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AUSTRALIAN SIROCIRC[□] RECIRCULATORY PHOSPHINE FUMIGATION SYSTEMS AT XIZUI GRAIN TERMINAL AND INLAND DEPOTS IN CHINA

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ABSTRACT

SIROFLO[□] fumigation technology was invented in Australia in the 1980's, for the purpose of fumigating grain in bulk using gaseous phosphine. Until recently the technology has been adopted in relatively few other countries because of the difficulties associated with the registration of gaseous phosphine products, despite the fact that their active ingredients are chemically identical to the less pure solid phosphide formulations that are in common use worldwide. However In the last two years, significant moves have been made to broaden the international market for SIROFLO technologies and gaseous phosphine products. Grain Tech Systems Pty Ltd (GTS) is a small Australian company that has participated in this process by introducing the technologies to the People's Republic of China. This paper briefly describes some of the projects that have been undertaken by GTS in China, and some of the emerging grain fumigation technologies that are being developed in competition with GTS.

INTRODUCTION

SIROFLO[□] fumigation technology was invented by Dr Bob Winks of CSIRO, Australia, in the early 1980's and was developed for the fumigation of grain using a gaseous mixture of phosphine (PH₃) and carbon dioxide (CO₂). In Australia this fumigant mixture is sold under the registered name ECO₂FUME[®]. The fundamental aim of SIROFLO technology is to deliver and maintain a low concentration of PH₃ throughout a grain mass for an extended period of time in order to maximise the toxic effects of the PH₃ fumigant.

By creating and maintaining low PH₃ concentrations over extended time periods, the use of SIROFLO technologies not only increases the effectiveness of the fumigant, but also significantly reduces the quantity of fumigant used in a

fumigation, and thus minimizes emissions into the environment. At the same time, overall safety for fumigators and silo operators is enhanced since there is no direct contact with the fumigant. Fire hazards are eliminated and emissions from storages during fumigations are greatly reduced. Phosphine residues in the grain are also significantly reduced when using these technologies.

The SIROFLO group of technologies fall into three categories:

- SIROFLO for fumigation of non-gas-tight storages;
- SIROCIRC[□] for recirculatory fumigation in partly gas-tight storages;
- SIROFUME[□] for one-shot fumigation of fully-gas-tight storages.

All three technologies carry international patents, and are licensed to Cytec Industries of the USA, under a 10 year agreement signed in 1999.

SIROFUME differs from the other two in being a “one-shot” technique in which gaseous phosphine is dumped into a sealed storage. It will not be discussed further in this paper.

SIROFLO involves the mixing of ECO₂FUME in air at a predetermined concentration, and blowing it continuously at a controlled rate through the grain mass under a low positive pressure using a small fan and distribution ducting. Provided the walls of the storage are reasonably gas-tight, the low positive pressure ensures that fumigant leaks outwards through the storage structure, and minimizes ingress of air that could locally dilute the fumigant concentration.

SIROCIRC is identical to SIROFLO except insofar as it incorporates a return duct connected between the storage roof and the fan inlet. This allows the recovery of PH₃ from the headspace above the grain and its recirculation through the grain mass. In a reasonably well-sealed storage >90% of PH₃ can be reused.

Whilst SIROFLO is a set-and-leave operation, SIROCIRC requires a reduction in the fumigant flow-rate once PH₃ begins to recycle back from the top of the storage. This can be done manually, but control is facilitated by the use of an automatic electronic controller that intermittently adjusts the fumigant flow to generate a near-constant PH₃ concentration in the delivery duct. The automatic microprocessor-based controllers used in SIROCIRC systems, were designed and developed by Len Cherkson & Associates of Australia, and are manufactured by All-Systems Electronics also of Australia.

Since most new storages in China are reasonably gas-tight, GTS has concentrated on the development of a market for SIROCIRC[□] systems incorporating automatic controllers with a manual over-ride. So far GTS has installed 16 systems at eight sites and has contracts to install a further 28 with expectations of further orders in the future.

