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THE RESPONSE OF THE SILO MANUFACTURING INDUSTRY IN AUSTRALIA TO THE SEALING OF TRANSPORTABLE GRAIN SILOS

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ABSTRACT

Research in Australia in the 1970's suggested it was possible to seal farm-grain storages to create an environment in which fumigation would be effective. The information was communicated to all government advisory agencies across Australia for dissemination to manufacturers and users of grain silos. In 1982 in Western Australia this information was transferred by the Agriculture Protection Board through its extensive network of officers. Sealing standards were recommended to silo manufacturers and advice on the best fumigation practice was communicated to farmers. In the eastern states of Australia the extension network, although comprehensive, relied on individual efforts by advisers to create transfer opportunities.

In Western Australia sealing techniques were adopted by all manufacturers. The economics of manufacturing and the requirements of purchasers influenced refinements in design. In the eastern states of Australia, advice was acted on by only some manufacturers as there was low demand for sealed silos from growers. Later campaigns to stimulate interest in the production and use of on-farm sealed grain storages created interest in better fumigation techniques. The stimuli for a change to sealed silos and the developments in silo design are discussed.

INTRODUCTION

The silo manufacturing industry in Australia has undergone gradual change as the technology for sealing grain storages (Banks and Annis, 1980) has been adopted. Andrews *et al.* (1994), summarising the barriers to adoption of on-farm sealed silos, cited, among other reasons, the availability of contact insecticides in most Australian states, the lack of extension material and resistance to change.

Dean (1994) provided an overview of the Western Australian (WA) approach to integrated grain protection in which these barriers were overcome by restricting the availability of contact chemicals and providing good extension. Silo manufacturers were encouraged to experiment with modifications to existing manufacturing methods to create a sealed silo. Because in 1982 the extension campaign exerted influence on growers to request sealed storage from manufacturers, demand created supply.

In the eastern states of Australia (New South Wales, Queensland, Victoria and South Australia) the technology to create sealed structures was promoted, but it was not widely adopted by manufacturers. Early extension work was characterised more by individual effort than by a co-ordinated statewide approach. The initial publicity encouraging growers to switch their insect-control techniques from contact chemicals to fumigants did cause some demand for sealed silos, and subsequent extension work relied on generalised references to the use of sealed storages, newspaper articles, pamphlets (B.E. Wallbank, 1995, personal communication) and the manufacturers' own advertising. Some opportunities were created by individual officers in state departments of agriculture. Through the media of grower groups, field days and articles, the use of sealed silos was promoted among a wide range of grain management techniques (P. Botta, 1995, personal communication).

Later campaigns by the Grains Research and Development Corporation (GRDC) encouraged manufacturers to switch to the production of sealed silos by 1996. Commitment was achieved when manufacturers agreed to offer sealed silos as part of their range although not as their entire line. The grower-targeted campaign GRAINSAFE was outlined by Andrews *et al.* (1994); it had a significant impact on the adoption and understanding of the sealed-silo option. Despite widespread endorsement by growers, silo manufacturers and extension workers, due to lack of commitment in terms of funding and staff resources (A.S. Andrews, 1996, personal communication), the momentum of the project was not maintained.

In the eastern states, both the commercial availability of contact chemicals and anecdotal evidence circulating in the farming community about moisture problems in sealed silos remain a barrier to change. A much wider use of aeration and perceived problems in maintaining sealed storages in working condition have reduced the demand for fully sealed silos. Manufacturers, who are not committed to the production of sealed silos, suggest that the phosphine metering system, SIROFLO®, is the solution to grain insect control in silos.

SILO MANUFACTURERS SURVEYED

A telephone survey of 30 manufacturers across Australia, all members of the Australian Silo Manufacturers and Grain Storage Association Inc., revealed the different approaches to extension taken by the various states.

In WA, where the use of sealed silos was strongly promoted, manufacturers reported that sealed silo production comprised 80 to 100% of their total silo production, including speciality silos for fertiliser and finely divided grain products. For on-farm storage of whole grain, sealed silos now comprise 100% of production. Problems arising from the use of sealed silos are usually answered promptly or passed on to Agriculture Western Australia.

