recommendations for good fumigation practice were drawn
er the supervision of a working party sponsored by the
N Food Handling Bureau and the Australian Centre for
tional Agricultural Research. The working party was made up
ialists from the main agencies concerned with fumigation of
all countries in the region.

commendations are aimed primarily at fumigation of grain
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re and monitoring of gas concentrations during fumigation.

of the recommendations lays down the principles and general
es essential for effective fumigation. Parts 2 onward give
l operational procedures for particular types of fumigations.

Suggested Recommendations for the Fumigation of Grain in the ASEAN Region

Part 2

CARBON DIOXIDE FUMIGATION OF BAG-STACKS SEALED IN PLASTIC ENCLOSURES: AN OPERATIONS MANUAL

SUGGESTED RECOMMENDATIONS FOR THE FUMIGATION OF GRAIN IN THE ASEAN REGION

Part 2. Carbon Dioxide Fumigation of Bag-Stacks Sealed in Plastic Enclosures: an Operations Manual

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Australian Centre for International Agricultural Research, Canberra

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Requests for copies of these Recommendations should be directed to AFHB.

This manual has been prepared as a guide to planning and carrying out carbon dioxide fumigations of bag-stacks sealed under plastic covers. Where limitations to knowledge have been recognised they are clearly indicated. However, the publishers and editors can accept no responsibility whatsoever for adverse effects either to commodities or to personnel caused by its use however closely the directions are followed.

No endorsement of products named in this manual is intended, or is criticism implied of similar products that are not mentioned.

AFHB–ACIAR

Suggested Recommendations for the Fumigation of Grain in the ASEAN Region

Part 1. Principles and general practice
Part 2. Carbon dioxide fumigation of bag-stacks sealed in plastic enclosures: an operations manual
Part 3. Phosphine fumigation of bag-stacks sealed in plastic enclosures: an operations manual

In preparation:

Fumigation of shipping containers with carbon dioxide: an operations manual

Fumigation of shipping containers with phosphine: an operations manual

Fumigation of shipping containers with methyl bromide: an operations manual

Typeset and laid out by Arawang Information Bureau Pty Ltd, Canberra, Australia

Printed by Media Works Enterprise, Kuala Lumpur, Malaysia

Contents

Preface

We have written this manual to help plan and carry out carbon dioxide fumigations of bag-stacks sealed under plastic covers. Presented as a step-by-step, 'how to' operations manual, it is aimed at fumigators-in-charge and other people with experience in the practical aspects of fumigation*.

The use of carbon dioxide to fumigate bag-stacks is a relatively recent process. There are, therefore, some potential applications of the technique for which there is at present insufficient practical experience to make firm recommendations. This does not affect those that we have described here, because they are based on extensive experience gained using the technique on most of the major commodities stored in the ASEAN Region.

Where limitations in knowledge are recognised, these are clearly indicated in the text. This does not mean that the technique is not suited to a particular application that has not been mentioned in this manual. What it does mean is that further advice should be sought and we have indicated where that advice is available.

During the course of adoption and use of this new technique of fumigation and storage, the practical experience gained with it will lead to innovations and improvements. We believe one obvious innovation that should be explored is the use of polyethylene sheeting, as already occurs in the People's Republic of China.

We invite you, as users of this manual, to cooperate in the further development of the technique by recording not only any shortcomings or errors that you may encounter but also any innovations that you might have successfully applied. To assist you in this regard, we have included, at the end of the manual, a 'Notes' section where such records can be kept. Similarly, we suggest that you use the spaces left at the end of the appendices to add to and extend these listings .

As successful improvements are developed, it may be necessary to collate and publish them in further editions of this manual so that they can be more widely adopted in the region. We suggest that fumigators who use this first edition of the manual keep in touch with the ASEAN Food Handling Bureau for this purpose.

The compilation of this manual would not have been possible without the enthusiastic help of a large number of individuals and many organisations, who have been involved

* It is advisable that this operations manual be used in conjunction with 'Suggested Recommendations for the Fumigation of Grain in the ASEAN Region Part 1. Principles and General Practice', copies of which are also available from the ASEAN Food Handling Bureau.

in the development of the technique. Initial trials undertaken in Australia, Indonesia, and Papua New Guinea showed it was technically feasible. In Indonesia, BULOG proceeded with further trials and subsequently adopted the technique as one of its standard storage methods. We have enjoyed a fruitful collaboration with workers in Malaysia, the Philippines, and Thailand where the technique was further investigated to test its reliability and range of applicability. We are grateful to all those who so generously assisted us with our work, made us welcome in their countries, and very expertly adopted sealed storage of bag-stacks. This expertise is reflected here by drawings for a gas inverter provided by NAPHIRE in the Philippines (Appendix 6), and a summary of BULOG's operational instructions for the application of the technique in their godowns (Appendix 7).

Fumigators seeking to carry out phosphine fumigations of sealed stacks are referred to 'Suggested Recommendations for the Fumigation of Grain in the ASEAN Region Part 3. Phosphine Fumigation of Bag-Stacks Sealed in Plastic Enclosures: an Operations Manual'.

P.C.A.
J. van S.G.
Stored Grain Research Laboratory
CSIRO Division of Entomology
Canberra, Australia

1 USES AND LIMITATIONS

1.1 Applications

The use of carbon dioxide in sealed bag-stacks (piles) is particularly suitable for:

- Dry commodities destined for long-term storage (greater than approximately 6 months).

- For insect control in commodities requiring total freedom from chemical residues.

- In situations where there are particularly cheap and convenient sources of carbon dioxide.

1.2 Speed of treatment

The objective of a carbon dioxide fumigation is to maintain toxic concentrations of carbon dioxide throughout the enclosure for long enough to kill the most tolerant stage of the most tolerant species that may be found. This means maintaining *a concentration of carbon dioxide of 35%, or greater,* in all parts of the enclosure *for 15 days or more*, at ambient temperatures at, or above, 25°C.

Carbon dioxide *cannot* be used if more rapid fumigation is required. In this case other fumigants will have to be considered.

NOTE

Fumigation with carbon dioxide is a slow treatment and requires *a minimum exposure of 15 days.*

It is impossible to decrease this exposure period and still obtain reliable insect control.

1.3 Commodities

Carbon dioxide is probably suitable for all dry commodities that enter into storage in good condition. No deleterious quality effects have been shown on the following (but see Section 1.7 if grain is intended for seed):

barley (unprocessed or malted)
cocoa
coffee
ground nuts (peanuts)
maize (corn)
paddy
mung beans
rice (brown and white)
rye
soy beans
wheat

This list is increasing as experience is gained with the technique but it is suggested that advice should be sought for commodities not listed here (see Appendix 1).

1.4 Situations where sealed stack fumigation *should not* be undertaken

There are three situations that would make a carbon dioxide fumigation of a sealed stack totally ineffective so that fumigation should not be attempted:

- When after sealing and repeated testing, the enclosure fails to meet the required pressure test standard for gas-tightness.

- When there is a requirement for a fumigation to be completed in less than 15 days.

- When *Trogoderma* species are known to be present in the commodity.

1.5 Moisture content

Carbon dioxide treatments require at least 15 days, and are therefore best used as a prelude to long term storage. It is unwise to proceed if the moisture content of the commodity is above that which is normally considered safe for the storage of the commodity concerned.

The maximum safe moisture content for commodities fumigated and stored in sealed stacks is consequently the same as that established for safe long-term storage in unsealed bag-stacks. The following list* of maximum moisture contents for safe storage can be used as a guide for sealed storage:

beans	15.0%
cocoa beans	7.0%
copra	7.0%
cotton seed	10.0%
cowpeas	15.0%
groundnuts (shelled)	7.0%
maize (corn)	13.5%
millet	16.0%
paddy	15.0%
palm nuts	5.0%
rice	13.0%
sorghum	13.5%
wheat	13.5%

Some postharvest organisations might wish to alter these moisture contents to fit in with their own established limits. However, it is suggested that caution be exercised before these limits are raised. In cases where the treatment is not used as a prelude to long-term storage it may be possible to exceed these levels, but currently there is inadequate information to recommend this as a routine procedure.

NOTE

The storability of all grains is affected by temperature, moisture content, variety, and its previous history. These factors should always be taken into consideration before any grain is taken into storage.

Grain in poor condition will not store well under any conditions.

Thus, carbon dioxide fumigation followed by long-term storage in sealed stacks, is not recommended for any grain in poor condition.

* Hall, D.W. 1970. Handling and storage of food grains in tropical and subtropical areas. FAO Plant Production and Protection Series No. 19, 300 p.

1.6 Oil seeds

The technique has been used successfully for a number of years to store groundnut (peanut) seed in Australia. Other than very limited work in the Philippines by NAPHIRE (see Appendix 1) on soybeans, there is no further information currently available.

1.7 Seeds for planting

Caution should be exercised with seed for planting, sprouting, or malting. There is some evidence that, if seed destined for such use is in poor condition at the start of treatment, carbon dioxide may increase the rate of deterioration.

Germination is unaffected in:

barley
green peas
groundnuts (peanuts)
maize (corn)
paddy
rye
sunflower
wheat

The storability of all seeds is affected by temperature, moisture content, variety and its previous history. These factors should always be taken into consideration before any seed grain is taken into storage.

1.8 Refumigations

Refumigation should normally be unnecessary after carbon dioxide treatment, because a gas-tight enclosure (i.e. one that has passed the pressure test standard) should also be insect-proof.

If reinfestation does occur (for example, through holes made in the stack cover by handling equipment, rodents, etc., or even by insect penetration through the stack cover), refumigation can be carried out only after any such damage has first been repaired and the enclosure again pressure-tested.

1.9 Residue

Fumigation with carbon dioxide leaves no permanent residues on the commodity. A commodity removed from high carbon dioxide atmospheres will have some carbon dioxide 'sorbed' to it, which is released rapidly on airing (see Section 9).

NOTE

The storability of all seeds is affected by temperature, moisture content, variety, and its previous history. These factors should always be taken into consideration before any seed grain is taken into storage.

Seed in poor condition will not store well under any conditions.

Thus, carbon dioxide fumigation followed by long-term storage in sealed stacks, is not recommended for seed grain in poor condition.

2 EQUIPMENT REQUIRED

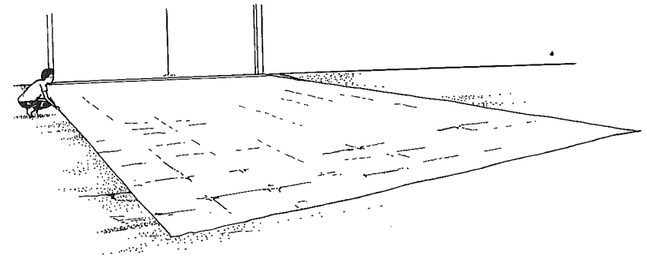
2.1 Fumigation Sheets

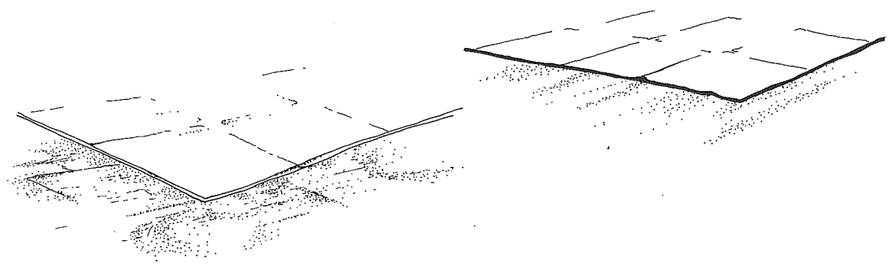
2.1.1 Floor sheet

In sealed stack storage all stacks are built on a floor sheet, which is one of the most critical components of the technique. The floor sheet must be made of strong, gas-proof sheeting able to withstand the weight of the stack and any stresses associated with the stacking (piling) processes.

Many types of plastic sheet may be suitable for this: in practice 0.75 mm unreinforced PVC sheeting has proved satisfactory. However, in situations where stacks may be built on coarse or unrendered floors, an increased thickness or double sheets may be necessary to prevent puncturing.

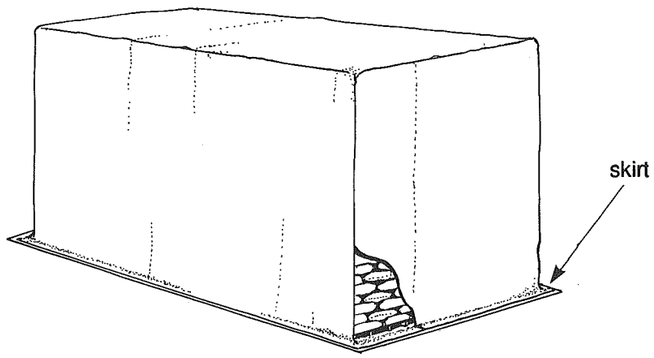
The size of the floor sheet should be such that it is at least 1 metre longer and wider overall than the base of the stack to be built on it.





2.1.2 Cover sheet

In this technique, unlike sheet fumigation,the stacks are covered with plastic fumigation sheeting *that has been cut and 'tailored' to the shape and size of the stacks*. The covers should be cut so that they are slightly larger than the stack. It is suggested that an overall increase, in both breadth and width, of 30 cm is adequate as otherwise problems may be encountered during the sealing stage. At the bottom or 'open'



end, the covers must be manufactured so that they have lateral extensions, or 'skirts', at floor level. These skirts should be at least 0.5 m wide.

Many types of plastic sheeting are suitable for making cover sheets. Therefore it is impossible to identify any particular material to use for this purpose. Any plastic sheeting meeting all the following general requirements should be adequate:

- When a representative sample of the sheeting is examined under a microscope there must be no obvious holes in it.

- If fibre reinforced sheeting is selected, preference should be given to sheeting in which the reinforcement is sandwiched between two layers of plastic film. There must be a continuous film of plastic on at least one side, as otherwise gas leakage may occur along the fibres.

- The sheeting should be strong enough to withstand normal handling, as well as the minor knocks and abrasion that are likely in a normal, well managed warehouse.

- Consideration must be given to the weight of the sheeting. Tailored covers must be lifted up to the top of stacks, where the working environment is usually oppressive and where there is little room to move while carrying heavy weights. In practice this normally limits the size of stacks that can be covered to the range 200–300 tonnes.

- The method used to seal the cover sheet to the floor sheet at the storage site must be portable and convenient. The seal so formed must be strong and permanent.

