# Pest management

Preventing losses from occurring is always better than having to introduce remedial measures afterwards. However, the trader or storekeeper must decide whether it is cost-effective to undertake precautionary measures. This will depend on the type of commodity to be stored, its intrinsic value, and the period for which it will remain in store. However, even though a grain consignment might only be in transit and in storage for a few weeks, successive deliveries and despatches of grain may well require prophylactic treatments be undertaken to ensure that none of the consignment is put at risk. In areas of high humidity, such as in much of South East Asia, insect development can be very rapid and it is not uncommon for overwhelming populations of *Psochidea* or book lice to appear in a matter of a few weeks.

Good hygiene and store maintenance are prerequisites for employing measures to prevent losses from occurring. Pest control measures will fail if the store is dirty or in poor condition (Figure 18). Another essential is to ensure a high level of store and stock management. In a clean, well-managed store pest control practices can be easily employed. This is very often not the case if the stock is not well stacked; if bicycles are repaired in the store; if metal drums, old sacks and pesticide containers are left haphazardly; if spilt grain is not swept up; if the store is used as a meeting place or café.

FIGURE 18 **Example of a badly managed store in which it is impossible to undertake pest management procedures**

## CONTROL OF INSECT PESTS

### Fumigation

Grain and grain products can be protected against storage insect pest damage by eliminating existing populations, i.e. by disinfestation, or by preventing infestation occurring in the first place. Fumigant gases are used for disinfestation and contact insecticides are used as protectants to prevent infestations.

Fumigation is achieved by the action of a gas, phosphine, which is released from aluminium phosphide or magnesium phosphide when these come into contact with moisture in the air. Phosphine is extremely poisonous to insects, man and animals, and so very great care must be taken when it is used. Fumigation must only be undertaken by trained personnel.

Fumigation must take place inside a gas-tight container or enclosure. This can be a metal or plastic structure such as a 20 or 40 tonne freight container, a 3-4 tonne high density polytank, or a sealable 200 litre oil drum. Most commonly, fumigations are carried out in food stores under a non-porous fumigation sheet, which is held down onto the floor with 'sand snakes', long narrow tubes of cotton cloth or similar material filled with sand. The weight of the sand snakes keeps the sheet flat on the floor and prevents gas leakage (Figure 19).

If the container or enclosure is not gas-tight phosphine will escape into the environment and be a hazard to people and livestock in the vicinity. Gas leakage will also result in an ineffective

FIGURE 19 **Measuring phosphine gas concentration in stack covered with thick polythene sheeting and anchored to ground with sand snakes**

fumigation as phosphine will not be in sufficient concentration long enough to kill all the insects in the commodity. If insects survive they may become resistant to the gas so that in future, even when good quality fumigations are undertaken, they may not be fully effective.

Some of the commercial formulations of phosphine are shown in Table 2 below. Of these, tablets of aluminium phosphide, which release 1 g of phosphine, are in most common use in grain and feed stores in the tropics and sub-tropics. Pellets are useful for disinfecting individual sacks.

Once a bag stack has been properly covered with a fumigation sheet the tablets are introduced under the sheet, which is then resealed. Tablets can be put inside a small paper envelope or piece of cotton cloth. They must be spread out around the stack, no more than six tablets in one lot. The application rate is 3-5 tablets for every tonne of grain or cubic metre of store volume (Table 3). It is easier calculating the dosage on the weight of grain to be treated if the stack is under a sheet. If the grain is in a polytank or metal container the dosage should be calculated on the volume to be treated, it should be the same whether the tank is completely full, half full or nearly empty.

Fumigation with phosphine takes a minimum of seven days to complete whatever type of container or enclosure is used (Table 4). If the fumigation is ended after a shorter period it is very likely that some insects will survive, the treatment will be a failure and will probably need to be repeated.

