CONSTRUCTION AND OPERATIONAL PROBLEMS ARISING IN SEALING LARGE CAPACITY HORIZONTAL STORAGES

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ABSTRACT

This paper describes development work undertaken by New England Industries Pty. Ltd., in the design and construction of large horizontal grain stores incorporating controlled atmosphere or fumigation techniques, automatic outloading and aeration. It has been accepted as a precept that storages must be capable of controlled atmosphere storage and total store fumigation, but it is considered pointless or futile having this capability unless all other essential functions of a modern grain storage facility can be undertaken without the need to regularly break the gastight integrity of the store to permit these operations to be carried out. The developments so far undertaken have culminated in a low cost "total concept" 60,000 tonne capacity storage at Moura in the state of Queensland due for completion in 1983. This storage is thought to represent a world "first" in its design concept and it is expected to be completed for less than 50% of the cost per tonne of more conventional vertical storages with the same functional capabilities.

Some of the problems associated with inloading, outloading and aerating grain in the sealed and gas charged situation have not been finally solved, as the store is not yet completed; this paper identifies the main problem areas remaining.

INTRODUCTION

The costs of vertical steel or concrete silos with a range of operational capabilities are now increasing to uneconomic and unacceptable levels. Since 1979, New England Industries Pty. Ltd. have attempted to develop low cost storage systems capable of providing the range of capabilities required in vertical silos. The functions required of grain storage systems are not static, but are subject to change as new materials and technologies become available and as market demands and statutory requirements change also. The functional capabilities of storage systems must therefore be both comprehensive and capable of modification. Taking this into consideration, it was found that the functional parameters used in this development were not necessarily compatible, they could appear to be contradictory. For this reason, as will be shown later, not all the functional requirements have so far been incorporated into the development.

The operational functions included:

(a) Mechanical handling for inloading and outloading at rates between 400 tph and 2,000 tph.

(b) A capability to control internal store atmospheres or for total store fumigation to meet the most stringent requirements for minimal or nil levels of insect infestation.

(c) Remotely controlled operations of inloading and outloading of grain, if necessary simultaneously, whilst the storage is sealed or charged with gases for fumigation. It is assumed that personnel could not/would not enter the storage to control the handling operations.

(d) Provision of inbuilt aeration systems to simultaneously cool and dry high moisture grain and to be able to carry out cooling and drying at the same time as fumigating and handling into and out of the store.

(e) Segregation of grain using free-standing dividing walls, capable of being loaded to a full height one side and with no supporting grain on the other side. It is necessary also to design free-standing walls and reclaim equipment in order that it can move past the walls from one area to another.

(f) Remote controlled monitoring of temperature; moisture levels; gas density and infestation levels.

(g) Safe working access to the most important mechanical equipment whilst the storage is charged for fumigation.

(h) The highest levels of safety and environmental protection to staff and others in the immediate surroundings of the store through control measures and safety systems.

THE PHASES OF DEVELOPMENT

The design and development has been a staged process with the various problems being identified and solved in discrete operations over a four year period.

During initial studies in 1979, a wide range of structural designs was analysed in order to arrive at the cheapest possible structure to provide permanent storage. An A-frame building design with low (2.8 metre) walls was selected. The concept is that an A-frame is the most economical covering of grain subject to its natural angle of repose. During the latter part of 1979, a 60,000 tonne storage was constructed at Trangie, N.S.W., for the very low cost of A $16.00/tonne of capacity. This storage has a 300 tph capacity inloading system, but it is not sealed and it does not have automated outloading.

However, the signficance of this first stage is that it highlighted the very substantial margin of capital cost available for sealing, automated outloading, segregation walls, and aeration when compared to the cost of the same capacity of vertical storage at A $150.00 per tonne of capacity but including the additional functions of outloading, aeration, etc. From this base of A $16.00/tonne, it therefore seemed feasible to develop a new type of permanent storage with considerable savings in capital cost.

In the years 1980-81, a 110,000 tonne capacity storage facility was constructed at Moree, N.S.W., and this became the first large horizontal storage in Australia in which special consideration was given to the structural design in order to maximise the benefits of controlled atmosphere storage and fumigation.

