

*Standard Operating Procedure  
for Aluminium Phosphide  
Fumigation*

*Submitted to PACT*

*By*

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## PREFACE

Very common facts that need to be understood by the concerns in the field of fumigation is that a mechanism to hold fumigants long enough to kill the target pest(s) is the basic principle of fumigation no matter what type of structures is chosen. However, chambers are convenient way to treat high valued and quarantined products. A successful and efficient fumigation system to function need committed and skilled human resource who comply work procedures consistently and accurately and in disciplined manner. This to happen requires all to contribute their experience, knowledge, and ideas for better performance seeking constant improvement for the future. This Standard operating procedure (SOP) is basically supporting to point out and get the answer of what, when, where and how it is to be done while handling Phosphine fumigation. It also supports in driving all HR in fumigation toward outstanding performance and success. Most people naturally want to do a good job, but they need technical back up. A good standard operating procedures (SOPs) is like a technical adviser which provide technical back up, direction, improve communication, reduce training time, and improve work consistency and support manager to achieve the target. Experience show that Standard operating procedures used in combination with planned training and regular performance, feedback lead to develop positive working environment.

The need for chemical pesticides, particularly the fumigants, is likely to continue for many years to come so Government of Nepal, Ministry of Agriculture, Land Management and Cooperatives, has established Fumigation and Post Entry Quarantine facilities at Kirtipur, under the Project for Agriculture commercialization and Trade (PACT). Thus, in order to run it effectively SOP, Training Manual and Management model has been prepared and presented.

SoP followed by the Training manual works both as management checklist as well as technical guidelines. The operators as well as the trainers can use it as reference source to dig out require information and develop technical confidence. It is suggested to follow the Standard Operating Procedure (SoP) while explaining basic information on fumigation. The Operation Manual contains all necessary information, procedures and instructions to ensure the safe fumigation operations.

During the preparation of this SOP and Manual, the guidance and cooperation from Project for Agriculture commercialization and Trade (PACT) team is highly appreciated. I acknowledge the support from Dr, Govinda Sharma, Project Director, Dr. Prabhakar Pathak Technical Advisor, Mr Mahesh C. Acharya, Senior Monitoring and Evaluation Officer and Dinesh Sapkota, Senior Manager for their positive cooperation and support.

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## SOME FACTS ON SOP

Prior starting the write up to develop the SOP for Phosphine gas fumigation - deskwork on the available documents to find out the minimum requirements that must be included in a SOP was carried out. The three documents namely “The Guidance for Preparing Standard Operating Procedures (SOPs) EPA”..<https://www.epa.gov/sites/production/files/2015-06/documents/g6-final.pdf> , DOC]; Standard Operating Procedure - ASU <https://www.asu.edu/ehs/forms/sop-standard-template.docx> and the Standard Operating procedure“; [www.fao.org/emergencies/programmes/CMC-AH](http://www.fao.org/emergencies/programmes/CMC-AH) were reviewed and used as guideline for preparing this SOP. Since this SoP is meant to improving the performance of the chamber fumigation and a PEQ laboratory, and the points stated in "SoP should be helpful to improve the quality of the performed activity and the quality of the product along with the tips for getting precision in the analytical results in PEQ laboratory works. It is also to comply the requirements of clients as many times the clients require the reliability of fumigation process and the produced data and if the required precision and accuracy cannot be given along with the adopted procedure then the embarrassing situation may occur if the necessary documentation is lacking.

Step by step process adopted for developing this SOPs within are as followings.

1. Reviewed available documents and interaction with the subject matter experts (SMEs) to determine the “must include topics in standard SOP and procedural techniques to develop a SOP was done as done.
2. The contain frame was developed and chapter wise technical matters to be included was discussed and finalized. Effort to include every aspect of the fumigation as checklist maintaining the consistency was done. Side by side the included subject matter was also discussed with NPQP chief and PACT technical team conforming/ explaining the accuracy of the included information.
3. Repeatedly, it has been discussed and informed that this SOP need to be approved from NPPO after it is validated from the concern participants. Further, technical auditing of the fumigation work need to carried out. Training Manual and SOP need the endorsement from government
4. After the SOP is approved from the NPPO a guideline for Assessment, Audit and Accreditation of Fumigation Agencies for Undertaking Aluminum Phosphide Fumigation should be prepared by NPQP as mentioned in this SOP
5. A framework that was adopted while preparing the SoP is attached and is thus recommended to act accordingly to give it authorized status. Then only it should be printed and distributed. Typically, this is the responsibility of NPPO-Nepal. SOPs can be distributed electronically to the responsible persons.
6. Finally, a validation workshop was conducted and comments and suggestion was collected. Most of the issues raised during the workshop have been covered in the document. However, suggestion related to Nepal government’s Civil Service Act and Regulation related comments need to be dealt separately. Similarly, the specific points related to annual

budget program can be addressed while preparing next years, budget program, such as budget for calibration of the phosphine generator, provision for securities, etc. Issues and suggestion from the participants are given below for further action from NPPO /NPQP.

- Provision of risk allowance, insurance, incentives, Regular health checkup for staff conducting fumigation needs to be mentioned
- Lobbying for human resource, budget, organization structure. This Fumigation facility also can be used for exporting handicraft, yak oil, animals' fur.
- Provision for a well-trained Safety officer's recruitment / placement in the complex with required equipment and tools and budget for rescue operation.
- Work out for international recognition/accreditation of our treatments.
- Provision of budget for calibration of equipment and training is missing be there
- Currently, Federal restructuring/ changes is going on thus remember this whole structure should be under NPPO which is an autonomous body to manage the fumigation chamber.
- Extra room for shower needed
- Both internal and external auditing is needed
- SoP record keeping should be developed for entry, release of samples and calibration so that trace back can be done during dispute settlement
- Assurance of spare parts
- Fumigation chamber is essential in Dry Port, Birgunj rather than Kirtipur in aspect of consignment quantity
- Challenge to develop human resources, thus involvement of training service providing institutions, universities in developing post graduate courses on quarantine
- To run the fumigation chamber efficiently there is need of coordination among private and research center. Also need to notify stakeholders about the capacity and facilities of fumigation chamber.
- For conducting the fumigation and PEQ effectively, coordination is necessity with all related organizations, thus a joint meeting is required for the technical feedback.
- Set up some rules to periodically review the SOP for relevancy and accuracy as the business grows. Review at least every two years. Some SOPs may need to be reviewed on a more frequent basis.
- Facilitate the periodic review process and keep SOPs up to date.

Following steps need to be taken for making this document complete by the NPPO -Nepal.

<b>Responsible Department/ Programme:</b>	7/3/2018
<b>Date SOP was written:</b>	_____
<b>Date SOP was approved by PI/lab supervisor:</b>	_____
<b>Principal Investigator:</b>	Ganesh KK C
<b>Fumigation Safety Coordinator:</b>	_____
<b>Fumigation unit Phone:</b>	_____
<b>Office Phone:</b>	_____
<b>Emergency Contact:</b>	_____
<b>Location(s) covered by this SOP:</b>	_____

Type of SOP:     Process         **Hazardous Chemical**         Hazardous Class

All concern with fumigation please keep it in mind that Aluminum phosphide decomposes in water forming flammable and toxic phosphine gas. It can ignite spontaneously in air. It may be harmful if ingested, inhaled, or absorbed through the skin. Aluminum phosphide is used as a rodenticide, insecticide, and a fumigant.

**Physical & Chemical Properties/Definition of Chemical Group**

See SOP Chapter I & II

Class: **Toxic, flammable**

Molecular Formula: **AIP**

Form (physical state): **Solid**

Color: **Dark grey, dark yellow**

Boiling point: N/A

**Potential Hazards/Toxicity**

Decomposes in water forming flammable and It is a toxic gas. Reacts violently with water, diluted strong acids, and carbon dioxide. Can ignite spontaneously in air. Acute exposure may result in

headache, cough, tightness and pain in the chest, shortness of breath, and dizziness. Muscle pain, fatigue, chills, tremor, lack of coordination, seizures, coma, pulmonary edema, and cardiac irregularities may also be observed. May cause severe burns to skin and eyes. REF: Chapter I& II and IV also

## **Personal Protective Equipment (PPE)**

### **Respirator Protection**

**Chapter II and IV. for further information see following link**

<http://www.asu.edu/ehs/documents/asu-respiratory-protection-plan.pdf>

[http://www.ansellpro.com/download/Ansell\\_8thEditionChemicalResistanceGuide.pdf](http://www.ansellpro.com/download/Ansell_8thEditionChemicalResistanceGuide.pdf)

OR

<http://www.allsafetyproducts.biz/page/74172>

OR

<http://www.showabestglove.com/site/default.aspx>

### **First Aid Procedures**

**See chapter IV**

#### **If inhaled**

Move person into fresh air. If required, administer oxygen. Consult a physician.

#### **In case of skin contact**

Take off contaminated clothing and shoes immediately. Wash skin with soap and plenty of water. Consult a physician.

#### **In case of eye contact**

Flush eyes with plenty of water for at least 15 minutes lifting lower and upper eyelids and removing contact lenses. Consult a physician.

#### **If swallowed**

Never give anything by mouth to an unconscious person. Rinse mouth with water. Seek medical aid immediately.

### **Special Handling and Storage Requirements**

**Precautions for safe handling:** Provide adequate exhaust ventilation at places where dust is formed. Keep away from sources of ignition - No smoking.

**Conditions for safe storage:** Keep in a cool, well-ventilated place away from water, oxidizing agents, and mineral acids. Never allow contact with water. Handle and store under inert gas.

**Medical Emergency Dial 01 221988 or**

**Nepal Police: 100**

**Life Threatening Emergency, After Hours, Weekends and Holidays** Note: all injuries and incidents must be reported to NPPO –Nepal

**Non-Life Threatening Emergency** –Report to your NPQP and nearest health Services Center. Note: all injuries and incidents must be reported to Police, Medical and NPPO/NPQP

**Decontamination/Waste Disposal Procedure**

Do not flush with water. Sweep up or scoop. Avoid formation of dust. Dispose as hazardous waste following the SOP

**NOTE**

Any deviation from this SOP requires approval from NPPO Nepal

**Documentation of Training** (signature of all users is required)

**I have read and understand the content of this SOP:**



**Flow Chart of PH3 Operational Procedures**

**STEP A: Location Preparation**

**1. Preparing Fumigation Management Plan ( FMP)**

Education/Preliminary  
Planning and Preparation

Personnel  
Management

Notification



**STEP B: Precaution/ Safety Recommendations**

Adequate care by wearing cap, mask, foot cover, spectacle etc., ..



**STEP C: Fumigation**

**2. Understanding of Phases of Application**

Pre-application  
(Before Fumigation)

During Fumigation  
(Fumigation Period)

Post-application (After  
Fumigation)



**3. Calculation of Fumigation Chamber/Container Volume**



**4. Calculating PH3 Dosages**

**5. Loading the Chamber or Container/Commodity Loading**

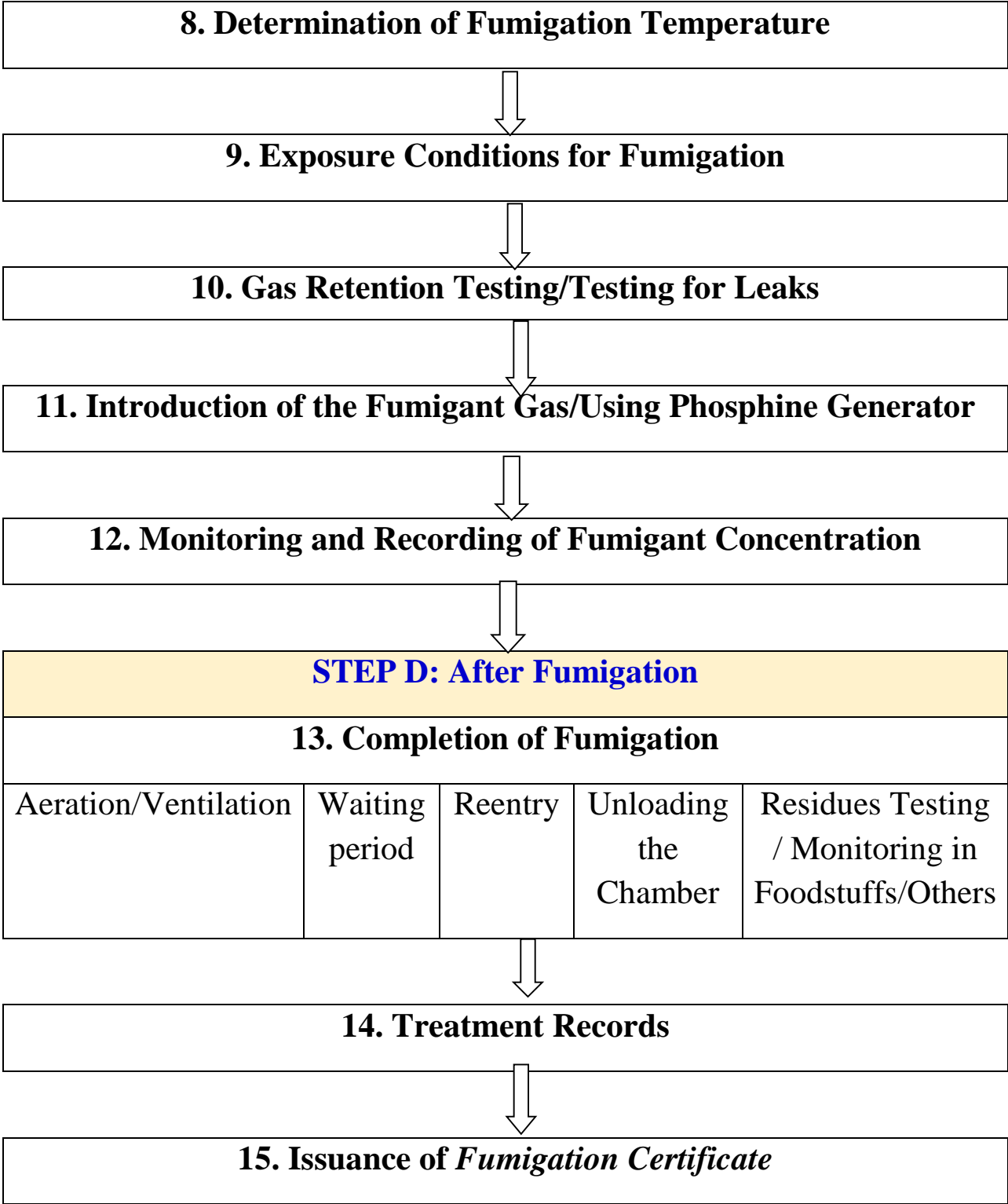


**6. Sealing the Chamber/Container**



**7. Fumigation Placards**







# CHAPTER I: INTRODUCTION

## 1.1 Background

This document consists of Standard Operating Procedures for running Phosphine fumigation chamber established at Kirtipur under National Plant Quarantine Programme of Government of Nepal for clearance plants/plant products requiring fumigation treatment as per the Plant Protection Regulation under the Plant Protection Act, 2010. The purpose of this document is to provide guidance for an operation of a national import regulatory system and prescribe standard operating procedures to ensure effective clearance for Import/Export of consignments of plants/plant products and also to fulfil the international obligations entrusted under the International Protection Convention (1997) and WTO-SPS Agreement.

## 1.2 Rationale

In order to comply with fumigation requirements of importing country ensuring safe use of fumigants by fumigation operator, this standard operating procedure has been developed. All contracting parties of IPPC are “to prevent the spread and introduction of pests of plants and plant products, and promote appropriate measures for their control” (Article I.1 of the IPPC). Similarly, the contracting parties have a sovereign authority to regulate, prescribe and adopt Phytosanitary treatments concerning the importation of plants, plant products and other regulated articles to prevent the introduction and spread of regulated pests. Thus, as fumigation is most accepted Phytosanitary treatment for fulfilment of plant quarantine requirement for eliminating pests of agriculture commodities, it is essential to have, knowledge skill and appropriate facility to facilitate agriculture trade (e.g. India prescribes *Methyl Bromide* (MBr) or equivalent treatment provisions for imported commodities). So there is need to have fumigation chamber treatments facility and expertise for bulk consignments for export of agricultural commodities.

In Nepal also the use of MBr has been restricted but allowed to use for the quarantine purposes however, only after taking approval and also the import of MBr fumigant is a lengthy process complex. Therefore, phosphine gas fumigant has been recommended by NPPO of Nepal to be used for fumigation treatment procedures, as Phosphine gas is known to have a minimal residue, and is acceptable to most global markets too. Thus, a fumigation chamber is required for treatment of agricultural commodities in which fumigations can be carried out efficiently, safely and economically as it is handled only by the trained personnel including the fumigation operator in charge.

In short, this SOP provides guidance on the application procedure to be followed by fumigators/agencies/or companies those which are certified by the National Plant Protection (NPPO) of Nepal.

NPPO thus, first should authenticate this document and then should ensure that the guidelines procedure is strictly followed, whenever fumigation is performed by the NPPO certified agencies or individual operator.

### **1.3 Subject Matter special**

- The concept, procedures and tactics for pest management is changing at global level. However, the fumigation is still occupying important role in pest management as most fumigants by virtue of their nature can be used in different situation where other forms of pest control techniques are not effective. Most importantly, Aluminium phosphide as fumigants is accepted by most member countries of WTO. In this context, all technicians and operation managers, need to be trained in handling and management of fumigants and understand the basic fumigation codes.
- A working knowledge of the principles of fumigation is a prerequisite for fumigation technicians. In addition, physical fitness, mental alertness and the ability to understand verbal and written instructions is required.
- A hazard communication program should be developed and known to everybody assigned to fumigation in the area.
- Provision of a well-trained Safety officer in the fumigation is essential.

### **1.4 Know the fumigants**

- In the stringent sense, fumigants are chemical which, at a required temperature and pressure, can exist in the gaseous state in sufficient concentration to be lethal to a given pest. And fumigation is the practice of using gaseous pesticides applied directly to commodities or to part or all of a structure, including vehicles used to store, handle, process, or transport raw commodities or finished food products as they are ideal for penetrating commodities and protected parts of buildings and food containers.
- Chamber fumigation is a type of fumigation apparatus used for fumigating a product in confined space comprising an inlet and outlet port, providing fumigant via the inlet port, controlling a flow of displacement gas to selected parts of the chamber and extracting the fumigant and so essential to understand the factors influencing the diffusion of gases in the structures loaded with materials into which the gas is required to penetrate.
- The fumigation chamber should be:
  - soundly constructed to be gas tight in order to treat the infested commodities conveniently and there is less chances of risk occurring.
  - provided with an efficient system for applying and distributing the fumigant;
  - provided with an efficient system for removing fumigant at the end of treatment;

- Further, the importing country may require the fumigation operator and NPPO authorized Officer responsible issue the fumigation certificate indicating in detail the type of treatment used on the commodity.
  - A chamber with more than 10 feet high, 25 feet wide, or 50 feet long is not recommended for use;
- Fumigant particularly useful for certain fruits; may be injurious to growing plants. It is to be well remembered that fumigated products if not handled properly after fumigation also may be prone to infestation again.
- Most fumigants including ALP are heavier than air and so need to be stirred or agitated by fans or other means, otherwise the heavier dosage introduced into a chamber filled with air will sink to the bottom and form a layer below the air causing even some residual problems.
- Similarly, if the moisture content of the commodity is higher (more than 18 or more percent) the Fumigants may form residues on foodstuffs. Thus to disperse the gas properly from the very beginning by employing singly or in suitable combination: multiple gas inlets, fans or blowers and/or circulation by means of ducts and pipes.
- Most importantly the fumigators must understand the Dosages and concentrations principles of fumigation. From the moment that a given dosage enters the structure being fumigated, molecules of gas are progressively lost from the free space either by the process of sorption and solution or by actual leakage from the system.
- The concentration is the actual amount of fumigant present in the air space in any selected part of the fumigation system at any given time. The concentration is usually determined by taking samples from required points and analysing them. The dosage is known because it is a pre-determined quantity. Concentration has to be determined based on the exposure time because it varies with time and position according to the many modifying factors encountered in fumigation work.
- NPPO of Nepal needs to ensure that the fumigation chamber treatment using phosphine gas SOP and the procedure need to be accredited and harmonized with its trading partners and also enhance the mutual recognition of treatment efficacy.
- Fumigants are toxic to all forms of life and control all life stages of the pest and the fumigant gas does not leave unsightly, odorous, or hazardous residues if it is properly aerated after fumigation. Phosphines gas, is easily detected by human senses. Unfortunately, no one fumigant has all the above properties, however Phosphine have many of these characteristics.
- 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 the pest less susceptible. Fumigation at lower temperatures requires a higher dosage rate.
- Phosphine gas give Garlic-like or carbide odour due to impurities. It damages Copper, brass, gold and silver severely damaged; electronic equipment damaged. Other metals slightly affected in high humidity. Evolved from aluminium phosphide or magnesium phosphide preparations

- Fumigants vary greatly in their mode of action. In sub lethal dosages, fumigants may have a paralyzing effect on the pest. Phosphine ( $\text{PH}_3$ ) (There are two chemicals used for phosphine, Al-Aluminium phosphide and MP—magnesium phosphide)
- All countries do not accept the ALP fumigants because of suspected adverse effects when the moisture of the commodity is high. Phosphine gas is heavier than the air. It is necessary to make sure that the use of the fumigants is not against the regulations of the country to which the treated commodity is to be exported.
- Phosphine gas, may form some reactive chemicals form irreversible compounds, which remain as undesirable residues in products. In foodstuffs such reactions may lead to taint or the formation of poisonous residues. Other materials may be rendered unfit by visible staining or by the production of unpleasant odours.
- Some insects like Khapra beetle, *Trogoderma* sp. and the cadelle are difficult to control with normal dosage of ALP fumigants when moisture content of the grain is more than 12 percent.
- Chemicals applied as aerosols, smokes, mists, and fogs are suspensions of particulate matter in air and are not fumigants
- ALP gas reacts with the Copper compound silver and gold to cause corrosion. This reaction is enhanced by the presence of ammonia, which is given off during the decomposition of some proprietary formulations. High humidity and temperature appear to favour the reaction, particularly in air with a salt content as found near the sea especially electrical apparatus, may be severely damaged (If fumigation of buildings is to be done special attention should be given especially, electric motors, electric wiring, switches, fire alarm systems, electronic systems or other pieces of equipment that contain copper (Bond et al, 1984) need to be covered or waxed).

