

2

Treatment Manual

Chemical Treatments

Fumigants, Phosphine

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Properties and Use

There are a number of phosphine formulations registered with the United States Environmental Protection Agency (EPA) to control a variety of insects currently infesting raw agricultural commodities, processed foods, animal feed, feed ingredients, and nonfood commodities, including tobacco. Aluminum phosphine (AP), magnesium phosphide (MP), ECO₂FUME[®] and VAPORPH₃OS[®] are phosphine formulations that are currently approved for use by the Plant Protection and Quarantine (PPQ). Always refer to the PPQ *Treatment Manual* to determine if there is an available treatment. There are commodities and pests listed on the labels that are not authorized for treatment by the United States Department of Agriculture (USDA), PPQ.

AP and MP are solid products and are available under various trade names ([Figure 2-10-2](#) on [page 2-10-9](#)) as tablets, pellets, prepacks, bags, or plates. In the presence of moisture, phosphine (hydrogen phosphide, PH₃), a colorless gas, is emitted from the solid product

The flash point of PH is 212°F. Direct contact with a liquid could cause spontaneous combustion. In case of fire, a CO₂ dry chemical fire extinguisher should be used. *Never use water to extinguish a PH-ignited fire.* PH has an odor somewhat like garlic, which enables the gas to serve as its own warning agent. However, under some conditions, the odor can be lost, even at high toxic concentrations.

ECO₂FUME[®] fumigant gas is a nonflammable, premixed mixture of phosphine and carbon dioxide. The phosphine is liquefied and mixed with carbon dioxide in high-pressure cylinders for shipment. Phosphine, the active ingredient, makes up 2% by weight (2.6% by volume) of the product. The carbon dioxide is used as a propellant and a flame inhibitor, making the product nonflammable in air. Do not store the fumigant near heat or open flame. Do not drop, puncture, or incinerate the cylinder.

Under pressure, ECO₂FUME[®] is a poisonous liquefied gas. The product is withdrawn from the cylinder as a liquid, but dispensed as a gas. When expanding from a liquid to a gas, ECO₂FUME's volume is multiplied by hundreds. Proper dispensing equipment (See [Dispensing ECO₂FUME[®] Fumigant Gas](#) on page 2-10-11) is necessary to ensure a safe and effective fumigation; therefore, always contact the manufacturer concerning proper dispensing equipment for the fumigant. Fumigators should provide PPQ with all [Cytec[®]](#) equipment authorization documentation. The documentation should be on file and available for periodic audits by the USDA.

The rate at which phosphine is dispensed is not dependant on temperature or humidity, but on the dispensing equipment used. Unlike metal phosphide fumigants, the phosphine is not generated through a chemical reaction and its release is instantaneous. The choice of dispensing methods will depend on the type and duration of the fumigation planned.

VAPORPH₃OS[®] consists of 100% phosphine gas packaged in high-pressure gas cylinders. Unlike solid phosphide fumigants, the phosphine is not generated through a chemical reaction and its release is instantaneous. Phosphine is pyrophoric and will spontaneously ignite in air. Phosphine is dispensed as a gas from the cylinder and can be safely blended with carbon dioxide to less than 3% volume (30,000 ppm) or diluted with the surrounding air to 1% volume (10,000 ppm) to eliminate the flammability hazard. Contact the manufacturer for approved blending equipment necessary to ensure a safe and effective fumigation. Never store the cylinders where the temperature will exceed 125°F. Fumigators should provide PPQ with all [Cytec[®]](#) equipment authorization documentation. The documentation should be on file and available for periodic audits by the USDA.

Phosphine

Phosphine (PH) is highly toxic to humans and other animals. Avoid exposure to nontarget organisms. The current U.S. OSHA Permissible Exposure Limit (PEL) for phosphine is 0.3 ppm as an 8-hour time weighted average. The Short Term Exposure Limit (STEL) for phosphine is 1 ppm as a 15-minute time weighted average.

Phosphine is colorless and, at concentrations below the OSHA PEL, has the odor of decaying fish or garlic. Intermittent low concentration exposure may cause headaches, malaise, ringing of ears, fatigue, nausea, and chest pressure. Moderate exposure causes weakness, vomiting, and pain in the stomach and chest with difficult breathing. Phosphine gas reacts with moisture to form phosphoric acid, which causes pulmonary edema.

Phosphine may spontaneously ignite in air at levels above its lower flammability limit of 1.8% v/v (18,000 ppm). Do not exceed this concentration because, under these conditions, explosions can occur that could cause severe personal injury. Never allow the buildup of phosphine to exceed explosive concentrations.

Under high vacuum conditions, phosphine gas can cause an explosive hazard. **Do not apply either fumigant in vacuum chambers.**

Phosphine can react with certain metals and cause corrosion (especially at higher temperatures and lower relative humidity). **Gold, silver, copper, brass, and other copper alloys are susceptible to corrosion.**



Remove or protect the following items prior to fumigation:

- ◆ Batteries and battery chargers
- ◆ Brass sprinkler heads
- ◆ Communication devices
- ◆ Computers
- ◆ Electric motors
- ◆ Electronic or electrical equipment
- ◆ Fork lifts
- ◆ Smoke detectors
- ◆ Switching gears
- ◆ Temperature monitoring systems

Fans and blowers used with phosphine products should be manufactured from materials resistant to the fumigant. Aluminum or plastic wheels and housings are preferred. For phosphine fumigations, always contact the manufacturer for recommended fan and blower types.

Carbon Dioxide

In a liquefied state and when contact is made with exposed areas of the body, carbon dioxide can cause frostbite and freeze burns. Overexposure to carbon dioxide at low levels can cause headache, nausea, weakness, confusion, and labored breathing. Overexposure to higher concentrations can cause excitation, dizziness, euphoria, loss of consciousness, coma, and death.

The current U.S. OSHA PEL for carbon dioxide is 5,000 ppm as an 8-hour time weighted average.

Leak Detection: Gas Analysis

Phosphine levels can be detected using either colorimetric detector tubes or any approved electronic instrument such as the “Porta-Sens” detector. (See [Equipment](#) on [page 8-1-1](#) for instructions on how to use the Porta-Sens.) This equipment is used to determine both the high (fumigation concentration) and low (personnel safety) levels of PH. **Do not use** thermal conductivity (T/C) units (e.g., Gow-Mac or fumiscope) for PH.

Safety

Applicator Requirements

Before using ECO₂FUME[®] and VAPORPH₃OS[®], all users (fumigators) are required to attend the fumigant gas product stewardship course offered by [Cytec](#)[®] Industries. PPQ Officers are not required to attend the stewardship courses, but attendance is recommended.

It is a violation of federal law to use AP, MP, ECO₂FUME[®] and VAPORPH₃OS[®] fumigants in a manner inconsistent with their labeling. These fumigants are **Restricted Use Pesticides** that can only be used by certified applicators. Prior to using the fumigants, submit to PPQ all documentation concerning applicator certification and stewardship program completion by personnel working for the fumigation company. The documentation should be on file and available for periodic audits by the USDA.

A certified applicator must be physically present, responsible for, and maintain visual and/or voice contact with all fumigation workers during the application of the fumigants and during the initial opening of the fumigation structure for aeration.

Storage and Handling

Although PH is flammable and can ignite when exposed to excessive moisture, the commercial precautions of AP and MP are considered fire safe and explosion safe when used in accordance with the manufacturer's instruction. Place no more than 10 pellets of Phostoxin in a single envelope, which is supplied by the manufacturer. A Fumi-Cel plate should not contact another Fumi-Cel plate or the commodity.

Store containers of AP and MP in a cool, dry, locked, ventilated, protected area not subject to extremes of temperature. Never allow water to come in contact with AP or MP. The shelf life of unopened containers is virtually unlimited. When a tube or container is first opened, the odor of PH (garlic) and ammonia will be noticeable and a blue flame sometimes occurs. However, the quantity of free PH present within that container should not be considered dangerous.

When planning a storage area for ECO₂FUME[®] and VAPORPH₃OS[®] cylinders, consider the needs of the local authorities. Provide all emergency response personnel with Material Safety Data Sheets (MSDS) and detailed information regarding the quantities of product stored and the nature and location of the storage area.

Develop an Emergency Response Plan that defines procedures and outlines responsibilities in the event of an accident. Train all site personnel in the plan. Store all cylinders with the valve discharge cap securely in place.