- The sheeting must leave no unacceptable permanent residue or odour in the stored commodity.

2.2 Sealants

2.2.1 PVC solvent glue

A quick setting PVC solvent glue is required. A number of proprietary PVC solvent glues are available, however, the glue selected must be quick setting.

NOTE

The cements used to join PVC plumbing fittings are unacceptable and should not be used

BULOG, in Indonesia, use a polyurethane adhesive, Rakoll Ultra-DX, (manufactured by PT Indria, under license from Isar-Rakoll Chemie GmbH, Federal Republic of Germany).

An effective glue can be made for this purpose, by dissolving PVC in methyl ethyl ketone, which gives a strong, permanent and flexible bond. In the People's Republic of China, a glue made by mixing dichloroethane and perchloroethane (4:1) is reportedly used.

The solvents used in many of these glues can have toxic vapours and excessive inhalation of them should be avoided. The risk of inhalation can be greatly minimised by ensuring that the godown is well ventilated, and by keeping its doors and ventilators open during sealing. The use of gloves and brushes is recommended to minimise skin contact with glues while sealing the enclosure.

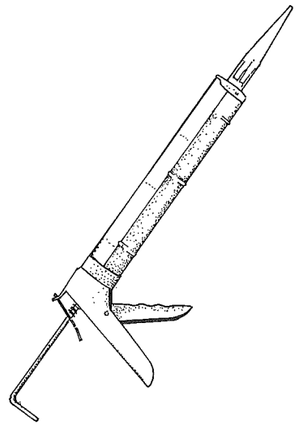
Some of the solvents contained in these glues may be toxic or cause allergies and skin irritations. In the interests of worker safety, bare-handed application of glue is, therefore, not recommended.

2.2.2 Paint brushes

Paint brushes (2 cm wide) are required to apply the solvent glue. It is advisable to have at least a dozen available as the glue sets after use. Despite this it is possible to reuse the brushes once experience has been gained with the technique.

2.2.3 Cotton waste or cotton rags

Cotton waste is used to spread the glue whilst sealing and patching, and to apply pressure to the seal. A generous supply is needed at all times.



2.2.4 Spare PVC sheeting

A quantity of spare sheeting of the types used for both the floor and cover sheets are required for operational purposes and to repair and maintain the sheets in good condition.

2.2.5 Sealing mastic

Sealing mastic in tubes (silicone rubbers are the best but butyl mastics are satisfactory).

A mastic 'gun' is required to apply this sealant.

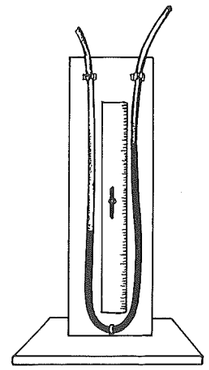
2.2.6 Self adhesive tape

Rolls of self adhesive tape : PVC duct tape and masking tape both 5 cm wide are required.

2.3 Pressure testing equipment

2.3.1 Manometer

A manometer capable of registering 1000 Pa is needed for pressure testing. For the purposes of this work it is unnecessary to purchase an expensive scientific instrument. Simple laboratory manometers, as used in schools, are ideal. It is possible to make up a manometer with any of the following commonly available materials:



- a glass 'U' tube (internal diameter 0.5–1.0 cm) with arms at least 20–30 cm long

- glass tubing (internal diameter 0.5–1.0 cm) that can be cut to give two, 20–30 cm lengths,which when joined with 10–15 cm of plastic (or rubber) piping, will form a 'U' tube

- clear plastic tubing 60–80 cm long that can be bent to make a 'U' tube with arms 20–30 cm long.

- a 30 cm long ruler, graduated in millimetres

- a board or plank (about 1 metre long), on which to mount the manometer.

The 'U' tube is attached to the top of the board,with its arms straight and vertical and open ends uppermost. The ruler is fixed close up against one arm of the 'U' tube.

Before the manometer can be used it must be half filled with water. It has been found that mixing some ink with the water beforehand makes it easier to take readings during the pressure tests.

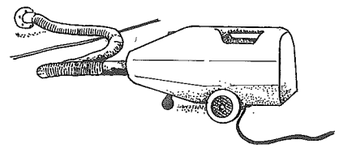
During pressure testing one end of the manometer is attached to the gas sampling pipe (6.1) while the other must be left open to the atmosphere.

NOTES

For pressure testing sealed stacks the approximation of 1 cm of water = 100 Pa is adequate.

Do not use carbonated soft drinks (cola drinks etc.) in the manometer tube.

2.3.2 Vacuum cleaner



A vacuum cleaner (or a large flow low pressure vacuum pump) capable of evacuating the sealed stack to minus 1000 Pa.

2.3.3 Power

An electric power source and power cord for vacuum cleaner.

2.3.4 Flexible tubing

Flexible tubing to connect vacuum cleaner to gas inlet on the sealed stack with an internal diameter greater than 25 mm so that it can slip over the gas inlet port (see Section 2.3.5).

2.3.5 Low pressure PVC (conduit or plumbing) piping

One length (about 2 metres) low pressure PVC piping (25 mm external diameter), is required to make up gas inlet and gas sampling ports.

2.3.6 Stopper for gas inlet

The gas inlet must be sealed after the carbon dioxide purge. For this a stopper or bung is required.

Electrical sealing compound (electrician's putty) or refrigeration putty has proven to be very suitable for this purpose. The material, which remains pliable and does not set into a solid mass, is easily moulded into shape to plug the gas port and can, later, be withdrawn without difficulty.

In Indonesia polybutene sealant putty ('Neogum Sealer' or 'Neosealer MS F 10' manufactured by Insulation Specialis, Mahkota Raja) has been used for this purpose by BULOG.

2.3.7 Timer

A watch, clock, or stop watch that indicates seconds is required to time the pressure tests.

2.4 Gas

2.4.1 Estimating gas requirements for delivery in cylinders

It is usually necessary to ensure availability of carbon dioxide well in advance of the fumigation. For this purpose, it is necessary to estimate the gas requirement. There are two methods for estimating the approximate amount of gas required to fumigate a stack:

Firstly, in relation to the mass of grain in the stack:

gas required (kg) = tonnes × 2

Secondly, in relation to the volume (length × width× height in metres) of the stack:

gas required (kg) = volume (m^3) × 1.7

Note that the value obtained by this calculation *does not* represent the dose applied to the stack.

2.4.2 Estimating gas requirements for delivery in bulk

Carbon dioxide is introduced into a sealed stack more rapidly when it is delivered in bulk. This factor, combined with the greater difficulty of controlling the rate of gas introduction (the purge), can cause more mixing of the gases within the enclosure. This has a diluting effect, which may cause an increase in gas requirement per stack.

In Indonesia, where gas is delivered for BULOG in bulk, gas requirements are estimated using the following formula:

gas required (kg) = tonnes × 2 . 8

2.5 Gas source

Carbon dioxide supplied in portable cylinders (80 kg gross) or mini bulk containers (200 kg gross), and in mobile bulk containers (several tonnes), may be used for the purpose of fumigating sealed stacks.

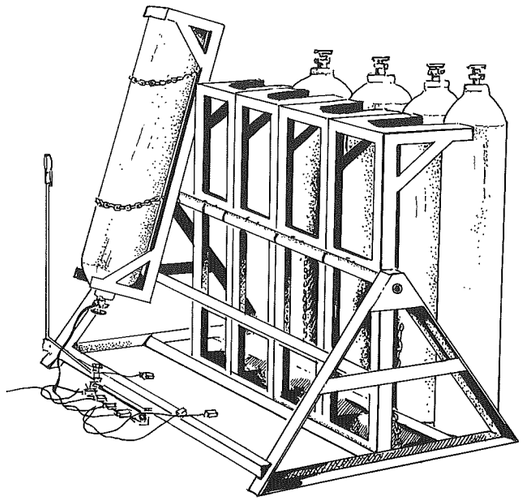
2.6 Gas introduction equipment

2.6.1 Copper piping

The piping used to carry the gas into the stack should have an approximate internal diameter of 15 mm and be capable of delivering gas at a pressure of 7,000 kPa (1,000 psi) at a high velocity. It is required where gas is discharged into the stack from cylinders. The pipe must be long enough to reach the stack from the point at which the gas cylinders will be positioned within the godown and extend half way into the stack when inserted through the gas introduction port (see Section 7.3).

2.6.2 Cylinder inverter(s)

It is important to ensure that gassing is continuous and fairly rapid to ensure the most economical use of the gas. When using gas in cylinders, the best way to do this is by inverting the cylinders so that the gas is discharged as a liquid under its own pressure. A practical way to do this is by using two banks of inverters, which are loaded, discharged and reloaded one after the other.



The carbon dioxide is delivered into the stack as a mixture of gas and dry ice (or 'snow'), which then very rapidly gasifies without passing through a liquid phase (i.e. it sublimes).

The inverters must be of sturdy construction, able to carry the weight of up to four cylinders and remain stable whilst in use. When fabricating gas inverters, it is essential that the cooperation of gas suppliers is enlisted to ensure that safety standards are maintained. This is of particular importance in respect of the high pressure connecters (pigtails) that must be used to manifold the cylinders.

2.6.3 Heat exchanger

Where carbon dioxide is supplied from bulk or mini bulk containers, it is preferable to use a heat exchanger provided with a heat source, to ensure that the carbon dioxide is delivered into the stack as a gas. When ordering gas in bulk, it is prudent, to make certain that a heat exchanger will be provided.

It is possible to introduce the carbon dioxide as a liquid ('snow-shoot') it into the sealed stack but this process has two operational disadvantages (see Sections 5.4 and 7.4).

2.6.3.1 Heat exchanger valve

When a heat exchanger is used it is important to ensure that a valve is fitted at the downstream end. This is essential for maintaining a degree of back-pressure within the heat exchanger so that the liquid carbon dioxide within it does not freeze solid and delay the gas purge.

In practice the valve frequently has to be fitted at the same time as the gas delivery pipe.

2.6.3.2 Heat exchanger delivery pipe

As bulk containers and heat exchangers cannot be brought into godowns, it is necessary to specify that a suitably strong pipe is used to deliver the gas over the increased distance between the gas source and the stack.

NOTE

Failure to use the correct gas fittings can result in considerable gas (monetary) loss and presents a serious worker safety hazard!

2.6.4 Gas fittings

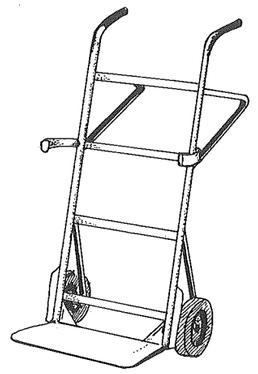
Because of the high pressures and velocities at which carbon dioxide is delivered from cylinders, it is essential to obtain the proper brass fittings to join the copper piping to the gas source used. These fittings vary from country to country, and even within countries from supplier to supplier.

2.6.5 Tools

A tool kit including an appropriate range of spanners for the pipe fittings and keys for gas sources, a large pair of scissors, and a pocket knife will be needed.

2.6.6 Cylinder trolley

A trolley for moving gas cylinders within the storage.



2.7 Gas monitoring equipment

It is essential to monitor the carbon dioxide concentration inside the sealed stack at various stages:

- during gas addition (the purge) — to ensure that the correct dose has been administered
- during the 15 day exposure period — to ensure that there has been no sudden gas loss through the sealed sheets
- at the end of the exposure period — to ensure that the correct final carbon dioxide concentration has been achieved
- during long-term storage — when a sudden drop in carbon dioxide concentration can indicate that the cover has been damaged.

A wide range of gas sampling and monitoring devices suitable for carbon dioxide detection is available in the ASEAN Region (see Appendix 2).

NOTE

Polythene tubing is unsuitable for gas sampling because it absorbs carbon dioxide and therefore leads to incorrect readings.

2.7.1 Gas sampling pipe

It is necessary to sample the gas inside the sealed stack at intervals during the fumigation. To do this nylon or PVC pipe (approximately 2 mm internal diameter) is used. The pipe used in Australia is described as 'hydraulic tubing'.

For each stack treated, enough piping is needed to run from the top centre of the stack down to floor level, plus an additional 2 m length at the end.

2.8 Safety equipment

Precautions must be taken to ensure the safety and to preserve the health of all workers involved in the fumigation of sealed stacks.

2.8.1 Plastic gloves

Plastic gloves should be worn while sealing the enclosure with PVC solvent glues. Disposable polyethylene gloves have been found suitable for this use.

2.8.2 Leather gloves

Leather gloves should be worn during handling of cold gassing equipment.

2.8.3 Overalls

2.8.4 Protective footwear

2.8.5 Warning signs (see Section 4.6)

2.8.6 Self contained breathing apparatus

2.8.7 Cotton waste

2.9 General items

2.9.1 Dunnage (pallets)

Sufficient dunnage is required to elevate the whole of the base of the stack off the floor sheet.

All dunnage used for this purpose *must be dry* as the moisture content of the stored commodity can be raised significantly if wet dunnage is used inside sealed stacks. It is important, in this respect, to ensure that new pallets, if they are used, are made of dry, well seasoned timber.

2.9.2 Gas recirculation equipment

Recirculation equipment *is not required for bag-stacks up to 5.0 metres high*, where natural processes of mixing should be adequate.

Stacks that exceed 5 metres in height will, however, need recirculatory facilities.

2.9.3 Fumigation record sheets

It is usual to keep records of pest control operations. These are required both for accounting purposes and as part of the stack/commodity history whilst it is held in storage.

A proforma fumigation record sheet, suitable for fumigation of sealed stacks, is presented in Section 7.8

3 WORKFORCE REQUIREMENTS

3.1 Fumigator-in-charge

At least one member of the work force employed in each fumigation must be a trained and experienced fumigator, holding (where applicable) a fumigation licence issued by the appropriate government department. He/she should be designated 'fumigator-in-charge', and be given responsibility for safe and effective execution of the work. He/she *must* be present at all times during the active phases of each fumigation.

The requirements of carbon dioxide fumigation, in terms of both the required standard of sealing and gas retention, are rigorous. For a treatment to be successful it is essential that the fumigator-in-charge:

- understands the requirements of the technique;
- can carry out the tests needed to ensure the fumigation will be successful; and
- can recognise a successful fumigation.

This implies that he/she

- understands the requirements for a successful carbon dioxide fumigation
- recognises a fumigation failure
- can carry out a pressure test
- knows how to carry out estimations of carbon dioxide concentration
- is aware of the hazards associated with use of carbon dioxide.

