MODIFICATION OF A VERY LARGE GRAIN STORE FOR CONTROLLED ATMOSPHERE USE

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ABSTRACT

Controlled atmosphere techniques of insect control in stored grain are receiving widespread interest as alternatives to chemical protectants. The very large grain storage shed, No. 1 Horizontal Storage (capacity 300,000t wheat) at Kwinana terminal, is currently being sealed and modified so that it can be treated with 40% Co_2 in air as a controlled atmosphere. The storage is close to an inexpensive source of the gas, which will be supplied by pipeline. the various operations required to fit the storage for this use are described. These include use of white acrylic and PVC - based materials to treat the roof and walls, giving a heat-reflective coating and seal, and the fitting of fans to recirculate the gas within the store, vent it after use and, when necessary, prevent build up of airborne dust and CO_2 in the store and work spaces. The cost of CO_2 use, as applied at Kwinana compares favourably with that of the other possible insect control measures available.

INTRODUCTION

In Australia and elsewhere, many of the pest control measures in current use for stored grain are rapidly becoming unacceptable. This may be either through development of insect resistance or because of costs or marketing preferences and requirements. There are several alternatives under consideration, mainly as replacements for the organophosphate insecticides that have hitherto provided such excellent service to the industry. Of these, controlled atmosphere techniques have so far received most attention.

The fact that an atmosphere of sufficiently low oxygen or high carbon dioxide content will control grain pests is not in question, although some of the finer detail of the action of such atmospheres is not known (see Bailey and Banks, 1980). Putting the concept into industrial practice is now the main problem. This paper summarises the work carried out by Co-operative Bulk Handling Limited at its Kwinana export terminal to modify a very large grain storage (dimension and capacities see Table 1) to accept controlled atmospheres generally and CO_2 - based atmospheres in particular. Delegates to this Symposium will be shown the current progress in the conversion and sealing of this shed, believed to be the largest project of this kind yet undertaken in the world.

METHODS

Site

Co-operative Bulk Handling Limited's Kwinana Terminal occupies a 21 hectare site, 40km south of Perth. It is one of the largest integrated grain terminals in the world, with a capacity of 912,300t wheat, held in a large cell block and two large horizontal shed-type storages. The No. 1 Horizontal Storage, a 300,000t capacity shed, was selected for sealing and modification to accept CO_2 as an insecticidal controlled atmosphere.

Use of CO_2

CO_2 was chosen as the basis for the controlled atmosphere systems at Kwinana for three reasons. Firstly, there was a ready cheap supply of the gas close to the site (3km), permitting delivery by pipeline. The gas was produced as a by-product of ammonia production at the Western Mining Nickel Refinery. Secondly, CO_2 will control insects at a much lower concentration than the alternative, nitrogen, and its action is much less sensitive to temperature. Provided the exposure time is long enough, CO_2 atmospheres need only contain greater than 35% CO_2, whereas nitrogen atmospheres must be greater than 98% N_2 (i.e. less than 2% O_2) and preferably greater than 99% N_2 (less than 1% O_2). The exposure periods required for complete control of insects with nitrogen - based atmospheres can be commercially excessive at low grain temperatures (Banks and Annis, 1977). We considered that with CO_2 - even at 40% CO_2, the atmosphere chosen for use at Kwinana - an exposure period of 3 weeks would be adequate no matter what the grain temperature was. Thirdly, we were unsure whether nitrogen could be used to purge such a structure efficiently. Indeed we saw problems in this regard, but we knew that the density of CO_2 gas would assist the efficient distribution of the gas and purging of the bulk from our own and other experience in smaller sheds (Co-operative Bulk Handling Limited, unpublished work; Banks et al, 1980).

Sealing of the Storage

The sealing of the No 1 Storage involved the creation of an almost gastight enclosure of 550,000 m^3 capacity. The contract for the sealing specified that the shed be sealed to a level such that, when full, an applied excess pressure of 200Pa in the shed would decay to 100Pa in not less than 30 minutes under stable temperature conditions. Sealing to this standard would ensure that gas loss from the store was minimised and thus as little CO_2 as possible was required to create and maintain the desired CO_2 concentration within the store.

