Comparative Evaluation of Integrated Pest Management, Heat Treatments and Fumigants As Alternatives to Methyl Bromide for Control of Stored Product Pests In Canadian Flour Mills

Canadian National Millers Association
Ottawa, Canada

March, 2007

Acknowledgements: Study Sponsors and Participants

The Canadian National Millers Association (CNMA) wishes to thank Agriculture and Agri-Food Canada (AAFC) for the department's financial (ACAAF contribution agreement) and in-kind support for the pest control trials conducted within the scope of this project. The ACAAF program guidelines and project officer support are ideally suited to this type of collaborative applied research and development. We express our appreciation to the AAFC Adaptation Division for their ongoing advice and administrative support.

In particular, we wish to thank Dr. Paul Fields and his research assistant, Tannis Mayert of AAFC's Winnipeg-based Cereal Research Centre. Dr. Fields devoted many days of travel and on-site observation during trials to assemble the efficacy data presented in his appendix to this descriptive summary of pest control challenges and individual company experience.

CNMA also wishes to thank the pest control technology and service providers who participated and provided technical and in-kind support to the trials conducted in 2005 and 2006 under the scope of the ACAAF contribution agreement.

The association also thanks its milling member companies who volunteered their facilities for the trials and invested funds and in-kind resources in this collaborative research. The findings of this series of trials are of significant assistance to not only participating milling facilities but to all grain milling companies and their respective pest control service providers.

Note to readers:

The opinions expressed in the main body of this report are those of the CNMA and do not necessarily reflect the views of Agriculture and Agri-Food Canada or Environment Canada.

The appended efficacy report (Appendix 1 - technical summary) authored by Dr. Paul Fields should be considered to be a research paper that fairly represents the data assembled and observations made during the pest control treatment trials. Opinions expressed in Dr. Fields' paper are those of the author. Dr. Fields' report has been peer reviewed. CNMA has also carefully reviewed Dr. Fields report to find that it fairly represents the efficacy observed by the participating firms.

Complete texts of CNMA's and Dr. Fields' 2004 report on comparison of alternatives to methyl bromide can be found at:

www.canadianmillers.ca

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I Introduction - Project Overview

The Canadian grain milling industry is comprised of firms that are primary processors of wheat, oats, corn and other cereal grains. The products of this industry are used principally as food ingredients. Some by-products of grain milling are used as ingredients in pet foods, livestock feeds and other non-food industrial products.

Grain mills are prone to naturally occurring infestation with insect species that are indigenous to Canada and found in most other temperate climates. Grain milling companies share the challenge of minimizing insect populations at all times.

Changes in Canadian federal regulations are affecting the availability of pest control products and technologies. Technologies available today may not be available in future, among them a chemical fumigant, methyl bromide (MeBr or simply MB in some references). Technologies commercially available and permitted for regulated use in other countries are not necessarily yet available in Canada and some are still undergoing pre-market evaluation.

The Canadian National Millers Association has encouraged its member companies to evaluate alternatives to methyl bromide. Supported financially by Agriculture and Agri-Food Canada (AAFC) and in a scientific capacity by Dr. Paul Fields of AAFC's Cereal Research Centre, a number of CNMA member companies have undertaken trials of alternatives to methyl bromide in 2005 and 2006. This report provides additional information on the context for the trials and a number of case studies highlighting the findings of the trials.

Appended is Dr. Fields' scientific report of efficacy (insect mortality data) and an excerpt from the report of a similar project completed in 2004.

II The Need for Alternatives to Methyl Bromide in Grain Mill Pest Management Programs

This introductory section is intended to provide readers with a brief context for the collaborative research and case studies that are described in following sections and Appendix A (Efficacy Assessment) in this report. For additional detail on the subjects touched upon below, readers are invited to consult the references provided in Appendix 2.

Regulated Phase-out of Methyl Bromide

Methyl bromide is used commercially in Canada and many other countries as a fumigant to:

- control soil-borne plant pathogens that can damage horticultural crops
- fumigate commodities at port prior to export or prior to release on importation to ensure that pests and pathogens are not transmitted from the exporting to the importing country (quarantine and pre-shipment fumigation)
- fumigate ship holds and in rare instances, commercial aircraft
- control vermin and fungal diseases in buildings of historic significance
- control insects and mites in certain unprocessed and semi-processed commodities
- fumigate grain milling and pasta manufacturing facilities.

In Canada, use of methyl bromide for other than quarantine and pre-shipment purposes has been banned under federal Ozone-depleting Substances Regulations pursuant to the Canadian Environmental Protection Act (1999). There are exceptions to this ban known as Critical Use Exemptions (CUEs) and Emergency Use Exemptions that are administered by Environment Canada.

CUEs that have been approved for post-harvest use in 2007 are approximately 80% of traditional methyl bromide use in grain mill and pasta plant fumigation. The CUEs approved and/or recommended for 2008 and 2009 are significantly lower still. As a consequence, milling and pasta facilities must make use of alternative means of pest control in 2007 and beyond, as Environment Canada reduces supply through ongoing regulatory intervention.

Grain Milling in Canada

Grain milling is the manufacturing process in which the seeds or kernels of cereal grains (wheat, oats, corn, rye, triticale, barley) are fractionated (ground and separated) into various components. These components are used mainly as food ingredients in bakery products, biscuits, cookies, breakfast cereals, pasta, snack foods and a wide range of other prepared foods. Some products of grain milling are also used as ingredients in animal feeds and pet foods. A small portion of milled grain products finds uses in personal care products (cosmetics, skin care products) and other non-food industrial use.

The pest control trials examined in this report were not conducted in wet milling facilities. Wet milling of cereal grains also involves grinding of seed kernels, but separation of components takes place using large volumes of water in which the ground grain is suspended in a slurry. This method is typically used in the production of starch, gluten (proteins) and ethanol.

The grain milling facilities referenced in this report all employ a dry milling technology. Only very limited amounts of water are used to adjust grain moisture content at the beginning of the milling process for wheat or to inject steam in the case of certain stages of oat and corn milling.

Grain mills (dry milling process) of commercial industrial size are broadly dispersed across Canada in 7 provinces, from British Columbia to Nova Scotia. There are approximately 40 such mills. The majority are wheat mills (32), producing wheat flours, semolina (coarsely granulated flours for pasta manufacturing), food grade bran and by-products. The second largest milling sub-sector is oat milling (6), followed by corn milling (2). Of this total number of facilities, 31 are operated by companies that are members of the Canadian National Millers Association.

Pest Species Found in Grain Mills in Canada

Cereal grains and grain products are staple foods in the diets of most Canadians, and in fact, most human populations around the world. Unfortunately, cereal grains are also a favourite food of a number of organisms that are commonly referred to as "stored product pests". One of the more difficult aspects of operating a grain milling facility is achieving continuous control over populations of stored product pests. The activities used to control these pest species are generally referred to as "pest management programs".

The stored product pests of principal concern in grain mills in Canada are:

- confused flour beetle (*Tribolium confusum)*
- red flour beetle *(Tribolium castaneum)*
- rusty grain beetle *(Cryptolestes ferrugineus)*
- carpet beetle (*Trogoderma variable)*

These insect species are very small. As a consequence, they can find refuge, breed and survive in almost any area of a grain mill where there are even extremely small quantities of grain particles to serve as food. These species can therefore infest unmilled grain, grain milling equipment, milled grain product bins and cracks, crevices and dead space (confined cavities in walls and floors) and grain and flour dust residues on mill structure components (beams, ledges).

Less commonly found in grain and grain milling structures are:

- flour mill beetle *(Cryptolestes turcicus)*
- grain weevils *(Sitophilus species)*
- Indian meal moth *(Plodia interanclella)*

Weevils and meal moths are found more often in stored grain and grain storage areas than in the processing areas of grain mills.

Also of concern are rodents (rats and mice) but both are more easily controlled through trapping and disposal as a consequence of their size and more predictable mobility.

Why Pest Management in Grain Mills is a High Priority

Effective pest management in grain mills is a high priority because it contributes to a sanitary manufacturing environment and a predictable operating and production schedule.

- **Mill sanitation is a regulatory requirement.**

  Provisions (Sections 4 and 7) of the Food and Drugs Act require that all food processing facilities, including grain mills, be maintained in a sanitary condition at all times. This requirement is in turn reflected in the Canada Grain Act and Regulations under which the transfer and sale of infested grain is prohibited. However, the latter provisions are not a guarantee against infestation of grain mills through grain deliveries. It should be noted that Health Canada has historically not viewed the presence of insects in mills as being a food safety concern. In fact, the current regulatory framework includes tolerances for insect fragments in grains and milled grain products.

- **Mill sanitation and effective pest management are not only an expectation on the part of customers but requirements of being accredited (non-regulatory) as a supplier to further processors and retailers.**

Most grain milling industry customers (further processors, foodservice firms and grocery retailers) require that grain milling companies demonstrate effective pest management as a component of integrated quality control, quality assurance and food safety systems. Most Canadian grain mills are re-qualified as suppliers at least once per year by each major customer through on-going third party audit programs. Such services are offered by organizations such as the American Institute of Baking and the U.S. Food Processors Association. However, customers have a wide range of audit service suppliers to choose from. In this environment, it is not uncommon for grain mills with a diversified customer base to undergo a third party audit at least once per month on average. By implication, the non-regulatory, market-driven (customer) requirements for pest management have become more onerous than actual regulatory requirements.

- **Effective pest management contributes to the productivity of milling facilities.**

  Canadian grain milling facilities typically operate 24 hours per day, 6 to 7 days per week, meeting most customer requirements on a just-in-time delivery schedule. This is a reflection of the fact that grain mills need to operate at a very high level of capacity utilization in order to be profitable. It is also an indication of the fact that customers do not maintain large ingredient inventories, require frequent, predictable deliveries and have little if any room in production schedules for delayed ingredient deliveries. In this operating environment, prevention of shut-Dow AgroSciences for unplanned pest control treatments is an essential capability.

- **Mills cannot rely upon pest control measures in the grain handling and transportation sector to prevent infestation in milling facilities. The supply chain of unmilled cereal grains is actually a source of re-infestation.**

  Stored product pests are indigenous (naturally occurring in the Canadian environment) and capable of migration (crawling and flying) into grain storage, grain transportation equipment and milling facilities from other environments. Some grain deliveries to mills are likely to contain live insects, particularly in warmer months.

Why Methyl Bromide Has Been Such an Important Pest Management Tool

As noted above, grain mills and wheat flour mills in particular present ideal environments for flour beetles and the rusty grain beetle.

- These insects thrive at temperatures typically experienced in milling facilities.
- Milling equipment and mill structures offer an abundant choice of hiding and breeding locations.
- Fine particles of grain created in the milling process that escape from the mill processing and dust collection equipment offer an abundant food supply.

In other words, these insects can live and reproduce in areas that are difficult, if not impossible to reach by milling personnel in ongoing manual cleaning of storage, processing equipment and mill structure.

The other factor that contributes to the survival rate of insect populations in grain mills is the short life cycle of the insects. Flour beetles mature from newly deposited egg to adults in less than 30 days. Newly matured adult beetles can lay hundreds of eggs in a very short time frame. As a consequence, mill cleaning methods and/or pest control products that do not physically remove or kill the egg and larvae stages of flour beetles will reduce insect population levels for a very limited time in most mill locations.

Methyl bromide has been an important pest control tool for several decades because when used as a fumigant, methyl bromide penetrates well into mill structures (cracks crevices), flour and grain dust residues, unmilled grain and milled grain products. In penetrating into hiding and breeding places of insects, methyl bromide is able to kill all life stages (eggs, larvae and adults), thereby interrupting the insect population life cycle. Establishment of new populations requires the introduction of new adult insects. This requires the physical migration of insects into the mill from surrounding areas or the introduction of insects in grain deliveries. That is not to say that methyl bromide delivers a permanent interruption of the life cycle. Rather, as an effective fumigant killing all life stages, methyl bromide significantly delays re-establishment of insect populations, particularly where other pest control methods and pesticides are actively employed in an integrated pest management program. This is illustrated in the efficacy assessment report (Appendix A).

Methyl bromide has also been of value as a consequence of the relatively short time it has taken to conduct fumigations of mills with methyl bromide. Including extensive dismantling and cleaning of milling equipment and re-assembly, a methyl bromide fumigation has been completed in most Canadian mills in less than 72 hours.