## 1.5 What is Fumigation?

Fumigation is the act of releasing and dispersing a toxic chemical to control/manage pests in an enclosed space. The space is ensured that it is sealed to prevent the gas escaping to areas that are not being treated, for environmental and public safety, and to keep the gas at the required concentration for the appropriate time to be effective. The ideal fumigant would have the following characteristics:

- Controls the target pests effectively and do not react with fumigated products.
- Leaves no undesirable odour
- Vaporizes readily.
- Penetrates rapidly to location of target pests.
- Has low sorption on wood and other building materials
- Can be aerated readily.
- Fumigants, in addition to chamber, are used to manage pests in a wide range of environments such as:
  - ship holds;

- grain stores;
- shipping containers;
- whole buildings;
- food processing equipment.

**It is also used to:**

- agricultural commodities, woods and wood materials, NTFP;
- goods that require treatment for inter-government import or export control; and
- smaller objects such as museum items that need preserving without damage.

**Commonly used fumigants at global level (For reference only)**

The authorized fumigants are as following:

Methyl Bromide, Chloropicrin, Aluminium phosphide, Dichloro propene, Methyl isocyanate, hydrogen cyanide, sulfuryl fluoride, formaldehyde etc.

Methyl Bromide and Phosphine are the two most common fumigants used for treating raw commodities, processed food and wooden packaging material. Among fumigants, Methyl Bromide is commonly and widely used for fumigation followed by Aluminium phosphine Chloropicrin, Dichloro propene, Methyl isocyanate, hydrogen cyanide, sulfuryl fluoride, formaldehyde etc.

There are two chemicals used for phosphine gas

- AP—aluminium phosphide and
- MP—magnesium phosphide

**1.6 Limitations of fumigation**

Fumigants are classed as toxic and they are harmful if not used according to the respective standard regulated operating procedures. It therefore requires a well-trained experienced and skilled technicians and is suggested to be legally licensed as fumigators for operating the fumigation chamber by the NPPO upon the recommendation if NPQP.

Fumigation can be conducted successfully in enclosed spaces, structures, areas and sites, provided these are tightly sealed. All living non-living thing that are not to be treated need to be removed from the fumigation site until the fumigation is job is completed.

**1.7 Fumigation chamber.**

The basic elements for design and construction should be incorporated in all chambers with variations made to suit individual country’s needs. However, an effective fumigation chamber must have:

- Refined construction for air tight condition;
- Easy to apply the fumigants and in the same manner easy to remove the poisonous gas at end of treatment and easy to handle infested goods conveniently.

- Safe and easy to operate as well as the availability of adequate resources to run the chamber with increased efficiency and ease of operation.
- Chambers must be separated from the working space.
- Convenient to loading and unloading the chamber, so the site should permit the handling of goods in an efficient and economical manner.
- After the removal of treated materials from a chamber, fumigants continue to diffuse. Therefore, the commodity must be kept on an open platform or in a well-ventilated room for 24 hours after treatment.
- Must have well designed and powerful exhaust system. This system should be equipped with one or more fans or blowers powerful enough to draw a continuous draught of air through the door into the outside atmosphere. A movement of air equivalent to one complete air change every one to three minutes in the empty chamber is recommended.
- The exhaust pipe should terminate well above the roof of the building so that fumes may not enter occupied rooms during the aeration process or the spent fumigant can be absorbed by passing the exhaust gases through absorbing material and degrading to harmless end products (Mori, 1980).
- However, in the chamber constructed at Kirtipur has mechanism to absorb the leftover gas using the high quality absorbing scrubber material imported from Australia and a medium type of exhaust fan on the roof top also has been designed.
- Remember that the chamber size should be such that it can normally be loaded to its full capacity. There is, however, no difficulty in fumigating a partly filled chamber. As a general guide a chamber should be approximately twice as long as it is wide with a height of 2-3 m. Even distribution of fumigant is more easily obtained in such a chamber than in a square one or one more than 3 m high.
- A fumigation chamber is a purpose-built structure, normally containing solid walls, used primarily to conduct fumigations. Chambers are normally fitted with built-in circulation and extraction equipment. A fumigation chamber must be pressure tested every 6 months to ensure it is still fit for purpose and calibration of gas generator and other related equipment need to be done.

**Fumigation generally involves the following phases:**

- First the area intended to be fumigated is sealed properly;
- Next the fumigant is released into the space to be fumigated;
- Then, the space is held for a set period while the fumigant gas percolates through the space and acts on and kills any infestation in the product
- Next the space is ventilated so that the poisonous gases are allowed to escape from the space, and render it safe for humans to enter.

If successful, the fumigated area is now safe and pest free. And ensure that there are no residual chemicals after the gas evaporates. However, in chamber, first all the unwanted material and gas is exhaust out and then based on the size of the chamber and commodities to be treated the required amount of ALPH3 is put in tablet box and after completing the sealing and other labelling process the gas is released

## **1.8 Possible effects of fumigants**

### **1.8.1 Physiological effects**

#### *Nursery Stock and Living Plants*

- Stimulation of growth
- Retardation of growth
- Temporary injury and subsequent recovery
- Permanent injury, usually followed by death

#### *Seeds*

- Stimulation of germination
- Impairment or total loss of germination

#### *Fruit and Vegetables*

- Visible lesions
- Internal injury
- Shortening of storage life
- Delay of ripening
- Stimulation of storage disorders

#### *Pest and beneficial organisms*

- Death or
- Stimulation of growth or metamorphosis
- Stimulation of symptoms of disease

### **1.8.2 Physical and chemical effects on non-living materials**

- Production of foul or unpleasant odours in furnishings or materials stored in premises.
- Chemical effects that spoil certain products.
- Reaction with lubricants followed by stoppage of machinery (clocks will often stop after fumigation with HCN).
- Corrosive effects on metals (phosphine reacts with copper, particularly in humid conditions).

## **1.9 Purpose of SoP**

**The purpose of this standard is to:**

- Develop harmonized fumigation treatment standard for mutual recognition among trading partners
- Provide information to fumigators/agencies/companies so that they can follow appropriate procedures, doses efficiently and appropriate time exposed as per quarantine requirements demanded by the importing country
- Facilitate exports of agriculture products in pest free condition

## **1.10 Scope**

This standard provides specific guidance on dosage, duration, type of equipment and other aspects deemed essential for the application of the treatment procedures to be applied in the fumigation chamber through safe handling of fumigants, tools

## **1.11 Definitions & Terms**

Definitions of Phytosanitary terms used in the present standard can be found in NSPM and ISPM 5 (Glossary of Phytosanitary terms). Some specific ones include

Residue: A pesticide chemical, its derivatives and adjuvants in or on a plant or animal. Residues are expressed as parts per million (ppm) based on fresh weight of the sample. The residues from the use of phosphine fumigants are:

- reaction products of the formulation,
- unchanged phosphine absorbed in commodity
- products formed by chemical combination of phosphine with components of the commodity.

### **Acceptable daily intake:**

- The daily dosage of a chemical which, during an entire lifetime, appears to be without appreciable risk on the basis of all the facts known at the time. "Without appreciable risk" is taken to mean the practical certainty that injury will not result even after a lifetime of exposure. The acceptable daily intake is expressed in milligrams of the chemical, as it appears in the food, per kilograms of body weight (mg/kg/day).

### **Permissible level:**

- The permissible concentration of a residue in or on a food when first offered for consumption, calculated from the acceptable daily intake, the food factor and the average weight of the consumer. The permissible level is expressed in ppm of the fresh weight of the food.

### **Tolerance:**

- The permitted concentration of a residue in or on a food, derived by taking into account both the range of residue actually remaining when the food is first offered for consumption (following good agricultural practice) and the permissible level. The tolerance is also



expressed in ppm. It is never greater than the permissible level for the food in question and is usually smaller

- Threshold Limit Value-Time Weighted Average (TLV-TWA), i.e. the time weighted average concentration for a normal eight-hour work-day or 40-hour work-week, to which nearly all workers may be repeatedly exposed, day after day, without adverse effects.
- Threshold Limit Value-Short Term Exposure Limit (TLV-STEL) - the maximum concentration to which workers can be exposed for a period up to 15 minutes continuously without suffering from irritation, chronic or irreversible tissue change or narcosis of a sufficient degree to increase accident proneness, impair self-rescue, or materially reduce work efficiency, provided that no more than four excursions per day are permitted, with at least 60 minutes between exposure periods, and provided that the daily TLV-TWA also is not exceeded. The STEL should be considered a maximum allowable concentration, or ceiling, not to be exceeded at any time during the 15minute excursion period. The TWA-STEL should not be used as engineering design criterion or considered as an emergency exposure level.

## **1.12 Responsibilities**

### **1.12.1 Responsibilities of Fumigation Operators**

- a. Fumigation technicians must be trained before he/she handle /operate fumigation, not only with the pests and the pesticide, and potential factors for maintaining a safe and healthy environment. Plant, plant products, pests and human beings and environment in which the fumigants are placed in are important factors. So the concerned fumigation personnel need to be clear with working principles of chamber fumigation. They should:
  - have license or authority from NPPO to carry out the fumigation
  - Follow the guidelines stipulated in the standard and abide by instructions issued by the Plant Protection Director from time to time;
  - Ensure fumigation complies with the relevant laws, security or licensing codes within the jurisdiction of the fumigation area
  - Ensure all items are suitable for AIP fumigation before conducting the fumigation
  - Coordinate with the Directorate of Plant Protection for any enquiries pertaining to the procedures or consignments inclusive under this scheme
  - Display warning signs and take adequate safety precautions during fumigation
  - Check if the commodities are of type that can be adversely affected by fumigation;
  - Carry out a pressure test to ensure the containers are gas tight;
  - Monitoring of gas concentrations; and should demonstrate the use of safety equipment and possess knowledge of poisoning, first aid and emergency and safety measures by the management.
  - Concern HR involved in fumigation should have knowledge and skill on chamber fumigation process
  - Check the leakages and take appropriate measures.

- Monitor the status of essential fumigation /safety equipment/ and other critical spare parts of the fumigation chamber.
- Supervision and monitoring mechanism in place during all fumigation operations.
- After the fumigation monitor gas concentration and aerate the fumigated commodities as per the requirement.
- Ensure safety of workers during fumigation operations undertake supervision of all fumigation operations.
- Maintain proper records on stock/use of fumigants
- Do not underestimate fumigation whether a small lot or big one.
- Detect gas leakage and take appropriate measures to seal leakage, monitor gas concentration and aeration of fumigated commodities.
- Dispose- off empty containers of fumigants in safe manner.
- Review the doc SOP and any other relevant fumigation related reference material regularly.
- Comprehend the label requirements and hazards associated with the use of fumigant;
- Carry out the tests needed to ensure that the treatment is successful;
- Measurement of fumigant concentration in enclosure with the help of monitor and Threshold Limit Value (TLV) in/around the chamber with the help of leak gas detector.
- ensure adopting right fumigation practices and follow safety precautions, while undertaking treatment operations;
- Submit monthly report of various activities of agency including stock and use of restricted pesticides.
- Ensure only certified fumigator is allowed to conduct fumigation under this scheme
- Issue fumigation certificates after ensuring fumigations are carried out in effective manner;

### **1.12.2 Responsibility of NPQP/NPPO**

- Organize training for the new comer in the services and refresher type for the on the job personnel/s.
- Provide required Budget an HR for the fumigation PEQ unit.
- Get latest development of fumigants, and technology and regularly circulate it to concern authority.
- Coordinate with different agencies for any new technology and encourage Private sector to join hands in running the fumigation unit
- Conduct quarterly Auditing of the unit.
- Coordinate with the Directorate of Plant Protection/NPPO for any enquiries pertaining to the procedures or consignments inclusive under this scheme. Be updated with any technical change in the fumigants.

- Inform the client of any other factors that affect treatment of commodity such as impervious package or sportive nature of commodity;
- If the chamber management for treatment is to be given to private fumigation company, then prepare the TOR well in advance and discuss with experts and even with traders on technical requirement. However, company should hold a valid registration certificate granted by the Plant Protection Directorate and a license to purchase, stock and use of restricted pesticides.
- This SOP is subject to periodic review and amendment as may be decided by NPPO. Where necessary the statement made in this chapter if needed be included in the PP regulation 2010 with necessary amendments.
- The NPPO- Nepal have to accredit the Fumigation Operators for undertaking Aluminium Phosphide fumigation in future for treatments and quarantine purposes including ware houses. The use of Aluminium Phosphide should be used under the supervision of persons authorized by NPPO/ Plant Protection Directorate.

### **1.12.3 Responsibility of Traders**

- Know your products fully
- Comply with all fumigation requirement.
- Inform in advance to the Fumigation office about your requirements
- Seek from the client any specific conditions they require before the consignment is fumigated
- Know about the terms and conditions of the Chamber fumigation unit before sending the consignment.

## **1.13 Treatment Endorsement**

Phosphine gas fumigation treatments should be undertaken by approved/registered fumigation agencies/personnel under the supervision of accredited fumigation operator. However, in instances, where fumigation treatments are carried out by non-accredited agencies, they shall be supervised by the specified officer of Directorate of Plant Protection. Issuing fumigation Certificate after noting

- that correct dosage of fumigant is applied and appropriate concentration of fumigant is maintained to make it effective
- affix an official stamp on the fumigation certificate with a unique accreditation number assigned;
- record all the details of fumigation in prescribed format confirming that the fumigation was carried out in accordance with this Standard Operating procedure.

## **1.14 Requirement**

### **1.14.1 Applying for fumigation treatment**

An application for requesting the fumigation treatments of plant and Plant products should be made by the client. The client could be the owner of the commodity; an agent; a warehouse manager; an agent representing buyer; an exporter or importer. Along with the application, the fumigation requirements of the commodity, the type, volume and composition of consignment and where applicable import requirements need to be provided by the client.

### **1.14.2 Eligibility of Fumigation Operator and supervisor**

#### **Educational Qualifications**

Fumigation Supervisor. The fumigation Supervisor seeking accreditation for fumigation from the Directorate of Plant Protection should possess the educational qualifications B. Sc. Agriculture or equivalent Degree, and training on fumigation.

Similarly, for the fumigation operators the educational requirement is I.Sc. Ag and training on fumigation from a recognized institution or Persons who has experience working as JTA in Plant protection with training in fumigation can be eligible to work as Operators also.

#### **Training Requirements**

The eligible operators shall be required to undergo training for a period of at least one week at any of the training institute accredited by the NPPO-Nepal and working knowledge of MS Word, MS Excel and internet on computer. The training program shall be as per the guidelines prescribed by the NPQP and should be structured to impart technical skills and competency in performance of effective fumigation operations. The training programs need to cover the following topics viz.,

- Regulations/National Standards
- Role of Regulating Agencies & Responsibilities of Fumigation Operators
- General principles of fumigation
- The fumigation chamber and stepwise process of fumigation
- Handling of the Phosphine gas generator
- Physico-chemical properties /formulations of Aluminium Phosphide (ALP) and their safe use.
- Correct fumigation practices with ALP (correct / recommended dosage of fumigant; proper fumigant distribution; required exposure period; correct concentration of gas within fumigation chamber; proper understanding of temperature, humidity relationships and C X T relationship for effective fumigation)
- Detecting gas leakages / Measuring and monitoring gas concentration
- Use of safety equipment, first aid and safety precautions
- Factors contributing to success/failure of fumigation
- Ship fumigation, container / stack fumigation etc.

- The training program shall demonstration of good fumigation practices as well as group interactions on specific problems and issues related to fumigation operations.
- A post training evaluation to assess adequacy of skills of fumigation operator is necessary.

### **1.15 Equipment & Facilities**

The fumigation unit must have essential equipment and accessories (Appendix-I) that are required for undertaking Aluminium Phosphide treatments and their working condition, proper upkeep and maintenance of safety equipment (gas masks / SCBA) and calibration of measuring equipment etc.

### **1.16 Organization & Personnel**

This fumigation unit chief must have an organizational chart with clear job descriptions of the all the personnel's involved in the job for fumigation. At minimum level, it shall have fumigation supervisor and 4 operators so as to form two sets of all level of staffs who shall be responsible for to carry out each fumigation activity.

All technical aspects of the fumigation unit should be directly handled by NPQP and it should maintain its website with updated information on this fumigation chamber, computer, mass storage device, camera for photo and videography. Fumigation operator must be aware of all the regulatory requirements including the licensing requirements regarding use of fumigants and the operational requirements outlined in the Aluminium Phosphide standard of the NPQP. They must be aware of their responsibilities and the need to acquaint everyone associated with fumigation treatment procedure.

### **1.17 Fumigation Certification**

Authorized fumigation operator shall issue a certificate of approval in the prescribed format (Appendix-III Chapter 1)

### **1.18 Some dos and don'ts**

After fumigation, the chamber/ storage should be aerated and thoroughly cleaned. The collected trash should be removed away from the storage area to prevent further breeding of insects and re-infesting the grains.

Before carrying out fumigation operation, it is important to know how to detect and measure the concentration of released gas in the air and the precautions to be taken to avoid hazards.

#### **Do's**

- Fumigants should be kept safely and outside the reach of ordinary persons. Only trained persons should carry out the fumigation work.
- Use a gas mask with the correct filter.

- Wash and preferably take bath after fumigation.
- Use a display board indicating the fumigant being used, date of application and person in charge.
- Do keep gas monitoring device to determine the gas concentration during fumigation.
- Aerate after uncovering.
- Fumigation should be carried out away from office/residential areas.
- Collect the residues after fumigation and throw in water. Bury the used containers.
- Keep first aid treatment box handy to deal with accidental exposures to the fumigants

**Don'ts:**

- Never work alone/Applicators work alone
- Do not eat, drink or smoke during or immediately after fumigation.
- Throwing pesticide waste in the garbage does not mean the hazard is gone.

## CHAPTER II : FUMIGATION OPERATIONAL PROCEDURES

### 2.1 Fumigation operation

Fumigation Operational Procedures for AIP is briefly described. Different types of Phytosanitary treatments depending upon the types of commodity and pest could be prescribed for treatments including, heat treatment, cold treatment, radiation and Chemical treatments which include AIP fumigation. Aluminium phosphide for commercial use comes packaged in pellets, tablets, application bags along with accessories like ropes, and tape. Factors such as the commodity to be treated, pest and stages present, type of structure, and cost need to be considered while selecting a fumigant.

### 2.2 Fumigation Management Plan

Fumigation units must have a Fumigation Management Plan (FMP) with clear description of required steps involved to help ensure a safe, legal and effective fumigation. It will also assist in complying with pesticide product label. The guidance that follows is designed to help assist in addressing all the necessary factors involved in preparing for and fumigating in a chamber structure. The FMP should have the following steps:

#### 2.2.1 Preliminary Planning and Preparation

Most important is understanding of the equipment and commodity one need to treat and the phosphine gas and airflow patterns within a chamber. Always review diagrams of the facility and inspect the machinery (See Annex 1chapt II). Make the site can be made sufficiently gastight. Initial Planning should include:

- Become fully acquainted with site and commodity to be fumigated, including:
  - General layout of the structure, connecting structures, adjacent structures, and escape routes, above and with specific focus on its structure. What does the structure it consists of: wood, brick, concrete, iron, steel? Note the locations of doors, windows and dividing walls. Check airflow patterns. If possible, get a previous treatment history;
  - Record the Number and names of everyone who routinely enters the area to be fumigated;
  - Note the proximity of other nearby people and animals. Keep children, unauthorized persons and pets away from the application site.
  - Location of the telephone or other communication facility and Post/ current emergency telephone numbers, i.e., Fire, Police, Hospital, and Physician
  - Location of the emergency shut-off stations for electricity, water, and gas
- Safety provisions -Fumigators must use protective equipment to prevent injury or loss of life if they are likely to be exposed to gas levels above the allowable limits and Check and adjust all safety and application equipment;

- Obtain and have handy telephone numbers for local health, fire, police and medical emergency services. Know how to contact the parties responsible for the structure and/or commodity you plan to fumigate;
- Only select a fumigant registered by the government Pesticide Committee ;
- Read and re-read the label information. Study the directions and precautions. Make sure the fumigant is labeled for the required work (site, commodity, etc.);
- Notify the local health and fire departments, police and security personnel and hospital. Give them the following information: the location, the chemical name(s), the date and time of application;
- Arrange for standby equipment and replacement parts for application equipment and Personal Protective Equipment's (PPE)
- Have first aid equipment (including antidotes and plenty of fresh water) handy;
- Preplan how you will aerate the area after treatment;
- Know how to operate the gas detection devices;



### 2.2.2 Personnel

- Instruct all fumigation personnel to read the Operators Manual regarding the health hazards.
- Provide required Personal Protective Equipment (PPE,) viz; gloves, respirators.
- Confirm that all personnel involved in the fumigation know how to proceed in case of an emergency.

### 2.2.3 Notification

- Notify all personnel around the structure prior to application of the fumigant.
- Notify appropriate fire departments, police departments as per label instructions
- Prepare a written “Emergency Response Plan” with instructions if phosphine gas levels are exceeded and could be dangerous to bystanders around the surroundings.



## 2.3 Sealing Procedures

- Sealing must be adequate to control the pests.
- Warning placards must be placed on every possible entrance to the fumigation structure.
- Lock out entry and discharge points, i.e. spouts



## 2.4 Application Procedures

### 2.4.1 Pre-Application/ Before Fumigation

- Pre-application activities, including, but not limited to:
  - i) Arranging for the application of the fumigant
  - (ii) Loading the fumigant
  - (iii) Making necessary preparations for the application of the fumigant
- All areas where a fumigation is to be done must be inspected before the fumigation to ensure that it can be carried out safely and effectively and if any doubt, on safety then do not fumigate.;
- Make a final check. Be sure all occupants, pets and livestock have been removed from the structure;
- Study directions, warnings, antidotes, and precautions on the label and on the manufacturer's instruction manual;
- Follow exactly the label recommendations concerning specific protective equipment and clothing for each fumigant product;
- Place warning signs at all entrances and exits;
- Placarding should be bilingual if workers do not read English
- Security provisions during treatment need to be ensured;
- Assign someone to observe all entrances and exits;
- Make sure no open fires, motors or hot surfaces (heat pipes or electric fixtures) are within the space that you plan to treat. 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
- Determine the dosage/ rates. Consider the type of structure and its size, temperature, humidity, how well the structure can be sealed, label restrictions;
- Be sure people will not be exposed during the fumigation;
- Make a final check to clear all personnel and non-target animals from the space to be fumigated

### 2.4.2 During Application/ Fumigation Period

The Total Fumigation Period is the sum of the time required for Exposure to phosphine gas and the time needed to ventilate the grain. A shortened Exposure Period will not be effective for pest control and a reduced Ventilation Period poses a serious risk of phosphine gas poisoning to workers and bystanders.