Table 1 - Dimensions, construction and capacities of No 1 Horizontal Storage, Kwinana.

Dimensions	305m long, 76m wide, 31m high
Construction	Concrete walls and floor, truss roof with aluminium cladding
Wall area	6000m^2 concrete and 3670m^2 aluminium sheeting
Roof construction	Corrugated aluminium sheet, 30^o pitch
Roof area	28000m^2
Enclosed volume	550,000m^3
Rated capacity	300,000t wheat
Filling ratio	0.60
Calculated gas volume when full	310,000m^3

The general approach to the sealing of the storage was based on the technique employed at Harden, New South Wales (Banks et al, 1979) as modified by our experience in our sealing programme for large horizontal storages in Western Australia, of which 24 have so far been completed.

Prior to sealing, the structure was cleaned of contaminants and salt deposits using high pressure water jets. Two materials were used for most of the sealing work: Envelon 441 (Dominion Plastic Industries, Shepperton, Victoria) and Flexacryl (Taubmans Paints, Sydney). Envelon 441 is described as a solvent-based PVC solution that produces a self-supporting membrane. It was applied to lap joins in the aluminium cladding at 800 to 1800 micron thickness without reinforcement. Flexacryl is a thick, modified acrylic, water-based emulsion. It was applied at 150 micron thickness over the roof and externally over the concrete walls at 100 microns to provide a white, heat-reflectant finish and give protection to the Envelon against UV-degradation. The roof temperatures were noticably reduced on painting (Fig 1). The concrete walls were also coated internally at 500 microns thickness with Flexacryl, with a PVC - membrane applied first over any cracks or joins in the wall. The floor of the store was treated with a silicone based sealer (Raffles Floor Sealer) which penetrated into the concrete. The few large cracks in the floor were filled with an acrylic filler. Large holes, such as where the aluminium cladding met the top of the concrete wall, were filled with rigid polyurethane foam before the acrylic top coat was applied.

