HOT AIR

Your Green Alternative

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Burnsville, MN, USA
Fumigation – Pest Management

- Methyl Bromide - Ozone depletion
- Phosphine - Insect resistance, Corrosion
- Sulfuryl Fluoride - Residues? Dosage?
- Contact Insecticides - Fogging, Penetration?
Heat Treatment – Historical Look

- 1762, France: 69°C / 156 °F for 3 d, moth
- 1860, England: 57°C / 135 °F for grain
- 1910, USA: heat treatment of mills
- 1920, USA: 30 mills use heat in OH, PA
- 1932, France: MB as insecticide

Used first 252 yrs ago!
History of Heat Treatments

- 1950’s: Quaker Oats using heat
- 1983: EDB banned
- 1990’s: increased interest in heat
- 1992: MB found ozone unfriendly
- 1994: Dursban in Cheerios
- 2005: MB to be phased out
- 2006: MB extension US, Canada ??
Heat in mills to control insects
100 Years ago.....Manhattan, Kansas

...Writer noticed on several occasions that the common insects were dead, although they were surrounded with an abundance of food.....April, 1911
Heat in mills to control insects
100 Years ago.....Manhattan, Kansas

...In Kansas the heating of more than twenty mills has absolutely proven that no stage of insect, even in the most inaccessible places, could withstand the heat.....February, 1913
Drivers - Heat Treatment (HT)?

- Consumer Preference
  - Pesticide-free Products
- Eco-Friendly Technology
  - Montreal Protocol
  - US Clean Air Act
- Insect Resistance
  - Higher dosage, Life stages?

Green IPM
Heat - Advantages

Safe • Effective • Co-friendly

- Non Chemical
- People-Safe
- Kills all life stages
- No ozone depletion
- No Toxicity or Corrosion issues
- No evacuation of People • No Sealing • Spot Treatments
Temperature Effects on Insects

Targeted temp. spectrum 120 - 140°F (50-60°C)

Temperature (°C)

DEATH IN MINUTES

DEATH IN A DAY

SLOWER GROWTH

MAXIMUM GROWTH

SLOWER GROWTH

DEATH IN WEEKS OR MONTHS

DEATH IN DAYS, OR MONTHS IF ACCLIMATED

DEATH IN MINUTES

Source: P. Fields, AAFC, Canada
Heat treatment concept: Raising the ambient air temperature of the complete facility, or a part of it, to 122-140°F (50-60°C), and maintaining these temperatures for at least 24 hours.
Efficacy to Control Pests

• MBr – Methyl bromide
• PH₃ - Phosphine
• SF (Profume)
• CO₂ – Carbon dioxide
• O₃ - Ozone

Efficacy – function of temperature
Heat Treatment

Insects – lethal threshold temperatures

HT Process

Ambient temperature

High Temperature

[120 - 140°F/(50 - 60°C)]

Gradual

Low Humidity (≤ 25%)
(Desiccation/Dehydration)
• Lower humidity = Quicker kill
• Cold air expands as it is heated and can absorb more moisture
Heat & Insect Death

- **High temperature** -
  - Death by Dehydration (low RH)/desiccation

- **Above 50 °C / 120 °F**
  - Cell membranes “melt”
  - Enzyme destruction
  - Change in salt balance
  - Protein coagulation
# Heat Vs MB - Downtime Comparison (hours)

<table>
<thead>
<tr>
<th>Methyl Bromide</th>
<th>Thermal Remediation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sealing...........0</td>
<td>Set up.............0</td>
</tr>
<tr>
<td>Set up..........4-6</td>
<td>Heat up...........6-8</td>
</tr>
<tr>
<td>Fumigation.......24</td>
<td>Kill Period.......24</td>
</tr>
<tr>
<td>Aeration......12-24</td>
<td>Cool down.......2-4</td>
</tr>
<tr>
<td>TOTAL......40-54</td>
<td>Tear down.......1-2</td>
</tr>
</tbody>
</table>

- Plant evacuation mandatory
- Untreated areas operational
Effectiveness of heat treatments against insects
Important Pre-heat Treatment Checklist

- Remove tension from drive belts to avoid stretching
- Perform sanitation and remove all food products
- Sprinkler heads should withstand 127°C
- Protect heat sensitive equipment
Make a list of heat susceptible equipment
Sanitation is the key