In addition to instructions and precautions found on the label, be certain to:

- ◆ Study and follow the recommended application procedure
- ◆ Comply with all regulations
- ◆ Allow only properly trained personnel to conduct fumigations under the supervision of certified pesticide applicator(s)
- ◆ Ensure that first aid equipment, MSDS sheets, and fumigant labels are readily available at the fumigation site
- ◆ Placard the area to be fumigated and an area extending 30 feet from the fumigation enclosure—refer to the fumigation label for appropriate wording on all placards

- ◆ Always work in pairs, never alone—a minimum of two people must be present during the introduction, sampling, and aeration of the fumigant
- ◆ Never eat, drink, or smoke when handling PH products
- ◆ Remove placards when aeration is complete and concentrations are below the TLV
 - ❖ Only certified pesticide applicators or individuals under the direct supervision of the certified applicator should remove placards
- ◆ Do not apply either PH fumigant in vacuum chambers
- ◆ Wear leather or leather-faced cotton gloves when connecting or disconnecting ECO₂FUME and VAPORPH₃OS[®] cylinders from the dispensing or blending equipment
- ◆ Wear dry cloth gloves when handling AP or MP products
- ◆ Wear steel-toed shoes
- ◆ Always wear safety glasses when handling pressurized equipment
- ◆ Read and understand sections XI. STORAGE OF CYLINDERS and XII. TRANSPORT in the ECO₂FUME[®] and VAPORPH₃OS[®] Application Manual

First Aid Treatment

Mild inhalation exposure causes:

- ◆ Malaise
- ◆ Ringing of the ears
- ◆ Fatigue
- ◆ Nausea
- ◆ Pressure in chest

Moderate inhalation exposure causes:

- ◆ Weakness
- ◆ Vomiting
- ◆ Epigastric pain
- ◆ Chest pain
- ◆ Diarrhea
- ◆ Dyspnea (difficulty breathing)

Severe inhalation poisoning can occur within a few hours or up to several days—symptoms may be:

- ◆ Pulmonary edema (fluid in lungs)
- ◆ Dizziness
- ◆ Cyanosis (blue or purple skin color)
- ◆ Unconsciousness
- ◆ Death



Get the victim to fresh air, treat for shock, and call a physician.

Respiratory Protection

When applying AP, MP, ECO₂FUME[®] and VAPORPH₃OS[®], respiratory protection must be available at the site. An adequate number of NIOSH-approved self-contained breathing apparatus (SCBA) with full face piece and operated in pressure-demand mode must be available.

The slow evolution of PH from the AP or MP enables the operator to dispense the tablets, pellets, packets, plates, or pre-pack ropes safely, usually without the need for wearing an SCBA.

However, wear SCBA during exposure to concentrations in excess of permitted limits ([Figure 2-10-1](#) on [page 2-10-8](#)) or when concentrations are unknown. If the concentration of phosphine is unknown or known to exceed the STELs for phosphine and/or carbon dioxide, wear SCBA during troubleshooting for leaks. Use respiratory protection according to local regulations, including regular worker training in using respiratory protection equipment properly, medical clearance for respirator use, fit testing, inspection, maintenance, and cleaning and storage of respiratory protection equipment.

Phosphine Gas (ppm)	Minimum Respiratory Protection
0.3 - 3.0	Supplied-air respirator
3.1 - 7.5	Supplied-air respirator operated in a continuous-flow mode
7.6 - 15	<ol style="list-style-type: none"> 1. SCBA with full face piece OR 2. Supplied-air respirator with full face piece OR 3. Air-purifying full face piece respirator (gas mask) with chin style front or back-mounted canister
16 - 50	<ol style="list-style-type: none"> 1. Supplied-air respirator with a full face piece and operated in pressure-demand mode OR 2. SCBA with a full face piece and operated in pressure-demand mode

FIGURE 2-10-1: : NIOSH-Recommended Respiratory Protection

MP, AP, ECO₂FUME® and VAPORPH₃OS®

Packaging

AP and MP are packaged in a variety of ways, depending on the manufacturer. Use [Figure 2-10-2](#) on [page 2-10-9](#) to determine the amount of phosphine liberated by each product.

Product	Type	Unit and weight in grams	Grams of phosphine
Degesch Fumi-Cel	MP	1 plate; 117.0	33.0
Degesch Fumi-Strip	MP	20 plates; 2340.0	660.0
Degesch Phostoxin	AP	1 tablet; 3.0	1.0
Degesch Phostoxin Tablet Prepac Rope	AP	1 prepac; 99.0 (strip or rope of 33 tablets)	33.0
Detia	AP	1 tablet; 3.0	1.0
Detia Rotox AP	AP	1 pellet; 0.6	0.2
Detia Gas EX-B	AP	1 bag or sachet; 34.0	11.4
Fumiphos tablets	AP	1 tablet; 3.0	1.0
Fumiphos pellets	AP	1 pellet; 0.6	0.2
Fumiphos bags	AP	1 bag; 34.0	11.0
Fumitoxin	AP	1 tablet; 3.0	1.0
Fumitoxin	AP	1 pellet; 0.6	0.2
Fumitoxin	AP	1 bag; 34.0	11.0
Gastoxin	AP	1 tablet; 3.0	1.0
Gastoxin	AP	1 pellet; 0.6	0.2
"L" Fume	AP	1 pellet; 0.5	0.18
	AP	1 pellet; 0.6	0.22
Phos-Kill	AP	1 tablet; 3.0	1.1
Phos-Kill	AP	1 pellet; 0.6	0.22
Phos-Kill	AP	1 bag; 34.0	12.0

FIGURE 2-10-2: Amount of Phosphine Liberated by Various Products

ECO₂FUME® fumigant gas is packaged in a steel compressed gas cylinder designed, manufactured, maintained, and filled in compliance with regulations established by the United States Department of Transportation (DOT). (Figure 2-10-3 on page 2-10-10) The product flows to the dispensing equipment through the cylinder outlet valve, which is equipped with a "dip tube." This tube extends to the bottom of the cylinder to facilitate the withdrawal of the liquefied gas mixture. As liquid is withdrawn from the cylinder, some of the product vaporizes to fill the remaining space in the cylinder. Through this vaporization, the cylinder pressure is maintained.

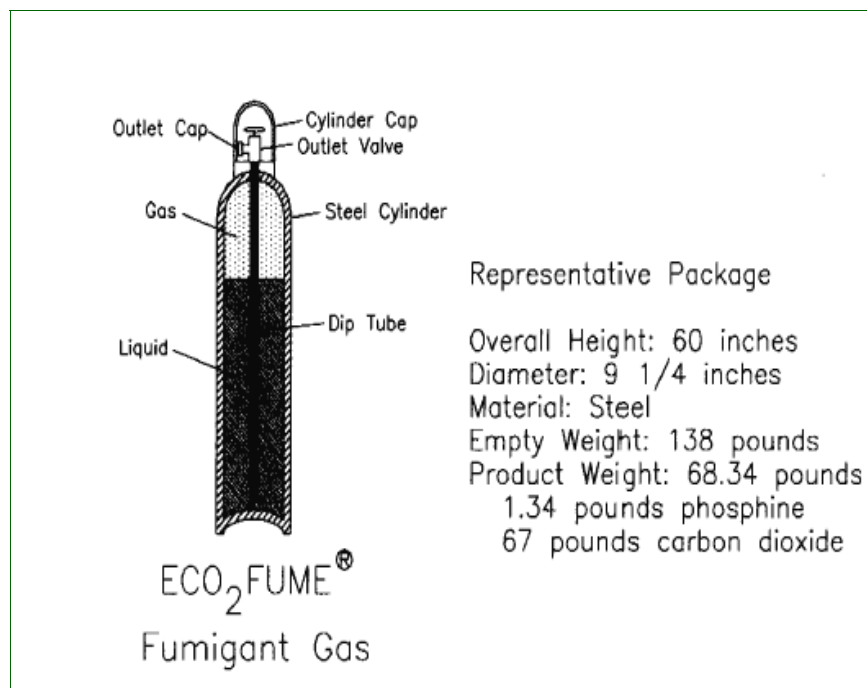


FIGURE 2-10-3: Diagram of ECO₂FUME® Gas Cylinder

The capacity of one ECO₂FUME® cylinder at 200 and 500 ppm is 78,000 and 31,100 ft³ respectively. With the volume of ECO₂FUME® at 500 ft³, the internal volume of the cylinder is 49 liters. The maximum cylinder pressure is 2,400 psig.

The Compressed Gas Association (CGA) established the valve outlet fitting as a CGA350. The valve outlet is protected by a threaded gas tight outlet cap, which must be secured whenever the cylinder is not in use. To dispense ECO₂FUME® fumigant gas at the time of fumigation, attach only **Cytec®**-provided (or approved) dispensing equipment to the cylinder valve outlet. Using any other dispensing equipment is prohibited.

Most compressed gas cylinder valves are equipped with a safety device that releases the cylinder contents due to fire exposure or over-pressurization. Because ECO₂FUME® and VAPORPH₃OS® fumigant gases are poisonous, Hazard Class A, the DOT regulations prohibit using such a device.

Each cylinder is supplied with a cylinder cap designed to protect the outlet valve. Secure this cap whenever a cylinder is not in use. It is unlawful to transport an ECO₂FUME® or VAPORPH₃OS® fumigant gas cylinder without the valve outlet cap and the cylinder cap securely in place.

ECO₂FUME® and VAPORPH₃OS® fumigant gas cylinders can only be refilled by authorized distributors. They can be filled countless times within a five-year period. Every five years, however, the cylinder is required, by law, to be tested by a qualified facility.

VAPORPH₃OS® is packaged in much the same way as ECO₂FUME® with two critical exceptions. First, VAPORPH₃OS® does **not** contain a dip tube, which means the fumigant is withdrawn from the cylinder directly through the outlet valve. Second, the capacity of one VAPORPH₃OS® cylinder at 200 and 500 ppm is 175,000 and 700,000 ft³ respectively. With the volume of VAPORPH₃OS® at 500 ft³, the internal volume of the cylinder is 49 liters. The maximum cylinder pressure is 2,400 psig. One VAPORPH₃OS® cylinder contains 18,000 grams of phosphine and is capable of fumigating 2.2M ft².



