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CONTROLLED ATMOSPHERE AND FUMIGATION IN WESTERN AUSTRALIA - A DECADE OF PROGRESS

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ABSTRACT

The late 1970s saw the long-term future of conventional grain protectants in Australia being seriously challenged by escalating insect resistance to these compounds and markets indicating increased sensitivity to pesticide residues on grain. Following successful evaluation trials conducted in three 23,000-tonne horizontal storages during 1980, Co-operative Bulk Handling Ltd. adopted controlled atmospheres (CA) and fumigation as the principal insect control techniques for the future. This policy required progressive and extensive structural modification to hundreds of existing grain storages, none of which had been designed for the purpose, and the development of a range of technologies to achieve both a sufficient degree of airtightness and enable controlled use of gases. One decade later, the Company has modified some 68% (4.9 million tonne capacity) of permanent storage and is now the world's largest single user of CA storage. These storages range from vertical to horizontal and individual capacities from 500-300,000 tonnes. The 1980 decision proved correct, and the Company is now in a pre-eminent position to provide Australian and international markets with grain that is insect-free and nil or low in pesticide residue.

INTRODUCTION

Co-operative Bulk Handling Ltd., founded in 1933, is owned, financed, and controlled by the grain growers of Western Australia. The Company first received bulk grain from the 1933/34 harvest (total harvest 301,929 tonnes) into 53 receival points. In 1990/91, the harvest totaled 6,393,353 tonnes at 197 receival points. Grain receivals from 1980/81 to the present day have introduced into the company's facilities a total of 61,777,198 tonnes, averaging 5,616,108 tonnes/year (Table 1). Being a co-operative, funds earned from a handling charge placed on the growers' deliveries at receival time are re-invested into the handling and storage facilities for the benefit of the Western Australian grain growers.

Table 1: Tonnage of grains received by Co-operative Bulk Handling Ltd. during the years 1980/81 to 1990/91 inclusive.

Grain Type	Total Received	Average Annual Receival
Wheat	51,207,675	4,655,243
Barley	6,458,639	587,149
Lupins	3,053,299	277,573
Oats	999,066	90,824
Field Peas+	40,220	3,656
Triticale+	15,767	1,433
Canola+	2,532	230
Total All Grains	61,777,198	5,616,108

+Field peas, canola and triticale were not received annually.

The circumstances in Western Australia prior to the introduction and implementation of controlled atmosphere (CA) technology were totally conducive to insect infestation of stored grain. Grain is received direct from harvest from late October through the end of January (late spring/early summer). At receival time, the temperature of all grains is usually in the range of 28-32°C, with an average moisture content (m.c.) of 9.5-10.5%. Large quantities of bulk grain may be stored for long periods of time, thereby ensuring a suitable environment for a range of grain insects.

A brief history that led to the use of CA in Western Australia would be:

- Western Australia exports approximately 90% of its grain production.
- Prior to 1959, little attention was paid to the control of insects.
- From 1959-1963, hydrogen cyanide (HCN) and phosphine (PH_3) were used widely in unsealed structures.
- In 1963, the chemical grain protectant, maldison (malathion), was introduced.
- During the mid-60s, the Export Grain Regulations, that stipulated a nil tolerance to live insects, were introduced.
- Malathion was used to protect grain until the mid-70s. Resistance was becoming more widespread (mainly among *Tribolium* species and *Rhyzopertha dominica*).
- In response to this resistance, fenitrothion was introduced as a substitute for malathion, but it was realised that a limited life could be expected.

- In 1977, the synthetic pyrethroid bioresmethrin was introduced to combat resistant species of *R. dominica.*
- In 1979, first sealing trials were conducted on 3 vertical cells located at Fremantle, West Australia.
- In 1980/81, three sealed horizontal storages were introduced in country areas.

During the period from 1963-79, the cost of insect control measures had risen from Aust.$ 0.08-.10/tonne to over Aust.$ 1.00/tonne. The development and use of CA in sealed storages has reduced Co-operative Bulk Handling Ltd.'s overall cost of protecting grain in Western Australia to less than Aust.$ 0.05 tonne.

The progress made in Western Australia on CA technology during 1980/1982 prompted Co-operative Bulk Handling Ltd. to host "CAF '83", the Symposium on Controlled Atmosphere and Fumigation in Grain Storages, to which 28 countries sent some 270 participants. CA technology has evolved in Western Australia to a point where no permanent roofed horizontal, vertical cell, or bunker storage in the system is considered unsealable.