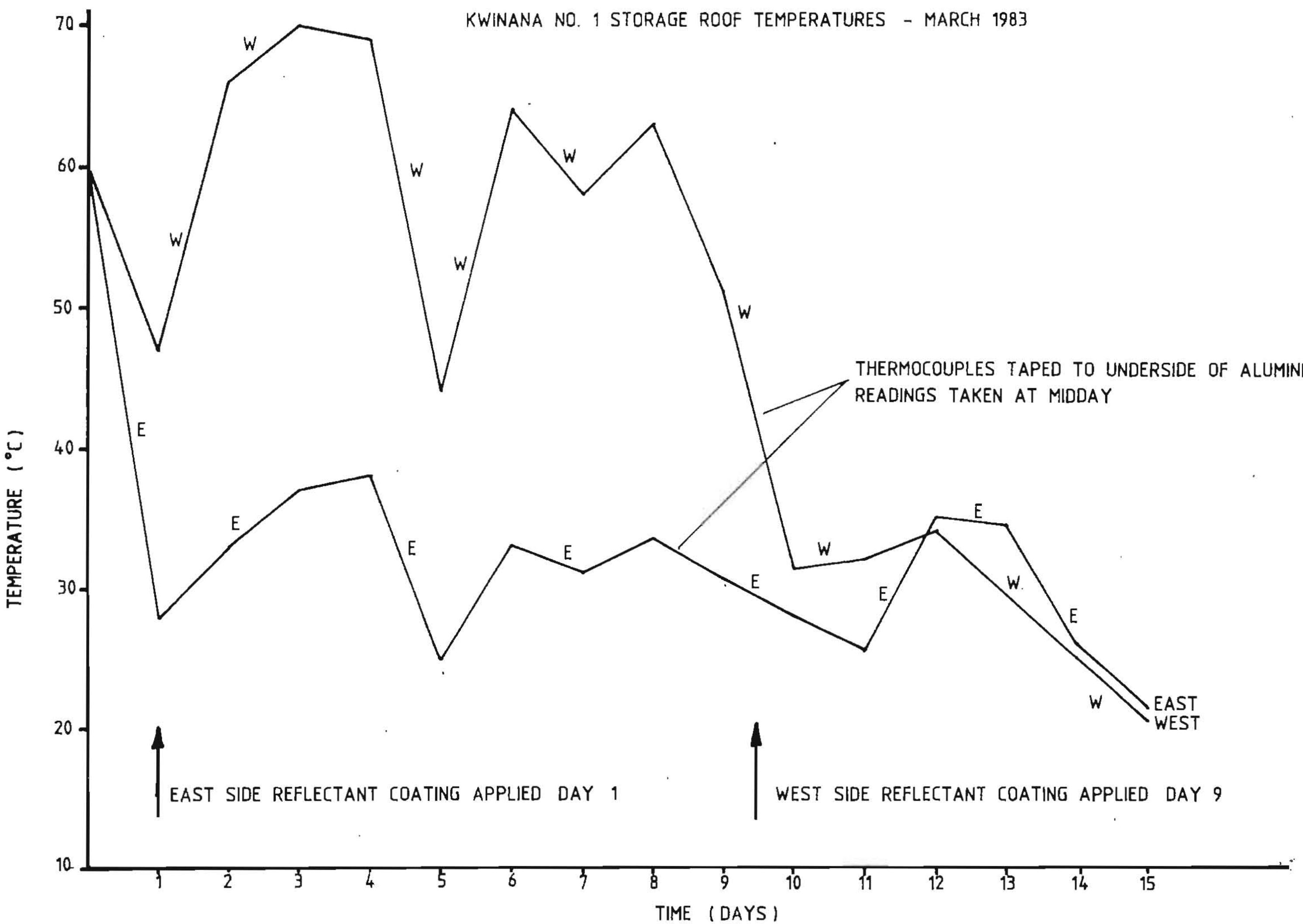
KWINANA NO. 1 STORAGE ROOF TEMPERATURES - MARCH 1983
TEMPERATURE (°C)
70
60
50
40
30
20
10
W
E
THERMOCOUPLES TAPED TO UNDERSIDE OF ALUMINIUM CLADDING
READINGS TAKEN AT MIDDAY
EAST
WEST
EAST SIDE REFLECTANT COATING APPLIED DAY 1
WEST SIDE REFLECTANT COATING APPLIED DAY 9
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
TIME (DAYS)

FIG. 1.

Blanking plates were made to fit over the large doors. These were fixed over the door frames externally with Flexacryl providing a removable seal. Existing man access doors were replaced by specially designed self-sealing doors. A removable form was made to clamp snugly over the conveyor belt to provide a seal at the point where the conveyor entered the reclaim tunnels and the above-grain area.

Modifications for Gas Introduction, Circulation and Removal

The store was equipped with 65 possible gas injection points: these being at ground level at 32 ports in the east and west walls (long axis of the store runs N-S) and at every third one of the reclaim valves in the floor of the store. The ports were fitted in the store with perforated baffles to prevent wheat blocking them. The reclaim valves were modified to admit gas and not to pass wheat by placing a perforated removable screen over the opened valve. The valves are above the two outloading tunnels that run the length of the storage below the floor. The tunnels themselves were converted and sealed to act as the ducts to deliver the gas to the valves. We recognise that the number of introduction points may be excessive, but were provided to ensure that purging and venting could be controlled efficiently. Since neither purging with CO_2 nor venting of such a size of storage had been attempted previously we were not certain how many or few points would, in fact, be required.

To maintain an even concentration of CO_2 in the store after purging, we recognised that it would be necessary to provide recirculation. In particular this is to avoid the formation of regions of low concentration which otherwise tend to form in the top of tall structures under CO_2 (Wilson et al, 1980). The recirculation system fitted (Fig 2) consists of eight ducts on both the east and west walls and a further two similar systems on the north and south gable walls.