ECO₂FUME® cylinders are painted yellow with a dark green shoulder and cap. If you receive a cylinder of a different color or without a **Cytec®** ECO₂FUME® label, do not use the cylinder. Contact your distributor or **Cytec®** with the cylinder serial number.



VAPORPH₃OS® cylinders are painted silver with a red shoulder. If you receive a cylinder of a different color or without a VAPORPH₃OS® label, do not use the cylinder. Contact your distributor or **CYTEC** with the cylinder serial number.

Dispensing ECO₂FUME® Fumigant Gas

The following instructions are intended to provide general guidelines for typical ECO₂FUME® fumigation. There are a number of critical factors involved in the design of dispensing equipment. (See [Figure 2-10-4](#) on page 2-10-12) As such, dispensing equipment must meet both high-pressure standards and chemical compatibility requirements. Improper or inappropriate use of dispensing equipment can result in severe injury or death. Application inconsistent with the

labeling and Application Manual is a violation of federal law. Buyer assumes all risk should the product be used contrary to label or Application Manual instructions.

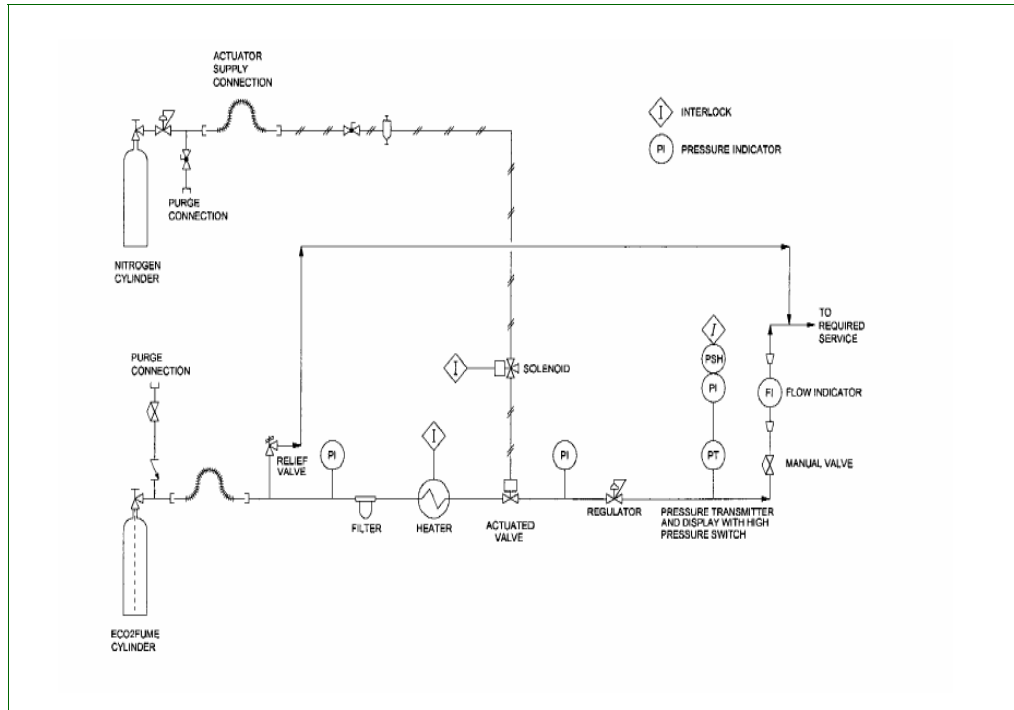


FIGURE 2-10-4: Diagram of One Type of Dispensing Equipment

Equipment Specification and Use

The equipment used to dispense ECO₂FUME® provides a means of containing the gas during the fumigation and controlling the release of the product into the desired space. While some dispensing equipment has been developed and used to date, it cannot be expected to cover all possible fumigation scenarios. The development of suitable dispensing equipment is an ongoing process based on the needs of the users and available technology.

The design of dispensing equipment must account for a number of technical issues including pressure rating, material compatibility, temperature limitations and operator safety. For this reason, use only appropriate equipment when dispensing ECO₂FUME®. Only persons trained in the proper use of ECO₂FUME® and the dispensing equipment shall be permitted to use ECO₂FUME® for fumigation. Consult the instruction materials provided with the dispensing equipment for their proper use and maintenance.

Unapproved Dispensing Methods

It has been common practice, with other cylinderized fumigants, to place the cylinder in the space to be fumigated and the cylinder outlet valve opened to allow the fumigant to release. This is **not** an approved dispensing method and should **not** be used with ECO₂FUME®.

Approved Dispensing Methods

The approved dispensing methods for ECO₂FUME® include using pressure-reducing regulators for slow release and selected piping components for quick release. The slow release of ECO₂FUME® is generally used for fumigating bulk storage facilities such as silos or bins, or for small fumigation chambers or spaces and for fumigating stacked materials under tarpaulins. The quick release method is used for space fumigation, or where the commodity to be treated is warehoused. The selection of the dispensing method will depend on the size of the fumigation, the time required, and facility limitations.

Two gas regulators, ambient and heated, have been developed for use with ECO₂FUME®. Each of the regulators is designed to reduce the high cylinder pressure (less than 30 psig) and provide the heat necessary to vaporize the fumigant. Once reduced to this lower pressure, the fumigant can be distributed to the desired dispensing points using inexpensive and easy-to-use materials, such as plastic tubing. Flow indicators are used with regulated dispensers to measure and set the dispensing rate.

Ambient Heater Regulated Dispenser

The slower of the two dispensers relies on ambient heat to vaporize the fumigant and is limited to a dispensing rate of about one-half pound of ECO₂FUME® per hour.

Heated Regulated Dispenser

The heated regulator uses an external heating vaporizer to provide the energy required to vaporize the liquid fumigant at a much higher rate than the ambient heat regulator. This regulator is limited to a dispensing rate of about 24 pounds of ECO₂FUME® per hour. The equipment is designed for a service pressure up to 3,000 psig. From the cylinder, the liquid mixture flows down a flexible hose or pigtail through a filter and into a heater. The heater is thermostatically controlled and the temperature setting can be adjusted. Exiting the heater, ECO₂FUME® gas flows through an actuated valve that can be used for emergency shutdown purposes. ECO₂FUME® gas then flows through a gas regulator that drops the pressure to 30 psig. A diaphragm valve is used to control the gas flow at any desired value up to 100 liters/minute as indicated by the flow rotameter. The heater provides 1,000 watts of power that can vaporize a maximum of 100 ppm. Lower rotameter ranges are possible. ECO₂FUME® regulator assemblies, equipped with basic features, are available through authorized ECO₂FUME® distributors. Multiple regulators may be used together to achieve higher fumigant flows than available through a single regulator and custom equipment can be developed for specific types of applications.

Quick Release Dispensing Equipment

When the fumigation space is very large, such as a mill, warehouse, or large fumigation chamber, using a number of cylinders is anticipated, a quick means of dispensing ECO₂FUME® is available. Specially selected components can be used to direct the cylinder discharge into the fumigation space, without the need to enter the space during the fumigation. Using this method, a single cylinder can be completely discharged in as little as 15 minutes. Unlike the regulated dispensing methods, the dispensing rate is not adjustable and generally, entire cylinders are emptied using this process. If partial cylinder contents are needed, the ECO₂FUME® cylinder can be placed on a weight scale and the amount of released fumigant can be measured. The quick release method must **not** be used for fumigation of small-sized stacked materials under tarpaulins, however, the quick dispensing method will be used for most applications. Three techniques of quick dispensing are presented in this section, with the major difference being the tubing size.

1. One technique uses high pressure tubing (stainless steel or hydraulic hose with a nylon core) connected directly to the cylinder valve. The tubing is then routed into the fumigation space. When the cylinder valve is opened the majority of the liquid will be dispensed in four to five minutes. The last few pounds below the cylinder internal dip pipe will require several additional minutes to vaporize and be dispensed. When the cylinder is empty of liquid, approximately 18 pounds of gas will remain in the cylinder. For larger fumigations, manifolds may be used with the cylinders to make the dispensing faster. Always leak test the dispensing piping and cylinder connection before opening the cylinder valve.
2. When a slower dispensing rate is desired, use smaller tubing (stainless steel or hydraulic hose with a nylon core). The fumigator must not throttle the cylinder valve to slow the dispensing rate; to do so will cause a high pressure drop through the valve. The pressure drop will result in cooling and dry ice formation. This solid dry ice formation will plug the dispensing pipe and possibly the cylinder valve. Attaching a short section of 1/8 inch tubing to the end of the 1/4 inch tubing will slow the dispensing rate to approximately 5 pounds/min. Use a calibrated scale to ensure the proper amount of product dispensed.
3. If a dispensing rate of less than 5 pounds/min is required, a small section of 1/16 inch tubing, 0.04 inch internal diameter (stainless steel or hydraulic hose with a nylon core) can be attached to the end of the 1/4 inch tubing to slow the dispensing rate to approximately 1.6 pounds/min. Use a scale to ensure the proper amount of product is dispensed. The tubing is also available in smaller internal diameters (I.D.) for reduced

dispensing rates. When 1/8 inch tubing or 1/16 inch tubing is used a filter is recommended to prevent plugging of the smaller tubing.

