Session 6

Sealing Techniques and Methods of Determining Gastightness

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FUTURE BULK GRAIN BIN DESIGN NEEDS RELATED TO SEALING FOR OPTIMUM PEST MANAGEMENT: A RESEARCHER'S VIEW

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For decades, U.S. grain elevators have experienced fumigation failures in steel bins due to inadequate sealing of the bins. At the present time, U.S. grain bin manufacturers do not sell bins with seal kits as standard equipment and not all manufacturers have adequate kits to seal the bin wall panel joints. Aeration and drying fans, conveyors, and sidewall access doors are not designed for insect exclusion and are difficult to seal adequately. Research has shown that the headspace in steel bins should not be completely sealed, except during fumigation or CA/MA treatment, as this can create storage damage if the grain manager does not monitor the grain adequately. However, U.S. grain elevators and farmers should be able to purchase bins with base and sidewalls that are sealed or 'sealable'. Steel bin roofs should be designed to exclude insects and allow movement of fresh air through the headspace, but which can be quickly sealed during bin treatments. Newly constructed sealed bins should be capable of meeting a U.S. bin sealing standard (not yet developed). Research also indicates there are other storage design improvements that should be incorporated into the standard bin design. For example, white painted bins keep grain cooler and flat bottom bins can be made self-cleaning using advanced aeration system designs to eliminate insect harborages in the bottom of future steel bins.

FUTURE BULK GRAIN BIN DESIGN NEEDS RELATED TO SEALING FOR OPTIMUM PEST MANAGEMENT: A MANUFACTURER'S VIEW

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Small-scale corrugated grain bins have been adequately sealed at Purdue and Oklahoma State Universities for use in research. Actual full-scale corrugated bins have also been adequately sealed in pistachio facilities in California. The challenge to accomplish this in normal grain facilities is to convince the user of the need to spend the extra money and to train the commercial bin erector in the proper method. Special vents must also be designed to keep the fumigators from having to seal the vents manually. In the future, U.S. bin manufacturers will be challenged to provide bins with accessory kits that will provide complete sealing to hold a reasonable gas level for PH_3, CO_2 or other modified gas atmospheres. Buyers should also be able to purchase 'stock' bins that will exclude insects from entry (insect barriers at fans, conveyors, access doors, eaves, vents, roof junctions, peaks and conveyor entry points). Thus, new research is needed to develop IPM methods in tightly sealed bins with possible changes in aeration technology for early control of insects. New eave and fill-point sealing and roof venting technology that can exclude insects will be required to maintain adequate head space air exchange that will prevent excess moisture condensation on the underneath sides of bin roofs, with resultant

dripping on the grain surface. Research has shown that galvanized steel does not reflect solar radiation as efficiently as white bin coatings. Work in the future may need to focus on more reflective sidewall and roof coatings. Self-cleaning aeration floors would also improve grain storability by removing grain dockage and foreign material that insects feed on under false floors or in aeration ducts.

FUMIGANT CONFINEMENT AND HALF-LOSS TIMES IN FOOD INDUSTRY STRUCTURES AND SHIPPING CONTAINERS

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Fumigant dosages are calculated using the formula concentration $\times$ exposure time = dosage (g h m^{-3}). Fumigant lost from the fumigation atmosphere ceases to contribute to the accumulating dosage. The rate of fumigant loss during the exposure is represented as half-loss time (HLT) in hours. The more quickly fumigant escapes from the confined area, the shorter the HLT. Results from studies in which fumigant loss was monitored from a variety of food industry structures indicated that tape & seal confinement procedures achieved relatively short HLTs, generally less than 20 h, while tarping increased HLTs severalfold. HLTs within untarped multi-story mills were not consistent across floors, the upper floors generally having shorter HLTs than the lower floors. HLTs also varied during the exposure time, due to external environmental changes. A possible fumigation efficiency strategy in complex mills is to isolate floors, dosing each floor based on its HLT. Due to the apparent similarity in construction of shipping containers, fumigant confinement was predicted to be consistently high. Results of monitoring a series of containers fumigated with sulfuryl fluoride, however, revealed a wide range of HLTs, from ~ 4 to > 80 h, most likely due to differences in the gas permeation qualities of the wooden floors in the containers. Knowing, or predicting HLT accurately, is critical to fumigation cost-effectiveness. Understanding sealing options and the associated costs and benefits enables the knowledgeable fumigator and customer to prepare the most appropriate fumigation management plan. Improving fumigant confinement makes economic sense when additional labor and material costs for sealing are less than the cost of using more fumigant.