The store dimensions are 205 metres x 75 metres with walls 5 metres high. Grain is held to a height of 2.5 metres on the wall panels. Ridge height is 26 metres. Structural engineers for the project were D T Cohen & Associates. The basic sealing specification and test standards were provided by Banks and his colleagues from CSIRO and the sealing contract was undertaken by Programmed Maintenance Pty. Limited, on a guaranteed performance basis.

The following features were included in the design, some only minor in operational importance.

(a) Design pressures:

(i) Internal negative pressure of 2500 Pa. This is identical to the design live load, and it is considered they do not act simultaneously.

(ii) Internal positive pressure of 3000 Pa which is added on to the design external wind pressure.

Excess pressure is vented using "Protectoseal" two-way valves which actuate at $\pm$ 400 Pa.

(b) End wall and side wall cladding is placed inside the girts and finished flush to the top of the wall panels. Consideration was given to fixing roof cladding to the underside of the purlins in order to prevent dust trapping, but was ruled out due to excessive cost.

(c) All internal structural steel members and purlins are fabricated with downturn flanges so as not to collect dust.

(d) The floor finish is 50mm thick asphalt placed to highway standard. This finish has proved durable to oilseeds over a seven year period in other storages. It is found less prone to cracking and cheaper than concrete.

(e) Wall panels are pre-cast concrete slabs with the lower edge extending 300mm below floor level for protection from vermin.

(f) As far as possible all dust collection areas such as ledges were eliminated in the design.

(g) Gas venting is by natural air flow from a series of end wall and roof vents designed by the CSIRO and intended to ensure the structure will undergo several air changes in 24 hours. The vents are 14 metres above ground level. If natural venting is not successful, extraction fans will be installed.

(h) All inloading can be remotely controlled.

(i) The internal electrical system was designed to prevent corrosion from phosphine gas.

The integrity of the sealing of the store has been tested by CSIRO and found satisfactory under empty conditions. Unfortunately it has not been tested with grain because of the serious and continuing drought in that region. It has been loaded once only for a short period with 46,000 tonnes of wheat, sufficient only to commission the mechanical handling equipment.

Once again this store design did not include automated outloading equipment or provision for segregation. These two omissions led to considerable, and quite valid, criticism of the design and this has provided a further incentive to continue the design development.

Nevertheless, a number of the design features included in the Moree store, particularly relating to sealing and grain hygiene, have led to important lessons being learned from this development:

(a) As with Trangie (1979) the floor space is too large and the walls are too low for optimum economy when providing for automated outloading.

(b) No dust extraction equipment is provided, but it is interesting to note that under normal light wind conditions the building is kept sufficiently free from dust during inloading only using the end wall vents. If no vents are open, the dust becomes dense in a very short time.

(c) The purlins attach to cleats fixed to the top chord of roof trusses which create dust collection areas. This problem can be eliminated by placing the cleats to the side of the chord member.

(d) Pre-cast concrete wall panels are not entirely satisfactory as they may require sealing to prevent possible corrosion of the reinforcing steel, this is a matter still under study.

FULLY AUTOMATED OUTLOADING SYSTEMS FOR HORIZONTAL STORAGES

Studies in 1980 suggested that no efficient or proven system existed in Australia and enquiries were then extended to North America, Eastern and Western Europe. Three different systems were subsequently inspected and of these, the Nordon T.M.S. equipment in France was judged to best suit the requirements of unloading from a sealed storage. In May 1982 an inspection of this equipment in operation was carried out by engineers from Queensland State Wheat Board; mechanical engineering consultants, H Platt & Associates; and the structural engineering consultants, McWilliam & Partners. This inspection confirmed the suitability of the equipment and subsequently an order was placed after completing the design of a suitable structure; details of which are described below.

Several ideas for free standing segregation walls have been investigated by McWilliam & Partners. The principal limiting factors being foundation requirements and required wall heights of 10-15 metres. There are two possible solutions, both in reinforced in situ concrete. In general terms they can be described as:

(a) An inverted T tied into bored pier foundations.