Once a fumigation is complete the stack or container must be fully aired to blow off any remaining gas before the trader can take the produce away. Airing is a short process that can be completed in 2–8 hours depending on the size of the stack. By the end of the fumigation, the aluminium phosphide tablets will have degraded leaving a grey powder, aluminium hydroxide. This powder must be stirred into a bucket of water and then poured away.

Individual 50 kg lots of grain or feed can be separately fumigated when placed inside a suitable sack. The sack must have an inner polythene liner of at least 500µm and a second outer layer of jute, hessian or woven polypropylene to protect the liner. Ideally, once a pellet is placed inside the sack the polythene should be heat sealed. However, it is acceptable to twist and

**TABLE 2** FORMULATIONS APPROPRIATE FOR SMALL TO MEDIUM SCALE USE

| Formulation | Unit weight (g) | Phosphine released (g) |
|---|---|---|
| Pellets | 0.6 | 0.2 |
| Tablets | 3.0 | 1.0 |
| Mini bags | 9.0 | 3.0 |
| Bag (sachet) | 34.0 | 11.3 |
| Bag (sachet) with strings or chains | 340.0 | 113.0 |
| Blanket | 3,400.0 | 1,130.0 |
| Plates | 117.0 | 33.0 |

**TABLE 3** RECOMMENDED DOSAGE RATES FOR PHOSPHINE

| Type of fumigation | Recommended dosage[a] | |
|---|---|---|
| | g $PH_3$ per tonne | g $PH_3$ per $m^3$ |
| Bulk fumigation in gas-tight silos | 2 to 4 | 1.5 to 3.0 |
| Bagged commodities under gas-proof sheets | 3 to 5 | 2 to 3.5 |
| In-bag fumigations | 0.2 g per bag[b] | |
| Space fumigations, e.g. empty store | | 1.0 |

turn the mouth of the polythene on itself and tie it off with string. Pellets of aluminium phosphide, releasing 0.2 g phosphine were designed to be used in this manner.

## Contact insecticides

Inspection will indicate the need for pest control measures. In many storage complexes insect control is conducted on a routine calendar basis. Fumigation may be carried out every three months and spraying the store walls every two months, regardless of real need. This is a costly and inefficient way to control insect pests because frequently, the fumigation will be applied to a commodity with no pests or because the spray application may only be effective for one or two weeks. It is therefore important to undertake pest control operations only when needed and this will be indicated by inspection.

Before any control operations are undertaken the store or mill areas to be treated must be cleaned. Walls, floor and machinery must be swept with brooms and the sweepings removed. Immediately prior to fumigation, the internal store fabric and any machinery should be treated with a contact insecticide spray to kill off any insects that might be lurking in cracks in concrete or in concealed places around machinery. This treatment is designed to kill at the time of application, not to provide residual protection.

**TABLE 4** MINIMUM EXPOSURE PERIODS RECOMMENDED USING PHOSPHINE

| Temperature (ºC) | Exposure period (days after application of the fumigant) |
|---|---|
| below 15 | do not use |
| 15 to 25 | 10 |
| above 25 | 7 |

It is always advisable to clean and spray an empty store immediately before a new stock is to be received. This will disinfest the building of any over-wintering insect pests, which otherwise could attack the incoming commodity. It is usually not necessary to spray the roof fabric as it generally becomes too hot during the daytime to support insect development. However, if there is a ceiling present below the eaves this should be treated.

Hand-operated sprayers are convenient for small to medium sized stores. These may be of two types, continuously pumped or pre-pressurised. The former have to be pumped by the operator throughout the procedure (Figure 20a) but pressurised sprayers do not, and therefore require only one hand to operate. Pressurised sprayers should be fitted with a self-regulating valve and operated at about 4 bar (4 kg/$cm^2$). Larger areas can be covered with sprayers operated with petrol engines (Figure 20b), including motorised knapsack sprayers. These last tend to be very wasteful of liquid as much of the spray is lost into the airspace.