Methyl bromide's pest control product registration permits the chemical to come into contact with unmilled grain and milled grain products. Methyl bromide does not adhere to grain or grain products and therefore does not leave a detectable pesticide residue.

Last, but not least, methyl bromide fumigations have been affordable tools in pest control. Methyl bromide is a by-product of manufacturing of other chemical substances and has been available to pest control service providers for many years at relatively modest cost.

Desired Characteristics of Alternatives to Methyl Bromide

Drawing from the brief overview above, the grain milling industry is eager to see the following characteristics exhibited by alternatives to methyl bromide:

- The technology and service providers are available throughout Canada.
- Treatments effectively reach insects in all areas of the grain mill, including cracks and crevices and all processing and storage equipment.
- Treatments effectively kill all life stages – eggs, larvae, pupae and adults.
- Treatments can be executed in 72 hours or less, including mill preparation, cleaning and re-assembly.
- Treatments can be completed without removal of all unmilled grain and milled grain products. This requires that there be no pesticide residue or that there is an established maximum residue limit that can be predictably met under commercial use.
- Treatments are feasible in a wide range of mill sizes and configurations.
- Treatments are affordable as measured within the traditional cost structure of Canada's grain milling industry and in comparison with costs faced by the U.S. grain milling industry. Canadian mills locations compete directly with U.S. mill locations in a North American free trade environment.

Pest Control Practices in Grain Milling Facilities in 2006

Section II of CNMA's March 2004 report on comparative evaluation of heat treatments with conventional methyl bromide fumigations provided an overview of current pest control practices. This section has been updated and edited and is appended to this report as Appendix C – Stored Product Pest Control in Canadian Grain Milling Facilities.

III Market Introduction and Commercial Scale-Up of Methyl Bromide Alternatives in Canada

The title of this section of the report is actually one of the subject areas that is of primary interest in the evaluation of Critical Use Exemption nominations by the Parties (signatory countries) to the Montreal Protocol. In evaluating nominations, MBTOC (Methyl Bromide Technical Options Committee) and TEAP (Technical and Economic Assessment Panel) of the Montreal Protocol take into account whether alternatives to methyl bromide are available in the nominating country by virtue of:

1. Having met regulatory approval
2. Having been commercially introduced for use
3. Being commercially scaled-up (broadly available to industry) in the nominating country

Since the completion of CNMA's March 2004 report on evaluation of alternatives, there have been a number of developments on market introduction and scale-up that are briefly summarized below as additional context for the trials described in the case studies that follow in this report.

Phosphine, CO_2 and Heat

Phosphine and CO_2 combined in gas form are available from Cytec Canada for use in grain mill structural fumigation under the trade name ECO$_2$Fume. This product is registered by Canada's Pest Management Regulatory Agency (PMRA) and available to pest control service providers in all provinces.

However, the product label (describing uses and dosage rates permitted by PMRA)does not yet reference use of ECO$_2$Fume in conjunction with added heat to the structure being fumigated, the application method recommended by Cytec and pest control service provider with the most experience to date with this product. Cytec is expected to address this matter with PMRA in the early months of 2007, having demonstrated in cooperation with a service provider that such fumigations can be successfully managed and can be efficacious.

One of the impediments to wider acceptance by end users (grain milling firms) is a lingering concern that the phosphine present in ECO$_2$Fume can cause corrosion of conductive metals in electrical, electronic and microelectronic equipment in mills. It has been the industry's experience in the past that while effective in terms of insect mortality, phosphine can cause corrosion, contributing to equipment damage/failure. In addition, laboratory research conducted by CANMET at the request of the Methyl Bromide Government-Industry Working Group indicated that corrosion can occur at a wide rage of concentration levels and relative humidity levels. (Brigham, 1998, 1999)

In an effort to allay milling industry concerns, Cytec's dosage rate (as little as 100 ppm.) is significantly reduced from historic levels achieved when using aluminum and/or magnesium phosphide. In addition, the pest control service providers have made isolation of potentially sensitive equipment a normal part of mill preparation and execution of the fumigation. This is achieved by encasing (wrapping and sealing) of the equipment and maintaining the enclosed area under positive pressure with a continuous supply of CO_2 or air throughout the fumigation until the ECO_2Fume is vented from the mill. Milling firms that have undertaken trial fumigations with this approach, dose rate and exposure time have reported no equipment damage resulting from exposure to the phosphine component of the ECO_2Fume.

On the assumption that Cytec is able to modify the product label for ECO_2Fume to expressly permit use in combination with heat added to a building (any source of heat), it is expected that ECO_2Fume fumigation services will be widely commercially available throughout Canada by the 2008 usual season (April to November) for mill fumigations.

Sulphuryl Fluoride

Sulphuryl flouride (SF) is approved by PMRA for use in structural fumigation of grain milling facilities in Canada and is available from Dow AgroSciences under the trade name of ProFume. This registration is relatively recent (early 2006) and has facilitated trials of this fumigant in mills in 2006.

However, the approved label does not provide for contact of ProFume with unmilled grain, milled grain products or flour enrichments and additives that may be present in a mill during methyl bromide fumigation, as is permitted by the U.S. Environmental Protection Agency. In fact, there are over 40 commodities for which MRLs (maximum residue limits) have been established in the United States.

The consequence of not having MRLs is the requirement to either completely empty a mill structure (including equipment and all grain and finished product storage bins) during a ProFume fumigation or to isolate (seal off) storage bins or an entire area of the mill that houses grain or milled grain products. The latter was the approach taken with one SF trial in Canada in 2006 in which the efficacy of the trial was deemed inadequate. However, a second trial in which bins were sealed was effective. Accordingly, the milling industry and pest control service providers are eager to see the approval of the expanded label (MRLs).

As of December of 2006, Dow AgroSciences AgroSciences had recently submitted a request to PMRA to amend the label to permit contact via the adoption of MRLs for these in Canada. PMRA is in the process of examining the possibility of replicating the U.S. MRLs in Canada. Once that is achieved, it is expected that ProFume will be widely available in a milling regions of Canada and that service providers and end users will be trained in its use.

Heat Treatment Technologies

There are three technology providers whose equipment is available for heat treatment of mills by pest control service providers in Canada.

Armstrong International Inc. has recently developed a portable steam-source heat treatment system that has been used in trials in 2006. An adaptation of the company's permanently ceiling-suspended models, each unit is a heat exchanger with an integral circulation fan mounted on wheels for mobility. Steam is delivered to the unit from a manifold adapted to either a mill's permanent boiler (if so equipped) or a mobile steam boiler. The same applies for return of condensate from each unit. The footprint (floor area covered) by each unit is approximately 5 ft. x 4 ft. (150 cm. x 120 cm.)

RooCan is a second manufacturer of portable steam-source heat treatment heaters. Each heat exchanger, also with an integral air circulation fan, is mounted on a tiltable dolly frame with one pair of wheels. Each unit is served by an individual steam supply line with attached condensate return line. In horizontal position when in use, the footprint of a heater is approximately 3.5 ft. x 6ft. (105 cm. x 180 cm.). Heaters are titled upright for storage, occupying a footprint of approximately 3.5 ft. x 3.5 ft. (105 cm. x 105 cm.).

Both the RooCan and Armstrong heat exchangers are meant to operate with the mill structure sealed (minimize heat loss) and at atmospheric pressure in order to prevent most of the heat from escaping from the structure. These technologies may be of particular advantage to milling firms who wish to take advantage of existing boiler capacity and purchase or capital lease the equipment for operation on a more frequent schedule by company employees rather than external service providers. There are at least three milling facilities in Canada who have taken this approach. All have incorporated more frequent part-facility heat treatments into their integrated pest management programs. However, their collective experience with this approach suggests that infestations can get out of hand periodically, implying a long-term need for access to a commercially available chemical fumigant such as ECO_2Fume or ProFume that performs similarly to methyl bromide.

TempAir heater units are not heat exchangers. Rather, they are very high BTU capacity direct fired by natural gas or propane. Heat is ejected from the heaters by a high volume fan into a flexible fabric distribution tube that is pre-fabricated to be zipped together on site to distribute heat to discharge sites. Some heat is lost through the tube along its route to point of delivery. However, the fabric tube can be cut to enable some additional heat to escape at various points along its length to aid in heat distribution. The heat delivered by the fabric tubes is further distributed by portable 110 volt circulation fans, typically 36 inches in diameter. The heater units operate on 220 volt electrical power supply.

The discharge fans in the heaters run continuously to maintain the entire mill structure under positive pressure. This is to ensure that hot air is driven into all cracks and crevices in the mill structure and through exterior walls to elevate and maintain heat in all structural dead spaces were insects might seek refuge during the heat treatment. Exterior walls and dead spaces in dividing walls can be a source of re-infestation if mortality is not achieved in all areas. During heat treatment, the TempAir process utilizes a large number of remote heat sensors to continuously monitor temperatures in all areas of the mill with the objective of keeping the temperatures within a prescribed range for the minimum period to achieve insect mortality.

Site-Specific Evaluation of Alternatives

The concept of "site-specific" evaluation, adaptation and adoption of alternatives to methyl bromide is one that the CNMA has communicated to regulators (Environment Canada and PMRA), pest control service providers and to MBTOC in it work to evaluate CUE nominations. As illustrated in case studies that follow in this report and for which efficacy assessments are provided in Appendix A, the successful adoption of alternatives to methyl bromide relies a process of evaluation of what works and how it works at each mill location.

The reasons for this are quite simple. In the case of heat treatments, they are:

- No two grain mills in Canada are alike. Each has unique structural characteristics, building configuration and equipment configuration. These characteristics invariably contribute to "hot spots" or areas of the mill that are more prone to insect infestation than others.
- Only a minority of mills have steam boiler capacity. Of those which do, some are for comfort heating only, lacking in capacity to generate sufficient steam for a heat treatment.
- Most mills are not equipped with fire protection systems that were designed to withstand heat treatments. At a minimum, such systems must be modified by replacement of sprinkler heads with a higher temperature tolerance. Due to fire code requirements, some mills may not simply replace sprinkler heads but would be required to replace entire sprinkler systems.
- The 220 volt and 110 volt electrical supply and distribution systems in most mills will not accommodate the usual number of heater units and circulation fans required for heat treatments using any of the heat treatment technologies described briefly above. Modification of the systems (permanent or portable increased transformer capacity) and addition of 100 volt receptacles are usually necessary before heat treatments can be conducted.
- The locations of heaters and distribution equipment to achieve and sustain required temperatures are also a process of trial and error. It would be unlikely that any single milling facility would "get it right" the first time. As reported in CNMA's 2004 report and in this report, there are typically areas of mills that are under and over heated during initial trials.

In the case of fumigations with alternative fumigants, experience has illustrated that:

- Service providers need to determine through experience the actual gas volumes required.
- Ambient weather conditions acting in conjunction with mill configuration and gastightness can significantly affect gas retention and therefore the volume of fumigant and amount of sealing required.
- Migration of gas into areas of the facility not intended for fumigation can occur.

Finally, the success of alternatives is also largely predicated on additional measures implemented in enabling modifications to mill structures, equipment configuration, operating practices and mill sanitation measures that are continuous between major pest control treatments. Experience has shown that these additional measures require significant investment decisions and time to implement, particularly where new human resources (staff hiring and training) are involved. It has been the experience to date of most Canadian mills that additional staff and reallocation of mill sanitation responsibilities are prerequisites to eliminating reliance upon methyl bromide.

A Word About Costs of Alternatives

Pest control costs being borne by Canadian grain milling firms have escalated dramatically between 2002 and 2006, as the regulated phase-out of methyl bromide and CUE process have been implemented. CNMA's 2004 report acknowledged the apparent increase in costs. With the benefit of three additional years of experience, the order of magnitude of cost increases is better understood. However, it is not yet fully experienced in that significant reductions in methyl bromide supply are beginning in 2007. Where participating companies have agreed to provide the information, we have included some cost comparison in the case studies in this report.

IV Trials of Alternatives – Case Studies

Each of the case studies described in this section represents efforts to evaluate alternatives by firms who have received financial assistance under CNMA's contribution agreement with AAFC. These case studies do not represent all of the milling industry's effort to move their pest control programs away from reliance upon traditional methyl bromide fumigations. In the interest of commercial confidentiality, the mill locations are identified by number only. This number corresponds to the number assigned in the efficacy assessment in Appendix A.

