HOT AIR

Your Green Alternative

41st Annual Latin America Region Conference & Expo

Feb 6-8, 2018

Panama Marriott Hotel

Panama City, Panama

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Scientist & Product Manager,
Temp Air, INC.
Burnsville, MN, USA

HOT AIR

Your *Effective* 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: 69ºC / 156 ºF for 3 d, moth
- 1860, England: 57ºC / 135 ºF 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

appreciation of entomology here, and have a corner on that subject so far as the university is concerned. This institution opens its arms to you—every door and every place you want to go into is yours.

…Writer noticed on several occasions that the common insects were dead, although they were surrounded with an abundance of food…..April, 1911

HEAT AS A MEANS OF CONTROLLING MILL INSECTS[1]

By George A. Dean, *Manhattan, Kan.*

In connection with investigations relative to the inspection and fumigation of flour mills, the writer noticed on several occasions that the common mill insects were dead, although they were surrounded with an abundance of food. Upon further investigation it was observed that these insects were most frequently found dead in those parts of the mill where, owing to the surrounding conditions, they could easily have been subjected to a temperature varying from 105° to 120° F. for four or five hours per day and for a period of several days.

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New York, Prof. J
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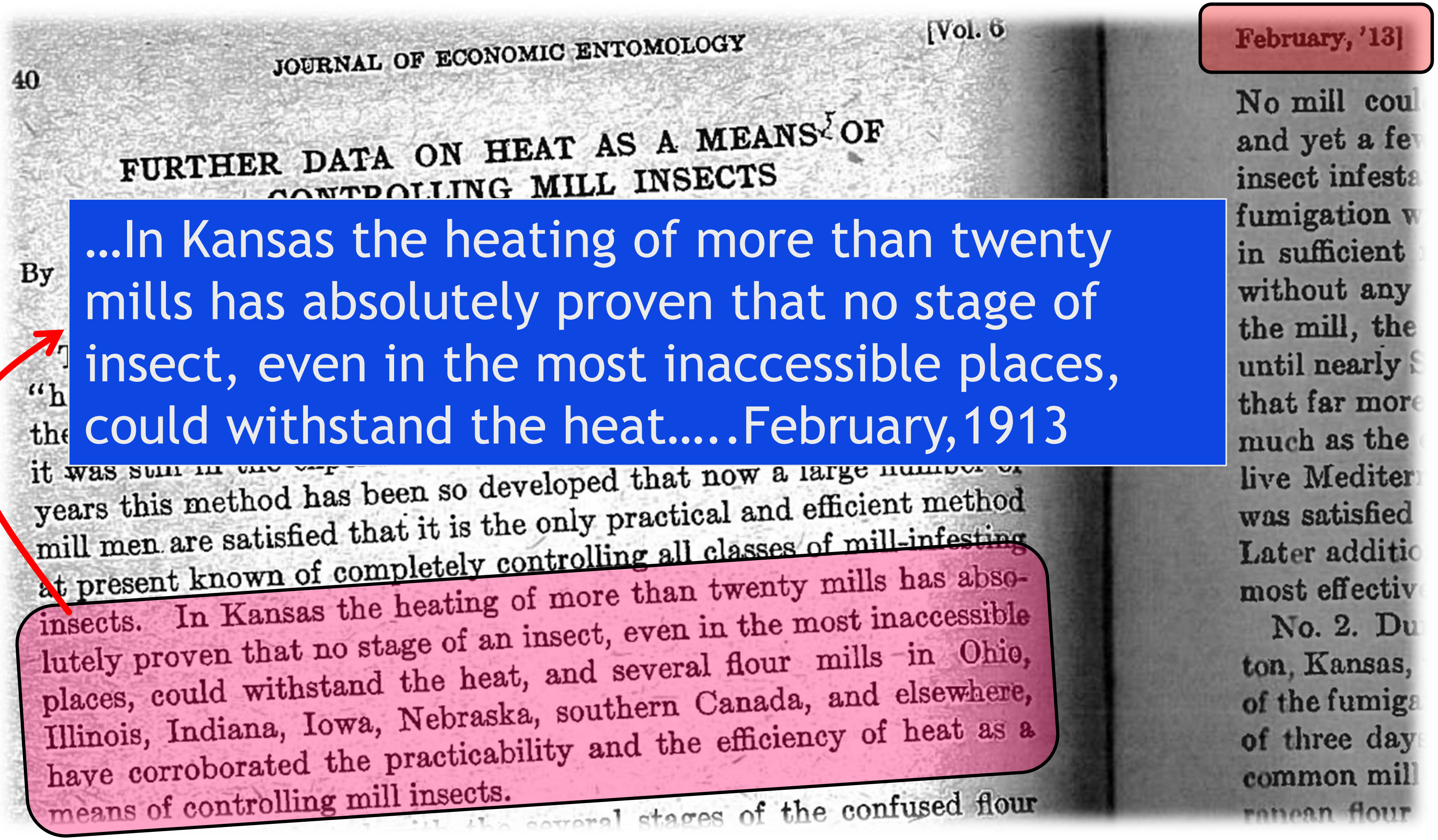
Heat in mills to control insects
100 Years ago…..Manhattan, Kansas



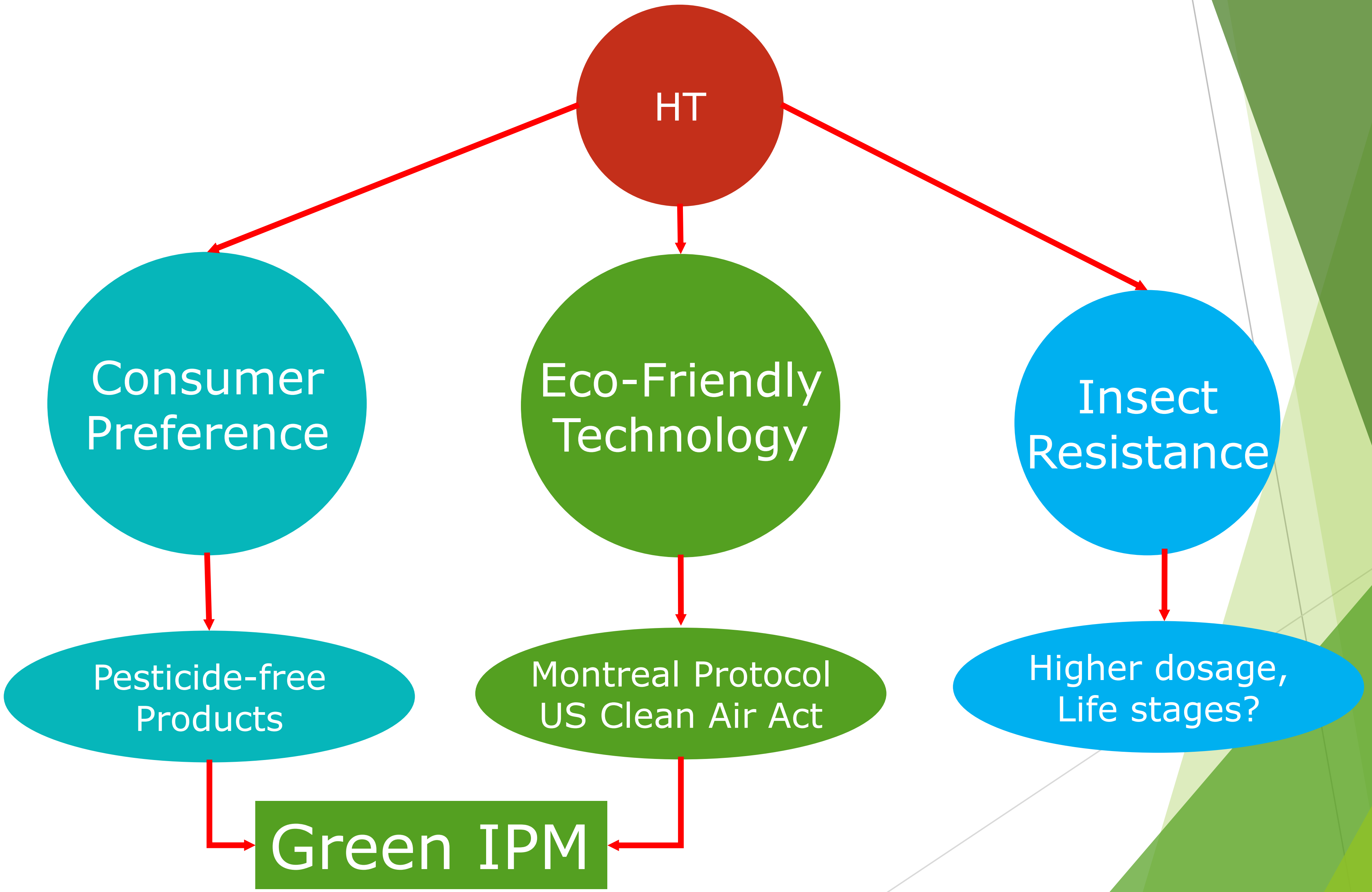
FURTHER DATA ON HEAT AS A MEANS OF CONTROLLING MILL INSECTS

By

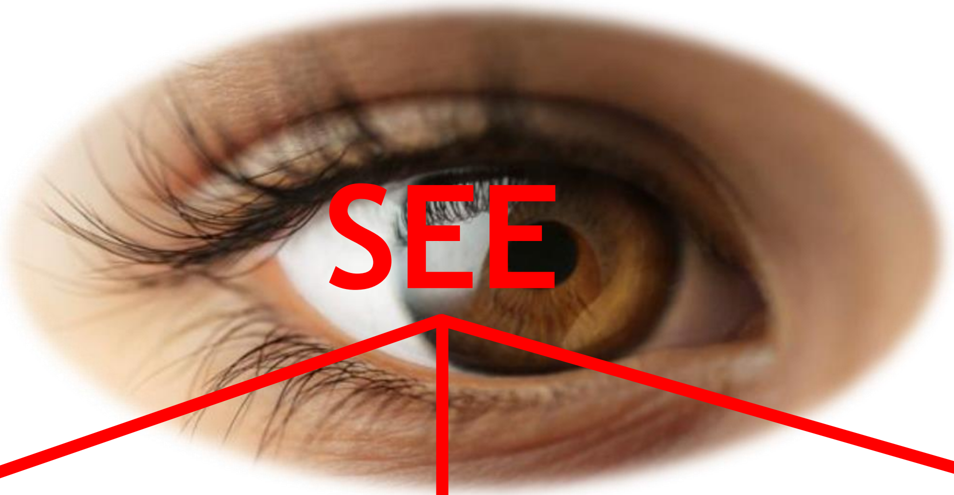
…years this method has been so developed that now a large number of mill men are satisfied that it is the only practical and efficient method at present known of completely controlling all classes of mill-infesting insects. In Kansas the heating of more than twenty mills has absolutely proven that no stage of an insect, even in the most inaccessible places, could withstand the heat, and several flour mills in Ohio, Illinois, Indiana, Iowa, Nebraska, southern Canada, and elsewhere, have corroborated the practicability and the efficiency of heat as a means of controlling mill insects.

…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)?