- Apply all fumigants according to the directions in the label information;
- All fumigations must be carried out under the supervision of fully trained personnel;
- Do not allow unauthorized persons to enter the treated area(s) prior to aeration;
- Do not enter the area where fumigant gas is being discharged, except in extreme emergencies;
- Prepare warning signs to post near treated areas. Arrange for someone to monitor all entrances and exits during treatment;
- Wear dry cloth gloves when handling ALP products;
- Always work in pairs, never alone—a minimum of two people must be present during the introduction, sampling, and aeration of the fumigant;
- Comply with all regulations;
- Fumigator must be fully protected until readings indicate gas level is below the TLV;
- After all areas are below the TLV, signs can be removed and authorities notified that all is clear;
- The fumigation must be recorded in a register by the Fumigator-in-Charge giving date, fumigant used, dosage, period under gas, type of commodity and any other treatments that may have been carried out. A fumigation certificate must be issued giving details of the fumigation.

### 2.4.3 Post-Application Operations (After Fumigation)

- Allow enough time and use fans to ventilate and aerate in accordance with structural limitations;
- Consider temperature when aerating;
- Turn on ventilation fans where appropriate;
- Check for gas concentrations in areas that aerate slowly;
- Avoid reentering treated areas when you can still detect the fumigant odor;
- Before reentering a treated area, use a suitable gas detector to determine the fumigant concentration. Some fumigants do not provide an adequate odor warning.
- Respect “*waiting period*”. The waiting period is the number of days between when you apply a fumigant and when aeration is complete;
- Remove warning signs only when aeration is complete;
- Containers must not be loaded until 24 hours after fumigation;
- Dispose of or return empty containers as per the manufacturer’s instructions;

- When using metal phosphide fumigants, return any unused, solid chemicals to clearly labeled containers. Store them properly;
- Report any accidents to your employer or supervisor;
- Make sure there is enough water on site to wash or flush skin and eyes if an accident should occur;
- Inform business/client that employees/other persons may return to work or otherwise be allowed to re-enter the aerated structure;
- Keep written records of monitoring to document completion of aeration

#### **2.4.4 Factors Affecting Fumigation Efficacy**

In general, most fumigation treatments are recommended on the basis of a dosage given as the weight of chemical required for a certain space and expressed as grammes per cubic metre or as volume of liquid applied to a certain weight of material. Usually, dosage should be recommended based on the length of the treatment and the temperature range of at which a level of fumigant concentration is required. The weight or volume of the commodity and moisture content of the commodity to be treated must be known before deciding the dosage to be applied. Similarly, the length of the time period and range of temperature of the area where the commodity is kept for treatment also decides the dosage.

Most critical issue that need to be considered in Chamber fumigation is regarding the amount of a.i. fumigants and concentration required for particular period of time acting on the pests. For example, to kill 99 percent of larvae of *Tenebroides* sp (L.) at 20°C, a concentration of 33.2 milligrams per litre of methyl bromide must be maintained for 5 hours (Bond and Monroe, 1961). Thus in order to apply this method of treatment designated to practical fumigations, it is necessary to make reasonably correct determinations of the fumigant concentrations required to kill the insects keeping in view the temperature and humidity.

#### **Factors affect fumigation efficacy.**

- Fumigant concentration, and exposure time,
- commodity temperature and atmospheric temperature
- Gas tightness of the enclosure, commodity load pattern and load factor directly influence gas distribution and gas concentration during fumigation.

**Fumigation conditions are important;** consequently, the dose to be used depends on the conditions, in particular relative temperature and humidity; commodity temperature and moisture levels; and gas-tightness of the container. If due to some unavoidable situation, these conditions are not acceptable during fumigation, it is important to use a longer exposure time. The exposure periods recommended in the schedule are minimum periods. Most data for fumigation with phosphine was obtained at 60% humidity and 20°C. Fumigation should not be performed below a temperature of 10°C.

Understanding the relationship of **fumigant concentration, exposure time, and temperature during fumigation** is critical for determining the proper dosage for control of the pest of interest. For ALP the dosage of the fumigant is calculated by the “CT concept” as follows:

$$\text{Dosage (D)} = \text{Concentration (C)} \times \text{Time (T)}$$

The units for C = grams (g) of fumigant/1,000 cubic ft (ft<sup>3</sup>) or grams (g) of fumigant/cubic meter (m<sup>3</sup>).

The unit for T = hours (hrs), which equals exposure time defined as the number of hours the target pest is exposed to the fumigant.

Therefore, CT is the product of Concentration (C) and exposure Time (T) expressed as gm-hrs/1000 ft<sup>3</sup> or gm-hrs/m<sup>3</sup>.

$$D = C \times T = \text{g-hr}/1000 \text{ ft}^3$$

or

$$\text{g-hrs}/\text{m}^3 \text{ dosage}$$

If you increase the exposure time, less gas will be required to achieve the dosage level (CT) for control. Contrarily, if you decrease the time of exposure more gas will be required to get to the appropriate dosage (CT) for control. **The longer the fumigation time, the more effective the fumigation.** At the proper temperature + time + concentration phosphine will kill all stages of target pests.

Phosphine is most effective over longer exposure times of 1 day or longer. In general, longer exposures to phosphine even at low concentrations result in better efficacy than shorter exposures at higher concentrations. For phosphine the egg stage is also primarily the most tolerant stage, but depending on species, temperature, and exposure duration, pupae have also been shown to be the most tolerant stage.

### 2.4.5 Units used in fumigation

Concentrations of fumigants around the levels used to kill pests – typically measured in grams of fumigant per cubic meter of air (g/m<sup>3</sup> or g m<sup>-3</sup>) with examples,

Conversion factors for g/m<sup>3</sup> and ppm v/v for various fumigants at 25<sup>0</sup>C, 760 mm Hg

Fumigant	Concentration in g/m <sup>3</sup>	Equivalent conc. in ppm v/v
Phosphine	1.0	718

One (1) PHOSTOXIN tablet or five (5) PHOSTOXIN pellets will produce a concentration of 25 parts per million (ppm) of phosphine gas (PH<sub>3</sub>) in a volume of 1000 cubic feet (1 gram PH<sub>3</sub>/1000 cu.ft. is equivalent to 25 ppm).

### Relation between dosages and concentration of gas in air

Dosage	Concentration in ppm
1 g/m <sup>3</sup>	718
16g/m <sup>3</sup> or 1 lb/1000 c.ft.	11493

- Dosage Rate = the dosage rate from the treatment schedule (grams)
- 20 grams of phosphine per 1000 ft<sup>3</sup>
- Each pellet of 0.6 gm yields approximately 0.2 gm of phosphine and 3 gm of tablet releases 1 gm Phosphine (PH<sub>3</sub>). Magnesium phosphide (MP) is similarly manufactured in tablets and plates. Each plate weighing 117 gm. contains 32.3 percent of MP and liberates 33 gm. of phosphine (Refer Table...)
- 1 gm phosphine = 1 tablet (3gm) » 700 ppm.

#### 2.4.6 Schedule of treatment with AIP

The ‘Recommended usage’ of fumigant is given below. This includes commodities, pest organisms, dosage and permissible concentration in air, aeration/waiting period and maximum number of fumigation suggested. However, if there is specific stipulation by the importing country in respect of above parameters, the same is to be adopted.

To be effective, the fumigant must be applied in sufficient quantity. The correct amount depends on published fumigation schedules that are applicable to the infested commodity, pest, temperature, and certain other considerations. Failure to follow the specifications outlined in the schedules will result in faulty fumigation treatments.

#### Important consideration in Treatment (For reference only)

- Do not re-circulate, follow normal diffusion. Not recommended for vacuum fumigation.
- *In order to ensure 100% mortality of all the stages of insects a 10 days’ exposure would be necessary especially in bulk grain treatment.*
- In order to generate PH<sub>3</sub> from tablets free moisture is required. Hence, too dry commodity should not be fumigated with PH<sub>3</sub> tablets.

Treatment: Phosphine at Normal Atmospheric Pressure (NAP)-Chamber

Temperature	Dosage Rate (g/1000ft <sup>3</sup> )	Minimum Concentration Readings (ppm) at	
		96 hrs	144 hrs
Greater than 68 <sup>0</sup> F(20 <sup>0</sup> C)	33g*	200	-
61-68 <sup>0</sup> F(16-20 <sup>0</sup> C)	33g*	-	300

\*33g/1,000 ft<sup>3</sup> is equivalent to 1.17 g/m<sup>3</sup>.

Treatment: Phosphine at NAP—Chamber

Temperature	Dosage Rate (g/1000ft <sup>3</sup> )	Minimum Concentration Readings (ppm) at	
		96 hrs	144 hrs
Greater than 68 <sup>0</sup> F(20 <sup>0</sup> C)	20g*	200	-
61-68 <sup>0</sup> F(16-20 <sup>0</sup> C)	20g*	-	300

\* 20g/1,000 ft<sup>3</sup> are equivalent to 0.71 g/m<sup>3</sup>.

Packaging and Phosphine Liberated by Various Products

AP is packaged in a variety of ways, depending on the manufacturer. Refer given Table ---to determine the amount of phosphine liberated by each product.

## Amount of Phosphine Liberated by Various Products

Product	Type	Unit and Weight in Grams	Grams of Phosphine gas
Phos-Kill tablet	AP	1 Tablet; 3.0	1.1 g of phosphine
Phos-Kill pellet	AP	1 pellet; 0.6	0.2g of phosphine
Phos-Kill bag	AP	1 bag; 34.0	12.0 g of phosphine
Fumiphos tablets	AP	1 tablet; 3.0	1.0 g of phosphine
Fumiphos pellets	AP	1 pellet; 0.6	0.2 g of phosphine
Fumiphos bags	AP	1 bag; 34.0	11.0 g of phosphine
Degesch Fumi-Cel	MP	1 plate; 117.0	33.0 g of phosphine
Detia Gas EX-B	AP	1 bag or sachet; 34.0	11.4 g of phosphine

### Note:

- Calculate amount of product needed by using the amount of phosphine released as shown in the right column
- Reacts with moisture in the air to yield grams of phosphine

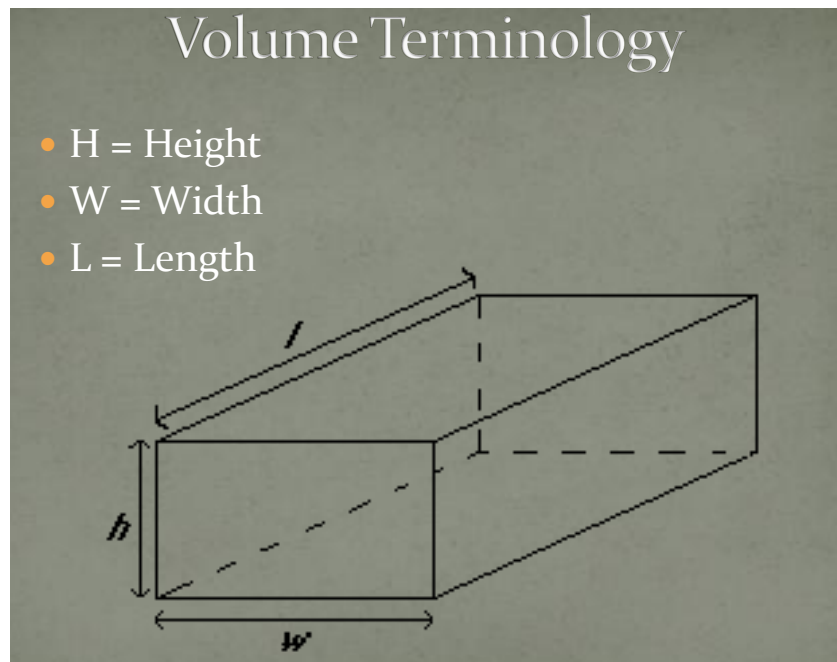
### 2.4.7 Calculation of Fumigation Chamber Volume

The volume of the space to be fumigated is the volume of the total space enclosed for fumigation. Measure the length, width and height of the chamber. Multiply the three measurements together to find the volume in cubic feet or meter. It is to be calculated using a measuring tape or other suitable device to determine length, width and height and is to be expressed in cubic feet (ft<sup>3</sup>) or cubic meters (m<sup>3</sup>). Never estimate the measurements. An error in measurement can result in miscalculation of the dosage by as much as 15 percent. When measuring, round off to the nearest quarter foot (example 3 inches =0.25 foot).

### Formula for calculating volume

The following calculation may be used to determine the volume of the chamber in cubic feet (ft<sup>3</sup>)

Total chamber volume (ft<sup>3</sup>) = Chamber Height (ft) x Chamber Length (ft) x Chamber Width (ft)



## 2.5 Calculating the Dosage

The total weight of fumigant to be applied is a product of the required dosage rate and the volume of the enclosure. Excess sorption or leakage from the fumigation enclosure should be taken into consideration. **A correct measurement of the enclosure volume is therefore important.**

### Formula for Calculating the Dosage

The dosage rate for ALP 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.

### Calculate dosage by doing the following:

1. Refer to the treatment schedule for the correct dosage rate (gms. /1,000 ft<sup>3</sup>) based on temperature
2. Multiply by the dosage (gm/1,000 ft<sup>3</sup>) rate by the volume (ft<sup>3</sup>) to get the dosage in gms.
3. Rules for rounding.

### Dosage calculation:

Once the chamber volume has been determined the weight of fumigant required should be calculated as follows:

Dosage ( gm)= volume (ft<sup>3</sup>) x dosage rate ( gm./1,000 ft<sup>3</sup>)

$$\text{volume ft}^3 \times \text{dosage rate (gm) = 1,000 ft}^3$$

**ALP:** To calculate the number of tablets or pellets of ALP required for the fumigation:

Dosage Rate = the dosage rate from the treatment schedule (grams)

Volume of Chamber (Enclosure)= Length x Width X Height (ft<sup>3</sup>)

Grams of phosphine liberated =

### Step 1:

Grams of PH<sub>3</sub> = (Dosage Rate x Volume of enclosure)/1,000 ft<sup>3</sup>

### Step 2:

Number of Tablets or Pellets needed =Grams of PH<sub>3</sub> / Grams of phosphine liberated

EXAMPLE: A Chamber requires 20 grams of phosphine per 1000 ft<sup>3</sup> for 72<sup>0</sup>F (22.2<sup>0</sup>C) (air and commodity temperature). The size of the chamber is 100' x 75' x 50'. To determine the number of Fumiphos tablets and pellets to introduce, use the following procedure:

Size of the Chamber: 100 x 75 x 50 =375,000 ft<sup>3</sup>

### Step 1:

(20 g x 375,000 ft<sup>3</sup>)/1000 ft<sup>3</sup>= 7,500 g

## Step 2:

**Tablets:**  $7,500/1.0 = 7,500$  tablets

**Pellets:**  $7,500/0.2 = 37,500$  pellets

Or

## Example:

You need to determine the dosage for a Chamber with a volume of  $375,000 \text{ ft}^3$  for  $72^\circ\text{F}$  ( $22.2^\circ\text{C}$ ) (air and commodity temperature), the treatment schedule lists the dosage rate at 33 gm Phos-Kill Tablet and pellets/ $1,000 \text{ ft}^3$ . Determine dosage by doing the following:

1. Volume =  $375,000 \text{ ft}^3$

2. Dosage Rate =  $33 \text{ gm}/1,000 \text{ ft}^3$

3. Dosage (gms) = Volume ( $\text{ft}^3$ ) x Dosage Rate (gms/ $1,000 \text{ ft}^3$ )

$375,000 \text{ ft}^3 \times 33 \text{ gms AP}/1,000 \text{ ft}^3$

$375,000 \text{ ft}^3 \times 33 \text{ gms AP} = 12,375 \text{ gms}$

$1,000 \text{ ft}^3$

Required Phos-Kill Tablet AP:  $12,375/1.1 = 11,250$  Tablets

Required Phos-Kill Pellet AP:  $12,375/2.2 = 5,625$  Pellets

Another Example:

Length=(L)=6 m Breadth=(B)= 4 m Height (H) = 3 m

Calculate the volume of the stack (arrange (a number of things) in a pile, typically a neat one):

$L \times B \times H = 6\text{m} \times 4 \text{ m} \times 3 \text{ m} = 72 \text{ m}^3$

Calculate the number of tablets or pellets in accordance with the recommended application rate, e.g. 0.5-5 tablets/ $\text{m}^3$  depending on the type of fumigation:

Suppose 2 Tablets /  $\text{m}^3 \times 72 \text{ m}^3 = 144$  Tablets

Round the number up or down according to the size of the packs in order to use up all open tubes (with 30 Tablets tube use 5 tubes of 30 Tablets = 150 Tablets).

## One more another important formula

$$\text{Amount of fumigant (g)} = \frac{\text{Volume of Chamber}(\text{ft}^3) \times \text{Dosage}(\text{g}/\text{ft}^3)}{\% \text{ Fumigant Release} \times 1000}$$

Volume of the Chamber (Enclosure):  $100 \times 75 \times 50 = 375,000 \text{ ft}^3$

Dosage:  $20\text{g}/\text{ft}^3$  Amount of Phosphine (Fumiphos Tablets) release (% Fumigant): 1.0 g of phosphine

$$\text{Amount of fumigant (g)} = \frac{375,000 \times 20}{1 \times 1000}$$

$$\text{Amount of fumigant (g)} = \frac{7500000}{1000} = 7500\text{g}$$



**Tablets:**  $7,500/1.0 = 7,500$  Tablets

**Pellets:**  $7,500/0.2 = 37,500$  Pellets

### Calculation of Dose in ppm

- Dose of 1080 ppm required 1.5 Tablets/m<sup>3</sup>  
(i.e. Dose of 720 ppm required 1 Tablet)
- Divide 1080 (ppm) by 1.5 (Tablets) and multiply K figure by 8493 (Total no. of Tablets) and this give 6115 ppm
- Divide 1.5 (Tablets) by 1080 (ppm) and multiply K figure by 6115 (ppm) and give 8.49 Tablets (Rounding the figure 9 Tablets)  
or
- Divide 1(Tablet) by 720 (ppm) and multiply K figure by 720 (ppm) and give the same figure i.e. 9 Tablets.

### Recommended Dosage

Dosages are usually listed on the label in the ranges of pellets or tablets that may be needed. If the temperature, humidity, grain moisture, and air-tightness of the structure are ideal, the lower end of the range should be used. Here are some dosage ranges for PH<sub>3</sub>fumigation:

Type of fumigation	Dosage	Exposure period
Bulk grain in silos, large bins and similar vertical storage	2-4 tablets per cubic meter(35.31 cubic feet)	Long periods typical e.g. 8 to 10 days at 5-12°C
Bulk grain and raw commodities in flat storage	3-5 tablets per cubic meter	Min. 120 to 168 hrs at 10-15 C, 98 to 120 hrs at 16-20 C, 72 to 96 hrs above 20 C
Space fumigation of packed foods and feeds, non-food items stacked under gastight covers enclosures	1 to 1.5 tablets per cubic meter	Min. 120 to 168 hrs at 10-15 C, 98 to 120 hrs at 16-20 C, 72 to 96 hrs above 20 C
Space fumigation of empty enclosures	0.5 to 1 tablets per cubic meter	Min. 120 to 168 hrs at 10-15 C, 98 to 120 hrs at 16-20 C, 72 to 96 hrs above 20 C

### Note:

- The above recommendations are to be regarded as guidelines only.
- National regulations have to be observed strictly.
- The most important factor for a successful fumigation is proper sealing.
- Do not fumigate when temperature is below 5°C (10°F).
- Each 3-gram tablet generates 1-gram phosphine gas (PH<sub>3</sub>)
- Effective Phosphine Fumigation is a Challenge in Outdoor Stacks

### Conversion factors

- 1 Cubic Meter= 35.31 Cubic Feet or
- 100ft<sup>3</sup>= 2.83m<sup>3</sup>

## Measuring the Temperature

- Using a calibrated thermometer, take temperature readings of the air (space) and of the commodity
- For pulpy fruits, pulpy vegetables, or logs use only the commodity temperature.
- For all other commodities, use Commodity or Air Temperature for Determining Dosage Rate

### Example:

You are about to fumigate the commodity temperature is 82 °F (27.77°C) and the air temperature is 69 °F (20.55 °C). Average the air and commodity temperatures to determine the dosage rate because the air is 13 degrees (-10 °C) lower than the commodity temperature. The average of the two temperatures is 75.5 °F (24 °C). Use 75 °F (24 °C) to determine the dosage rate.

### 12.10 Threshold concentrations for space fumigant/ Permissible Exposure Limit

Gas concentration in the air which is safe for human being is known as threshold limit value of the fumigant.

### Limiting values of fumigants

1. Fumigant	2. Threshold Concentration (ppm)/ Exposure Limits
3. Hydrogen phosphide 4. (Phosphine)	5. The PEL/TLV for phosphine is 0.3 ppm as an 8-hour TWA 6. The STEL for phosphine is 1 ppm as a 15-minute TWA 7. Exposures to phosphine must not exceed the 8-hour Time Weighted Average (TWA) of 0.3 ppm or the 15-minute Short-Term Exposure Limit (STEL) of 1.0 ppm phosphine. All persons are covered by these exposure standards. 8. Applicators must not be exposed to hydrogen phosphide levels above 0.3 ppm as an 8-hour Time Weighted Average (TWA) during application. 9. At any time other than during application the allowable limit for hydrogen phosphide exposure is a ceiling of 0.3 ppm.