Important as heat does not penetrate products well.
Apply a residual pesticide such as cyfluthrin (Tempo) or diatomaceous earth.
Susceptibility Differences Among Life Stages and Insect Species
Red flour beetle

Young larvae are heat tolerant

Source: Dr. Subi, KSU, KS
Old larvae are heat tolerant

Source: Dr. Subi, KSU, KS
Cigarette beetle

Time to kill 99% of the eggs as a function of temperature

Source: Dr. Subi, KSU, KS
## Comparison of Heat Tolerant Stages of Four Species (LT₉₉ in minutes (95% CL))

<table>
<thead>
<tr>
<th>Species</th>
<th>Stage</th>
<th>46°C</th>
<th>50°C</th>
<th>54°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cigarette beetle</td>
<td>Eggs</td>
<td>598.1</td>
<td>165.45</td>
<td>37.87</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(571.21-633.10)</td>
<td>(152.62-182.84)</td>
<td>(35.14-41.56)</td>
</tr>
<tr>
<td>Red flour beetle</td>
<td>Young larvae</td>
<td>430.7</td>
<td>432.8</td>
<td>81.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(364.3-573.6)</td>
<td>(365.3-572.6)</td>
<td>(60.4-207.7)</td>
</tr>
<tr>
<td>Confused flour beetle</td>
<td>Mature larvae</td>
<td>299.46</td>
<td>90.05</td>
<td>55.71</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(281.81-324.88)</td>
<td>(81.80-102.26)</td>
<td>(48.75-67.25)</td>
</tr>
<tr>
<td>Indianmeal moth</td>
<td>Mature larvae</td>
<td>69</td>
<td>34</td>
<td>Not tested</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(62-80)</td>
<td>(29-43)</td>
<td></td>
</tr>
</tbody>
</table>

Source: Dr. Subi, KSU, KS
Optimizing Heat Treatments

- Using the right amount of heat energy
- Eliminating cool spots (Temp. <50°C)
- Determining when to stop a heat treatment
  - Achieving 100% kill of insects without adverse effects on structure or equipment
- Making it cost-competitive with other responsive tactics
- Delaying population rebounds
A successful heat treatment depends on...........

• Estimating the amount of heat (BTUs) required (through heat-loss calculations)

• Improving pest management efficacy
  ✓ Eliminating cool spots through uniform heat distribution (use of fans)
  ✓ Assessing pre- and post-heat treatment insect counts
  ✓ Following good exclusion and sanitation practices
Temperature profile from start to the end of Heat Treatment (30 hours)
(Each line is for individual temperature sensor placed in heated space)

Approx. 6 hr to Reach > 120°F
49 Celsius

Start-up 8 AM

Hold for approx. 24 hours or less depending on application
Process
Positive Pressurization – Forced ambient air
(Patented Process)

US & Canadian Patents

- Positive pressure
  - Good air distribution
  - Hot air is pushed into corners, cracks and crevices
- Calculated and controlled infiltration - air changes
- Lower relative humidity
Re-circulating Inside Air

- Negative pressure
- Poor air circulation
- Uncontrolled infiltration
  - No air changes

Low temperature zones (cold spots)
Recirculating heaters promote thermal stratification and infiltration
Make-up air heaters provide uniform temperatures, pressurize the structure, and exhaust moisture and fumes
Steps in Heat Treatment

1. **Visit & Feasibility**
   - Setup, HT, Document & Review

2. **Engineering, Equipment & Estimate**
   - Equipment mobilization
Real-time Wireless Temperature Monitoring

Untreated Area (Office)

Treated Area

Temperature transmitters

Heater

Heater

Heater
Real-time Wireless Temperature Monitoring System

- Monitor Temperatures throughout heated area
- Manage airflow for Uniform Temperature Profile

HOT Pockets

- Real-time adjustment
- Documentation for QC
- Worker Safety & Savings
Start of the Heat Treatment

Fig. 1: Realtime Temperature Profile from Sep 16, 2006, 06:35 AM to 09:05 PM

Temperature (°F)

(60°C)

(49°C)

(38°C)

(27°C)

Tx:49 sensor in office on 5th floor
End of the Heat Treatment

Temperature (°F)

(60°C)

(49°C)