Heat - Advantages



Safe

- Non Chemical
- People-Safe

Effective

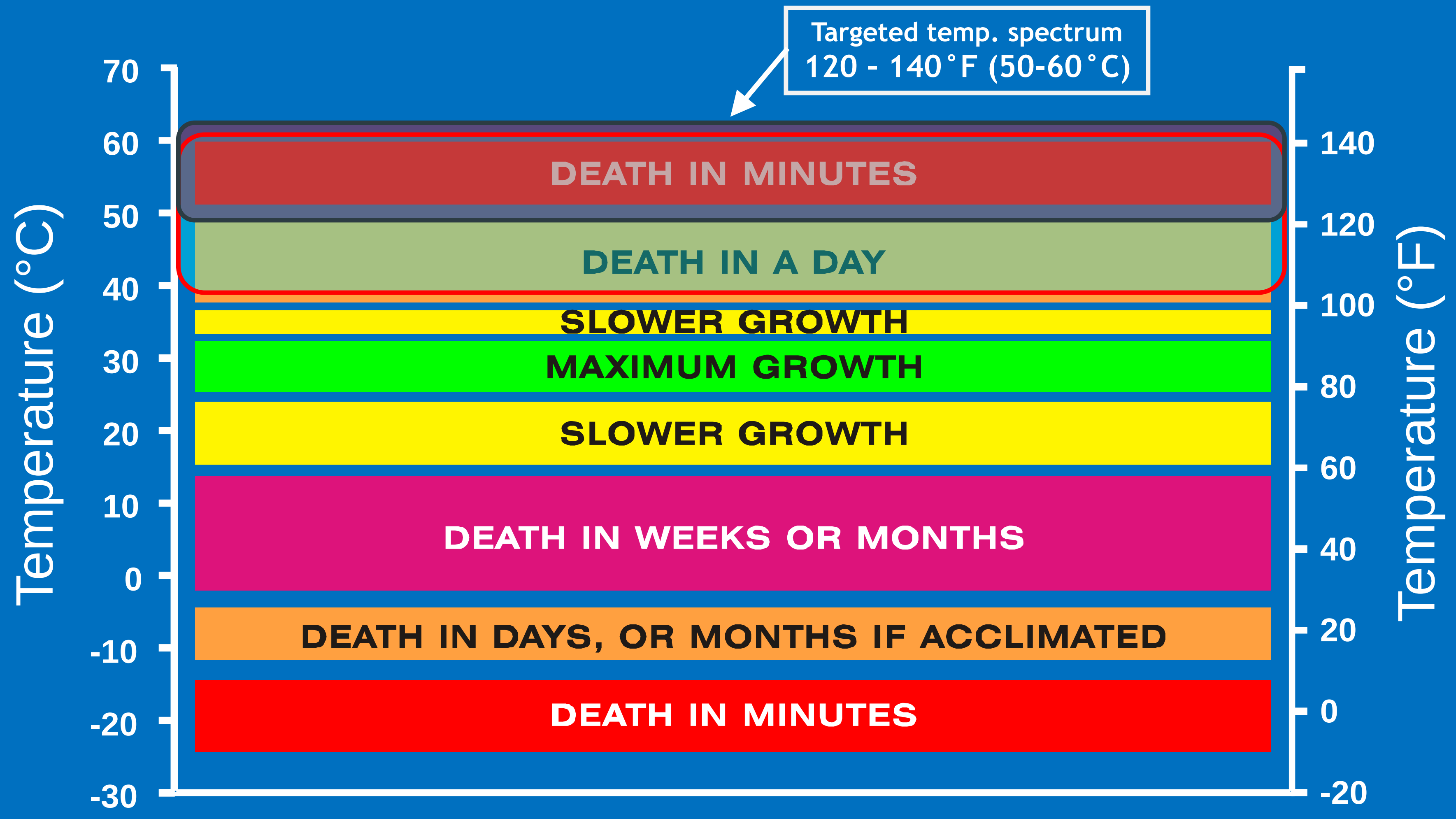
- Kills all life stages 50°C

Eco-friendly

- No ozone depletion
- No Toxicity or
- Corrosion issues

• No evacuation of People • No Sealing • Spot Treatments

Temperature Effects on Insects



WINTERPEG!!

Source: P. Fields, AAFC, Canada

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

HT Process

Ambient temperature

gradual

High Temperature

[120 - 140°F/(50 - 60°C)]

Low Humidity (≤ 25%)

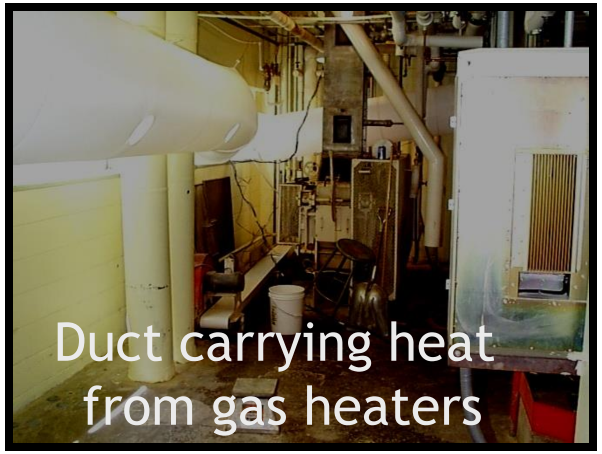
(Desiccation/Dehydration)

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

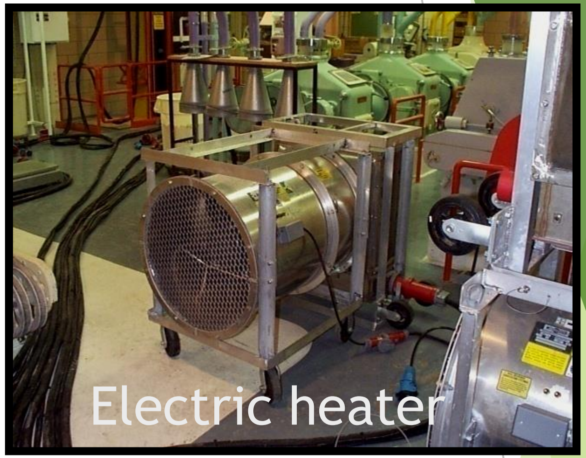
Heat treatment concept: Raising the ambient air temperature of the complete facility, or a part of it, to 122-140^{o}F (50-60^{o}C), and maintaining these temperatures for at least 24 hours

Gas heaters



Duct carrying heat from gas heaters

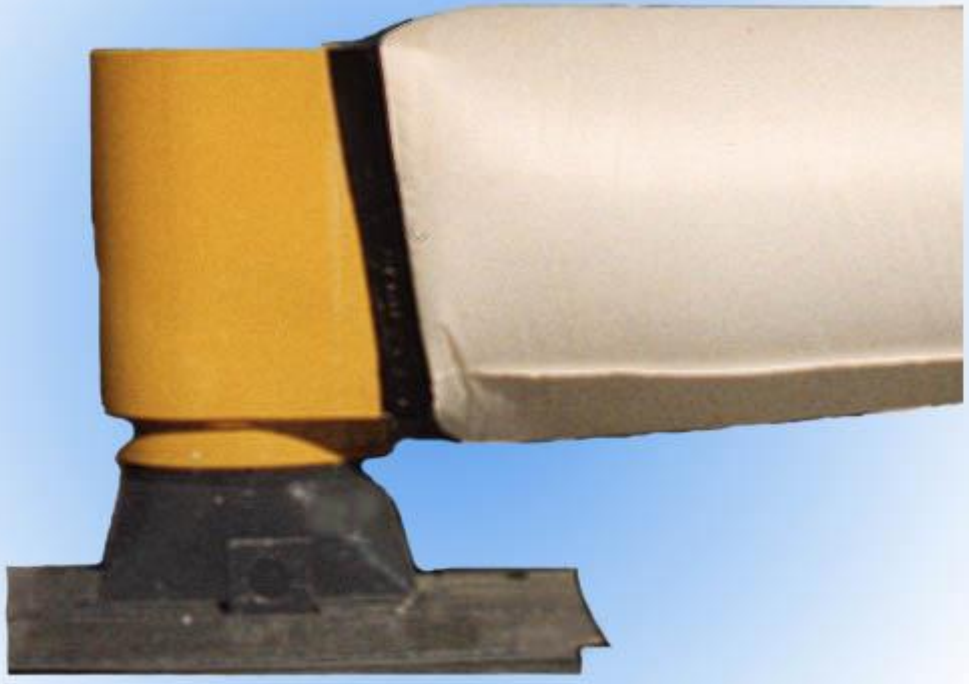
Steam heater



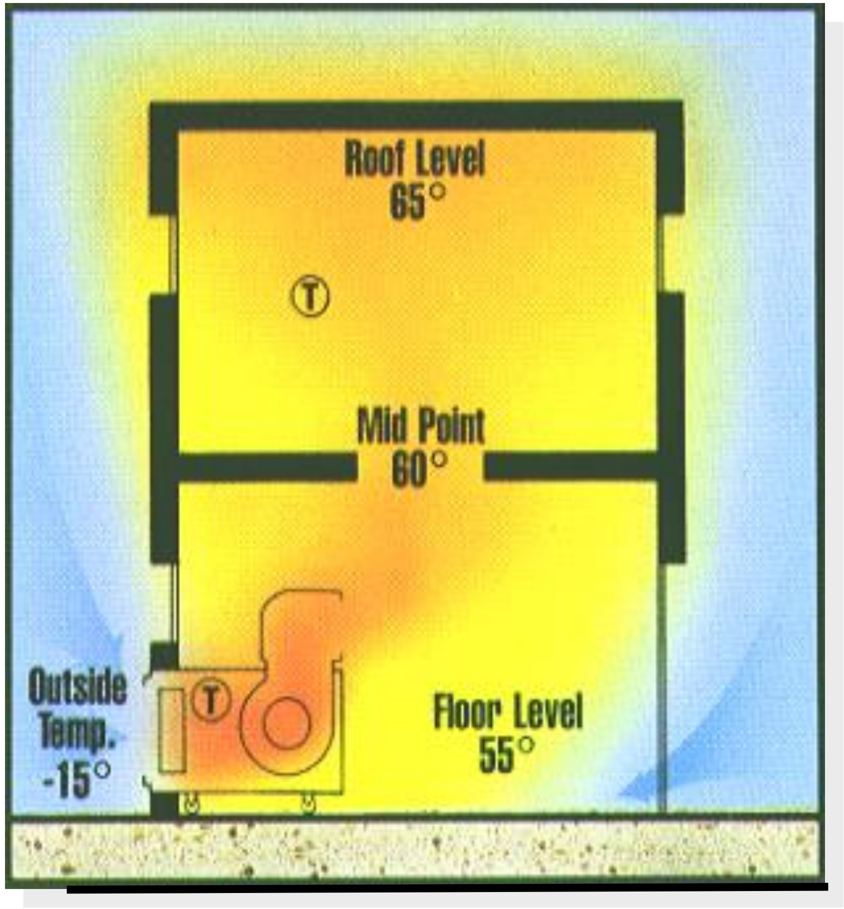
Electric heater

Fan

Process



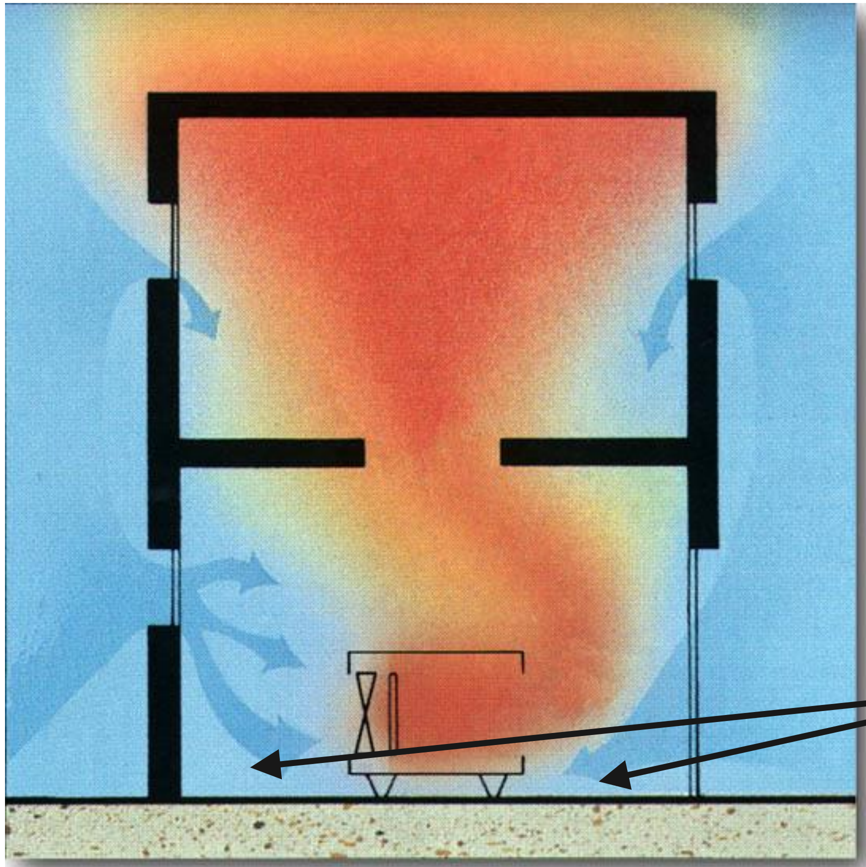
Positive Pressurization – Forced ambient air (Patented Process)



<u>US & Canadian Patents</u>

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

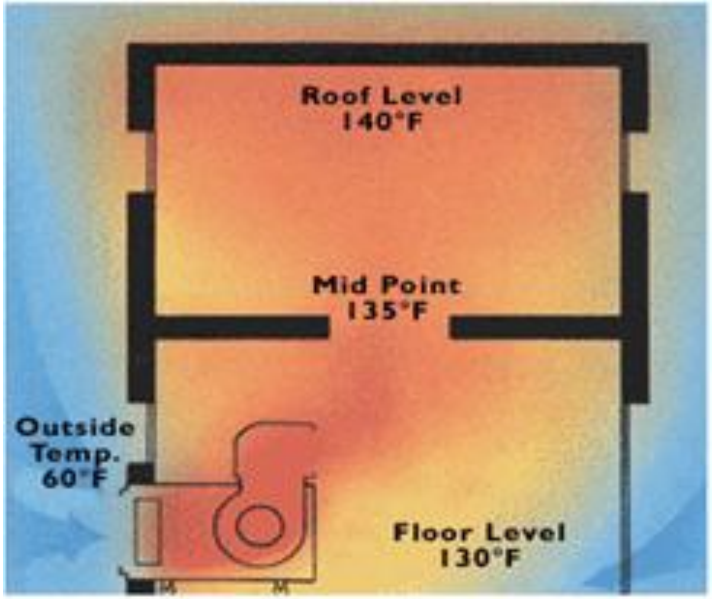
Re-circulating Inside Air



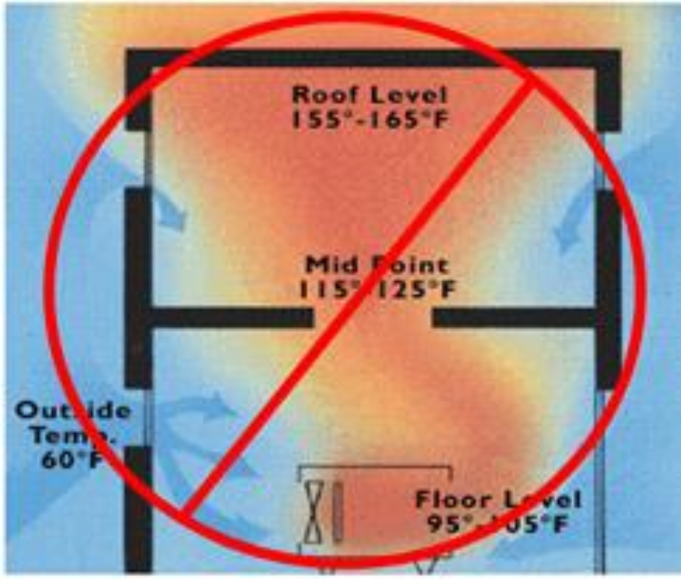
- Negative pressure
- Poor air circulation
- Uncontrolled infiltration
  - No air changes