Sprays are best applied with a nozzle producing a flat fan pattern, although cone patterns are also acceptable. The nozzle head should be kept about 15 cm from the wall to provide adequate cover, but to prevent too much bounce and back

FIGURE 20 Hand operated pneumatic sprayer

(a)

(b)

spray. Sprays should be applied until run off occurs, as this will allow the liquid to penetrate into cracks and crevices where insects may be hiding.

Only sufficient spray solution should be prepared to treat the areas to be covered. Inevitably, some dilute spray solution may remain once the operation is completed. If this happens the remnants of the solution should simply be applied to the walls or floor until the sprayer is emptied. After completing the operation the sprayer must be washed out thoroughly with water.

Contact insecticides are sold in several different formulations. Those that are appropriate for treating surfaces include wettable powders (wp: solids which are dispersed in water), emulsifiable concentrates (ec: liquids which are dispersed in water to form an emulsion) and soluble concentrates (sc: liquids diluted in a solvent such as oil to form a true solution). Ecs tend to be the most commonly available and are the most convenient to use in hand operated sprayers. Insecticide concentrates generally contain 20-40% (some deltamethrin formulations only contain 2.5%) active ingredient and must be diluted before use.

Manufacturers' recommendations on the label must be adhered to when applying contact insecticides and other pesticides. Depending on the chemical used, between 0.1-1.0 g of active ingredient must be applied per $m^2$, and usually the application rate of the diluted solution to cement surfaces is 5 l/100 $m^2$. The appendix provides an example of how to calculate the dilution of a contact insecticide to be applied to the walls of a store.

Freight wagons and containers should be treated in the same way except that less diluted solution needs to be applied as the metal surfaces do not absorb any of the solution; a rate of 2 l/100 $m^2$ is usually sufficient.

There are several commercially-available insecticides that can be used for this purpose. These are broadly classified into two groups, organophosphates (OP) and pyrethroids (P) (see Box 1). Each chemical is known by a common name and a commercial name. Although common names remain constant the commercial name changes depending on which company is marketing the product.

Some of these chemicals, such as dichlorvos, are highly volatile and give off a lot of chemical vapour. These are particularly useful for flushing insects out of cracks and are also used for spraying or fogging the air space in stores to kill flying insects especially adult moths. OP and P chemicals are often used together to control different

**BOX 1 INSECTICIDES AVAILABLE FOR SPRAYING SURFACES**

| Common name | Commercial name |
|---|---|
| *Organophosphate (OP)* | |
| Pirimiphos-methyl | Actellic |
| Chlorpyrifos-methyl | Reldan |
| Fenitrothion | Folithion; Sumithion; Accothion |
| Dichlorvos | Nuvan; Vapona |
| Malathion | Cythion; MLT; Agrothion |
| *Pyrethroid (P)* | |
| Permethrin | Ambush; Talcord; Eksmin |
| Deltamethrin | K-Othrine; Decis |
| Fenvalerate | Sumicidin; Fenkill; Sumitox |
| Bioresmethrin | Isathrine |

insects; the former are particularly effective in controlling weevils whilst the latter are better at dealing with borers, especially the larger grain borer. Diatomaceous earths (DE) are not suitable for treating store fabric in this way prior to fumigation as their rate of activity is too slow to ensure rapid kill; but they can be used to provide persistent, residual protection.

These chemicals, especially the organophosphates, have high or moderately high mammalian toxicity, so great care must be taken when they are handled. Gloves must always be worn when handling concentrates as should other protective clothing, such as overalls and boots, during spraying. During any spraying operation a bucket of water must be close to hand to pour over affected areas that become contaminated accidentally. Spraying should never be undertaken by a single person, a second individual must be present to ensure remedial measures are put into place in case of accidents. A summary of safety considerations is given in Box 2.

