THE USE IN AND RECIRCULATION OF CARBON DIOXIDE IN WELDED STEEL BINS IN VICTORIA

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ABSTRACT

Different techniques are used to attain and maintain a high carbon dioxide atmosphere in stored grain in well sealed grain structures. This paper presents details of sealing, pressure testing, gas application and maintenance for typical Victorian welded steel bins. Costs for bin conversion and carbon dioxide applications are summarized. Lack of attention to any detail can reduce the CO_2 levels to a point below the level lethal for insects. Details are also given on a purge/recirculation pipe and on a simply manufactured pressure safety valve.

INTRODUCTION

The insecticidal properties of carbon dioxide (CO_2) in a controlled atmosphere storage situation have been realized in Australia for over sixty years. Since 1975, over 250,000 t of wheat have been treated with carbon dioxide. Currently, over 2.5 million t of storage space in the Australian bulk handling system requires little effort to seal to a standard which permits economical treatment of grain with CO_2. This paper stresses the need for extra care in all aspects of sealing and recirculatory layout in storage similar to typical Victorian Ascom type welded steel bins.

TYPE OF STORAGE

The bins used in Victoria for commercial usage of CO_2 are silver in colour, and are being progressively painted white as recommended by Banks and Annis, 1980. These bins vary in capacity between 1,500 t and 2,000 t and the measurements of a typical 1,900 t bin are height to eaves: 14.8 m; height of cone: 3.4 m; diameter: 13.9 m; and volume: 2,418 m^3.

The storages are flat bottomed with a central opening at the roof apex and a central outlet at the base. All bin openings and areas around the bin perimeter have been sealed.

SEALING

Wall to floor joint:

Because of slight movement of both steel and concrete, the base perimeter area of these bins is prone to gas leaks. This internal perimeter area is raked and cleaned, as are any floor cracks. Filling is done with a bitumen emulsion sealer. (Mightyplate plastic cement, Provence & Co., North Brighton, Vic.) This emulsion, a patented phosphorus stabilised material, was chosen because of its stability in weather extremes and its ability to fulfil requirements set out by the Co-ordinating Committee on Silo Sealants (Banks & Annis, 1980). Grain may stick to this compound so a 12 hour hardening period is desirable before treating the area with a polymetic vinyl plastic protective coating (Envelon, Dominion Plastics Industries, Shepparton, Vic.). Two coats of this flexible membrane are used and they provide a semi-hard cover upon which grains cannot attach. One coat is not sufficient to prevent the grain from sticking.

Doors:

The perimeter area of the door and cell opening are lined with 40mm width by 8mm thickness silicone rubber. The two areas are tightly joined by fastening the door with bolt pressure. However, for complete sealing, it is necessary to spray the outside perimeter with Envelon or cover with a mastic type seal.

Walls:

Thorough examination of all welds must be made. Signs of seepage (green discoloration) can be readily detected. 'Slag' holes and porous sections can be sealed successfully with 2-3 coatings of Envelon. Special care must be taken when spraying over these protruding slag sections or even bolts since gravity can cause a weaker upper area on the protrusion or bolts, and this small area of plastic coating can become perforated.

Roof hatch:

A sealed hinged disc hatch has been designed with rubber to rubber seals held under pressure to make this area gas tight (Fig. 1). This figure shows that a disc-shaped door folds diagonally for placement below the opening, and returns back to the original disc shape for holding fast against the base of the circular grain entry. The disc door is held secure by a bolt action across a 'T' piece at the bin apex. For a perfect seal, it is necessary to cover the hinged and perimeter areas with a mastic type seal.

PRESSURE RELIEF VALVE DESIGN

Pressure variations in a sealed storage may fluctuate because of wind velocity and diurnal temperature changes or during grain outloading or gas purging operations (Banks and Annis, 1980). A simple pressure relief valve is shown in Fig. 2. The 200mm diameter recirculation and vent pipe leads from the bin apex area downward and over the 75mm pipe which is fitted into the tank structure of the pressure relief valve. Water is added to the tank for sealing to cover the end of the 200mm pipe by exactly 75mm. A thin oil layer on the water surface can prevent evaporation. This device does not allow the internal bin pressure to go over 750Pa (75mm water guage). If the pressure in the bin exceeds this limit, the seal is broken allowing the bin to come to equilibrium with the atmosphere.