Low temperature zones (cold spots)

Construction Heat Principles: Make-Up vs. Recirculating



100% OUTSIDE AIR



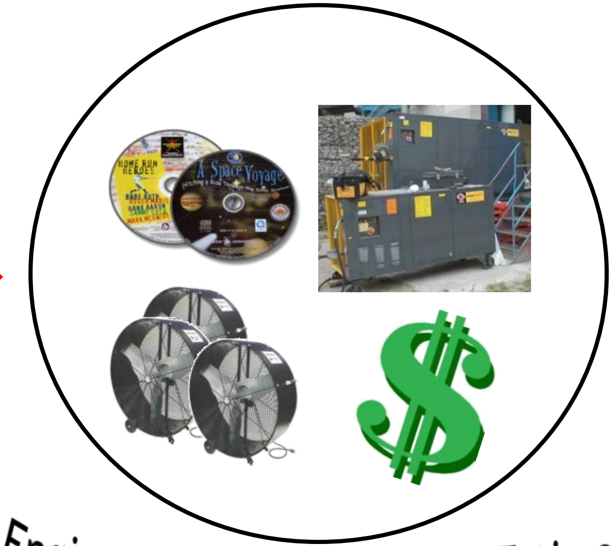
RECIRCULATING INSIDE AIR

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

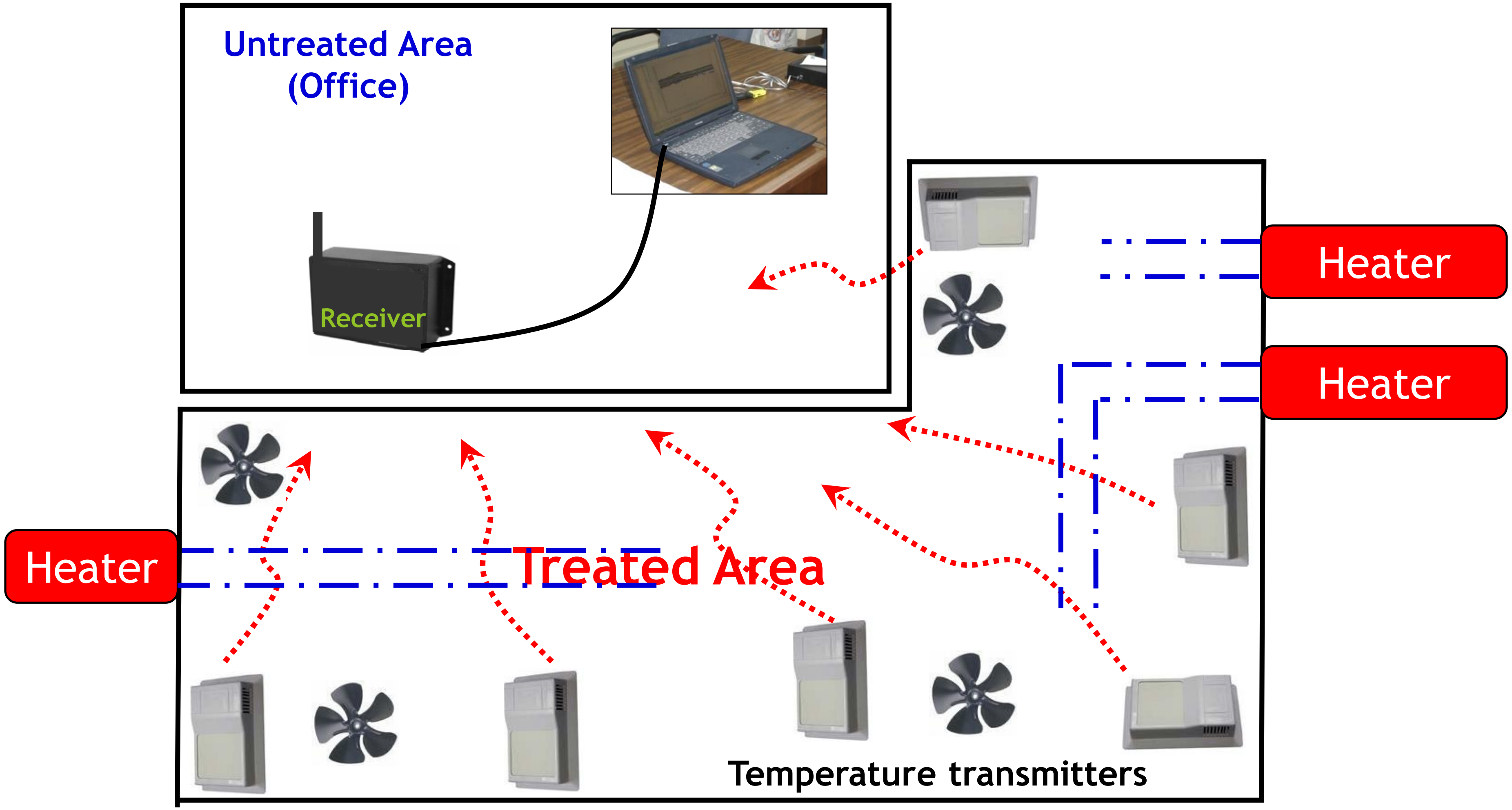


Engineering, Equipment & Estimate

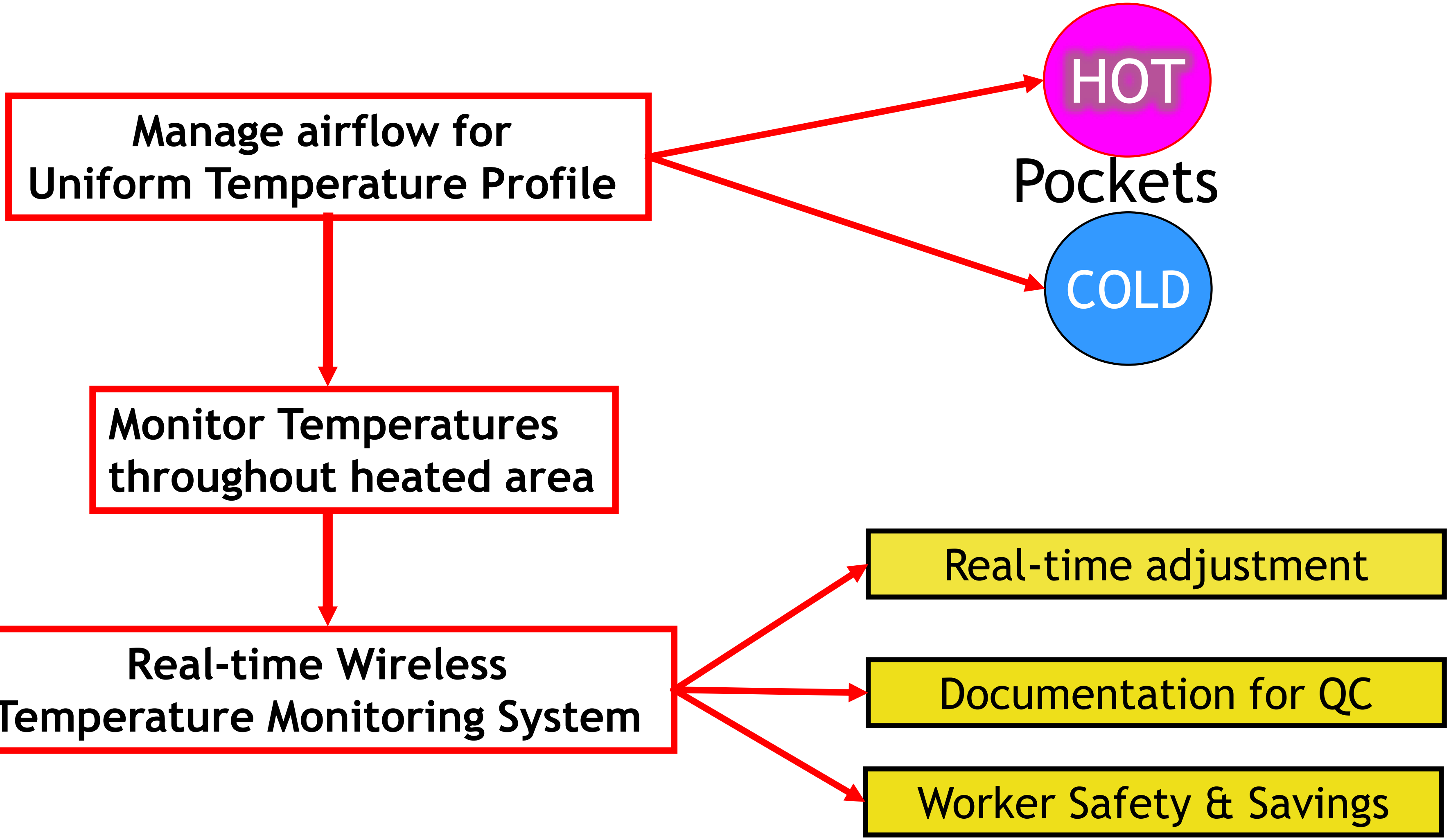
Setup, HT, Document & Review

Equipment mobilization

Real-time Wireless Temperature Monitoring



Effective Heat Treatment



Start of the Heat Treatment

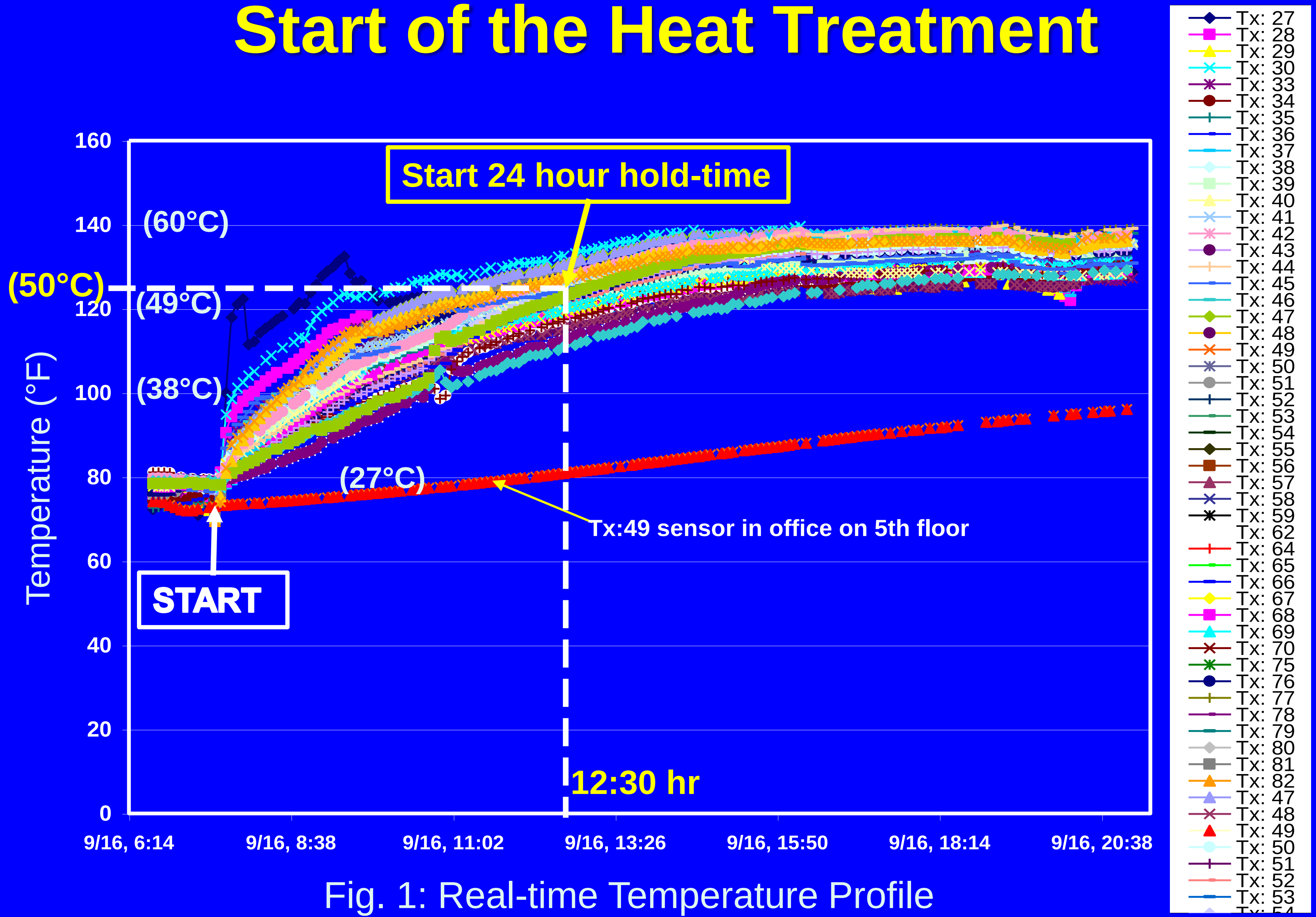


Fig. 1: Real-time Temperature Profile

End of the Heat Treatment