Mill 1 – Heat Treatment

This milling facility underwent a heat treatment during the summer of 2006. This was essentially a repeat of a heat treatment conducted in 2003, modified to apply lessons learned from the 2003 treatment. As a consequence, the efficacy of the two treatments has been compared, as reported in Appendix 1 to this report.

Facility Situation, Configuration and Structure

This wheat flour milling facility is of small capacity by Canadian standards, having a 24 hour daily flour production capacity of less than 5000 hundredweights. The facility has been situated on the current site and operating as a flour mill for more than 50 years. The mill is the only industrial property in the immediate surrounding area of the municipality. All adjacent properties are residential. Several houses are situated within a 75 metre radius of the mill.

Like many mills in Canada, this flour mill was constructed in a number of phases over its operating life. Although most of the current facility has been constructed over the past 20 years, the grain receiving and storage components are much older and less well designed from a maintenance and pest control perspective. The majority of the structure is steel and poured concrete, with a metal cladding on all exterior walls. Although the staged modernization projects that were undertaken were not designed with this in mind, the location and orientation of loading docks are well suited to positioning of exterior heaters used in heat treatments.

The mill has limited grain storage capacity that experiences frequent turnover of wheat stocks. All wheat is received by truck. Frequent deliveries of small quantities of wheat also represent a frequent potential source of re-infestation. The company historically accepted many producer deliveries. However, such deliveries are now rare. Most wheat is supplied by grain companies.

The mill operates as both a bulk shipment and bagging facility with the majority of product being shipped in bulk. Although this is a small facility, it has several substantial food processors among its customer base, requiring that it operate on a just-in-time delivery schedule that includes shipments seven days per week.

Processing Equipment

The major processing equipment is of various ages. However, much of the spouting and connecting conveyors are readily accessible and can be disassembled for heat treatments.

Between 2003 and the time of the 2006 heat treatment, a number of modifications were made to this mill's equipment and structure. These included:

- Modification of the bulk flour loading systems, providing sealed and sanitary finished product handling
- Replacement of several pieces of equipment, including conveyors, spouting with the objective of improving sanitation and IPM capability.
- There was also extensive upgrading of the control room and electrical supply that has contributed to execution of heat treatment.

Pest Control Challenges and Measures Taken 2004-2006

The facility began to significantly upgrade its mill hygiene and pest control program in 2003. As part of these efforts, the company undertook its first whole facility heat treatment at this site in the summer of 2003, using TempAir equipment and services, supported by PCO pest control personnel.

Prior to 2003, this facility did not operate under what would be considered to be an integrated pest management program as these are currently being provided by the pest control industry. The pest control service provider used contact insecticides. Without the certain ability to conduct fumigations due to proximity of adjacent residential properties, some areas of the facility structure were prone to infestation by grain and flour beetles. However, the grain cleaning and processing equipment within this mill that includes entoleters and rebolt sifters allowed it to consistently meet the ingredient quality standards of food manufacturers.

Between 2004 and 2006, this mill implemented a number of changes to its pest management program to respond to the challenges faced. A complete IPM program was adopted. This included dedicated cleaning and sanitation staff, augmented by specific measures provided by external service providers.

As a consequence of its proximity to residential buildings, methyl bromide had not been considered an option prior to 2003. However, the mill was successfully fumigated with methyl bromide in 2005.

Although a small structure, the range of construction methods and materials used in the phased modernization presents many structural interfaces and potential areas of harbourage for insect pests. During the past 3 years, some harbourage areas were addressed by sealing. However, others exist as a consequence of and are integral to the mill structure and structure-equipment interfaces and cannot be entirely eliminated through affordable modifications.

Some milling equipment such as roll stands has a very long productive life if properly maintained. A large percentage of Canadian flour mills continue to operate roll stands manufactured prior to 1970. The older designs are more difficult to clean manually and/or disassemble for cleaning. Some are also more likely to accumulate flour and dust residues that can gradually contribute to infestation. This mill has a number of older roll stands that fit this description.

Bulk customer delivery schedules strictly limit frequency and duration of entire mill shutdowns, requiring major pest control treatments to be planned many weeks in advance. This is particularly true for the heat treatment technology (TempAir) that was employed in both 2003 and 2006 since there is a limited amount of this equipment in Canada and the equipment owners are selective in their use of qualified carriers (truck transportation service providers).

As a result of all measures taken, this mill achieved American Institute of Baking certification in summer of 2006.

2003 Trial Heat Treatment

A whole facility heat treatment was conducted in the summer of 2003, using propane fired TempAir heaters as the heat source. Hot air is expelled from the heaters by high speed fans approximately 36 inches in diameter. A total of seven heaters were used. Heat was conducted into the mill to various locations using a system of flexible, connectible fabric tunnels approximately 36 inches in diameter. Heat was further distributed and circulated by a total of 30 36-inch rotary fans placed in various locations throughout the mill. The exterior heaters require a 220 volt power supply. The 30 circulating fans require 110 volt power supply. The mill's electrical system had to be augmented by a rented transformer in order to deliver enough power to all the equipment used in the heat treatment.

Since the heaters require the delivery of such a large volume of propane, two large liquid propane tanks were trucked onto the site and off-loaded into a portion of the parking lot normally used for loading trucks with bagged flour. Since the propane must be vaporized and heated before reaching the heaters, a temporary "manifold" of several vaporizers and metal pipe had to be constructed to fuel the seven heaters. Delivery and fabrication of this equipment, coupled with the placement of the heaters, flexible ducts and circulating fans took approximately 12 hours. This took place while the mill staff and temporary workers conducted a top to bottom cleaning of equipment and the mill structure that began at 7:00 a.m. on a Friday morning of a three day (statutory holiday) weekend.

Some small equipment items and packaging materials that were believed to be heat sensitive (possibly damaged by the heat if left in the mill) were loaded into standard 40 foot truck trailers. These were sealed, kept on site and fumigated with methyl bromide essentially in the same manner as quarantine and pre-shipment fumigations are conducted in port facilities. The quantities of methyl bromide used are very small and do not pose a significant risk to workers or nearby building occupants. The equipment and packaging materials were unloaded back into the mill during the cooling and reassembly period.

Stairwells and floor services along exterior walls were sprayed with contact insecticide to deal with adult insects that might migrate during the heat treatment.

Since both cleaning and heating equipment assembly took longer than anticipated, the heaters were not fired up until approximately 7:00 a.m. on the Saturday morning. Vials of adult beetles and insect larvae (both laboratory reared and some collected on site during mill cleaning) were positioned throughout the mill for collection and mortality counts at two hour intervals. 100 remote wireless temperature sensors were also positioned throughout the mill to monitor and record temperatures throughout the heat treatment.

The 2003 heat treatment, including mill preparation and reassembly was completed within 72 hours.

The key findings and observations from 2003 heat treatment were:

1. Detailed advance planning is of critical importance. Mill staff and management need to understand well in advance how large the "footprints"(required parking/surface area to be occupied) are for all of the equipment being brought on site to conduct the heat treatment. This is particularly important to know in order to schedule delivery and set up in a manner and in locations that will not interfere with loadout and shipment of finished flour and millfeeds that must continue during set up and possibly for the duration of the heat treatment.

2. Mill staff must be advised of and make a check list of all equipment and materials that may be heat sensitive and need to be removed from the mill prior to heat treatment. This could include packaging and labelling materials and food and beverage dispensing machines and/or their contents.

3. Consideration must be given to relocation of testing laboratory refrigerators and freezers that could malfunction during the 24 hour period of high temperatures, jeopardizing the quality of stored ingredients and flour and grain samples.

4. Electrical rooms may need temporary additional ventilation to avoid equipment overheating and malfunction during the heat treatment.

5. It should be noted that the small number of production and maintenance staff at this facility was insufficient to conduct all cleaning and disassembly required in the short period of time available. Additional workers were essential here and could be required at other mills contemplating similar heat treatments and with limited experience in rapid disassembly and reassembly if fumigations have not been conducted in the recent past.

6. Some plastic materials such as air hoses and enrichment feeder lines may not be able to tolerate the heat required to kill insects. These should be removed in advance of the heat treatment or not kept under pressure during the treatment.

7. Since an initial heat treatment is a learning experience and each facility is unique in its design and configuration, it may be preferable to schedule more down time to permit gradual and more even heating of the facility. This will allow for experimentation in the

placing of heat delivery ducts and circulating fans that could render subsequent heat treatments more predictable and efficient.

8. Heat treatment is costly. This trial heat treatment for a small facility cost in excess of $75,000 in Canadian funds. This was not the full commercial value of the treatment since some labour and transportation costs were absorbed by the pest control service providers as a contribution to the research nature of the trial. Full commercial value would have been approximately $90,000, representing approximately three times the cost of a methyl bromide fumigation for a mill of comparable size in 2003.

9. Heat treatment can use a lot of energy (propane in this case).

10. Care must be taken to remove all residues from equipment. They can bake during the heat treatment and become very stubborn to remove during reassembly and mill start-up.

2006 Heat Treatment

The preparation of the mill for the 2006 heat treatment was similar to 2003. Roll stands, sifters and other equipment were opened and disassembled to the extent that design permits to facilitate thorough cleaning and removal of wheat and flour residues. Similarly, the interior of the mill structure, equipment surfaces and supporting structure were swept down and vacuumed. Disassembly and top to bottom cleaning takes approximately 10 hours, during which time, the heat treatment equipment can be gradually put in position and connected to the gas supply.

Loadout bins were not emptied but as in 2003, used to continue shipments to customers through a portion of the weekend on which the heat treatment took place.

Based on lessons learned in 2003, the different steps taken in 2006 were:

- Preparation of the mill was begun several days earlier to accommodate a more extensive manual cleaning.
- Certain materials were removed from the mill, including labelling and packaging materials.
- Additional 120 volt receptacles installed since 2003 reduced the requirement for temporary power supply (extension cords) for portable circulating fans.
- The contractor brought to the site additional portable transformer capacity to support the electrical load requirements of the heat treatment equipment.

Planned Use of Methyl Bromide Alternatives

This company has a high degree of confidence in the efficacy of heat treatment at this milling facility based on the success of both the 2003 and 2006 heat treatments. Despite the high cost of individual heat treatments, heat treatment is likely to be the preferred whole-facility pest control method when such measures are required in future. The frequency of whole-facility treatments will be difficult to predict. Ideally, other IPM measures will achieve sufficient control to not require a whole-facility treatment each year.

Mill 3 – Heat Treatment Compared to Methyl Bromide

This wheat milling facility presents an excellent case study in that the mill participated in CNMA's 2003 project to evaluate heat treatments by undertaking a methyl bromide fumigation as a benchmark for comparison with other mills and also with the intention of evaluating heat treatment in a subsequent year. This heat treatment evaluation took place in the summer of 2006.

Facility Situation, Configuration and Structure

This wheat flour milling facility is of medium-sized capacity by Canadian standards, having a 24 hour daily flour production capacity of between 5000 and 7500 hundredweights. The facility has been situated on the current site for more than half a century, during which time, the site has become essentially surrounded by buildings of multiple uses (residential, commercial, foodservice). The site is bordered by a major road that is heavily traveled by local residents, commuter and commercial industrial traffic.

The facility has been constructed in a number of phases over its operating life. Although the processing and control equipment has been extensively modernized in the older portions of the mill, many portions of the mill structure in this are in excess of 50 years old. They include wood, masonry, concrete and steel, reflecting a gradual process of reconstruction to accommodate repairs and equipment modifications. In contrast, other portions of the structure that house a new milling unit added within the past 10 years, are entirely of modern steel and concrete construction designed with mill hygiene as a primary objective.

As is the case with the majority of Canadian flour mills, grain receiving and cleaning equipment is integrated within the main mill structure. The mill has limited grain storage capacity that experiences frequent turnover of wheat stocks. Longer term on site storage is used to retain certain classes of wheat for blending with others that are used in higher volumes. The company does not normally accept producer (direct from farm) deliveries and receives virtually all wheat by truck from commercial elevators.

The mill operates as both a bulk shipment and bagging facility, serving virtually all its customers on a just-in-time delivery schedule. Very little finished product is warehoused for more than a few days.