In the eastern states, sealed-silo production as a percentage of total production varied among manufacturers from 1 to 100%. Many manufacturers expressed doubt about their ability to answer growers' queries concerning grain management or fumigation in sealed storage and said that they did not have ready access to a source of expert advice.

The survey asked questions, discussed in greater detail below, about silo design and construction.

THE CHANGE TO SEALED SILOS

Some manufacturers effected change quickly. These manufacturers were usually those already producing a silo close to a sealed standard such as silos that were fully welded or had sealed eaves. Some manufacturers took 12 months to modify the design so it would accept a sealant to produce a durable seal. Modifications continue to be made in response to both buyers' requests and the economics of the construction process. Enthusiasm for the concept of sealed storages among the manufacturers surveyed varied, some endorsing and some rejecting the idea. The attitude of each manufacturer was usually related to the design of his original silo. If the silo was too difficult to re-design, it was decided not to change it so long as sales remained steady. In WA this was the decision of one manufacturer. The extensive publicity campaign in that state, however, caused consumers to switch to sealed silos, and that particular manufacturer's sales plummeted; silo production is now a minor part of that enterprise.

Wall construction

Most manufacturers of transportable sealed silos in Australia use either fully-welded or riveted-wall construction methods.

The majority of the walls of transportable sealed silos are riveted. They are made from 1–1.2 mm galvanised steel sheeting or ZINCALUME® (aluminium/zinc coated steel sheeting). The steel, purchased in coils, is passed through a series of rollers to create a circle (Fig. 1). During this process, indentations (such as ribs for rigidity or a flange to lock consecutive wall sections together) are pressed into the sheet. The ends of the sheet are overlapped by approximately 150–200 mm to form a ring and then riveted. Fully welded silos use a thicker, 1.6–2 mm, steel and the formed ring is butt-welded. Transportable sealed silos range up to 190 m^3, with an average farm silo being about 64 m^3.

A silo is usually constructed by joining a completed ring to a finished roof section; the joined sections are then lifted and the next wall ring moved underneath for fixing. One manufacturer, however, constructs the silo barrel from narrow coils of sheet steel in a continuous lock seam, starting from the completed roof and forming the walls in a spiral.

Silos that are manufactured for on-site erection use short curved wall sections which are punched, curved and ribbed prior to delivery and then bolted into a circle before being joined to the completed roof.

In WA 40% of manufacturers use the flange/cap system of wall joining. In the rolling process both edges of the sheet are turned down at an angle of 120–90°. When joining two

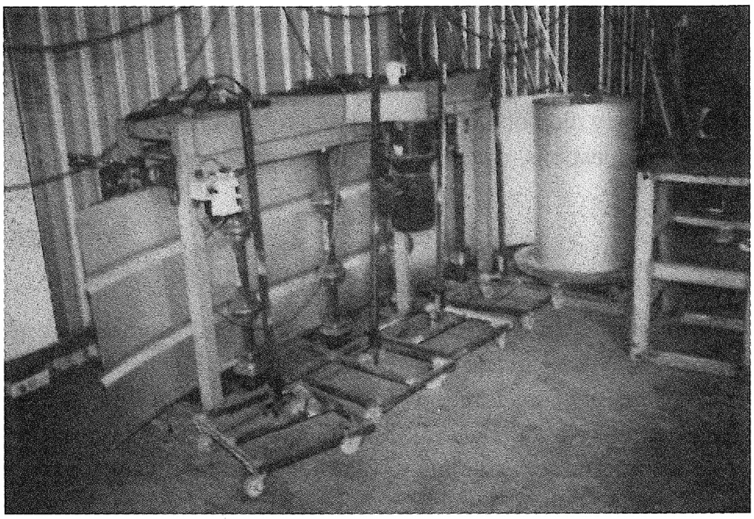

Fig. 1. Rolling machine used to form the silo sections.

consecutive rings, rivets are punched through the flange and cap on the outside of the wall and sealant pressed into the natural vee that is formed on the inside (Fig. 2). The alternative wall-jointing technique is to overlap consecutive sheets about 50 mm and rivet through. The sealant may be applied either between the sheets or over the top of the completed join (Fig. 3). Some manufacturers use high-tensile, sealed, lock-stem rivets, while others use a two-piece swaged-rivet fastening system that requires two people to