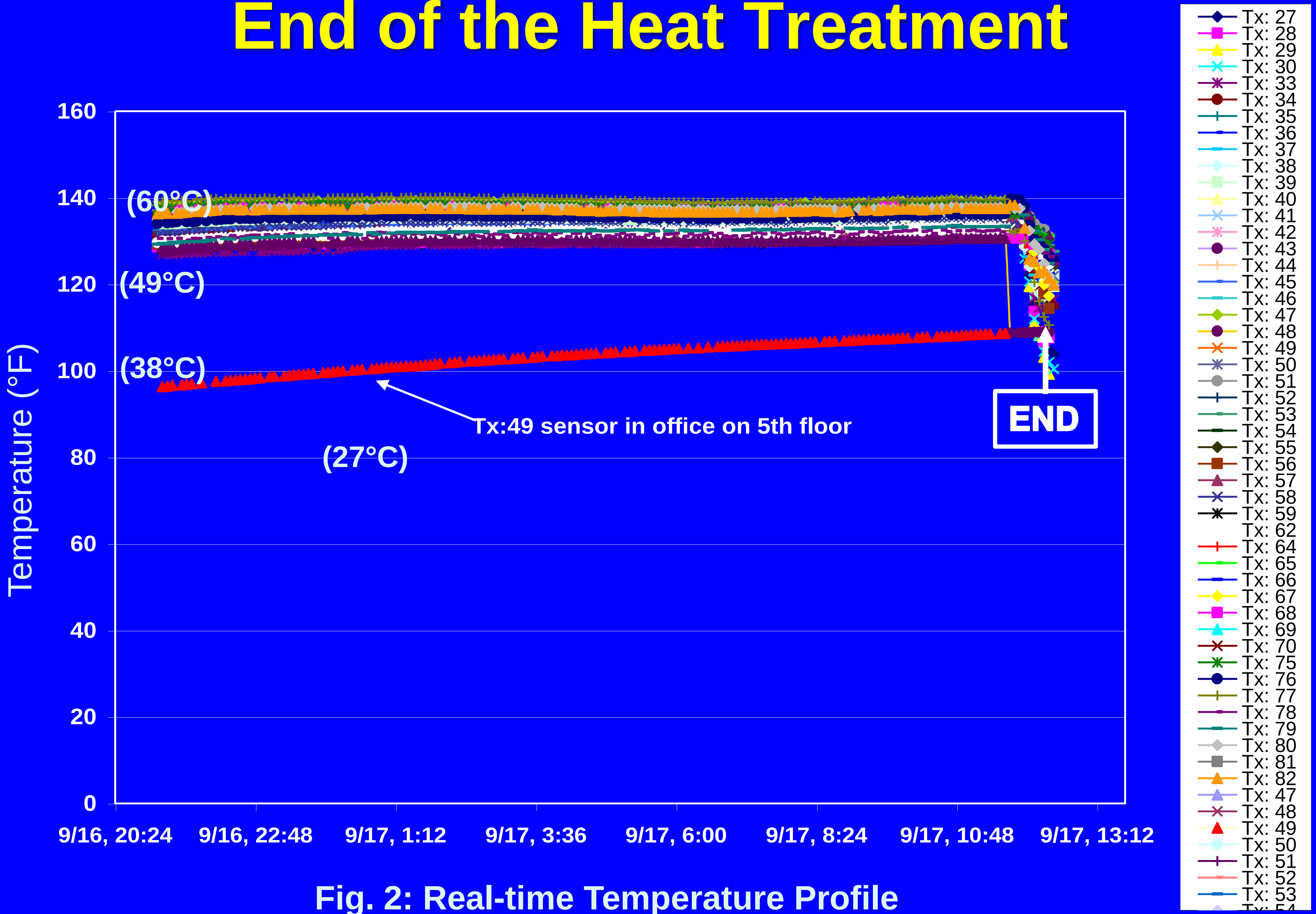


Fig. 2: Real-time Temperature Profile

Effectiveness of heat treatments against insects

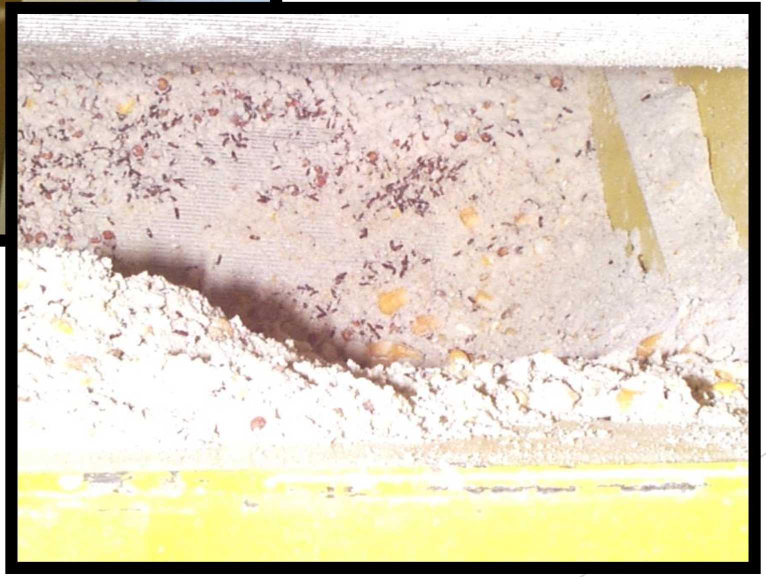
Important Pre-heat Treatment Checklist

- Remove tension from drive belts to avoid stretching
- Perform sanitation and remove all food products
- Sprinkler heads should withstand 127^{o}C
- Protect heat sensitive equipment

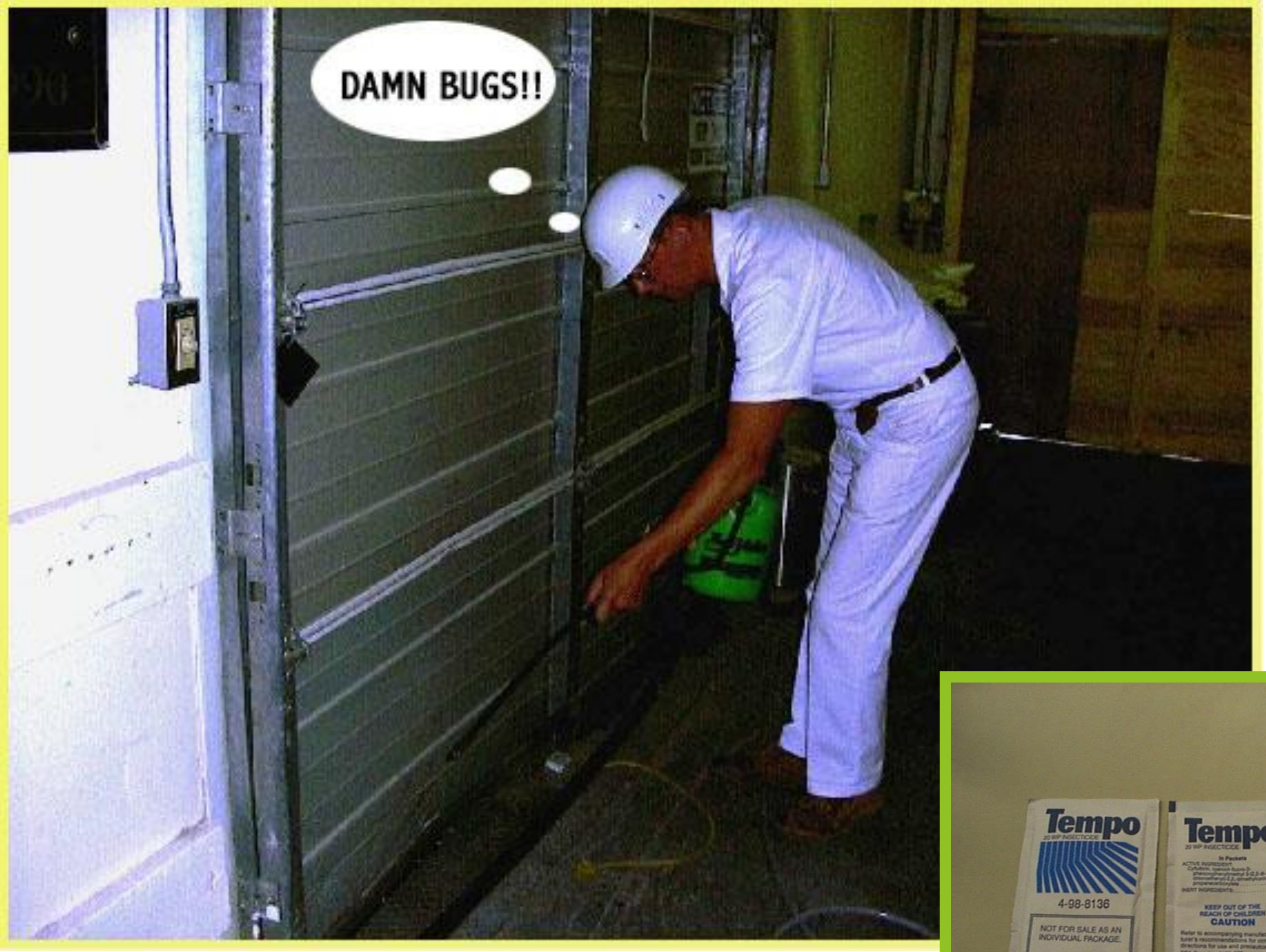
Heat Damage

Make a list of heat susceptible equipment

Sanitation is the key

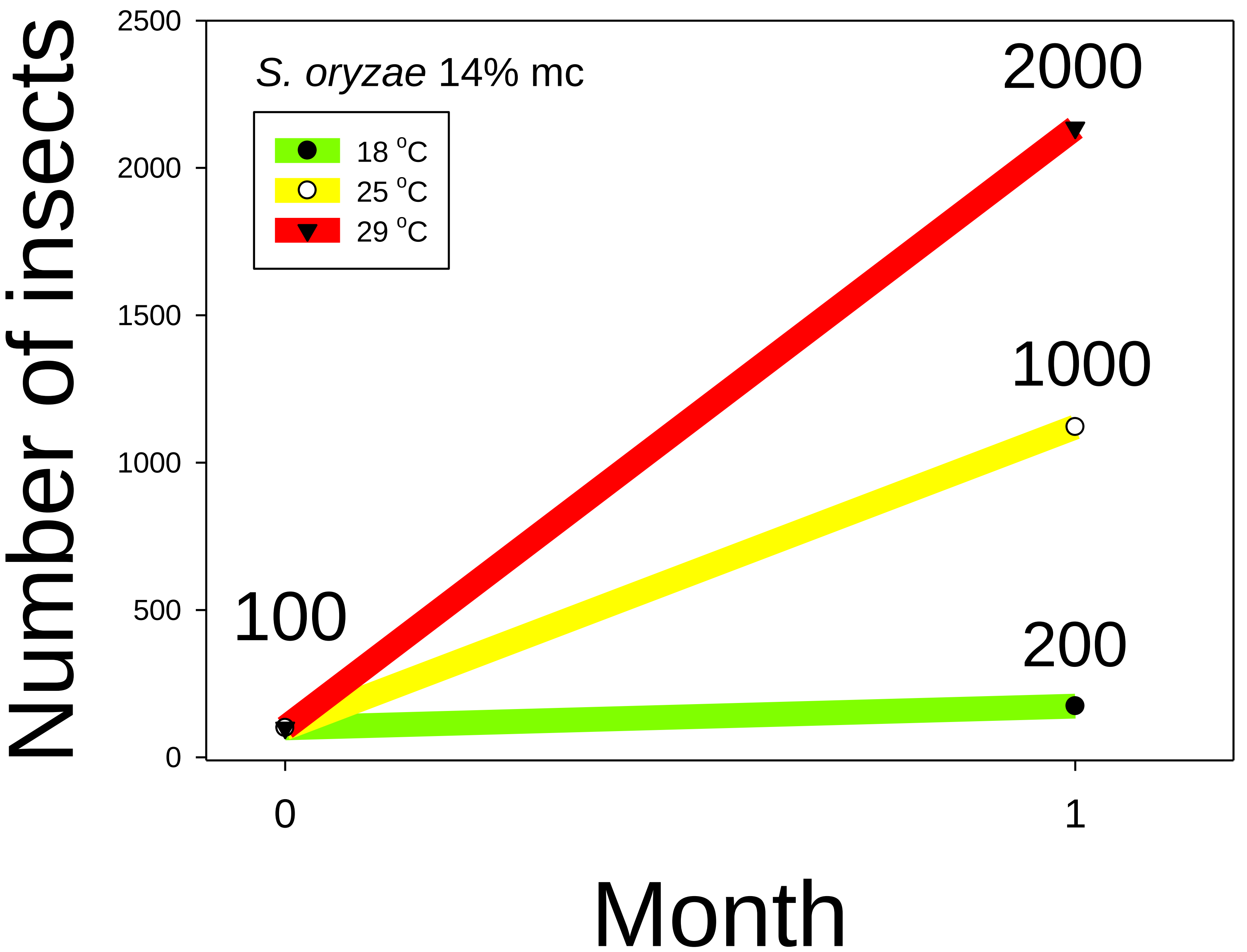


Important as heat does not penetrate products well.