Blending VAPORPH₃OS® Fumigant Gas

The following instructions are intended to provide general guidelines for typical fumigations. There are a number of critical factors involved in the design of blending equipment. As such, blending equipment must meet both high-pressure standards and chemical compatibility requirements. Improper or inappropriate use of blending equipment may result in severe injury or death. Application inconsistent with the labeling and Application Manual is a violation of federal law. Buyer assumes all risk should the product be used contrary to label or Application Manual instructions.

Equipment Specification and Use

The equipment used to blend VAPORPH₃OS® on site with carbon dioxide or surrounding air into a nonflammable gas mixture provides a means of containing the gas during the application and controlling the release of the product into the desired space. While some blending equipment has been developed and used to date, they cannot be expected to cover all possible fumigations scenarios. The development of suitable blending equipment is an ongoing process based on the needs of the users and available technology.

Blending equipment design must account for a number of technical issues, including pressure rating, material compatibility, temperature limitations and operator safety, and controlling the phosphine concentration between 2.0 and 2.9% volume for carbon dioxide blending and less than 10,000 ppm (1% volume) for dilution with air. For this reason, use only **Cytec**®-approved equipment in VAPORPH₃OS® blending. Only persons trained in the proper use of VAPORPH₃OS® and the dispensing equipment shall be permitted to use VAPORPH₃OS® for fumigation. These persons must also be licensed pesticide applicators.

Consult the instruction materials provided with the blending equipment or dilution equipment for their proper use and maintenance. FOSFOQUIM, the authorized manufacturer of the phosphine air blending equipment, will provide training and written instructions for the use and maintenance of its HDS equipment.

Unapproved Dispensing Methods

It has been common practice, with other cylinderized fumigants, to place the cylinder in the space to be fumigated and the cylinder outlet valve opened to allow the fumigant to release. This is **not** an approved dispensing method and should **not** be used with VAPORPH₃OS®. VAPORPH₃OS® phosphine fumigant is pyrophoric and will spontaneously ignite in air. VAPORPH₃OS® must be properly blended with carbon dioxide or diluted with air to eliminate the flammability hazard.

Blending Equipment for VAPORPH₃OS® and Carbon Dioxide

Phosphine gas (VAPORPH₃OS®) from high-pressure cylinders flows into the blender unit where it combines with carbon dioxide gas sourced from bulk storage, mobile bulk truck, semibulk, or cylinders. Various models of on-site blending equipment have been designed, built, and tested. All of the designs have incorporated engineering safeguards to ensure that the blended product is a nonflammable mixture.

One design uses a pressure regulator and flow control orifice on both the VAPORPH₃OS® and carbon dioxide gases to control the flow rate and to properly blend VAPORPH₃OS® with carbon dioxide. The size of each orifice is engineered for a specific fixed flow rate and, therefore, the blending rate cannot be adjusted. By controlling the pressure drop across the orifice plates, the phosphine concentration can be controlled around 2.5% v/v.

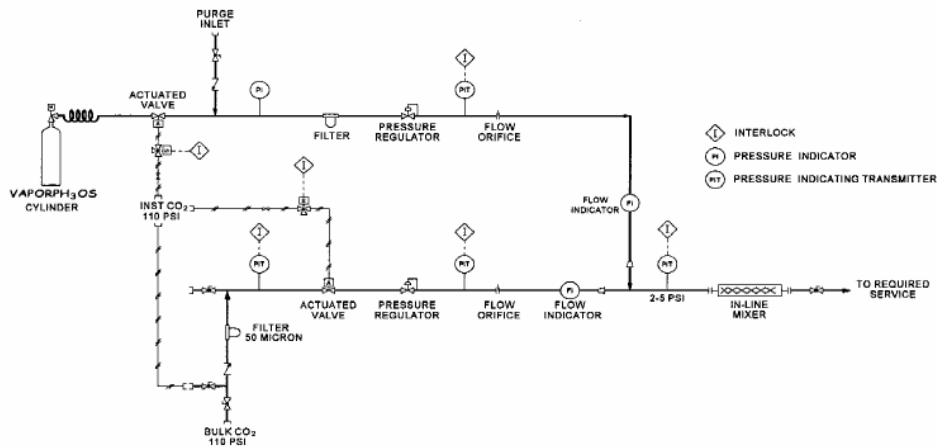


FIGURE 2-10-5: Diagram of One Type of Blending Equipment

A more sophisticated design uses mass meters, control valves, and the electronics to allow an adjustable blending rate while maintaining the proper blend of phosphine concentration from going outside the range of 2.0 to 2.9% volume (1.6 to 2.2% weight). The product from this equipment is equivalent to ECO₂FUME® fumigant gas. Blending equipment is intended for large facilities that have on-site carbon dioxide bulk storage and vaporizing equipment or facilities where it is feasible to bring in bulk carbon dioxide and vaporizing equipment for the fumigation. The blending equipment is designed for use only with carbon dioxide gas; therefore, a bulk supply of liquid carbon dioxide must be equipped with suitable vaporizing equipment. Contact [Cytec®](#) Industries Incorporated for blending equipment design specifications and recommendations. For smaller fumigation jobs, it is recommended that preblended

**Blending
Equipment for
VAPORPH₃OS®
and Forced Air**

ECO₂FUME® cylinders be used. VAPORPH₃OS® fumigant gas can only be blended with registered carbon dioxide products. Never allow the buildup of phosphine to exceed explosive concentrations. When phosphine is blended with carbon dioxide, the LFL is raised to 3% v/v. The fumigator should always check with **Cytec®** for approved blending equipment. Fumigators should provide PPQ with all **Cytec®** equipment authorization documentation. The documentation should be on file and available for periodic audits by the USDA.

Phosphine gas (VAPORPH₃OS®) can spontaneously ignite in air if the concentration is greater than 1.8% (18,000 ppm). With specialized equipment, pure phosphine can be safely blended with a forced air stream to ensure the final concentration does not exceed 10,000 ppm (55% of the Lower Flammability Limit of 18,000 ppm). The equipment has incorporated engineering safeguards to ensure the flammable concentration is never exceeded.

Various models of phosphine/forced air blending equipment have been designed, built, and tested. The Horn Diluphos System (HDS) from FOSFOQUIM is approved by **Cytec®** and the **Treatment Quality Assurance Unit** to blend VAPORPH₃OS® with forced air (see section on HDS80 and HDS200 Blending Equipment). One design uses inert gas (nitrogen or carbon dioxide) to prepurge the phosphine lines and equipment. Once purged, phosphine flows through a pressure regulator and flow controller to the mixing point. Here, phosphine is safely blended into the forced air stream. The forced air can be supplied by various fans, blowers, or compressors. The air flow is measured and the phosphine flow will stop if the air flow is insufficient.

If the phosphine flow is stopped for any reason, post-purging of the phosphine lines and equipment is automatic.

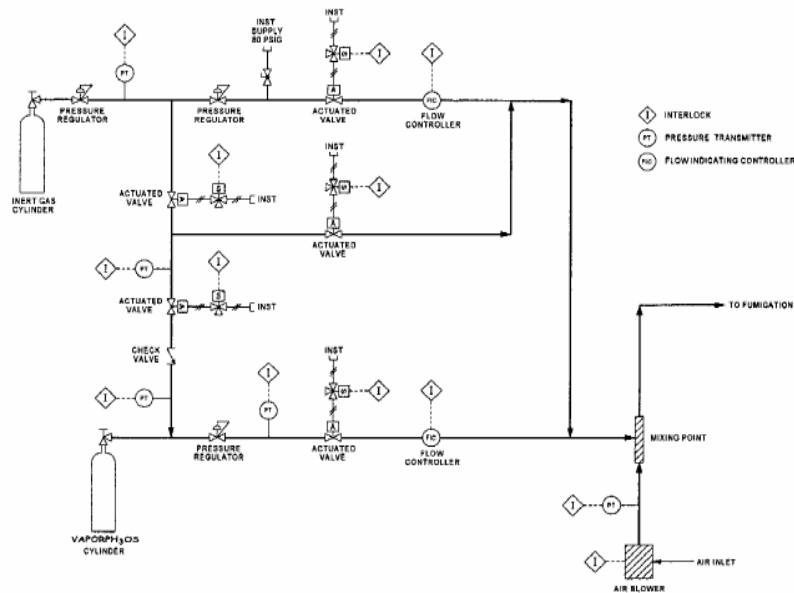


FIGURE 2-10-6: Diagram of VAPORPH₃OS® and Forced Air Blending Equipment

Dosage

The dosage rate for AP, MP, ECO₂FUME® and VAPORPH₃OS® is measured in grams per 1,000 cubic feet or grams per cubic meter and varies with the commodity, treatment temperature, and type of enclosure. The initial fumigant dose is determined by the volume of the space to be fumigated and the required phosphine dose rate needed to kill the target pest. ECO₂FUME® and VAPORPH₃OS® fumigant gas and carbon dioxide/forced air can be added if the desired target concentration changes due to a loss of the fumigant through leaks in the fumigation enclosure.