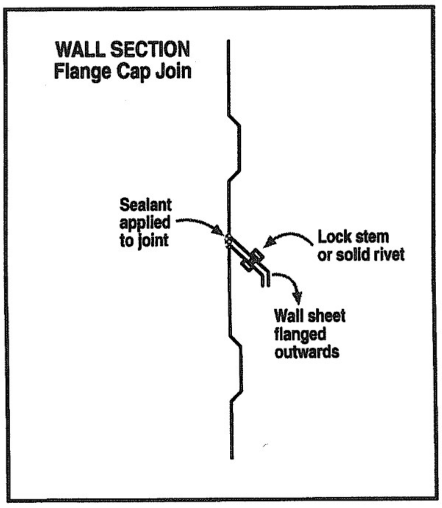

Fig. 2. Wall section, flange cap join.

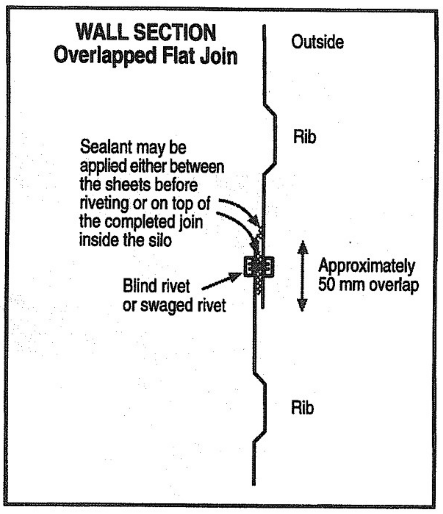

Fig. 3. Wall section, overlapped flat join.

install, one to place the locking nut on the inside before the bolt is pulled through into place and the other on the outside.

Flat floor silos, ranging up to 1,280 m^3 for on-farm use, are constructed by assembling the roof section and then raising the structure on jacks before bolting on the lower sections. A sealing kit, offered as an optional extra, can be fitted during construction. A more expensive alternative is to seal the silo externally or internally with sprayed-on membrane-type paint.

Elevated on-farm silos constructed on site usually have a capacity of 128–833 m^3. The cone base is transported to the site in sections and either welded or bolted together. Because ZINCALUME® is not available in thicknesses over 1.2 mm, the silo walls are typically constructed from 1,200 × 2,400 mm plates of flat, galvanised 1.2–2 mm sheet steel. The silo is again constructed roof first, but it is then raised by a mobile crane to enable the fixing of the cone base to the last ring (Fig. 4). Silicone is applied between the joints and the bolts are sealed with a neoprene washer.

Roof construction

Silo roofs are either segmented, lock-seamed or fully welded. The traditional segmented style is commonly found on vertical silos in Australia. It is a strong roof and does not require bracing except over a very wide area, but a higher labour input is needed to seal the individual segments. A development of this style is the fully lock-seamed roof that has fewer joins to seal but requires additional support for strength (Fig. 5). The choice of roof appears to depend largely on the construction preferences of the particular manufacturer. The factories that have adopted a lock seamed style claim the roof is simpler,