GTS has also lodged an application with the Ministry of Agriculture in Beijing for registration of the ECO₂FUME fumigant mixture in China under the apt name “Yi Ke Fu” (meaning “easy to kill insects”). GTS has also lodged an application for the registration of VAPORPH₃OS (gaseous PH₃) under the equally apt name “Wei Ke Fu” (meaning “powerful to kill insects”). Applications have been lodged on behalf of

Cytec Industries Inc of the USA, the global manufacturer and supplier of these products. Both applications are expected to be approved in the immediate future.

GTS's entry into the China market, and its successful demonstration of a small SIROCIRC systems near Beijing in 1997, generated a much greater level of interest than expected. Since then several Chinese companies have developed their own technologies for fumigation of grain based on the use of gaseous phosphine, either derived from cylinders or from on-site generators.

This paper briefly describes some of these installations projects that have been undertaken by GTS in China, and some of the emerging grain fumigation technologies that are now being developed in competition with GTS.

Changping Demonstration Trial

With the help of CSIRO, BOC Gases and the Beijing Central Grain Depot, and using equipment manufactured and supplied by GasApps Australia, a demonstration SIROCIRC system was established at the Changping grain depot, near Beijing in 1997 for the purpose of demonstrating the technology to anyone who was interested in seeing it, and also to obtain test data to be used for the registration of ECO₂FUME in China. The system was still in operation in late 1998 when the opportunity was taken to invite participants at the 6th International Working Conference on Stored-Product Protection (IWCSPP) in Beijing to see it.

The demonstration trial was a temporary arrangement and was built accordingly, using PVC pipework to deliver and recirculate the fumigant through 12 x 600 tonne quite poorly sealed brick silos. Trials were conducted using specially-bred phosphine-resistant insects placed in cages inside the silos, to demonstrate the effectiveness of the technology in delivering PH₃ at a constant concentration over a controlled period of time. The results of these tests, together with smaller-scale tests conducted in Guangzhou (south China) have been used in an application for registration of ECO₂FUME in China.

Dalian Xizui grain terminal – Phase 1 development

Dalian Xizui Grain Terminal Phase 1 Development was GTS's first commercial SIROCIRC[®] venture, (and only its second commercial venture). Xizui Grain Terminal is a new grain terminal that has recently been constructed by the Dalian Beiliang Company and is located just outside the city of Dalian in the Northeastern province of Liaoning. Funding for the silo component of the project was jointly provided by the World Bank and the Chinese government under the auspices of the World Bank's Grain Distribution and Marketing Project. Approximately 150 x 3,000 tonne silos have been constructed, plus 8 x 1,400 tonne working bins, and the facility has a planned throughput capability of some 9.3 million tonnes per annum of corn exports and (mainly) wheat imports.

Only 27 x 3,000 tonne silos plus 4 x 1,400 tonne working bins have been fitted with fumigation (which we considered to be too few to effectively control insects in such a large facility, no matter how good the fumigation system). Five separate

fumigant distribution systems were established, all fed from a central ECO₂FUME delivery system.

Instead of pre-mixed ECO₂FUME, GTS elected to offer site mixing of CO₂ and VAPORPH₃OS (PH₃) as a means of reducing fumigant costs and inventory of cylinders. The central mixing facility incorporates a 5 tonne cryogenic liquid CO₂ storage tank, a storage compound for VAPORPH₃OS cylinders, an electric vaporizer for vaporizing the CO₂ as it is delivered from the tank, and an automated mixing system. Control of gas delivery and mixing, including automatic switching from VAPORPH₃OS cylinder to another, is via a local PLC. ECO₂FUME is reticulated to each of five dispensers, which control the flow-rate of ECO₂FUME into the ductwork where it is mixed with an air-stream delivered from the adjacent fan. A SIROCIRC controller automatically adjusts the flow rate to maintain a constant concentration of PH₃ in the ductwork. The dispensers and mixing system were all developed and supplied by GasApps Australia, while the VAPORPH₃OS gas was supplied by Cytec Industries.