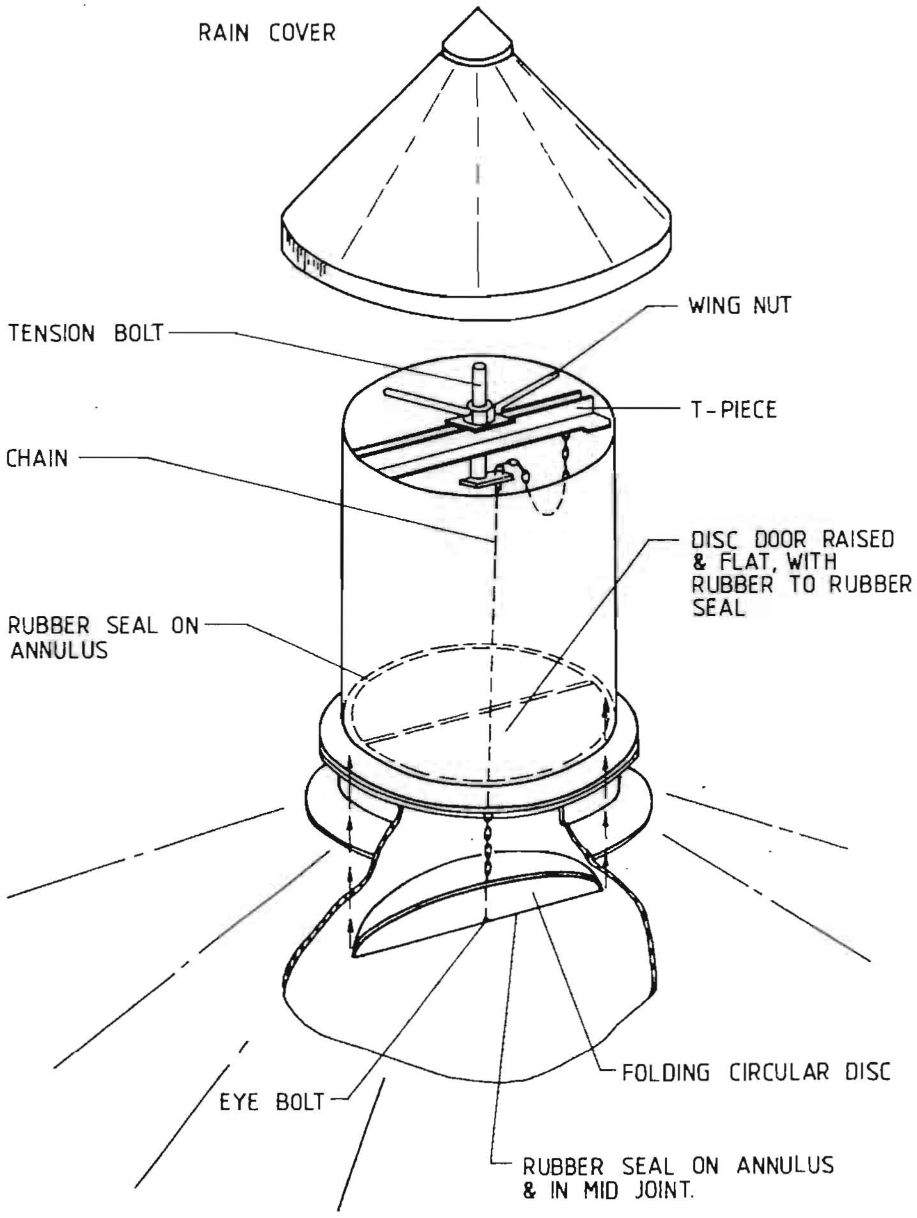

FIG. 1

DESIGN OF A TYPICAL BIN ROOF HATCH SEAL

GAS INTRODUCTION

Carbon dioxide is supplied in liquid form from road tankers of aproximately 20 t capacity. The tankers normal head pressure of 2000 kPa is used to force the liquid CO_2 through a vapourizer which converts it to gas at a temperature from 25 to 35^{o} C. This introduction temperature prevents condensation and subsequent moisture migration in the grain bulk.