Processing Equipment

Since 2003, the mill has undergone some further structural and equipment modifications. These are:

- Modification of the fire protection sprinkler system to permit use of treatment.
- Minor modification of the steam boiler system to accommodate steam supply to heat treatment equipment.
- Other modifications to and modernization of processing equipment.

Pest Control Challenges and Measures Taken 2004-2006

The company has been be operating with an integrated pest management program for more than five years.

- The pest control program relies heavily on plant hygiene and ongoing manual cleaning to limit accumulations of grain and flour dust.
- Major processing equipment units are opened, disassembled and cleaned as often as running times will permit.
- Unscheduled shutdowns due to chokes or the need for repairs are used as opportunities for other cleaning and maintenance.
- Virtually all production workers share in the responsibility for mill cleaning.
- Some production workers are entirely dedicated to cleaning milling equipment and the building structure.
- Insect populations are monitored closely by visual inspection of more easily infested areas and with the use of pheromone traps placed and maintained by a pest control service provider.
- The service provider uses residual contact insecticides where practical to encounter migrating adult insects during and in between fumigations.
- The mill has been fumigated annually with methyl bromide during summer months to reduce insect populations to a minimum in as much of the facility as can be legally fumigated with methyl bromide.

The design and exterior configuration of some of the grain storage silos will permit the use of chemical fumigants in the event of infestation in the silos. However, this has rarely been required.

Insect pests in product streams are prevented by careful maintenance and adjustment of grain cleaning equipment, use of many entoleters and rebolt sifters and frequent cleaning of screw conveyors and areas of equipment that are prone to accumulation of small quantities of milled grain products.

As a consequence of its proximity to other buildings and a major roadway, the provincial government department of the environment will permit the use of fumigants such as methyl bromide in only a portion of the milling facility. There are no known feasible means of addressing this issue of setback (distance from buildings and roads) as the cost of mill reconstruction would be prohibitive.

The multi-storey portion of the mill for which a permit cannot be obtained was not designed and built for heat treatment. However, the company has become quite interested in heat treatment as the preferred whole-facility pest control treatment method, leading to the 2006 trial, taking advantage of existing on-site steam boiler capacity.

The range of construction methods and materials (masonry, concrete, wood, metal cladding) presents many structural interfaces and potential areas of harbourage for insect pests.

As each modification is made to the mill structure, equipment and equipment support infrastructure, pest control objectives are taken into account and some harbourage or difficult to clean areas are being addressed.

Over the past several years, the trend toward just-in-time delivery of ingredients and packaging materials in the food processing sector has continued. Reducing inventories of ingredients and packaging materials represents a significant opportunity to reduce operating capital and carrying costs.

This mill continues to operate at a high level of capacity utilization 24 hours per day for more than 300 days per year (six-days per week on average), requiring careful planning and some accommodation by bulk delivery customers. The company would like to limit the duration of shut-downs for pest control treatments to 48 hours.

Benchmark Fumigation in 2003

In the case of this fumigation, as is standard procedure, the mill was shut down except for the packaging, warehouse and bulk loadout areas early on a Friday morning to permit disassembly and cleaning of all roller mills, sifters and other equipment that can be opened and manually cleaned and vacuumed. The entire mill structure and equipment surfaces are manually swept and vacuumed, to the extent possible sequentially from the top floors down. This pre-fumigation cleaning takes approximately 10 to 12 hours.

During the last few hours of the pre-fumigation cleaning, the pest control service providers arrive and begin preparing the mill for the fumigation, in cooperation with mill employees. This preparation involves sealing off (tarps, plastic film barriers, tapes, caulking) the portions of the facility that are not included in the fumigation as well as exterior windows, doors and points of passive and mechanical air exhaust as soon as ventilation and access are no longer required. The objective of the separation and sealing is to make the area(s) of the structure and equipment to be fumigated as gas tight as possible to be able to use the precise minimum quantity of methyl bromide required to achieve a concentration of the gas sufficient to kill the insect pests in all areas of the mill.

Before fumigation, the pest control service provider placed methyl bromide supply lines and monitoring equipment in the normal locations. This is done to ensure an even concentration of methyl bromide throughout the mill during fumigation for a minimum required duration. In this case, the objective was to achieve the desired initial methyl bromide concentration of 3.2 grams per cubic metre and for the fumigation to last) for a period of approximately 24 hours.

After cleaning and sealing and before any methyl bromide was injected into the area to be fumigated, all mill production and maintenance staff were evacuated from the mill. Methyl bromide was injected until the desired concentration was reached.

The company's pest control service provider normally places a number of vials of insects within the mill in order to be able to confirm insect mortality of the resident population of insects that might not be visible. In the case of this fumigation, many additional vials of insects provided by AAFC's Cereal Research Centre laboratories plus vials of insects collected from the resident populations were placed throughout the mill100% of insects in test vials in all locations within the mill were dead by the end of the fumigation.

After the required 24 hour period, pest control service staff entered the mill to open doors, windows, roof hatches and remove sealing materials to permit the gradual escape of the methyl bromide to the external atmosphere, using points of ventilation to permit the gas to escape predominantly from the roof and rear of the building, away from the nearby buildings and street. Ventilation is normally conducted at night when vehicle and pedestrian traffic are at their minimum levels. This was the case in this fumigation.

When the pest control service staff indicated that ventilation was complete, mill workers entered the building to reassemble all equipment that had been disassembled prior to the fumigation. This process normally takes less time than the pre-fumigation preparation. The mill was in operation on the Monday evening approximately 8 hours after ventilation was complete and approximately 84 hours from shutdown the previous Friday morning.

During the six-week controlled monitoring period following the fumigation, insect populations were at less than 10 per cent of levels observed in the six-week period prior to the fumigation. The mill management staff judged the fumigation to be typical of previous methyl bromide fumigations in terms of efficacy.

The key findings and observations from the 2003 benchmark fumigation were:

1. Methyl bromide predictably and effectively reduces insect populations in all of the area of the mill that is able to be fumigated under provincial permit restrictions.

2. Incorporation of many entoleters into the newer milling unit and addition of rebolt sifters has eliminated all insect presence in finished milled wheat products.

3. A strong program of sanitation and IPM had not eliminated the need for a chemical fumigation or other whole-facility treatment at least once per year to control insect populations in the mill structure.

2006 Trial Heat Treatment

This heat treatment trial had originally been planned for 2005. Due to operational requirements, the trial was delayed to summer of 2006. The technology chosen was Armstrong's portable steam-source heat exchangers with integral circulation fans. This required modifications to the existing steam boiler in the mill to provide a manifold for connection of portable steam distribution and condensate return lines. Additional circulating fans were used for heat distribution.

Preparation and cleaning of the mill and equipment for the treatment was similar to that normally undertaken for a methyl bromide fumigation. Disassembly and cleaning of equipment was routine. Equipment was left open during heat treatment to facilitate air circulation and heat dispersion.

The mill was brought up to the desired heat treatment temperature (45 to 50 degrees C.) in approximately 8 hours. This temperature level was reached and maintained in nearly the entire mill structure for a period of 16 hours, less than desired.

There was, however, a small area of the mill in which the desired temperature was not reached and maintained. This was in a lower floor level area where recently installed equipment is supported by a very substantial poured concrete floor structure. Typical of concrete construction in many recently built or modernized mills, this particular concrete area acted as a heat sink and could not be brought up to ideal temperature in the available time with the heat exchange capacity put in place for the heat treatment. This may have been as a result of the space below this floor not being heated during the heat treatment. As a consequence, insect mortality in vials placed for efficacy monitoring in this area was not 100%. However, 100% mortality was achieved in test vials placed in all other areas of the mill included in the heat treatment. Please refer to Appendix 1 for the efficacy assessment and comparisons.

Planned Use of Methyl Bromide Alternatives

Based on the partial success of the 2006 heat treatment, the company is planning a second heat treatment trial in 2007 with a second heat technology. The company is attracted to longer term use of heat treatment because it can be successful from a mortality perspective when executed properly and may provide greater operating and timing flexibility when IPM measures do not obviate the need for a structural treatment.

Mill 4 – Trial Fumigation With Sulfuryl Fluoride (ProFume)

This mill location also presents an interesting case study for several reasons. The mill site has two mill structures, one many decades old and the other constructed since 2000 in which benchmark methyl bromide fumigations were conducted in 2003 for which insect mortality data were gathered. Not one but two sulfuryl fluoride (ProFume) fumigations were completed in December of 2004 and November of 2005 using different dose rates. Pre and post-treatment monitoring data are quite extensive and are included in Appendix 1.

Facility Situation, Configuration and Structure

This wheat milling facility is of medium to capacity by Canadian standards, having a 24 hour daily flour production capacity of between 5000 and 7500 hundredweights. The facility comprises two mills that are housed in adjacent buildings on the same site. Adjacent properties are mixed commercial and retail foodservice locations. The site is in a semi-industrial and commercial district, bordered on two sides by streets that carry mainly commercial traffic.

The older of the two mill buildings has been situated on the current site for more than half a century and contains a complete range of construction materials, including wooden beams and floors, masonry, concrete and steel. The newer of the two facilities is of modern construction and design, steel and concrete.

As is the case with the majority of Canadian flour mills, grain receiving and cleaning equipment is integrated within the main mill structures. This milling operation has a relatively large amount of grain storage capacity and normally accepts producer (direct from farm) deliveries as well as wheat by larger trucks from inland elevators and by rail.

The mill operates as both a bulk shipment and bagging facility, serving virtually all its customers on a just-in-time delivery schedule. However, a high percentage of customers are at some distance from the mill, requiring a variety of truck, intermodal and rail shipping.

Processing Equipment

The milling equipment is this location's 2 structures ranges from less than 10 to more than 50 years old. There is the typical range of roll stands, sifters, purifiers and grain cleaning equipment found in most mills.

The older milling unit has undergone extensive modernization and upgrading of aspiration and dust control equipment.

Pest Control Challenges and Measures Taken 2004-2006

This mill exports product to the United States and offshore markets for which phytosanitary certificates may be required. The facility is regularly subjected to third party audits required by customers. As a consequence, there is very low tolerance for live insects within the mill structure, even if end product and in-process product streams are completely free of insects.

Key attributes of the pest control program used since 2000 are listed below.

- The pest control program relies heavily on plant hygiene and ongoing manual cleaning to limit accumulations of grain and flour dust.
- Major processing equipment units are opened, disassembled and cleaned as often as running times will permit.
- Unscheduled shutdowns due to chokes or the need for repairs are used as opportunities for other cleaning and maintenance.
- Virtually all production workers share in the responsibility for mill cleaning.
- Some production workers are entirely dedicated to cleaning milling equipment and the building structure.
- Insect populations are monitored closely by visual inspection of more easily infested areas and with the use of pheromone traps placed and maintained by a pest control service provider and mill personnel.
- The service provider uses residual contact insecticides where practical to encounter migrating adult insects during and in between fumigations.
- The mill has been fumigated twice annually with methyl bromide to reduce insect populations to a minimum in as much of the facility as can be legally fumigated with methyl bromide. When fumigations are carried out, the mill is entirely emptied of all grain and milled grain products to permit thorough cleaning and fumigation of all storage bins. This procedure permitted use of ProFume in the mill since that product does not yet have registration (a maximum residue limit) that permits contact with unmilled wheat or milled wheat products.

Precautions taken in methyl bromide fumigations are similar to those that have been used in the two ProFume trials completed in 2004 and 2005. The pest control service provider schedules venting to avoid peak nearby traffic flows.

The range of construction methods and materials (masonry, concrete, wood, metal cladding) in the older of the two facilities presents many structural interfaces and potential areas of harbourage for insect pests. Its construction also may present prohibitive retrofitting costs to permit effective heat treatments. Methyl bromide has been highly successful in controlling pests in this mill.

There have been equipment and structural since 2003. These have included:

- Unused doors and windows have been sealed off with new masonry construction
- All ceiling openings onto the roof have been removed.

- Cyclones have been relocated inside the building to enhance maintenance access and reduce operating wear in cold weather temperatures.
- Addition of three pieces of equipment in the mill to increase grain cleaning efficacy and ensure prevention of infestations from grain entering the mill.