FUMIGATION PRACTICES IN FOOD PROCESSING PLANTS: STRIVING FOR 'BEST PRACTICES' THROUGH IMPROVED EFFICIENCIES WITH SULFURYL FLUORIDE

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The food processing industry faces new challenges as a long-time pest management commodity-fumigant favorite, methyl bromide (MB), is phased out. Many of the wide variety of MB uses have already been replaced with alternative pest management strategies, while many others continue unchanged. Among alternative strategies to MB are a limited number of other fumigants, one being sulfuryl fluoride, developed by Dow AgroSciences. Ongoing field trials are conducted to improve the efficiency of fumigation through better gas introduction and structure sealing techniques. Four years of research fumigations of empty food processing plants have shown that relatively simple enhancements in gas introduction procedures and structure sealing techniques can result in considerable improvements in shortening gas introduction times and lengthening gas retention times. This results in an increase in fumigant efficiency through equal or better insect pest efficacy using less fumigant. In case studies of monitored sulfuryl fluoride fumigations of empty food processing plants, with efforts to achieve best fumigation practices, results have demonstrated the following improvements in gas efficiency: *(a)* $>$ 50% reduction in gas introduction times; *(b)* 1.5- to 8-fold increase in gas retention; *(c)* $>$ 70% decrease in variation of gas retention across structures; *(d)* nearly 80% decrease in variation of gas concentrations across structures; and *(e)* accumulation of 44–66% greater Ct dosages with 27–36% less fumigant. These kinds of fumigation improvements are critical to the continued viability of fumigation as a tool in stored-product pest management programs of the future.

PHOSPHINE FUMIGATION FAILURES IN CONCRETE SILOS IN THE SOUTHWESTERN U.S.A.

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For decades, U.S. grain elevators have experienced fumigation failures in concrete silos with dosages applied by automatic pellet machines while turning grain from full to empty silos. Using dispensers that place pellets uniformly in grain, was the ideal traditional concrete silo fumigation method. Random concrete silo fumigation failures have not aroused the interest of USDA or university researchers. In the mid 1990s, a U.S. phosphine manufacturer conducted field tests on four silos with gas sampling tubes at 0 (headspace), 20, 60 and 117 ft from the surface, to identify causes of failure. Results were startling. Uniformly dosed silos lost most of their gas in less than 48 h. Silos with pellets hand applied in the bottom half of the silo maintained gas levels beyond 72 h. Headspace readings were very low in all tests. The apparent failure cause was wind currents through silo under-roof exterior wall vents that suck gas out. In 1999–2000, OSU researchers studied sealed *vs* unsealed concrete silos, sampling gas at 0, 25, 50, 75 and 100% of silo depths during 7-day tests. Sealing involved sealing under-roof exterior vents, roof (fill and vent) and base openings (conveyors, hatches, etc.). All test treatments included minimum commercial recommended levels of PH_3 for concrete silos. Pellets were applied automatically *vs* hand-placed in batches at the bottom 1/4, 1/2 and 3/4 of the grain. Weather conditions were documented by OSU MESONET. Headspace gas levels were low in all unsealed silos. Gas readings in all unsealed bins decreased rapidly at all levels in automatically dosed silos, but more slowly at all in-grain levels in hand-dosed silos. Generally, all readings were very low after 7 days. Gas levels remained higher in sealed silos, regardless of dosage method. Some leakage occurred in sealed silos through cracks between roof decks and irregular sidewall surfaces. Sealing of silo under-roof exterior wall vents makes a major difference in efficacy during PH_3 fumigation in concrete silos. Further sealing of the roof deck to silo wall crack may only add minor gas level improvements, but may help exclude insects from silo headspaces.