Tankers and vapourizers are now designed to inject CO_2 at 3.5 t/h. This flow rate would create too great a pressure build up for a single bin so several bins are normally purged simultaneously (V. Guiffre, 1979, pers. comm.). The gas distribution piping is designed for minimum pressure drop so that uniform bin purging is obtained no matter which group of bins are being purged simultaneously. At a total CO_2 flow rate of 3.5 t/h the pressure difference in the CO_2 injection tubes is only a few kPa.

Victorian cells are purged in pairs using an 80% CO_2 - 20% air mixture. Gas introduced into the base of the bin is forced upwards and out through the 200mm recirculation pipe until measurement of the outflow stream at the base of the pipe indicates a level of 80% CO_2 (Fig. 3). The normal dose rate is approximately 1 t/CO_2 per 1000t of grain. Bin sealing is then completed by filling the pressure relief valve with water at the base of the overflow pipe, and closing the slide valve on the gas inlet pipe. Measurements of the CO_2 concentration are taken during purging and throughout balance of the treatment at the test point in the 200mm recirculation pipe (Fig. 2) using a Drager tube and pump.

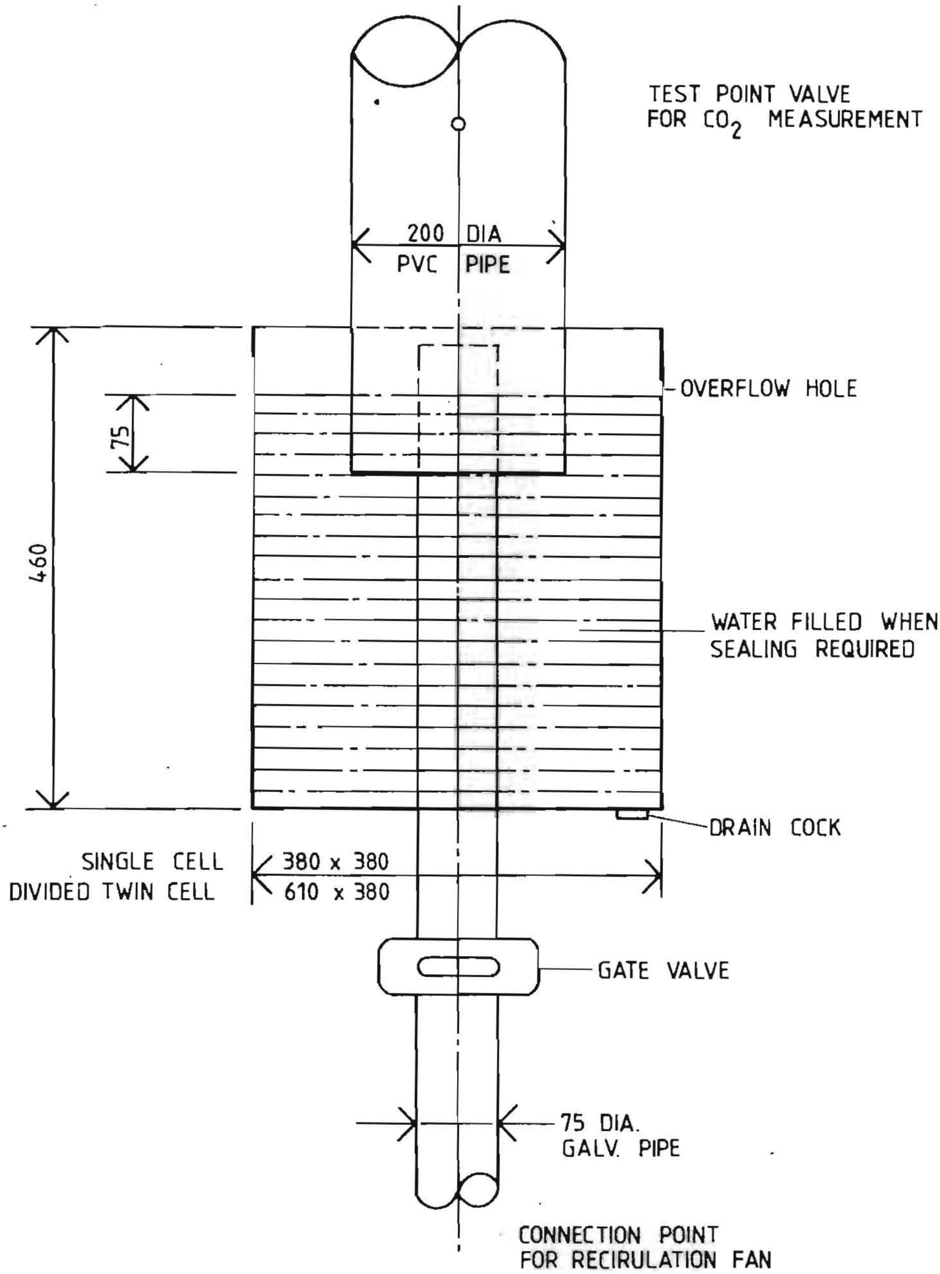

FIG. 2

CORRESPONDING PRESSURES FOR VARYING OUTLET PIPE DIAMETERS.

Only one inlet point is necessary for CO_2 introduction because of the nature of the gas (Banks 1978). The inlet and piping from the CO_2 vapourizer are both 75mm dia. The purge exit/recirculation pipework consists of a 200mm PVC pipe extending from near the bin apex down to the pressure relief valve, which is located approximately 1.5m from ground level. When the gas introduction technique is performed as described, a 200mm dia. outlet limits the pressure build-up in the bin to approximately 0.17 kPa. Outlets smaller than this cause excessive pressures in the bins, unless the gas is applied at a slower rate. Slower rates of application are more costly since the road tanker and driver are on site for longer periods. Smaller purge main diameters and corresponding bin pressures are shown in Table 1. (A. Segal, 1978, per. comm.).

RECIRCULATION OF CARBON DIOXIDE