Delivery ductwork is connected to several silos (up to seven in this case), and the airflow rate into each silo is controlled so that near-equal distribution of fumigant is achieved in all silos regardless of the state of filling or airflow resistance of the silo contents. Valves are fitted to the ductwork above and below each silo to allow isolation of silos that do not require fumigation. A condensation trap is provided above each silo to catch and remove condensation during cold conditions, and so prevent it dripping back onto the grain surface. Because the silos are not fitted with aeration ductwork, special diffusers had to be designed to diffuse the fumigant into the grain mass within each silo. Instead of on-floor diffusers normally used, GTS elected to use external diffusers bolted to the silo hopper outlets.

Because of the high grain throughput rates expected at the terminal, all five systems were designed substantially oversized for normal SIROCIRC operation. This was done to provide the capability for fast fumigation of individual silos, and for this purpose, each system has been designed with the capability of delivering high concentrations of PH₃ (>700 ppm) in a short period of time (around 12 h distribution time) to any single silo. Fan and duct sizes are therefore much larger than otherwise needed.

GTS completed installation of the fumigation system in May 2000 but commissioning was delayed until September because of late completion of other works. Commissioning is now practically (and successfully) completed, a concentration of 100 ppm having been successfully maintained for an 18 d period in 11 differentially filled 3,000 tonne bins. All 11 silos were sealed to a 3-min sealing standard, with the result that very high rates of PH₃ recovery were achieved. Whilst the rate of VAPORPH₃OS consumption was not specifically recorded, measurements taken indicate that the recovery rate was in the order of 90 to 95% once stable recirculation conditions had been achieved.

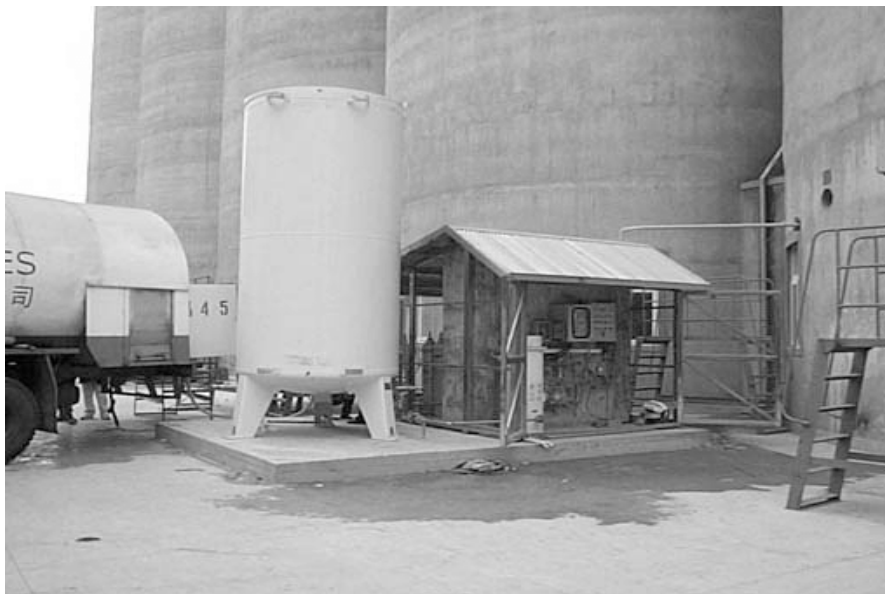


Fig. 1. The 400,000 Tonne Dalian Phase 1 silo block of 144 x 3000 tonne cells, bulk liquid CO₂ storage tank and on-site ECO₂FUME mixing enclosure.



Fig. 2. VAPORPH₃OS enclosure and ECO₂MIXER with automatic cylinder valve operation

Dalian Xizui grain terminal – Phase 2 development

Coincident with finalization of its contract to install the fumigation system for the Xizui Phase-1 silos, GTS won a second contract to install similar SIROCIRC fumigation systems in the Xizui Phase-2 silos on behalf of the same owner, the Dalian Beiliang Company.

The Phase-2 component of the project was financed independently from the Phase-1 component, and used only Chinese funds. The storage consists of 20 x 30,000 tonne silos – perhaps the largest silos of their type in the world. Each bin is 32 m in diameter with an eave height of 45 m. Floors are flat and each silo is fitted with eight large fans delivering air to eight separate in-floor aeration ducts. Roofs are *in-situ* concrete cones, and being designed for long-term storage, silo construction has been designed to achieve a degree of gas-tightness suitable for successful fumigation.