CAUTION!

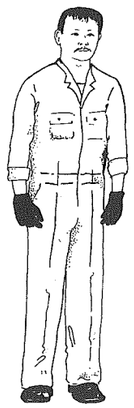
Never perform fumigations alone!

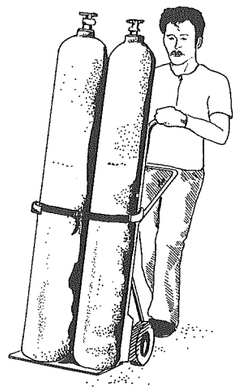
3.2 Personnel for applying gas from cylinders

Addition of carbon dioxide requires a fumigator-in-charge and two assistants.

3.3 Personnel for sheeting stacks

The tailored cover sheet for a 200 t stack of bagged rice can weigh over 80 kg or 0.27 kg/m^2. It requires a team of five persons to correctly place the sheet over the stack, at least four on the stack and one on the ground. Two operators, one of whom should be the fumigator-in-charge, are needed for sealing and pressure testing.





4 PERSONNEL PROTECTION AND SAFETY

4.1 Respirators

As a general rule respiratory protection is not needed in the routine conduct of carbon dioxide fumigation of sealed bag-stacks. Gas concentrations are unlikely to reach dangerous levels in unconfined spaces at or above ground level. Localised areas below floor level, or small enclosed working spaces around the fumigated enclosure, could contain dangerous levels of carbon dioxide.

Carbon dioxide only poses a threat to life and health at significantly high concentrations, *for which canister-type gas masks are inappropriate.* Where it is necessary to enter an area, in which carbon dioxide concentrations are above about 5%, a self-contained breathing apparatus must be used.

4.2 Protective clothing

All fumigators releasing gas should wear overalls.

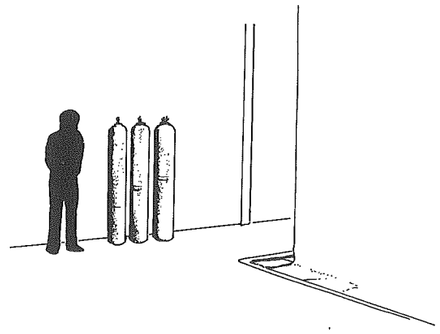
Carbon dioxide discharged as liquid from either bulk containers or cylinders is very cold and direct skin contact may lead to 'cold burns'. Pipes carrying newly vaporised gas can also become very cold and contact with them may also cause skin damage. Gloves should be worn where hand contact with any of these sources of cold is likely.

4.3 Handling of cylinders

Cylinders filled with carbon dioxide are under considerable pressure (approx 7000 kPa at 30°C) and should be stored, handled and used with care. They are also heavy — 80 kg when full — and therefore appropriate care should be taken when lifting them. It is suggested that trolleys should be used to move them within godowns. Cylinders should not be left standing unrestrained where there is a risk of them being knocked over. Temporary storage against a godown wall is preferred to storage in an aisle in the godown.

Particular care should be taken not to leave unrestrained cylinders close to stacks about to be purged with carbon dioxide, because, as the stack covers become inflated during gas addition, they can easily knock over a free standing cylinder. Where carbon dioxide cylinders are inverted to obtain carbon dioxide 'snow' they must be secured in a rigid frame (inverter) constructed for this purpose.

YES



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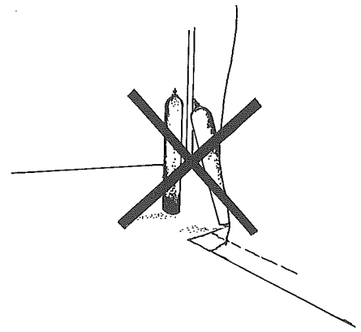
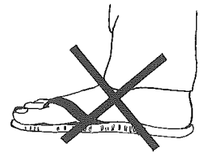


4.4 Footwear

All staff working with carbon dioxide in cylinders should wear protective footwear as a precaution against injuries that can result when cylinders fall onto unprotected feet.

NO



4.5 Gas detection in the workspace

The normal concentration of carbon dioxide in air is about 0.03%. The maximum concentration to which a worker may be continually exposed has been set at 0.5% in many countries. This is known as the Threshold Limit Value (TLV), or hygienic standard.

In unconfined, well ventilated areas, concentrations of carbon dioxide above the TLV (0.5%) are very unlikely to occur. However, when the area around the stack is used as a normal working area, occasional concentration measurements should be made to ensure the TLV is not exceeded. Where there are sub-floor or basement working areas adjacent to the stack, routine monitoring is necessary in these areas during gas addition and during the initial storage period.

4.6 Warning notices

All people at a site must be adequately warned when a fumigation:

- is planned;
- is in progress; and
- is being cleared.

4.6.1 Fumigation warning

During the actual process of fumigation and any post-fumigation unventilated storage period, notices should always be displayed giving warning of the specific hazard of

high carbon dioxide concentration. These signs should contain:

• a warning symbol appropriate to the country/culture concerned

• in the local language(s) convey the information of the following English text:

WARNING

FUMIGATION IN PROGRESS

Under fumigation with carbon dioxide:

Fumigator .....

Name of company .....

Address .....

Date of fumigation .....

4.6.2 Hazard areas

Where there are unventilated and confined areas surrounding the fumigated enclosure or confined spaces lower than the stack; a notice warning of the potential accumulation of carbon dioxide should be displayed. These signs should contain:

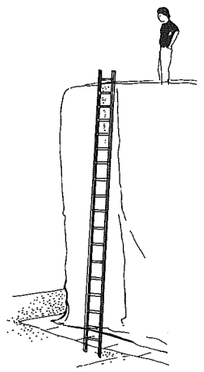
• a warning symbol appropriate to the country/culture concerned

• in the local language(s) convey the information of the following English text:

WARNING

This area may contain
toxic levels of carbon dioxide

CHECK BEFORE ENTERING



4.7 Ladders

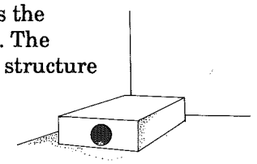
Ladders should be used whenever it is necessary to get to the top of the stack. The practice of climbing up the sides of the stack should be prevented in the interests of worker safety.

5 PREPARATION FOR FUMIGATION

5.1 Site preparation

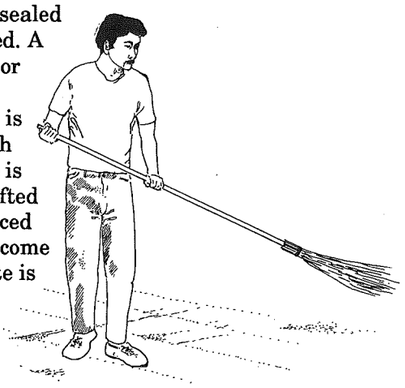
5.1.1 Storage hygiene

The most important aspect of site preparation is the initiation of routine storage hygiene procedures. The essential components of this are to clean up the structure and remove all spilt commodity and dust, and establish a rodent baiting program.



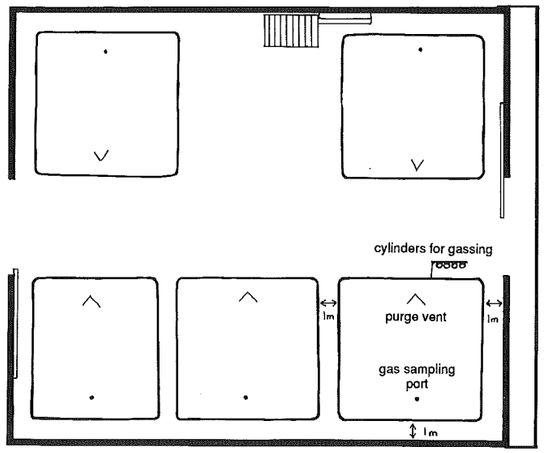
5.1.2 The godown

Godowns in which stacks will be constructed must be carefully swept and inspected. The floor, on which the sealed stacks will be built, should be smooth and well rendered. A floor sheet laid out on a coarse unrendered concrete floor tends to be compressed and becomes thinner along the points of contact with the dunnage, on which the stack is built. At these points the sheet can be punctured, which only becomes evident and causes problems when a site is used for a second time — after the dunnage has been lifted to recover spillage. Inevitably the dunnage is not replaced in the same place, so exposing the punctures, which become noticeable as leaks when the next stack built on the site is pressure tested.



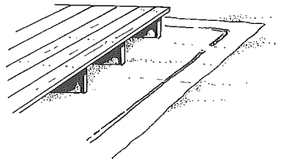
5.2 Spacing of stacks

All stacks should be built, in accordance with good storage practice, so that at least one side fronts onto a large or central gangway along which it is possible to move gas cylinders and set up the equipment necessary for the fumigation process.



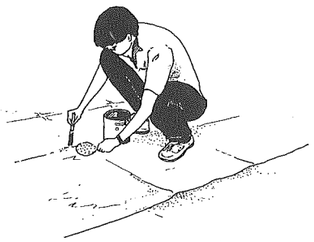
Similarly, the stacks should be spaced at least one metre apart, and at least one metre away from walls and other fixed obstructions.

5.3 Floor sheeting



The floor sheet is one of the most critical components of the sealed stack fumigation technique. Once the stack has been built, it is very difficult, time consuming and expensive to patch holes or otherwise maintain it.

The floor sheet should be at least 1.0 m longer and wider than the base of the proposed stack.



After it has been laid out on the floor and trimmed to size, it is essential that the floor sheet be carefully inspected for holes, tears, weak spots, and manufacturing faults . These should be marked, and patched when the inspection has been completed.

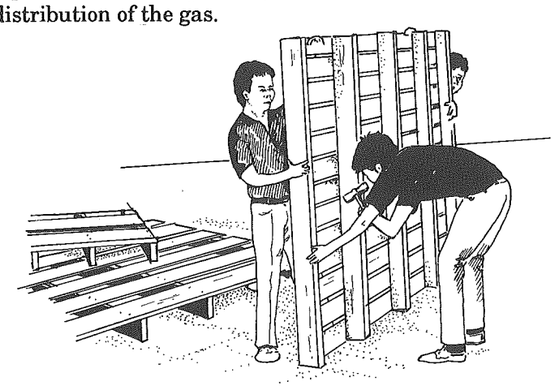
In a godown where it is necessary to build stacks on a coarse or unrendered floor, double floor sheets (or otherwise a single sheet of increased thickness), may be considered.

5.4 Dunnage

In carbon dioxide fumigation of sealed stacks the dunnage has two roles:

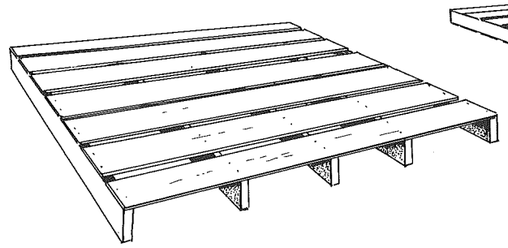
- it reduces the contact between cold newly delivered carbon dioxide and the commodity; and

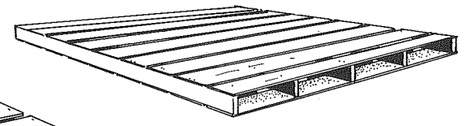
- provides a space (plenum) that helps in the initial distribution of the gas.



Before it is placed onto the floor sheet, the underside of all dunnage used for sealed stacks *must be inspected to ensure that there are no nails or other sharp projections that may puncture the floor sheet. Any that are found must be removed before the dunnage is placed on the floor sheet.*

Single-decked dunnage





Double-decked dunnage

The total area of dunnage (the pallet base) should not exceed the size of the stack to be built on it. Indeed if the pallet base is reduced by 3–5 cm at each edge of the stack this is preferred.

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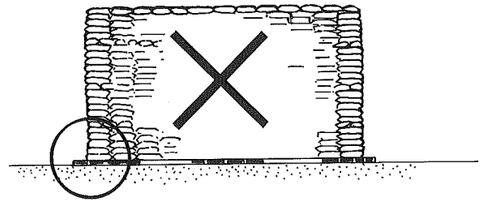
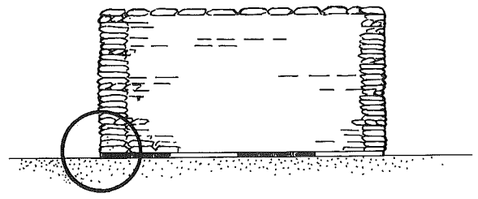
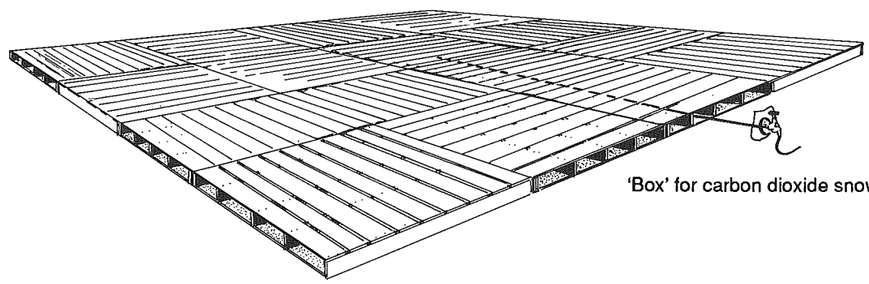


YES



The pallets should be positioned in such a way as to allow the gas introduction pipe to extend, through the gassing port under the pallet base, to about the centre of the stack. Where it is intended to 'snow shoot' the gas into the stack, it is important to make certain that the pallets are arranged to form a 'box' that will contain the carbon dioxide snow. If snow does accumulate against the sides of the cover sheet it can cause excessive cooling of the plastic, which becomes brittle and can then crack very easily.



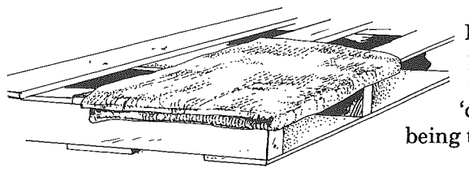
'Box' for carbon dioxide snow

When handling the dunnage, workers should be instructed to lift it up and place it carefully onto the floor sheet to avoid damaging the sheet.

Dunnage should not be dragged across the floor sheet!

For the same reason, consideration should be given to laying sheets of plywood over the floor sheets in situations where 'single decked' pallets are used. This precaution has the added benefit of protecting the floor sheet from any damage that might occur whilst the gas pipe is inserted.

