HOT AIR

Your Green Alternative

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HOT AIR

Effective

Your Green Alternative

Mills, Processing Plants, Warehouses & Storage Structures
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 256 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 ???
- 2015: MB deadline developing countries?

Source: P. Fields, AAFC, 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

SEE

Safe
• Non Chemical
• People-Safe

Effective
• Kills all life stages 50°C

Eco-friendly
• No ozone depletion
• No Toxicity or Corrosion issues

• No evacuation of People • No Sealing • Spot Treatments
Temperature Effects on Insects

Source: P. Fields, AAFC, Canada

WINTERPEG!!
Efficacy to Control Pests

- MBr – Methyl bromide
- PH$_3$ - Phosphine
- SF (Profume)
- CO$_2$ – Carbon dioxide
- O$_3$ - Ozone

Efficacy – function of temperature
Heat Treatment

Insects – lethal threshold temperatures

High Temperature
[120 - 140°F/(50 - 60°C)]

Low Humidity (≤ 25%) (Desiccation/Dehydration)

HT Process
Ambient temperature
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 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.
Process
Positive Pressurization – Forced ambient air (Patented Process)

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

US & Canadian Patents
Re-circulating Inside Air

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

Low temperature zones (cold spots)
Construction Heat Principles: Make-Up vs. Recirculating

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

Visit & Feasibility

Engineering, Equipment & Estimate

Setup, HT, Document & Review

Equipment mobilization
Real-time Wireless Temperature Monitoring

Untreated Area (Office)

Receiver

Heater

Treated Area

Temperature transmitters
Real-time Wireless Temperature Monitoring System

Monitor Temperatures throughout heated area

Manage airflow for Uniform Temperature Profile

Effective Heat Treatment

HOT Pockets

COLD Pockets

Real-time adjustment

Documentation for QC

Worker Safety & Savings
**Start of the Heat Treatment**

![Graph showing real-time temperature profile with labels and annotations](image)

**Fig. 1: Real-time Temperature Profile**

- Start 24 hour hold-time
- Tx: 49 sensor in office on 5th floor
- Temperature (°C): 27, 38, 49
- Temperature (°F): 80, 120
- Start time: 9/16, 6:14
- Maximum hold time: 12:30 hr

Date and time:
- 9/16, 6:14
- 9/16, 8:38
- 9/16, 11:02
- 9/16, 13:26
- 9/16, 15:50
- 9/16, 18:14
- 9/16, 20:38

Temperature (°F):
- 27°C
- 38°C
- 49°C
- 60°C
- 50°C
- 24 hour hold time
End of the Heat Treatment

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

Tx: 49 sensor in office on 3rd floor

Fig. 2: Real-time Temperature Profile

- (60°C)
- (49°C)
- (38°C)
- (27°C)

Temperature (°F)

End

End of the Heat Treatment

Fig. 2: Real-time Temperature Profile
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
Heat Damage

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.
Exponential Growth of Insect Populations
The graph shows the number of insects of *S. oryzae* 14% mc over two months at different temperatures: 18 °C, 25 °C, and 29 °C. The number of insects increases significantly with higher temperatures and longer periods.
S. oryzae 14% mc

Month
0 1 2
Number of Insects

18 °C
25 °C
29 °C

50,000
10,000
300
100
0

0 1 2
Month
Susceptibility Differences Among Life Stages and Insect Species
Red flour beetle

Young larvae are heat tolerant

Source: Dr. Subi, KSU, KS
Confused flour beetle

Old larvae are heat tolerant

Source: Dr. Subi, KSU, KS
Comparison of Heat Tolerant Stages of Four Species (LT$_{99}$ 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 (571.21-633.10)</td>
<td>165.45 (152.62-182.84)</td>
<td>37.87 (35.14-41.56)</td>
</tr>
<tr>
<td>Red flour beetle</td>
<td>Young larvae</td>
<td>430.7 (364.3-573.6)</td>
<td>432.8 (365.3-572.6)</td>
<td>81.9 (60.4-207.7)</td>
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<tr>
<td>Confused flour beetle</td>
<td>Mature larvae</td>
<td>299.46 (281.81-324.88)</td>
<td>90.05 (81.80-102.26)</td>
<td>55.71 (48.75-67.25)</td>
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<tr>
<td>Indianmeal moth</td>
<td>Mature larvae</td>
<td>69 (62-80)</td>
<td>34 (29-43)</td>
<td>Not tested</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
Heat versus Fumigants
<table>
<thead>
<tr>
<th>Insect stage</th>
<th>Sanitation level</th>
<th>Treatment</th>
<th>% Mean (SE) mortality</th>
<th>F</th>
<th>P</th>
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<tr>
<td>Adults</td>
<td>MB</td>
<td>100a</td>
<td>69.90 (0.0)</td>
<td>&lt;0.0001</td>
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<tr>
<td></td>
<td>SF</td>
<td>100a</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Heat</td>
<td>90.1 (1.2)b</td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>SF</td>
<td>100</td>
<td>1.00 (0.0)</td>
<td>0.4219</td>
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<tr>
<td></td>
<td>MB</td>
<td>100</td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>Heat</td>
<td>98.7 (1.3)</td>
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<tr>
<td>Pupae</td>
<td>MB</td>
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<td>2.56 (0.0)</td>
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<td>SF</td>
<td>100</td>
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<tr>
<td></td>
<td>Heat</td>
<td>95.4 (2.9)</td>
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<td></td>
<td>MB</td>
<td>100</td>
<td>0.60 (0.0)</td>
<td>0.5787</td>
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<td>SF</td>
<td>98.7 (1.3)</td>
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<td>Heat</td>
<td>97.3 (2.7)</td>
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<tr>
<td>Large larvae</td>
<td>MB</td>
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<td>100 (0.0)a</td>
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<tr>
<td></td>
<td>Heat</td>
<td>96.1 (1.3)b</td>
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<td>MB</td>
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<td>Heat</td>
<td>98.2 (1.3)</td>
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<td>Small larvae</td>
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<td>100a</td>
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<td>Heat</td>
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<td></td>
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<td></td>
<td>MB</td>
<td>100</td>
<td>3.69 (0.0)</td>
<td>0.0901</td>
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<tr>
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<td>Heat</td>
<td>99.4 (0.3)</td>
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<td>Eggs</td>
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<td></td>
<td>Heat</td>
<td>99.3 (0.3)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MB</td>
<td>99.9 (0.1)</td>
<td>1.25 (0.0)</td>
<td>0.3523</td>
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<td></td>
<td>SF</td>
<td>88.7 (10.0)</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Heat</td>
<td>99.8 (0.1)</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

K-State Study (2009-2010)

n = 3/trt

Trt time=24 h for all
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

- **S E E**
- 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
  - 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
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
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
Partial heat treatment, Canada

Philippines
Pasta Mill, Monterrey, Mexico

Flour Mill, Philippines
Heating in Mill

Time Lapse Thermal Image

Time (h)

0
0
1
3
4.5
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