CONTROLLED ATMOSPHERE GRAIN STORAGE

...state of the art...

The G.E.B. storage at Harden after sealing and painting.

Many different forms of non-chemical protection of grain are receiving world-wide attention as the need for alternative methods of pest control becomes more widely recognised, particularly in the face of increasing development of pesticide resistance by many of the important insect pests of stored grain.

Controlled atmosphere appears to be the most promising, both technically and economically, of the available physical methods of control. In the following article, Dr. Banks outlines the advances made to date through research into this particular area in Australia.

JONATHAN BANKS

Stored Grain Research Laboratory
C.S.I.R.O. Division of Entomology, Canberra

Methods of food preservation such as drying, salting and pickling were known to ancient man and are still in use today. Pit storage is a method of storing grain that has been in use for thousands of years and still is in parts of Africa and the Middle East. There has been little change in the basic method of use over the centuries, so the Iron Age grain storage pits in England were not substantially different from those in use in Ethiopia today. Pit or "hermetic" storage, as it is sometimes known, requires only that the grain be put into a sealed system. Insects in the grain then use up the oxygen in the air producing an atmosphere which kills them. The composition of the atmosphere in a pit is typically 13% carbon dioxide, 2% oxygen and 75% nitrogen.

The pit storage system is attractive because it is so simple. Furthermore, the problem of pests developing tolerance to low oxygen atmospheres seems unlikely to arise as it would require a basic change in the insects' metabolism. Attempts have been made this century, both here and overseas, to use the hermetic storage technique on a large scale. Successful trials were run at Wallaroo, South Australia, in 1918-1920 and the process has been used occasionally since then. Large scale use of hermetic storage is rare. However in Kenya and Argentina large permanent structures are in use. Because the grain in a pit can be stored in good condition for long periods of time without attention, pit storage is ideal for buffer stocks or famine reserves. The stocks in the Kenyan system are removed and replaced every three years. At the G.E.B.'s Cunningar site, there is a small model, 50 tonnes capacity, of an Argentinian hermetic storage. Wheat has been successfully stored in it for 14 years without attention.

If pit storage is so simple and successful why is it not widely used in Australia? Its main disadvantage is that currently available and tested systems are difficult to outload. Furthermore, the sealing of the storages must be very good, so that no air gets in. If air does leak in, it can allow insects in restricted regions to survive and reproduce, causing damage and moulding over a long period. The bulk handling authorities have a very large investment in above ground storages. Even if these cannot be made to operate as hermetic storages, the question is raised: can the general principle of controlling the oxygen and carbon dioxide levels be used in the existing system? Research to this end started in Australia after the First World War. It was found that carbon dioxide added to fairly gastight structures could control grain pests. In the July, 1921 issue of the *Agricultural Gazette of NSW*, Froggatt published suggestions for its use on bulk maize. Experiments in which bag stacks were fumigated under sheets with carbon dioxide were carried out in the same period in South Australia. Research continued sporadically both here and overseas until the late 1960's, when interest in the process again revived.