Do not place empty jute (gunny) bags under the floor sheet as protection against coarse and unrendered floors. This practice has been found to increase the damage.

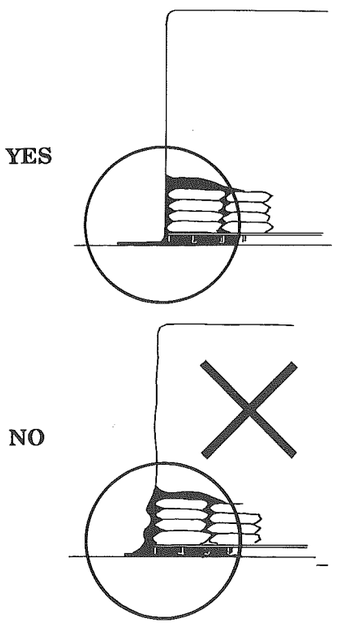


Finally, before the stack is built, it is advisable to place a folded, empty gunny (jute) bag over the corners of the pallet base. This provides a 'cushion' that protects the cover sheet against being torn during pressure testing and gassing.

5.5 Stack (pile) building

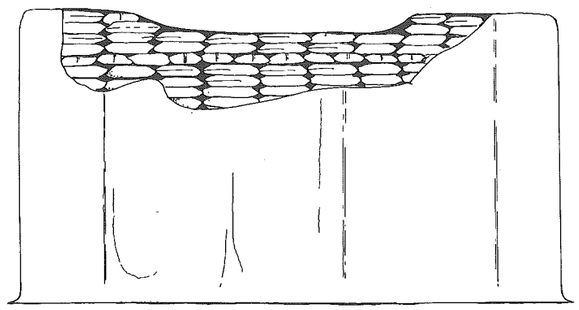
Stacks (piles) should always be built to the full size of the stack cover.

This is important, because in situations where the surplus material is allowed to fold up (or 'concertina') at the base of the stack, it has been found that this area provides harbourage for rodents. In such situations considerable damage has been caused by rodents chewing holes through both the cover and floor sheets!



It is possible to trim the cover sheet to the size of smaller stacks but this then limits the use of such sheets.

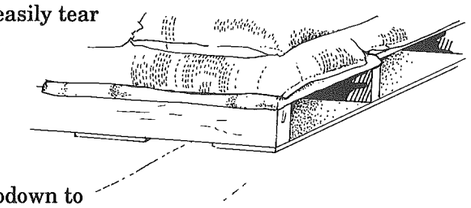
In situations where the stack is 2–3 layers short of the final height of the standard stack; it can be built so that the top is 'dished', with the outer layers built up to standard height and the centre of the stack lower than the edges.



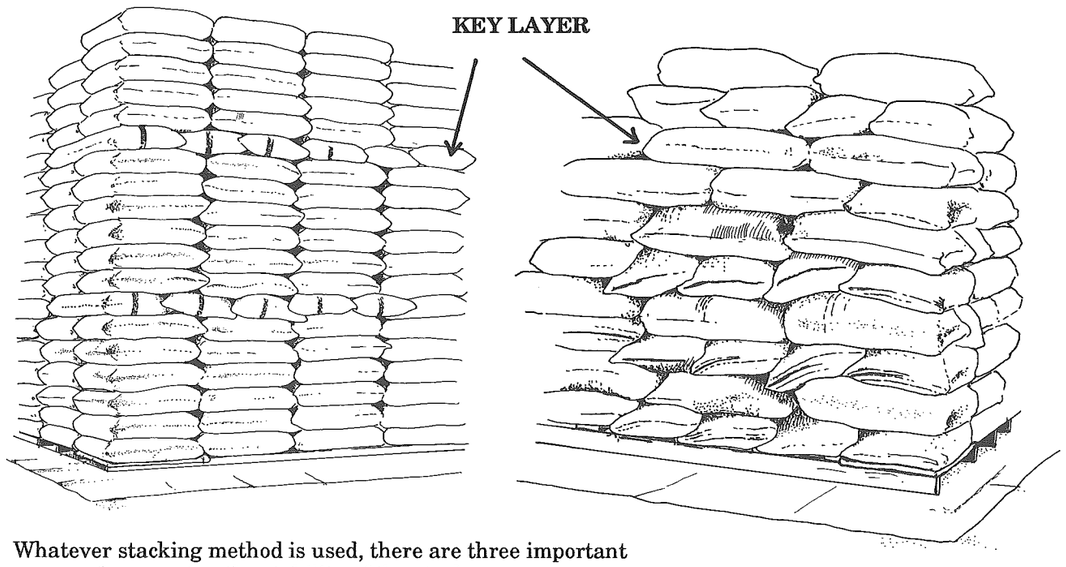
***Safety warning**: if this procedure is used it is necessary to ensure that the outermost layer of bags is: **1.** well 'locked', and **2.** wide enough for sheet handling activities.*

5.5.1 Stacking (piling) methods

It is important that the first layer of bags is placed on the dunnage so that it just overhangs the edge of the timber by about 3–5 cm. This is particularly important at the corners where the exposed timbers of the dunnage can easily tear the cover sheet during pressure testing and gas introduction. As a precaution against this occurring,it is prudent to place a folded, empty gunny bag over the corners of the pallet base before the bag- stack is built.



Methods of stack construction can differ from godown to godown and from country to country. However, if the commodity is entering long-term storage, consideration should be given to fully 'locked' ('keyed' or 'bonded') stacking, which gives greater stability to a bag-stack particularly with commodities stored in polypropylene bags. Locked stacking also allows a larger number of bags to be stored than some other stacking methods, a matter that can be important in situations where space is critical (i.e., so the available volume- to-mass ratio is fully utilised). Stacking bags in this way reduces the total air space within the stack, which has an important effect on the efficiency of the fumigation.



Whatever stacking method is used, there are three important reasons for ensuring the stability of the stack:

- worker safety: to ensure that the stack is sufficiently stable to allow personnel to work safely at its top—particularly at the edges.

- to prevent stacks breaking in earthquake-prone areas

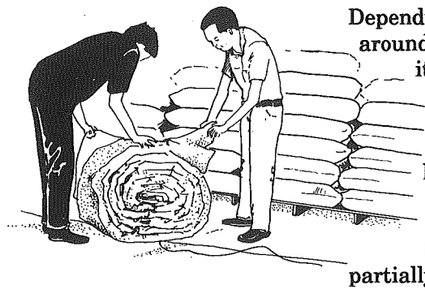
- to ensure that stacks do not collapse and break the cover sheets

5.5.2 Channels in stack

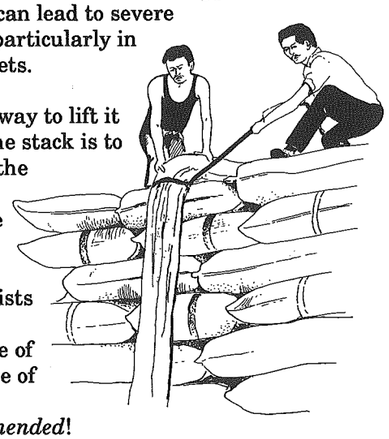
Efficient purging of air by carbon dioxide is best achieved by reducing the air space within the stack (see Section 5.5.1 earlier). Therefore, it is essential to reduce the space between bags as much as possible. In manual stacking this is easy to achieve but when palletised loads are stacked this may be difficult to achieve.

5.6 Cover sheet

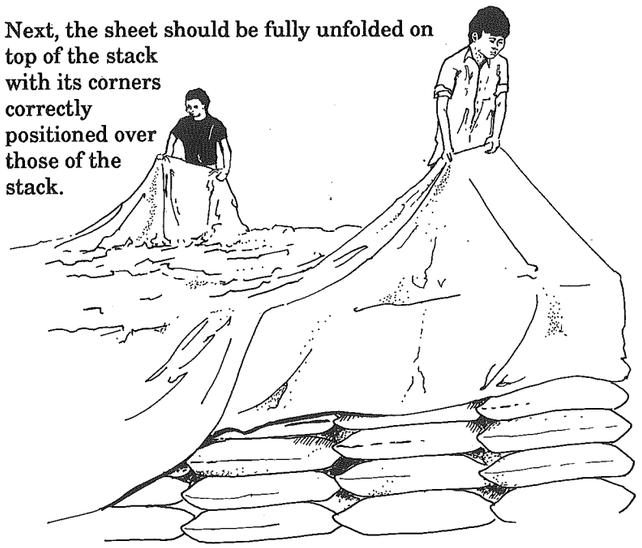
5.6.1 Sheeting the stack



Depending on the material used, the cover sheet can weigh around 80 kg and this needs be considered when handling it. When the sheet has to be moved, care should be taken to ensure that it is not dragged along the floor, which can lead to severe puncturing, particularly in laminated sheets.



The simplest way to lift it to the top of the stack is to partially unfold it on the godown floor then hoist it up with a rope fastened around one end, like a snake. Where mechanical hoists or fork lifts are available, these can be of help. However, the use of bag elevators for this purpose is *not recommended*!



Next, the sheet should be fully unfolded on top of the stack with its corners correctly positioned over those of the stack.

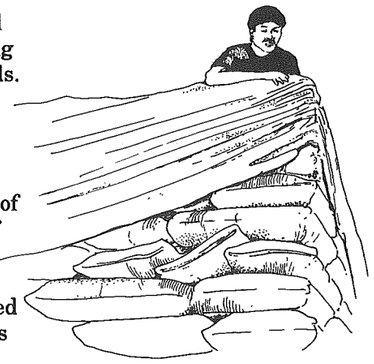
NOTE

The team involved in sheeting a stack *must* use a ladder.

This is important in ensuring the safety of personnel who have to carry materials and equipment up and down the stack during this and the succeeding stages of the fumigation.

To avoid tearing or other damage, personnel must not climb up the sheet. The damage caused may be such that repairs can, at best, only be carried out with difficulty *in situ* or, at worst, require the stack to be uncovered.

At this stage, the sides of the cover sheet must be gathered at the edge of the stack with the bottom edge uppermost.

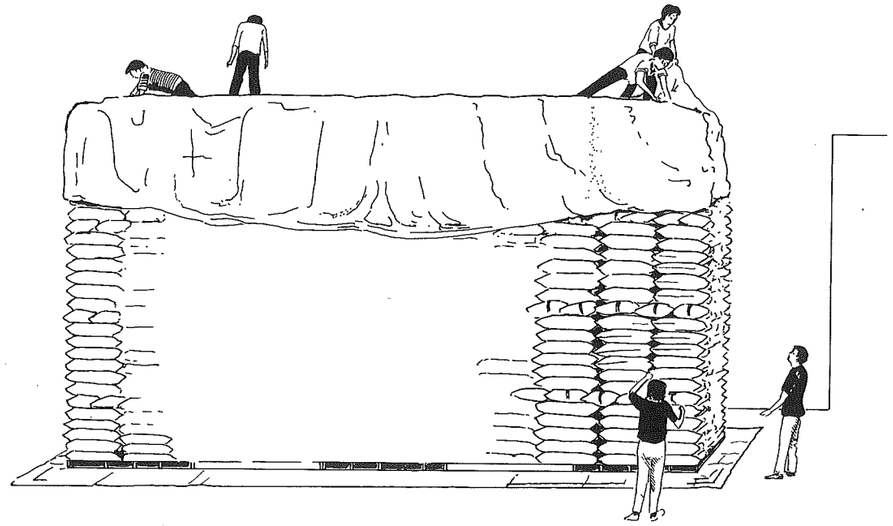


The next step in this operation requires that the personnel handling the sheet lie prone at the edge of the stack looking down at the godown floor, with their feet extending inwards. Thus the sides of the cover sheet must be so arranged to allow it to be dropped over the sides of the stack without interruption.

With experienced personnel it is possible to drop the sides of the cover sheet over the stack with a team of four on top of the stack while the fumigator-in-charge coordinates their operations from floor level. However, in practice a team of six is usually most effective, with a team member positioned at each corner and the others at the centre of the long sides of the stack.

As the sheet is dropped down the side of the stack, the fumigator-in-charge must ensure that the four sides are lowered at the same time. Failure to do this can 'jam' the whole operation.

Occasionally a cover sheet appears to be too small for a stack. The difficulty is commonly encountered when all but the bottom 1– 2 metres of the stack have been successfully sheeted over.



This problem can be overcome by widening the sheet at floor level, which can be done by:

- slitting the sheet vertically upwards from the edge of the skirt for 1–2 metres

- preparing patches from spare sheet material. The patches must be 20–30 cm wide and about 30 cm longer than the slit to be covered

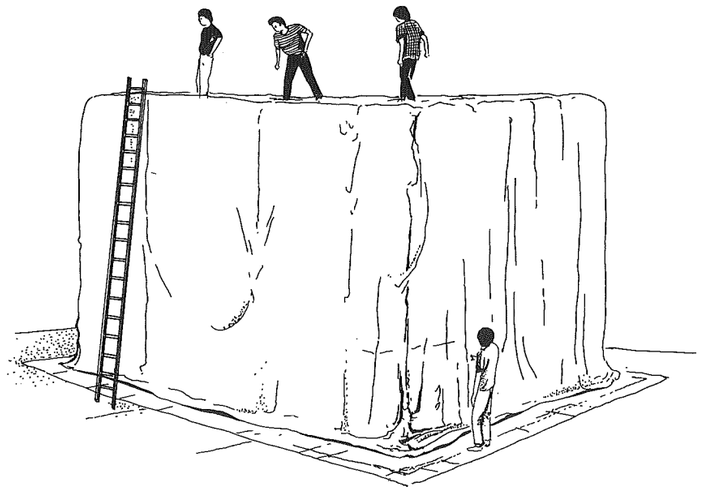
• marking a margin 3–4 cm wide along the cut edges of the cover sheet

• starting about 10 cm above the top of the slit; glueing the patch to the cover sheet. This must be done so that the edge of the patch covers the margin marked along the edge of the slit to increase its length (or width). The spreading must be gradual at the top of the patch, with excess material being taken up as folds (see Section 5.8.1), until it is possible to spread the cut cover sheet over the whole width of the patch

• the end of the patch is then trimmed to match that of the cover sheet.

• more of these patches (or gussets) can be added until the sheet is wide enough to fall over the bottom of the stack and be sealed to the floor sheet.