STORAGE TYPES

The many types of horizontal and vertical storage systems within Western Australia reflect the many crop varieties and segregations handled by Co-operative Bulk Handling Ltd. The construction methods and materials used highlight its on-going commitment to provide the best possible service at the lowest possible cost to the grain growers. Individual capacities range from 500-300,000 tonnes. Construction materials are concrete, steel, and timber. A breakdown of these storage types is shown below:

	Horizontal	Vertical	Bunker (open bulkhead)
Capacity range (tonnes)	1,300 - 300,000	500 - 10,000	2,400 - 38,000
Average capacity (tonnes)	21,682	1,954	17,776
Total capacity (tonnes)	6,374,550	1,146,733	3,021,950

Total storage available	= approx. 10.5 million tonnes
Total storage considered sealable	= approx. 7.2 million tonnes
Total storage capacity sealed by the end of 1992 (Fig. 1),	= approx. 4.9 million tonnes (approx. 68%)

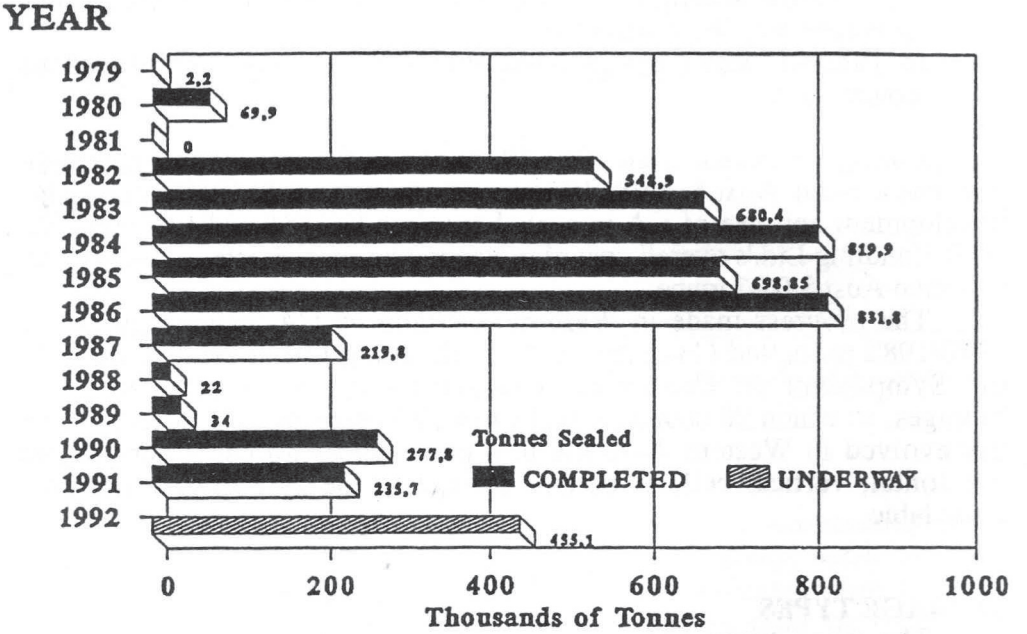

Fig. 1: Grain storage sealing between 1979-1992 by Co-operative Bulk Handling Ltd. (capacities in thousands of tonnes).

It should be noted that some storages are not considered sealable due to 1) limited life expectancy of the storage and 2) receival and outloading of grain within a very short period of time.

PRACTICAL ASPECTS OF STORAGE SEALING

Given the variety of storage types, designs, construction methods and materials, it is not possible to cover all aspects within the scope of this paper. Therefore, only a brief overview will be given. Three country sites were selected in 1980 to evaluate the practical application of CA in Western Australia. The storages averaged a capacity of 23,000 tonnes and were sealed with three different materials: 1) Solvent-based PVC; 2) Water-based acrylic, and 3) Full polyurethane foam application. After extensive trials, all were considered successful. In the ensuing years, the water-based acrylics have been the most widely used.

Prior to presenting materials for sealing to Co-operative Bulk Handling Ltd., the product manufacturer must complete a series of

laboratory tests in order to meet specific technical and practical criteria. These tests are conducted by a local university in Western Australia. Modifications to existing storages (both vertical and horizontal) are carried out prior to the actual sealing process. Extensive maintenance on horizontal storages is carried out on roofs, walls, floors, and doors, and the internal wash-down of storage surfaces ensures the best possible surfaces for sealing. Work on hatches, chutes, and valves is also conducted in both horizontal and vertical storages. The addition of axial flow fans, dual activating pressure relief vents, platforms, specifically designed conveyor sealing plates, door frames, chute valves, and in some cases recirculation systems, are all part of the storage preparation (Fig. 2).