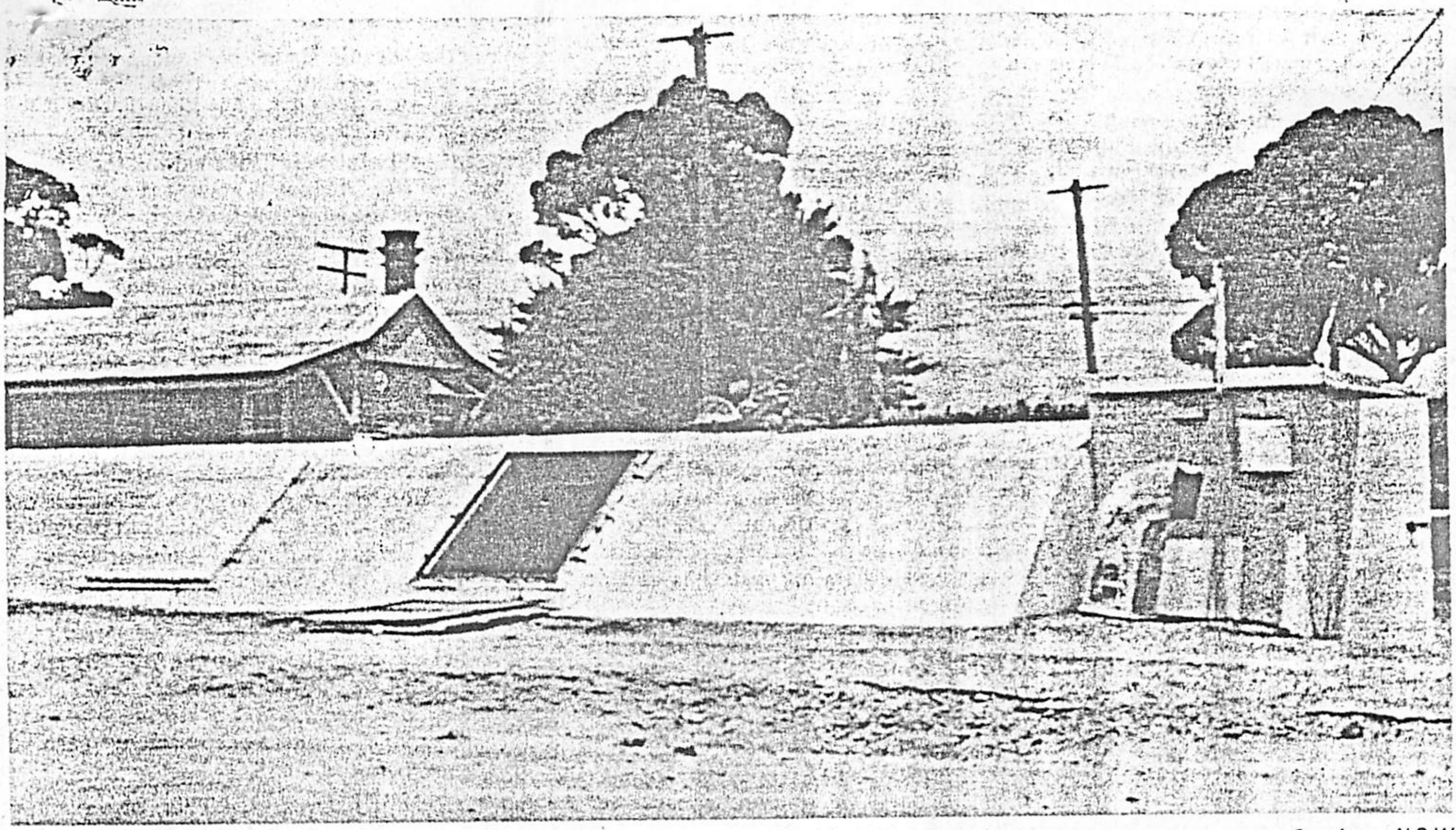
The use of nitrogen-rich atmospheres has been investigated. Air contains 78% nitrogen but if the oxygen, normally at 21%, can be reduced to 2% or less by the addition of more nitrogen or removal of oxygen, an insecticidal atmosphere is produced which is similar to that in pit stores.

Today, the use of both nitrogen and carbon dioxide atmospheres looks technically possible under most Australian conditions. Development to the stage where commercial feasibility can be assessed has been carried out in Australia by the C.S.I.R.O. since 1972, when the first large scale trial using nitrogen was carried out.

Nitrogen

The first research with controlled atmospheres was carried out with the nitrogen atmosphere system because it was simple to generate and the biological effects of the gas on the pests were known. Five of the eight trials conducted to date have been in welded steel bins as these are cheapest and easiest to seal to the required standard. One was in a specially sealed, bolted metal bin and two were in standard untreated concrete cells (at Cunningar). Nitrogen was supplied to the site as a liquid in a pressurised, insulated tanker (nitrogen boils at −196°C). The liquid was vaporised in a forced draught heat

Horse-drawn wheel scoops excavating trenches for grain storage pits (South Australia, circa 1918).



Model hermetic storage at Cunningar, N.S.W.

exchanger and introduced into the base of the grain bulk in a sealed storage. This initial phase, the "purge" phase, requires rapid input of gas. The nitrogen gas displaced the air in the bin which was blown out through the inloading hatch. When an atmosphere of about 1% oxygen in nitrogen was reached, the rapid introduction of gas at the base was stopped, the bin was sealed and a slow bleed-in of nitrogen was set up into the headspace. The continuous introduction of gas, the "maintenance" phase, is required to keep the correct composition of the gas in the storage. Without additional gas, air leaking in raises the oxygen content to the point where it is no longer insecticidal. When the grain is warm, as it is soon after harvest, two weeks to one month of exposure to 1% oxygen in nitrogen is needed to ensure complete "kill" of all stages of storage pests. The nitrogen bleed-in can then be stopped. In theory, a bin sealed to the required standard is insect-proof and when all the insects inside are dead, the grain should store indefinitely without attention if it is left undisturbed. However, if the seal is broken for inspection or outloading, insects may get in and build up an infestation. Long term storage systems using nitrogen have not been fully tested and can be only if the method is used on a commercial scale over a number of years. Nevertheless, in the two most recent trials (at Bungunya, Qld. and Balaklava, S.A.) the grain remained in storage without nitrogen input for five and eight months after treatment, respectively, without reinfestation. Infestations were present in adjacent bins. Both the State Wheat Board in Queensland and the Grain Elevators Board in Victoria have conducted their own successful nitrogen storage trials.