• to ensure that the gusset is gastight, it is prudent to apply silicone mastic up and down along the edges of the join between the cover sheet and the patch

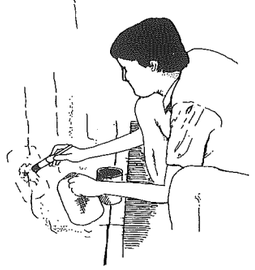


5.6.2 Inspection

Next the cover sheet must be carefully inspected to find all holes, tears, weak spots and manufacturing faults that represent potential leaks. This inspection should be as thorough as possible and *special attention must be given to seams and old patches*. Where faults are found, these should be marked and only patched after the inspection has been completed.

It is suggested that the inspection should commence immediately after the stack has been sheeted — while the fumigation team members are in position, at the top of the stack.

5.7 Patching and mending holes



Methods of mending holes will depend on the material and size of the hole. Whatever the type of sheeting, large holes are best patched with a piece of the same material and sealed using a solvent based PVC glue.

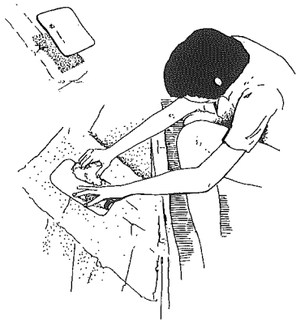
Patches should be cut so that they will generously overlap the hole they are intended to cover. Circular patches, or patches with rounded corners, are most robust. The area to be patched should first be cleaned with cotton waste to remove surface dust and grease. Next brush glue onto the cleaned area and place the patch on it. Then spread the glue by pressing cotton waste onto the patch, using a circular motion from the centre of the patch outwards to its edges. Where large or long patches are required, it is useful to outline the shape of the patch on the damaged area. The holed sheet is then glued and patched in stages, applying pressure with cotton waste. With very large holes it is helpful to place a sheet of plywood behind the damaged area so that it lies flat.

Care should be taken not to apply excessive glue. If this occurs, considerable effort is needed to ensure that the patch sticks. Additionally, when reinforced laminated sheets are used, excessive glue can separate the laminations.

The bond made by solvent glues is rapid and can be tested after 20–30 minutes.

Silicone mastics that set hard are useful for sealing small holes; butyl mastics will also work but are less permanent.

While very convenient for temporary sealing, *self adhesive tapes should be avoided* for permanent repairs as the seal they produce is rarely reliable for more than a short time. Also self adhesive tapes are easily rubbed off and frequently fall off as the adhesive ages.



5.8 Sealing the sheets together

Unlike conventional sheet fumigation of bag-stacks, it is essential that the stack is sealed inside a fully gastight enclosure, consisting of:

• a gas-proof floor sheet

• a gas-proof cover sheet tailored to the size of the stack

• a truly gas-proof seal between the two sheets.

It is impossible to achieve a gas-proof seal between the two sheets by simply weighting down one sheet onto the other using sand snakes, timber, chains, etc. as in conventional sheet fumigation.

NOTE

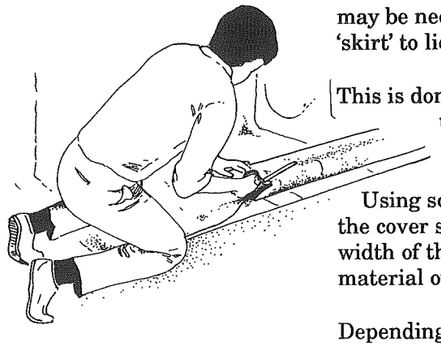
Sealing sheets together with self-adhesive tapes has not been satisfactory.

When fumigating sealed stacks the seal must be strong and permanent. *The use of solvent based PVC glues has been the only satisfactory method implemented to date.*

5.8.1 The sealing procedure — new sheets

Position the cover sheet so that it hangs flat against the sides of the stack.

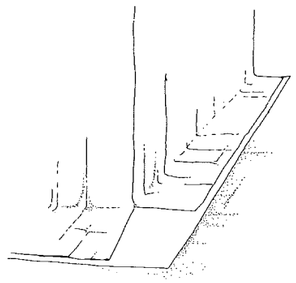
At the base of the stack, fold it through a right angle so that it extends to the edge of the floor sheet to form the 'skirt'. It may be necessary to cut the sheet at the corners, for the 'skirt' to lie flat.



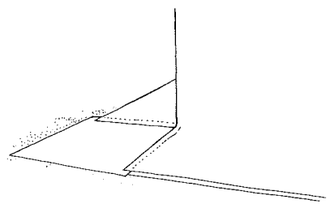
This is done to prevent the excess sheeting resting in folds on the floor, where it can provide harbourage for rodents.

Using scissors, trim any excess material from the skirt of the cover sheet so that it matches, but does not exceed, the width of the floor sheet. This is easily done by folding the material over and running the scissors along the fold.

Depending upon how the cover sheet is made (and whether it was necessary to split its corners), it will now be necessary to fit corner pieces. These are square patches that have to be attached to the skirt on either side of a corner so that the skirt completely surrounds the stack.

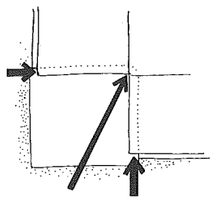


Corner pieces are cut 10–15 cm larger overall than the gap to be filled. Each corner piece is placed under the skirt so that it is overlapped by 5–10 cm. The overlaps are then glued, one at a time, to attach the corner piece to the skirt.



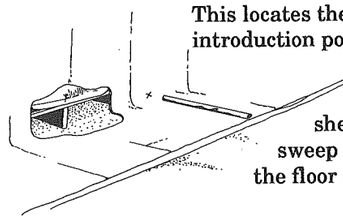
It is helpful later, during the sealing process, not to round off the the outer edge of the corner piece. However, in Indonesia, where considerable experience has been gained with this technique, the corners are routinely rounded off.

It has been found that the corner of the patch that 'points' at the corner of the stack, is very difficult to seal using solvent glues. Thus, after the bond between the rest of the corner piece and the skirt on each side of the corner has been made, this area can be sealed by filling any gaps in the bond with silicone mastic.



Particular attention should be paid to the corner patches during pressure testing. Leaks frequently occur at the inner corner of the patch and where the skirt overlaps it on either side.

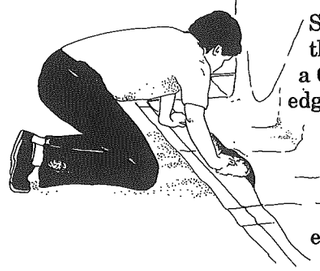
At this stage, it is necessary to identify the side of the stack through which the gas will be introduced into the sealed enclosure. It important to locate the pallets that were laid to allow free access for the copper gas introduction pipe (Section 5.4). This should be marked on the cover sheet at floor level.



This locates the position where the gas introduction port will be attached.

The next step, before the sheets can be sealed, is to sweep any spilled commodity off the floor sheet.

Now glue, paint brushes, and cotton waste are required. It is usually easier to decant the glue into small containers for ease of application.



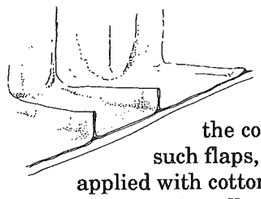
Starting from a corner, clean the dust and surface grease off a 0.5 m strip along the outer edge of floor sheet.

With a paint brush apply a 2 cm wide band of glue along the cleaned edge of the floor sheet.

Next lay the cover sheet onto the treated area so that their edges meet. Then using cotton waste, firmly press the cover sheet down onto the floor sheet by rubbing along the treated area. If excessive glue has been used it will be spread by the rubbing action, which is best carried out from the corner to the centre of the stack (in the direction of the work).

Continue in this manner (in 0.5 m stages) to the centre of the side being sealed. Repeat this procedure from the other corner until the side has been completely sealed.

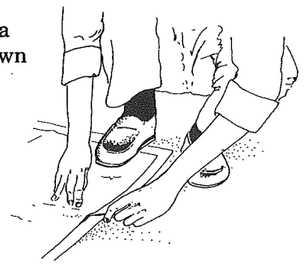
Sometimes the sides of a cover sheet may be longer than the floor sheet. When this occurs the surplus material is taken up by folding the cover sheet back on itself and sealing it together, to form a flap. This process may, occasionally, have to be repeated a number of times as the cover is sealed to the floor sheet. With such flaps, prolonged pressure (3–5 minutes) applied with cotton waste, is often required to ensure a fold of this type is well sealed. Pressure is specifically needed at the floor sheet and at apex ends of the fold.



Continue to seal the remaining sides of the stack in the same manner and complete the enclosure.

The seal should now be examined for any obvious leaks. These are easily recognised by their 'bubble-like' appearance, which stand out against the 'solid' look of well sealed sheets.

It has been found useful to test suspicious areas with a probe — a twig or a piece taken from a godown broom for example. Where large gaps are found in the seal, these are opened up and fixed by applying more glue. It has been found simpler to fill smaller leaks by filling them with silicone or butyl mastic using the probe as a guide for the mastic.



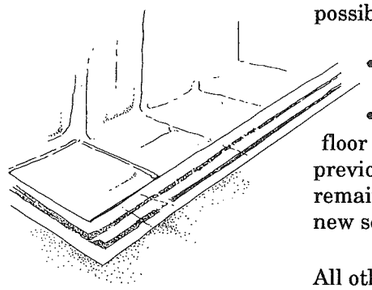
5.8.2 The sealing procedure — used sheets

Enclosures may be sealed and opened several times. There are only a few differences in the sealing procedure with sheets that have been previously used:

- It is not necessary to trim the floor sheet.

- it may be necessary to cut through the corners to fit the skirt to the floor sheet

- the width of the skirt will have been reduced when it was cut open and it may have been left with a ragged edge. For ease of sealing this should be straightened. This is done by folding 3–5 cm of the outer edge over, from corner to corner and using scissors cutting it to give as straight an edge as possible. The procedure is repeated for each side of the skirt.



- if necessary, new corner pieces must be attached

- the cover sheet is unlikely to reach to the edge of the floor sheet, and (if the floor sheet has also been used previously) will only extend to a few centimetres of the remains of the previous seal made with the floor sheet. The new seal is therefore made at this point.

All other procedures are unchanged.

5.8.3 Attaching the gas introduction and gas sampling ports

5.8.3.1 Making up the ports

The gas introduction and sampling ports are fabricated on site. They are made by attaching short lengths of low pressure PVC (conduit or plumbing) piping to square patches of sheet material, which are then glued onto the cover sheet at the appropriate place. This is done as follows:

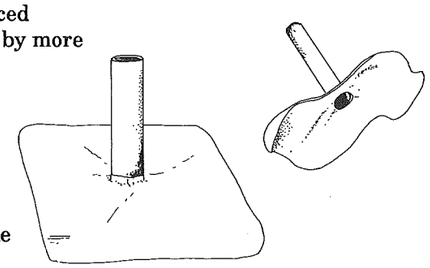
- cut the PVC pipe into 10 cm lengths

- cut out 15 cm squares of sheet material

- punch (or cut) a hole out of the centre of the patch

The hole should be smaller than the external diameter of the piping.

The exact size of the hole depends on the type of sheet material used. Where unreinforced PVC sheeting is used (such as that recommended for floor sheeting) it may be a third (1/3) smaller, however with fibre reinforced sheeting , the hole cannot usually be reduced by more than a quarter (1/4) of the outside diameter.



- Clean one end of the pipe and apply a ring of glue 1 cm wide at the end.

- push the other end of the pipe through the hole in a patch and draw it down onto the glue treated end to make a seal.

5.8.3.2 Attaching the ports to the cover sheet

The ports are glued onto the cover sheet with PVC solvent glue. The site for the gas introduction port should already have been located and marked. Make sure it is positioned over a gap in the dunnage.

The concentration of carbon dioxide within the enclosure is measured by taking gas samples from the top of the stack. It must, however, be positioned well away from the purging vent. For operational reasons, it is convenient to open the purging vent in the area above the gassing port, thus the gas sampling ports should be located about two-thirds of the length of the stack away from the purging vent.

- Outline the margins of the port onto the site where it is to be attached.

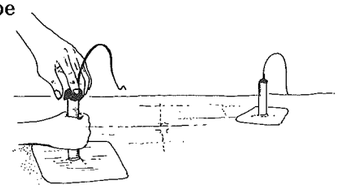
- Cut out a hole in the centre of this area.

• Apply glue to the marked area.

• Attach the port to the sheet, ensuring that the pipe is positioned above the hole in the cut sheet.

• Using cotton waste, spread the glue evenly to ensure that a good seal is achieved. Silicone mastic can be used to complete the seal where gaps are found.

• In the case of the gas-sampling port, it is necessary to insert one end of the gas-sampling pipe through the port onto the top of the stack. The port is then sealed with electrical sealing compound to hold the gas-sampling line in position.



6 PRESSURE TESTING

Sealing is an essential component of carbon dioxide fumigation of sealed stacks. Where it is intended to use only a single dose of carbon dioxide, it is essential that the sealed enclosure meets a pressure decay standard — the pressure test.

If the enclosure fails the pressure test it should not be used for the combined processes of carbon dioxide fumigation and sealed storage. Where repeated attempts to seal an enclosure are unsuccessful, the stack may need to be broken and the floor-sheet inspected for holes, before it can be used for sealed storage.

It is important that all obvious leaks are sealed even if the enclosure passes the pressure test. *This is fundamental where the sealed enclosure will also act as an insect-proof barrier to protect the commodity from reinfestation during a long-term storage period.*

Where the pressure test is not passed, it is technically feasible, but usually not economically justifiable, to top-up the gas to keep the carbon dioxide concentration above 35% for the 15 days required to give a complete disinfestation. A sub-standard enclosure of this nature cannot, however, be used for long-term sealed storage without further gas addition during the rest of the storage period.

6.1 Preparation for the pressure test

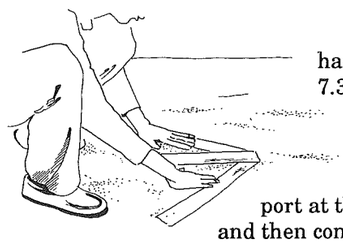
• Check the enclosure for any obvious holes and seal any that are found.

Leaks are commonly found where:

– the cover sheet is sealed over 'seams' (the joints formed when sections of material were welded together) in the floor sheet; and

– the floor sheet is severely folded; and

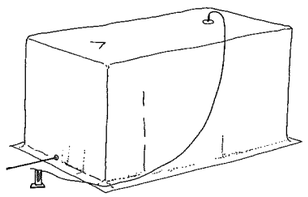
– at the corner pieces.