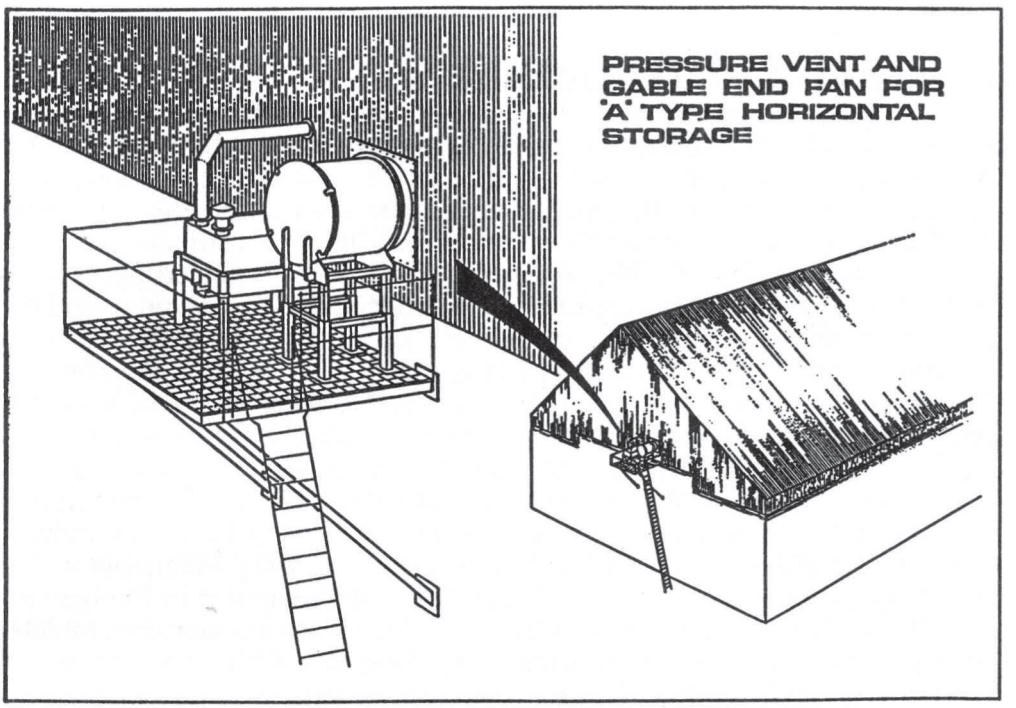

Fig. 2: Schematic presentation of typical pressure vent and gable end of axial fan employed in horizontal storages used by Co-operative Bulk Handling Ltd.

All phases of the sealed storage process from initial design, manufacture, installation, tender preparation and evaluation, awarding contracts, supervision, and final acceptance testing, are carried out or supervised directly by the Co-operative Bulk Handling Ltd. staff. Contracts for the sealing works are granted in March/April (autumn) of each year. Thereafter, the sealing contractor carries out the sealing works in accordance with the contract by applying specified membranes, foams, and topcoating materials to designated parts of the storage. The actual sealing

process, depending on the size and type of storage, takes between 15-30 days. Upon completion of each storage seal, a pressure retention test is conducted to establish that the specified degree of seal is obtained. This test is carried out by "pumping up" the storage using one of the gable end mounted fans. A positive pressure of approximately 180-200 Pa is provided by the fan and then the drop in pressure is recorded as a function of time. The actual standard or pressure drop vs. time is variable, depending on the storage size and construction, e.g., concrete storage - 15 min, different types of steel storage - from 10 to 5 min. By December 1992, Co-operative Bulk Handling Ltd. will have expended Aust.$ 22.8 millions on sealing storages and Aust.$ 750,000 on sealing maintenance.

FUMIGATION OF SEALED STORAGES

Initially, Co-operative Bulk Handling used phosphine in the country storages, and HCN in the terminals. By using the different fumigants in the two separate areas, the risk of resistance to either fumigant was kept to a minimum. In the early 70s, HCN manufacture ceased and the Company purchased all that was available at that time. Owing to diligent use. this supply lasted to the mid-80s. When the Company introduced phosphine fumigation to the seaboard terminals, it was decided to upgrade the method of introducing the fumigant to eliminate the risk of tablet residue contamination of the grain. To this end, the cells were sealed internally and a recirculation system installed. This allowed lowering of the tablets into cells supported on a mesh-covered tray and suspended above the grain mass. As the tablets broke down through the mesh, the residue was caught in the bottom tray. The tray was then removed once the fumigation was complete.