**FIGURE 21** A space sprayer in position on the roof lintel

**FIGURE 22** Fogging a store

## CONTROL OF RODENTS AND BIRDS

Stored grain and grain products must also be protected against rodents and birds. This may be almost impossible to achieve if doors are left open. Even when closed, rodents may still gain access if there are gaps between doors and walls, if ventilators are left open, through gaps in the roofing and through entry points for cabling

**BOX 2 SAFE USE OF CONTACT INSECTICIDES**

- Always read the pesticide label and follow the instructions
- Wear clean and appropriate clothing; gloves are essential; a face mask is advisable but if not available a clean piece of cloth should be tied over the mouth; boots should be worn, trousers should be worn outside the boots; a face shield is useful to protect eyes
- Always keep insecticides under lock and key and when in use, never leave bottles unattended
- Never transfer insecticides to other containers, particularly soft drink bottles
- Never reuse insecticide containers for other purposes; dispose of empty containers, ensure they cannot be reused
- When working with insecticides do not eat or drink, do not rub your eyes, do not smoke
- Keep food and drink away from insecticides
- Have plenty of soap and water available, and a change of clothing
- Always wash after handling insecticides
- Destroy heavily contaminated clothing; after spraying wash clothing and protective gear
- If spills occur wash the area immediately; wash off any dribbles that might have contaminated the outside of the insecticide container and any vessel used for dilution
- Nobody except those involved in the insecticide application should be allowed in the store whilst spraying is in progress; nobody should be allowed to handle insecticide containers except authorised personnel
- Workers should be made to cover their feet to prevent contamination from the floor
- The electricity supply should be turned off before spraying begins
- Excess spray solution should be applied to the walls or floor

and ducting. Similarly, birds are able to enter through ventilators and doorways. To prevent entry, all gaps should either be filled in with cement or fitted with wire netting. If doors have to be left open they should be fitted with a metal kick plate which will prevent rodents from gaining access; a flexible curtain will keep out birds.

Thus it is important to manipulate the environment to restrict access by these pests. Water and food are essential for rodents and birds so that by restricting availability the pests will look elsewhere. This of course is very difficult to achieve around buildings holding grain and grain products. However, it is possible to restrict access by proofing, which prevents pests from accessing the food in the store or mill. This has to be undertaken by manipulating the surroundings outside of the store as well as managing conditions inside.

**FIGURE 23** Screening a drain pipe to prevent rodent entry

All holes in the fabric of the building must be blocked up, either with cement or with wire netting; the netting must be fine enough (5mm

or less) to prevent small mice gaining access if these are known to be present in the vicinity. Doors must not have gaps larger than 5 mm and if a kick plate is fitted it should be a least 1 m high to prevent rats jumping over. The ends of rainwater pipes should be fitted with mesh, and down pipes, for rainwater and electrical cables, should be fitted with metal baffles to prevent rodents climbing. Debris and vegetation must be cleared away from the sides of buildings. A trench 30 cm depth and 20 cm wide should be dug around the exterior walls and filled with fine gravel. To prevent rodents tunnelling, a concrete layer 10 cm thick and extending 60 cm below ground, with the base turned out to form an L shape for 50 cm should be laid. Food spillage must be immediately removed and sources of water either proofed, turned off or removed.

It may not be feasible, because of the design of the premises or their location, to put into practice all of the requirements to make a building rodent proof. Nevertheless, it is important to try as far as possible to achieve this aim. If the store is adjacent to other storage buildings, such as in a market, it is essential that all the stores be treated together because if one is left unproofed it will become a magnet for pests and will facilitate access to all the other stores.

Cleanliness inside the store, the separation of stacks and the removal of non-food items will assist in keeping rodents out. However, this may not be sufficient to prevent losses and it may be necessary to use rodenticides.

Unlike insecticides, which work simply on contact, rodenticides must be ingested to exert their effect. Rodenticides fall into two main groups, acute and chronic poisons. Acute poisons have been in use for very many years. They kill the target very rapidly, perhaps in a matter of minutes or hours. The effect can be very dramatic as the rodent dies out in the open and is visible. However, many individuals will not be affected so that damage and nuisance levels will remain significant, especially as the rodent population will quickly recover. Acute poisons may be of use in rapidly reducing a population so long as mass baiting is done. These chemicals are cheap, widely available and commonly used.