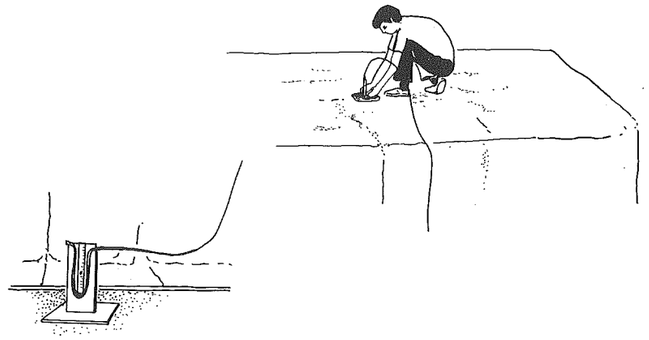


• Check that the purge vent at the top of the stack has been closed (see Section 7.3).

• Ensure that the gas sampling pipe has been attached to the sampling port at the top of the cover sheet and then connect it to the manometer.

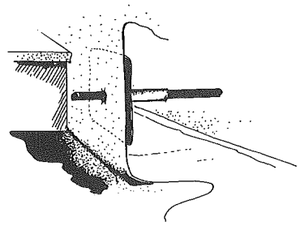
The manometer should be placed close to the gassing port and positioned so that it can be read easily.



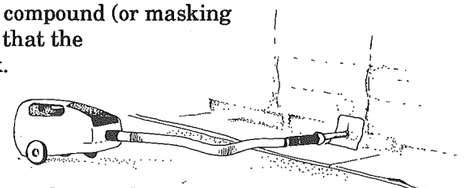


• If more than one gas sampling pipe has been installed, seal the ends of the others. Use silicone mastic or electrical sealing compound.

• Ensure the membrane inside the gas inlet port has been cut open.



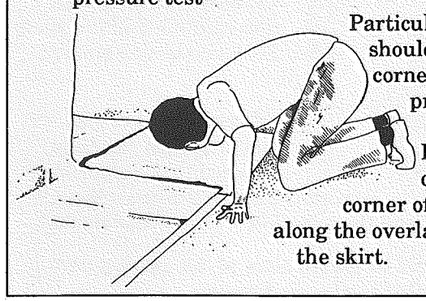
• Connect the vacuum cleaner to gas inlet and, using electrical sealing compound (or masking tape), make sure that the join does not leak.



• Turn on the vacuum cleaner. As the air is pumped out of the enclosure, the pressure inside it will be less than the atmospheric pressure in the godown and the stack is under 'negative pressure'.

NOTE

Whilst the enclosure is under negative pressure it should be examined for leaks. These can often be heard hissing as air enters the enclosure through them during the pressure decay test. All leaks found must be sealed—even if the enclosure passes the pressure test



Particular attention should be paid to the corner patches during pressure testing.

Leaks frequently occur at the inner corner of the patch and along the overlaps made with the skirt.

6.2 The pressure test

• When the vacuum (negative pressure) inside the enclosure reaches approximately 100 mm water gauge, remove vacuum cleaner and seal the gas inlet port with electrical sealing compound.

It is suggested that pressure testing of the enclosure should not exceed 100 mm of water gauge as excessive vacuum may, in certain circumstances, tear the sheet seams apart.

• Record the pressure reading on the manometer and wait for 5 minutes.

• After a 5 minute wait record the pressure reading on the manometer and start the stopwatch.

• Record the time taken for this pressure to halve. If the time taken is longer than 10 mins, the enclosure passes the test.

• If the halving takes longer than 10 minutes continue observing the pressure drop for a total of 15–20 minutes.

Record the pressure reached and the time taken to reach it.

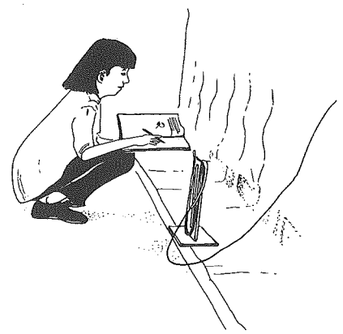
• If the enclosure fails the test, inspect it. Pay special attention to all seams and joints. Remember also to check the top of the stack. In addition to the seams and joints, the gas sampling port and the gas purge vent must be examined.

Sealing the latter is frequently overlooked where sheets have been used before. If the inspection produces no result, it may

The Pressure Test Standard

The gastightness of the enclosure is measured by the time taken for a negative pressure of 500 Pascals (5 cm of water gauge) to fall to 250 Pascals (2.5 cm of water gauge).

The target is 15 minutes or more, *with 10 minutes being the* ***absolute minimum*** acceptable for carbon dioxide fumigation.



WARNING

It is important that sealed stacks are not left untreated overnight. Where stacks cannot be treated until the next day, it is advisable to leave one side unsealed and propped open to expose the pallets and floor sheet. Failure to do this can lead to rodents damaging both cover and floor sheet while attempting to escape from the sealed enclosure.

Similarly where heavily infested stacks of a commodity have been enclosed, these must not be left untreated because moisture migration can occur very quickly and further damage the commodity.

Fumigation of a stack that has failed the pressure test, is likely to be unsuccessful. This will put the commodity at serious risk of damage due to insect infestation and consequent moisture migration.

then be necessary to unstack the commodity and inspect the floor sheet.

• Repeat the pressure test after any significant leaks are found. Record all manometer readings and the time intervals between them.

When the enclosure has passed the pressure test it is ready for fumigation.

Fumigation should be carried out as soon as possible after sealing and pressure testing have been completed.

7 THE FUMIGATION

7.1 Time required to gas a sealed stack

The time needed to apply the required dose of carbon dioxide depends on the source of gas used:

With bulk carbon dioxide; it should be possible to add gas at about 10 kg per min (i.e. about 40 mins per 200 tonne stack). Care should be taken not to significantly exceed this delivery rate, as carbon dioxide snow is very cold (– 78°C). At such low temperatures PVC becomes very brittle and can crack easily.

With inverted cylinders gas addition is slower, due to the time needed to change cylinders. In practice it has been found that a 200 tonne stack can be gassed in about 1¼ hours.

Introduction of carbon dioxide from the gas phase of cylinders standing upright is not recommended because it is time consuming and inefficient. As the gas is released, the pressure inside the cylinder falls rapidly, causing the temperature to fall substantially and the carbon dioxide to freeze. Thereafter, gas is available only at low flow rates and it takes a long time before full flow can be re-established.

7.2 Dosage required

The required dosage is determined by monitoring the concentration of carbon dioxide at the top of the enclosed stack during gas introduction (the carbon dioxide purge). Gas samples are drawn through the sampling pipe fitted into the sampling port at the top of the sealed enclosure.

Gas addition should cease only when the concentration of carbon dioxide in the atmosphere purged from stack exceeds 75%.

IMPORTANT NOTE

The figure of 75% carbon dioxide in the purge atmosphere cannot be reduced. The dosage is not calculated directly from the mass of commodity or volume of the enclosure.

7.3 Gas introduction from cylinders

The best way to gas a sealed stack is by fairly rapid, continuous gas introduction (purging) into the enclosure. During this process, carbon dioxide, because it is heavier than air, replaces the air inside the stack by pushing it upwards and out of the enclosure through the purge vent cut at the top of the stack.

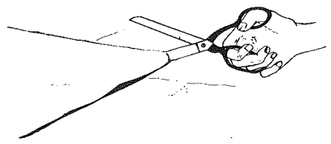
To get the most efficient purging, the gas must be delivered at an even rate to prevent excessive gas mixing. A purge rate of about 10 kg per minute is adequate and not excessive.

The procedure for purging from cylinders is as follows:

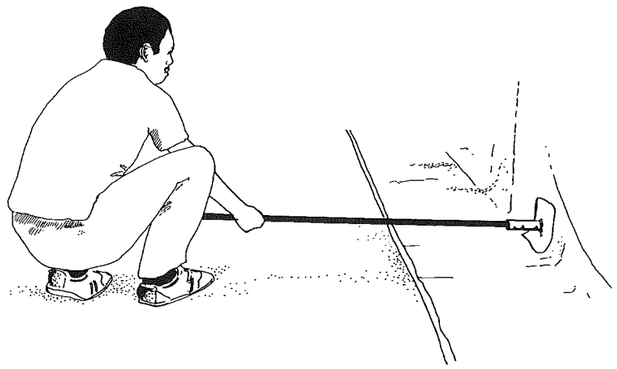
• Place fumigation warning notices to mark the hazard area.

• Ensure that adequate carbon dioxide is available on-site (see Section 2.4.1).

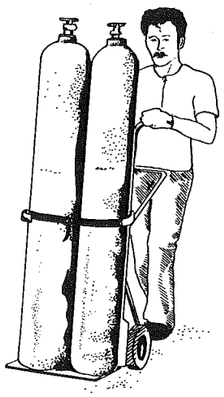
• Open the purge vent at the top of the stack. The vents should be located about one-third (1/3) of the way along the stack from the end where the gas will be introduced. The vent is opened by making two cuts through the top of the cover sheet. The cuts should be at right angles to each other and about 30–40 cm along.



• Insert the copper pipe under the stack through the gassing port, taking care not to damage the floor sheet. The pipe is temporarily sealed into the gassing port using electrical sealing compound.

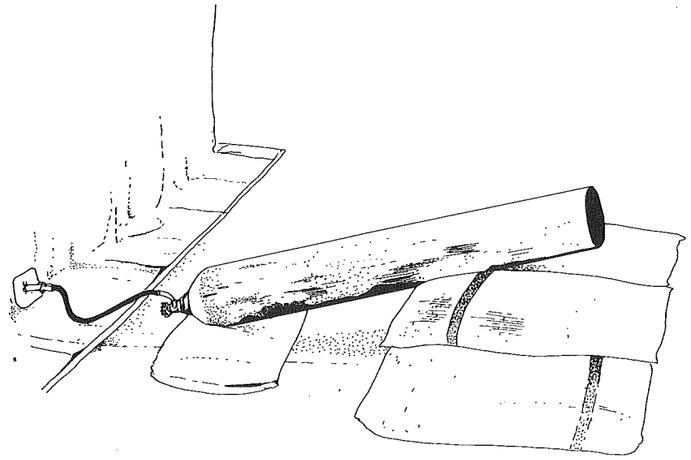


• Invert the cylinder(s) and connect it (them) to the inlet pipe. This is most easily done using a gas cylinder inverter (see page 15 and Appendix 6).



Where an inverter is unavailable, a makeshift inverter can be constructed using grain (or sand) filled bags. This is done by building two 'walls' about 1.5 metres apart. The first wall is one or two bags high and the second three or four bags high. Both walls should be about 2 metres long. Cylinders are inverted with their 'shoulders' resting on the lower wall and the other ends resting on the higher wall.

When cylinders are inverted in this manner care should be taken to ensure that sufficient personnel are available to lift and restrain cylinders. It is important that the safety requirements for handling cylinders are fully complied with (see Section 2.8).

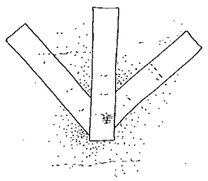


• Open cylinder valve fully.

• When a cylinder (or a bank of cylinders) stops discharging remove and replace with another (more) as quickly as possible.

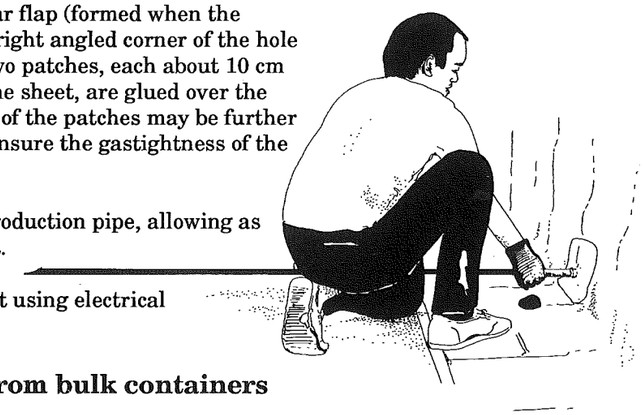
• Start to measure the concentration of carbon dioxide at the top of the stack when about half the estimated dosage has been discharged . The measurements should be repeated as every other cylinder (or bank of cylinders) is emptied.

When the carbon dioxide concentration reaches at least 75% stop adding gas — do not add any more.



• Seal the purge vent when the concentration of carbon dioxide at the top of the stack has reached at least 75%.

The vent is sealed with three patches, all of which should be about 6–8 cm wide. The first, about 10 cm long, is used to fasten the apex of the triangular flap (formed when the purge vent was opened) to the right angled corner of the hole in the cover sheet. The other two patches, each about 10 cm longer than the cuts made in the sheet, are glued over the cuts to seal the vent. The sides of the patches may be further sealed with silicone mastic to ensure the gastightness of the enclosure.



• Withdraw the copper gas introduction pipe, allowing as little gas as possible to leak out.

• Rapidly seal the gas inlet port using electrical sealing compound.

7.4 Gas introduction from bulk containers

Fumigating sealed stacks with carbon dioxide delivered from mobile bulk containers requires specialised equipment. It is considered that this operation should be carried out only by

contractors fully trained and experienced with the technical requirements for this operation.

This approach has been adopted in Indonesia, where BULOG has gas delivered in mobile bulk containers.

It is necessary, however, to ensure that:

- all ancillary equipment—for example, heat exchangers, heaters, valves, etc.—are properly installed

- safety requirements are met

- operational requirements for fumigation of sealed stacks are understood; for example, that care must be taken to establish a satisfactory gas flow.

Most importantly, it must be understood by the contractors that gassing cannot be terminated before the carbon dioxide concentration at the top of the stack reaches at least 75%.

7.5 Ballooning of sheets

During the purge, carbon dioxide accumulates inside the enclosure from the base of the stack upwards, driving air out of the purge vent. Due to its weight, the gas causes the enclosure to 'balloon'. This is normal and occurs irrespective of the type of plastic sheets used to manufacture the enclosure.

During this stage of the fumigation, it is:

- advisable to inspect the fabric of the enclosure to ensure that it is not punctured

- essential to make immediate repairs to any weak seams or joins that may otherwise fail

- necessary to ensure that no unsupported gas cylinders are positioned close to the stack under fumigation because they can fall over under the pressure of the ballooning and may damage the enclosure.