A further refinement to this system involved using PH_3 in cylinders, containing a 2% mixture of PH_3 in carbon dioxide (CO_2), available in 15 and 30 kg cylinders. The value of this system is the reduction in fumigation time (no waiting for the tablets to diffuse). Prior to sealed storages, tablets were probed into the grain or aluminium phosphide (AlP) blankets were used under PVC sheets. These tasks were both onerous and time-consuming. Currently, in sealed storages, the tablets are placed in aluminium trays along the catwalks, enabling a much cleaner and speedier operation.

Tablets are used to fumigate bunker type or internally-tarped storages using a half-barrel covered with mesh to support the tablets. Once again, as the tablets break down the residue is held in the barrel and so does not contaminate the grain. By using this method, Co-operative Bulk Handling Ltd. has been able to stop the use of PH_3 blankets at great savings to the Company.

The Company's major port facility at Kwinana is set up for application of CO_2, which is piped to the site from a nearby industrial complex. Its 700,000 tonnes of sealed storage can be fumigated with either CO_2 or PH_3.

In 1981, 0.6 million tonnes of grain out of a 5 million tonne harvest was not treated with contact pesticide. None of the grain received in the 1991/92 season (6 million tonnes) was treated with contact pesticide (Fig. 3). Surveys conducted on 1987/88 to 1990/91 receivals show that the number of times insects were found dropped from 148 to 81 (Fig. 4).

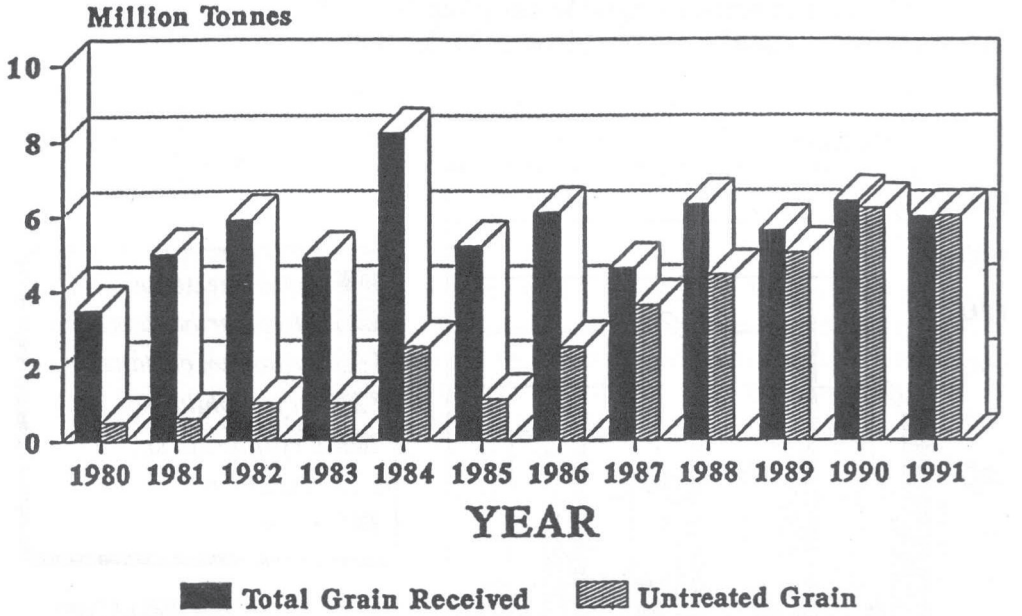

Fig. 3: Amount (in million tonnes) of total grain received and amount of untreated (no contact chemical pesticides used) grain over the period from 1980-1991 by Co-operative Bulk Handling Ltd.

ADVANTAGES OF CA STORAGE

The most obvious advantage comes from the saving in chemical costs and the infrastructure associated with them. In July 1987, an extensive economic impact study on sealed storages was carried out and it was established clearly that the savings were in the order of Aust.$ 30 million. Although it is now difficult to quantify total cost savings for many reasons, it is not hard to appreciate that the savings would have substantially increased.

Other advantages that are generated from CA storage include:

- Minimal delays to outloading programmes.