Customer specifications dictate that a portion of the products produced at this mill are not passed through entoleters as a means of killing all insect life stages (including eggs) that may be present in the processing equipment or unmilled wheat. As a consequence, pest control in all areas of the milling process takes on added importance since the added assurance normally gained using entoleters in other product streams is not available. This takes on further importance taking into account long distance rail shipment of some products.

Bench Mark Methyl Bromide (MB) Fumigation in 2003

In the case of this fumigation, as is standard procedure, the mill was shut down to permit disassembly and cleaning of all roller mills, sifters and other equipment that can be opened and manually cleaned and vacuumed. The entire mill structure and equipment surfaces are manually swept and vacuumed, to the extent possible sequentially from the top floors down. Pre-fumigation cleaning takes approximately 48 hours.

All cleaning and mill preparation are completed by company employees. This preparation involves sealing off the portions of the facility that are not included in the fumigation as well as exterior windows, doors and points of passive and mechanical air exhaust as soon as ventilation and access are no longer required. The objective of the separation and sealing is to make the area(s) of the structure and equipment to be fumigated as gas tight as possible to be able to achieve a concentration of the gas sufficient to kill the insect pests in all areas of the mill.

After cleaning and sealing and before any methyl bromide was injected into the area to be fumigated, all mill production and maintenance staff were evacuated from the mill. In the case of this mill, the inclusion of the business offices within the mill structure requires that office and management staff evacuate the facility for the entire duration of the fumigation. This usually means scheduling the fumigation during a three-day weekend.

Before fumigation, the pest control service provider placed methyl bromide supply lines and monitoring equipment in the normal locations. This is done to ensure an even concentration of methyl bromide throughout the mill during fumigation for a minimum required duration. In this case, the objective was to maintain the desired methyl bromide for a period of approximately 24 hours. Methyl bromide was injected until the desired concentration was reached.

Company staff normally places a number of vials of insects within the mill in order to be able to confirm insect mortality of the resident population of insects that might not be visible. In the case of this fumigation, many additional vials of insects provided by AAFC's Cereal Research Centre laboratories plus vials of insects collected from the resident populations were placed throughout the mill. All adult insects contained in the vials were dead in all locations at the end of the fumigation.

After the required 24 hour period, pest control service staff entered the mill to open doors, windows, roof hatches and remove sealing materials to permit the gradual escape of the methyl bromide to the external atmosphere. Ventilation is normally conducted at night when vehicle and pedestrian traffic are at their minimum levels. This was the case in this fumigation.

When the pest control service staff indicated that ventilation was complete, mill workers entered the building to reassemble all equipment that had been disassembled prior to the fumigation. This process normally takes less time than the pre-fumigation preparation. The mill was in operation on the Monday evening approximately 8 hours after ventilation was complete and approximately 96 hours from shutdown.

The key findings and observations of the 2003 MeBr fumigation were:

1. The mill management staff judged the fumigation to be typical of previous methyl bromide fumigations in terms of efficacy.

2. One unexpected finding was that the new mill structure in this site exhibited poorer gas retention (gas tightness) than the old structure. Half loss time for the old structure was 7.0 hours as compared to 0.6 hours for the new structure.

2004 and 2005 ProFume (Sulfuryl fluoride) Trial Fumigations

Dow AgroSciences accepted an invitation to use this mill location for a fumigation to demonstrate use of ProFume at a Canadian mill location in 2004. At that time, ProFume was not yet registered and the trial required a research permit which was granted by the Pest Management Regulatory Agency.

The 2004 fumigation was scheduled for end of November/beginning of December. This is the latest date at which the second annual methyl bromide fumigation had historically been carried out. The weather conditions were not conducive to a ProFume fumigation. External air temperature was low. Areas of the mill buildings were below optimal temperature. These conditions were compounded by the fact that Dow opted to use a low concentration of gas for a duration that would not usually be expected to kill all life cycles of insect pests (including eggs), based on experience in fumigating mills in the United States. Post-fumigation monitoring revealed significant rebound of insect populations in the mill in relatively short time frame as compared with methyl bromide.

Unhappy with these results, Dow and the company agreed to conduct a second trial fumigation that was scheduled for November of 2005. This fumigation was undertaken with warmer external and internal air temperatures and what was considered to be a high rate of gas application. In this second fumigation, a very satisfactory rate of mortality was achieved. The efficacy comparisons are included in Appendix 1.

Readers should note that both trials were conducted on the mills when completely emptied of unmilled grain, milled grain products and all additives. Most mills have not traditionally conducted whole-facility treatments in this manner, preferring to have unmilled grain and milled grain products in some bins. This highlights the importance of PMRA approving MRLs for unmilled cereal grains and their respective milled grain products.

Planned Use of Methyl Bromide Alternatives

At the time of writing this report, mill number 4 has access to methyl bromide through the Environment Canada CUE process for importation and use in 2007 and 2008. However, the quantities available are insufficient to carry out the usual whole-facility fumigations annually.

As a consequence, this company will likely conduct two whole-facility methyl bromide fumigations in the older of the two mill facilities on site in 2007 and 2008. The newer mill will be managed with IPM and use of alternative fumigant, likely ProFume, in a single annual fumigation.

The company has plans to evaluate heat treatment. Key considerations will be cost and safety as compared to fumigation with alternative fumigants.

Mill 5 – Trial Fumigation With ProFume and New IPM Program

This milling company has approached adoption of methyl bromide alternatives quite aggressively, undertaking a part-facility heat treatment in 2003, implementing an intensive IPM program in late 2005 and undertaking a trial fumigation with ProFume (SF) in the summer of 2006.

Facility Situation, Configuration and Structure

This wheat milling facility is of medium capacity by Canadian standards, having a 24 hour daily flour production capacity of approximately 10,000 hundredweights. The mill has been on the current site for over 50 years. The site is bordered by residential neighbourhoods. This mill is situated within 25 metres (75 feet) of the access street that is used by through residential traffic as well as commercial traffic required by mill operations.

The foundation and basement area floors are of poured concrete. Mill floors are predominantly wooden, supported by wooden and steel posts and beams. Some interior and exterior walls are of brick masonry. Metal cladding has been added to portions of the brick exterior walls.

Although the grain receiving and cleaning equipment is integrated within the main mill structure, it is separated from the main production area by a brick masonry wall. While this can assist in managing air flows for dust control, typical of masonry walls, the wall presents potential harbourage for insect pests.

The mill operates primarily as a wheat flour mill and is equipped for both bulk shipment via tanker trucks and as a bagging facility. Because the facility also carries out some grain product blending and packaging intended for retail sale, insect pest control in the packaging area is of paramount importance. This is why the company opted to evaluate heat treatment and sulfuryl fluoride as alternatives to methyl bromide in conjunction with a new integrated pest management (IPM) program.

Processing Equipment

There is nothing particularly unusual about the processing equipment in this mill. The equipment is of varying ages ranging from less than 5 to more than 50 years old. The mill has undergone an expansion in recent years with the addition of a separate milling unit.

The mill is equipped with a central vacuum system and comprehensive dust control systems. Dust collection and ventilation systems have been modified in recent years to reduce the surface areas that required manual cleaning and other harbourage for insects.

Pest Control Challenges and Measures Taken 2004-2006

The mill was taking a variety of measures in its pest control program prior to 2003.

- Major processing equipment units are opened, disassembled and cleaned regularly
- Virtually all production workers shared in the responsibility for mill cleaning.
- The mill has been fumigated annually with methyl bromide during summer months to control insect populations that other measures have failed to control.

The company launched an intensive IPM program in the last quarter of 2005. This included the hiring of two individuals whose responsibilities are mill sanitation and pest management. The key attributes of this new IPM program are:

- Two additional workers were added to be entirely dedicated dedicate to IPM activities.
- Insect populations are monitored closely by visual inspection and documented tracking carried out by a pest control service provider on a weekly schedule.
- In addition, pheromone traps are used much more intensively and are strategically placed throughout the older portions of milling facility where adult insects have been observed.
- The service provider uses residual contact insecticides where practical to encounter migrating adult insects during and in between fumigations.

The pest control challenges for this mill and how they are being addressed are described below.

Because of this mill's range of products that includes the blending of a number of grain products into mixes and retail packaged goods, there is a particularly high emphasis on pest control in a portion of the facility that is largely but not completely separated from the main production area of the mill. If chemical fumigants such as methyl bromide or other pesticides that pose a high risk to workers must be used, the more frequent treatments dictated by the product mix and lower tolerances for insect pests will be disruptive to operation of the entire facility. Low toxicity pest control product methods are desirable.

Methyl bromide has been highly successful in controlling pests in this mill in the past, despite the age and configuration of the facility. There have been extensive modifications to the mill since 1990 to accommodate the increased packaging activity and to eliminate rail receiving and shipping in favour of bulk shipment by truck. These were not made with heat treatment in mind. There would be significant retrofitting costs to permit adequate heat retention during heat treatments. As a consequence, the company has demonstrated a greater interest in alternative fumigants, leading to the 2006 trial fumigation using ProFume.

Opportunities for Use of Alternatives - Trial Heat Treatment in 2003

This trial heat treatment was conducted in early summer of 2003 by a qualified pest control service provider that had been conducting annual methyl bromide fumigations at the mill for a number of years and applying other pest control products. The heat treatment was conducted only in the areas of the mill used for packaging and bulk shipment load-out.

Although the heat treatment was limited in scope to the packaging and bulk-load out areas of the mill, the company opted to carry out the trial during a three day holiday weekend to facilitate added cleaning and disassembly of packaging lines, interior building surfaces and structural interfaces (joints, cracks, floor and wall openings for plumbing, electrical, mechanical). Ingredient bins supplying the packing lines were emptied and cleaned.

The areas to be treated were closed off from adjacent areas of the mill. No special insulation or tarping was added other than at several door frames where polyethylene film and tape were used to reduce air flow and escape of heat.

The source of heat was portable propane fired heaters typical of those used in building construction to provide temporary heat to assist in curing concrete, drying paint and drywall compound. These were not heaters or heat exchangers designed or specially modified for heat treatment. The treated areas were heated for approximately 16 hours. However, no sophisticated devices were used for temperature monitoring with the objective of ensuring even and sustained temperature levels in the entire area being treated. Several 110 volt powered fans were used to assist in distributing the heat.

Following heating, the treated area was allowed to cool with passive ventilation. Equipment was reassembled. The packing lines and bulk load-out areas were ready for operation approximately 48 hours after shutdown.

This mill did not use a long term (six week) pre-treatment insect population monitoring before conducting the trial heat treatment. The reason is that the monitoring protocol recommended by AAFC and used in other heat treatment and methyl bromide comparative fumigations was not written and available in advance of the date of this heat treatment trial.

However, the mill was visually inspected by the pest control service provider. Adult insects were observed in harbourage areas along exterior walls of the packaging area and structural spaces within the bulk load-out area. No adult insects were observed in any of the ingredient or load-out bins or related conveying and spouting equipment. This is attributable to the entoletion, aspiration and sifting of products during milling that normally remove all adult insects and larvae that may be present in unmilled grain.

The pest control service provider reported visible mortality of adult insects in the treated area (dead adult insects on floor surfaces). However, mill staff and the pest control contractor staff observed adult insects within the treated areas within 4 weeks of the heat treatment.

The key findings and observations of the 2003 heat treatment were:

1. The temperature during treatment and/or duration of temperature was insufficient to penetrate some of the harbourage areas within the treated areas and exterior walls and achieve insect death.

2. Adult insects appear to have migrated into the treated areas from other areas of the mill soon after the heat treatment was undertaken.

3. Small scale heaters designed for construction use are not effective in heat treatment of grain mills.

2006 Trial Fumigation Using ProFume

The initial registration (without MRLs) of ProFume facilitated a trial fumigation at this mill in summer of 2006. The pre-fumigation mill preparation (cleaning of structure and equipment disassembly and cleaning) was similar to that conducted historically for methyl bromide fumigations. However, the treated area of the mill was emptied of all unprocessed grain, milled grain products and additive premixes. Some bin storage area was sealed and isolated from the fumigation.

The staging and setup of the fumigation equipment are described and illustrated in photos in Appendix 1. ProFume is shipped in "banks" (groups) of gas cylinders. Gas is drawn from the cylinders during fumigation through a specially designed and calibrated manifold. Gas lines are placed at various locations within the mill and terminate at a circulation fan for even distribution. Gas levels are continuously monitored by remote sensors placed in various locations before injection of the gas. This monitoring capability allows the applicators to continuously monitor gas levels and inject additional gas where, when and if required at any time during the fumigation.