Carbon Dioxide

With the nitrogen system refined to the point where it could be used commercially, research attention turned to the use of carbon dioxide. Carbon dioxide can act as an inert atmosphere with stored product pests. Thus its action at 98% CO_2, 2% oxygen is similar to 98% nitrogen, 2% oxygen. However it is also toxic to these pests at lower concentrations. The biological optimum level for the toxic action has been found to be about 60% CO_2 in air. This mixture contains about 8% oxygen, which is sufficient in the absence of CO_2 for survival of most stored product pests. Carbon dioxide at a concentration of 35% CO_2 in air still kills insects but at a reduced rate. Thus a substantial amount of air can leak into a CO_2-filled storage before the atmosphere loses its effect. Recent experiments with CO_2 have aimed at a "one-shot" treatment. The CO_2 is introduced into the storage as with nitrogen. However, no additional gas is added to maintain the atmosphere. Natural leakage is restricted only by sealing. We have shown that it is possible to keep enough CO_2 in long enough for insect control in a large welded steel bin (7,000 tonnes capacity) at Bordertown, S.A. without additional gas. In our most recent trial in co-operation with the G.E.B. at Harden, the leakage rate observed showed that this was possible in a horizontal storage too. The Victorian Grain Elevators Board has also carried out successful trials.

When carbon dioxide is used in a one-shot operation a standard of sealing similar to that for nitrogen is required. Bin modifications are also similar. It has been found that a gentle rate of recirculation, about 0.1 air changes per day, is required to keep the CO_2 levels in the structure even. This requires a small extra fan and ductwork. The carbon dioxide system is now at a stage where it, too, is ready for commercial trial. A few questions remain to be answered. The minimum exposure time required under commercial conditions is not yet known exactly and long term storage in an insect-free condition after CO_2 disinfestation has not yet been demonstrated.

Small Enclosures

Carbon dioxide is a convenient material for disinfestation of small quantities of grain under gastight conditions if a long exposure, possibly more than 10 days, is acceptable. In co-operation with the

G.E.B. and other authorities, the use of CO_2 for the in-transit disinfestation of grain has been investigated. Wheat was loaded into 12 freight containers on a train at Boggabri, the containers having been selected to meet a gastightness standard. Some wheat was in bulk but some was in bag to demonstrate that the method could be applied to bagged commodities. Carbon dioxide was added as dry ice to the grain surface and a further quantity was added in a polystyrene foam box. This box gives a slow release of CO_2 over 10 days to compensate for leakage. The train was run to Sydney Terminal Elevator at Glebe Island and after a holding period was outloaded. The initial natural infestation of *Tribolium castaneum* was eliminated, as was an artificial infestation of *Sitophilus oryzae* which had been added for experimental purposes. Following this success a container of pesticide-free wheat was exported under CO_2 to West Germany. It was found to be insect-free by the German plant quarantine authorities although it left Sydney (under a special permit) with insects present.

Sealing

The efficient use of either nitrogen or CO_2 is dependent on the level of sealing of the storage. The sealing must be such that the leakage is low enough to allow an acceptable usage of nitrogen or avoid the need for an additional gas for carbon dioxide atmospheres. Experiments are in progress to determine how best to seal the various types of structure found in the bulk handling systems.

There are three distinct types of structure: welded steel bins, concrete cells and bolted metal bins or sheds. Examples of each kind have now been sealed to a suitable standard. It has been found to be easy and inexpensive (about 50c per tonne capacity) to seal the welded steel bins. The fabric is usually gastight and only the penetrations, doors, and the wall to floor joint require attention. The walls of vertical concrete cells are often too porous and cracked to meet the standard. Experiments at Sydney Terminal and at Cunningar have shown that both open top and capped concrete cells can be sealed to an acceptable standard with wall coatings. More experiments are required to optimise the coating process, find the most suitable sealing materials and determine the life of the coating.

The largest sealing experiment to date was carried out recently in the G.E.B. horizontal storage (capacity 16,400 tonnes) at Harden. This was sealed satisfactorily at a cost of about $3.70 per tonne capacity, using special acrylic sealers and reinforcing tapes on the lap joins. The ventilators and open eaves were filled in with sheeting and sealed. The whole roof was then painted white to reduce the temperature in the store and provide a pleasing appearance. The sealing process used is suitable for most bolted steel stores.

Future Application

With the development of adequate techniques for sealing most types of storage to a standard that permits controlled atmosphere storage, and following successful field trials with both nitrogen and CO_2, the way is now open for commercial assessment of the method. There is a requirement for detailed information on the economics and management problems that may be encountered, and proof over an extensive series of trials that it can provide a feasible system, compatible with existing requirements.

Controlled atmosphere storage is the only method currently available to the grain industry which will provide disinfestation of large bulks within one month without use of chemical pesticides.

Nitrogen storage of grain is already in use in Italy and controlled atmosphere systems in general are under development in the U.S.A., U.S.S.R., Israel and elsewhere. The technique will, I believe, eventually provide a cheap, reliable and residue-free method of storing grain, with possible application in many parts of Australia.

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Re-introducing carbon dioxide to steel bin at Bordertown, S.A.