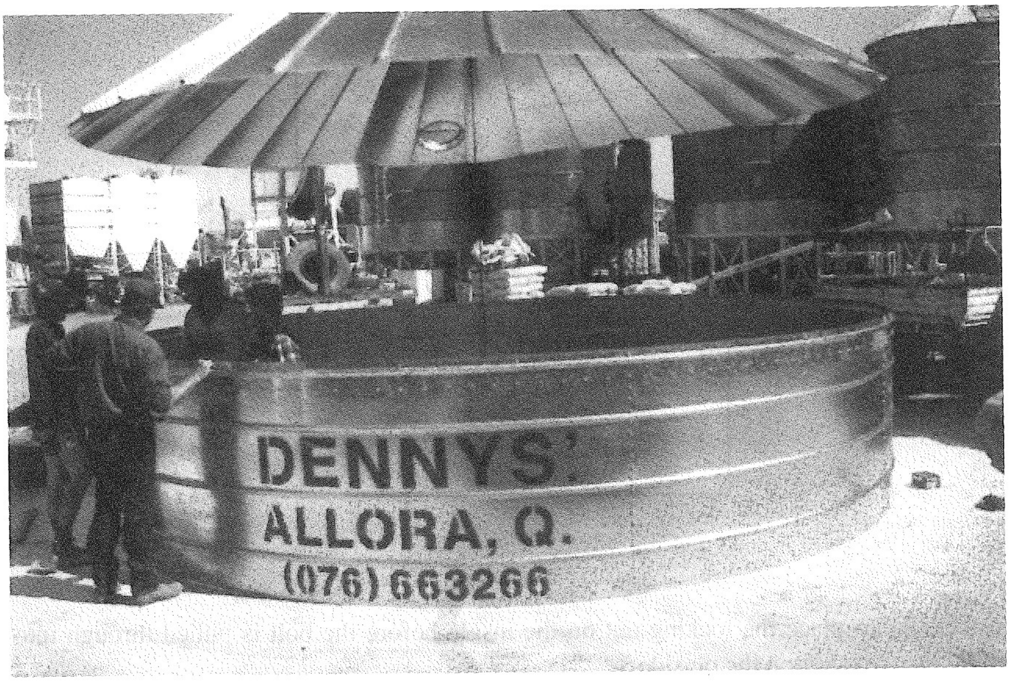

Fig. 4. Assembling silo section on site before joining to the roof.

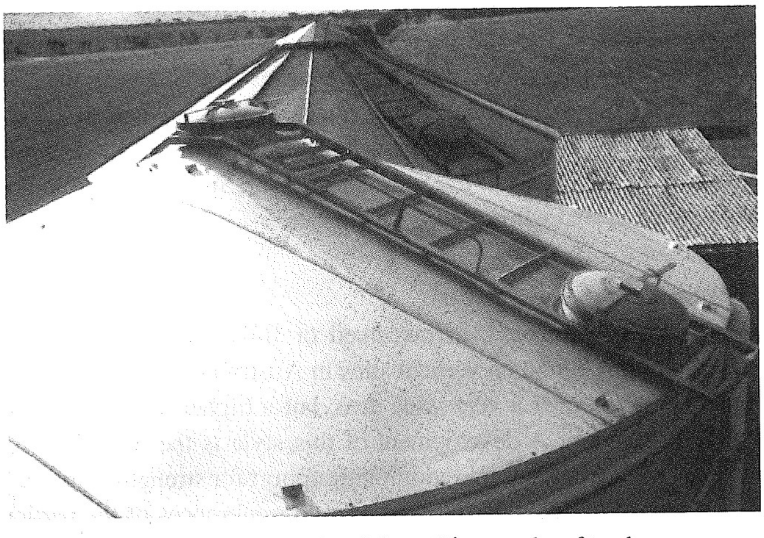

Fig. 5. Lock-seamed roof-front. Sègmented roof-track.

more economic to construct and easier to seal. The manufacturers that construct a segmented roof contend that it is more convenient to their operation and that sealing presents no problems.

Cone-base construction

Almost all transportable elevated steel silos made in Australia have a fully welded 1.2–2 mm sheet steel base. One manufacturer in WA is producing a lock-seamed cone base with some welds for support. The majority of silo manufacturers use sheets of hot rolled steel; the rest use galvanised sheet steel. Some manufacturers in the eastern states have developed automatic devices to weld the seams of a galvanised cone base. The support frames vary considerably in design and materials. A large proportion of manufacturers use SILO TUBE® as the upper support ring. This is a modified rolled hollow section (RHS) tube, made from black or galvanised steel, designed for use in silo construction. One edge is angled to allow better sealing of the cone to the wall sections. Sealant is applied on the inside in the angle formed by the joint (Fig. 6). The base support ring may be made of rectangular RHS. Some support frames use galvanised pipe for the upper and lower rings. The legs, of the same material, are crimped at each end for ease of welding to the pipe curve. A few silo base frames are made with curved angle irons for the upper support ring, and some have a bar of flat steel curved around the silo to which the legs can be welded.