AP and MP

To calculate the number of tablets or pellets of AP or MP required for the fumigation:

Dosage Rate = the dosage rate from the treatment schedule (grams)
 Volume of enclosure = Length * Width * Height (ft³)
 Grams of phosphine liberated = [Figure 2-10-2](#) on page 2-10-9

Step 1: Grams of PH₃ = (Dosage Rate * Volume of enclosure) / 1,000 ft³

Step 2: Number of Tablets or Pellets needed =
 Grams of PH₃ / Grams of phosphine liberated

EXAMPLE: **T308-b-2**. Tobacco for Export in a warehouse requires 20 grams of phosphine per 1000 ft³. The size of the warehouse is 100' * 75' * 50'. To determine the number of Fumiphos tablets and pellets to introduce, use the following procedure:

$$100 * 75 * 50 = 375,000 \text{ ft}^3$$

$$\text{Step 1: } (20 \text{ g} * 375,000 \text{ ft}^3) / 1000 \text{ ft}^3 = 7500 \text{ g}$$

Step 2:

$$\text{Tablets: } 7500 / 1.0 = 7500 \text{ tablets}$$

$$\text{Pellets: } 7500 / 0.2 = 37,500 \text{ pellets}$$

ECO₂FUME®

Method 1:

$$\blacklozenge \text{ 1 gram of phosphine (PH3) = 25 ppm PH3/1000 ft}^3$$

To calculate the total amount of ECO₂FUME® required for each treatment:

$$\blacklozenge \text{ Target concentration in ppm = } \\ \text{(Dosage rate in grams from Treatment schedule} * 25 \text{ ppm)}$$

$$\blacklozenge \text{ Grams of PH3 = } \\ \text{(Target concentration} * \text{Volume of enclosure)} / 25,000$$

$$\blacklozenge \text{ Pounds of ECO}_2\text{FUME}^\circledast = \\ \text{(Target concentration} * \text{Volume)} / 226,800$$

EXAMPLE: **T301-d-1-2** on page 5-4-5. Cotton and cotton products infested with boll weevil requires 36 g of phosphine per 1000 ft³. The volume of this enclosure is 10*10*10*. To determine the pounds of ECO₂FUME® gas to introduce, follow these steps.

Step 1: Convert grams of phosphine to ppm:

$$36\text{g} * 25 = 900 \text{ ppm} / 1000 \text{ ft}^3$$

Step 2: Determine total volume of the enclosure

$$10 * 10 * 10 = 1000 \text{ ft}^3$$

Step 3: Apply the formula to determine the amount of ECO₂FUME® to introduce (900 ppm * 1000 ft³) / 226,800 = 3.97 pounds

Therefore, 3.97 pounds of ECO₂FUME® will be introduced into the structure.

Method 2:

- ◆ **1 pound of ECO₂FUME® = 9.07 grams PH₃**
- ◆ Divide the dosage rate from the treatment schedule (in grams) by 9.07.

EXAMPLE:

Assuming the same treatment schedule as the previous example ([T301-d-1-2](#) on page 5-4-5):

$$36 / 9.07 = 3.97 \text{ pounds}$$

NOTE: When the amount of gas introduced is less than 68 pounds, use a calibrated scale to determine when the proper amount of gas has been introduced into the space.

VAPORPH₃OS®

To calculate the amount of VAPORPH₃OS® required for the fumigation:

- ◆ **1 pound of VAPORPH₃OS® = 454 grams PH₃**

Target concentration = the desired phosphine concentration (ppm) from the treatment schedule

Step 1:

$$\text{Grams of PH}_3 = (\text{Target concentration} * \text{Volume of enclosure}) / 25,000$$

Blending with CO₂

Once the amount of phosphine has been determined, the appropriate amount of carbon dioxide must be calculated. It is recommended that twice the amount of carbon dioxide be available to ensure an adequate supply for the initial dose, the addition of gas, and equipment purging.

To calculate the amount of carbon dioxide required for the fumigation:

Step 2:

$$\text{Pounds of CO}_2 = (\text{Grams of PH}_3 / 454) * 105.3$$

EXAMPLE: [T301-d-1-2](#) on page 5-4-5. Cotton and cotton products infested with Boll weevil requires 36 g of phosphine per 1000 ft³. The volume of the enclosure is 75,000 ft³. To determine the amount of VAPORPH₃OS® gas to introduce, follow these steps:

Step 1: $(36\text{g} * 75,000 \text{ ft}^3) / 25,000 = 108 \text{ grams PH}_3$

Step 2: $(108/454) * 105.3 = 25 \text{ pounds CO}_2$

Blending with Forced Air

When blending with forced air, only the amount of phosphine needs to be calculated. A closed circulation system is created if the air supply is sourced from inside the fumigation enclosure. This will prevent a positive pressure from developing within the fumigation space. If recirculation is not used the perimeter of the fumigation site will need to be monitored because the air will be displaced from the fumigation space. The HDS 80 blending equipment used with forced air dispenses at 50g/min. If the minimum air flow is not maintained, the blending equipment will automatically shut down and phosphine will no longer be dispensed.

Adding ECO₂FUME® and VAPORPH₃OS® Gas to an Enclosure

Depending on the sealability of the type of space to be fumigated, it may be necessary to add additional gas to the structure in order to maintain the target concentration required by the treatment schedule.

To calculate the amount of ECO₂FUME®/VAPORPH₃OS® to be added:

$$\text{Grams of PH}_3 = (\text{Target Concentration} - \text{Actual Concentration}) * \text{Volume} / 25,000$$

The target and actual concentrations are measured in ppm and must be monitored with a device approved by CPHST, TQAU.

Preparing to Fumigate Break Bulk Cargo

Break bulk cargo has been unloaded from a ship hold, a container, or rail car. This cargo can be fumigated by covering the pallets, boxes, or raw cargo with an impervious tarpaulin.

Always check the PPQ *Treatment Manual* to determine if there is an approved treatment schedule using either AP, MP, ECO₂FUME® or VAPORPH₃OS® fumigant for the infested commodity. Treatment schedules typically list the commodity to fumigate with its associated pest(s). If the commodity in question does not have a treatment schedule, contact the [Treatment Quality Assurance Unit](#) on **page 2-10-38** to determine if there is an alternative treatment available.

Step 1: Site Selection

- ◆ Select sites that are well ventilated and in a sheltered area
 - ❖ Well-ventilated site is required for exhausting gas before and when the tarpaulin is removed from the stack
 - ❖ When applying ECO₂FUME® or VAPORPH₃OS®, a sealed fumigation enclosure will typically see an increase of eight inches water pressure
 - ❖ It is advisable to have a vent area in one or more of the openings to the space to allow air to escape as ECO₂FUME® or VAPORPH₃OS® fumigant gas is applied
 - ❖ Seal the space after the target concentration is obtained
- ◆ Use portable or permanent fans to decrease the amount of time required for aeration
 - ❖ To ensure the exhausted gas does not reenter the building where the fumigation is being conducted nor endanger people working outdoors, monitor gas levels at the property lines and near inhabited structures adjacent to the fumigation site
- ◆ If fumigations are conducted outside, select a site that is semisheltered such as the leeward side of a warehouse, pier, or building that offers some protection from strong winds

Ability to Heat Area

- ◆ When cool temperatures (below 40°F) are expected, heat the site to maintain commodity temperatures above 40°F; take the ambient temperature 12 inches above the floor
- ◆ Because phosphoric acid will be produced if phosphine is burned, never use flame or exposed electrical element heaters during treatment
 - ❖ Contact the [Treatment Quality Assurance Unit](#) on page **2-10-38** for appropriate heating sources

An Impervious Surface

- ◆ To fumigate on a porous surface, cover the surface with asphalt (tar) paper or plastic tarpaulins
 - ❖ For large fumigations, covering the surface is not usually practical because pallets must be rearranged and heavy equipment used to move the commodity
 - ❖ On docks, wharfs, and piers, check for cracks, holes, and manhole covers that will allow the phosphine gas to escape through the floor
 - ❖ Seal all cracks, holes, and manhole covers with plastic or asphalt paper

A Nonwork Area

- ◆ Select a secure nonwork area where traffic and people are restricted from entering
 - ❖ The fumigation area is considered either the entire structure area or an area that extends 30 feet from the tarpaulin and is separated by a physical barrier such as ropes, barricades, or walls
 - ❖ If a wall of gas-impervious material is less than 30 feet from the tarpaulin, the wall may serve as the edge of the secured area
 - ❖ Additional guidelines may be required by some states Department of Agriculture. Some states, California, for example, require a 100-foot buffer zone

- ◆ Place placards clearly in sight of all who come near
 - ❖ Placards must meet label requirements regarding specific warnings, information, and language
 - ❖ Placards generally include the name of the fumigant, the fumigation date, time, and the name of the company conducting the fumigation
 - ❖ Restrict access to the fumigation area to the fumigator's employees and PPQ employees monitoring the treatment
 - ❖ Use rope or marker tape to limit access within 30 feet of the enclosure
 - ❖ Do not allow motor vehicles (including forklifts) to operate within 30 feet of the enclosure during fumigation and aeration periods
 - ❖ The area outside the 30-foot perimeter is usually regarded as a safe distance from the tarpaulin
 - ❖ The 30-foot perimeter is not specifically mentioned on the AP, MP, ECO₂FUME® and VAPORPH₃OS® labels, but is required for safety to PPQ Officers



Important

Gas concentrations should never exceed 0.3 ppm phosphine and 5,000 ppm carbon dioxide in the safety zone (30 feet from the enclosure where officers are taking gas concentration readings).