(38°C)

(27°C)

Tx:49 sensor in office on 5th floor

Fig. 2: Real-time Temperature Profile
THERMAL REMEDIATION
Industrial Applications

- Food Processing
- Rice Mills
- Flour Mills
- Pet Food
- Corn Mills
- Cereal Processing
- Bakeries
- Warehouses

- Baby Food Plants
- Wood Packaging
- Tobacco Companies

Organic processing plants/storages
Entire structure or spot treatment
Heat Treatment of Bins & Silos

Proactive - Preventative
 &
Reactive - Response
Bins & Silos

- Pre-loading or Pre-harvest HT
  - On-farm bins
  - Elevators storages
  - Processing facilities
  - Organic processing plants

- Bin/Silo types
  - Concrete
  - Metal
    - GI bins
    - Tanks
Empty Bin Sanitation

- Accumulation of BGFM under bin floors
  - Insect harborage
  - Mold spore accumulation

- Difficult to clean bin floors

- Available tools difficult to use or unavailable
  - Insecticide sprays have to drip through floor perforations
  - Blowing DE through fan does not guarantee uniform application
  - Chloropicrin no longer available
  - Phosphine requires applicator license
HT of bins and silos

Hopper bottom

Flat bottom
Advantages of HT of Bins/Silos

- Shorter treatment times (4 to 12 hours)
- Bins/Silos in facilities
  - Treated in rotation without shut-down
- No retrofitting – existing transition, bin-entry
- On farm or warehouses – no extensive sealing or evacuation
Collaborative Research

- **Kansas State University**
  - Basic research (1999) – Dr. Subi (Stored Product pests)

- **CNMA – (2002-06) Canadian National Millers Association**
  - In collaboration with Dr Paul Fields, Winnipeg

- **PERC – Propane Edu. Res. Council**
  - Purdue University (2007-08) – Dr. Maier (bins/silos)
  - University of Minnesota (2008) - Dr. Kells (bed bugs)

- **Oklahoma State University (2007)**
  - concrete silos

- **GTI – Gas Technology Institute (2007-08)**
  - Soil Nematodes – MB alternative
Conclusions

- Heat kills all life stages of insects
- **Good method to locate insect problems in industrial plants**
- Repeat customers = efficacy of heat
- Viable alternative to methyl bromide
- Economies of scale - will make it more affordable
Spread of Heat Treatment

- **North America**
  - USA, Canada and Mexico

- **Europe**
  - Greece, Romania

- **Asia**
  - India, Philippines, Taiwan
On Site Images

Heater Placement on multiple floors

Heater Placement under rolling shutter
Heater Placement & Layout

Heater Partially inside Packaging Plant

Duct & Fan Layout - Packaging
Wireless Temperature Sensors Placed Inside Sensitive Equipment
Detecting hidden infestations

Wireless temp sensor

Overhead electrical junction box

10,000s of adults, larvae, pupae!!
Partial/Spot heat treatment in a warehouse

A temporary Poly-tarp – no sealing
Partial/Spot heat treatment in a warehouse
Sprinkler heads and opening the machines
Temperature Profile, Beetles, & Rats!!!!
Concrete Bins, Basement and Head house
Concrete Bins, Basement and Head house
Christmas Heat treatment
December – Snowing!

Outside temperature: 26-30°F/ -1 to -3°C
Flour Mill, Celaya, Mexico

High temperature duct through the ‘well’ of Stairwell to six floors of the mill
Iloilo, Philippines

Partial heat treatment, Canada
Pasta Mill, Monterrey, Mexico

Flour Mill, Cebu, Philippines
Infrared Images/Thermal Print

40.4

41.2

40.3

53.7

73.6

30.1

31.6

31.9

32.1

5/13/2012 4:54:49 PM

°C
Heating in Mill

Time Lapse Thermal Image

Time (h)

0
0
1
3
4.5

50.0
46.8
43.5
40.0
36.5
32.7
28.5
24.3
19.9
Packaging Hall
Concrete floor
Concrete floor & wall

Hole in the duct
Metal clad insulated wall
Thermal Print from outside
Thermal Print Inside & Height
Temperature Profile from ground to a height of 80 feet (25 m)
Heat Treatment: Patented Scientific Process

It’s more of an Art – **HOW** you apply it
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