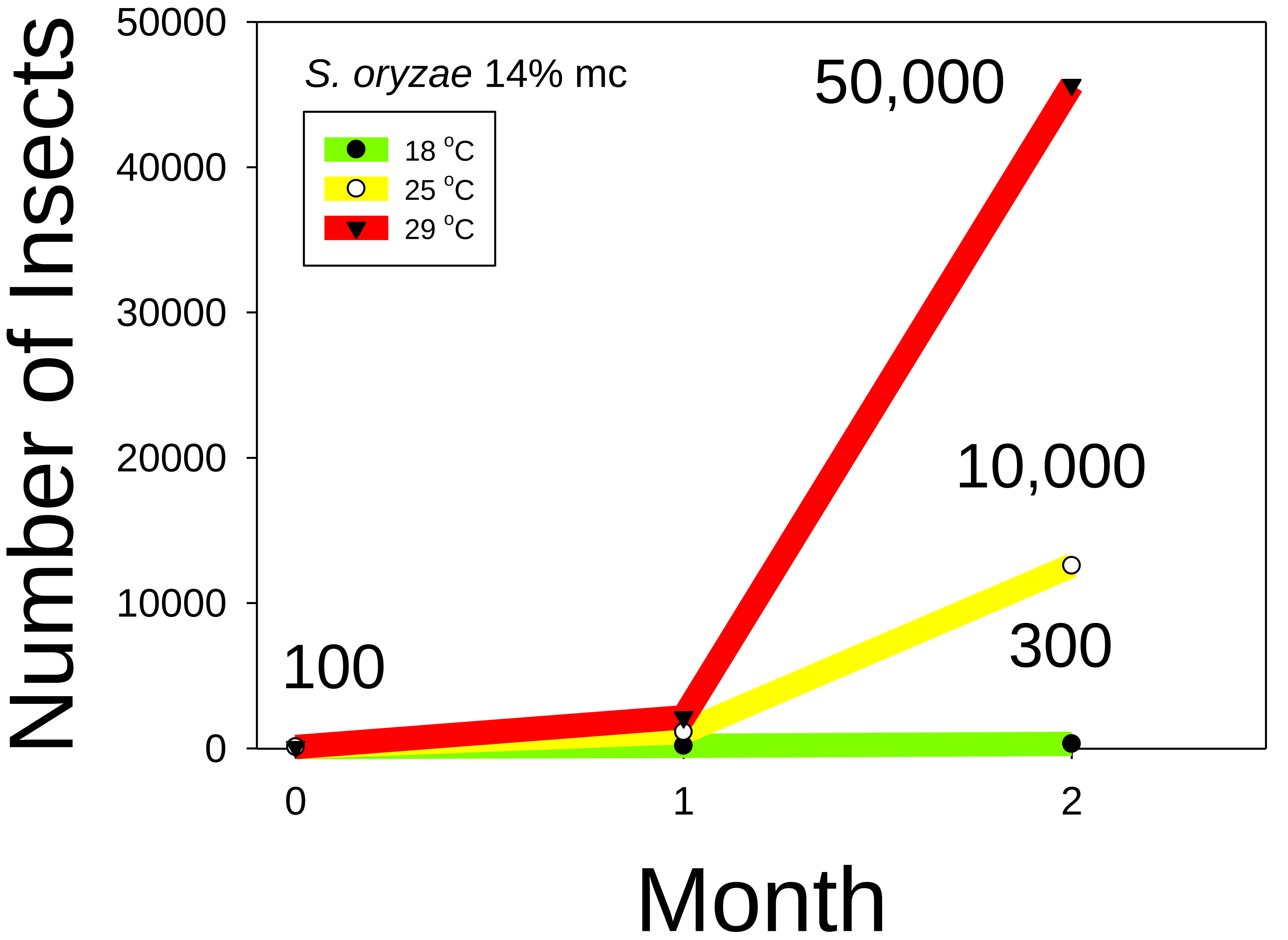


Apply a residual pesticide such as cyfluthrin (Tempo) or diatomaceous earth

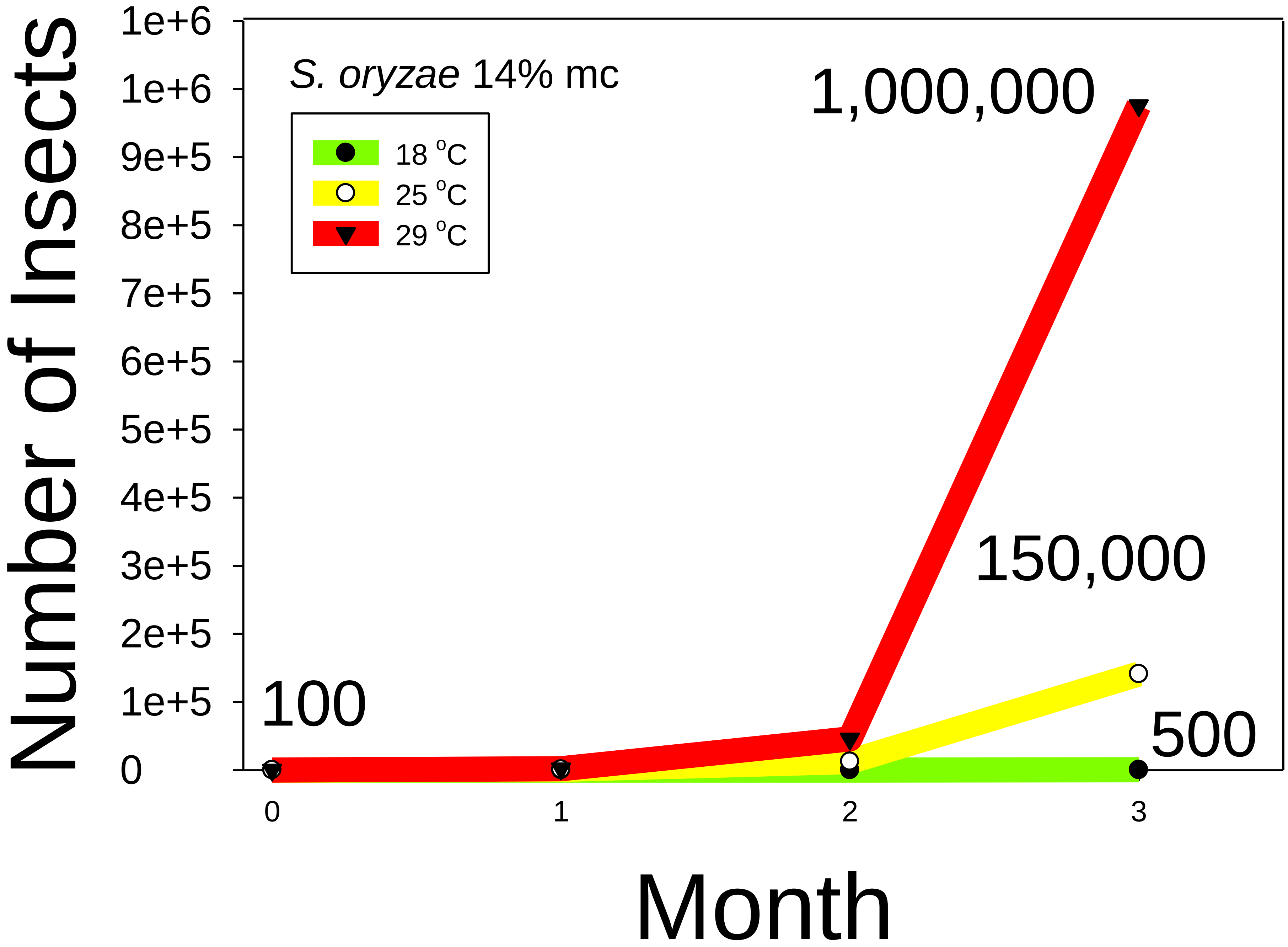
Exponential Growth of Insect Populations



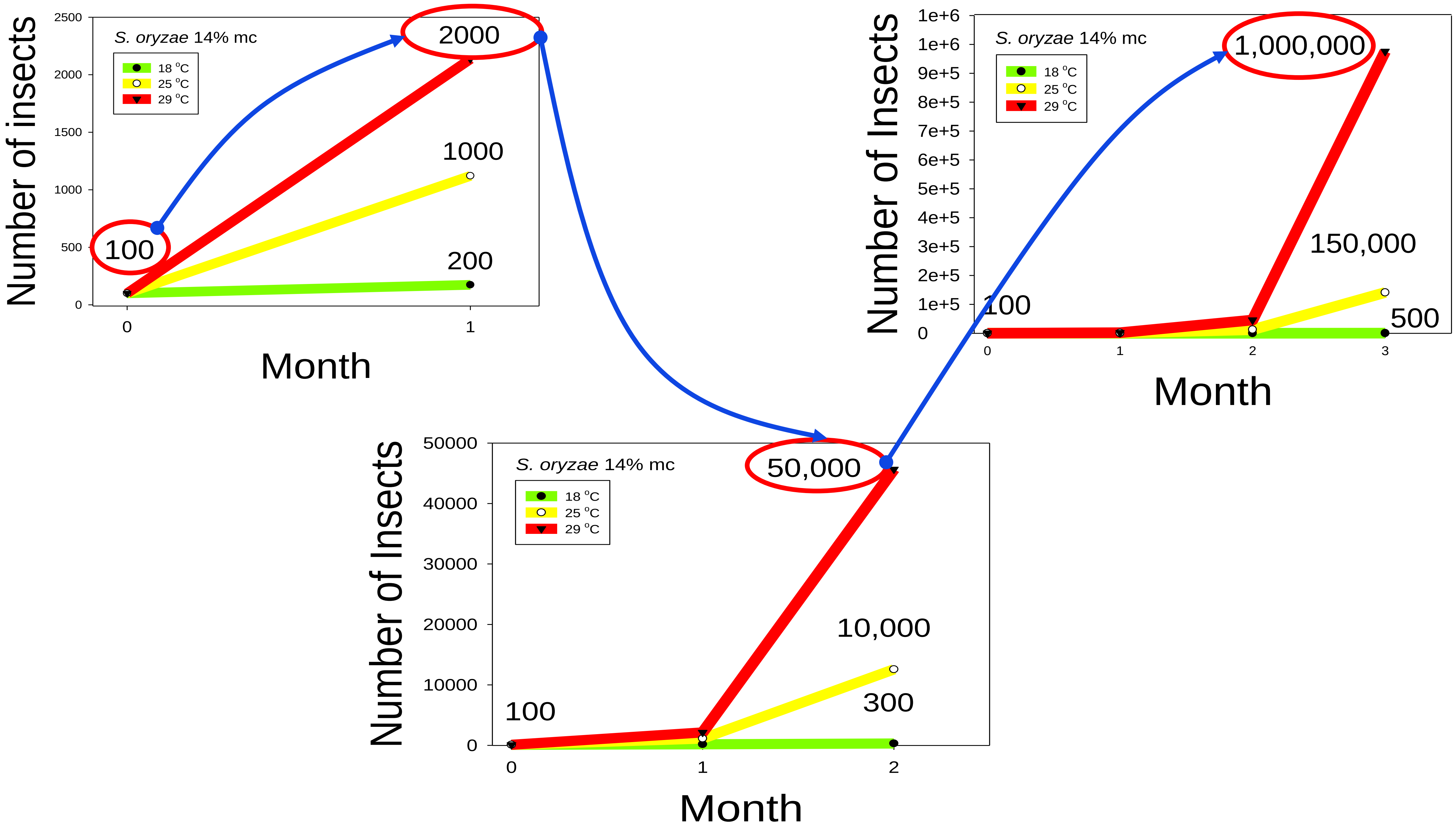
Number of insects
2500
2000
1500
1000
500
0
S. oryzae 14% mc
18 °C
25 °C
29 °C
2000
1000
100
200
0
1
Month



