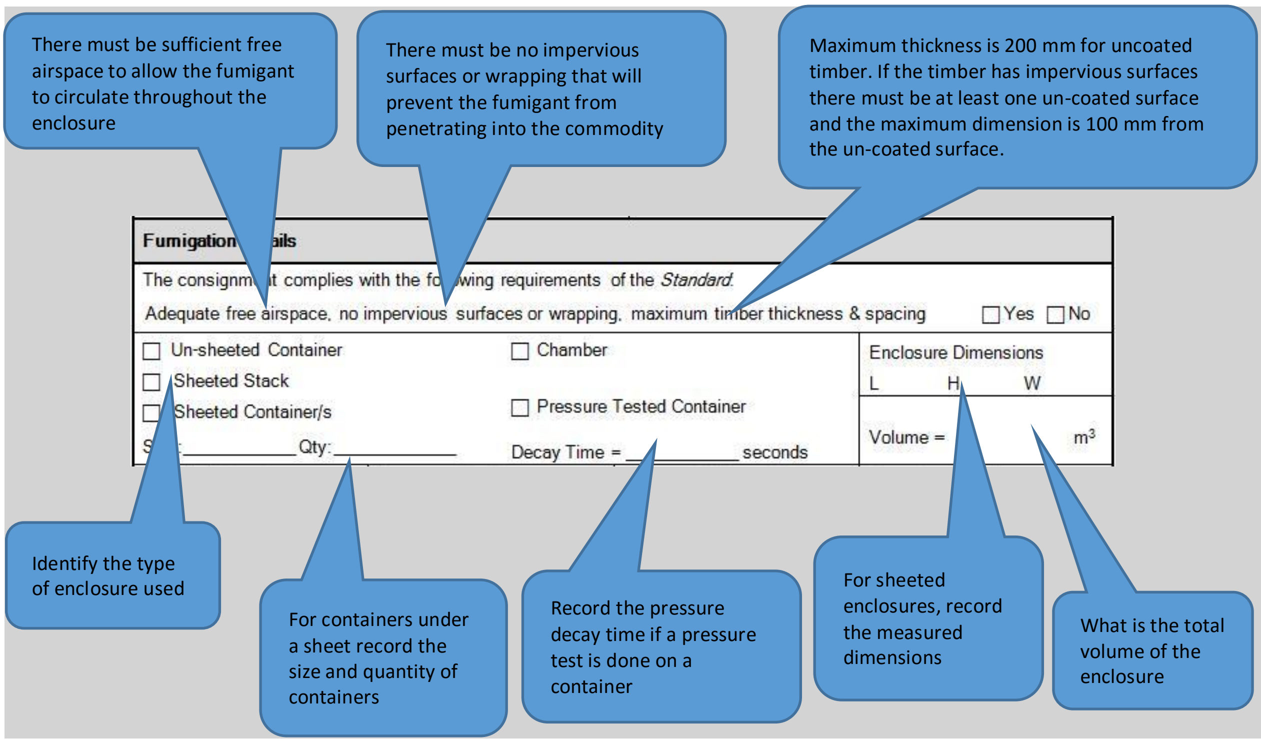
The fumigator is responsible for the consignment while it is being fumigated. It can only be released from the fumigator's control once it has demonstrated that the concentration is at or below safe levels (5ppm for methyl bromide).