GTS's design includes an ECO₂FUME mixing and reticulation system identical to the Phase 1 design, feeding only four dispensers – each dispenser connected to five silos. Fumigation delivery ductwork is connected to the aeration ductwork – with eight delivery points per silo. A single recovery point is provided at the apex of each bin. GTS completed its installation work in June 2000 but has not been able to undertake full commissioning yet due to non-completion of other works. Preliminary commissioning has been conducted however, which verified that the

required air-flows and gas-flows can be achieved, and no problems are expected when full commissioning is conducted.



Fig. 3. One of 5 “Dispensers” for metering ECO₂FUME gas mixture into an airstream delivered to a group of up to seven silos. The dispenser enclosure includes an air-pressure gauge, fumigant regulator, flow control valve, flow meter and electronic SIROCIRC controller. Behind the cabinet is the fan that recirculates fumigant through the silos.

Country silo projects

GTS has recently signed contracts to supply 35 fumigation systems to newly constructed storages in 31 depots the Northeastern provinces of China. All storages are of the “squat silo configuration (large diameter, short wall height), and most are in the range of 5,000 to 10,000 tonne capacity. It is expected that all silos will be sufficiently gas-tight to justify the provision of SIROCIRC fumigation systems.

At most sites, a single fan and dispenser are sufficient to deliver fumigant to the storages, though at larger sites two separate systems are being supplied. In all cases, the fumigant mixture is being supplied pre-mixed in cylinders because of the

difficulties of delivering bulk CO₂ to the mostly remote locations involved. At the time of writing, seven of these systems have been completed and several more are in the process of installation.



Fig. 4. Undersilo delivery ducting feeding a “diffuser” mounted to the hopper discharge (prior to installation of valves and chutework).



Fig. 5. Oversilo ducting including condensation traps above each silo roof connection

Chinese fumigation systems

Whilst GTS has concentrated its efforts towards marketing and adapting tried and proven technologies from Australia, competing technologies are being developed locally at great speed, aimed at penetrating what is a new and quickly-expanding market.

Whether or not GTS's early activities at Changping really sparked this hasty activity is uncertain, but the evidence suggests that it probably did, since shortly after the start of the Changping trial, Chinese central government decided that all future grain stores should be fumigated using gaseous PH_3 as the fumigant. Thereafter a large number of new firms were established to try to take a share the market. One at least produced a working copy of the SIROCIRC controller, however without a proper understanding of the engineering behind it, its performance was apparently short-lived and it is not believed to be in commercial production. It appears that most of the Chinese fumigation systems that are finding their way onto the vast number of new Chinese storages that are currently being constructed, are based on the use of PH_3 generators that use tablets as the source of phosphine. How successful these will prove in practice remains to be seen, but so far as is known, all of the many varieties of Chinese PH_3 generator are designed to produce a high concentration of phosphine over a period of a few hours, and are thus to be used for "one-shot" fumigations (with top-up capability). They do not appear to be suited to extended delivery periods as would be necessary for SIROFLO-type fumigations. Their success is thus likely to depend ultimately on the gas-tightness of the storages that they are attached to, and/or the resoluteness of local grain storage operators and handlers (still under government control) to contain the spread PH_3 resistant pests. As in most countries, local understanding of insect resistance appears to be limited and while that continues to be the case, very little is likely to happen in terms of a widespread and active approach to combating it.

GTS hopes that by introducing new fumigation technology into China, it may serve to broaden the level of awareness of the existence of such technology, and the benefits that it offers.



Fig. 6. Dalian Phase-2 Silos: 20 bins each 30,000 tonne capacity. The GTS's CO₂ storage - tank and ECO₂FUME on-site mixing enclosure are dwarfed by the silos. Fumigant delivery ducting can be seen around the lower part of each silo.



Fig. 7. Phase-2 over-silo recirculation ducting including exhaust vent over nearest bin.