All rodenticides must be offered in the form of a bait. It is generally useful to lay down bait before adding the rodenticide to allow the rodents to familiarise themselves with something new in their environment. Many rodent species, especially the house mouse, are neophobic, suspicious of and avoiding new objects, so they must be allowed to become used to objects. Even when they begin to eat bait, they may only nibble at it and consume a sub-lethal dose. The acute poison will cause unpleasant feelings that will prevent further feeding in the future, the rodent becoming 'bait shy'. Pre-baiting will allow the rodent to become familiar with the bait but may take several days and even weeks with house mice. Even so, it remains difficult to achieve complete mortality with acute poisons.

There are some compounds, sub-acute poisons, which are similar to acute poisons but where the symptoms are slower to appear. A lethal dose may therefore be consumed in several feedings rather than in a single meal. Death may be delayed for several days.

Chronic poisons are all anticoagulants. Death may occur in 2-3 days but more usually in 7-8 days. The discomfort felt by the rodent is much less than with acute poisons so that feeding will continue unabated, until death occurs. However, it is necessary to ensure that the bait is placed correctly so that it is consumed by the rodents regularly. Therefore, care must be taken to ensure that rodents are given the best opportunity to feed; the bait must be sited optimally. When rodents regularly feed nest partners, young and adults will be encouraged to feed in the same location. Furthermore, rats like hoarding and often take bait back to the nest to eat in familiar surroundings, where others may share. In this way, it is possible to achieve 100% kill in a target population.

Warfarin was the first chronic poison to be marketed some 50 years ago. Others quickly followed but there is now widespread resistance to most of these early, first generation chronic rodenticides. More toxic, second generation compounds have largely superseded earlier chemicals but there is increasing evidence that rodents are becoming resistant to these as well. It is therefore important to ensure that the application of rodenticides is as efficient as possible and is carried out by a trained pest control operator.

There are a number of ready-made edible baits available including loose cereals and other foods, pellets, wax blocks, gels and pastes. Soluble forms of rodenticide may be added to water, useful in food stores where free water supply is usually absent. Loose baits are perhaps the most effective but have to be used with care especially in food storage and preparation premises. It is probably most efficient to buy the rodenticide concentrate and mix it in with whatever food is locally available and cheap. Great care must be taken doing this as concentrates are themselves highly toxic. Rodents are mammals like man, and any chemical toxic to rodents will also be toxic to man.

**BOX 3 RODENTICIDES**

**ACUTE**
Alphachloralose
Mono sodium fluoroacetate
Fluoroacetamide
Red squill (extract of plant Drimia maritima) or purified as Silmurin
Thallium sulphate
Zinc phosphide

**SUB-ACUTE**
Bromethalin
Calciferol

**CHRONIC *(2ND GENERATION)***
Defenacoum
Bromodialone
Brodifacoum
Floucamfen
Difethialone

Baits can be laid directly on rodent pathways either loosely or placed on trays, in bait boxes or containers. The use of a closed container will prevent bait being disturbed in public areas, where people work, such as in stores or mills. In these locations it may be useful to provide a source of water next to the bait as an attraction to rodents.

Untreated baits can also be used in rodent traps. There are two types of trap, those that kill and those that capture. Kill traps are 'break back' traps (Figure 24) in which a spring, released by the activity of the rodent, is released and drives down a metal bar, breaking the back of the rodent. Live traps entice the rodent into a cage from which it cannot leave (Figure 25). There are many designs but all are passive, depending entirely on the behaviour of the rodent. Many rodents are 'trap shy'. Traps may play a part in controlling the population in a store but it is likely they will lose their appeal over time; traps should be moved to different locations to counter the learning capability of rodents. Their main advantage is that they are non-toxic and will not contaminate the food store.