As the carbon dioxide is sorbed by the commodity during the exposure and the storage period, the ballooning slowly subsides. Typically, after 2–3 months, only the bottom of the cover sheet remains ballooned.

7.6 Exposure period

Only one exposure period is recommended — 15 days.

During that 15 days, the concentration of carbon dioxide at the top of the enclosed stack *must remain at or above 35%.* This should be attained if the procedure described here has been followed correctly.

7.7 Monitoring gas concentrations

7.7.1 Measurements of concentrations in stacks

The concentration of carbon dioxide within the enclosure is measured by taking gas samples from the top of the stack through a sampling pipe attached to the sampling port.

Gas samples should be taken:

- During gas addition — when the target concentration required is at least 75%. At this stage the gas purge is stopped and the purge vent must then be sealed.

- On days 5, 10, and 15 after gassing (AG) — to ensure that the final target concentration of 35% or more carbon dioxide is met.

7.7.2 Calculation of *CT* products

The $C \times T$ product calculation is irrelevant to carbon dioxide fumigations because:

- Carbon dioxide dosage is *not* based on concentration × time.

- It is not possible to compensate for lack of concentration by increasing the exposure time and/or vice versa.

7.8 Fumigation records

Good storage practice requires that full and accurate records of all pest control treatments are kept. It is suggested that two records of the fumigation should be kept; a stack history record card and a fumigation record sheet.

7.8.1 Stack history/record card

The date and fact that a carbon dioxide fumigation has been carried out should be noted on the stack history/record card.

7.8.2 Fumigation record sheet

A fumigation record sheet should be completed. A record of this sort is essential to investigate a treatment failure. An example of a record suitable for carbon dioxide fumigations of sealed stacks is given on page 46.

Record Sheet

CARBON DIOXIDE FUMIGATION

Location of fumigated stack: .....

Commodity and grade: .....

Tonnes of commodity: .....

Moisture content: .....

Date of start of treatment: .....

PRESSURE TEST RESULTS

	Test 1		*Test 2*		*Test 3*	
	Time	Pressure	Time	Pressure	Time	Pressure
a Immediately after inlet sealed	.....	.....	.....	.....	.....	.....
b Five (5) minutes later	.....	.....	.....	.....	.....	.....
c When pressure recorded in **b** is halved	.....	.....	.....	.....	.....	.....
d When test is terminated	.....	.....	.....	.....	.....	.....

CARBON DIOXIDE CONCENTRATION AT TOP OF STACK

When gassing was stopped ..... %

5 days after gas addition ..... %

10 days after gas addition ..... %

15 days after gas addition ..... %

Number of cylinders used .....

Amount of gas added (kg) ..... kg

8 LONG-TERM STORAGE

Fumigation will usually be the first stage in the long-term storage of a commodity.

Even though the commodity has been sealed inside gastight (and insect-proof) enclosures, it is essential that an efficient program of godown hygiene and rodent control is maintained. This must be supported by regular inspection of the godowns.

The inspections are essential to ensure:

- godown hygiene is being maintained
- rodents are not chewing holes through the enclosures
- birds are not making holes in the enclosures
- insects are not penetrating through the cover sheets — this has occurred in storage complexes where large stocks of infested grain are stored in godowns close to those in which sealed stacks are held
- to monitor the concentration of carbon dioxide inside the enclosure. *During long-term storage a sudden drop in the concentration of carbon dioxide can indicate that the enclosure has been punctured so making the commodity vulnerable to damage*
- to refumigate the commodity when the concentration of carbon dioxide falls to a predetermined level.

Management strategies for long-term storage of bag-stacked commodities sealed in plastic enclosures lie beyond the scope of this manual. There are, however, a number of papers on the subject. Details are given in Appendix 8.

NOTE

Insect penetration of enclosures can occur in complexes where large quantities of ordinary bag-stacked commodities are stored under conditions of poor hygiene and pest control.

If reinfestation does occur (for example, through holes made in the stack cover by handling equipment, rodents, etc., or even by insect penetration through the stack cover), refumigation can be carried out only after any such damage has first been repaired and the enclosure again pressure-tested.

9 OPENING THE STACK

9.1 Clearing the fumigant

9.1.1 Residual quantity expected

The amount of residual gas present in the enclosure at the time of opening will vary depending upon the duration of sealed storage. If the stack is to be opened close to the minimum exposure time (15 days after gassing) it is advisable to measure the gas concentration just before opening, as any residual gas may be unpleasant for the personnel opening the stack. Hence, it may be necessary to open the purge vent at the top of the stack, open one side and leave the stack to ventilate for several hours before opening the remaining sides of the cover sheet.

9.2 Desorption

Commodities taken out of a high concentration of carbon dioxide continue to desorb the gas for some time. The amount of gas desorbed will vary between commodities but is unlikely to cause any hazard in the case of bag-stacks.

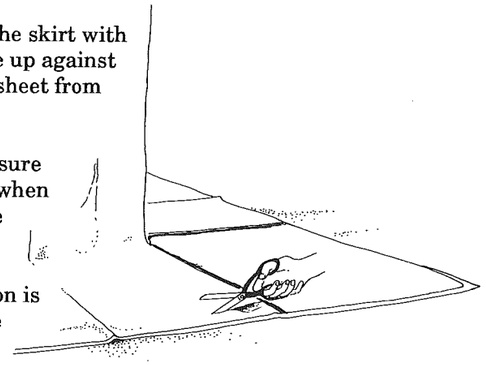
9.3 Clearance

No special clearance procedures are needed.

9.4 Opening the covers

The covers are opened by cutting through the skirt with a pair of sharp scissors, which are run close up against the inside of the seal to separate the cover sheet from the floor sheet.

It is easiest to commence opening the enclosure where flaps (Section 5.8.1) had to be made when the enclosure was sealed. Alternatively, the skirt can be lifted between thumb and forefinger, snipped open and the scissors then run up against the seal. If the operation is carried out whilst kneeling on the skirt, the skirt can be held by firm pressure applied from a knee and a hand.



When opening the enclosure do not cut through the floor sheet as it is important to maintain its original size.

10. CHECK LIST OF OPERATIONS FOR CARBON DIOXIDE FUMIGATION OF SEALED STACKS

This list can be photocopied and copies used as a check-list before and during each carbon dioxide treatment.

1. Ensure that a hygiene program including rodent control is operating in the godown; if not start one.
2. Ensure that the commodity is dry enough for long-term storage.
3. Ensure that adequate carbon dioxide will be available on site when the fumigation is carried out.
4. Inspect the godown floor and if rough make it smooth. Where this is impractical use a double thickness floor sheet (or an underlay to protect the floor sheet).
5. Clean up the stacking site, remove as much spilled grain and dust as possible.
6. Spread out the floor-sheet and examine it for holes.
7. Repair any damage to the floor sheet.
8. Ensure there is enough dunnage for the stack base.
9. Examine the underside of all dunnage for possible sources of damage to the floor sheet.
10. Carefully place the dunnage on the floor sheet.
11. Build the stack.
12. Raise the folded cover sheet to the top of the stack.
13. Working from the top of the stack, fit the cover sheet over the stack.
14. Inspect the top of the cover sheet. Patch all holes, weak spots and manufacturing faults.
15. At floor level, trim the cover sheet to match the floor sheet; fit corner pieces if necessary.
16. Sweep any spilled commodity off the floor sheet.

17. Identify the pallets placed to allow gas introduction and mark the location of the gassing port on the cover sheet.

18. Seal cover sheet to the floor-sheet.

19. Display fumigation warning signs.

20. Attach the gas sampling port and connect the gas sampling pipe to it.

21. Ensure that the purge vent is sealed.

22. Attach gas sampling pipe to manometer and commence pressure test. Check for leaks and seal those found. Record pressure drop and time on record sheet.

23. Repeat test at least twice.

24. Ensure purge vent is open and disconnect gas sampling line from manometer.

25. Insert copper gas inlet pipe into the gassing port and make temporary gas tight seal.

26. Add gas until concentration of carbon dioxide at the top of the stack reaches at least 75%. Record number of cylinders used.

27. Seal purge vent.

28. Remove gas introduction tube and seal gassing port.

29. Display hazard area warning notices where necessary.

30. Measure carbon dioxide concentration at 5, 10, and 15 days after treatment. Record on fumigation report sheet.

31. After 15 days, if the concentration of carbon dioxide at the top of the stack is at or above 35%, the stack can be retained for long term storage.

32. Arrange for the stack to be inspected carefully at least once a week for obvious physical damage to the enclosure.

33. Ensure that rodent control program will continue.

34. Ensure that a high standard of hygiene is maintained around the sealed stack and throughout the godown.

APPENDIXES

Appendix 1. Further information

Sources of further information about carbon dioxide fumigation of bag-stacks in sealed plastic enclosures.

The Director General
Bulog–Rodiawat
Jln. Jend. Gatot Subroto
Kav. 49A
Jakarta Selatan
Indonesia

The Director
MARDI
Food Technology Division
Peti Surat 12301
50774 Kuala Lumpur
Malaysia

Executive Director
NAPHIRE
CLSU Complex
Muñoz, Nueva Ecija
Republic of the Philippines

Director General
Department of Agriculture
Division of Entomology and Zoology
Bangkhen, Bangkok 9
Thailand 10900

Stored Grain Research Laboratory
CSIRO Division of Entomology
GPO Box 1700
Canberra ACT 2601
Australia

CSIRO Division of Plant Industry
Wheat Research Unit
PO Box 7
North Ryde NSW 2113
Australia

Appendix 2. Gas monitoring equipment

Suppliers of equipment in the ASEAN region.

It is impossible to list all suppliers and the following list is provided solely as an initial guide to further information on the subject.

Brunei Darussalaam
Czarina Traders
Peti Surat 888
Bandar Seri Begawan–1908
Brunei
Tel: 29388
Fax: 44735

Indonesia
P.T. Erindo Megah Prima
Jalan R.P. Suroso 32
WKC Building
Jakarta
Tel: 310 5283
Fax: 310 4724

P.T. Kartini Utama (Ltd)
Jalan Pasir Putih 1
No. 1, 2nd Floor
Ancol Timur
Jakarta 14410
Tel: 68 3766
Fax: 68 0352

P.T. Wahana Perisai
Jalan Pintu Air Raya
No. 38H, 2nd Floor
Jakarta 10710
Tel: 275 551
Fax: 365 504
Telex: 44623 SEA IA

Malaysia
Bujang Long Sdn Bhd
Lot 3.12, Tingkat 2
Medan Mara
Jalan Raja Laut
50350 Kuala Lumpur
Tel: 292 0660
Fax: 274 4317

DMT International (S) Pte Ltd
101 Cecil Street No. 22–11
Tong Eng Building
Singapore 0106
Tel: 223 9066, 225 9229
Fax: 223 2165
Telex: DMTINT RS 34138

Filtarite Company
11 (2nd Floor) Jalan 19/22
46300 Petaling Jaya
Selangor
Tel: 755 8582, 755 8646
Fax: 757 5525

Spectron Sdn Bhd
7th Floor UMBC Tower Annexe
Jalan Sulaiman 5000
Kuala Lumpur
Tel: 274 3380
Fax: 230 2730

Philippines
Filiminers Multitech Corporation
MCC P.O. Box 663
Makati, Metro Manila
Tel: 521 7911 (20)
Fax: 818 9720
Telex: 23312 RHPPH

Maschinen & Technik Inc
Technology Center Building
106 E. Rodriguez Sr. Avenue
Quezon City, Metro Manila
Tel: 722 5571
Fax: 817 1056
Telex: 42250 MACTEC PN, 27299 MCTN PH

Polychem Industries, Inc.
Suite 308, 601 & 602
Cattleya Condominium Building
Salcedo Street
Legaspi Village
Makati, Metro Manila
Tel: 818 5266
Fax: 818 1965

Singapore
DMT International (S) Pte Ltd
101 Cecil Street
No. 22–11 Tong Eng Building
Singapore 0106
Tel: 223 9066, 225 9229
Fax: (65) 223 2165
Telex: DMTINT RS 34138

Dreager Services South East Asia Pte Ltd
336 Circuit Road
Swee Hong Industrial Building
Singapore 1337
Tel: 743 0800
Fax: 745 9853

Gimexpo Enterprises Pte Ltd
Block 7, Kallang Place
No. 03-04
Singapore 1233
Tel: 291 6666
Fax: 291 6969

Johnson Scientific Equipment Co.
Blk 81, MacPherson Lane
#01–29 Singapore 1336
Tel: 745 7977
Fax: 747 8228

Thailand
Engineering and Science Associates Co., Ltd
755/79 Soi Watpakineenard
Bangplad
Bangkoknoi
Bangkok 10700
Tel: 435 1982
Fax: 433 4378

B. Grimm Healthcare Co Ltd
1643 Phetburi Road
Bangkok 10310
Tel: 252 9131
Fax: 253 9867

Sithiporn Associates Co Ltd
113/4 Soi Nomchit
Naresh Road
Bangruk, Bangkok
Tel: 236 0032
Fax: 236 8629
Telex: 21450 SITHIPN

Appendix 3. Gas suppliers

Known suppliers of gas in the ASEAN region

Indonesia
P.T. Aneka Gas
Jalan Minangkabu 60
Jakarta
Tel: 829 6108
Telex: 48362 AKGAS IA

P.T. IGI
Jalan Pulogadung
Km 21 Pulogadung
Jakarta
Tel: 489 7908
Telex: 49425 IGIGAS IA

Malaysia
Malaysian Oxygen Berhad
13 Jalan 222
Petaling Jaya
PO Box 633
Kuala Lumpur 01-02
Malaysia
Tel: (03) 554233
Telex: MA 37663

Industrial Oxygen Incorporated Berhad
Jalan Pengisir15/9
(off Jalan Utas 15/7)
Shah Alam
PO Box 77
Shah Alam
Selangor Malaysia
Tel : 591 006–9 (4 lines)
591 059

Philippines
Consolidated Industrial Gases Inc
CIGI Building
Sheridan Cor. Pioneer Street
Mandaluyong
Metro Manila
Tel: 773 761
631 8251-63
Fax: 631 5083

Phil Industrial Gas Corporation
525 M Naval Navotas Metro Manila
Tel: 221 263
902 425

Superior Gas and Equipment Co Inc
6J Tiosejo Street
Mandaluyong
Metro Manila
Tel: 784 986, 784 991
Fax: 721 8539