PEL: Permissible Exposure Limit

TLV: Threshold Limit Value (at any time during fumigation)

TWA: Time Weighted Average over an 8-hour period for applicators

STEL: Short Term Exposure Limit

## 2.6 Fumigation Procedures in chamber

A fumigation chamber is a purpose-built structure, normally containing solid walls, used primarily to conduct fumigations. Chambers are normally fitted with built-in circulation and extraction equipment. A fumigation chamber must be pressure tested every 6 months to ensure it is still fit for purpose.

The primary purpose of fumigation is to obtain quarantine control of the pests in all stages of development in, on, or with the product being fumigated. The objective of using fumigation as a

phytosanitary measure, alone or in combination with another phytosanitary measure is to manage pest risk by achieving a specified level of pest mortality (either immediately or eventually).

Factors which can affect fumigation efficacy include fumigant concentration, exposure time and commodity/atmospheric temperature are crucial factors. Gas tightness of the enclosure, commodity load pattern and load factor are directly related to gas distribution and gas concentration during fumigation. Therefore, good preparation of fumigation is essential for the achievement of the target efficacy.

## **2.7 Loading the Chamber/Commodity Loading**

A fumigation chamber is a stationary enclosure into which the product can be loaded and where the fumigant will be maintained at the prescribed concentration for the required exposure period. The Fumigator shall calculate loading rates within the chamber to ensure specified loading rate and are not exceeded for the commodity or commodities being fumigated. Chamber loadings shall be recorded as a percentage of the chamber volume for each fumigation.

- Before fumigation, the commodity should be loaded into the fumigation enclosure in a manner that ensures sufficient space for adequate circulation of the fumigant. To ensure fumigant penetration into the commodity, separators such as pieces of wood should be used.
- Prior to stuffing of the containers, each empty container is fully inspected on the exterior and interior
- check for the presence/absence of pest
- The condition of commodities (Raw materials, agricultural and other primary products as objects of large-scale trading) and their moisture level
- Provide digital photos of commodities where possible

### **Key factors to consider when loading a container include:**

- **Weight Distribution-** The weight of the goods should be spread evenly over the entire length and width of the floor of the container.
- **Space Utilization-** Use the whole space of the container, wall to wall, filling empty spaces with dunnage.
- **Goods Variation & Compatibility-** Weight, size, density, and properties such as solid or liquid, and even odors of commodities are factors to be considered when loading your cargo into a container.

### **Loading rates within the chamber must be –**

- for fruit and vegetables – not less than 30% nor more than 50% of the volume of the chamber when empty.
- For all other plants and plant products – not more than 50% of the volume of the chamber when empty.

### **2.7.1 Sealing the Chamber**

A fumigation chamber is an example of a tight seal. Little gas escapes from a well-constructed chamber. Once all of the produce has been placed in to the chamber, the Fumigator shall ensure the chamber is gas tight by closing all vents and access pints and checking all possible leak sites such as doors, gaskets and joints.

### **2.7.2 Determination of fumigation temperature**

Sub-lethal concentrations of the fumigant gas may result if fumigation is done at abnormally high or low temperatures. At low temperatures, the fumigant vaporizes and diffuses slower. Insect activity and metabolism are likewise slower. These factors tend to retard killing action, especially at temperatures below 10° C (50°F); thus, at lower temperatures, you must use higher dosages and longer exposure time for a successful fumigation.

Conversely, at excessively high temperatures, fumigants vaporize faster and may dissipate too soon for lethal concentrations to be maintained long enough to kill pests, especially if the seal of the fumigation site is not perfect.

In the range of normal fumigating temperatures (60° to 80° F), the fumigant concentration needed to kill a given stage of an insect species decreases with the rise in temperature; this is mainly due to the insects' increased respiration rate, in response to the rise in temperature. Death occurs faster in the higher end of the normal temperature range. Fumigant labels generally warn not to use the product at temperatures below 40° F (5° C). Generally, the effectiveness of a fumigant depends in part on the respiration rate of target organism. Generally, the lower the temperature, the lower the respiration rate of the organism and the greater the dose of fumigant required to achieve the required level of efficacy.

### **2.7.3 Exposure Conditions for Fumigation**

The amount of time for exposure of the gas to the commodity must be long enough to provide for adequate control. The time required for fumigation varies depending on the type of infestation, dosage, temperature, size of the structure and other factors. Lengthen the time at lower temperatures because insects are more difficult to kill under these conditions. The toxicity of phosphine to insect's declines as the temperature falls to 5°C, so that longer exposure times are required for it to exert its effect. Fumigant is a chemical which can exist in gaseous state in/at a required temperature and pressure and is lethal to pests if they are exposed to a sufficient concentration and for a sufficient length of time. The following table may be used as a guide in determining the minimum length of the exposure period at the indicated temperatures:

**Table: Minimum length of exposure periods for fumigation**

Temperature	Minimum Exposure Periods	
	Pellets(0.6 g)	Tablets(3 g)
Below 40°F (5°C)	Do not fumigate	Do not fumigate
41°-53°F (5-12°C)	8 days (192 hours)	10 days (240 hours)
54°-59°F (13-15°C)	4 days (96 hours)	5 days (120 hours)
60°-68°F (16-20°C)	3 days (72 hours)	4 days (96 hours)
above 68°F (20°C)	2 days (48 hours)	3 days (72 hours)
As a rule- of- thumb a minimum of one day should be added to the exposure time listed above		

A good rule of thumb: Time, not dosage, is your best friend when fumigating. With that said, no matter how long you fumigate, it must be long enough to kill the insect pests and long enough for a complete reaction of the pellets and tablets. But no amount of time will help if it is too cold, too dry (humidity and grain), or if the grain storage facility is leaking the gas to the outside.

#### **2.7.4 Gas Retention Testing/ Testing for Leaks**

Prior to the fumigation (preferably immediately prior to any fumigation) a gas tightness test should be performed. Phosphine levels can be detected using either colorimetric detector tubes or any approved electronic instrument such as the “Porta-Sens” detector. This equipment is used to determine both the high (fumigation concentration) and low (personnel safety) levels of PH.

Fumigation is the act of introducing a pesticide into an enclosed space in such a manner that it disperses quickly and acts in a gaseous state on the target organism. During a fumigation, the chamber must be completely sealed otherwise the fumigant used will leak causing the fumigation not to kill insects and may be harmful to any person.

The space is sealed to prevent the gas escaping to areas that are not being treated, for environmental and public safety, and to keep the gas at the required concentration for the appropriate time to be effective.

It directly addresses the need to treat wood materials of a thickness greater than 6mm, used to ship products between countries. Wood packaging material made of unprocessed raw wood is a pathway for the introduction and spread of pests. As origin of wood is often difficult to be determined. Therefore, approved measures are required.

Phosphine gas has excellent diffusion characteristics; hence there has been little problem in achieving uniform concentration inside during fumigation. Pesticides formulated as fumigants have physical characteristics which cause them to occupy all air spaces within an enclosed area and to penetrate the commodity within these areas. After the building is sealed, it is a good idea to check it for leaks before beginning fumigation. Check for leaks by using thermal smoke generators against the walls.

Any leaks detected shall be repaired immediately. If leaks are detected that cannot be repaired during the treatment, the fumigation must be aborted and the chamber repaired before further use.

### **2.7.5 Introduction of the fumigant gas**

If the chamber is sealed properly and the correct dosage is applied for the required exposure time, phosphine gas will penetrate with no mechanical aid to the very center of the containers and will kill all life stages of any pests present. As soon as the fumigant is placed in the chamber, everyone should leave through the escape door, which should then be sealed tightly. Just before phosphine is released from the product, an ammonia-like odor will be released to warn the applicator(s) to leave the area at once. This usually occurs about 10 minutes before phosphine is released. Only actual measurements can accurately tell the concentration. For best results, chamber should be exposed for 96 hours. chamber should be aerated for at least three days. Fans are not needed for hydrogen phosphide fumigations

Gas concentrations are measured in "parts per million." It is generally agreed that if the phosphine gas concentration is 50-100 ppm at the end of 96-hour fumigation, there will be a 100% insect mortality rate.

### **2.7.6 Monitoring and recording of the fumigation**

Effective fumigation is dependent on maintaining a satisfactory level of fumigant within the chamber during the fumigation. Fumigant concentration readings/recordings should indicate if the amount of Ph<sub>3</sub> fumigant applied is correct and if any heavy leakage or sorption of the commodity exists. Sorption makes the fumigant unavailable to kill the plant pest. There are three types of sorption—absorption, adsorption, and chemisorption. Sorption rate is high at first, then gradually reduces to a slow rate. Sorption increases the time required for aeration. Commodities or packaging known or believed to be highly sportive should not be fumigated in chambers unless concentration readings can be taken to ensure the required minimum concentration is met.

The fumigation time begins once all the gas has been introduced and has distributed throughout the enclosure/chamber. Concentration readings should be taken a number of times during the treatment and in a number of locations in the fumigation enclosure to ensure the fumigant is evenly distributed in the enclosure over the duration of the treatment and achieves the targeted levels. Fumigant concentration should be monitored and recorded either continuously or in sufficient frequency to provide suitable confidence that the target dose(s) has been achieved and maintained or to allow adequate CT product calculations to be made.

Gas monitoring involves measurement of phosphine concentrations inside a fumigation enclosure (to check the level of insecticidal concentration) and in the area around the fumigation enclosure (to determine leakage and safety of the work place). Monitoring gas levels with appropriate detection equipment is to knowing the delivered concentration of a fumigant. When the cause has been rectified the produce must be re-gassed at the specified rate.

### **Controls during fumigation**

- Make regular checks of the seals
- Ensure that no unauthorized persons enter the store during the entire fumigation period

- Only allow the most essential work to be performed in the store and care for good ventilation when work is taking place
- Measure the concentration of the gas from time to time in order to ensure that there is no danger to staff.
- Monitoring of fumigant concentrations must be conducted in areas to prevent excessive exposure.
- Keep a log of monitoring tests for each fumigation structure.
- Include the time and date, number of readings taken and level of concentrations

### **2.7.7 Completion of the Fumigation**

Once the treatment time has been completed and the concentration and temperature readings indicate that the required minimum readings have been achieved, the fumigation should be considered to be applied in accordance with this standard and the treatment schedule.

Indications of fumigation success can be obtained by inspection to verify target pest mortality. For much fumigation an extended post-fumigation period may be required before full pest mortality is achieved. Required treatment effects should not necessarily be expected on non-target pests on the fumigated commodity.

Remove placards when aeration is complete and concentrations are below the TLV. If it is ever necessary to enter a structure when it is under fumigation, enter with a partner and the proper respiratory protection. After aeration, do not occupy fumigated premises until the fumigation supervisor has tested the fumigated area with the proper equipment and has announced the premises clear and safe to enter. After the treatment is complete, move the commodity from the chamber into the quarantine area.

Fumigation's effectiveness can easily be checked by placing test cages of live target insects in various parts of the treated area, or commodity to be fumigated. Retrieve test cages after fumigation for a mortality count of the insects.

### **2.7.8 Unloading the Chamber**

Unloading of the chamber may commence after the Fumigator has released the produce. The ventilation system should be kept running during this process.

### **2.7.9 Always Work in Pairs**

One of the most important things you can do to protect yourself during fumigation is to always work with another person when applying fumigants. This person can assist you immediately if you become injured or incapacitated while working around these products. In fact, many fumigant labels require fumigators to work in pairs during application or gas monitoring.



## **2.8 Phytosanitary system security**

The NPPO should ensure that treatments are properly applied to meet the Phytosanitary requirements of the importing country and those consignments are protected from infestation, re-infestation and loss of integrity.

### **2.8.1 Labeling**

Commodities may be labeled with treatment lot numbers or other features of identification (e.g. locations of packing and the fumigation site, dates of packing and treatment, identity of operator) allowing trace-back.

### **2.8.2 Monitoring and Auditing**

- The monitoring programme to be administered by the NPPO in which fumigations are conducted
- The fumigation facility or operator and the processes should be verified through monitoring and auditing of fumigation records that includes, as necessary, direct oversight.
- The level of oversight should be appropriate to detect and correct deficiencies promptly.
- Corrective action to be taken in cases of non-compliance

### **2.8.3 Aeration after Fumigation**

Treated produce shall be given sufficient time to air after treatment to allow adequate dispersal of the fumigant out of the produce. It is the process by which fumigated air is replaced with fresh air. This can occur in a large warehouse or in an individual piece of equipment. Sometimes aeration involves opening doors and windows. Other times you can use fans and ventilators. Aeration procedures vary according to:

- The fumigant that is used
- The area in which fumigation is done
- The commodity(ies) that is treated
- Every situation is different.

Proper aeration is important for safety, the safety of staffs. Read and follow the instructions in the label information for your product exactly.

Using approved detectors, test confined spaces with poor airflow, stacked commodities and other items to make sure that no gas is remaining. The first rule of reentry is to “check it first.” Remember that the same molecular velocity that permits deep penetration also produces highly desirable aeration characteristics. With normal ventilation procedures, PH concentrations will be removed from both the product and the fumigated stack within 60 minutes.

### **2.8.4 Waiting Period**

The chamber can be used only when monitoring instruments show that gas concentrations have fallen to, or are below, the toxic level value (TLV) set for phosphine gas. Consumption of stored products



is allowed after the product (phosphine) has completely dissipated. Follow the following schedule in case of chamber located at Kirtipur.

The use of Phosphine Generator which shall generate phosphine using Aluminum Phosphide tablets 56% which are already available in Nepal and used widely. Four chambers of about 33 cubic meters' volume capacity is available and a weekly table which shows the usage for the fumigation chambers. Normal fumigation time using a phosphine generator is about 72 hours for temperature above 20 degrees centigrade, however keeping in mind the other factors the fourth day also has been used for treatment.

**Fig 1: Fumigation schedule**

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
Chamber 1	Chamber 2	Chamber 3	Chamber 4				
				Chamber 1	Chamber 2	Chamber 3	Chamber 4

The phosphine generator will provide pure phosphine into the chamber, however since phosphine is flammable as well as explosive after a certain concentration, it will be mixed with carbon dioxide so as to maintain the phosphine concentration at less than 2%. This will ensure safe operation.

**2.8.5 Residual Effect**

A fumigant gas generally does not leave unsightly, odorous, or hazardous residues. With normal ventilation procedures, PH with normal ventilation procedures, PH<sub>3</sub> concentrations will be removed from both the product and the fumigated stack within 60 minutes. Fumigants are easy to use and generally inexpensive, but their future is very uncertain because of the potential negative effects of residues on human health and the environment.

**2.8.6 Approved marking for regulated wood packing material**

The wood packing material must be stamped in a visible location on each article, with a legible and permanent mark that indicates the article has met the treatment required. The mark must be approved by the International Plant Protection Convention (IPPC). The currently approved mark is shown in Figure.2. XX would be replaced by the country code, 000 by the producer number, and YY by the treatment type (PH).

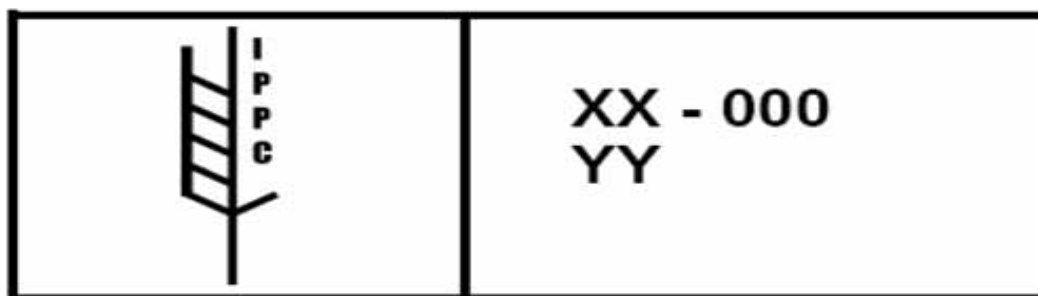


Figure 2. Example of International Plant Protection Convention Marking



## CHAPTER III : AUDITING & COMMUNICATION

Effective management of the fumigation system largely depends upon how, NPPO in coordination with NPQP manage regularly to conduct technical auditing of the fumigation unit and ensure that the SOP is adopted properly and communicate with new developments in fumigation system /technique. Further, un-announced audit while undertaking pre-shipment treatments with Aluminium Phosphide may also be done. The Auditor / team need to carry out detailed physical inspection/ audit/ assessment of the fumigation facility especially focusing the, HR status, whether duties and responsibilities are carried out as envisaged in SOP or not. The team should in detail discuss the status of execution of the SOP by the operators and officer in-charge. The situation report should be submitted to NPPO. NPPO accordingly should take necessary action.

Similarly, standard operational procedure is documented in line with the provisions of the standard established by the NPPO of Nepal. The fumigation Unit must ensure that the records and documents relating to supervising, monitoring and testing of compliance with the procedures are maintained in prescribed format and kept up to date.

Auditors/team should audit considering the followings areas whether these have been put into execution or not;

### **1. For Smooth implementation of Fumigation chamber;**

- Adequate qualified fumigation operators are there or not and also their transfer been done within the Quarantine program.
- Check if the new comer must have /had the fumigation training prior joining the unit, or not. The level of knowledge and skill of the persons working there. Personnel working in Fumigation unit should have both technical knowledge and practical experience.

### **2. Fumigation Operator level**

- Level of adoption of the SOP and instructions issued by the NPPO/NPQP from time to time
- Proper records on stock and use of fumigant status record
- System of display warning signs and take adequate safety precautions during fumigation. Safety Measure of workers adopted during fumigation operations.
- Supervision of all fumigation operations.
- Practice of monitor whether gas leakage detection equipment's are there or not whether the problem has been addressed properly taking appropriate measures to seal leakage, monitor gas concentration and aeration of fumigated commodities.
- Status of essential fumigation /safety equipment's.
- System or mechanism of disposal of empty containers of fumigants in safe manner as per the Insecticides Act and Rules.

- Registration status of Fumigation Operator at NPPO
- Issue fumigation certificate after ensuring that fumigation has been carried out effectively

### **3. The traders or exporter/importer level:**

- Whether the traders have given full information on the commodity to be treated especially regarding any specific conditions of the consignment.
- informed any other factors that affect treatment of commodity such as impervious package or sportive nature of commodity to ensure adopting correct fumigation practices and follow safety precautions, while undertaking fumigation treatment operations
- ensuring not to undertake fumigation if proper safety measures are not followed
- Regularity of Report sending to NPPO/ NPQP of various activities concerned in relation to fumigation in the unit including stock and use of pesticides in the prescribed format /RPQS

### **4. Fumigation Certification:**

Audit how the fumigation certification is being issued. Whether the Fumigation Operator, before issuing Fumigation Certificate, has:

- monitor the fumigation treatment to ensure that correct dosage of fumigant is applied and appropriate concentration of fumigant is maintained to make it effective and proper documentation being done.
- affix an official stamp on the fumigation certificate with an accreditation number assigned
- Record all the details of fumigation
- Medical Certificate of Fumigation Operator and Fumigation Assistants is updated
- Calibration Certificate of Equipment
- ALP Stock Register & Attendance Register

### **5. Educational Qualifications**

As mentioned in Chapter 1. sub-section 1.14.2.1

#### **Training Requirements**

- The practice of pest control is becoming increasingly specialized and requires professionals who are familiar, not only with the pest and the pesticide, but who also have a good knowledge of the many factors related to pest infestation and control and a working knowledge of the principles of fumigation is very essential. It is to be remembered that just by having idea of insect's pest and chemical properties of the chemical would not of much value in safe handling of the fumigants. It requires both theoretical and practical experience in handling the fumigants. Thus all technicians under Plant Protection and Plant quarantine may not be capable of handling the fumigation.

- The operators shall be required to undergo training for a period of at least 7 days organized by the NPQP or by the agencies authorized by NPPO. The Course and duration should be As mentioned in 1.14.2.2.

## **6. Equipment & facilities**

- Status of the essential equipment and accessories that are required for undertaking Aluminium Phosphide treatments and their working condition, availability of a separate secured place for stocking fumigant, proper upkeep and maintenance of safety equipment's (gas masks) and calibration of measuring equipment's and gas detection equipment etc.

## **7. Documents of Fumigation:**

The following records and documents relating to supervision, monitoring and testing of compliance with the due procedure for ALP fumigation if are maintained or not will be audited.

- Stock and Issues Register for fumigant (AIP)
- Monthly report of various activities of agency including stock and use of Aluminium Phosphide in the prescribed format
- Record of Servicing of Equipment & Replacement of Accessories
- Test Report of sheet permeability provided by the manufacturer
- Personal Health Records of Fumigation Operators & Co-workers
- Details of personnel trained in First Aid
- Record of Accredited Fumigation Operators
- Copy of Job order
- Fumigation Certificates
- Equipment stock register
- Monthly Report - fumigation certificate wise

## **8. Reporting of Fumigation Activities:**

- The Chief of the fumigation unit must report to NPPO and respective NPQP on monthly basis regarding the stock / use of Aluminum Phosphide fumigant and the details of all the fumigation operations carried out in the preceding month.

## **9. Detectors for Alp:**

- Paper strip detectors sensitive to 0.3 ppm.
- Detector tubes sensitive to 0.01 mg PH<sub>3</sub>.

## **10. Check if the recommended safety measures are properly exercised and if the required detection device are updated and ready to use condition.**

- Some fumigants react with components of commodities to form new compounds. Ethylene oxide can combine with the chlorides and bromides in food to form toxic chlorohydrins and bromohydrins (Scudamore and Heuser, 1971). Methyl bromide is decomposed in wheat to

form several non-toxic derivatives (Winteringham et al, 1955) and hydrogen cyanide can combine with sugars in dried fruit to form laevulose cyanohydrin (Page and Lubatti, (1948). Other fumigants may also react with materials being fumigated.