Use colorimetric tubes or other approved devices to measure gas concentrations.

Electrical Power Supply

- ◆ An adequate electrical source must be available to run the dispensing equipment (ECO₂FUME® and VAPORPH₃OS® only)
 - ❖ A separate line should be available for the dispensing and blending units
 - ❖ Electrical outlets must be grounded and conveniently located in relation to the fumigation area
 - ❖ Except under emergency conditions, do not use generators as a power source

Water Supply

- ◆ A water supply is necessary for safety purposes; if no permanent water source is present on site, the fumigator must provide a portable, five-gallon supply of clean water

Well-Lighted Areas

- ◆ The area should have adequate lighting for safety purposes and for ease in reading the gas monitoring devices, thermometers, and for determining whether a tarpaulin has holes or tears

Step 2: Arranging the Stack

- ◆ Arrange the cargo in a square or rectangular shape, if possible, to make it easy to cover and to calculate the volume of the stack
 - ❖ An even-shaped stack is easier to tarp
 - ❖ The height of the stack should be uniform so dosage can be calculated accurately
 - ❖ By arranging the stack evenly and with space between pallets or cartons, the fumigant will be effectively distributed
- ◆ The maximum size for an enclosure is 25,000 ft³
 - ❖ Contact the [Treatment Quality Assurance Unit](#) on **page 2-10-38** to get approval for any enclosures larger than 25,000 ft³
 - ❖ For very large enclosures it may be necessary to add more sampling leads or introduce the fumigant at several sites
- ◆ When the fumigation involves multiple stacks, allow 10 feet of space between each uncovered stack; after the stack is tarped, there should be approximately five feet between enclosures

Step 3: Padding the Corners

Examine all areas that typically tear tarpaulins, e.g., corners and sharp angles. If the sharp angles or corners cannot be eliminated, they must be covered with burlap or other suitable padding (e.g., old tires or cloth).

Step 4: Covering the Stack

After covering the stack, check the tarpaulin for rips, tears, and holes. Look at the taped areas and verify they are properly sealed. Have the fumigator repair all holes.

The tarpaulin must be made of a tough material such as vinyl, polyethylene plastic, or coated nylon. The tarpaulins should be a minimum of 2-mil thickness, however, it is recommended to use 6 mil tarpaulins whenever possible.

The tarpaulin must be large enough to provide a floor overlap of at least 18 inches around all sides of the stack. Carefully lay the tarpaulin out to prevent excess folds or wrinkles along the floor, especially around corners.

Step 5: Sealing the Tarp

The goal in sealing the tarpaulin is to get it to lay flat against the floor to prevent gas from leaking out. Seal the tarpaulin with loose, wet sand, sand snakes, water snakes, adhesives, or a combination. If there is danger of crushing or crimping the gas sampling or introduction tubes, use the loose, wet sand. If using snakes, use two rows of snakes along the sides and three rows on the corners. The snakes should overlap each other by approximately one foot. Seal corners by laying two sand snakes around the corner and working the tarpaulin until it is flat. To force the tarpaulin against the floor, place a third snake on top of the two other snakes to provide additional weight. Loose, wet sand can be used in the area where the gas introduction line, electrical cords, and gas sampling tubes extend from under the tarpaulin.

Step 6: Introducing the Gas

Depending upon the type of AP or MP formulation used, the gas may be dispensed in a variety of methods. Follow the Application Procedures from the manufacturer's label for detailed instructions on gas introduction.

For ECO₂FUME® and VAPORPH₃OS®, install the gas introduction line(s) at ground level on the floor or secured onto a pallet. These lines should not be located in or attached to commodity package and should be secured to eliminate the movement of the line(s). Direct the discharge toward the center of the space being treated and away from equipment if possible. For tarpaulin enclosures, control the dispensing rate of the gas. The tarpaulin can become damaged and sealing undone if the fumigant is dispensed at high speeds. For small enclosures, a cylinder pressure less than 100 psig is recommended. A regulated dispenser with a pressure regulator and flow restricting nozzles are options to control the rate of the fumigant.

Place the fumigant cylinder with gas introduction line on a calibrated scale and take an initial weight reading. Ensure the gas introduction line is attached to the cylinder. After obtaining the correct weight, subtract the dosage to be introduced into the enclosure. After introducing the proper amount of gas, the scale will be balanced.

When no further fumigant is required to maintain target concentration levels, close all cylinder valves, depressurize the dispensing equipment, and disconnect all ECO₂FUME® or VAPORPH₃OS® cylinders. Replace the cylinder cap after the valve discharge cap is securely installed.

Step 7: Placing Gas Sampling Lines

Place a minimum of 3 gas sampling leads for fumigations up to 10,000 ft³. Position the gas sampling tubes in the following locations:

- ◆ Front—low and front of the load, 3 inches above the floor
- ◆ Middle—center of the load (inside the box with the commodity), midway from bottom to top of load
- ◆ Rear—high and rear of the load, at the extreme top of the load

For fumigations from 10,001 to 25,000 ft³, use 6 gas sampling leads. Position the gas sampling leads in the following locations:

- ◆ Front—low and front of the load, 3 inches above the floor
- ◆ Upper front quarter section (inside the box with the commodity)
- ◆ Middle—center of the stack (inside the box with the commodity), midway from bottom to top
- ◆ Upper rear quarter section
- ◆ Lower rear quarter section (inside the box with the commodity)
- ◆ Rear—high and rear of the stack, at the extreme top of the load

For approval of fumigations larger than 25,000 ft³, contact the [Treatment Quality Assurance Unit](#) on **page 2-10-38** for instructions regarding the number of gas sampling leads, and for other technical information.

Before inserting into the commodity, cover the end of the gas sampling lines with burlap or wire gauze taped to the tube.

Use gas sampling lines of sufficient length to extend from the sampling position inside the enclosure to at least 30 feet beyond the tarpaulin. Connect all the gas sampling lines in one area for ease and safety in recording gas concentration readings. Do not splice gas sampling lines. Fix all gas sampling lines securely in place under the tarpaulin

and label each one where the gas concentration readings will be recorded. By labeling each gas sampling line, concentration readings can be easily recorded.

Step 8: Testing For Leaks

To ensure they are within acceptable levels outside the fumigation area, monitor phosphine and carbon dioxide levels at the fumigation site and 30 feet from the fumigation enclosure. Phosphine and carbon dioxide levels can be detected using chemical-specific colorimetric tubes or electronic monitor's, e.g., Draeger and PortaSens detection kits. Do not use a Gow-Mac or Fumiscope to record gas readings.

The fumigator should leak test all connections and fittings before opening the cylinder valve. Instructions concerning cylinder leak detection can be found under the section "Poison Gas Hazards-Leak Detection and Repair" of the ECO₂FUME® and VAPORPH₃OS® fumigant Application Manuals.

Step 9: Monitoring Gas Concentrations

Take concentration readings within the enclosure using sampling lines connected to an APHIS-approved phosphine monitoring device. The fumigation does not begin until all of the gas has been introduced. Monitoring must take place 30 feet or more from the enclosure.

Phosphine and carbon dioxide levels can be detected using chemical-specific colorimetric tubes or approved electronic monitor's, e.g., Draeger and PortaSens detection kits. To determine if additional gas is needed, check gas concentration levels 30 minutes after the fumigant is added and periodically throughout the fumigation. Record gas concentration readings on PPQ Form 429 at the time intervals prescribed by the treatment schedule in the PPQ *Treatment Manual*.

The 30-minute reading shows the initial concentration and distribution of gas and can indicate leakage, incorrect dosage calculation, or error in fumigant introduction.

If the desired phosphine concentration is met before all of the gas is introduced, stop the addition of ECO₂FUME® or VAPORPH₃OS® and check all calculations. When fumigating with ECO₂FUME®, 200 ppm of phosphine will release 7,700 ppm of carbon dioxide.



Erroneous readings can occur if the monitoring leads become blocked or crimped. It would be impossible to install a new monitoring lead during a fumigation treatment; therefore, always test monitoring leads before the treatment begins.

In order to detect blocked monitoring leads, follow the procedure below using a Mityvac hand-held pump (for supplier see Vacuum Pump, Appendix H).

- Prior to fumigant introduction, connect the Mityvac hand-held vacuum pump to a monitoring lead
- Squeeze the handle on the Mityvac unit. If the lead is blocked, a vacuum will be indicated on the vacuum gauge of the Mityvac unit. For monitoring leads longer than 25 feet, squeeze the handle two or three times. The Mityvac hand-held pump has the capacity to attain and hold 25 inches of Hg vacuum and a minimum of 7 psig pressure
- Disconnect the Mityvac hand-held pump from the monitoring lead, and repeat this procedure for each monitoring lead. Connect monitoring leads to the gas analyzer prior to fumigant introduction

Preparing to Fumigate Containerized Cargo

Containers require small amounts of phosphine, therefore, AP, MP, or ECO₂FUME® fumigant gas (not VAPORPH₃OS®) is recommended for all container fumigations for which an approved treatment exists.