Since CO_2 is 1-½ times as heavy as air it is necessary to recirculate the atmosphere gently within the storage to ensure that an even gas concentration is maintained for the duration of treatment (Wilson et al, 1980; Banks and Annis, 1980). This is achieved by installing a duct from the top to base of the bin, and utilizing a small fan for recirculation (Fig. 3).

Table 1.
Corresponding Pressures for Varying Outlet Pipe Diameters

Internal Diameter of Purge Main (mm)	Pressure in Bin (kPa)
100	3.45
150	.58
200	.17

The purge exhaust and recirculation pipe must be placed as near to the apex of the bin as possible. Experience has shown that the grain peak must clear the pipe opening by approximately 1m so that the high point of the grain does not prevent an even distribution of the recirculated CO_2 in the conical area. The elbow at the roof-to-wall joint consists of .5m flexible PVC hose (200mm dia.). A rigid joint can leak because of structural movement and climatic variation.

A fan (0.4KW, 75mm bore suction) is attached via a 75mm flexible hose to the base of the pressure relief valve and to the inlet port to complete the recirculation system. The fan achieves the rate of at least 0.1 atmosphere change per day (i.e. 10% of storage), which is stated to be adequate by Banks (1978). Experience has shown that under normal working pressure, hair-line fractures can form on the enamel along the seal-line at the side of the fan flanges which allows air entry during operation. These areas must be unbolted, retightened and sealed with covering layers of a mastic compound. The fan must have a tight fitting gland bearing with a grease cup around the shaft to prevent air ingress at this point.

PRESSURE TESTING

Prior to purging with CO_2, a standard pressure test as described by Banks and annis, (1977) is carried out on the bin. These standards state that it should take more than 5 minutes for pressure generated by a blower in a 90–95% full structure to decay from 500 to 250 Pa for storages of 300–10,000 tonnes capacity. Recent Victorian results using this pressure test resulted in decay times from 13 to 25 min which is substantially in excess of the required gastightness specification. The high levels of CO_2 maintained after two weeks recirculation, can be correlated with the standard of sealing as shown in Fig. 4 where longer decay times resulted in higher CO_2 concentrations at the end of this treatment period.