Number of Insects
50000
40000
30000
20000
10000
0
S. oryzae 14% mc
18 °C
25 °C
29 °C
50,000
10,000
300
100
0
1
2
Month



S. oryzae 14% mc
18 °C
25 °C
29 °C
1,000,000
150,000
100
500
Number of Insects
1e+6
1e+6
9e+5
8e+5
7e+5
6e+5
5e+5
4e+5
3e+5
2e+5
1e+5
0
0
1
2
3
Month


S. oryzae 14% mc
18 °C
25 °C
29 °C
Number of insects
Month
100
2000
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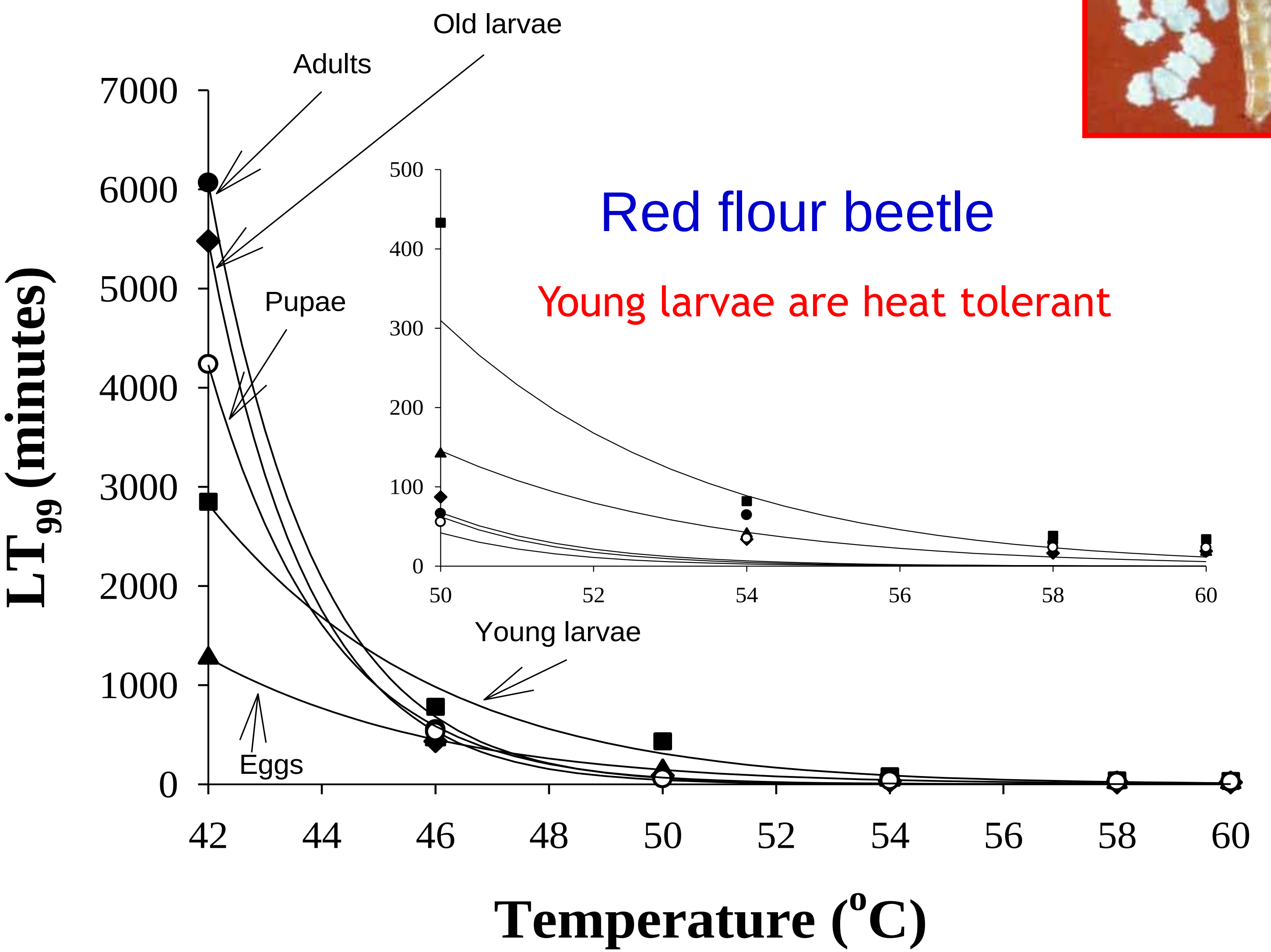
200
Number of Insects
50,000
10,000
300
1,000,000
150,000
500

Susceptibility Differences Among Life Stages and Insect Species

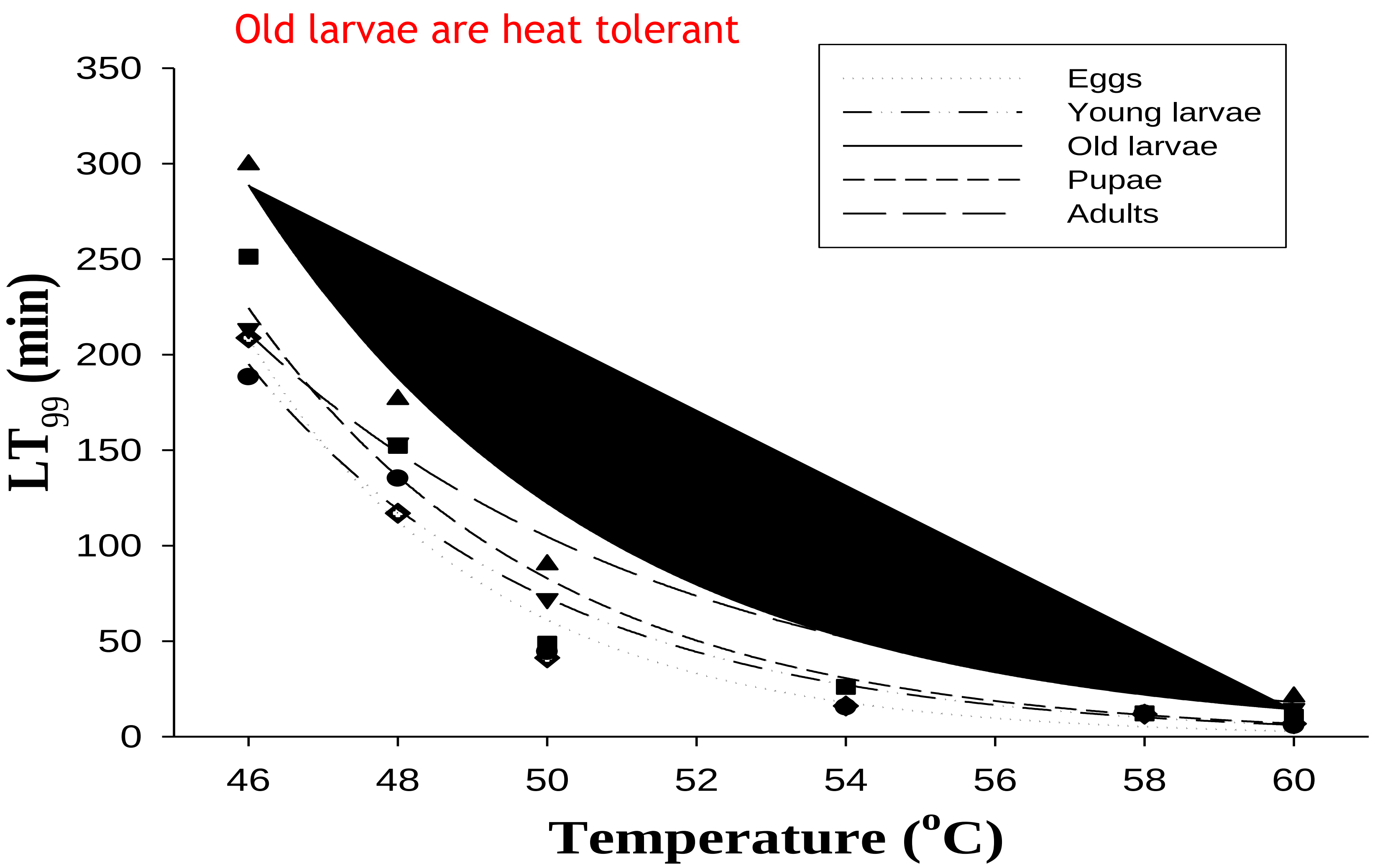


Red flour beetle

Young larvae are heat tolerant

Source: Dr. Subi, KSU, KS

Confused flour beetle



Source: Dr. Subi, KSU, KS

Comparison of Heat Tolerant Stages of Four Species (LT_{99} in minutes (95% CL))

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

Source: Dr. Subi, KSU, KS

Optimizing Heat Treatments

- Using the right amount of heat energy
- Eliminating cool spots (Temp. <50^{o}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

Insect stage	Sanitation level	Treatment	% Mean (SE) mortality[a]	*F*	*P*
Adults	2 cm	MB	100a	69.90	<0.0001
		SF	100a		
		Heat	90.1 (1.2)b		
	dusting	SF	100	1.00	0.4219
		MB	100		
		Heat	98.7 (1.3)		
Pupae	2 cm	MB	100	2.56	0.1568
		SF	100		
		Heat	95.4 (2.9)		
	dusting	MB	100	0.60	0.5787
		SF	98.7 (1.3)		
		Heat	97.3 (2.7)		
Large larvae	2 cm	MB	99.8 (0.1)a	8.62	0.0172
		SF	100 (0.0)a		
		Heat	96.1 (1.3)b		
	dusting	MB	99.9 (0.1)	1.73	0.2552
		SF	100		
		Heat	98.2 (1.3)		
Small larvae	2 cm	MB	100a	5.39	0.0457
		SF	100a		
		Heat	93.5 (2.8)b		
	dusting	MB	100	3.69	0.0901
		SF	100		
		Heat	99.4 (0.3)		
Eggs	2 cm	MB	99.9 (0.1)	1.02	0.4145
		SF	92.3 (7.3)		
		Heat	99.3 (0.3)		
	dusting	MB	99.9 (0.1)	1.25	0.3523
		SF	88.7 (10.0)		
		Heat	99.8 (0.1)		

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

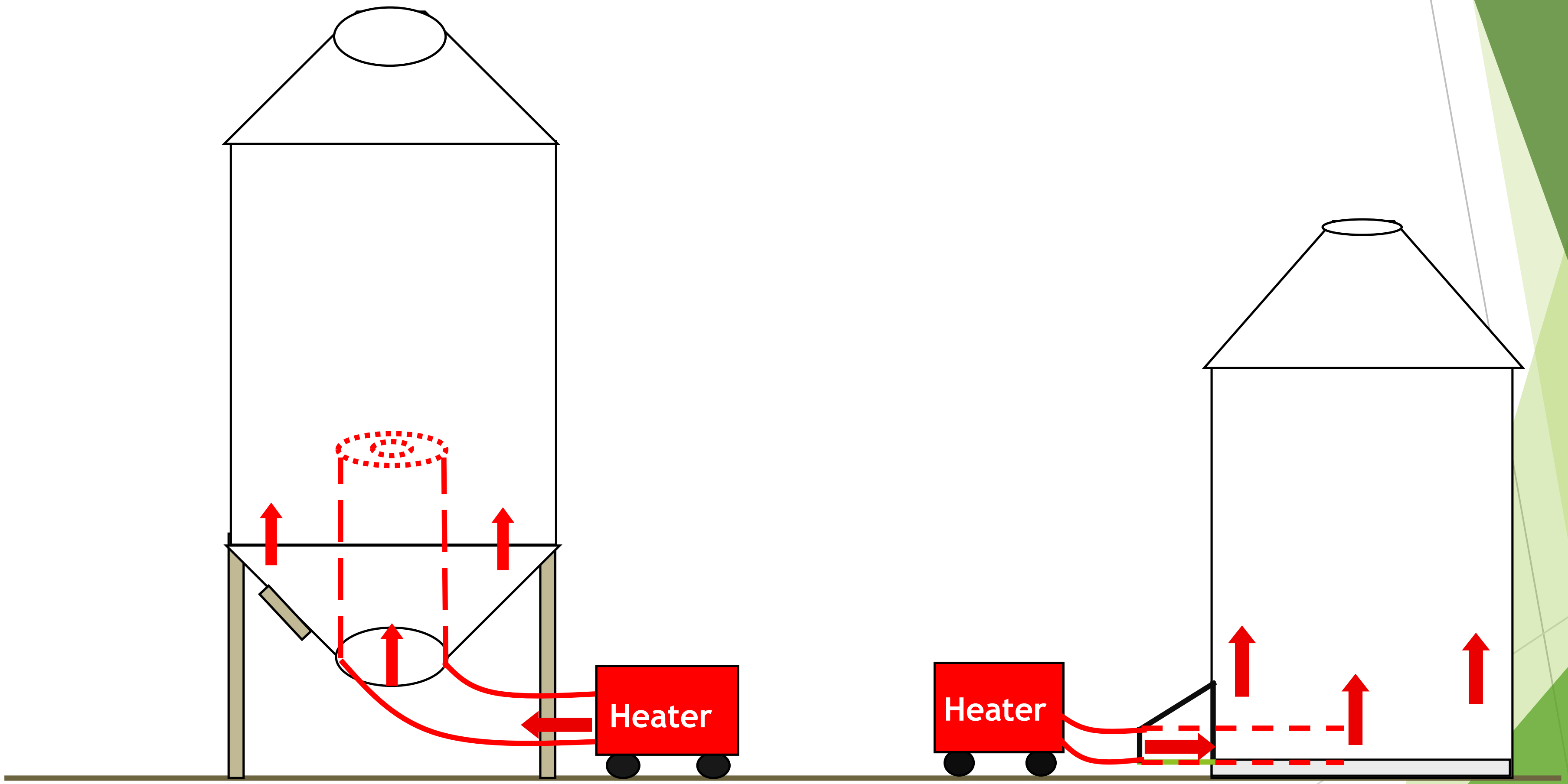
Empty Bin Sanitation

- 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
- 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