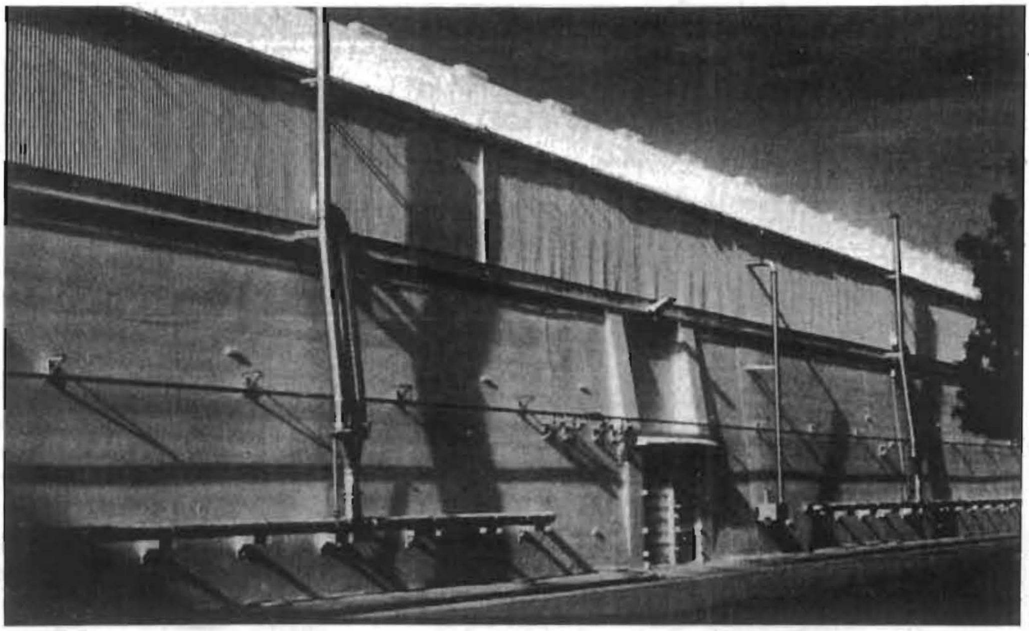

Fig 2 (a) Recirculation/venting ducts - side wall.

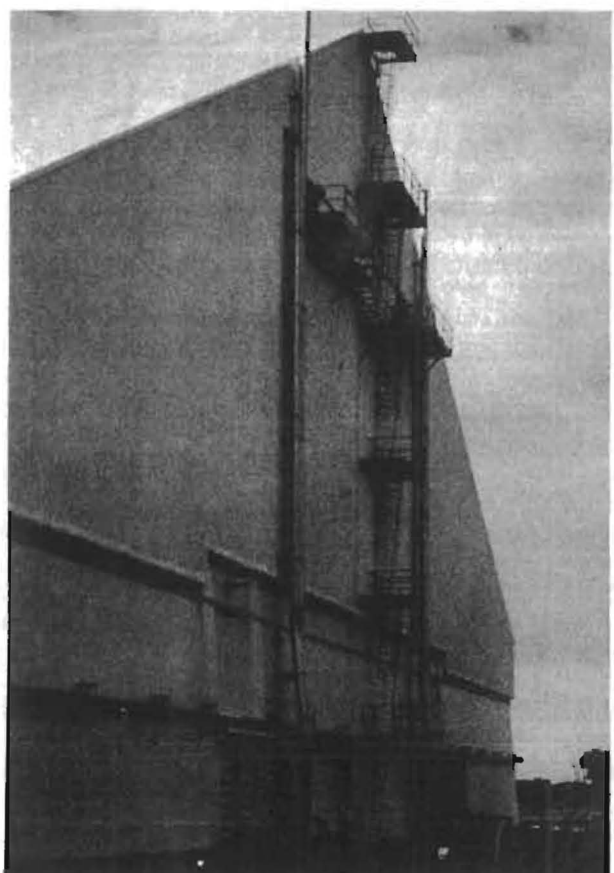

Fig 2 (b) Recirculation/venting ducts - end wall.