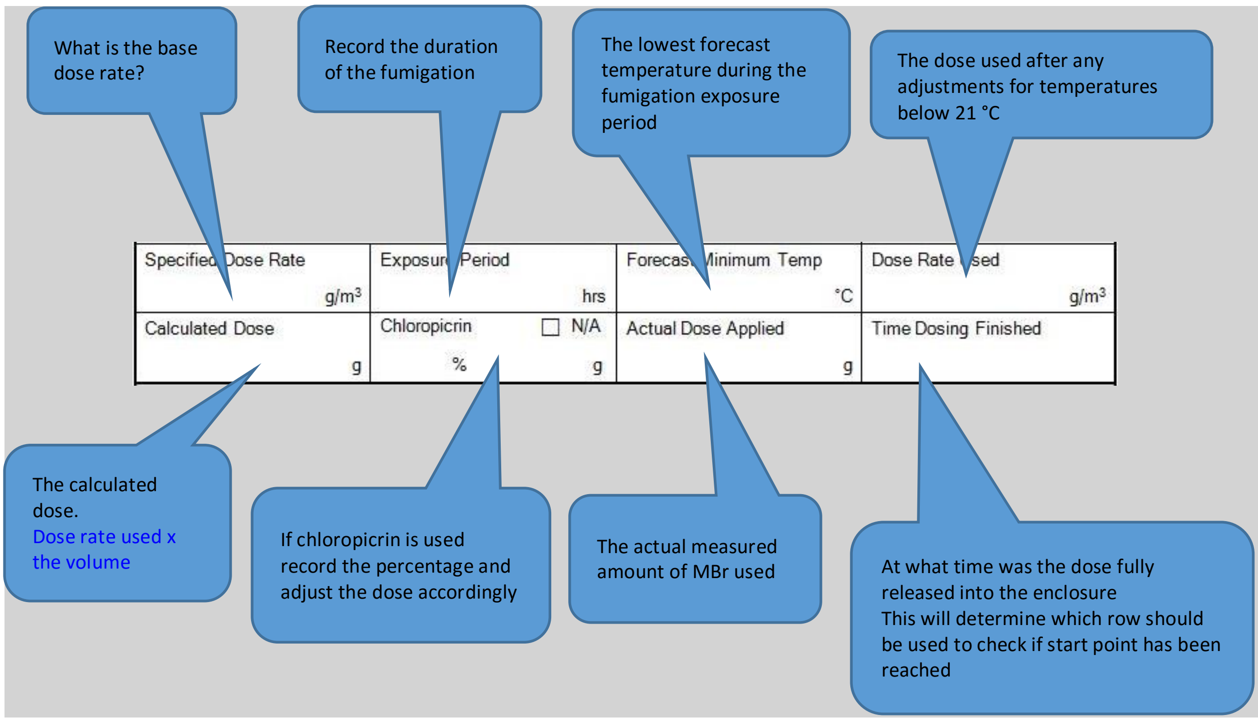
11 Documentation

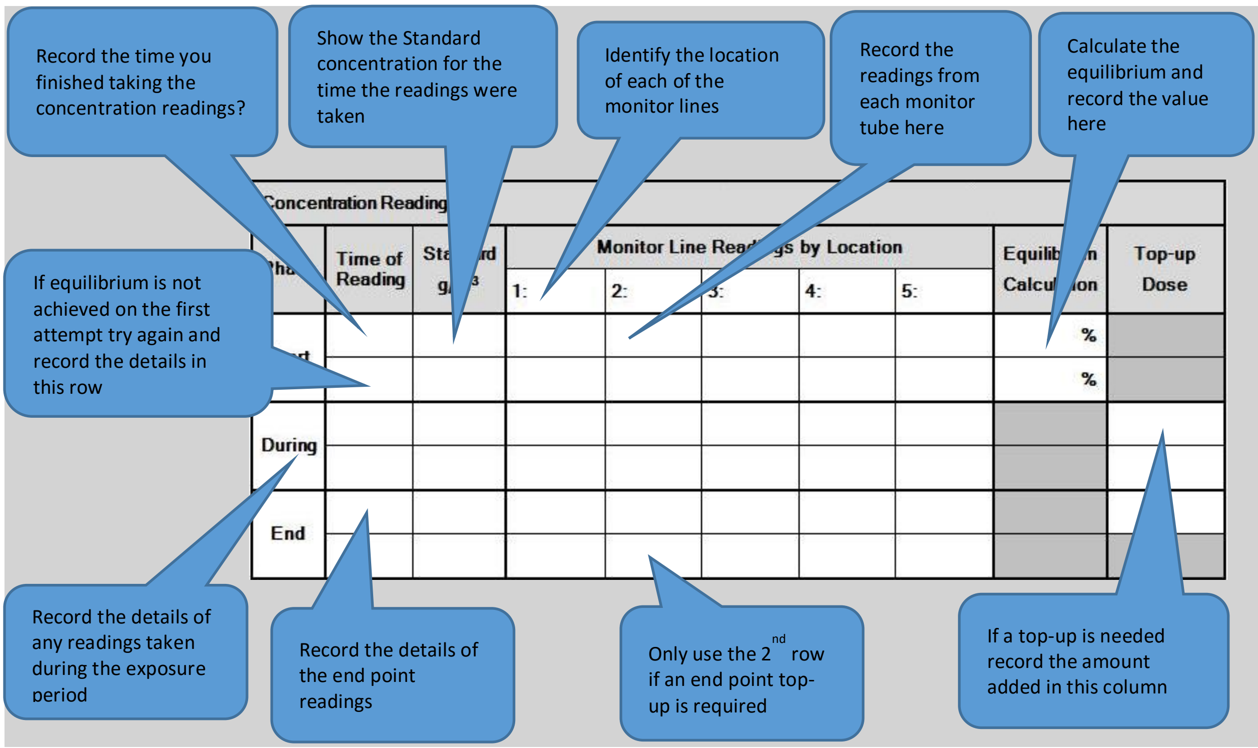
The specific details for each fumigation must be recorded to the extent necessary to demonstrate that the fumigation complied with all the requirements of the methodology. If