The external and internal temperatures were typical of summer days in this region, contributing to the efficacy of the treatment. The sulfuryl fluoride dose rate used approached the maximum permitted level under current registration. Gas levels around the exterior perimeters of the structure were also monitored during the fumigation.

Insect mortality was excellent. Post-fumigation monitoring of insect populations indicates a highly successful fumigation. However, readers should note that this mill continues with its intensive IPM program that is in all likelihood, a synergistic factor in the efficacy of the trial fumigation. The question remains whether the IPM program can obviate the need for an annual whole-facility fumigation. With access to methyl bromide under CUE in 2007 and 2008, this mill now has the option to delay its fumigation to as late a date as possible in either year to fully evaluate insect control success arising from intensive IPM.

Success of the IPM Program

The new IPM program has been in place for about 14 months. The company advises that the scaled up IPM program has changed the entire philosophy of pest control within the facility, generating benefits that include:

- A generally heightened awareness among all production and maintenance staff of the need for sanitation of both processing equipment and structure, fostered in part by the documentation required under the IPM program.
- More frequent recommendations from employees to further improve sanitation and pest control, particularly in the area of minor modifications to structure and structure/equipment interfaces (sealing of cracks, crevices)
- A closer working relationship between the external pest control service provider and company staff.
- Enhanced ability to meet requirements of third party and customer audits.
- A more efficient program of sanitation and pest control.

In summary, the company would not consider doing without intensive IPM in future.

However, the company also notes that the costs of scaling up IPM are significant, adding approximately $100,000 annually to pest control costs. IPM has not yet been demonstrated to allow the facility to operate without an annual fumigation. The IPM costs,, coupled with the higher costs of sulfuryl fluoride fumigation (or heat treatment) (50% or more as compared to current cost of MB), represent a significant increase in annual operating costs when expressed as a percentage of total manufacturing costs.

Planned Use of Methyl Bromide Alternatives

The registration of ProFume allowed a trial fumigation in 2006. This was timely since a fumigation was required and the company did not have a CUE allocation of methyl bromide for 2006 calendar year. The company is pleased with results to date. However, cost of the fumigation was significantly higher than for a methyl bromide fumigation. The company may therefore opt to use its CUE allocation in 2007 for a part-facility fumigation with methyl bromide to determine how that works in tandem with its intensive IPM efforts.

The lower 2008 CUE allocation will encourage fumigation with an alternative. Based on results in the public domain to date of trials with ECO_2Fume, the company may consider a trial with that fumigant in selected areas of the facility where there may be less risk of corrosion of electrical equipment.

Setting cost considerations aside, the more precise application procedures taken in a ProFume fumigation, coupled with efficacy results to date indicate that ProFume fumigations are equal to or better than typical methyl bromide fumigations.

The company has not ruled out future use of heat treatment but has concluded the structural components and configuration would make a whole facility heat treatment very difficult and costly.

Regardless of alternatives used, the company plans to continue and improve upon its IPM program.

Mill 6 – ECO$_2$Fume With Carbon Dioxide and Heat

The trials conducted at this facility and recent methyl bromide fumigations make for an excellent case study. Two sections of the mill were treated alternately with ECO$_2$Fume (in combination with additional carbon dioxide and heat) and methyl bromide, permitting direct comparison of efficacy and operational considerations.

Facility Situation, Configuration and Structure

This milling facility is one of many in Canada that over time has experienced changes in its surroundings due to new and reconstruction on adjacent sites. The end result is that the mill has less setback (distance) than historically from adjacent properties whose uses are varied, including other commercial and residential. This has driven to large degree, significant investment in noise abatement and dust control.

The facility is yet another example of a modernized mill with expanded throughput capacity that continues to operate on foundation and within multi-layer brick walls constructed well before 1950. In recent years, the structure has undergone very significant changes that include:

- Replacement of exterior windows
- Upgraded wiring and lighting
- Replacement of wooden support infrastructure with steel and reinforced concrete

However, much of the mill structure is original, rendering elimination of all harbourage areas in the structure itself impossible.

The mill operates as a bulk shipping and bagging facility more than 310 days per year (24 hour six-day week on average). The mill is configured in a manner that permits treatment of the packing facility separately from the remainder of the production area. This has rendered the mill an ideal candidate for comparative evaluation of alternatives to methyl bromide.

Processing Equipment

Some of the milling equipment in this facility predates 1950 but as in other mills with equipment of various ages, remains productive as part of a modernized, electronically controlled and integrated manufacturing facility. The design of this older equipment makes disassembly and cleaning more labour-intensive and time-consuming than the more modern equipment, some of which was added in recent years. The older equipment, rollstands in particular, have ledges and cavities that retain milled grain fractions that are ideal environments for flour beetles. This is really quite typical of equipment of this age.

At the other extreme, the mill has received very significant investment in dust collection and make-up air systems. The dust collection and aspiration equipment in the mill is very modern, contributing to a high level of sanitation.

This is a large mill in terms of throughput capacity as compared to the Canadian industry average. Similarly, the structure is quite large in terms of its volume, height and footprint.

Pest Control Challenges and Measures Taken 2004-2006

The company has taken many steps to reduce harbourage. This includes enhancing worker access to structure and equipment surfaces to facilitate manual cleaning and removal of flour and grain dust residues. Many cracks and crevices have been filled and sealed as part of a more intensive IPM approach taken with the benefit of ongoing assistance from pest control service providers. To facilitate cleaning, exterior walls and ceilings have been epoxy painted. The same is true for floor areas and structural interfaces on exterior walls are beveled. The company has also increased labour and attention to mill sanitation, complementing the very large investment in dust control equipment and structural modifications noted above.

Typical of many Canadian flour mills, residential use of nearby land has increased significantly over the past 20 years with urban growth and rezoning. In effect, such mills have become "non-compliant" with current zoning and permitted use. These mills are forced to incur significant costs for noise abatement and dust control in order to meet regulatory requirements and remain good corporate citizens in their respective communities. Since such grain mills are also "clean" in the sense that grain and milled grain products are hazardous substances that might be found in other manufacturing industries, grain mills are permitted to adapt and operate in urban environments that were originally zoned and developed for a variety of industrial use.

Opportunities for Use of Alternatives to MeBr Fumigation

Taking into account all operating requirements, this company has already been able to evaluate of ECO_2Fume in comparison with methyl bromide in two whole-facility treatments in 2006. A part-facility (packing area only) fumigation with ECO_2Fume was conducted in the second half of 2005. Efficacy results are compared in Appendix 1.

The site would also permit trials with ProFume (sulphuryl fluoride) on the assumption that MRLs are established to permit contact with grain and milled grain products. However, the mill configuration and equipment density (tight spaces) would likely render heat treatments impractical unless the technology employed were to be integrated (stationary, permanently installed equipment). The cost of modification to accommodate heat treatments using permanently installed equipment would be very substantial.

Observations About the 2005 and 2006 ECO$_2$Fume Trial Fumigations

What is particularly interesting from an experimental standpoint about the ECO$_2$Fume trials conducted in this mill is the fact that they were conducted at very low gas concentration levels (100 to ppm phosphine), facilitated by the addition of carbon dioxide (5%) and heat during the fumigation period to increase the respiratory rate of insect pests. The increased respiratory rate renders insects more susceptible to phosphine. It should be noted that the carbon dioxide contained in ECO$_2$Fume is not at a level that is biologically active in that during fumigations, it raises carbon dioxide levels in a mill by about 0.1%. Accordingly, additional carbon dioxide is added from separate gas cylinders.

The trials also demonstrated the efficacy of low dose rates of phosphine, believed by the product manufacturer and applicators to eliminate risk of electrical/electronic equipment failure due to phosphine-induced corrosion. The applicators have further reduced corrosion risk by extensive wrapping and sealing off of sensitive electronic equipment that is kept under positive pressure by small supply lines of air. In these areas, additional care was taken in cleaning and in some, a small quantity of diatomaceous earth was placed.

However, test strips of conductive metals left exposed in the fumigations demonstrated that minor corrosion still occurs at these low concentrations of phosphine. Based on the experience at this location, if left unprotected, there may be minor damage to some lighting and electrical contacts, but there is insufficient long term repeat use experience to determine this with certainty. Laboratory experiments conducted by Natural Resources Canada (Brigham, 1998, 1999) demonstrated that corrosion due to exposure to phosphine can occur at very high or very low relative humidity. Relative humidity or high temperature may have been a factor in these trials with ECO$_2$Fume.

Planned Use of Methyl Bromide Alternatives

This mill will have access to sufficient methyl bromide in 2007 and 2008 through CUE to conduct a part-facility fumigation. Treatment of the remainder of the facility with alternatives will likely be essential. Given the experience with ECO$_2$Fume to date, it would appear likely that ECO$_2$Fume will be the alternative of choice in the near term, particularly because of its more active dispersion and penetration capability.

The company has found that use of ECO2FUME in combination with carbon dioxide and heat dictates a longer down-time to execute as compared with methyl bromide (2.5 to 3 days, versus 1.5 to 2 days). As a consequence the fumigation is somewhat more costly when time, labour, service and fumigant costs are all taken into account. However, when considering the modified low-phosphine dose used in this facility, the company views these fumigations as being considerably more environmentally responsible. The trade-off is that these fumigations provide less margin for error that conventional methyl bromide fumigations, presenting a higher level of commercial risk.

Taking all operating and efficacy considerations into account, including use of IPM methods between fumigations, ECO_2Fume's characteristics offer 2 fumigations annually as a positive alternative to frequent spot treatments and fogging.

Mill 7 – Comparison of MeBr Fumigation & Heat Treatment

The trial heat treatment at this facility in 2006 permitted a comparative evaluation with methyl bromide fumigations conducted previously.

Facility Situation, Configuration and Structure

Atypical of many mills, the mill is not adjacent to residential land use properties and remains in an industrial area with sufficient setback to reduce concern over use of chemical structural fumigants and related emissions of gas during and at the end of the fumigation process.

This wheat milling facility is a relatively modern structure less than 50 years old that has been extensively modernized in many respects, including the addition of a second milling unit accommodated by an extension to the original mill structure. Typical of milling facilities, the building is multi-floored and sufficiently large to make temporary enclosure for the whole facility impractical. However, the mill exterior is essentially without windows, reducing gas loses during fumigation. Some fumigant gas loss is unavoidable.

The facility also houses a mix facility that blends flour, other milled grain products, sugar and other ingredients to prepare dry premixes for a wide range of bakery products produced in in-store bakeries and other wholesale and retail bakery establishments. The presence of the bakery mix facility increases the need for a high level of insect control in the mill structure in addition to the processing equipment. The mill has been historically reliant upon methyl bromide but has met with some success in using intensified mill sanitation efforts and IPM methods.

Because of its phased construction and gradual modernization, this mill is like others described in this report and many others in Canada. The construction methods and materials are varied. There are many structural and equipment interfaces and very large surface areas of interior walls and supporting structure. In total, there are many structural areas that offer harbourage and food sources (flour and grain dust) to flour and grain beetles.

Processing Equipment

The combined flour production capacity of this mill is medium (between 5000 and 10,000 cwt. Daily) by Canadian industry standards. There is some variation in the age of roll stands, sifters, purifiers and grain cleaning equipment, but not as much in some other facilities where older equipment may not have been designed for aspiration. There has been extensive addition of dust collection and aspiration equipment throughout the plant.

The mill also houses mix ingredient storage and blending equipment, plus the associated packaging lines used for mixes and for various flour products. Pest control in the mix and packaging areas is a very high priority.

One noteworthy modification is the installation of insect screens at loading doors and personnel doors, particularly important in summer months to help control migrating stored product pests. Also installed are devices to deter entry and roosting of birds.

Pest Control Challenges and Measures Taken 2004-2006

The mill serves Canadian markets as well as customers in export markets. As a consequence, this mill is subject to a large number of third party audits each year that are required by customer organizations and supply chains to maintain approved supplier status. This is not at all unique. Rather, as food ingredient suppliers to a wide range of further processors, Canadian grain mills must meet ongoing audit and supplier qualification standards.