The latter systems run from each end of the tunnels. All systems run up to the ridgeline of the roof, running externally up the concrete wall, passing through the bottom of the aluminium cladding and then along the roof trusses or end walls to the roof ridge inside. The total system was designed to recirculate one gas volume of the store per day. The types and ratings of the various fans fitted are given in Table 2. It is expected that it will be found that some of these will not be required, but again in the absence of any experience with CO_2 in such large sheds as a guide we wished to err on the side of caution. It is planned to carry out trials to determine the actual quantity of fans and ductwork required.

A further duct was fitted above each recirculation fan in the recirculation system on the walls (Fig 2). This duct led to atmosphere above the gutter line and was fitted with a valve that could be opened so that gas was drawn out of the shed and vented rather than recirculated. Four large sealable fans (Table 2) were fitted in the gable ends above the wheat level, two at each end to provide ventilation in the headspace. It was so arranged electrically that the fans in one gable blew air into the shed while the others sucked out, thus creating a through draft to remove CO_2 or airborne dust as necessary. The venting fans were sized such that the storage could be cleared of CO_2 in two to three days. The fans can be operated to give flows in either direction through the shed, the direction being chosen so that the wind at the time assists the ventilation rather than blowing against the fans. Two small fans were installed in the bulkhead sealing the tunnels where the reclaim conveyors emerged. These were to clear any residual gas in the tunnels, after the venting of the store, so that it was safe for personnel to enter.

Table 2 - Details of fans fitted to No 1 Storage, Kwinana.

Fan Position	Number	Size	Ratings
On east and west walls	16	300mm axial, 2900rpm, 0.375kW	$0.16m^3s^{-1}$ at 425Pa
On north and south ends connected to tunnel	4 of 2 fans in series	300mm axial, 2900rpm, 0.375kW	$0.45m^3s^{-1}$ at 500Pa
On gable ends above wheat line	4	1500mm axial, 720rpm, 11kW	$27m^3s^{-1}$ at 180Pa
In tunnel at entrance	2	300mm axial, 1480rpm, 0.375kW	$0.45m^3s^{-1}$ at 180Pa

Monitoring of Gas Concentration

In view of the experimental nature of CO_2 use in the shed, some 60 gas sampling lines were arranged to give samples of gas from within the storage and grain bulk. Further sampling lines were fitted to give samples from points outside the seal to check for safety, particularly in low lying areas such as by the entrance to the reclaim tunnels where the dense CO_2 gas may collect if it leaked from the store.

Pressure Relief Valves

Twelve oil-filled pressure relief valves (Fig 3), six on the east wall and six on the west, were fitted to the storage. The fitting was arranged to relieve pressures high in the storage. These valves were set to begin to pass air or gas at 70 Pa pressure differential and to give a full flow of air or gas at 300 Pa.