Heat reduction

Hill *et al.* (1989) investigated steel silo-wall materials to find out which reflected the most solar radiation, thus reducing the internal temperature. They found that a white coated sheet-steel silo provided the most reflection and that a weathered galvanised silo

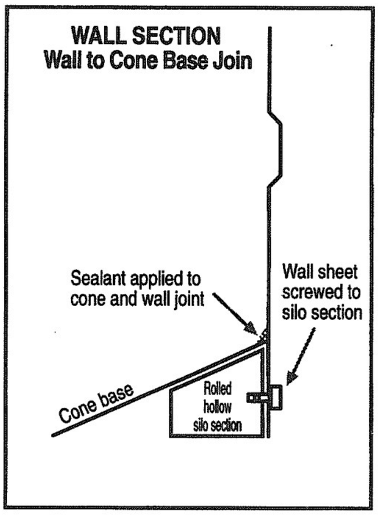

Fig. 6. Wall section, wall to cone base join.

was most absorptive of solar radiation. ZINCALUME® was rated close behind white steel sheeting.

Most manufacturers of silos in WA have changed their silo wall material from galvanised to ZINCALUME® steel sheeting. A white silo is not offered as part of the range for sale because, manufacturers point out, they are more expensive, and in addition the colour is often damaged in transit which results in the delivery crew's being delayed while the paint is repaired. Despite the research and extension to outline the advantages of a white silo, few farmers in WA have painted their silos either because the paint has to be maintained or because ZINCALUME® retains its reflective ability for many years. Silos are usually painted white only when existing farm silos are sealed.

In the eastern states of Australia, ZINCALUME® is used by a smaller number of manufacturers but still represents a significant portion of the market. A few manufacturers build a fully welded silo from hot rolled steel which is then painted white. Others construct riveted, galvanised silos and offer a painted white silo as part of their range. One manufacturer offers part of its range of silos in white COLORBOND®. Overall demand for white silos is, however, low.

Inlets and outlets

Most manufacturers of sealable silos use inlet ports of a similar design. The lid is spun from a single sheet of galvanised steel. The ring or band on which the lid sits may be a single spinning or a rolled band with a welded seam. Rubber stripping is affixed to either component to create a seal (Fig. 7).

The design of the outlets is influenced by the users of the silo and varies considerably. In WA some manufacturers produce a fully sealed rotating boot for the lower outlet; others construct a simpler fixed, sealed design (Fig. 8). The outlet boots are sealed with rubber stripping when the door or lid is closed. A recent trend in WA has been the production of an optional removable hopper, but in eastern Australia it is more common for silos to have a separate auger hopper.

The grain control is most commonly a slide gate, but some silos are fitted with a butterfly valve operated by a remote lever system (Fig. 9). Where a boot is fitted, the control is located inside it and may be operated externally or internally.

All elevated steel silos are now fitted with a safety access hatch in the cone base facilitating cleaning when the silo is empty. In New South Wales this is a mandatory requirement, and all other states have followed voluntarily. The hatch is fitted inside the cone base and may only be opened when the silo is empty, thus preventing accidental discharge. The silo can be cleaned from this base hatch, partially obviating the need for an internal ladder. Some manufactures are now removing internal ladders entirely and fixing a permanent guard in the upper hatches to prevent personnel entry.

Seals and sealants

Strips of rubber are used to seal the inlet ports. The type and shape of the rubber used varies considerably among manufacturers. The most common is the rectangular

Fig. 7. Spun lids with rolled welded band.