necessary information, such as, concentration readings or times, are not recorded then they are considered to have not taken place and will result in non-compliance with the methodology.

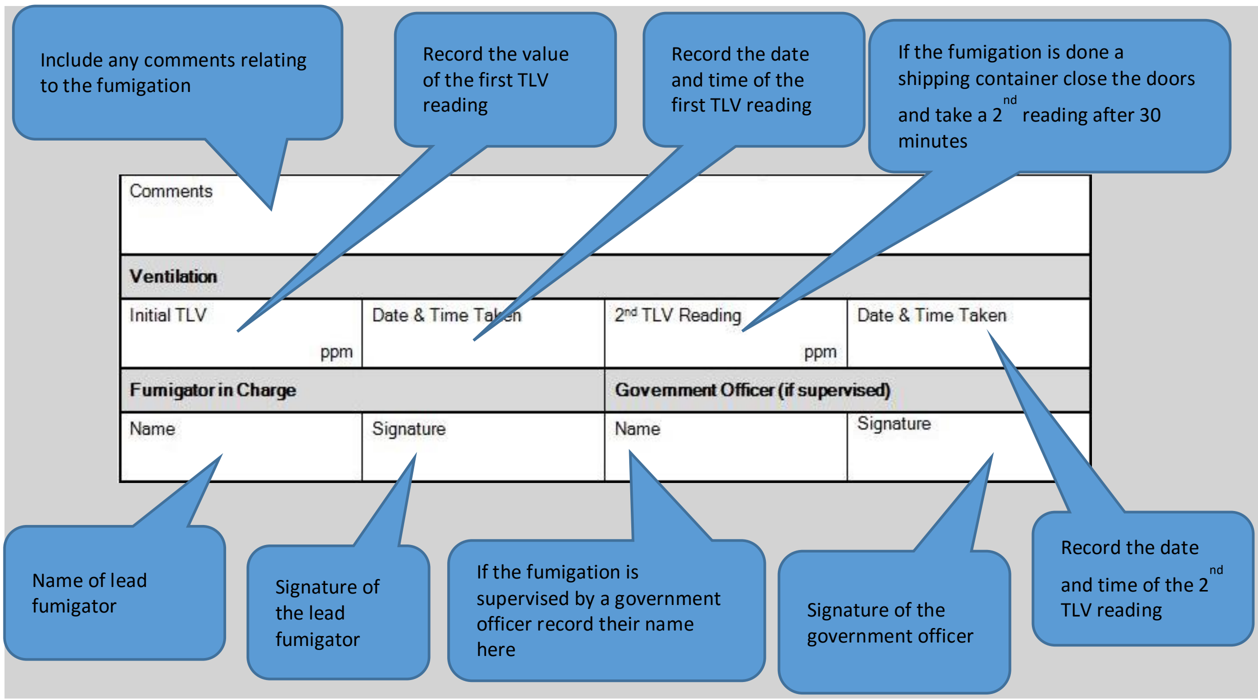
11.1 Completing the record of Fumigation Example