PPQ **does allow** the fumigation of nontarped containers provided the container can be completely sealed in order to prevent gas loss.

To fumigate containerized cargo, follow Steps 1 through 9 in the previous section [Preparing to Fumigate Break Bulk Cargo](#) on page 2-10-21.

Additional Considerations for Fumigating Containerized Cargo

If fumigating a **nontarped** container:

- ◆ Close and secure one of the doors
 - ❖ Seal all openings and joints
 - ❖ If possible, caulk all joints and drape entire doorway with polyethylene sheeting, securing the edges to the inner walls, floor, and ceiling with duct tape
- ◆ Inspect the roof, floor, and walls for holes and cracks
 - ❖ Seal all openings with either duct tape or caulking compound
 - ❖ Containers require close inspection and a great deal of sealing to prevent fumigant leakage

- ◆ If possible, drape **remaining** doorway with polyethylene sheeting before the door is closed
 - ❖ Secure edges to door jambs and floor
 - ❖ Close door and secure
 - ❖ If doorway is draped with polyethylene, it may **not** be necessary to seal the door from the outside
 - ❖ If doorway is **not** draped, seal all cracks, openings, and joints with masking tape and caulking compound from the outside
- ◆ Placard all doors of the container with the appropriate warnings before fumigation begins

If fumigating a **tarped** container:

- ◆ If unable to completely seal the container, use a tarpaulin to cover the entire container
- ◆ Use a 4, 6, 10, or 12 mil vinyl, polyethylene plastic, or coated nylon tarpaulin
- ◆ After covering the container with a tarpaulin check for rips, tears, and holes
 - ❖ Examine all taped areas and verify they are properly sealed
 - ❖ Have the fumigator repair all holes
- ◆ The tarpaulin must be large enough to provide a floor overlap of at least 18 inches around all sides of the container—carefully lay the tarpaulin out to prevent excess folds or wrinkles along the floor, especially around corners

Preparing to Fumigate Bulk Commodities

AP, MP, ECO₂FUME® and VAPORPH₃OS® can be used to fumigate any type of bulk commodity storage for which there is an approved treatment in the PPQ *Treatment Manual*. These include, but are not limited to bins, tanks, flat storage, and bunkers. The most important aspects of a successful fumigation, as with any fumigant, are the degree to which the space is sealed and the assurance that the minimum fumigant concentrations are maintained for the required time.

To fumigate bulk commodities, use the procedures outlined in the section, [Preparing to Fumigate Break Bulk Cargo](#) on page 2-10-21.

AP and MP Fumigation

Probing

When large quantities of grain or other commodity in bulk are to be treated, it will be necessary to “probe” tablets or pellets into the mass of the commodity for adequate distribution. Specially constructed probes made of steel tubing one and one-quarter inch in diameter are generally available as described below:

- ◆ **Head Piece**—Dosing device and numerical counter to indicate number of tablets used
- ◆ **Tubing**—Usually in three-foot sections that can be added to one another to provide the desired length
- ◆ **End Piece**—Cut obliquely and provided with a hinged flap, closing the entrance to the tube
 - ❖ When the tube is inserted into the commodity, the flap is closed and prevents the commodity from entering
 - ❖ When the probe is withdrawn, the flap opens due to the slightly larger diameter on the flap
 - ▶ The tablets or pellets are then released one at a time as the probe is withdrawn

Grain or other bulk or loose commodities up to 30 feet deep can be probed. Best results are obtained by probing twice every square foot and as regularly as possible. Penetration of phosphine is up to 10 feet below the area in which the tablets are placed. When large bulk grain stores are treated, many probes can be placed prior to treatment. One head piece can be moved from probe to probe, or pellets or tablets can be placed in the tubes by hand (use surgical or disposable thin rubber or polyethylene gloves).

Gas generation starts within four hours of placing the pellets or tablets (depending on relative humidity). Therefore, the whole procedure of pellet or tablet placement or tarpaulin covering must be accomplished within this time frame. It is possible to work in a probed area if the area is covered with a gas-proof tarpaulin. Monitor gas concentrations to determine if toxic levels are approached take corrective action to prevent exposure.

**Additional
Considerations
for Fumigating
Bulk
Commodities**

- ◆ For large storage facilities (>25,000 ft³), consider multiple dispensing points to assist in fumigant distribution
 - ❖ Contact the [Treatment Quality Assurance Unit](#) on [page 2-10-38](#) for a determination on the number of sampling lines for large fumigations
- ◆ Based on the size of the structure being fumigated, refer to the ECO₂FUME® and VAPORPH₃OS® Application Manuals for acceptable dispensing equipment
- ◆ If it is known ahead of time that grain or cottonseed will require treatment prior to placement in a means of conveyance or storage, the space should be properly sealed before loading—tarpaulins of at least 6 mm thickness should be used if walls are permeable since lighter tarpaulins may tear

- ◆ If a bulk shipment is in a large storage facility with a high roof, it may be better to tarp on top of the grain rather than seal the roof
 - ❖ When side walls of the facility are not gas impervious, tarpaulins (minimum 6 mm thickness) can be placed around the outside of the facility to the height of the commodity

In Transit Ship Board Fumigation

Until further studies provide the appropriate efficacy data, the [Treatment Quality Assurance Unit](#) on [page 2-10-38](#) **does not allow** the use of ECO₂FUME® or VAPORPH₃OS® fumigant aboard vessels.

However, the solid formulations of AP and MP are approved for use on wood chips for export in ship holds. For guidelines on how to conduct this type of fumigation, refer to the section below, [In Transit Fumigation of Wood Chips](#) on [page 2-10-32](#).

In Transit Fumigation of Wood Chips

The TQAU has approved the use of a low-flow recirculation system for the fumigation of coniferous wood chips within ship holds. The technique is based on a patented system for recirculation of phosphine gas in commodity storages such as silos, ship holds, flat storages and other structures. The recirculation system facilitates the rapid and even distribution of phosphine throughout the stored commodity. Phosphine gas is pumped through ductwork using specially designed low volume fans which operate either continuously or intermittently. The gas is drawn from the head space of the ship hold and is blown, via ducting, to the bottom of the hold where it moves upwards through the wood chips to the top of the hold. This recirculation system is a critical component of the fumigation process and is required for all in-transit wood chip fumigations.

Pest of Concern

Coniferous wood chips exported from the United States of America are fumigated to eliminate the pinewood nematode (*Bursaphelenchus xylophilus*) which is a concern to certain importing countries. Heat generated from oxidative processes in the center of the wood chip pile is typically sufficient to kill the pinewood nematode. However, those nematodes that inhabit the wood chips in the outermost layers of the piles and at the bottom of the hold where temperatures are optimal for their survival are the targets of the fumigation. The incorporation of a recirculation system guarantees phosphine gas will reach all areas of the ship hold to eliminate the pinewood nematode.

Fumigant

Prior to fumigation, the fumigator must verify that the certified applicator follows the EPA-registered label requirements for aluminum phosphide tablet fumigants and the U.S. Coast Guard regulations regarding shipboard fumigation (See Coast Guard Regulations in Appendix B regarding 46 CFR 147A) and applicable State and local laws and regulations.

Aluminum phosphide tablets are preferred over pellets because tablets release the phosphine gas at a slower rate, thus minimizing peak gas concentrations and slowing gas leakage rates. Fumigate with phosphine at 115-145 tablets per 1000 cubic feet (ft³) according to the label requirements, however, verify the amount of phosphine to use from the EXCERPT database. Refer to [Figure 2-10-2](#) on [page 2-10-9](#) for the amount of phosphine liberated by various products. A PPQ officer must be present during the application of the tablets to verify the proper dosage has been dispensed. For exports, document the treatment in the treatment section of the Phytosanitary Certificate. Record all information regarding the fumigation in the electronic 429 database.

To determine the length of time to fumigate the wood chips while in-transit, refer to [Figure 2-10-7](#) on [page 2-10-33](#).

Temperature of Commodity	Exposure Period
Below 40°F	Do not fumigate
40-53°F	10 days (240 hours)
54-59°F	5 days (120 hours)
60-68°F	4 days (96 hours)
Above 68°F	3 days (72 hours)

FIGURE 2-10-7: Commodity temperature and exposure period

The temperature should be taken from the surface of the wood chip pile after the commodity is loaded into the ship hold. Insert a calibrated long-stem thermometer to a minimum depth of 6 inches. Measure the ambient air of the ship hold with a calibrated thermometer. It must be a minimum of 40°F. When the hatch is closed, air temperature will equilibrate to the commodity temperature rather quickly if the hold is filled to capacity. If the commodity and/or ship hold temperatures are below 40°F the treatment must be postponed until the minimum requirement of 40°F is met.

Equipment

Fans

The recirculation system must consist of one fan per ship hold. The type of fan used depends on the total volume of the hold. Fans used in recirculation fumigation systems are typically rated in bushels per minute.