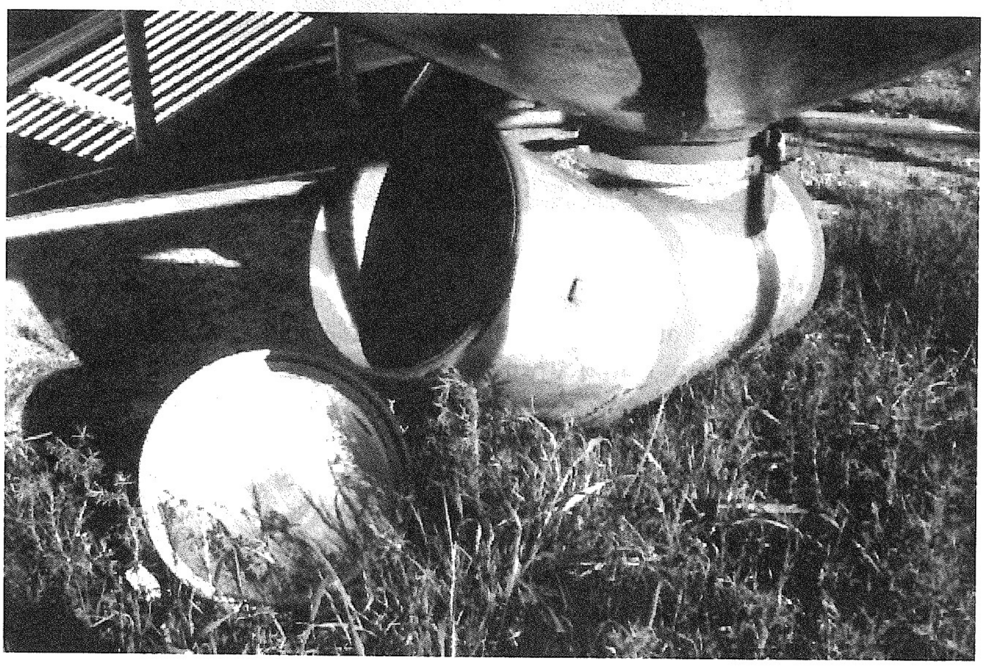

Fig. 8. Sealed rotating boot with internal grain control.

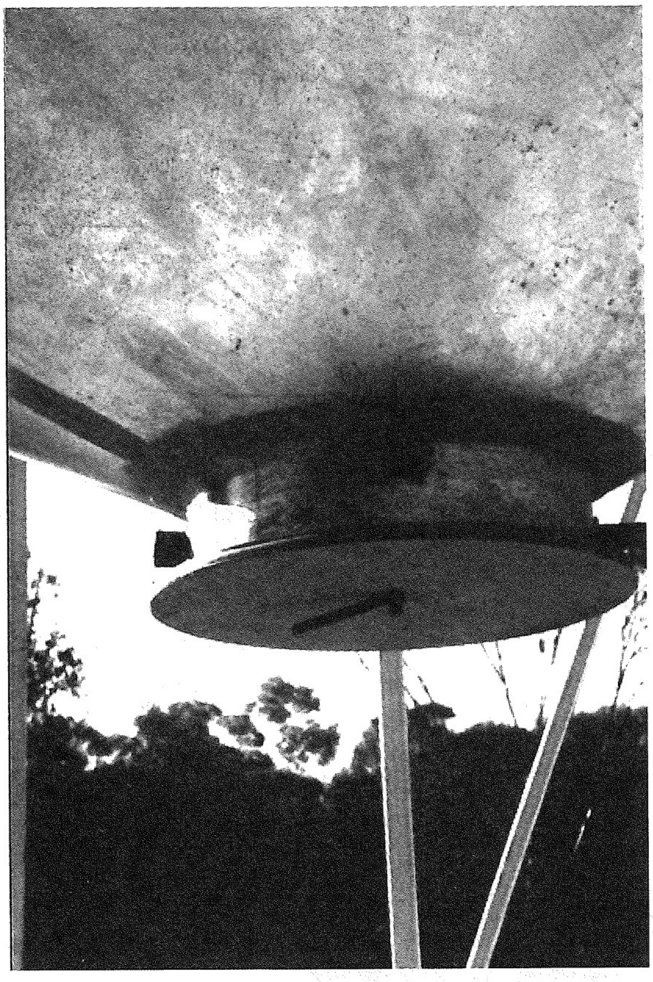

Fig. 9. Sealing plate for a butterfly grain control.

section. Others are round, and some manufacturers use a split section to fit over the ring or band. Some silos are delivered with a polyester foam rubber strip which needs to be replaced at least annually. More durable is the EPDM (Ethylene Propylene Diene Mixture) type of foam rubber that is being used by an increasing number of manufacturers. The outlet ports are fitted with a variety of rubber profiles to create a seal. Flat sheet rubber is used on grain control slides equipped with a levering or bolting device to create pressure on the silo. Most manufacturers seal their silos with a silicone-based neutral cure-caulking compound. Other commonly used sealants are of the polyester adhesive/sealant type. A few manufacturers use spray-on flexible membrane paints, but these are primarily confined to use in later sealing of existing on-farm silos.