Birds enter stores and mills to gain access to food. Their main deterrent is to ensure that no food is available. It is vital, therefore, that all spillage of grain, flour or feed be swept up as soon as possible and taken out of the building for disposal. However, birds can easily make holes in sacks of grain, flour or feed and action must be taken to deprive them of the opportunity of doing so. For most small to medium sized stores the most effective way of preventing damage by birds is to exclude them from the premises by fixing wire netting over entry points, for example, ventilation openings. Plastic or metal curtains can also be affixed to doorways to prohibit bird entry,

FIGURE 24 Rat being enticed to a break back trap by loose groundnuts

particularly useful where the door has to remain open for long periods.

## CONTROL OF MOULDS

Fungi gain access to grain through openings created by damage due to poor handling. They gain easier access to flour and feed as the 'openings' are purposely produced by the milling process; finely divided foods are relatively easily invaded by fungal spores.

Physical damage usually occurs in the field just before or during harvesting, then during threshing and winnowing. By the time the grain enters the store it may well be infected with fungal spores or even by fungal mycelia, which are recognised as mould growth. Spores germinate and moulds grow because the water activity of the host is sufficient to allow development. In humid conditions mould growth will occur quickly, less so in dryer climates. Flour and feed readily pick up moisture from the air, much more easily than grain, and thus provide an excellent substrate for moulds. Flour will go mouldy much more quickly than grain so it is imperative that flour is not stored too long, unless it is packaged in a non-porous container, such as a plastic bin or in polythene lined sacks. However, flour must have a water activity below 0.7 so that it does not release water to condense on the inside of the container. It is generally recommended that flour or feed are stored for no longer than two weeks in moderately hot and humid conditions and even shorter where the relative humidity exceeds 80%.

FIGURE 25 Rats in a live trap

The most common way to prevent mould is to dry grain down to a 'safe' moisture content. At 27°C, the lower limit of water activity that will permit mould growth is 0.7. This is equivalent to an equilibrium relative humidity in the air of 70%. For cereal grains this is a moisture content of 13-14%, for pulses 11-13% and for oilseeds such as groundnuts 7%. If grain is found to be wet at the point of purchase it is usually rejected. If the grain takes up moisture during storage then it must be dried artificially by the store owner.

However, mould growth can also be prevented by reducing the temperature of the grain. This can be achieved during storage by ventilating the stock, either using natural aeration or by forcing air through the commodity using a fan. Although this can be achieved in temperate climates – maize can be stored for a year at 15% moisture at 15°C – it is not so easily achieved in tropical countries; at 15% and 30°C maize would only last three months. A system for aerating a bag stack is illustrated in Figure 26. Drying depends on the moisture content of the air in the store as the system is dependent on aeration alone, there is no artificial drying. Drying bags is dif-

ficult because the air tends not to pass through the intergranular spaces but rather between the sacks, the line of least airflow resistance. However, the system is convenient because the grain can remain in sacks. For artificial drying grain must be unloaded from sacks, placed in the dryer and then put back into sacks after drying. Even grain stored in bulk must be shifted to a dryer.

There are many types of artificial dryer each designed for different throughput rates. A detailed description of all the types is beyond the scope of this booklet but a summary of the main types is given below.

Tray dryers: Tray dryers, sometimes called flat bed dryers are the simplest of the batch dryers. Grain is loaded onto mesh trays within the dryer to a depth of 600 to 700 mm and warm, dry air is blown through the trays until the grain has been dried sufficiently.

Radial dryers: The basic design of the radial drying bin consists of two vertical metal mesh cylinders, one inside the other (Figure 27). Grain is loaded into the space between the two cylinders and air is blown into the inner cylinder, from there, it passes through the mesh wall and the bed of grain, and out of the outer mesh wall. Air can be sucked out of the central cylinder, reversing the air flow through the grain. These dryers are popular, but there is a risk that grain nearest to the inner cylinder can be over-dried as this is where hot, dry air first makes contact with the grain. Grain towards the outside, where the air leaving the grain, is cooler and wetter. Transportable dryers can be rented out for occasional use; this makes drying affordable for even small-scale farmers who do not have sufficient capital to purchase a dryer of their own.