On Site Images

Heater Placement on multiple floors

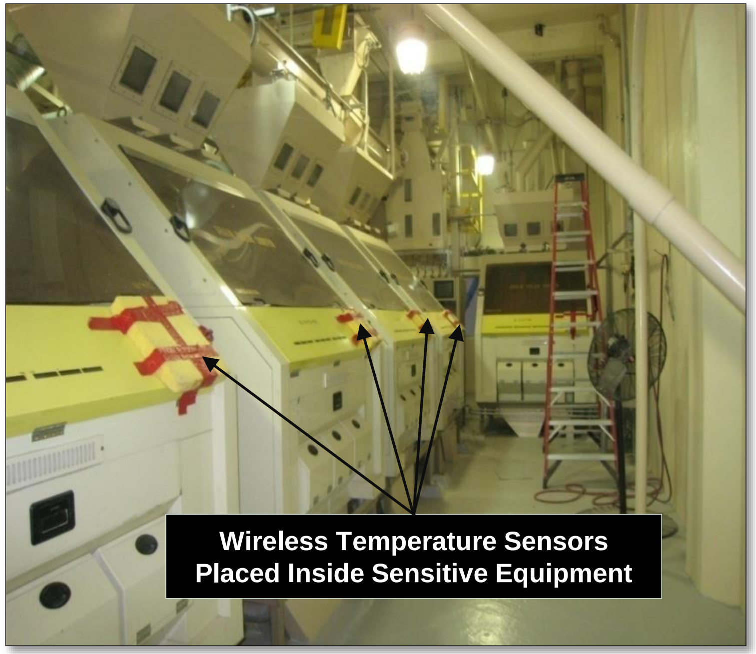
Heater Placement under rolling shutter

Heater Placement & Layout

Heater Partially inside Packaging Plant

Duct & Fan Layout - Packaging

Basement, Sensitive Equipment



Detecting hidden infestations

Overhead electrical junction box

10,000s of adults, larvae, pupae!!

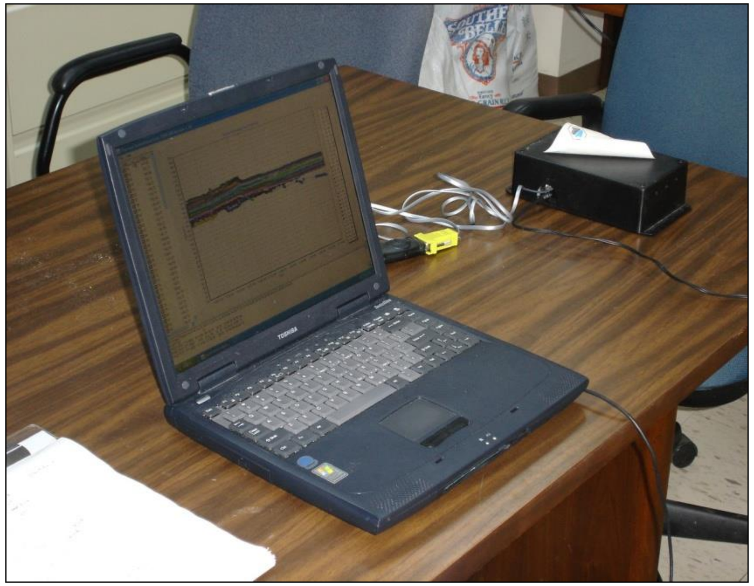
Partial/Spot heat treatment in a warehouse

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

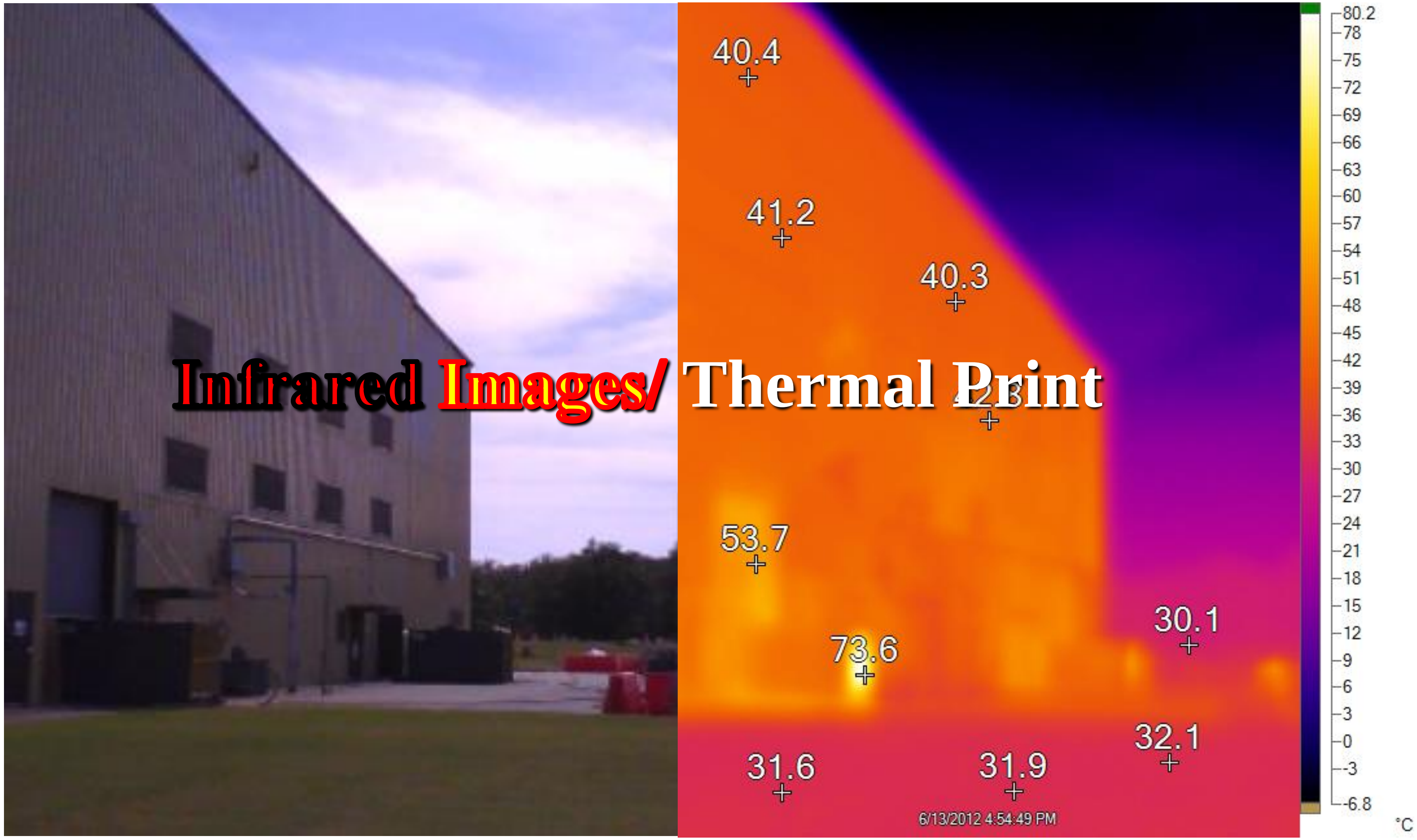
Philippines

Partial heat treatment, Canada

Pasta Mill, Monterrey, Mexico

Flour Mill, Philippines

Infrared Images/ Thermal Print

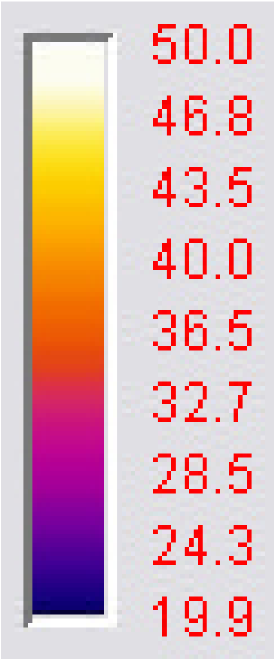


Heating in Mill

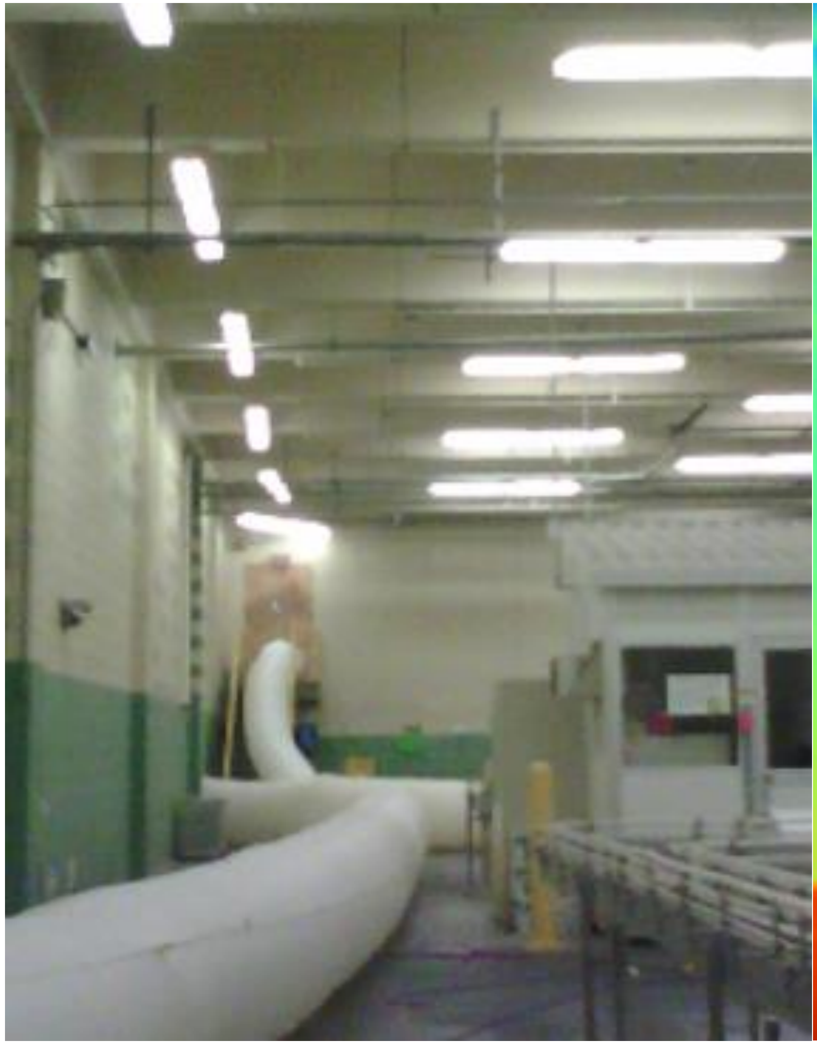
Time Lapse Thermal Image

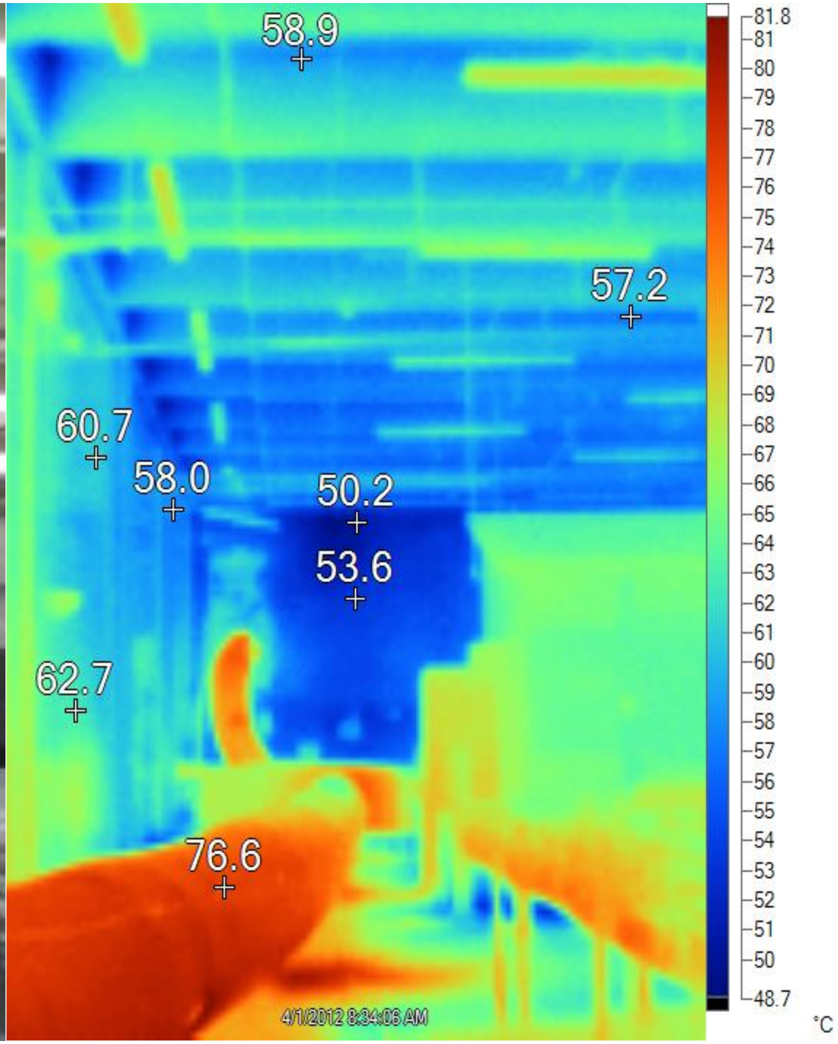
Time (h)