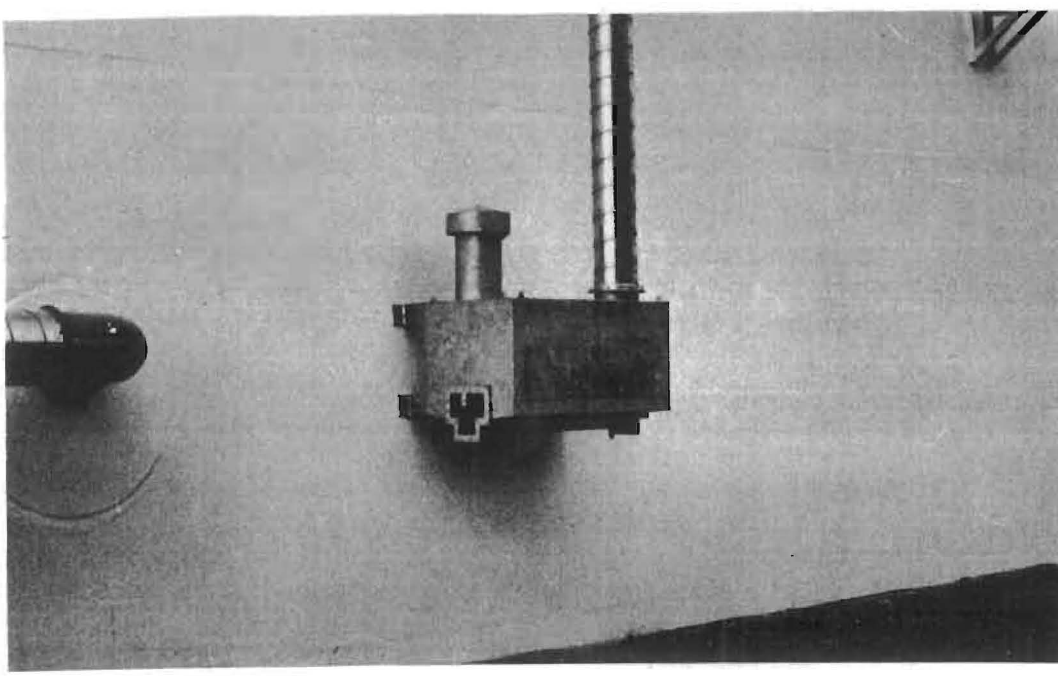

Fig 3 Pressure relief valve.

Safety Aspects

The installation is designed to be at least as safe as the storage was, prior to sealing. Provision has been made for continuous monitoring of CO_2 levels in and around the storage. Self-contained breathing apparatus is available in case of accident for conditions where CO_2 levels may be hazardous to humans.

The four gable end fans (Table 2) are of a size that can provide significant through-flow of air in the storage, thus removing airborne dust and minimising worker discomfort and dust explosion hazard during grain handling.

The skylights in the storage have been sealed into the roof, so that adequate daylight still enters the storage. The white finish on the walls internally is designed to assist visibility within the store.

The pressure vents, set at 70 Pa, are to prevent excessive pressures on the structure. The roof is designed to withstand up to 1000 Pa internal pressure.

Costs of CO_2 Use and Alternatives

One reason for choosing CO_2 as a disinfestation method for Kwinana No 1 Storage was that its cost compared favorably with alternatives. Table 3 summarises running costs of various processes. The cost of grain protectants used at Kwinana is currently much less than in much of Australia since bioresmethrin need not be used. It is unlikely that this situtation will persist and we expect that it will be necessary to use this or a similar material soon with the almost inevitable arrival of OP-resistant Rhyzopertha dominica in the region. It is thus realistic to use the 'most of Australia' cost of protectants as a comparison with that of various fumigants.

Table 3 - Cost of materials used for disinfestation of grain.

	COST (cents per tonne of grain	
	KWINANA	MOST OF AUSTRALIA
GRAIN PROTECTANTS		
Fenitrothion	9	11
Bioresmethrin	Not Used	70
Alternatives to fenitrothion	Not Used	15+
Total	9	81-85+
FUMIGANTS		
Methyl bromide	7	7
Phosphine	2-8	14
CO_2 (Vertical storage)	4	30
CO_2 (Horizontal storage)	5	50

The cost of sealing of a storage can be considered almost completely as a cost of use of fumigants and controlled atmospheres and must be included in a proper comparison of costs of different methods (Connell and Johnston, 1981). For No 1 Storage at Kwinana these costs are:

Sealing	\$1.16 per tonne
Fittings, duct work	\$0.99 per tonne
Maintenance	\$0.28 per tonne
Giving a total cost of	\$2.43 per tonne

Maintenance includes allowance for renewal of the heat reflectant coating on the roof after ten years.

By discounting the value of the capital cost suitably it is possible to make allowance for interest paid on capital invested and for inflation so that a proper comparison can be made with processes such as the use of pesticides in which capital charges can be negligible. Costs for CO_2 use in No 1 Storage adjusted in this way are given in Table 4.

Table 4 - Capital and maintenance costs (1983 prices) for conversion of No 1 Horizontal Storage, Kwinana for use with CO_2 disinfestation.