FURTHER CONSIDERATIONS

Moisture Migration:

In some studies with welded steel bins moisture migration to the hot upper areas has taken place, particularly if the grain received is at the Australian limit of 12% m.c. Areas of excess moisture are formed because the grain cannot reverse the moisture movement during the cooler night hours. Mould growth and bin scalding have been experienced under these circumstances.

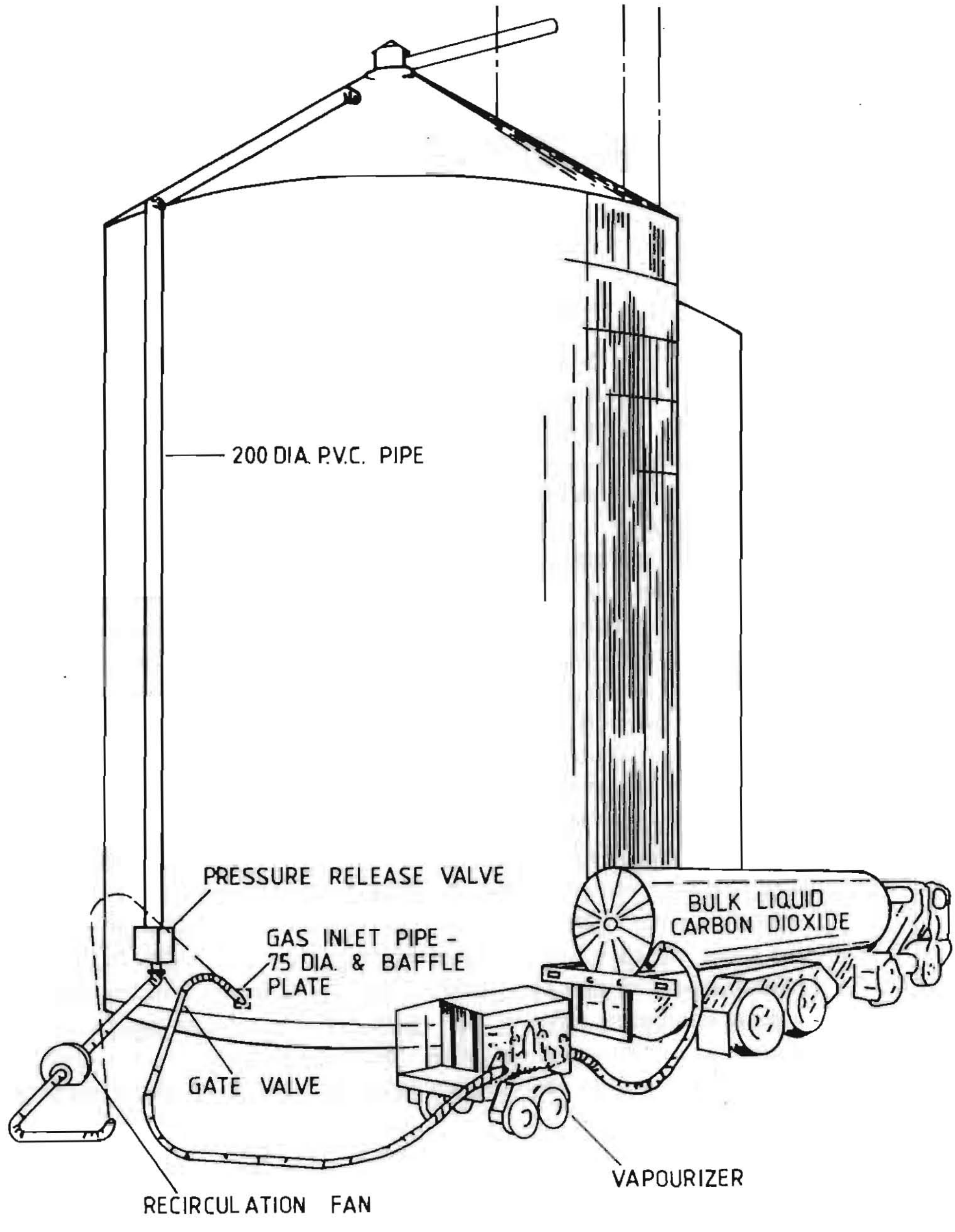

FIG. 3

A VICTORIAN TYPE STEEL BIN EQUIPED FOR USE OF CO_2 WITH TANKER AND VAPOURIZER ONSITE. ALL DIMENSIONS ARE IN mm.