VALIDATION OF MODELS FOR CONTROLLED ATMOSPHERE GAS LOSS FROM BOLTED-STEEL GRANARIES

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Predicting the loss of CA gas (CO_2) from metal grain bins caused by wind, temperature, and chimney effects will improve the efficiency and effectiveness of CA fumigation of stored grain. Two published mathematical models (Lawrence Berkeley Laboratory [LBL] and Banks and Annis [BA]) were evaluated for their ability to predict gas loss from a galvanized steel grain bin (5.56 m diam $\times$ 6.60 m height). Experimental tests were conducted to provide validation data for the models. The effective leakage areas (ELA) of the empty bin were determined using fan pressurization tests for the bin. A CO_2-impermeable plastic sheet was attached to the inside wall at 2.5 m above the floor. This excluded the upper half of the bin including the roof, resulting in an ELA of approximately 7.69 cm^2. When the bin contained wheat, the LBL model over-predicted the wind effect by an average of five times the rate of the measured gas losses (CO_2, introduced as dry ice). The predicted effect of temperature on gas loss was within 1% of the rate from the bin. Error in predictions may be because the shielding and terrain coefficients used in the model do not account for the direction of the prevailing wind and are subjective for each bin site. Also, overestimation of the ELA would cause significant differences between predicted and experimental data. Predicting the rate of gas loss caused by wind with the BA model was difficult because the model was sensitive to an unknown pressure coefficient. The predicted gas loss rate for the bin due to the chimney effect was 15 times the experimental rate. Further experimental studies are needed to separate the wind, temperature, and chimney effects so that the models can be improved for estimating gas leakage losses.

CRITICAL LIMITS OF SEALING FOR SUCCESSFUL APPLICATION OF CONTROLLED ATMOSPHERE OR FUMIGATION

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A fundamental requirement for the successful application of gaseous treatments to control stored-product insects is a well sealed structure. A flexible fumigation structure (marketed as ‘Grain Pro Cocoon’ or ‘Volcani Cube’) of 7.5 m^3 capacity that is used for outdoor storage of stacked commodities was used to demonstrate the critical limits of the degree of sealing using the variable pressure test. Time in minutes for the half-life pressure decay was correlated with daily ventilation rates of O_2, CO_2, phosphine and

methyl bromide (MB). The ventilation rates were tested using different sizes of cross-section leak areas with orifices of 1.6, 3.2 and 6.4 mm i.d. To evaluate the influence of temperature on the rate of gas exchange, the cube was tested when it was under cover by providing shading to minimize the direct solar heating effect, and when it was exposed to direct solar heating. O_2 infiltration rate for modified atmospheres was 0.5 O_2% day^{-1} at 5 min half-life pressure decay when the chamber was under shade. For the same level of gastightness, gas loss was 0.8 O_2% day^{-1} when exposed. CO_2 loss rate was 2% day^{-1} at 5 min half-life pressure decay when the cube was under shade and 3% day^{-1} when the cube was exposed. Loss rate of PH_3 from the cube for the shaded conditions was 100 ppm day^{-1} at a 3-min half-life pressure decay time. A sealing equivalent to a 4.5 min half-life pressure decay time was required when exposed. The MB loss rate of 1.0 g m^{-3} day^{-1} was equivalent to $\sim$ 5 min half-life pressure decay time. At the time tests were carried out with MB, ambient temperature differences were not large enough to show different loss rates between the shaded and the exposed cube.