	Time Scale (Years)	Cost (\$A)
Sealing	20	348,000
Fittings, ductwork, electrical	20	297,000
Replacement of reflectant finish[a]	10	74,000[b]
Maintenance	1	5,000

Discounted Annual Cost (\$A) (c)	Annual Cost Per Tonne (\$A, One Fill Per Year)	Annual Cost Per Tonne (\$A, Four Fills Per Year)
23,300	0.18	0.04
19,800		
4,800		
5,000		

a) Cost of initial roof treatment included in sealing

b) Cost allows for replacement at 10 and 20 years

c) Costs discounted at a real discount rate of 3% per annum over 20 years

These figures obviously provide justification for our choice of CO_2 as an insect control process at Kwinana. The actual cost is much reduced compared with that for a country site by economies of scale, cheapness of pipeline CO_2 as compared with liquid CO_2 and multiple use of the store each year.

CONCLUSION

Controlled atmosphere techniques are simple in concept. There is now information that they can be applied successfully and routinely in Australia on a commercial scale (Co-operative Bulk Handling Limited, unpublished results; Banks et al, 1980).

The use of CO_2 at the No 1 Storage at Kwinana has several features not yet investigated fully. There is thus an element of experiment in this work. In particular, we plan to use only 40% CO_2 in air as the atmosphere and to maintain this atmosphere for an extended period (several weeks) by adding further CO_2 from the pipeline supply as required to compensate for losses by absorption and leakage. The storage is larger than any which hitherto has been sealed and treated with controlled atmospheres and there is little data to guide us on how gases will disperse and distribute within the store. Despite these unknowns we are confident that the technique will prove successful in this large structure.

In the coming years, assuming the treatment of the No 1 Storage is commercially successful, Co-operative Bulk Handling Limited, plans to extend its program of sealing silos and horizontal stores to a standard suitable for fumigation or controlled atmosphere use. Both the cell block and the No 2 Horizontal Storage (250,000t capacity) at Kwinana are to be included in the program, giving a facility capable of holding over 900,000t of grain under CO_2.

Note Added in Proof

The No 1 Storage at Kwinana gave a satisfactory pressure test (full store, 30 minutes pressure decay, 180-90 Pa) on 5/9/83. it was filled with CO_2 in the period 6th September-13th October 1983 using 527t CO_2 and giving an atmosphere of 40% CO_2 throughout the structure. On 14th October 1983 the atmosphere was removed. Most of the 300,000t of pesticide-free grain, treated in the store was shipped from Kwinana over the period 3/11/83 to 5/2/84. 34,000t still remains in the store. No live insects have been detected in the store or in the grain exported, despite extensive sampling. There was no survival of caged test insects (all developmental stages of Rhyzopertha dominica, strain KRD6 multi O.P. resistant fenitrothion RF114) exposed in the store during CO_2 treatment.

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REFERENCES

BANKS, H. J. and ANNIS, P. C. (1977). Suggested procedures for controlled atmosphere storage of dry grain. C.S.I.R.O. Australian Division of Entomology Technical Paper No 13, 1-23.

BAILEY, S. W. and BANKS, H. J. (1980). A review of recent studies on the effects of controlled atmospheres on stored product pests. In Controlled Atmosphere Storage of Grains. (ed. J. Shejbal). Elsevier: Amsterdam. pp. 101-118.

BANKS, H. J., ANNIS, P. C., HENNING, R. C. and WILSON, A. D. (1980). Experimental and commercial modified atmosphere treatments of stored grain in Australia. In Controlled Atmosphere Storage of Grains. (ed. J. Shejbal). Elsevier: Amsterdam. pp. 207-224.

BANKS, H. J., ANNIS, P. C. and WISEMAN, J. R. (1979). Permanent sealing of 16000-tonne capacity shed for fumigation or modified atmosphere storage of grain. C.S.I.R.O. Australian Division of Entomology Report No. 12, 1-16 + pl.

CONNELL, P. J. and JOHNSTON, J. H. (1981). Costs of alternative methods of grain insect control. Bur. Ag. Econ. Occasional Paper No. 61. Australian Government Public Service Canberra.

WILSON, A. D., BANKS, H. J., ANNIS, P. C. and GUIFFRE, V. (1980). Pilot commercial treatment of bulk wheat with CO_2 for insect control: the need for gas recirculation. Aust. J. Exp. Agric. Anim. Husb. 20, 618-624.