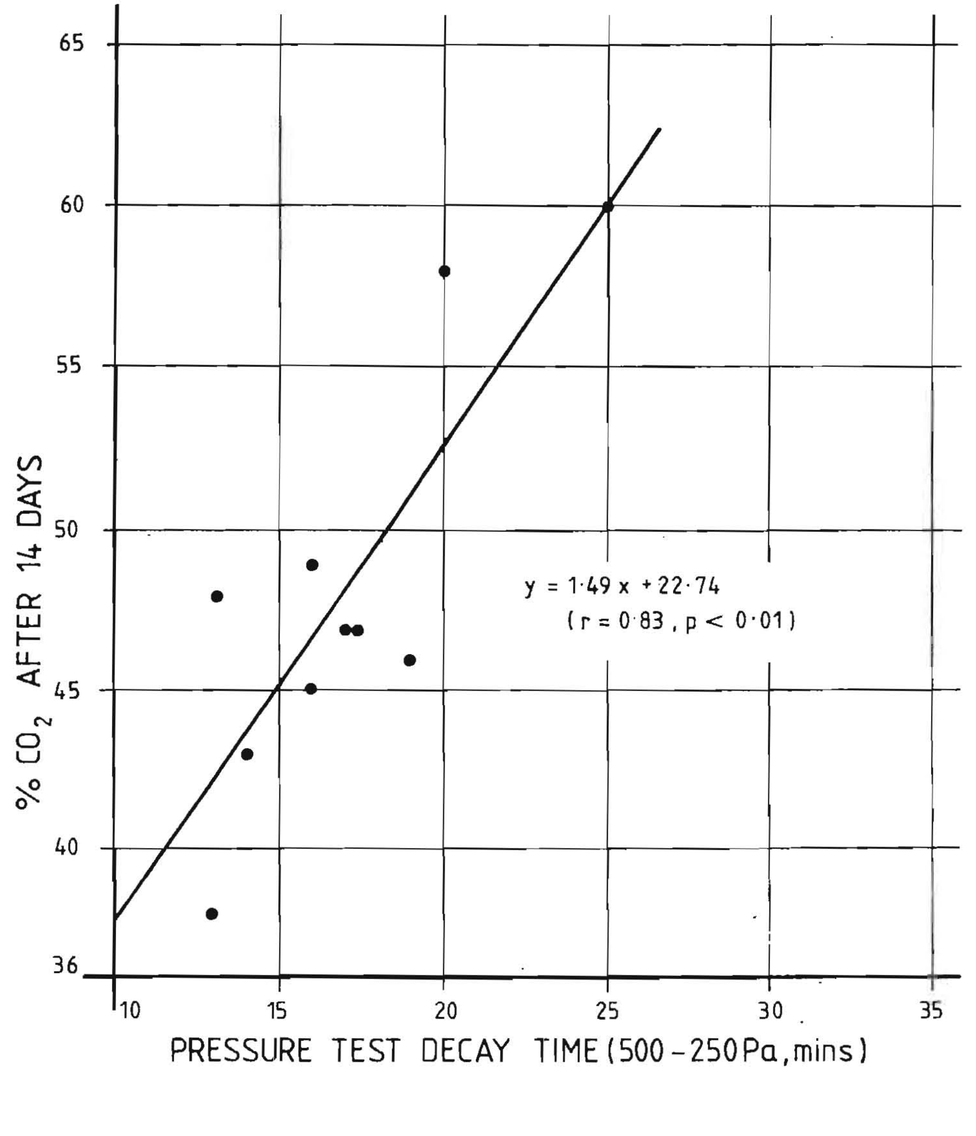

FIG. 4

PRESSURE DECAY AND CO_2 DECLINE 14 DAYS AFTER PURGING. STUDIES WERE CONDUCTED AT YARRAWONGA AND RENNIE, VICTORIA IN 1981 AND 1982.