Pressure relief valve types and position

The positioning of the pressure relief valve has a bearing on the speed at which air can be drawn into the silo under vacuum conditions which may occur in a thunderstorm on a hot day or during outloading. A valve fitted into the upper wall of the silo, giving the most rapid compensation, also allows faster dilution and loss of fumigant gasses. In this position it is also difficult to see the oil level in order to check the half-life pressure-decay test.

A valve fitted into the lower wall of the silo below grain-load level gives slower air compensation on demand but reduces the dilution of fumigant gasses to a minimum. It has also been suggested that when the silo is under fumigation the lower valve provides a haven for insects due to some admixture with outside air (P.C. Annis, personal communication, 1995).

A compromise between the valve-placement options is a low-set valve with a tube leading into the headspace. This position, due to its remote location, reduces admixture of the headspace gasses. The valve is also more accessible and easier for the operator to read, particularly when he is conducting the annual check of the silo to determine its gastightness.

Of the silos purchased as sealed which were tested by Newman (1994), only 27% passed a standard gastightness pressure test (a half life of 3 min for a full silo and 5 min for an empty silo from a 25-mm head of water gauge). The silos that passed this test were found to be less than 3 years old (Newman, 1989). It was estimated that less than 1% of silo owners test their sealed silos annually for gastightness.

Most manufacturers place the valve where it is convenient to their manufacturing process or where it will be protected from damage when installed.

The most commonly used pressure-relief valve is the box type with a double interconnecting chamber (Fig. 10), made and supplied by plastics manufacturers in various designs. Valves constructed by silo manufacturers tend to be of the PVC tube-and-fittings type (Fig. 11).

During outloading, the pressure relief valve alone is not large enough to allow air inflow without risking the collapse of the silo roof. Several roof collapses have been reported in WA. Operators must open the loading hatch or else fit a vacuum-relief valve large enough to allow sufficient air into the silo when outloading.

Moisture in sealed silos

Most manufacturers report a few complaints from growers about moisture in a sealed silo. Investigation of the problem usually reveals that grain with a higher than acceptable moisture content (m.c.) was stored or that, because no fumigation was conducted at inloading, insect activity has increased. If it is instead found to be a manufacturing fault, the silo is either repaired on site or replaced.

The author investigated a typical complaint from a grower that high moisture occurred in a sealed silo several months after inloading. Two silos were tested for grain m.c. which was found to be just below 12%. Phosphine (PH_3) tablets were added at the recommended rate of 1.5 g/m^3 and the silos monitored over 6 months. The m.c. remained almost constant

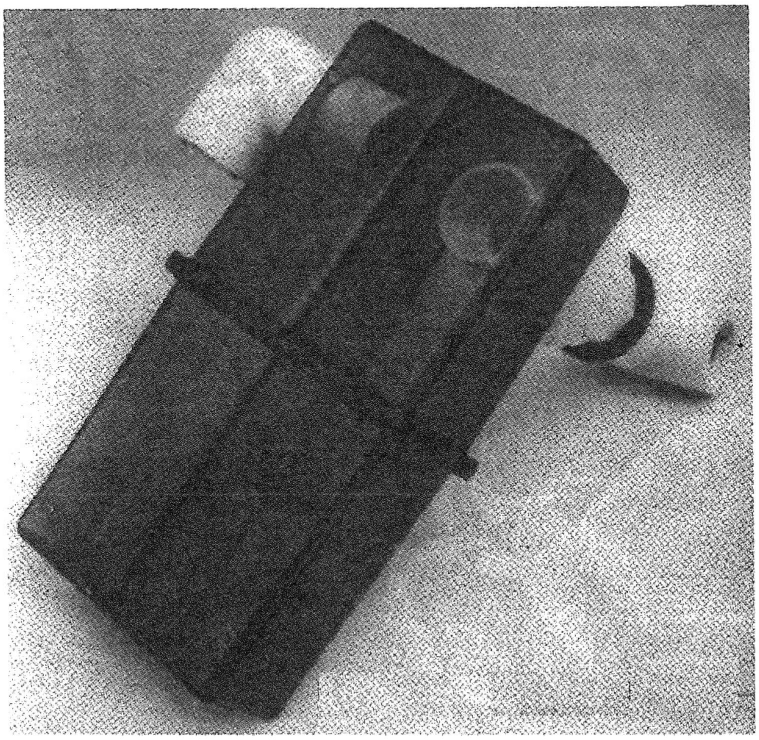

Fig. 10. Box-type pressure relief valve.