Continuous flow dryers: These are designed to remove moisture from the grain rapidly by blowing or sucking hot air through the grain as it passes through the system from top to bottom. The simpler designs of continuous flow dryers have a holding bin on top of the tall drying section. A final cooling section, where air at ambient temperature is blown through the grain is usually incorporated at the base of the dryer to avoid conveying hot grain into the rest of the system. The bed of grain may be vertical, horizontal or inclined. Grain may be moved by vibration, scrapers, conveyors, or by gravity. The degree of drying is determined by the rate of grain flow through the dryer, and is usually controlled by varying the speed of outlet conveyors or the size of the outlet itself.

Tower (mixed-flow) dryers: These dryers resemble tall rectangular storage bins, fitted with a large number of horizontal, triangular shaped ducts across the width of the dryer. Approximately half of these ducts introduce warm, dry air into the grain whilst the others remove the cooled, damp air. Grain is fed in at the top and passes down, around the ducts, by gravity. With the dryer full of grain, the grain moves slowly down through the dryer, first through the drying section and then a final cooling section using ambient air.

Louvered-bed dryer: This dryer is similar in design to the tray batch dryer except that the grain is dried as it passes over louvered-beds through which heated air is blown rather than being dried in situ. The depth and speed of the moving bed of grain is controlled to determine the degree of drying. There are two basic designs, the cascade dryer and conveyor dryer.

FIGURE 26 **Ventilation of conventional bag stack**

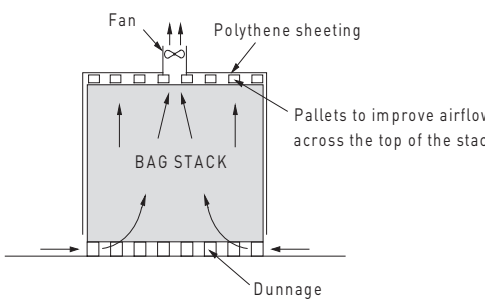
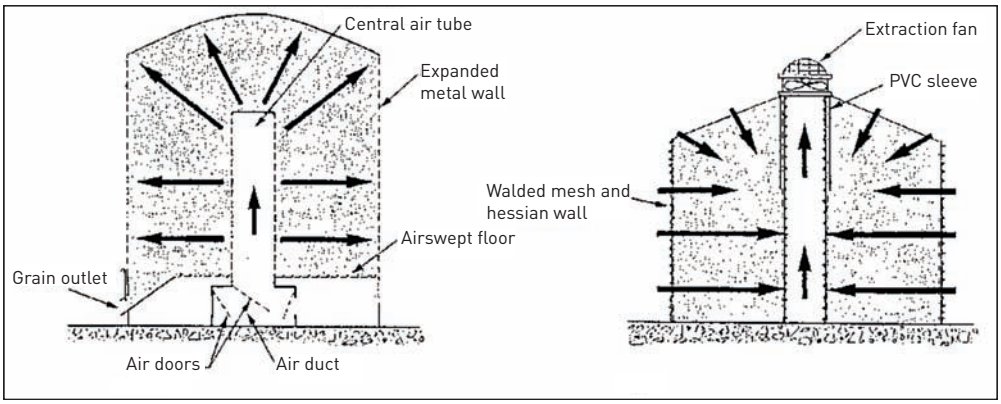


FIGURE 27 Operating principle of simple radial drying bins




The cascade dryer is a gravity fed cross-flow dryer with grain depth controlled by a series of roller dams along the length of the louvered-bed. The degree of drying is controlled by the speed of the output elevator. To avoid excessively long lengths, larger dryers may involve several changes in direction of grain flow.

In conveyor dryers grain is also supported on an inclined louvered-bed through which air is blown, but grain flow through the dryer is by a variable speed, heavy duty, roller chain conveyor. These dryers may be single-directional, two-directional or multi-directional. The changes in direction of grain flow mixes the grain, allows some of the dried waste material to be blown from the grain and reduces the overall size of the machine.

FIGURE 28 Operating principle of a single direction cascade dryer