Important

To determine the appropriate fan capacity to be used, convert bushels to cubic feet (1 bushel is equal to 1.24 cubic feet) and then refer to [Figure 2-10-8](#) on [page 2-10-34](#).

Volume of Hold (ft ³)	Fan Capacity (cfm)
62,000 - 248,000	199
248,000 - 372,000	343
372,000 - 744,000	490

FIGURE 2-10-8: Fan sizes required based on volume of the hold

EXAMPLE: 124,000 bushels of wood chips are to be fumigated for export. Calculate the total fan capacity (cfm) to be used in the ship hold.

$$124,000 * 1.24 = 124,000 \text{ ft}^3$$

Therefore, use a fan that has the capacity of 199 cfm.

The fans are secured in the headspace, either to a man way ladder or to a platform inside the hold ([Figure 2-10-9](#) on [page 2-10-35](#)). After the fan is installed, connect it to a data logger that has the ability to record the amount of time the fan is operational and when the fan motor was turned on or off during the fumigation. Contact the [Treatment Quality Assurance Unit](#) on [page 2-10-38](#) for approved data loggers. The information must be presented to the importing country upon arrival to verify the fan was operational for a minimum of 48 hours during the fumigation process. If the records indicate the fan was not operational for a minimum of 48 hours, the treatment should be documented as incomplete and the [Treatment Quality Assurance Unit](#) on [page 2-10-38](#) should be contacted immediately. Record the initial time the fan was turned on in the comments section of the electronic 429 database.

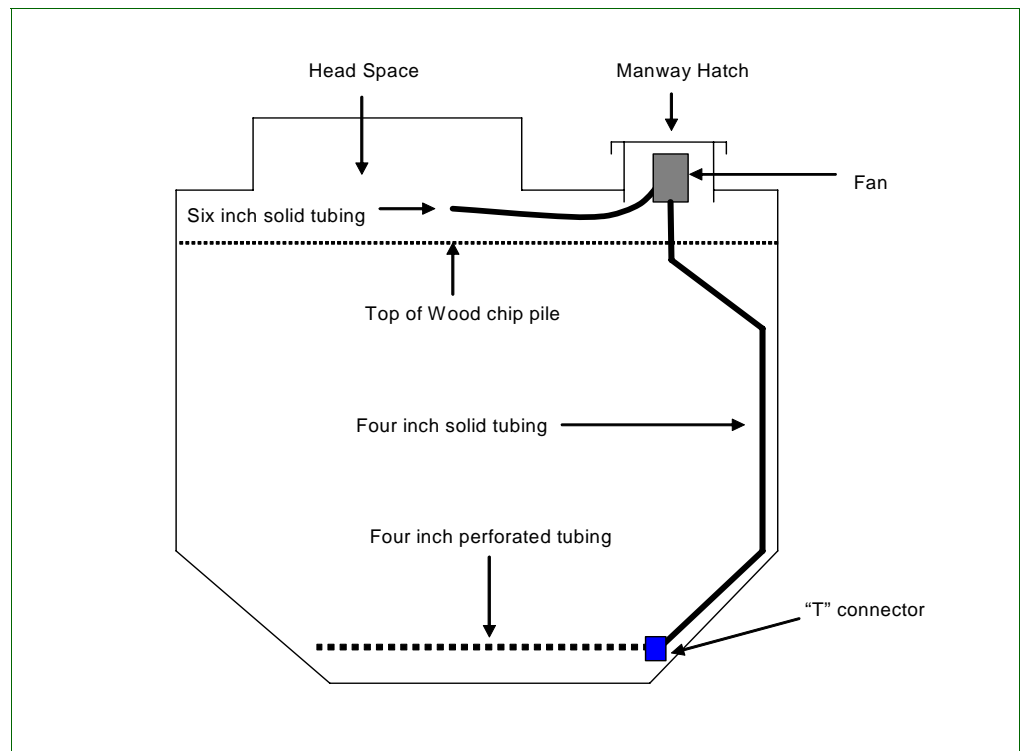


FIGURE 2-10-9: Side view of a recirculation system

Tubing

Different types of high density corrugated polyethylene tubing are used for the recirculation system ([Figure 2-10-10](#) on [page 2-10-36](#)). Connect 6" diameter solid tubing to the intake side of the fan and place on the surface of the wood chips in the headspace. Connect 4" diameter solid tubing to the exhaust side of the fan and attach behind or beside the man way ladder that runs to the bottom of the hold. Attach a polyethylene "T" connector to the bottom of the 4" diameter, solid tubing at the bottom of the hold. Each side of the "T" connector is attached to 4" diameter perforated tubing which runs in opposite directions around the perimeter of the hold along a minimum of three walls of the hold.

All of the tubing should be taped and/or glued in place before the commodity is loaded into the hold. Conduct a visual inspection of the recirculation system prior to the loading of wood chips. If the recirculation system is not installed properly, the fumigation will be delayed until necessary corrections are made to the system.

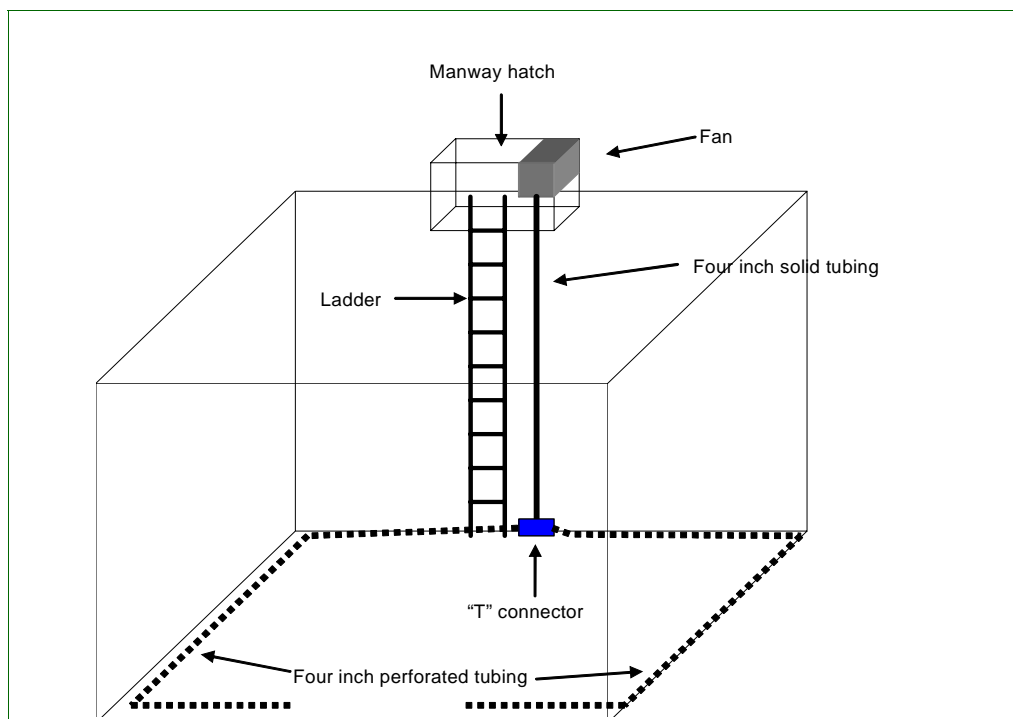


FIGURE 2-10-10: Three-dimensional view of a recirculation system

**Break Bulk,
Containers, and
Bulk
Fumigations**

Aeration Requirements

Following completion of treatment, phosphine-treated commodities must be aerated using either electric exhaust fans or by passive aeration in the open air. Personnel are **not** allowed to enter or reenter fumigated areas until gas concentrations are determined to be below the Threshold Limit Values (TLV) for phosphine and carbon dioxide. Check ambient air and the air inside the box, carton, bin etc. of the commodity during aeration. Measure gas concentration levels with a sensitive gas detection device. Aerate all commodities to acceptable tolerance levels (*Figure 2-10-11* on **page 2-10-37**). Because they can continue to release gas after the initial gas levels have dropped to acceptable levels, continue to monitor densely packed commodities. A certified applicator must be physically present, responsible for, and maintain visual and/or voice contact with all fumigation workers during the initial opening of the fumigation structure for aeration. Always follow the aeration instructions provided with the fumigant label.

Commodity	Tolerance of Phosphine Residues (ppm)	Minimum Aeration Period (hours)
Animal Feeds, Grains, Nuts, and Dates	0.1	48
Processed Foods	0.01	48
Fresh fruits and Vegetables	0.01	48
Nonfood Commodities	<0.3	None
Tobacco	<0.3	48

FIGURE 2-10-11: Tolerance Levels and Minimum Aeration Periods

**Disposal of AP
and MP Residue**

Following treatment with AP, a powdery residue, essentially aluminum hydroxide, will remain. Collect this material and mix it in a container of water to which liquid detergent has been added (two tablespoons of detergent per gallon of water). The liquid should then be buried or deposited in an approved pesticide disposal landfill.

Following treatment with MP, dispose of the plates by burial in an approved landfill or by burning where approved by local ordinances.

Follow the manufacturer’s label instructions for detailed disposal guidelines.

Contacts

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[http://www.cytec.com/business/phosphine/products/
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