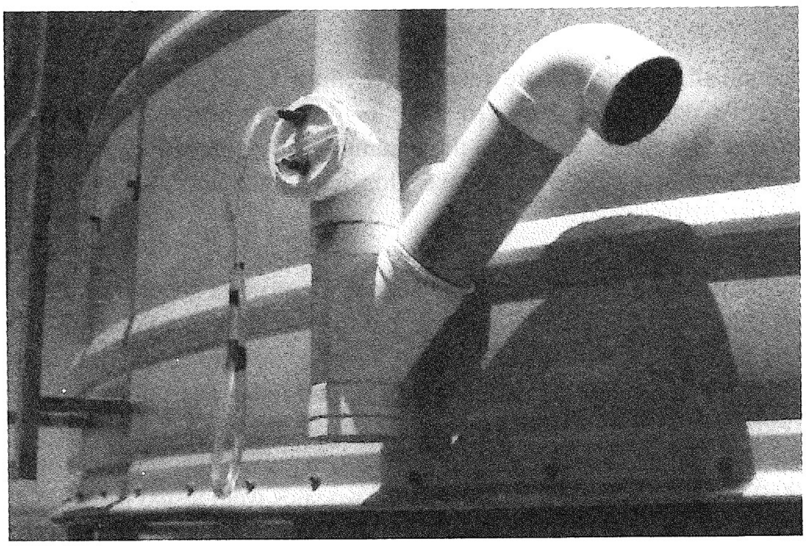

Fig. 11. Example of manufacturer-constructed PVC relief valve connected to the headspace.

in both silos with only minor fluctuations in humidity occurring in the headspace. Prior to this simple test, the grower had been applying PH_3 at the rate of a few tablets per truckload (7 t grain), and he did not possess a moisture meter.

Unless growers can guarantee that grain will be harvested at or below the recommended m.c., silo manufacturers now suggest the addition of a sealable aeration unit to the silo in order to equalise grain temperature and moisture levels and prevent moisture migration.

EXTENSION LITERATURE

Since the inception of sealed silos, government departments across Australia have produced a variety of pamphlets to advise farmers on their correct use and on the management of the stored grain. Manufacturers have produced information on the features of their own silos with additional limited information on grain management and sealed-silo maintenance.

In 1991 WorkCover Authority of New South Wales produced a Code of Practice for the safe design, manufacture, installation and operation of on-farm silos. It is anticipated that a 'code' similar to this will eventually be adopted by statutory Health and Safety authorities around Australia. Under this 'code' manufacturers must provide instructions for the safe operation of their silos. Newman (1995), in consultation with manufacturers across the country, compiled a manual on fumigation and safe operation for the on-farm silo. The GRDC provided the funding to produce this booklet and distribute it to all silo manufacturers in Australia.

Since 1987, the Agriculture Protection Board of WA has produced adhesive signs detailing the correct use and maintenance of a sealed silo. These are supplied to all silo manufacturers in WA to be affixed to the sealed silos leaving the factory. In 1995 this sign was reprinted and offered for sale to all silo manufacturers in other states in Australia.

CONCLUSION

The need to reduce dependence on chemicals for controlling stored-grain insects has driven the campaign to encourage the use of sealed silos. Actual adoption of sealed silos has been slower where there is continued access to chemical insecticides.

High profile extension campaigns led by advisory authorities have significant short-term impact. To maintain the momentum, long-term extension programs must be planned. Problems discovered by users when they adopt a new system can usually not be fully addressed by the manufacturer of the product.

Pressure from grain consumers for a residue-free product will eventually force growers to consider insecticide-free forms of stored-grain insect control. They will consider such alternatives as fumigation or controlled atmospheres in small sealed silos and SIROFLO® in large silos, as well as aeration to cool moist grain to a safe level before fumigation in a sealable silo.

In Australia, the silo manufacturing industry will respond to these challenges and change silo design to accommodate changing control techniques. To transfer this technology successfully, there must be continued input at both the manufacturing and user level, by advisory authorities across the country.

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