- In addition to residue from the fumigant, some by-products from formulations such as aluminum phosphide and calcium cyanide can leave residue on food materials. An ash-like residue of aluminum hydroxide, along with a small amount of undecomposed aluminum phosphide, is left after phosphine is generated. Calcium cyanide leaves a residue of calcium hydroxide after hydrogen cyanide is released.
- The residues remaining in treated materials after a fumigation may be of significance both as an occupational hazard to workers and others exposed to desorbing gas and as a hazard to consumers eating treated foods.
- Although desorbing fumigant may not be considered a residue in the usual sense, appreciable amounts can remain for long periods of time and create hazards for personnel in the immediate vicinity. When treated goods are kept in confined spaces, such as airtight bins or a chamber, the residual fumigant can be of considerable consequence. There is great concern over the possibility of long-term effects that may develop from exposure to desorbing fumigant.
- Some fumigant may remain in food materials and reach the ultimate consumer. Attention has been focused on residues of pesticides in food in recent years because of the harmful effects they may have on human beings. Concern over toxic chemicals in food has been heightened by sensitive detection methods that show traces of residue not previously suspected. The significance of very low levels of some compounds is not known. However, it is believed that the human body can tolerate small amounts without adverse effects.
- Good fumigation practice will normally require that treatments should be conducted in such a way as to keep residues to the lowest possible level

### **11. Records of Fumigation:**

Minimum information that may be required to be recorded includes, however, as per the requirements and working strategy some additional documentation may be further added.

- The names of all personnel engaged either on commodity handling or fumigation work during the application of fumigant, and the nature of their duties;
- The location of treatment;
- The type of produce treated;
- The quantity of produce treated;
- All temperatures measurements taken prior to fumigation;

## **Volume of enclosure;**

- The total quantity in grams of fumigant released in the fumigation;
- Results of gas tightness test;
- The date and time of commencement of fumigant application;
- The fumigation dosage rate used (expressed preferably in grams per ft<sup>3</sup> or m<sup>3</sup> or tablets, pellets, and exposure time;
- The completion time of the fumigation;
- Length of airing period;
- Record of Servicing of Equipment's & Replacement of Accessories;
- Test Report of sheet permeability provided by the manufacturer;
- Personal Health Record of Fumigation Operators & Co-workers;
- Record of Accredited Fumigation Operators;
- Details of any incidents or accidents;

## **12. Storage of Document**

Documentation of the whole activity related to fumigation as supporting evidence describing official controls treatments and this information upon the requested by the importing country/ies for the traceability of the products all the information as mentioned above need to be documented at the office of NPQP chief, NPPO and Fumigation units. Hard copy need to be maintained at Fumigation unit. The information if required by the NPPO of importing country should be made available through the NPPO only.

## **13. Record Keeping**

Information on the treatment should include to the extent possible:

- scientific name of pest and commodity
- date of treatment made and name of operator, time and concentration of the PH3 used
- Date of certification
- references, if any
- additional information, of pest occurrence on the commodity,
- Reports of new occurrences of pests should also include information on any measures taken, and such reports made available on request.
- Procedures
  - The NPPO should maintain guidance documents, procedures and work instructions as appropriate covering every aspect of the certification system.
  - control over issuance (manual or electronic)
  - identification of issuing officers

- inclusion of additional declarations
- completion of the treatment section of the certificate

## **Records**

In general, records should be kept concerning all activities mentioned in this SoP. A copy of each fumigation certificate should be retained for purposes of validation and “trace back”. For each consignment for which a fumigation certificate is issued, records should be kept as appropriate on. The NPPO should be able to retrieve these records when required, over an appropriate period of time. The use of secure electronic storage and retrieval is recommended for standardized documentation of records.

- any inspection, testing, treatment or other verification which was conducted on a consignment basis
- the names of the personnel who undertook these tasks
- the date on which the activity was undertaken
- the results obtained
- any samples taken.
- Traders name
- Export country

## **Consignment tracing**

- Consignments and their certification should be traceable as appropriate through all stages of production, handling and transport to the point of export. If the NPPO becomes aware after certification that an exported consignment may not have complied with the importing country’s phytosanitary requirements, the importing country’s NPPO should be so advised as soon as practicable.

## **Communication**

The NPPO should have procedures in place for timely communication to relevant personnel and to industry concerning changes in:

- importing country phytosanitary requirements
- pest status and geographical distribution
- -operational procedures.
- The NPPO may put in place, for non-conforming consignments, a procedure which enables rapid communication to all affected industry parties and certification personnel.

## **Outside the exporting country**

The NPPO should: liaise with the nominated representatives of relevant NPPOs to discuss fumigation requirements

- make available a contact point for importing country NPPOs to report cases of non-compliance



- liaise with the relevant Regional Plant Protection Organizations and other international organizations in order
- to facilitate the harmonization of fumigation measures and the dissemination of technical and regulatory information.

## **14. Review Mechanism**

### **System review**

- The NPPO should periodically review the effectiveness of all aspects of its fumigation system and implement changes to the system if required. effectiveness of Phytosanitary measures, auditing the activities of the NPPO and authorized organizations or persons, and modifying the Phytosanitary legislation, regulations and procedures as required

### **Incident review**

- The NPPO should establish procedures for investigating reports from importing countries of non-conforming consignments covered by a Phytosanitary certificate. If requested, a report of the outcome of the investigation should be supplied to the importing country.
- The NPPO should have procedures in place to review cases of non-compliance and emergency action. Such a review may lead to the adoption or modification of Phytosanitary measure

### **Means of Communication**

The NPPO should ensure that it has communication procedures to contact:

- importers and appropriate industry representatives
- NPPOs of exporting countries
- the Secretariat of the IPPC
- the Secretariats of the RPPO(s) of
- The relevant documents, supporting information and associated records should be kept for at least
  - one year after the date of treatment. Electronic record keeping should be maintained.
  - Facility records and traceability
  - Packers and treatment facility operators should be required to keep records. These records should be available to the NPPO for review, e.g. when a trace-back is necessary.
  - Appropriate treatment records for should be kept for at least one year to ensure traceability of treated lots. The operator should keep all records for every treatment.

### **Reporting of Fumigation Activities**

The fumigation agency must report to the NPPO on monthly basis regarding the stock/use of fumigant and the details of all the fumigation operations carried out as per the agreed format. Keep all treatment records at the treatment facility for one year after treatment. The facility must also maintain a record of all problems and/or breakdowns and any maintenance performed on the chamber. All the records listed above must be made available to the NPPO official upon request.



## CHAPTER IV: GENERAL PRECAUTIONS, SAFETY MEASURES AND EMERGENCY PREPAREDNESS

Perhaps, the first level of safety is to understand the importance of precautionary measure by the concern. Fumigants are toxic to humans as well as to insects; hence anyone dealing with fumigants must have some basic knowledge of toxic properties, the WHO classification level of the fumigant, safety measures and necessary precaution to avoid exposure.

Thus to comply the safety measure first step is to understand properties of phosphine gas. Note on the followings:

- Aluminium phosphide, is classified as the fumigant to be handled by trained technicians only.
- Read the instruction carefully as the shape, size and type of construction of each particular structure create special problems in achieving and maintaining the concentrations required for the control of the pest.
- Fumigation chamber would be the best option to fumigate the densely packed or absorbent materials.
- When handling and applying fumigants it is essential to know the level of concentration above which it is not safe to subject workers and also the maximum periods of exposure, including repeated exposures during normal working hours. Such concentrations are widely known as threshold limits and are usually, and most usefully, expressed in terms of parts per million by volume in air.
- Chronic or long-term effects may result from an overdose on a single exposure to a toxic gas or from exposure to low levels over a period of time. The effects may not appear until long after exposure and in some cases they may not be easily associated with the poison.
- To be updated in the preventing hazards the Fumigation institutions should gather all available technical information regarding fumigants especially information on threshold limits are published from time to time by responsible authorities or professional organizations in different countries.
- A comprehensive list for repeated daily exposure is published periodically in the United States by the American Conference of Government Hygienists and may also be found in journals, for example the Archives of Environmental Health, published bimonthly by the American Medical Association. These should be documented and circulated to the fumigation units regularly.
- Threshold Limit Value-Time Weighted Average (TLV-TWA), i.e. the time weighted average concentration for a normal eight-hour work-day or 40-hour work-week, to which nearly all workers may be repeatedly exposed, day after day, without adverse effects.
- Threshold Limit Value-Short Term Exposure Limit (TLV-STEL) - the maximum concentration to which workers can be exposed for a period up to 15 minutes continuously without suffering from irritation, chronic or irreversible tissue change or narcosis of a sufficient degree to increase accident proneness, impair self-rescue, or materially reduce work

efficiency, provided that no more than four excursions per day are permitted, with at least 60 minutes between exposure periods, and provided that the daily TLV-TWA also is not exceeded. The STEL should be considered a maximum allowable concentration, or ceiling, not to be exceeded at any time during the 15minute excursion period. The TWA-STEL should not be used as engineering design criterion or considered as an emergency exposure level.

- Phosphine is practically insoluble in water, fats anti oil and is stable at normal fumigation temperatures so that it has no appreciable reaction with most fumigated commodities.

## 4.1 General Precautions

Remember, accidents do not come only when invited it just happens, the risk and hazards can be minimized depending upon how alert and how good the emergency preparedness plan is prepared and implemented accordingly or kept in place. All known fumigants are toxic to humans to a greater or lesser degree and ways need to be devised for their safe handling under the required conditions of application. All members of fumigation crews should be thoroughly trained in basic first aid, with additional emphasis placed on artificial respiration techniques for gas poisoning. All persons engaged in pest control work should have access to, an adequately provisioned first aid kit. The most immediate concern is for the health and well-being of persons in and around the area. Call 100. for fire/rescue squad to obtain medical assistance for injured or contaminated persons. Post theses emergencies numbers in place where everybody can see it

### Emergency phone numbers and others in Kathmandu, Nepal (977-1):

Organization/Associations	Phone Numbers
Police (Emergency)	100
Ambulance, Bishal Bazaar	4244121
Ambulance, Nepal Chamber	4230213/4222890
Ambulance, Paropakar	4251614/4260869
Ambulance, Red Cross	4228094
Ambulance, Bhagawan Mahavir Jain Niketan	4418619/4422280
Bir Hospital	221988
Patan Hospital (Lagankhel)	4522278
Teaching Hospital (Maharajgunj)	4412707/4412505/4412808
B & B Hospital (Gwarko)	4351930/4533206
Teku Hospital (Teku)	4253396
AWON Kalimati Clinic (Kalimati)	4271873
Blood Bank	4225344
CIWEC Clinic (Durbar Marg)	4228531
Homeopathic Clinic (Kalimati)	4277431
Kunfen Tibetan Medical Center (Chhetrapati)	4251920
Himalayan International Clinic (Chhetrapati)	4263170
Synergy International Clinic (Thamel)	4225038
Tilganga Eye Centre	4476575/4474937
Homeopathic Treatment Centre	4522092
Friends of Shanta Bhawan	4470181
Nepal Oral Health Clinic	4245572
Ask me	4427806
Night Taxi	4224374
Tribhuvan International Airport (TIA)	4472256/4472257

## **4.2 Preparedness for emergency**

The following checklist emphasizes steps related to life safety and fire safety. The steps need to be applied in most fumigation operations. Use the checklist as an outline for a more detailed operating procedure in case of emergency. Location specific or fumigation specific preparedness plan also can be prepared.

### **Planning**

All staffs working in the site must be fully aware of precautionary measures and become fully acquainted with site and commodity to be fumigated, and action to be taken in case of emergency including:

1. General layout of the structure, connecting structures, adjacent structures, and escape routes, above and below ground.
2. Once in a week the emergency response chief should call office staffs meeting and discuss thoroughly the preventive and safety measures and check the critical areas in and around the office periphery and report the status to the chief and NPPO
3. Check over safety equipment to ensure that it is in good condition.
4. Check all spouts, conveyers, conduit heat pipes or other possible openings leading from the area to be fumigated.
5. It is necessary to follow exactly the label recommendations concerning specific protective equipment and clothing for each fumigant product
6. Number and identification of persons who routinely enter the area to be fumigated
7. The specific commodity and its biological properties.
8. The commodity's treatment history, if available, to be aware of possible food residues.
9. Accessibility of utility service connections.
10. Location of the nearest telephone or other communication facility.
11. Location of the emergency shut-off stations for electricity, water, and gas.
12. Post current emergency telephone numbers, i.e., Fire, Police, Hospital, and Physician.
13. Make sure that employees actively taking part in a fumigation are in good physical condition.
14. Instruct all personnel in first aid and other emergency procedures, including personal decontamination
15. Select a fumigant or combination of fumigants, registered by PRM for the work involved.  
MC and commodity status will not result in residues

## **4.3 Safety Measures**

- Inform corresponding authorities before fumigation (Management officials of, NPQP)
- In addition to warning signs, the entrances of the fumigated object have to be marked with safety tape.
- Never allow people/employees without special training to use fumigants

- Fumigators should wear protective equipment and never open fumigants in a place which is flammable and also avoid contact with water

Prior entering the chamber make sure the following activities completed and then only enter or start taking out the treated commodities for delivery to respective destination or agency.

- After the fumigant is applied in the closed chamber, the circulating fans are operated for 15 to 30 minutes. With many commodity treatments, this initial circulation will suffice. When continuous or intermittent circulation is required, as for some fruit and plants,
- The period of exposure to gaseous-type fumigants begins when the discharge of the fumigant is completed. With liquids and discs, the exposure should be timed from the moment the door is firmly closed.
- The exposure periods for the various kinds of treatment at atmospheric pressure are given in the fumigation schedules. Fruit, vegetables, plants, bulbs and nursery stock are exposed usually for 1.5 to 4 hours; seeds and plant products, for 16 to 24 hours. For particularly sorptive commodities that may substantially deplete fumigant concentration, some allowance for this depletion may be necessary (see Thompson, 1970).
- The Flammability Limit of Pure Phosphine-Air Mixtures at Atmospheric Pressure is another important area that needs to be considered seriously during the handling of Phosphine gas fumigation.
- Ventilate the rooms and measure the residual concentration before using the rooms again
- Do not open Alp containers with any sharp metallic device as contents may catch fire due to friction.
- Protective clothing like hand gloves and special respirator with reaction type canister must be worn during fumigation with aeration.
- Odour of the fumigant should not be relied upon as an indication of poisonous concentration of the fumigant.
- Phosphine detector strips or tubes be used before allowing workers entry into the fumigated premises.
- Smoking or eating at any time during fumigation should be strictly prohibited.
- Persons with punctured ear drums must not be employed for fumigation work.
- Although most formulations are designed to delay liberation of PH<sub>3</sub> from Aluminium Phosphide tablets, they liberate highly toxic Phosphine gas on opening the container. All fumigation work should, therefore, be planned so that operation of placing the tablets, covering with fumigation covers and closing doors and ventilators should be completed within shortest possible time but not more than 30 minutes.
- Before entering to place where phosphine fumigation has been done one need to wear respirators but it is equally important to have a thorough physical check of the condition of respirators before using it. Check if the canister in fresh enough condition to give the protection desired?

- If a person has not worn a mask before, a regular daily drill should be undertaken to rehearse the proper procedure and movements. This drill should be continued until the new fumigator can demonstrate full familiarity with the correct handling and use of the respirator.
- After the respirator is put on for actual use with a fumigant, the final check on tightness and proper fit is most important. Place the hand lightly over the air intake at the bottom of the canister and take a deep breath. If the respirator is properly adjusted, a strong draught of air will be felt as it enters the canister.
- Respirators need not be worn when tablets or pellets are being dispensed under conditions where the operator does not breathe the vapours of phosphine. Under normal conditions, there is a delay in evolution of the fumigant from the formulations described in this manual. Respirators equipped with a canister designed for protection against phosphine (see above) or other appropriate respiratory equipment should always be on hand in case of emergency.
- Odour of the fumigant cannot be relied upon as an indication of whether or not the operator is breathing poisonous concentrations. Detection equipment such as glass detector tubes or other detectors should be used to monitor concentrations of the gas and to determine when an area is free of fumigant after a treatment.
- Do not smoke or touch food at any time during the application of this insecticide.
- Any spaces adjoining silo bins or close to other structures undergoing treatment with phosphine should be kept continuously aired by leaving windows open or by providing artificial ventilation by means of fans or blowers.
- All persons working, or likely to work, in any place near the fumigation area must be notified that fumigation is in progress. Warning notices should be posted to prevent exposure of employees or the public at large to the gas.
- When the fumigation is completed and the grain is turned, or aeration of a structure is undertaken, full precautions must be undertaken to ensure that no person is exposed to residual vapours of the fumigant.
- Regularly exposed to phosphine as a result of inattention, negligence, failure to follow proper procedures or some other reason and, may result, symptoms consisting of *fatigue, ringing in the ears, nausea, or pressure in the chest appear*, s/he should go immediately into the open fresh air. Phosphine gas is not absorbed through the skin. There is no evidence of cumulative effects from intermittent, low level exposure of 10 ppm or less. At higher concentration, inhalation of Phosphine may produce symptoms including nausea, vomiting, diarrhea, headache, chest pain and massive accumulation of fluids in the lungs before death
- Symptoms of poisoning by a small quantity of phosphine will normally disappear when a person is removed to the fresh air. However, despite the seeming insignificance of even mild cases of poisoning with symptoms as described above, first aid measures are absolutely imperative before and until the arrival of a doctor.
- Under no conditions should an affected person resume work during the next 48 hours, particularly work dealing with fumigation, as it takes time for the body to eliminate the

poison completely. Complete abstinence from alcoholic beverages after any poisoning is strongly recommended.

- For personal protection against the vapours of phosphine at concentrations above the threshold limit, a respirator, gas blouse or other similar equipment for supplying uncontaminated air must be used. Respirators with a special canister for phosphine vapours will give protection up to 0.5 percent phosphine by volume in air (Kloos et al, 1966). Above this concentration, air must be supplied by an air-line or self-contained breathing equipment. Appropriate detection equipment for measuring concentrations of phosphine in air should be used in conjunction with respiratory protective devices to ensure adequate protection.
- Make sure that employees actively taking part in a fumigation are in good physical condition. They all must have a physical examination at least once a year and more often if health conditions require such.
- Fumigation businesses should maintain up to-date health records for each employee should abstain from alcoholic beverages and medical or recreational drugs for 24 hours before or and 24 hours after a fumigation job.
- Should NOT participate in a fumigation if they have colds or other respiratory problems that make breathing difficult.
- Make sure fumigators understand the use of specific antidotes, first aid procedures, and a symptomatic relief measures.
- Instruct employees to report any accidents immediately to the employer or supervisor. Caution personnel to report all indications of illness or physical discomfort regardless of their apparent minor nature
- Make sure employees understand the hazards that may be encountered because of carelessness or misuse of fumigants
- Teach employees in the selection, operation, and maintenance of all protective equipment and safety procedures required by the fumigant.
- Storing, Handling, & Disposing of Fumigants Store all fumigant products in a locked, dry, well-ventilated place away from heat.
- Post as a pesticide storage area. Do not risk contamination of water, food, or feed by storing these products in the same area as other pesticides.
- Remember that ALL PESTICIDES AND THEIR EMPTY CONTAINERS SHOULD BE KEPT OUT OF REACH OF CHILDREN.

## **4.4 Post-Application Operations**

### **4.4.1 Venting and aeration**

At the end of the treatment, venting should be commenced by opening the exhaust port or valve and starting the fan. The chamber door should be opened slightly to allow fresh air to flow in. At least 10 or 15 minutes should elapse before the door is fully opened. The time of this interval will depend on a number of factors, but the door should not be fully opened until the operator is assured by



appropriate chemical tests, instrumental tests, or from long experience, that it is safe to enter the chamber to begin unloading. First aid kits and gas masks should be available and in good condition at all times.

- Allow enough time and use enough fans to ventilate and aerate in accordance with structural limitations.
- Turn on all ventilating or aerating fans where appropriate.
- Before re-entry, use a suitable gas detector to determine fumigant concentration so that appropriate precautions may be taken.
- All the safety precautions as described under the Good Practice Checklist for Fumigation should be followed. Using the proper detection equipment, check the building thoroughly after aeration before re-entry.
- Phosphine is very corrosive to certain metals, such as copper wiring, brass sprinkler heads, and electronic equipment for safety reasons, the person doing the fumigation should be the only one who has a key to the building being fumigated.

#### **4.4.2 Additional Tips on safety Measures**

- Always read the label before use and follow the manufacturer's instructions also.
- Obtain a safety data sheet (SDS) from your chemical supplier which gives information about treatment and symptoms of phosphine poisoning, as well as chemical data.
- Wear correct respirator and protective clothing.
- Have an observer standing by who should have access to respiratory protection.
- Monitor the atmosphere around fumigation using a hand pump and gas detector tube; concentration should not be higher than 0.3 ppm.
- Never increase dosage to have a 'better kill' of insects.

#### **4.4.3 Respiratory protection**

- A full-face filter respirator or self-contained breathing apparatus must be worn if concentrations exceed 0.3 ppm.
- Self-contained breathing apparatus should be used for operations, such as breakdowns, when longer exposures at higher concentrations may occur.

#### **4.4.4 First Aid Kit essential**

- Scissors Tweezer, Irrigation syringe, Gauze Adhesive Tape Thermometer Oral dehydration solution Kidney tray. Prescribed drugs if you know the medical history. Dettol Crepe bandage and sling. Regular bandage.....
- a self-contained unit, using compressed air, carried on the person in one or more small cylinders (bottles);
- a type of self-generating apparatus whereby the oxygen is evolved from a special Check for Gas Tightness

#### **4.4.5 Precautions at Pre-fumigation stage**

In any fumigation, no person should work alone. No matter how small the dosage or the scale of the work, at least one other person should be present.

- Read and follow instructions on the label, including the SOP. Phosphine fumigants are valuable tools as long as they are used properly.
- Keep careful inventory so each container and package is accounted for. If you discover that any fumigant has been stolen, you are required to report the theft immediately to your local law enforcement authorities. Make sure the storage area is properly placarded as a pesticide storage area.

#### **4.4.6 Precautions during application**

Should wear proper respiratory protection, care should be taken to avoid direct exposure. Warning signs that indicate the type of fumigant in use and the date of the treatment should be put in appropriate places. They should be removed after the treatment is completed.

#### **4.4.7 Precautions Post application**

Only after adequate aeration of the treated area, gas detection equipment should be used to ascertain that all fumigant has been removed.

#### **4.4.8 First Aid measures**

First aid is one of the most important and basic life skills that one should learn. First aid must be started at once. If possible, one person should begin treatment while another calls a physician.