To overcome this problem, care must be taken to ensure that overfilling does not take place and that the grain surface is 1m below the roof apex. Grain should be turned from base to top prior to CO_2 purging to ensure redistribution of any hot spots, and to remove grain compaction pressures from the baffle plate area of the CO_2 entry pipe. During the turning process the centre core of grain goes through a lot of movement and the grain at the base and sides of the bin moves marginally. This process results in less compacted grain and allows for more successful penetration.

Roof Painting:

A white acrylic matt reflectant finish is desirable to help reduce moisture migration and gas loss due to diurnal temperature changes in the headspace (Banks and Annis, 1979).

Outloading and Reinfestation:

Reinfestation can occur quickly if there are delays in the outloading processes of CO_2 treated grain. If delays are inevitable openings should be covered with insect proof mesh screen and the surrounding area sprayed with a residual insecticide. A suitable insect proof mesh measures 0.6mm^2. A residual insecticide, azamethiphos, has proven successful in field experience. This spray has remained effective at 0.5% on metal surfaces, and at 1.0% on porous surfaces for more than 26 weeks (B. E. Wallbank, R. J. Hart, 1979, pers. comm.).

Back Pressure:

A Baffle plate, 600m x 600mm installed at the end of the inlet pipe will ensure that at a CO_2 injection rate of 1 to 1.5 t/h, the back pressure will be less than 10 kPa. Back pressure will vary only between 30/40 kPa. This plate is similar in design to those described by Banks and Annis (1977). Back pressure does vary between wide limits, depending on gas flow rate, grain condition, voidage and dust content.

Costing:

Total sealing, plumbing, labour and fan installation costs for the welded steel bins discussed here were carried out after works completion in 1978. The total cost per bin was Aus. $1,289.00 or 64¢/t grain capacity. This is equivalent to an amortized capital cost of 5.6¢/t calculated from a 6% real discount rate, an assumed average fill rate of 100% per annum, and an estimated sealing life of 20 years, with negligible maintenance cost per annum. Connell and Johnston (1981) by contrast, estimated capital costs of sealing similar bins to be 87¢/t, (or 13¢/t as an annual amortized figure calculated from a 6% real discount rate, and assumed average fill rate of 90% per annum, an estimated sealing life of 10 years and a life of engineering modifications of 15 years) and 4¢/t annual maintenance, giving a total annual equipment cost of 17¢/t. From 1978 the total carbon dioxide input costs have been approximately 25¢/t of grain treated as estimated by Connell and Johnston (1981). This gives a total annual cost of 30.6¢/t as compared with the estimate given by Connell and Johnston of 42¢/t. These figures show that total costs for carbon dioxide treatments are less expensive than the cost of the current chemicals in use, fenitrothion and synergized bioresmethrin, at application. These chemical costs have averaged 53¢/t of grain treated during 1978-83.

Safety:

Conveyor tunnelling beneath bins can be a danger area because small leaks from one or more bins could lead to a toxic accummulation of CO_2 in this area. Gas sampling pipes should be installed and access to the tunnel locked so that before unlocking after treatment gas samples can be drawn from the lowest area of the tunnelling. Grain must be thoroughly aired before outloading, with fans operating in confined areas where grain is moving. After purging the work areas of excess CO_2, the content of the air at any point must not exceed 1% CO_2. This is based on a time weighted average for up to a 10 hour shift in a 40 hour week with a maximum exposure of 3% CO_2 (V. Guiffre, 1978, pers. comm.).

CONCLUSIONS

The commercial work and details given are the cumulative effort of seven years work, and can be considered as a meaningful part of the general development of various modified atmosphere techniques of grain storage and disinfestation for Australian conditions. Attention to every structural detail and precise control of the use of CO_2 are all important in ensuring an economic outturn of the grain, especially when it is received at or near 12% m.c.

With the strategies described, and with continued attention to detail, CO_2 treatment of grain can be regarded as a viable and economic ally to the current chemical methods of grain protection. Further studies may indicate that it would be profitable to have stationery on-site CO_2 vessels to be refilled as needed at sites where large quantities are used. Certainly methods of insect detection and techniques for maintaining the grain insect free to its final destination need to be expanded.

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