Identifies the fumigation and links it to other related documentation
Name of the company or person who requested the fumigation
The date the enclosure was put under gas
The site or location the fumigation was performed
Job Details
Job Identification
Customer Name
Start Date of Fumigation
Location
Description of Consignment
Target of Fumigation
Container Numbers / Consignment Identification
Describe the commodity being shipped
Why is the consignment being fumigated? This could be either the commodity, the packing or both
This identifies the consignment after treatment and during subsequent transport to the final destination


There must be sufficient free airspace to allow the fumigant to circulate throughout the enclosure
There must be no impervious surfaces or wrapping that will prevent the fumigant from penetrating into the commodity
Maximum thickness is 200 mm for uncoated timber. If the timber has impervious surfaces there must be at least one un-coated surface and the maximum dimension is 100 mm from the un-coated surface.
Adequate free airspace, no impervious surfaces or wrapping, maximum timber thickness & spacing
Yes
No
Un-sheeted Container
Chamber
Enclosure Dimensions
Sheeted Stack
L
H
W
Sheeted Container/s
Pressure Tested Container
Qty:
Decay Time =
seconds
Volume =
m3
Identify the type of enclosure used
For containers under a sheet record the size and quantity of containers
Record the pressure decay time if a pressure test is done on a container
For sheeted enclosures, record the measured dimensions
What is the total volume of the enclosure


What is the base dose rate?
Record the duration of the fumigation
The lowest forecast temperature during the fumigation exposure period
The dose used after any adjustments for temperatures below 21 °C
g/m³
hrs
°C
g/m³
Calculated Dose
g
Chloropicrin
N/A
%
g
Actual Dose Applied
g
Time Dosing Finished
The calculated dose.
Dose rate used x the volume
If chloropicrin is used record the percentage and adjust the dose accordingly
The actual measured amount of MBr used
At what time was the dose fully released into the enclosure
This will determine which row should be used to check if start point has been reached


Record the time you finished taking the concentration readings?
Show the Standard concentration for the time the readings were taken
Identify the location of each of the monitor lines
Record the readings from each monitor tube here
Calculate the equilibrium and record the value here
Time of Reading
Top-up Dose
1:
2:
4:
5:
%
%
During
End
If equilibrium is not achieved on the first attempt try again and record the details in this row
Record the details of any readings taken during the exposure period
Record the details of the end point readings
Only use the 2nd row if an end point top-up is required
If a top-up is needed record the amount added in this column


Include any comments relating to the fumigation
Record the value of the first TLV reading
Record the date and time of the first TLV reading
If the fumigation is done a shipping container close the doors and take a 2nd reading after 30 minutes
Comments
Ventilation
Initial TLV
ppm
Date & Time Taken
2nd TLV Reading
ppm
Date & Time Taken
Fumigator in Charge
Government Officer (if supervised)
Name
Signature
Name
Signature
Name of lead fumigator
Signature of the lead fumigator
If the fumigation is supervised by a government officer record their name here
Signature of the government officer
Record the date and time of the 2nd TLV reading

11.2 Fumigation treatment certificate

The fumigation certificate is an official export document issued by the fumigator to declare that the fumigation has been done in accordance with the requirements of the Methyl Bromide Fumigation Methodology and must accompany the consignment.