#### **Measures in Emergencies to be taken before arrival of a physician**

##### **Inhaled poisons**

1. Carry patient (do not let him walk) to fresh air immediately.
2. Open all doors and windows.
3. Loosen all tight clothing.
4. Apply artificial respiration if breathing has stopped or is irregular.
5. Prevent chilling (wrap patient in blankets).
6. Keep patient as quiet as possible.
7. If patient is convulsing, keep him in bed in semi dark room; avoid jarring or noise.
8. Do not give alcohols in any form.

##### **Skin contamination**

1. Drench skin with water (shower, hose, faucet).
2. Apply stream of water on skin while removing clothing.
3. Cleanse skin thoroughly with water; rapidity in washing is most important in reducing extent of injury.

## **Eye contamination**

1. Hold eyelids open, wash eyes with gentle stream of clean water (running) immediately. Delay of a few seconds increases extent of injury.
2. Continue washing until physician arrives.
3. Do not use chemicals; they may increase extent of injury

## **Strain and sprains**

1. Overstretching muscles tissues resulting in tearing and bruising. While tending to this first check how much you can move the limb and if you can feel the sensation, put the strained limb in rest to limit its movement

## **Wound Management**

1. Use ice or water to cool the strained or swollen muscle a use bandage or cloth wrap the limb and compress it. Check circulation, sensation, and motion. Then elevate the muscle and keep it at higher level than your heart and take rest.
2. wound bleeding, can be open and closed. In case of open bleeding put direct pressure on the wound with a clean cloth or gauge or pad and elevate it. If the bleeding is heavy put multiple gauge over the wound with enough pressure so that the bleeding is stopped. Once the bleeding stops remove the pad slowly irrigate the last one attached to the wound if necessary. Wounds need to be cleaned and dried to heal it faster. Use gauge dipped in Dettol or betadine solution to disinfect the wound if these are not available then use at least the clean water.
3. Clean the wound and get medical help as quickly as possible.

## **Burns**

1. Put the affected area in cool water and clean the wound do not keep the wound open so apply thin bandage over the area. Seek medical help but very best thing to do is stay calm and not panic.

## **Choking / Airways Obstruction**

1. Choking is state when some foreign material gets obstructed in the tracheal and affects normal breathing.
2. First encourage the injured to cough forward and cough. If you are alone start coughing as much as you can.

## **Unconsciousness a/ fainting**

1. Unconscious faint follows the CAB (circulation –Airway – Breathing) rule. Check the pulse first follow by airway and breathing. The normal respiratory rate for adult is 10-20 per minute whereas heart rate is 50-100 per minute. Reposition their head by tilting chin up if airways comprised.

### **First Aid with Rescue Breathing:**

If a person has stopped breathing, don't delay. Give first aid immediately. Ask someone else to get medical help.

Is the person breathing then, place him flat on his back and put your ear close to his mouth? If S/he is breathing, you will feel his breath and see his chest rise and fall. 2. Open the airway. If the person has stopped breathing, lift up his neck with one hand and push down on his forehead with the other. This opens the airway and the person may start to breathe. If he doesn't, begin RESCUE BREATHING at once. 3.

### **Rescue Breathing.**

Keep one hand under the person's neck so that his head is tilted backward with his chin up. Pinch his nostrils shut with the fingers of your other hand. Take a deep breath and cover his mouth completely with yours. Blow air into his mouth. When his chest moves up, take your mouth away and let his chest go down by itself. Repeat this procedure every 5 seconds. Do not stop until the person starts breathing or medical help comes.

### **Medical aid:**

#### **Phosphine gas Poison symptoms**

#### **Mild Poisoning:**

Any discomfort can be an indication of mild poisoning or some other sickness. Individuals who are exposed to poison and who experience the following symptoms should be aware that more serious indications may follow. Headache, fatigue, skin irritation, loss of appetite, dizziness, weakness, nervousness, nausea, perspiration, diarrhea, eye irritation, insomnia, thirst, restlessness, irritation of nose and throat, loss of weight, soreness of joints, changes of mood.

#### **Moderate Poisoning**

Nausea, trembling, muscular incoordination, excessive saliva, blurring of vision, feeling of constriction in the throat and chest, difficulty in breathing, flushed or yellow skin, abdominal cramps, vomiting, diarrhea, mental confusion, twitching of muscles, weeping, excessive perspiration, profound weakness, rapid pulse, cough. Severe Poisoning Vomiting, loss of reflexes, inability to breathe, uncontrollable muscular twitching, constriction of pupils (to pinpoint pupils), convulsions, unconsciousness, severe secretion from respiratory tract, fever, intense thirst, increased rate of breathing

According to the amount of phosphine inhaled, symptoms may occur immediately or several hours after exposure. Slight or mild poisoning may give a feeling of fatigue, ringing in the ears, nausea, pressure in the chest and uneasiness. All of these symptoms will normally disappear in fresh air. However greater quantities will quickly lead to general fatigue, nausea, gastrointestinal symptoms with vomiting, stomach ache, diarrhoea, disturbance of equilibrium, strong pains in the chest and dyspnoea (difficulty in breathing). But very high concentrations rapidly result in strong dyspnoea,

cyanosis (bluish-purple skin colour), agitation, ataxia (difficulty in walking or reaching), anoxia (subnormal blood oxygen content), unconsciousness and death.

- Death can be immediate or occur several days later due to oedema and collapse of the lungs, paralysis of the respiratory system or oedema of the brain. Disturbances of kidney and liver functions (haematuria, proteinuria, uraemia, jaundice) and cardiac arrhythmia may occur.

### **For Physicians' reference:**

These statements are based on the suggestion made by the manufacturer.

- Make sure fumigators understand the use of specific antidotes,
- In its milder forms, symptoms of poisoning may take some time (up to 24 hours) to make their appearance, and the following measures are suggested: Complete rest for one or two days, during which the patient is kept quiet and warm.
- If the patient suffers from vomiting or increased blood sugar, appropriate intravenous solutions should be administered. Treatment with oxygen breathing equipment is recommended as is the administration of cardiac and circulatory stimulants.
- In cases of severe poisoning intensive care in a hospital is recommended where pulmonary oedema is observed, steroid therapy should be considered and close medical supervision is recommended. Blood transfusions may be necessary.
- In case of manifest pulmonary oedema, venesection should be performed under vein pressure control, and intravenous administration of glycosides (in case of haemo concentration, venesection may result in shock). On progressive oedema of the lungs, perform immediate incubation with constant removal of oedema fluid and establishment of oxygen positive pressure respiration, as well as any measures required for shock treatment. In Case of kidney failure, extracorporeal haemodialysis is necessary. There is no specific antidote known for this poison.
- Suicide may be attempted by taking solid phosphides by mouth. In such a case, empty the stomach by inducing vomiting and flush it with a dilute potassium permanganate solution or a solution of magnesium peroxide until the flushing liquid ceases to smell of carbide. Thereafter, administer medicinal charcoal.
- Scientific research has shown that phosphine poisoning is not chronic; the action of phosphine is reversible and symptoms will disappear by themselves
- Instruct employees to report ail accidents immediately to the employer or supervisor. Caution personnel to report all indications of illness or physical discomfort regardless of their apparent minor nature Signs of illness may include but not be restricted to any or all of the following. Fumigators: — should have a physical examination at least once a year and more often if health conditions require such



### Appendix I Basic information about fumigation chamber

*(For reference information given below is for providing in depth knowledge in general type of fumigation also)*

- If Fumigation chamber is to be constructed then the outside walls of the chamber may be constructed wholly or in part of concrete, concrete blocks, sheet iron, plywood or tongue and groove boards. All these materials may also form part of the inner lining, but careful sealing of all joints and seams is essential.
- Rough concrete and brick sorb fumigants and, if used, must be covered with hard finishing cement, with two or three layers of asphalt paint applied over its surface.
- Plywood sheets, held by a framework of 5 x 10 cm (2 x 4 in) timbers, may be used for the interior walls of chambers.
- All seams between sheets and at junctions of the floor with walls and ceiling must be carefully sealed with materials such as asphalt cement or similar caulking compounds. With plywood it is advisable to seal all the inside surfaces with a primer, which is then covered with a suitable resin-base varnish. This protects the wood from moisture and reduces loss of fumigant through sorption by the wood.
- Sheet or corrugated iron has been used successfully in warmer climates for the walls of chambers. When metal is used, great care must be taken to ensure proper sealing. All seams and joints are liberally filled with mastic and the edges of the overlapping sheets covered with mastic tape. In chambers of this type, the ends, top and bottom of the corrugated iron well rest firmly in neoprene gaskets. It is necessary to have more support members than in a standard sheet iron building, in order to reduce expansion and contraction (Barnes and Reilly, 1956).
- Ceiling. Lighter gauges of the materials recommended for the walls may be used for the ceiling. With plywood, a thickness of 1 cm (0.4 in) is usually sufficient. A detached permanent chamber must have a roof above the ceiling to provide all-year-round protection from the weather.
- Floor. When the chamber is in constant use, and especially for treating bagged goods, a concrete floor is best. This should be reinforced to bear the greatest expected load. The concrete must be hard-finished to provide a gas proof, non-absorptive surface. Tongue and groove lumber or plywood, satisfactorily sealed as described above, may be used if built to withstand the loads. Plywood flooring of 1.2 cm (0.5 in) is often suitable for plants and nursery stock if it is well finished in the way described above.
- Doors. The chamber can be provided with one or two doors, depending on its size and function. For larger chambers the use of two doors allows the loading of untreated material in one end of the chamber with unloading after treatment from the opposite end (Figure 24a and b). If a chamber is located inside a building, it may be built through a

dividing wall with loading and unloading doors on opposite sides of the wall. The segregation of untreated and treated stock in this manner reduces the possibility of cross infestation.

- The door should be as light as possible, it must give a gas-tight fit and it should be of good quality to withstand constant use. A stiff steel or timber frame clad with sheet metal on the inner surface may be satisfactory.
- Lift doors are very practical when a chamber is inside a building, because they are out of the way when open and do not interfere with the movement of the goods. Lift doors are operated by means of a counterweight and, if this works properly, opening and closing are easy.
- Doors sliding on rails are better for installation on the outside of a building, where they can be rolled out of the way along an outside wall. An ordinary hinged door may be installed in a chamber if the materials to be treated can be moved in and out easily. Generally, the doors may be made of the same wood or metal materials, suitably finished, as recommended for the walls.
- Door gasket. The best seal is provided by a continuous strip of rubber or neoprene that is soft enough to give a good seal but resilient enough to recover well after continued pressure. The best seal is obtained with three strips of rubber, two on one surface, with a gap between that is just wide enough to receive the third gasket, which is on the opposite face. Sliding doors will carry only one strip of gasket on one surface, and this should therefore be 2.5 to 5 cm (1 to 2 in) wide. With all types of doors, particular care must be taken to make a gas-tight joint between gasket strips, especially at the corners; this is best effected by liberal use of the adhesive material.
- If the floor of the chamber is above the outside floor or ground level, the clamps may be extended all along the bottom. A sloping ramp is then required to load and unload the chamber. This may be drawn back when the door is closed. If the chamber floor is at outside level, it is not possible to clamp the bottom of the door unless special provision is made. A suggested arrangement is a shallow trench in the cement floor, which should be wide enough to allow sideways movements of the door and fasteners.
- Proper circulation and venting of the fumigant/air mixture are essential in atmospheric chambers. Efficient circulation ensures that the fumigant is rapidly and evenly dispersed throughout the chamber so that no part of the load is overdosed or under dosed, while forced ventilation removes the fumigant so that the chamber can be safely unloaded after the treatment. Circulation and forced ventilation are essential in large fumigation chambers and advisable even for small ones. A variety of fan systems can be used to achieve adequate circulation or ventilation.
- It is suggested that with most treatments of commodities the rate of air flow should give approximately one complete change of air every one to three minutes, based on the volume of the empty chamber. The system should be designed so that the same fan will be used for circulation and venting. One method is to place the exhaust door, or port, near the fan



so that when it is opened the fumigant/air mixture will be blown out into the open air up to tolerable level

- Another way is to use a blower with a large inlet and outlet. A diameter of 18 cm (7 in) is suitable. The outlet is fitted to a pipe of the same size. By means of a suitable blast gate or valve operated from outside, the air can be recirculated throughout the chamber by means of ducts or blown out through the exhaust stack into the open air.
- If the pipes are used to draw the fumigant/air mixture from the bottom to the top of the chamber, distribution will be greatly improved from the beginning of the treatment. Ducts are best made from galvanized iron; the diameter required to give the suggested air flow of one complete change of air every one to three minutes will depend on the size of the chamber.
- Heating and lighting systems. A heating system is required if the chamber is used in cold weather. Sorption of fumigant on foodstuffs increases as the temperature decreases and, therefore, at lower temperatures larger amounts of fumigant are required and post fumigation ventilation is slower. As a general rule the temperature of the chamber and its load should be 15°C or above. A standard heating unit with blower may be used, which will also serve for fumigant circulation. However, such a blower should not be used for post fumigation venting unless the heat is turned off.
- Electric or radiant heaters may be used if they provide adequate heat at short notice and if the elements are totally enclosed so that glowing wires may not come in contact with the fumigant.
- Lighting inside the chamber is often necessary since windows are usually omitted from fumigation chambers. The lights should be arranged so that the loading does not obscure them and they must be adequately protected against damage.
- Application equipment. Gaseous-type fumigants are introduced from outside the chamber through tubing. The size and type of tubing will vary according to the fumigant used.
- Accessories. There are several items of equipment that contribute to safety or help to achieve good results in the use of a fumigation chamber. All chambers that are not under constant surveillance during actual fumigation should be padlocked from outside. Also, a warning notice should be hung, or tacked, on the door while treatment is in progress. A small window or marine port (obtained from a marine hardware store) permits a view of the inside of the chamber so that thermometers or other instruments can be read from the outside.
- One or more thermometers are essential for obtaining accurate readings of temperature in the free air space and in different parts of the load. The thermometers may be entirely inside the chamber or they may have gauges or dials on the outside with cables leading to the sensitive bulbs placed, as required, inside the chamber.
- When a chamber is inside a building, it is advisable to have a red electric light bulb over the door. This is turned on during the treatment to indicate that gas is inside the chamber. With fixed chambers, it is desirable to have an offset control panel on which as many as

possible of the recording instruments, electric switches, valve handles and other controls are situated. Such a unit simplifies operations and improves the appearance of the installation.

- Atmospheric chambers must retain the fumigant during the exposure period without appreciable loss through leakage to the surrounding atmosphere. The gas tightness of a chamber can be checked by a simple test where a positive air pressure is created and maintained in the chamber for a set length of time. An opening should be provided in the chamber to use a blower or other means to introduce air for creating the positive pressure. Inability to develop or maintain adequate pressure indicates considerable leakage and the chamber should be checked for leaks at seams, gaskets and other points.

- A smoke bomb or other device may be used in an effort to determine the areas of leakage.  
Operation

- Loading. The manner of loading the chamber will depend on the type of commodity and the method of handling it. A space of at least 30 cm (12 in) should be allowed between the top of the load and the ceiling.
- Goods can be stacked close to the side walls, provided they are not too near the heating units, but they should be kept clear of the end walls and at least 50 cm from the circulating fan. Bagged or packaged goods should not be placed directly on the floor. If these goods are not placed on platforms or pallets, a wooden floor rack with ample space between the slats should be provided. But in case fumigants like methyl bromide, no extra space between bags and wall may require as se this fumigant penetrates well.
- For the purpose of selecting the appropriate dosage of fumigant, it is best to take the lowest temperature recorded, either in the commodity or the free space. As a general rule the temperature of the chamber and its load should be 15°C or above.
- Computing the dosage. The dosages for fumigants need to be calculated based on the actual space and commodity weight. In some instances, the concentration x time (c x t) products have been worked out and are given also; their use is dependent upon an accurate determination of concentrations present in the chamber throughout the treatment.
- Closure. When it is time to start the fumigation, the door is firmly clamped. With most of the fumigants commonly used in chambers, the amounts introduced as dosage do not usually exert a significant positive pressure, especially when a full load sorb some of the gas, or when there is a small amount of leakage. All exhaust vents or ports must be tightly closed before the fumigant is introduced.

**Appendix II List of essential equipment for general type of fumigation where chamber facility is not available**

S. N.	Equipment	Specification	Minimum No. of Units	Purpose
1.	Fumigation covers (Tarpaulin) (a) Low density polythene films or (b) Rubberized polythene sheets	Pl refer ISI 4508 – 1963 and ISI 4810 - 1968	2	To carry out fumigation operations under a temporary enclosure
2.	Sand snakes	1 meter length, 15 cm. diameter	According to requirement	To make ground sealing of fumigation covers so as to make it air tight
3.	Hygrometer	As per ISI specification	1	For measuring relative humidity while undertaking fumigation with ALP.
4.	Tool Box	-	1	To maintain/repair of equipment
5.	Adhesive Tape (Plastic)	2” width	As required	For sealing
6.	Metal Probe for introducing ALP tablets	12 ft. length	1	For introducing ALP tablets for bulk grain fumigation in storage bins and ship holds.
7.	Gas mask (Full vision face mask)	As per IS:8523/1977 full vision face mask with corrugated tube, carrying strap	2	To protect against inhalation of toxic fumigant
8.	Canisters for use with ALP or Universal	-	2	To protect against inhalation of toxic fumigant
9.	Dust Masks	-	2	To protect against inhalation of chemical dusts, a aerosols etc.
10.	Portable oxygen cylinder with nose and mouth cap	-	1	Emergency supply of oxygen
11.	First Aid Box	-	1	To render first aid measure
12.	Goggles	-	4 pairs	To protect eyes while applying fumigant.
13.	Gloves	Rubberized/PVC	4 pairs	To protect hands from hazardous chemicals
14.	Resuscitator	-	1	To restore breathing in case of accidental exposure to fumigant.
15.	Gum boots	-	2 pairs	To protect feet from hazardous chemicals.
16.	Phosphine gas detection strips	Test strips impregnated with chemicals for detection of Phosphine gas	1 Box	To detect Phosphine gas leakages
17.	Drager type multi – gas detector tubes	Consist of carrying case spare parts set screw driver gas pump. Drager detector tubes Phosphine 25/a 8101621	1 unit tubes in packet	To detect Phosphine gas leakages during fumigation
18.	Phosphine: Alert personal monitor	-	1	To warn the operator of Phosphine presence

S. N.	Equipment	Specification	Minimum No. of Units	Purpose
19.	Fire Extinguisher	-	1	To protect against fire hazards
20.	Magnifier (pocket type)	10x magnification	2	To detect insect infestation by surface examination of stores
21.	Specimen tubes	Homoeopathic vials with cork or plastic cap	10	To collect pests for identification
22.	Plastic sampling bags	Self sealing 1 kg./500g. capacity	25	To collect samples
23.	Gas monitoring equipment	capable of measuring phosphine gas concentration up to 0.1 ppm or 0.1 mg/m <sup>3</sup>	01	To monitor phosphine gas
24.	Computer with mass store device and internet	-	1	
25.	Digital Camera having facility of video and photography	-	1	To take video and photography
	Laptop computer, camera for photo and videography.		2sets each	

**Appendix III Fumigation Certificate**

**Aluminum Phosphide Fumigation Certificate**

Certificate number:

**TARGET OF FUMIGATION DETAILS**

Target fumigation: of  Commodity  Packing  Both Commodity and Packing

Commodity: .....

Quantity: .....

Consignment link: .....

Country of origin: ..... Port loading: ..... of ..... Country destination: ..... of .....

Name and address of exporter:  
.....  
.....  
.....

Name and address of importer:  
.....  
.....  
.....

**TREATMENT DETAILS**

Date fumigation completed: ...../...../..... Place of fumigation: .....

Prescribed dose rate (g/m<sup>3</sup>): ..... Exposure period (hours): .....

Forecast minimum temp Applied dose rate (g/m<sup>3</sup>): ..... (°C): .....

---

How was the fumigation conducted?  Un-sheeted container  Sheeted container/s  
 Chamber  Pressure-tested container  Sheeted stack

Container number/s (where applicable):.....

---

Does the target of the fumigation conform to the plastic wrapping, impervious surface and timber thickness requirements at the time of fumigation? Yes  No

---

**Ventilation** Final TLV reading (ppm): ..... (not required for stack or permanent chamber fumigations)

---

**DECLARATION**

---

By signing below, I, the accredited fumigator responsible, declare that these details are true and correct and the fumigation has been carried out in accordance with all the requirements in the AFAS Methyl Bromide Fumigation Standard.

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**ADDITIONAL DECLARATIONS**

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.....  
.....  
.....

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**Appendix IV Request for treatment by exporter/Importer.**

From:

To:

M/s

On behalf of M/s \_\_\_\_\_

I/we undertake the following to carry out the fumigation by/ under the supervision of the Plant Quarantine (PQ) Officer for a consignment of \_\_\_\_\_ weighing \_\_\_\_\_ lying at \_\_\_\_\_ and agree to the following with reference to my Export/ Import inspection application no. dated \_\_\_\_\_.

1. to get the fumigation done at a site/ godown/ fumigation chamber by a fumigation operator approved by the Plant Protection Directorate.
2. to provide all facilities (including labour/ transport) for PQ officers nominated for undertaking/ supervising fumigation and degassing operations at our cost.
3. to pay the fumigation/ treatment fees/ supervision charges as prescribed.
4. to not to move / transport any part of the commodity/ container without approval from the PQ Officer.
5. to abide by the decision of the PQ Officer to disapprove a fumigation at any point of time if he is not satisfied with the treatment imparted.

**Assessment of Fumigation/ Supervision charges**

Assessment of fees			Receipt of payment
<b>Commodity*</b> <b>(details)</b> <hr/>	<b>Weight (Kgs or MTs or No. of Pieces/ Volume)</b> <hr/>	<b>Particulars of fee in Rs</b> <hr/> <b>Fumigation treatment fees:</b> <hr/> <b>Supervision charges :</b> <hr/> <b>TOTAL</b>  <b>Rs .....</b>  <b>Assessed by:</b>  ..... (Signature)	Received from M/S ----- an amount of Rs ----- (Rs -----) (in words) by cash/ demand draft No----- dated. -----drawn on ----- (name of bank and branch) towards inspection fees/ other charges. Date: Signature:

**\* Enter details of the import or export documents as the case may be.**

Permitted to undertake fumigation at \_\_\_\_\_ in \_\_\_\_\_ (fumigation chamber or gas-proof covers) under the supervision of \_\_\_\_\_ on \_\_\_\_\_

as per the fumigation /treatment schedule given below:

Chemical:                      Dosage:                      Duration of exposure:

Temperature :                      Under NAP/ Vacuum (mm):

Date:    Signature of Plant Quarantine Officer

Name and address of Check-post

**A**

.....