- Lowest ever levels of Dept. of Primary Industry insect shipping rejections.
- Availability of low, or nil, residue grain suitable for sensitive markets.
- Delays in the onset of resistant insect species.
- Reduction in the risk to staff in areas of occupational health and safety.
- Reduced cost in the transport, storing, recording, application, and supervision of pesticide application.
- Reduction in pesticide application equipment with savings on capital expenditure and maintenance.
- Reduction in the cost of storage hygiene.
- Reduction in pesticide residue sampling.

These are but a few of the more obvious advantages.

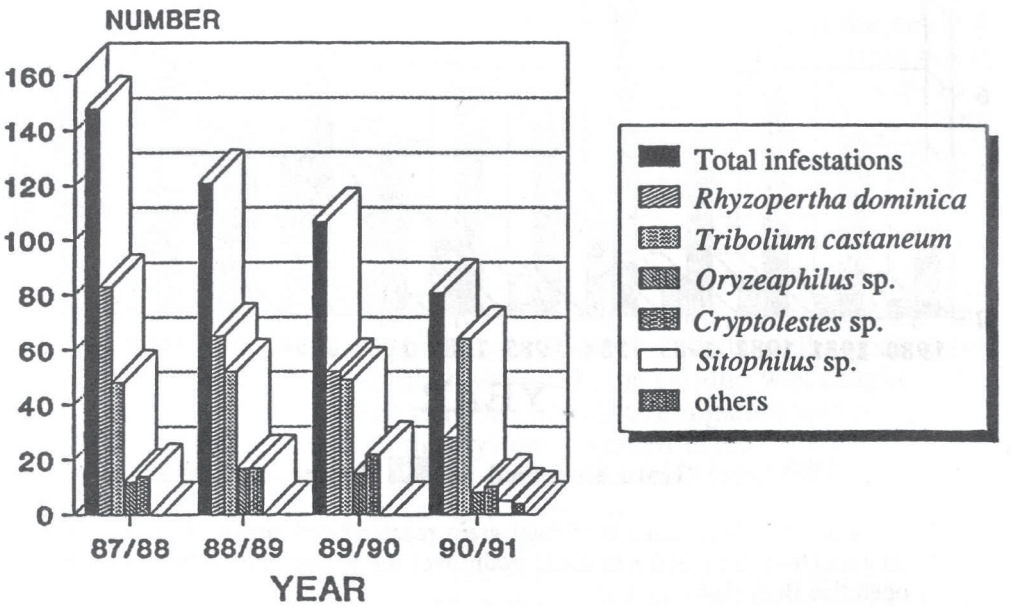

Fig. 4: Number of grain samples found infested by different insect species in grain received by Co-operative Bulk Handling Ltd. over the period 1987/88 - 1990/91 in Western Australia.

DISADVANTAGES OF CA STORAGE

The experience gained by Co-operative Bulk Handling Ltd. in utilising the CA concept as a mode of grain protection necessitated modification of the conventional methods of operating storage facilities and managing their contents.

Some of the difficulties that must be overcome in order to reap the benefits are:

- Management problems associated with the exposure periods necessary to control insect infestations and clearing the remaining gas before outloading can take place.
- Grain is received directly from the harvest, therefore manpower availability is at a premium.
- Once a storage is fumigated, access is restricted to all grain.
- Preventative maintenance to mechanical equipment, e.g., conveyors, bearings, and idlers, must be scheduled carefully.
- All staff employed in the fumigation of grain must be qualified and licensed.
- Time is required to train personnel in fumigant use and techniques.
- Re-infestation is possible once the storage is opened to the atmosphere.

OPERATING PROBLEMS

- Removal of translucent sheeting from roofs of horizontal storages created a lighting problem, particularly when outloading grain. Different sealing techniques now allow translucent sheets to remain in place with the addition of extra skylights as required, and those removed originally have been reinstalled.
- Dust accumulations and exhaust fumes also caused unpleasant working conditions in early sealed storages. This problem has been solved by installing larger fans at gable ends of storages.

CONCLUSIONS

Clearly, benefits such as chemical cost savings, provision of low or nil residue grains, and reduced contact to chemicals by staff serve to enhance the appeal of the CA technique in an integrated pest management system. Co-operative Bulk Handling Ltd. has now been utilising CA storage for 13 years, and is well-versed from the feasibility phase through to the commissioning of finished storages. Consideration by industry of this form of grain management must, in the final analysis, highlight a reliable, safe, and user-friendly control system.