How to complete the Approved Standard Fumigation Certificate

Details of the consignment and information relating to the fumigation must be included on the fumigation certificate for it to be accepted by the department. This information should be on a single page and in a format consistent with the above template. Following is advice on completing this fumigation certificate template.

Only fumigation certificates from (*insert name of arrangement here)* countries issued by a treatment provider on the (*insert name of arrangement here)* Acceptable Treatment Providers list will be accepted by the department.

Certificate must be on the treatment provider's letterhead

The letterhead must include the address of the fumigation treatment provider that matches the address published on the department's treatment providers list (TPL). Where a company has more than one branch the address on the letterhead must match that on the TPL for the branch that issues the certificate.

Certificate Number / Registration Number

Each certificate must include a unique certificate number issued by the treatment provider and the treatment provider's Registration Number. For audit and investigation purposes the certificate number must link to the treatment provider's fumigation records for the treatment covered by the certificate.

Target of the Fumigation Details

Select the option that best describes the target of the fumigation. This may be the commodity (goods), the packaging (including pallets and/or container) or both.

Consignment Link

The certificate must include a link to some other official documentation related to the consignment such as: a bill of lading number, a commercial invoice number, a preferential tariff certificate number, a packing list number, a letter of credit number or container number. If there is insufficient room on the certificate you may use the additional declarations field or attach a complete list to the certificate.

Consignment Details

The certificate must also include the quantity, the country of origin, the intended port of loading and country of destination as well as the name and addresses of the exporter and importer.

Treatment Details

- Date fumigation completed: is the date on which the fumigation exposure period is complete.
- Place of fumigation: is the general location in which the fumigation took place, e.g. Town / City.
- Prescribed dose rate (g/m^3): is the prescribed concentration of methyl bromide required to effectively treat the target of the fumigation.
- Exposure period (hrs): is the prescribed duration of the fumigation.
- Forecast minimum temperature (°C): is the minimum temperature in degrees Celsius forecast by an official source for the period of fumigation.
- Applied dose rate (g/m3): is the concentration of methyl bromide applied to the fumigation enclosure including adjustments made to the prescribed

dosage to compensate for forecast minimum temperatures between 21°C and 10°C.

- How was the fumigation conducted: Select the fumigation enclosure type and include container number/s if the treatment was conducted in the container/s the target of the fumigation will be shipped in.
- Does the target of the fumigation conform to the plastic wrapping, impervious surface and timber thickness requirements at the time of fumigation? This declaration identifies that at the time of fumigation all plastic wrapping, impervious surface and timber thickness requirements have been met. If there is no plastic wrapping or impervious surfaces on the target of fumigation, the fumigator should answer 'yes' as all plastic wrapping and impervious surface requirements are met. Where there requirements are not met the fumigation should not be conducted.
- Ventilation, final TLV reading (ppm): The final threshold limit value (TLV) reading is when the methyl bromide concentration within the enclosure falls to 5 ppm or below. Record the methyl bromide concentration reading to declare the enclosure is gas free. Where multiple containers are fumigated in one enclosure, TLV is required for each container. Where a stack or permanent chamber fumigation is performed, answer 'NA' (not applicable) as no TLV is required.

Declaration

The AFAS accredited fumigator (or accredited officer if the certificate is endorsed by the relevant regulatory authority) responsible for ensuring that the treatment is effective and performed according to the requirements of the *Methyl Bromide Fumigation Methodology* must sign and date the certificate and print their name and accreditation number. They may also wish to stamp the certificate with their company stamp.

Additional Information

Any additional information that the fumigator wishes to supply may be included in the Additional Declarations field.

False declarations may result in accreditation being revoked.