Signature

Date

.....

Name of Accredited Fumigator

AFAS Accreditation Number

Company stamp



## ANNEXES CHAPTER II

### Appendix I Fumigation Management Plan in short

1. An FMP is an organized, written description of requirements to help ensure a safe, legal and effective fumigation. It will assist you in complying with pesticide product label requirements.

2. It must be completed prior to actual treatment. A. Planning and Preparation

Read the fumigant label.

1. What is the purpose? Insect control

3. Acquaint yourself with

the site and the commodity:

a. The general layout - a map of the site with special note of the following:

particular areas of interest - fire or combustion hazards, copper or other sensitive materials (electric motors) that should be protected from phosphine gas Location of utility service connections - emergency shut-offs

Location of nearest phone

Fire number, if assigned

b. Identify those who may frequent the site \_\_\_\_\_

c. The commodity \_\_\_\_\_

storage situation \_\_\_\_\_

condition \_\_\_\_\_

d. Any previous treatment of this commodity? \_\_\_\_\_ With what? \_\_\_\_\_

e. Emergency phone numbers:

Fire dept \_\_\_\_\_ Police \_\_\_\_\_

Hospital or EMT \_\_\_\_\_

f. Check, mark, and prepare points of

fumigation application if you must enter the

structure.

Doors \_\_\_\_\_ Hatches \_\_\_\_\_ Other \_\_\_\_\_

e. What are the exposure time considerations?

1. Name of product used: \_\_\_\_\_ Form: Pellet

Tablet Gas Bag

2. Minimum fumigation time: \_\_\_\_\_ Grain Temperature: \_\_\_\_\_

Grain moisture: \_\_\_\_\_

3. Down time required to be available: \_\_\_\_\_ 4. What are the aeration requirements?

5. What are the clean-up requirements, if any? f. Calculate the dosage to use:

1. Cubic feet calculations:

2. Structure sealing capability and methods:

3. Label recommendations:

4. Past history of fumigation in this structure:

5. Fumigant/commodity exposure time required considering:

Commodity \_\_\_\_\_

Volume \_\_\_\_\_

Temperature \_\_\_\_\_

Sealing capability \_\_\_\_\_

Wind \_\_\_\_\_

B. Personnel

1. All personnel involved, in or around the area to be fumigated, must initial this form

indicating they understand the area is to be fumigated, the precautions they must adhere to, how to report an accident or incident, how to report a theft of fumigant or of fumigation equipment, and where the appropriate meeting place for all personnel in case of an emergency:

\_\_\_\_\_

2. All personnel actively involved in the fumigation must initial this form indicating they

have read the applicators manual, the product label, are aware of the hazards involved and of the personal protection equipment available.

\_\_\_\_\_

3. All personnel actively involved in the fumigation must initial this form indicating they are

aware of and how to proceed in case of an emergency

\_\_\_\_\_

C. Monitoring

1. Safety

a. Where and when will monitoring for phosphine (phosphide) take place?

\_\_\_\_\_

b. Where and how will monitoring be recorded to include times and levels?

\_\_\_\_\_

c. Was monitoring continued throughout aeration and levels recorded?

2. Efficacy

a. Were appropriate gas concentrations maintained throughout the fumigation period? \_\_\_\_\_ What readings were obtained and where were they recorded?

D. Notification

1. List all local authorities and emergency personnel that must be and have been notified that fumigations is/are about to occur with tentative dates and times:

\_\_\_\_\_

Fire Department

\_\_\_\_\_

Hospital Drs or EMT's

2. List emergency procedures if phosphine levels exceed dangerous levels:

E. Sealing Procedures

1. List procedures used to insure the bin(s) are properly sealed and will remain intact until the fumigation is complete:

How to be sealed: \_\_\_\_\_

How to keep intact: \_\_\_\_\_

Length of time required: \_\_\_\_\_

2. Where and how will warning placards

be placed on every possible entrance? \_\_\_\_\_

\_\_\_\_\_

F. Application Procedures and Fumigation Period

1. Who all will be involved in this fumigation? Always work in pairs!

\_\_\_\_\_

2. How will the fumigant be applied? \_\_\_\_\_

\_\_\_\_\_

3. How will the area be secured to prevent entry by unauthorized persons? \_\_\_\_\_

\_\_\_\_\_

4. Initial that all electric

lights are turned off and all non-essential electric motors are

both turned off and protect

ed from the fumigant: \_\_\_\_\_

G. Post-Application Operations

1. Initial that you have and will use a suitable gas detector before reentry into a fumigated structure:

\_\_\_\_\_

2. How will appropriate written records of monitoring to determine completion of aeration be obtained and maintained?

3. Who will remove warning placards when aeration is complete? \_\_\_\_\_

4. Who is to be notified when aeration is completed? \_\_\_\_\_

Application Procedures for Farm Bins

1. Obtain and read (study!) a copy of the fumigant label, Applicator's Manual, MSDS and related safety materials!

2. Can sensitive equipment (copper winding in motors) be adequately protected? \_\_\_\_\_

How will it be protected? \_\_\_\_\_

3. Can this bin be fumigated effectively? \_\_\_\_\_ Can it be completely sealed? \_\_\_\_\_

How will it be sealed? \_\_\_\_\_

Can the fumigant be contained at the appropriate concentration for the required time? \_\_\_\_\_

4. Is this bin located in an area where workers or bystanders could be exposed because of leakage from the bin? \_\_\_\_\_

What monitoring will be done to confirm leakage? \_\_\_\_\_

List the authorities to be notified

when and where you will be fumigating:

\_\_\_\_\_

5. What are the dimensions of  
the bin/grain to be fumigated? \_\_\_\_\_

Show your calculations to determine the amount

of fumigant to be applied to the bin you

described above:

6. Describe the method(s) of distributing the fumigant

in the commodity:

7. Where and when will warning placards be placed?

8. Following aeration how will fumigant levels be monitored for safety?

9. How and when will a protectant be applied to prevent re infestation?



### Appendix I Properties of Phosphine

*Alternative name: hydrogen phosphide*

#### Phosphine

Phosphine fumigants are widely used on farms and off farm storage to control insect, rodent and rabbit infestation in many different stored grains. However, there are various hazards associated with their use.

#### Hazards

Metal phosphide tablets release toxic phosphine gas when they contact moisture (either in air or fluids). However, consideration must be given to the associated hazards from inhalation of toxic gas and explosion. Aluminium Phosphide generates Phosphine gas when exposed to water molecules in atmosphere. The Phosphine is highly toxic to insects, human beings and other forms of animal life. In addition to its toxic properties, the gas may corrode certain metals and may ignite spontaneously in air at concentration greater than its lower flammable limit of 1.8% (V/V) (1790<sup>1</sup>0 ppm)

#### Inhalation

When phosphine gas is inhaled, it can react with moisture in the lungs to form phosphoric acid, which can be serious or fatal. Other symptoms of poisoning from inhalation are:

- coughing, chest tightness and headache
- double vision and dizziness
- nausea and vomiting.
- Exposure may also lead to anaemia, bronchitis, diarrhoea and visual, speech and motor disturbances.
- If a person has been overcome by phosphine gas, the rescuer must wear adequate breathing protection to avoid also becoming a victim.
- Phosphine gas has an odour of decaying fish. However, do not rely on the odour of phosphine to determine whether the atmosphere is safe, because the odour threshold for phosphine is above the exposure standard. If the odour threshold for phosphine is detected, evacuate the area immediately.

#### Flammability

- Phosphine gas is flammable and may ignite when concentration in the air exceeds 1.8%.
- Flammability risk is greater when humidity is high,
- Extinguish all potential ignition sources before opening.

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<sup>1</sup><http://plantquarantineindia.nic.in>

- Phosphine gas also reacts violently with acids and with compounds containing fluorine, chlorine, bromine and iodine.

Odour	Carbide or garlic-like odour may be due to impurities (see text)
Chemical formula	PH <sub>3</sub>
Boiling point	-87.4°C
Freezing point	-133.5°C
Molecular weight	34.04
Specific gravity gas (air = 1)	1.214°
liquid (water at 4°C = 1)	0.746(-90)
Latent heat of vaporization	102.6 cal/g
Lowest explosion point	1.79% by volume in air
Solubility in water	26 cc/100 ml at 17°C (very slightly soluble)
Method of evolution as fumigant	From preparations of aluminium and magnesium phosphide
Pertinent chemical properties	Reacts with copper and precious metals.

#### **Formulation:**

- Aluminium and Magnesium phosphide are manufactured in several different formulations. Aluminium or magnesium phosphide powder is compressed into hard round or flat tablets. Aluminium phosphide powder is also prepared in permeable paper bags or sachets. Additional materials such as paraffin and ammonium carbamate or ammonium bicarbonate are included in the formulations to regulate moisture uptake and to dilute the phosphine as it is generated. The products are supplied in sealed metal tubes, cans or flasks, which are packed in cases.
- Magnesium phosphide is also marketed in the form of a flat plate about 280 x 170 x 5 mm and weighing 2069. The active ingredients of the formulation are embedded in an inert polyvinyl acetate matrix fabricated in the form of a semi-rigid plate covered on both sides with moisture permeable paper. Every plate is individually sealed in a gas-impermeable foil pouch, or 16 plates interconnected to form a 4 x 480 mm strip, are similarly sealed in foil and packaged in tins - 32 plates per tin or two strips of 16 plates each.
- Once the plates or strips are removed from the foil pouches, they start evolving phosphine within one half to one hour. This formulation is intended to be used for fumigation of bulk goods and packaged and processed commodities. It can be applied successfully under almost nil space storage conditions provided that the structure is tightly sealed. According to the manufacturer, this formulation can also be used to fumigate fruits and vegetables at recommended dosages without any adverse effects, such as phytotoxicity.
- The plates and strips provide ease of application and collection after the treatment; there is no danger of contaminating goods with spent fumigant as the plastic matrix retains all such material. Magnesium phosphide formulations release the phosphine more rapidly



than aluminium phosphide products, with the maximum gas reading usually being achieved within the first 24 hours.

- Containers of aluminium or magnesium phosphide formulations have labels that give important information concerning use, hazards and precautions. The instructions on the labels should be carefully adhered to during fumigation.

### **Application**

- Phosphine is highly toxic, inhalation of even small quantities of the dust from the formulation, as well as the evolved gas, should be avoided. Pellets or tablets may be applied directly to a grain stream by hand (protected by gloves) or by means of automatic applicators. The rate that the gases evolves from the formulation varies, depending on type of formulation, moisture and temperature. Special probes are used for applying tablets below the surface of bulk grain. Sachets may be applied directly to the grain stream, pushed into the grain bulk or inserted into specially designed, permanently installed pipes in grain bins (Anon, 1980).
- For the treatment of bagged grains and other raw commodities in transport facilities, such as railway wagons, pellets or tablets may be spread evenly over the load or placed in moisture permeable envelopes to fit in some convenient location near the door before closing. When fumigating packaged commodities under gas-proof sheets the tablets or pellets can be spread out on trays to lay under the sheet before it is secured. In warehouses, after the structure is adequately sealed, the tablets or pellets are spread out on trays or sheets of Kraft paper so that residual material can be easily collected at the end of the treatment. The tablets or pellets should never be piled on top of each other or in a mass.
- On completion of the fumigation, all windows and doors should be opened and the space aerated for at least two hours. A gas reading should be taken with a suitable analyses before entering the fumigated area. If it is necessary to enter the fumigated space to open doors and windows a gas mask with a canister designed for phosphine must be worn.
- In fumigation treatments of raw agricultural commodities such as grain or bulk animal feeds, no special disposal procedures are needed because any of the phosphide formulation that may remain is further decomposed and removed along with grain dust in the handling and turning that accompanies further processing of the grain (Iscombe, 1963).

### **Solid-Gaseous-type Fumigants**

- Fumigants, Phosphine is discharged from gas generating containers placed outside the chamber. See the picture and Annex -3. Liquid-type Fumigants
- Fumigants which are liquids at room temperatures are poured into a shallow tray or trough inside the chamber or are poured onto burlap sacks. After the chamber door is closed, the circulating fans are started and the draught across the liquid or the sacked material hastens evaporation.
- Formulations of aluminium or magnesium phosphide leave mainly an inert residue of the metallic hydroxide. In formulations of aluminium phosphide, a small amount of unreacted

material may also remain, and hence some precautions should be taken to avoid hazards from the unspent formulation. When processed foods are Fumigated, or when space fumigations are carried out, residue from the formulation should be collected and properly disposed of.

- Residue from magnesium phosphide in the plate preparations remains in the plastic matrix in which it is embedded as magnesium hydroxide. The reaction with water vapour is substantially complete, so that no abreacted material remains, and elimination of the residue simply involves collection and disposal of plastic trays at approved sites.
- Unchanged phosphine does not remain in fumigated commodities in appreciable amounts. Tolerance levels of 0.1 mg/kg for raw grains and 0.01 mg/kg for processed foods have been established by many agencies and numerous investigations have shown that the gas desorbs rapidly during aeration to levels well below the tolerances (see review by Dietrich et al, 1967).

### **Ways to avoid resistance**

- When handling and applying fumigants it is essential to know for each fumigant the level of concentration above which it is not safe to subject workers and also the maximum periods of exposure, including repeated exposures during normal working hours. Such concentrations are widely known as threshold limits and are usually, and most usefully, expressed in terms of parts per million by volume in air. A comprehensive list for repeated daily exposure is published periodically by Archives of Environmental Health, published bimonthly by the American Medical Association.
- It is important to realize that if any TLV is exceeded, a potential hazard from that substance is presumed to exist.

## Appendix II Dosage table for fumigants used in smaller chambers

Taken for reference purpose Fumigation manual by Moonrow FAO

Table.1. Quantities of liquid in millilitres per 100 cubic feet at 20°C equivalent to dosages in pounds per 1 000 cubic feet (to be used for measuring smaller quantities of liquids before evaporation in small chambers).

	lb/1 000 ft <sup>3</sup>							
	0.0625	0.25	0.5	0.75	1	2	3	4
	Millilitres of liquid/100 ft <sup>3</sup>							
Acrylonitrile 34% + carbon tetrachloride 66%	2.1	8.5	17.0	25.6	34.1	68.2	102.3	136.4
Carbon disulphide	2.2	9.0	17.9	26.9	35.9	71.7	107.6	143.5
Carbon tetrachloride	1.8	7.1	14.2	21.3	28.4	56.8	85.2	113.6
Chloropicrin	1.7	6.9	13.7	20.6	27.4	54.9	82.3	109.7
Ethylene chlorobromide	1.7	6.7	13.4	20.1	26.8	53.6	80.5	107.3
Ethylene dibromide	1.3	5.2	10.4	15.6	20.8	43.7	62.6	87.4
Ethylene dichloride 75% + carbon tetrachloride 25%	2.1	8.4	16.9	25.3	33.8	67.5	101.3	135.1
Ethylene oxide at 7°C	3.2	12.7	25.5	38.2	51.0	102.0	153.0	204.0
Hydrogen cyanide	4.1	16.5	32.9	49.4	65.9	131.8	197.6	263.5
Methyl bromide* at 0°C	1.6	6.5	13.0	19.5	26.1	52.2	78.3	104.4
Propylene oxide	3.4	13.6	27.3	40.9	54.5	109.1	163.6	218.2

### Conversion factors

$100\text{ft}^3 = 2.83\text{m}^3$      $11\text{b} = 16\text{oz}$      $1\text{oz}/1000\text{ft}^3 = \text{g}/\text{m}^3$      $\text{mg}/\text{litre}$  (approx).  
 $1\text{ fluid oz (Br)} = 28.4\text{ ml}$   
 $1\text{ fluid oz (U.S.)} = 29.6\text{ ml}$   
 $1\text{ ml} = 0.035\text{ fluid oz (Br)}$   
 $1\text{ ml} = 0.034\text{ fluid oz (U.S.)}$

\* Methyl bromide is often dispensed as a liquid held under pressure in a graduated measuring glass, as a "280-ml applicator"

## **Appendix III Detection Device (For references only)**

A number of instruments or methods are available for the detection of fumigants: Regular checking if the available instruments are properly used or not is essential.

### **Detector Tubes**

- Gas detector tubes for determining low levels of several gases are available on the market. These are sealed glass tubes filled with an appropriate indicator chemical to react with a particular gas and give a colour reaction. To make a determination, the seals are broken at each end of the tube and a definite volume of the atmosphere being sampled is drawn through by a hand operated or mechanical pump. The tubes are marked off in scale divisions and the concentration is determined according to the length of discolouration of the indicator for a given volume of atmosphere. Detector tubes are simple, easy to use devices that can provide reasonably reliable, on-the-spot measurement of gas concentrations. Their accuracy may be in the range of 70 to 90 percent of the mean value if sampling is done carefully according to manufacturers' directions. For taking gas samples from difficult locations, extension tubes are available from manufacturers so that the detector tubes can be placed at the desired site.
- In addition to these tubes, which give an immediate reaction, long duration tubes for monitoring various toxic gases throughout the normal work day are available. These tubes can be carried anywhere on a worker's clothing in a special holder, while a lightweight pump continuously draws a measured volume of air through the tube. At the end of the shift, the tube can be evaluated to give a time-weighted average (TWA) of exposure for the working day.

### **Precautions to be taken:**

- Tubes will deteriorate with age - some makes have a shelf life of two years when stored at room temperature; above 30°C deterioration is more rapid.
- Direct sunlight can affect the properties of the tubes.
- At low temperatures, around freezing or below, tubes may not give reliable readings; they should be warmed to room temperature for best performance.
- Tubes may have cross-sensitivity to gases other than those for which they are designed. Information on cross-sensitivity should be obtained from the manufacturer.

### **Infra-Red Analysers**

- These are instruments that can measure concentrations of gases by the absorbing effect the gases have on a beam of infra-red radiation. Absorption is proportional to path length of the infra-red beam as affected by concentration of the gas. Fumigants have characteristic infra-red absorption spectra that allow both identification and quantitative analysis.
- Although these instruments are relatively expensive, their capabilities for instantaneous detection of low levels of harmful gases may warrant their use in some situations.

## Gas Chromatographs

- Portable gas chromatography is manufactured that can be used for analysis of fumigants in field projects. These instruments also are expensive but they are very effective for both identifying and measuring concentrations of gases at both high and low levels and can give results in the ppb range (0.001 mg/kg), is available on the market (Barker and Leveson, 1980).

## Other Detectors

- A whole air sampler known as "Critical Orifice Personal Sampler" has been successfully tested for several years and is commercially available. This is an evacuated stainless steel container with a valve allowing air to enter through a micron size critical orifice so that an 8-hour sample can be collected. Once the sample has been collected, the valve is closed and the sample returned to a laboratory for analysis. Several passive monitors that collect samples onto a collection medium are becoming available. A pocket-size gas chromatograph that will provide real-time warning to acute exposures and will accumulate a worker's 8-hour TWA exposure is in the developing stages.

Table II. DATA FOR ANALYSING FUMIGANTS WITH AN INFRA-RED GAS ANALYZER<sup>1</sup>

Fumigant	Analytical Wavelength in Microns	Min. Detectable Concentration at 20.25 metres <sup>2</sup>	Max. Detectable Concentration at 20.25 metres <sup>2</sup>	Max. Detectable Concentration at 0.75 metres <sup>2</sup>
		(ppm)	(ppm) approx.	(ppm) approx.
Methyl bromide	7.6	0.4	> 945	> 25,530
Sulphuryl fluoride	11.5	0.1	> 57	> 1,543
Phosphine <sup>3</sup>	10.1	1.0	1,000	

<sup>1</sup> Foxboro Analytical Company, South Norwalk, CT. 06856, U.S.A.

<sup>2</sup> Path length of gas cell

2. Phosphine can be detected at 4.3 microns in concentrations as 0.3 ppm; however, carbon dioxide also absorbs at this same wavelength.

## **Appendix IV Dosages and concentrations**

From the moment that a given dosage enters the structure being fumigated, molecules of gas are progressively lost from the free space either by the process of sorption and solution or by actual leakage from the system. The concentration is the actual amount of fumigant present in the air space in any selected part of the fumigation system at any given time.

The concentration is usually determined by taking samples from required points and analysing them. The dosage is known because it is a pre-determined quantity. Concentration has to be determined based on the exposure time because it varies with time and position according to the many modifying factors encountered in fumigation work.

Three methods of expressing gas concentrations in air are in common use: weight per volume, parts by volume and percent by volume.

### **Weight per volume**

For practical designation of dosages, this is the most convenient method because both factors - the weight of the fumigant and the volume of the space - can be easily determined. In our case use or go for the metric system, and express in grammes per cubic metre ( $\text{g}/\text{m}^3$ ).

By a fortunate coincidence in units of measurement, grammes per cubic metre are, for all practical purposes, equal to ounces per thousand cubic feet.

Conversion factors for the various units are given in Appendix 2.

Milligrams per litre ( $\text{mg}/\text{l}$ ), equivalent to grams per cubic metre.

### **PARTS OR PERCENT BY VOLUME**

Parts by volume and percent by volume modes of expression give the relative numbers of molecules of gas present in a given volume of air. The values for both modes have the same digits, but the decimal points are in different places (3 475 parts per million by volume of a gas is the same as 0.3475 percent by volume).

Parts per millions of gases in air are used in human and mammalian toxicology and in applied industrial hygiene. Percent by volume is used in expressing the flammability and explosive limits of gases in air.

### **Calculations for conversion of concentration values**

By means of simple calculations giving useful approximations, values may be converted from weight per volume to parts by volume and vice versa. These calculations take into account the molecular weight of the gas and the fact that, with all gases, the gramme molecular weight of the substance occupies 22.414 litres at  $0^\circ\text{C}$  and 760 millimetres pressure. (If precise values are needed for the other temperatures and pressures, corrections for absolute temperature and pressure may be made in the usual manner.)