Because this mill is actively exporting to a number of offshore markets, there is still a requirement for CFIA inspections to support issuance of phytosanitary certificates required by the regulators in some importing countries.

Sanitation is a high priority. Each piece of processing and transfer equipment is opened and thoroughly cleaned on a monthly schedule, several as often as daily. Wall surfaces are also cleaned on a schedule, followed by accompanying inspections. These procedures are consistent with AIB program requirements for ongoing certification.

The intensive sanitation program has been facilitated in part by a central vacuum system installed throughout the mill structure during the part 5 years.

The mill's external pest control service provider makes weekly site visits and undertakes any measures required under their highest level of service delivery, as indicated by the monitoring of dome traps and visual inspection of structure and equipment.

Potential Opportunities for Use of Alternatives to MeBr Fumigation

The newer portion of the mill is more open, horizontally and vertically. This may facilitate heat treatment in that portion of the mill even if use of chemical fumigants in the older portion of the mill is periodically required. The use of heat treatment in part of the facility may be supported by the fact that the two production areas are largely partitioned from one another. This was the case in the trial heat treatment of the bakery mix portion of the mill undertaken in summer of 2006 (described below).

2006 Trial Heat Treatment

This company opted to evaluate heat treatment using high volume, propane-fired heaters manufactured and operated by TempAir whose entire heat treatment equipment inventory is normally stored in Ontario. This mill is not in Ontario, requiring careful scheduling and logistical arrangements. TempAir equipment is expensive, scarce and requires knowledgeable handling and shipping – essentially requiring a dedicated (one only) truck freight provider. Because of the size, configuration and multi-sections of the mill, the company opted to conduct its initial heat treatment trial in the mix portion of the mill, where prevention of infestation is an absolute must. The planning for the heat treatment involved identification of areas that required partial sealing from other areas of the mill. These requirements were limited. However, in the case of TempAir treatments, escape of heat through exterior and partitioning walls is an objective to achieve mortality of insects in wall cavities, of which there are many in most mills, including this structure.

The treated area was thoroughly cleaned prior to the heat treatment. This involved removal of all mix ingredients, bagged and binned. Every piece of equipment that could be opened to facilitate heat penetration was opened and where feasible, partly disassembled.

The configuration of this portion of the mill required placement of heaters above ground level, requiring use of specialized hoisting equipment (crane) to temporarily install and remove the heating equipment from points on the exterior of the building. The elevated stationing of the heating equipment required additional pipefitting to provide for supply of gas to the burners. Also required were temporary concrete barriers to protect the propane supply tank temporarily on site. Given the volume of the mix facility, this heat treatment required a relatively small footprint for propane supply and distribution.

During the heat treatment, air is forced by 36 inch high volume fans (integral within heaters) through flexible fabric tubes that are configured and joined so as to deliver high amounts of heat to several sections of the structure. The heat is further circulated through the use of portable fans that can be moved as required during the fumigation to achieve even distribution of heat and relatively uniform temperatures throughout the structural area being treated. The delivery location of heat from the fabric socks and location of circulating fans are a matter of trial and error, particularly during the first heat treatment, since portions of the structure that absorb large amounts of heat (heat sinks) are not always easy to predict during planning.

The bakery mix area was brought up to a temperature of approximately 55 degrees Celsius and maintained at that temperature for a period of 24 hours. During the heat treatment, assay vials containing flour beetles placed at various locations before the heat treatment were collected periodically and examined for evidence of insect mortality. In this case, adult insects in all assay vials died within a period of approximately 5.5 hours.

Post-treatment insect monitoring in this area of the mill indicated that there was a high degree of control in the treated area. However, post-treatment monitoring also indicated that adult insects may have migrated from the treated portion of the mill to untreated. This suggests that in the case of this facility, simultaneous heat treatment of all areas of the mill would be desirable from an insect mortality point of view. However, this approach would significantly increase preparation time and labour and add to logistical challenges. The treatment would require 48 to 72 hours. The logistical challenges include the number of heaters required and their transportation and positioning. The fuel supply would also be significantly greater and require a much larger footprint on the site.

Planned Use of Alternatives to Methyl Bromide

This milling establishment has as its ideal target, the elimination of chemical fumigations through intensified IPM and use of heat treatments as necessary. One of the obstacles to substitution of heat treatments for fumigation is the increased cost. The mill structure is large and essentially divided into five components – two milling units, a bakery mix plant, packing area and a warehouse to accommodate storage of mix ingredients and shipment of bagged product. As a consequence, operations are somewhat more complex that for a mill that operates only as a regional bulk shipment flour mill. The company will require several additional years to evaluate efficacy and cost of heat treatment in each area of the mill and may compare other technologies with the TempAir method. Costs are a major consideration. Based on the 2006 trial, the company would foresee a tripling or quadrupling of annual structural treatment costs.

The company is well aware of the regulatory status of ProFume. A trial with ProFume will be delayed until the Pest Management Regulatory Agency completes a second evaluation and approves food tolerances (maximum residue limits), since it would be impractical to empty this facility of all grain and milled grain products.

Mill 8 – Trial Fumigation With Sulphuryl Fluoride (ProFume)

Facility Situation, Configuration and Structure

This wheat flour milling facility has been in operation for approximately 70 years. The mill is situated in mixed use light industrial areas on a major street that carries high volumes of commercial and personal vehicle traffic. The setback of the production and loadout areas from this and a second adjacent street is in places less than 20 metres. A large portion of the mill structure is on or immediately adjacent to the property line. With a rated daily capacity of less than 5000 cwt. of wheat flour, the entire mill has a relatively small footprint. However the entire property is not large, leaving the land area not covered by mill/office structure also quite limited.

Typical of most flour mills of similar vintage, the building has been updated and modified through a series of major and minor construction projects undertaken predominantly to accommodate increases in processing capacity and modernization. As a consequence, the structure has a wide range of construction materials and methods.

- The oldest portions of the mill are constructed of brick masonry (double brick with interior space/cavities), some concrete, wood post and beam frame and wooden floors.
- Portions of the mill constructed at a later date include steel superstructure and bin support structure.
- Older and newer exterior walls are metal clad.
- The most recent portion of the mill is concrete foundation/floor, steel support and insulated metal cladding.

- Original windows have been replaced by modern windows.
- The original double brick walls have been injected with insulating foam for both energy efficiency and to reduce insect harbourage.
- Some upper level flour areas are steel mesh. Some wood floor undersides are metal clad. Some wood floors have been overlaid with plywood to deal with gaps and uneven surfaces.
- Office space used for administration, sales and other non-production activities is contiguous (adjacent to) processing areas.
- The mill laboratory is situated within the dimensions of the processing structure.
- There are two bulk loadout areas.
- The warehouse for bagged product and input supplies is largely of wood construction and is unheated.
- The mill is equipped with two low pressure boilers that provide steam for pelletizing product and for comfort heating.
- The attached elevator and grain storage facility is wood framed and clad.

Processing Equipment

The mill is quite typical of older facilities in that rollstands, sifters and purifiers are of various vintages. Since the structure is small, there is a lot of equipment on each floor relative to total floor area. Space is quite confined, except in the grain cleaning areas where there is more room to navigate during operations and cleaning. Conveyance of grain, and milled grain products are by a typical mix of bucket elevators, gravity spouts, screw conveyors and pneumatic spouts. Production areas and processing equipment are aspirated for dust control. Ambient dust levels are relatively low in some areas of the mill. The mill is equipped with packaging equipment for commercial bagged products. The mill is equipped with a stone mill and a pellet mill for pelleting of millfeeds. The newer bulk loadout bins and loadout area are dedicated to a specialty product destined for food use. Controls are a mix of electrical and microelectronic.

Pest Control Challenges and Measures Taken 2004-2006

This mill has a history of use of methyl bromide fumigation as the primary means of interrupting insect population life cycles in the processing areas of the mill structure. During usual operations between annual fumigations, the pest control program is:

- continuous mill cleaning
- spot treatment with residual contact insecticides
- occasional fogging with an insecticide

This facility has some problem areas where infestations are frequent and substantial while others are relatively free of insect pests.

- The mix of age and materials of construction have resulted in many joints and interfaces between components, equipment support structure and equipment.

- Some of the older processing equipment is less easily cleaned than more modern equipment designed with better access and fewer internal seams, ledges, spaces where product residues can accumulate.
- Tight configuration makes manual cleaning of spouting, structure and bin support structure quite difficult and time consuming.
- Although the cleaning program has rendered the facility interior surface areas (floors, walls, equipment surfaces) quite clean, double brick masonry, even when foam filled, offers refuge for insects that is difficult to reach other than by chemical fumigation.

Included in the lower infestation areas are the warehouse and portions of the grain cleaning area, even where wooden floors have been overlaid with plywood. This layered floor does not appear to offer attractive harbourage and thereby contribute to insect populations. It has been the practice to not fumigate the warehouse and some limited production areas that can be sealed off and isolated during fumigations. These areas are spot treated and fogged, rather than fumigated. This has served to reduce the volume of methyl bromide required for the annual structural fumigation. The most recent methyl bromide fumigation was undertaken in summer months of 2005.

It has been the experience of the mill staff that one annual methyl bromide fumigation is required to achieve adequate control. In recent years, the staff planned to forego an annual methyl bromide fumigation, only to learn that the efficacy of the combined ongoing pest control methods declined dramatically. The mill has reverted to use of methyl bromide until 2006, when a sulphuryl fluoride (ProFume) fumigation was conducted to assess the suitability of that fumigant as an alternative to methyl bromide.

The pre-fumigation preparation of the mill is typical. Dust/milled product residues are removed to the extent possible through manual cleaning and disassembly of processing and conveyance equipment. Equipment that is normally closed during operation remains open during fumigation.

Potential Opportunities for Use of Alternatives to MeBr Fumigation

Since the mill has been successfully fumigated with methyl bromide for many years, it would appear that fumigation with alternative chemical fumigants might offer similar levels of efficacy. The configuration of the mill is such that it can be sealed during fumigation to provide two vertical spaces that can be managed separately for gas injection and concentration maintenance. Isolating the two vertical areas of the production portion of the facility may offer potential for heat treatment in one, the other or both, using existing boiler capacity. For reasons of occupational safety and health, the heat treatment activity could not be conducted at the same time as chemical fumigations.

Two separated bulk loadout areas could conceivably prolong shipping during heat treatment and preparatory stages of fumigations, subject to all occupational safety and health conditions being met. Some finished product bins might be able to be sealed and therefore isolated from areas being treated.

Apparent Constraints to Use of Alternatives to MeBr Fumigation

Like most mills, this mill operates on a continuous bulk delivery schedule to its larger bakery and other food product customers. This limits the amount of down time that can be allocated during mill cleaning/fumigation. The small property footprint and limited parking/paved surface area not covered by mill structure would render it difficult to stage a heat treatment using portable, exterior, propane or gas-fired heaters for heat treatment. The mill electrical supply and distribution was not designed to accommodate the number of electrical fans required for use of heat exchanger and circulation fans typically required for a heat treatment. There is currently little, if any, on-site storage capacity for storage of owned heat treatment equipment. Contiguous lab and office spaces dictate complete evacuation of the facility during chemical fumigation. The age of facility might also require significant other upgrades to address contemporary fire protection requirements, if triggered.

2006 Trial Fumigation

The 2006 trial fumigation with sulfuryl fluoride (*i.e.,* ProFume) was carried out with assistance and supervision by Dow AgroSciences, in cooperation with a Canadian pest control service provider. The trial was conducted over a 3-day holiday weekend to provide sufficient shut-down time, as would normally be the case with a methyl bromide fumigation.

The mill preparation was typical of that for a methyl bromide fumigation. However, the permitted use of ProFume (no MRLs) required that certain bins holding unprocessed wheat be sealed. This is not a requirement for MeBr.

The fumigation was executed in the usual fashion for ProFume at the high dose recommended to kill all insect life stages, with remote sensors s in place throughout the mill to monitor gas levels. Insect mortality in one series of test vials located in an area where they were subjected to ideal exposure conditions and could be removed at subsequent 4 hour intervals was rapid and successful, further demonstrating that ProFume is an effective fumigant when insects are exposed to it under ideal application methods.