(b) A profile of large vertical curves - this method is in use in France.

It is clear that portable pre-cast segregation wall units can be constructed where only low wall heights are required.

During 1982-83, designs were started for a 60,000 tonne capacity store at Moura, Queensland. The problem areas for the design of this facility will fall into two distinct categories:

(a) Separate operations of:

i. Controlled atmosphere storage or total store fumigation, without any grain movement.

ii. Aeration in an unsealed situation.

iii. Inloading and outloading in an unsealed situation.

(b) The ability to accommodate simultaneously, in a sealed situation, any two or all three of the following operations:

i. Phosphine fumigation or controlled atmosphere storage.

ii. Inloading and/or outloading.

iii. Aeration.

Design problems associated with the separate operations of the store are now largely solved. Nine proposed designs were analysed and costed before a final decision was taken on the Moura structural design. The great difficulties were in selecting wall height, internal width, foundation and column design. The selected design was intended for a new storage facility, but it now seems certainly possible that a range of existing stores could be modified to provide the same facility and accommodate the same or similar equipment.

For controlled atmosphere fumigation only, design problems have been reduced by changing to a new load bearing wall material "Siloclad" developed especially by Lysaght Brownbuilt Industries for the project. This is a deep rib vertical profile in 1.6mm high tensile galvanised steel. Purlin cleats have been reduced and the floor area reduced by 22% per unit of storage volume compared to Trangie.

To accommodate the unloading equipment, all aeration ducting (for use in an "unsealed" situation) is underfloor and the inlet ducts are below the concrete perimeter beam. Reversible fans are to be installed so that they may be used also for downward purging of fumigant gases.

The aeration ducting is also designed to provide drainage to the outside if washing down of the store is required.

The major changes in store design relate to the automatic outloading system provided by Nordon TMS of France. This equipment was chosen because:

(a) It is already proven;

(b) It can deal with level or inclined grain surfaces;

(c) The equipment can be operated remotely by Programmed Logic Control;

(d) It is accessible in the event of breakdown;

(e) It is programmable for different loading rates and has inbuilt sensors for following grain levels;

(f) It can be used for spreading grain as well as reclaiming.

The design changes required include:

(a) Sufficient headspace to allow longitudinal travel;

(b) Structural members to carry the equipment (which weighs 20 tonnes);

(c) Gantry rails for support of unloaders;

(d) The joint between wall and floor to be self cleaning;

(e) Construction of a series of continuous in-floor gravity hoppers and valves feeding to the underground reclaim conveyor. Initial design studies were directed towards an above ground fabricated steel walk-though tunnel with side valves feeding a drag conveyor but this idea was later abandoned.

The problems of integrating controlled atmosphere storage, fumigation, inloading/outloading and aeration still largely remain. There is no evidence that the simultaneous carrying out of these operations has been attempted previously in horizontal stores. The major operational problem is the control and containment of toxic substances such as phosphine. The safety aspects are vital considerations and control must be to such a degree that there is no possibility of leakage that will endanger employees. It is anticipated that control and containment of carbon dioxide and nitrogen will present far less hazard than phosphine, accordingly the development work and the gas removal specification will be based on phosphine.

The problem areas for containment and control that are presently being investigated are:

(a) Inloading - Transfer Chute to Ridge Conveyor

(b) Inloading - Wall Grain Levels Coupled to Trippers

(c) Placement or Retrieval of Fumigant Strips or Pellets

(d) Testing for Infestations

(e) Monitoring of Temperature, Moisture Levels and Gas Density

(f) Remote Control Operation of Reclaim Conveyors

(g) Design of Gas Tight Valves to Underground Reclaim Conveyor

(h) Remote Control Valve Operation

(i) Positive Fresh Air Pressure in Tunnel to Permit Maintenance

(j) Fresh Air Venting of Outloading Elevator Shaft

(k) Purging Gas of Outloading Grain Stream and Prevention of Excess Gas Escaping from Storage

(l) Monitoring Equipment for (k)

(m) Aeration

Some possible solutions have already been identified and it is hoped they will all be successfully implemented by the end of 1983.