A. To convert grammes per cubic metre (or milligrammes per litre or ounces per 1 000 cubic feet) into parts by volume.

1. Divide the given value by the molecular weight of the gas and multiply by 22.4; the resulting figure is the number of cubic centimetres (cm<sup>3</sup>) of gas per litre of air.
2. One thousand times the figure obtained is the value in parts per million by volume.
3. One tenth of the figure obtained in (1) is the percentage by volume.

**Example. To convert 1g/m<sup>3</sup> of PH<sub>3</sub> (molecular weight 34 approximately)**

(1x22.4)/34	= .659 cm <sup>3</sup> per litre = 659 parts per million by volume approximately = .0659% by volume approximately
-------------	---

B. To convert parts per million (or percentage of volume) of gases to grammes per cubic metre (or milligrammes per litre or ounces per 1 000 cubic feet):

1. Divide the parts per million by 1 000, or multiply the percentage by ten to give the number of cubic centimetres of gas per litre of air.
2. Multiply this figure by the molecular weight of the gas in question and divide by 22.4.

**Example. To convert 400 ppm of methyl bromide (molecular weight 94.95 = 95 approximately)**

400 ppm	= 0.04% of volume = 0.4cm (3) per litre = (0.4 x 95)/22.4 = 1.7g/m <sup>3</sup> (or mg/l or oz per 1 000 ft <sup>3</sup> )
---------	--

Comparative figures for weights and volumes at various levels have been calculated for the important gases, and these are given in the tables accompanying the subsequent discussion of each particular gas.

## Appendix V Phosphine Generator<sup>2</sup>

Outdoor Phosphine generator is a high –tech product that can be used in variety of condition. It is a Chinese product which can be used for fumigating food, herbal medicine, tobacco, fur, agricultural and sideline products, books, archives, import and export quarantine processing and other places of fumigation operations, at confined environment fumigation, or at facilities such as room warehouse or square warehouse, vertical silo, building warehouse, underground warehouse, mountain cave, open pit (stack), embankment and other facilities.

It is suitable for one-time dosage input fumigation or supplemented with dosage when in operation; or fumigation by controlled dosage input.

Combined with re-circulation facilities, it could effectively prevent and kill insects including the insects which is not easily killed or killed at one time, under some conventional methods, such as grain borers, etc.

### Performance parameters

One time dosage (aluminum phosphate tablet or pill)	1~ 8Kg ( no more than 9Kg)
Reactor water injection	80Kg
filter water injection	50Kg
Regular workpressure	2~15Kpa
Designed pressure for the whole tank	0.25Mpa
Designed pressure relief valve	0.23Mpa
Ventilation temperature limitation(adjustable)	Setting as 4 5 °C when in manufacture
Voltage and rated power	AC220 V 50HZ 0.18KW

### 2. The composition of the structure

CLFW1008-IV intelligent outdoor phosphine generator composition is shown in Figure below

The tank, item 8, is partitioned by the reactor 5 and the filter with function of coolers 7, 5 and 7 connected by special designed stainless steel tubing (omitted from the figure).

### 2.3 Index for the inlet and outlet of the Nozzle, diameter (connecting thread) and the role of the table as below:

---

<sup>2</sup> Copied from the user manual as given during the orientation training. All the important aspects of this manual has been covered in main text of the SOP



## Nozzle diameter

No.	Function	Diameter	Remark
1	Reactor water intake	φ 50	Water input and Water Limitation
2	CO2 inlet	φ 8	with φ 12 x 8 hose
4	reactor drainage	Φ 60	
6	Filter drainage	φ 60	
9	Filter water intake	φ 50	Water input and Water Limitation
11	Vent of mixing gas for ph3 and Co2	G2 "	with φ 50 hose
16	ALP dosage input	φ 76	

### 2.4 Full components are as follows:

- Reactor water intake
- CO2 inlet
- Stainless steel pressure gauge (measure the pressure in reactor)
- Reactor drainage
- Reactor
- Filter drainage
- Filter with function of cooler
- Tank as pressure cabinet
- Filter water intake
- Gas Mixing tube ( PH<sub>3</sub>+CO<sub>2</sub>)
- Vent of mixing gas for ph<sub>3</sub> and Co<sub>2</sub>
- Digital thermometer (mixing gas out Measurement)
- Safety valve
- Motor
- 15 . Reducer
- 16- ALP dosage input
- 17 – Pesticide container (cartridge)
- 18- Pesticide sprayer controller
- 19 - Electric control box
- 20 – Portable trolley

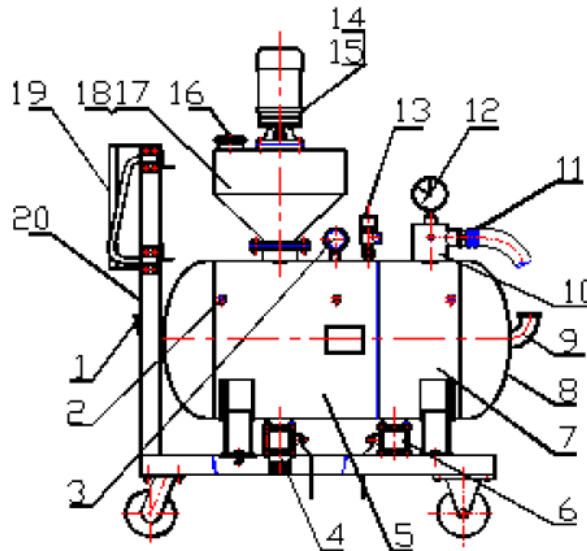
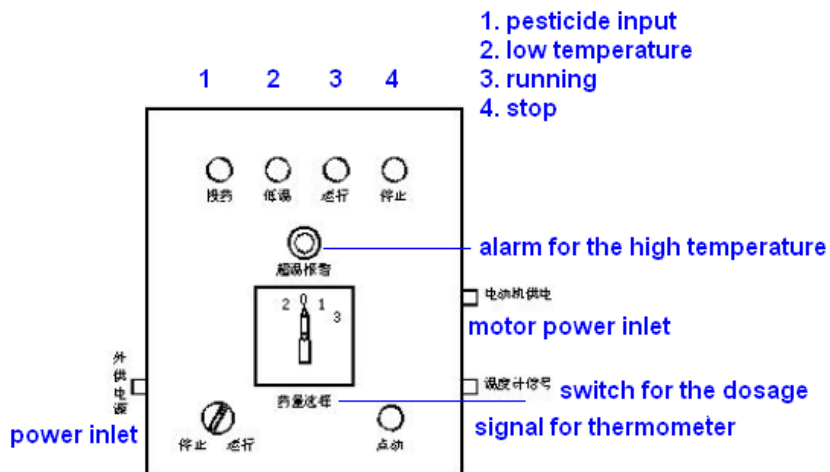


Figure 2. Generator composition

## 2.5 electronic control box



### Electronic Control

#### Features:

- ① Outdoor application: the whole operation of the machine is open to the outside environment, the operator in the warehouse outside put the aluminum phosphide into the cartridge, the program for the generation of PH<sub>3</sub> and importation to the warehouse are realized in a fully sealed environment, the operator does not touch the PH<sub>3</sub>, which avoid the harm of the gas on the operator.
- ② Synergistic fumigation, the use of CO<sub>2</sub> and phosphine as mixed fumigation, can increase the insecticidal effect, effectively maintaining the quality of storage, and saving about 50% of the dosage.
- ③ Computer control: control the pesticide spray rate and reaction temperature, to ensure safety, to prevent condensation.

- ④ Steel brush as cleaning device on the pesticide cartridge, to ensure that the tablets or pills all used up, without any remaining.
- ⑤ The whole structure is set up by vertical and horizontal arrangement, the reactor and the filter container with heavy weight, are arranged in a horizontal position, and the cartridge and the mixing cylinder which is light in the weight, are arranged vertically above the reactor and the filter. That is to ensure that the machine will not tilt and keep it smoothly safety when in movement, but also beneficial to dosage input and mixed gas output easily.
- ⑥ Easy operation: the product adopts imported industrial computer control (MITSUBISHI), users only need to operate three switches, and smooth fumigation operation could be achieved under varieties of working conditions.
- ⑦ simple maintenance: the main part of the machine can be basically free maintenance (including industrial computer). The remaining parts which are exposed are just some accessories such as external valves, sealed and low voltage appliances which are easy to purchase and easy to replace.
- ⑧ The drive motor and reducer in the phosphine generator are all aluminum alloy shell, and integrated in one installation, well assembled with good appearance.

### **3 Instructions for use**

#### **3.1 Operation preparation**

Prepare the suitable amount of phosphide agent, according to the warehouse capacity, air tightness, ambient temperature and insects.

According to the usage ratio, per 1Kg of phosphide agent matched with a cylinder (25Kg) CO<sub>2</sub> dose preparation. While CO<sub>2</sub> should not be less than 2 cylinders (50Kg), no matter small quantity of the dosage for the fumigation each time.

#### **3.2 Equipment inspection**

##### **3.2.1 Calibration thermometer**

As the working principle of the thermometer is highly related with local air pressure, the temperature shows a deviation, it should be calibrated thermometer before operation.

Take a common thermometer as reference, measuring the temperature from the output of gas, note the thermometer deviation, and modify the set figure in the temperature sensor.

Example: The factory setting is 45 °C, the temperature sensor before calibration is 25 °C, the measured ambient temperature is 23 °C, and then, the figure should be set to 47 °C.

**3.2.2** Check whether the power supply voltage is in work; the electrical wiring is in good connection; check the electrical control box work under no load (no medication, no water). Jogging to observe whether the steering direction match with the designed direction; If different, should change the connecting wiring to ensure proper steering.

### **3.2.3 Check the air tightness.**

Check each connection place, such as nozzle, the valve seal, any loose, leakage, check the reactor and filter whether there are debris and dirt, check the mixture air outlet and the warehouse connector connected hose is intact. Only all procedures are fulfilled and to be confirmed that everything is in order, the medication could start.

### **3.3 Water injection**

Water inject from the two water intakes, will keep injecting until there is water overflow. Then close tightly. 50kg to reaction tank is suggested for 8KG ALP load. For our re-build chamber with small volume, less water injection could be adjusted.

3.4 Open CO<sub>2</sub> gas before fumigation for 10 minutes in advance (. Outlet pressure of pressure reducer should be set as 0.1 ~ 0.2Mpa, flow rate of CO<sub>2</sub> should be not less than 120 L / min. For our re-build container, Small volume of Chamber, CBM as 20-50 m<sup>3</sup>, and the index change accordingly by the time of pre-connection of CO<sub>2</sub>, pressure, and flow. For example, the outlet pressure should be 2500~3500Pa (The adjustment is based on 4 containers PH<sub>3</sub> fumigation. Suggestion: The pressure should be considered by considering local atmosphere, temperature, ALP dosage, Ratio of mix gas and the tolerance of container.) It is available to release the extra pressure, when adjust the pressure and diffusion setting in the chamber.

### **3.5 Dosage input**

After 10 minutes of pre-CO<sub>2</sub>, close the CO<sub>2</sub> cylinder valve only, other control handle keep the same, such as keep the pressure regulator handle in same situation, (must follow, otherwise when re-connect CO<sub>2</sub>, the pressure reducer is easily be damaged).

Open the pesticide cartridge cap and place a predetermined amount of tablets or pills, into the cartridge. The charge should not exceed 8Kg at one time. Tighten the cap after loading. For our chamber(s), open the CO<sub>2</sub> cylinder valve, tighten the pressure regulator handle, and continue CO<sub>2</sub> transmission based on the required amount.

### **3.6 electronic control box operating instructions (see electronic control panel)**

**3.6.1** The electric control box power supply (AC220V, capacity 6A) with the plug to check whether the electricity is of leakage.

**3.6.2** Turn the run / stop phase switch to "Stop", open the electronic control box, close the automatic switch, then the "stop" indicator on the panel light

**3 Dosage selection:** SA, has 3 phase switch mark 1,2,3. All phases are automatically dosage input. According to the amount of fumigation required, choose the switch SA to the right gear: switch to gear "3" when the application of the amount is about 6.Kg ~ 9Kg ; switch to gear" 2" when the application of the amount is of 6Kg below; less dosage input, such as 0.5kg, then switch to gear "1". Under the Phase of "1", when the temperature is too low (less than 20 ° C), the temperature of water

intake is suggested to be heated above 25 ° C for better function. When the switch is in the "0" position, it is manually input (jog).

**3.6.4** After confirming the preparation work is correct, turn "on" phase, equipment will work according to "set mode": amount dosage and the frequency to complete all the ALP automatically. Select switch 3 (9Kg), 2 (6Kg), 1 (0.5Kg), the time to complete each delivery were 210 mins, 190 mins, 60mins respectively.

**3.6.5** After the automatic dosing is completed, the alarm box will alarm and the red and green lights will be lit at the same time, and the process is finished. While at least 10 mins more for the CO2 inlet to keep the operator of the safe handling after the operation (see 3.7).

**3.6.6** Each time when fumigation is completed, the run / stop switch should be turned to "stop", the switch should be turned to "0" and the power of the control box should turn off.

**3.6.7** Programmable controller (PLC) in electronic control box is of precision components, it is not allowed by the user to adjust freely.

### **3.7 Safe treatment after dosage input**

This product is specially equipped with a safe handling mode after operation, to ensure safety and all dosage absorbed.

3.7.1 After completion the procedure within the setting dosing time, the motor stops, and the red and green lights are on at the same time, and the CO2 gas keep continue. Dosage input phase switches to 0, and press the "jog" button, so that dosage spray keep "jogging" running for 1 minute. Make sure that the remaining dosage in the cartridge is all moved into the reactor.

3.7.2 red, green light keep working 10 minutes, later, the red light will automatically turn off, then the supply flow of CO2 gas can be reduced to 80 ~ 100L / min. Record the temperature of the outlet gas at this time.

3.7.3 Keep continuing CO2 gas, 15 to 20 minutes or more. Measure the temperature of the air outlet each 3 minutes, and convince that the temperature continues to decline. After that operator could close the CO2 cylinder valve and cut off CO2 gas supply.

### **3.8 drain contamination and cleaning**

**3.8.1** After the fumigation, cut off the power supply, put away power cable and plug, remove the CO2 supply hose, remove the mixture hose.

**3.8.2** Move the machine to the discharge point, first open the reactor drainage and discharge. Then open the filter drainage, remove the waste water. Water inject from item 1 and item 9, reactor water intake, and filter water intake, and item 11, vent of mixing gas, flush the reactor and the filter and the mixing cylinder.

**3.8.3** If stop fumigation, operator can open the cartridge cap, with water to clean the cartridge and pesticide sprayer, item 17 and 18, (Should wear an effective gas mask when in cleaning time). If a

short period of time to continue to charge dosage and take fumigation, operator should not use water to clean the cartridge and pesticide sprayer, avoid of the storage tank damp.

### 3.9 Job-site adjustment of the speed of dosing

When on-job site procession, it is found that the speed is too fast (the reactor temperature is too high, too fast) or the speed is too slow (outlet temperature thermometer is not active, not more than 35 ~ 38 °C), the user can adjust the speed of dosage in the site.

**3.9.1** Adjustment should be carried out by trained and professional staff, and other personnel are not allowed to adjust l, otherwise it may damage the original Installed PLC.

**3.9.2** Adjustment can be carried out simultaneously, without stopping the original administration process, when the industrial computer will keep the memory of the original dose has been put, control dosing time for the remaining dosage;

Adjustment can also be carried out after the shutdown; it is similar like second time dosage input.

When adjusting simultaneously, the operator should have the skills to work under the electricity, wear electrical insulation shoes, use the insulation tools to ensure the safety operation.

**3.9.3** When in adjustment, open the electronic control box, open the top of the industrial computer (PLC) cover, you can see the PLC internal assembled with two precision, micro-potentiometer, as shown in Figure 1 below. Adjust the top of the small potentiometer to adjust the speed of medication. In addition to the top of the small potentiometer, any other components remaining in PLC, it is not allowed for the user to adjust, otherwise it may cause confusion of the whole system and equipment damaged.

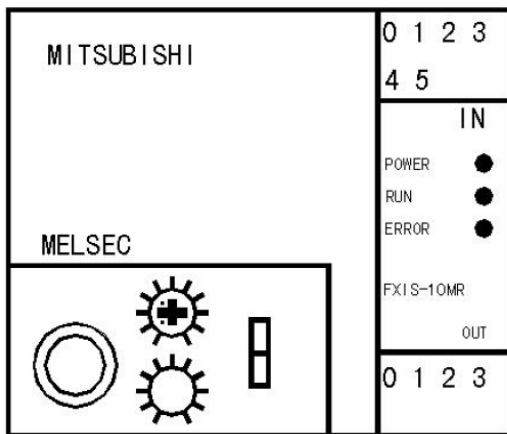


CHART 1: PLC

**3.9.4** The small slot in the small potentiometer can be rotated with a small screwdriver, and the direction between the two ends of the cross groove goes to the remarked figure of the outer circle where 11 lines corresponding to different feeding speed, the corresponding value as shown in Figure 2 below.

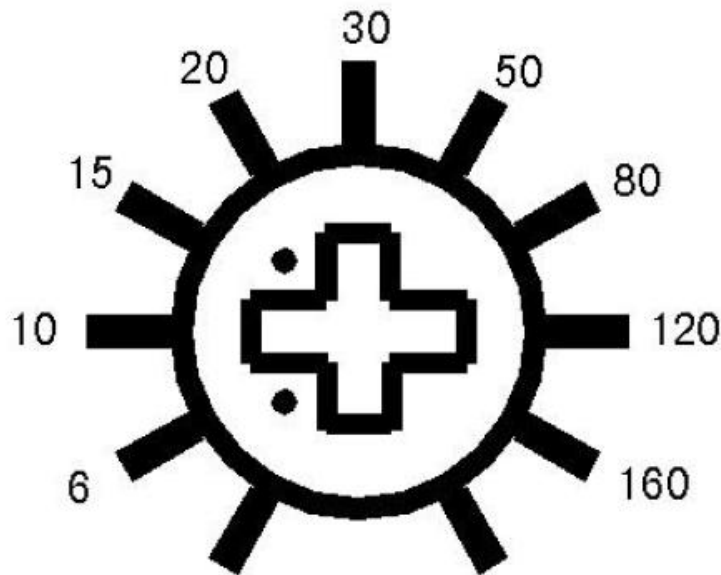


CHART 2

The number corresponding is the number of seconds of the motor rotation time in each dosing cycle. Such as pointing to ‘30’ Engraved line, on behalf of the motor every 30 seconds to stop 180 seconds, ... ..

**3.9.5** When the user adjusts, it is not necessary to align the mark, regardless of the position of the notch (even between the two lines). The computer will automatically find the closest set of data.

While because the user's angle of rotation and data is uneven corresponding, so it is better to match the mark line for smoothly understand the control is on our hand.

**3.9.6** Simultaneous adjustment should be under automatic mode of operation, that is, it is under any phase instead of Phase ‘0’. First align the selected alignment line, click the jog button, then select the speed of medication, when it was confirmed by the computer, the computer will turn round automatically according to the new setting in the next cycle.

**3.9.7** Original product setting in the factory, the motor rotation time is adjusted to 30 seconds, that is, the gap between the two points is at direction of 12 o'clock.

**3.9.8** Small potentiometer is very sophisticated, please note that the rotation of a small potentiometer must use a special instrument of the screwdriver, is strictly prohibited with iron, wood chips, electric screwdriver and other substitutes fiddle.

**Notice:**

- In normal situation, it is fixed setting since goods from factory.
- When it is necessary to adjust, it must be carried out by trained professional staff.
- If any other personnel adjust at random, may cause damage, to the control system or lead to a major safety incident.

#### 4. Precautions:

**4.1** Fumigation procession should be strictly implemented by the “PHOSPHINE RECIRCULATION FUMIGATION TECHNICAL REGULATION issued by the State Grain Reserve Bureau.

**4.2** Gas supply must be guaranteed throughout the fumigation process. Prior to loading, CO<sub>2</sub> gas must be input at least 10 mins and expel Oxygen in a pipe and containers.

**4.3** The water leverage in the reactor and cooler must keep the same level with the overflow.

**4.4** operators keep alert and observe the operation of the machine all the time and check if there is any leakage with the tool of phosphine alarm. In case, timely action is taken to prevent the worse situation.

**4.5** In case of power failure, should immediately open standby power or self-power generation.

**4.6** recommend fumigation special pressure reducer equipped by factory (optional).

Pressure reducer



**4.7** fumigation should avoid direct sun exposure to the machine, or electric control box was excluded from rain.

**4.8** Relief valve shall not bear any external attack or distortion.

**4.9** After the first dose (standard acceptable dosage of 8Kg), if need add dosage or continuous fumigation for another location. Total amount dose in two times,

- When the total charge does not exceed 12 Kg, operator could keep using the previous water in the container;
- While total amount is more than 12 Kg of pesticide dosage, operator must do drain contamination and change the water (to ensure the safety of fumigation, it is strongly recommended to input dose and wash each time).

In the whole filling dosage, operator should ensure that the gas outlet, (item 11) no congestion and smoothly working.

Safety valve, item 13, should bear the authority calibration, seal, before delivery to the factory. it is not allowed to change its calibration value.



## 5. Troubleshooting and maintenance

- in the fumigation, if the thermometer figure keeps rising and exceeds the high limit (alarm ring, for continuous 30 seconds, after 30 seconds, if the temperature is still above the limit while below the peak of the temperature, it will not alarm; that is, over temperature just one time alarm, but when the temperature drop, if again more than the setting limit, it will alarm again. ) CO<sub>2</sub> gas supply should be increased in time, if the gas flow rate is not enough, should check the CO<sub>2</sub> cylinder, the valve, the pressure reducer, and the air supply hose to find whether there is any problem. When the temperature returns to normal, the motor continues dosing.
- in the fumigation process, if pesticide could not immerse with water because of congestion of corn, could consider using the wooden sticker to knock the pesticide cartridge, and help easily immerse and function.
- If the external power supply is normal, while the indicator light is off when in the operation of the electric control box, should check the box, any problems about the fuse or loose
- After fumigation and cleaning, it should be ventilated and dry. After drying, all the nozzles should be sealed so as to avoid the sun and rain.



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