However, the reappearance of adult insects in rebolt sifter tailings within two weeks after the fumigation indicated that the fumigation was a failure from an operational perspective. This may be attributable to not having emptied all bins of wheat/milled wheat products. There is no way to determine the reason without a second trial conducted differently than the first.

Planned Use of Alternatives to Methyl Bromide

Although ProFume is promising, it will not likely be used again in this mill until the Pest Management Regulatory Agency approves MRLs for wheat and wheat products. The elevator and bins in this mill are not easily sealed or isolated from production areas that require at least annual fumigation.

ECO_2Fume will be considered if the manufacturer provides information confirming that there are no significant adverse aggregate effects (notably corrosion of conductive metals in electric and electronic equipment) from long term application, as will heat treatment, given the existing steam boiler capacity at the mill. However, concerns about structural characteristics would need to be conclusively addressed before a trial heat treatment would be carried out.

APPENDIX 1:

Efficacy Assessment Report

April 2007

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Appendix to: Harrison G. 2007. Comparative Evaluation of Integrated Pest Management, Heat Treatments and Fumigants as Alternatives to Methyl Bromide for Control of Stored Product Pests in Canadian Flour Mills. Report to Agriculture and Agri-Food Canada for project funded under Advancing Canadian Agriculture and Agri-Food Program, www.canadianmillers.ca

APPENDIX 2:

STORED PRODUCT PEST CONTROL IN CANADIAN GRAIN MILLING FACILITIES

Note to readers: **This appendix is largely reproduced from Section II of CNMA's March 2004 report on comparative analysis of heat treatment technologies with methyl bromide.**

State-of-the-art grain milling equipment has been globally available for decades, as have milling facility design, engineering and construction expertise. Most of the mill processing equipment that is commercially available in 2004 is manufactured in EU countries and in the United States. The majority of electrical and mechanical equipment used in Canadian mills is widely available throughout North America. Much of the product spouting, transfer and storage equipment is fabricated by Canadian manufacturers.

The Canadian grain milling industry has undergone extensive expansion and modernization since the early 1990's. The expansion has been achieved by three means. These are:

- construction of new mills
- addition of entire milling units to existing facilities
- increase in capacity through replacement of existing equipment and/or addition of roll stands, purifiers and sifters and related distribution equipment to existing milling units

Both wheat milling and oat milling have experienced significant capacity increases during the past 15 years. This has included construction of 4 new oat milling facilities in western Canada plus construction of 4 new wheat milling facilities in western and eastern Canadian provinces. Wheat milling capacity has increased by approximately 15% since 2000.

A major part of the modernization has been the addition of aspiration and dust collection equipment. This equipment serves a number of purposes. These are:

- capture of flour dust suspended in air within the processing equipment and return to the product stream to increase extraction rate (yield)
- reduction of particulate matter released into the external environment through passive and forced exhaust air
- removal of suspended grain and flour dust from the mill environment to reduce worker exposure to dust and reduce accumulations of grain dust on equipment and structure surfaces

This last point is of fundamental importance to the success of pest control programs in grain mills. Accumulations of grain dust and flour dust provide both food and shelter to grain and flour beetles that are the primary insect pests found in grain mills. When such dust finds its way into cracks, crevices and confined spaces that cannot be reached by brooms and vacuum equipment, grain and flour beetles that are indigenous (present in nature) have ideal refuge in which to feed, grow and multiply. As a consequence:

1. small populations of grain and flour beetles are normally present in the structural components of mills (cracks and interfaces) employing the best known hygiene and pest control practices

2. grain mills must employ physical means of pest control within the grain milling process to ensure that finished products are free of insects

Physical Means of Pest Control Within the Grain Milling Process

The physical or mechanical means of removing insects from unprocessed grain and milled grain product streams have been part of the grain milling process for decades. The three principal means of mechanical control during the milling process are:

- mechanical separation of foreign materials, including live and dead insects/insect parts by means of sifting and aspiration (air suspension under negative pressure)
- high speed centrifugal impact (entoletion) of milled grain product streams (flour fractions)
- re-bolt (final) sifting of milled grain products before packaging and shipment

All three are employed in the manufacture of grain flours where entoletion is the key step in achieving 100% insect mortality of all insect life stages that are not removed during the grain cleaning process. Re-bolt sifting provides added assurance that no live insects have entered the product stream following entoletion and before final binning.

However, entoleters cannot be used where certain minimum particle sizes must be maintained as in the case of semolinas, brans, flakes and pearled whole grains. Facilities manufacturing and/or receiving these milled grain products for further processing must rely upon other physical, chemical and good manufacturing practice means of ensuring absence of insect pests from finished products.

Plant Hygiene

The most important good manufacturing practice and component of an integrated pest management (IPM) program in the control of insect pests outside of the product streams in a grain milling facility structure (floors, walls, ceilings, equipment support infrastructure, packaging materials, spare equipment parts) is a continuous program of plant hygiene. The primary objective of a plant hygiene program in a grain milling facility is to prevent accumulation of grain and flour dust that escapes from processing equipment during the grain cleaning and milling processes. Although almost 100% of grain milling equipment is equipped with aspiration (negative pressure to remove airborne dust particles to air filtration equipment), escape of some dust into air within a milling facility is unavoidable. Grain and flour dust does not normally remain suspended in air, but instead settles onto facility and equipment surfaces. Because accumulated grain and flour dust acts as a source of food and refuge for insect pests as well as representing a fire and explosion hazard, these surfaces must be routinely cleaned by hand using brooms, vacuum equipment and under controlled circumstances (maintenance shut-downs) compressed air jets.

Since many milling facilities operate 24 hours per day, six to seven days per week, mill cleaning must be conducted during normal manufacturing operations. To achieve this, a small minority of grain milling industry production workers is completely dedicated to mill cleaning activities. The majority of production workers carry some responsibility for plant hygiene, tasked with cleaning of product spills as they occur, and with routine equipment maintenance and cleaning functions. With declining availability and increasing cost of methyl bromide, Canadian milling firms have been adding dedicated mill hygiene staff.

During scheduled maintenance shutdowns and unscheduled shutdowns due to equipment failure or chokes, processing and product transfer equipment is disassembled and manually cleaned to remove product residues that can also harbour live insects. More advanced designs of milling equipment have reduced cavities and surfaces where product can be accumulated and incorporated easier access for manual cleaning. In addition, mechanical elevation (bucket elevators), gravity spouts and where possible, screw conveyors have been replaced in new construction and renovations by pneumatic product transfer equipment. This has served to reduce the number of voids and surfaces where product can accumulate within the milling process and to reduce the amount of dust that escapes from product streams into the mill environment.

Contact Insecticides

Contact insecticides with low mammalian toxicity such as malathion and pyrethrins have long been used as part of pest control programs in grain milling facilities. They are particularly useful as residual insecticides in areas of the mill structure that do not normally come into contact with milled product streams.

In recent years, diatomaceous earth (microscopic sized exoskeletons of prehistoric ocean-dwelling single-celled algae found in mineral deposits) has been used as a contact insecticide in structural cracks and voids that cannot be reached through manual cleaning methods. DE is also approved as a contact insecticide in stored grain, recognizing that it can be effectively removed during the grain cleaning process prior to milling.

Grain Storage Fumigation

Because of the ongoing turnover (throughput) of wheat and other grains in milling facilities, fumigation of on-site grain storage bins is rarely conducted but can be used where significant insect infestation is apparent and must be eliminated as a source of infestation of the mill processing structure. In these circumstances, MB is not the fumigant that is normally used. Rather, the preferred fumigants are aluminum and magnesium phosphide, both of which generate phosphine gas. Although very effective in achieving insect mortality, phosphine is also highly and unpredictably corrosive to conductive metals that are used in grain milling electrical and electronic equipment. As a consequence, phosphine is rarely used for structural fumigation of grain mills.

Structural Fumigation

For more than the past 30 years, methyl bromide has been licensed and commercially available as the product of choice for control of stored product pests in grain milling and pasta manufacturing facilities in Canada. The majority of facilities have undergone one or two fumigations annually, normally conducted during the period April to November.
As noted above, the other fumigants that are licensed and commercially available in Canada are magnesium phosphide and aluminum phosphide, both used to generate phosphine gas. It has been the experience of the Canadian milling industry that phosphine gas can cause significant levels of corrosion to conductive metals (contacts and circuits) in electrical and microelectronic components of milling equipment and telecommunications (telephones, intercoms) equipment. Levels of corrosion sufficient to cause equipment malfunction have been observed as a consequence of as few as a single fumigation or the cumulative result of fumigations over a period of years. Laboratory research (CANMET, Brigham, 1998, 1999) conducted in Canada suggests that corrosion can occur at a wide range of temperatures and relative humidity. As a consequence of this practical experience and research, Canadian milling companies do not normally use phosphine as a means of insect pest control.

Cold Treatment - Freeze Outs

While it is recognized that prolonged (72 to 96 hour) exposure to sub-zero Celsius temperatures can result in a high rate of stored product pest mortality, cold treatments are not considered a practical means of insect control in Canadian grain milling facilities. However, no research has been conducted in Canada in recent years to assess.

Integrated Pest Management

The term "integrated pest management" or IPM, has often been portrayed as the most feasible "alternative" to chemical fumigation. While various pest control service providers offer variations on IPM programs, particularly in the latter stages of the regulated phase-out of MB, the core components of most IPM programs are:

1. effective dust collection systems to minimize accumulation of dust residues
2. aggressive and continuous mill hygiene program that includes frequent bin and processing equipment clean-outs
3. elimination of harbourage (hiding and breeding places) for insect pests
4. selective use of contact pesticides
5. careful monitoring of insect populations
6. periodic fumigation or heat treatments to achieve a level of insect mortality sufficient to interrupt the pest life cycle and temporarily eliminate the insect population in the treated area(s)

These key components essentially describe the normal good operating practices of Canadian grain milling facilities for most of the second half of the twentieth century. However, the regulated phase-out of methyl bromide has increased the importance of the first five components and focussed research and development efforts on more effective means of heat treatment.

Heat Treatment

Heat treatment as a means of insect pest control in the Canadian grain milling industry predates 1990, when it was incorporated as part of an integrated pest management program of a single grain milling facility. This use has been referenced in an earlier report (Alternatives to Methyl Bromide: Selected Case Studies, Agriculture and Agri-Food Canada) where it was described as an alternative to chemical fumigation. However, this portrayal was inaccurate in that the firm in question considers periodic use of chemical fumigation to be an essential component of its pest control program.

Heat Treatment Mode of Action in Insect Pest Mortality

Although the stored product insect pests typically found in Canadian grain mills thrive in warm temperatures ranging from 16 to 34 degrees Celsius, these same species have a very low tolerance for sustained temperatures in the range of 40 to 60 degrees Celsius that can be achieved and maintained in some milling facilities without risk of damage to mill structure or equipment. The physiological mode of action has been well researched and documented. When beetles are exposed to elevated temperatures, they experience elevated respiration rate and desiccation. In summary, the heat interferes with the normal metabolic and respiratory functions of these insects, albeit in a difference fashion than chemical pesticides.

However, in some respects, heat performs like a chemical fumigant. The heat is “carried” in gases (the air that is present in or forced into the facility during the heat treatment process) that can be dispersed throughout the milling facility and under ideal conditions, reach most, if not all areas of harbourage for stored product pests. Heat is a predictably effective means of achieving insect pest mortality, assuming ambient temperatures can be elevated and controlled throughout the entire structure being treated. Heat is neither toxic nor a significant health or safety threat to mill employees or pest control personnel during the multiple short term periods of exposure required during a heat treatment. When heat is lost into the environment during and after a mill heat treatment, it poses no apparent ecological threat or mammalian health and safety risk. With these attributes, heat would appear to be the ideal “fumigant” to serve as the alternative to methyl bromide in controlling insect pests in grain milling facilities. However, in practice, heat is actually more difficult to dissipate evenly throughout a grain milling facility structure than is a highly volatile substance such as methyl bromide in its gas phase. Unlike a fumigant such as methyl bromide, heat is rapidly absorbed in massive quantities by the facility’s structural components and processing equipment (steel beams and cladding, concrete floors, masonry walls, metal and equipment components). As a consequence, a great deal more heat (as measured in terms of the fossil fuel consumed during a heat treatment) is often required to achieve insect mortality than the volume of a chemical fumigant such as methyl bromide.