Island Air Products Corporation
170 Virata St
Pasay City
Metro Manila
Tel: 833 0771, 833 0773, 833 5075, 833 5076

Singapore
IMS Gas and Equipment (PTE) Ltd
38 Lokyang Way
Jurong Town
Singapore 2262
Tel: 268 0847, 265 8788
Fax: 265 7628
Telex: RS 26402 ANGTPT

Thailand
Thai Industrial Gases Limited
22/26 Poochaosmingprai Road
Samrongtai
Smutprakarn 10130
PO Box 1026
Bangkok
Tel : 394 421–9

Appendix 4. Cover sheet makers

Manufacturers of tailored sheets for sealed stack storage

Australia

Barrier Consolidated
Industries Pty Ltd
3/37 Church Avenue
Mascot NSW 2020
Australia
Ph (02) 693 5966
Fax (02) 317 5925

Commodity Storage
Lot 8, Annangrove Road
Rouse Hill NSW 2153
Australia
Ph (02) 679 1931
Fax (02) 679 1909

Indonesia

P.T. Abdi Inshan Medal
General Trading
Jalan Taman Sari IX No 15
Jakarta
Indonesia
Phones 629 0416, 669 8937,
082 120868

P.T. Sarana Utama Jaya
Jalan Kelapa Lilin IV
Ng 9/3 Kelapa Gading Permal
Jakarta
Tel: 451 2342
Fax: 451 242
Telex: 45742 RADJA IA

Appendix 5. Gas detection equipment

Gas detection equipment that can be used for carbon dioxide fumigation of bag-stacks sealed in plastic enclosures

Bacharach Fyrite gas analyzers

Draeger gas detector tubes and pumps

Riken gas interferometers

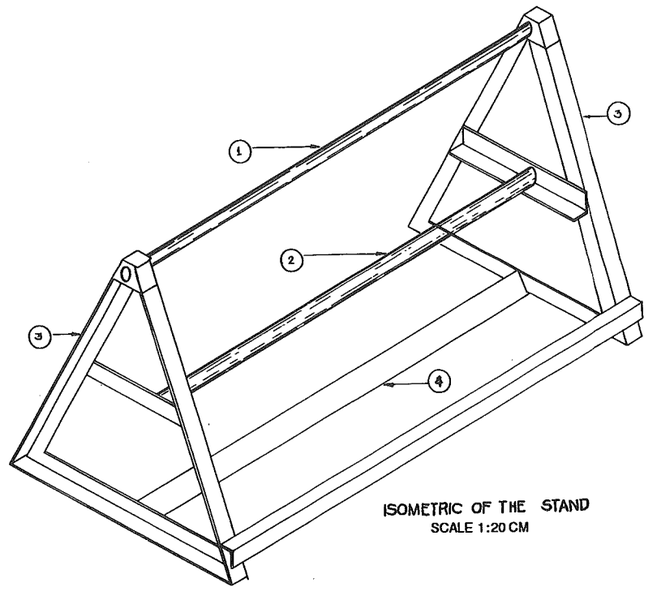
Kitagawa gas detector tubes and pumps

Gastec gas detector tubes

Cosmotech electronic carbon dioxide meter (used by BULOG in Indonesia)

Appendix 6. Gas cylinder inverter

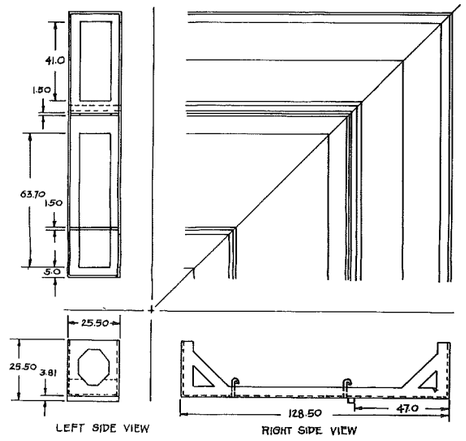
Technical drawings of gas cylinder inverter. These drawings are provided to illustrate the sort of apparatus required to invert carbon dioxide cylinders. It is important that the practical requirements for worker safety are included in any design for such equipment and it is suggested that gas suppliers should be consulted before manufacturing inverters.



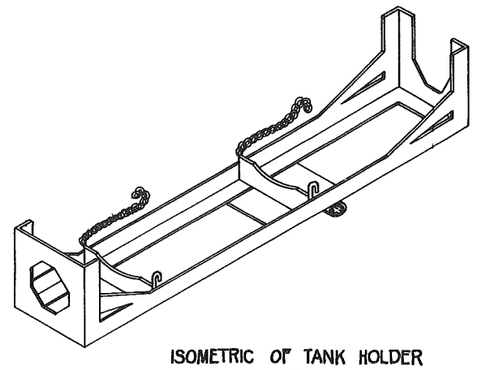
ISOMETRIC OF THE STAND
SCALE 1:20 CM

NOTE:

1. ITEM NO. 1 IS A SOLID STEEL BAR 168.0 CM. LONG, 3.18 CM IN DIAMETER.
2. ITEM NO. 2 IS A HOLLOW G.I. PIPE 148.0 CM. LONG, 3.81 CM IN INSIDE DIAMETER.
3. ITEM NO. 3 IS AN ANGULAR BAR, BASE LENGTH IS 81.50 CM, SAME WITH THE HEIGHT, 57.15 CM.
4. ITEM NO. 4 IS AN ANGULAR BAR, 5 X 5 CM, 0.30 CM IN THICKNESS, 148 CM. LONG.
5. ALL ANGULAR BAR ARE 5 X 5 CM AND 0.30 CM. IN THICKNESS.



ORTHOGRAPHIC VIEW OF TANK HOLDER
SCALE 1:30 CM



ISOMETRIC OF TANK HOLDER
SCALE 1:20 CM

Appendix 7. BULOG instructions

A summary of BULOG's instructions for the application of the CO_2 technique*

Preparation of the Stack and Enclosure

1. A PVC sheet (0.76 mm thick) is placed on the floor where the stack is to be built.

2. Wooden pallets, in good condition, are positioned on top of the sheet to leave a sheet margin of 50 cm.

3. A stack of milled rice is built on the pallets, using stock with a moisture content of about 13%. The upper surface of the stack should be level before a tailored plastic sheet is fitted over the stack.

4. The margin of the plastic base sheet, which will be glued to the plastic cover, is cleaned with detergent.

5. The edges of the base and cover are glued together using Rakol Ultra DX glue.

6. For the sampling of CO_2 gas, a plastic pipe (25 mm i.d.) is inserted through the cover at the base of the stack. The same pipe is also used for testing the gastightness of the stack and allows the insertion of the copper CO_2 filler pipe. A paralon pipe (12.5 mm i.d.) is inserted into a hole at the top of the stack. The paralon pipe is then connected to a plastic pipe (7.7 mm i.d.), using putty, which trails to the ground. This pipe is used for sampling CO_2 gas from the top of the stack and for air pressure measurements.

Checking for Leaks

1. A domestic vacuum cleaner is connected to the CO_2 filler pipe at the base of the stack. To monitor the vacuum, a manometer is attached to the pipe leading from the top of the stack. When the air pressure difference between the inside and outside of the stack reaches 40 cm on the manometer the vacuum cleaner is turned off. The stack is then checked for leaks and any found are repaired.

2. The vacuuming and repair are repeated until the plastic enclosure can hold a differential in air pressure of 50% for about 15 minutes.

Adding CO_2

1. The vacuum is released and a hole cut at the top of the stack to allow the escape of air when CO_2 is added below. The air pressure/CO_2 measuring pipe is closed.

2. Liquid CO_2 from cylinders, or more usually a tanker, is delivered to the stack through a copper pipe (17 mm i.d.) inserted at its base. The CO_2 will run in below the pallets. A dose of about 2.4 kg/tonne is administered, at which time the concentration of CO_2 is measured, via the CO_2 measuring pipe inserted at the top of the stack, using a 'Cosmotector'. When a concentration of 80% CO_2 is reached gassing is complete and the vent hole and CO_2 delivery pipe are sealed.

Monitoring

After gassing regular checks are made for the following:—

1. Gas Concentration

The concentration of gas is checked every day for the first 10 days by measurement at the base and top of the stack using a 'Cosmotector'. A minimum concentration of 50% is required for the first 10 days. Thereafter, measurements are made every 15 days or earlier if a leak is suspected. If the CO_2 level reaches less than 10% in the first 6 months regassing is required after a vacuum test.

2. Damage to the System

Daily inspections are made for

- the presence of holes in the plastic sheeting caused by rats, birds, or insects
- any loosening of the putty used to join the plastic pipe work
- any condensation under the covers
- the presence of living insects and/or microorganisms on the surface of the stack

3. Rice Quality

The quality of rice coming from the CO_2 program is checked by sampling at the beginning and end of the storage period. Samples are taken from five marked bags on each side of a stack before the covers are put on. This procedure is repeated at the end of the storage period and the results compared.

* From: Yun C. Nataredja and Hodges, R.J. 1990. Commercial experience of sealed storage of bag stacks in Indonesia. In: Champ, B.R., Highley, E., and Banks, H.J., ed. Fumigation and controlled atmosphere storage of grain: proceedings of an international conference, Singapore, 14–18 February 1989. ACIAR Proceedings No. 25, p. 202.

Appendix 8. Pubications

Publications relevant to long-term storage of commodities in sealed plastic enclosures. Copies are available from the ASEAN Food Handling Bureau, Level 3, G14 & 15 Damansara Town Centre, 50490 Kuala Lumpur, Malaysia.

Pest and commodity management

Annis, P.C. 1990. Sealed storage of bag-stacks: status of the technology. In: Champ, B.R., Highley, E., and Banks, H.J., ed. Fumigation and controlled atmosphere storage of grain: proceedings of an international conference, Singapore, 14–18 February 1989. ACIAR Proceedings No. 25, 203–210.

Annis, P.C., and van S. Graver, J.E. 1989. Sealed stacks as a component of an integrated commodity management system: a potential strategy for continued bag-stack storage in the ASEAN Region. In: de Mesa, B.M., ed., Grain postharvest systems: proceedings of the Tenth ASEAN Technical Seminar on Grain Postharvest Technology, Bangkok, 19–21 August 1987. Bangkok, ASEAN Crops Postharvest Programme, 224–230.

Conway, J.A., Mitchell, M.K., Gunawan, M., and Yusuf Faishal 1990. Cost-benefit analysis of stock preservation systems. A comparison of CA and the use of conventional pesticides under operational conditions in Indonesia. In: Champ, B.R., Highley, E., and Banks, H.J., ed. Fumigation and controlled atmosphere storage of grain: proceedings of an international conference, Singapore, 14–18 February 1989. ACIAR Proceedings No. 25, 228–246.

Yun C. Nataredja and Hodges, R.J. 1990. Commercial experience of sealed storage of bag stacks in Indonesia. In: Champ, B.R., Highley, E., and Banks, H.J., ed. Fumigation and controlled atmosphere storage of grain: proceedings of an international conference, Singapore, 14–18 February 1989. ACIAR Proceedings No. 25, 197–202.

Grain quality after storage in sealed stacks

Ab. Rahim Muda and Faridah Mat Elah 1990. Eating qualities of milled rice under carbon dioxide In: Champ, B.R., Highley, E., and Banks, H.J., ed. Fumigation and controlled atmosphere storage of grain: proceedings of an international conference, Singapore, 14–18 February 1989. ACIAR Proceedings No. 25, 257–260

Chuwit Sukprakarn, Kruawan Attaviriyasook, Lamaimaat Khowchaimaha, Kanjana Bhudhasamai, and Boodsara Promsatit 1990. Carbon dioxide treatment for sealed storage of bag stacks of rice in Thailand. In: Champ, B.R., Highley, E., and Banks, H.J., ed. Fumigation and controlled atmosphere storage of grain: proceedings of an international conference, Singapore, 14–18 February 1989. ACIAR Proceedings No. 25, 188–196.

Esteves, L.A., Sabio, G.C., Annis, P.C., van S. Graver, J.E., and Bason, M.L. 1988. Effects on quality of white maize (corn) stored in sealed bag stacks in the Philippines. Presented at 11th ASEAN technical seminar on grains postharvest technology. August 1988, Kuala Lumpur.

Gras, P.W., Bason, M.L., Esteves, L.A., Sabio, G.C., Annis, P.C., and van S. Graver, J.E. 1990. Quality changes in maize stored in sealed bag stacks. Journal of Stored Products Research, in press.

Hamel, D. 1990. Seed viability under different storage conditions. In: Champ, B.R., Highley, E., and Banks, H.J., ed. Fumigation and controlled atmosphere storage of grain: proceedings of an international conference, Singapore, 14–18 February 1989. ACIAR Proceedings No. 25, 265–267.

Sabio, G.C., Alvindia, D., Julian, D.D., Murillo, R., Jr., and Sambrano, M.S. 1990. Storage of bagged maize sealed in plastic enclosures in the Philippines. In: Champ, B.R., Highley, E., and Banks, H.J., ed. Fumigation and controlled atmosphere storage of grain: proceedings of an international conference, Singapore, 14–18 February 1989. ACIAR Proceedings No. 25, 180–187.

Appendix 9. Characteristics of carbon dioxide

General characteristics

The normal concentration of carbon dioxide in air is about 0.03%. The hygienic standard (i.e. the concentration to which a worker may be continually exposed without ill effects) in many countries is 0.5%. Concentrations in the range 2–5% cause a noticeable increase in the rate of breathing, from 5–10% breathing becomes laborious and at 10% it can voluntarily be endured for only a few minutes. Exposure to 12–15% causes unconsciousness, while 25% will lead to death in a few hours.

Recovery from exposure to high concentrations of carbon dioxide is generally complete, with no long term effects on health.

Monitoring of Health of Fumigation Staff

Where staff are part of a regular fumigation team, the fumigator-in-charge should ensure that regular health checks are performed on himself/herself and his/her staff. This should be done in consultation with and according to the requirements of local health authorities.

First Aid

A person who appears to have been affected by carbon dioxide must be taken at once into fresh air, kept quiet and warm, and medical attention should be obtained. If breathing stops or shows signs of failing, resuscitation must be commenced immediately.

Cold burns or frost bite caused by skin contact with solid carbon dioxide (dry ice) should be flushed with lukewarm water for at least 5 minutes, then treated as if they were heat burns. Hospital attention should be sought for all but the most superficial cases. Do not apply direct heat or give alcohol or cigarettes. Protect frozen parts from infection.

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