0
0
1
3
4.5

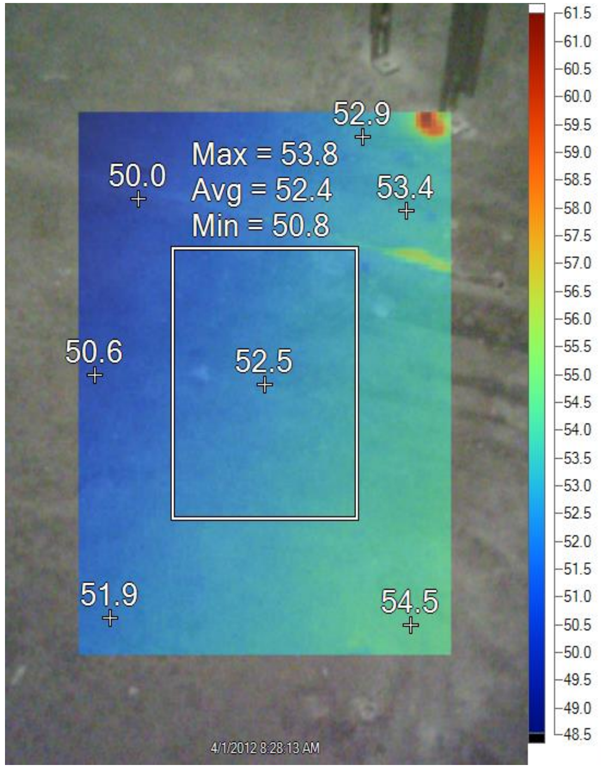


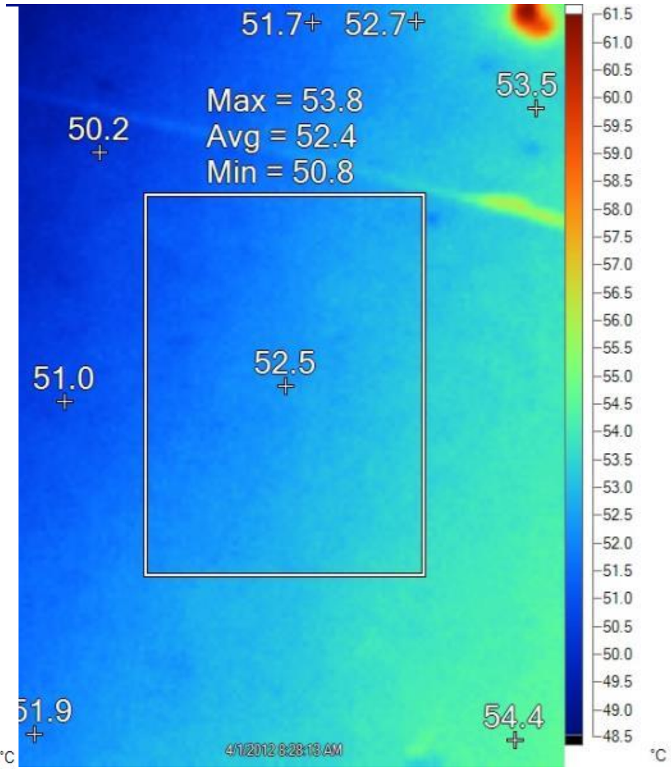
Packaging Hall



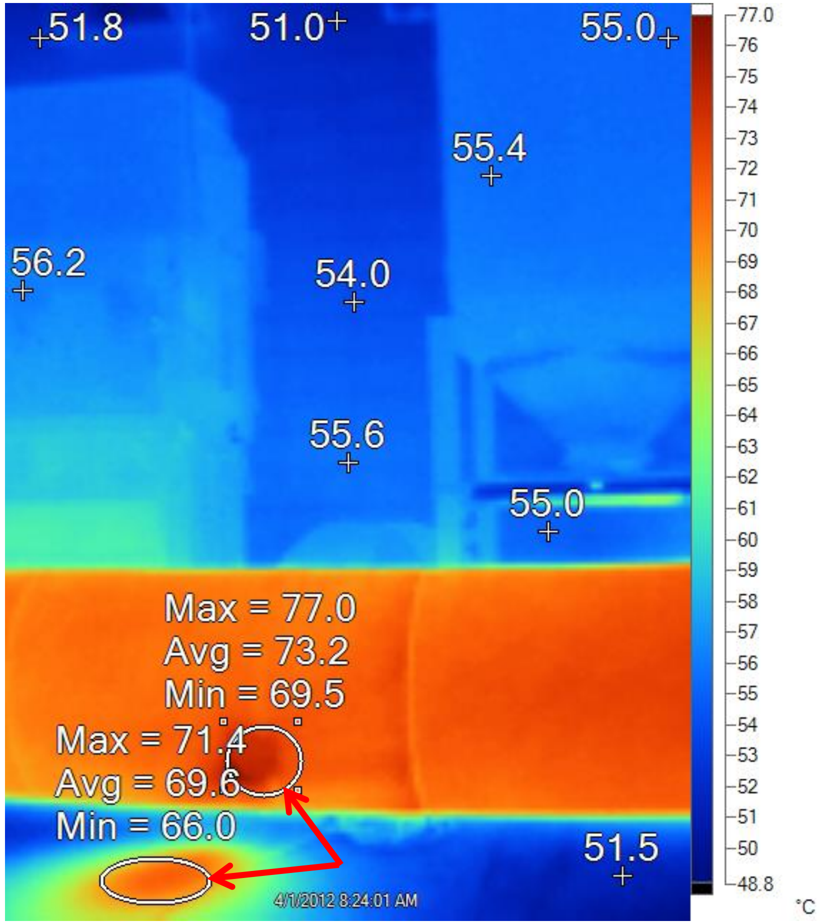


Concrete floor

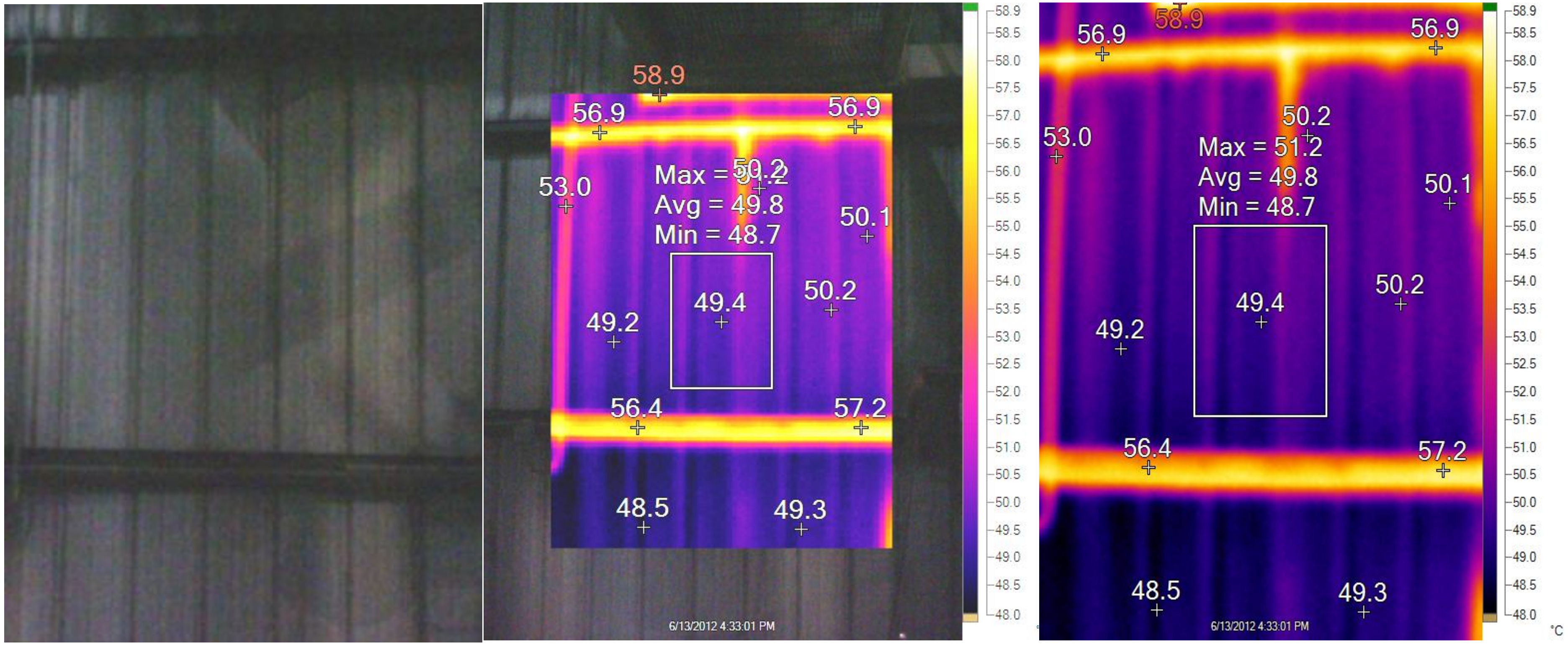




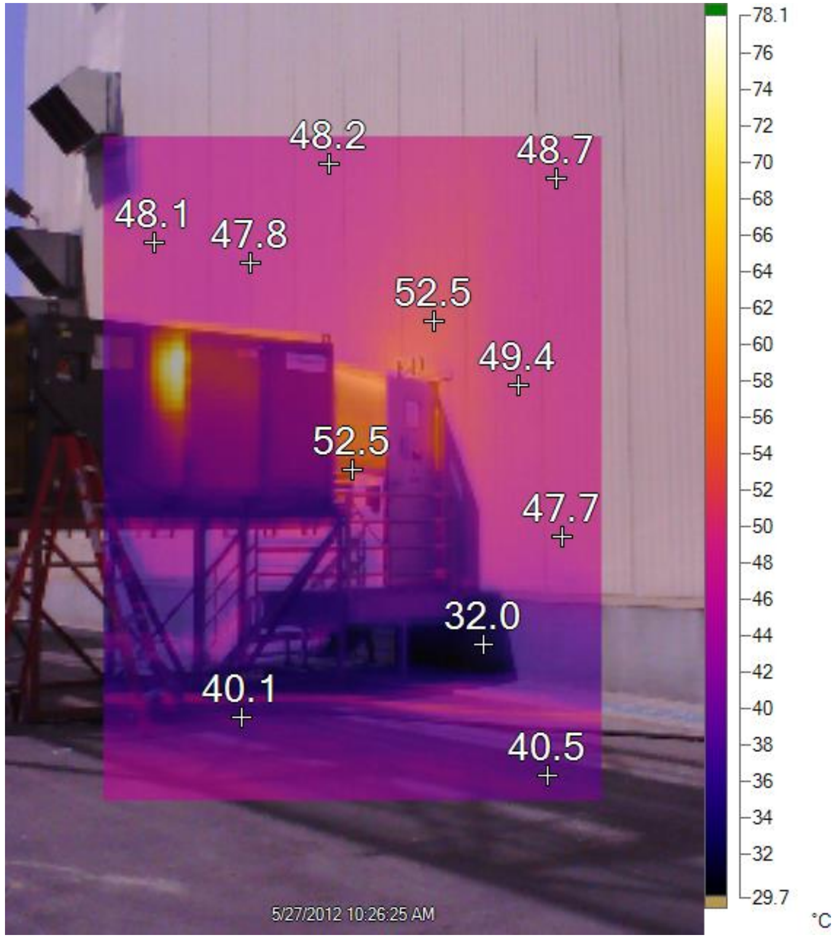
Concrete floor & wall



Metal clad insulated wall



Thermal Print from outside


48.2
48.7
48.1
47.8
52.5
49.4
52.5
47.7
32.0
40.1
40.5
5/27/2012 10:26:25 AM
78.1
76
74
72
70
68
66
64
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56
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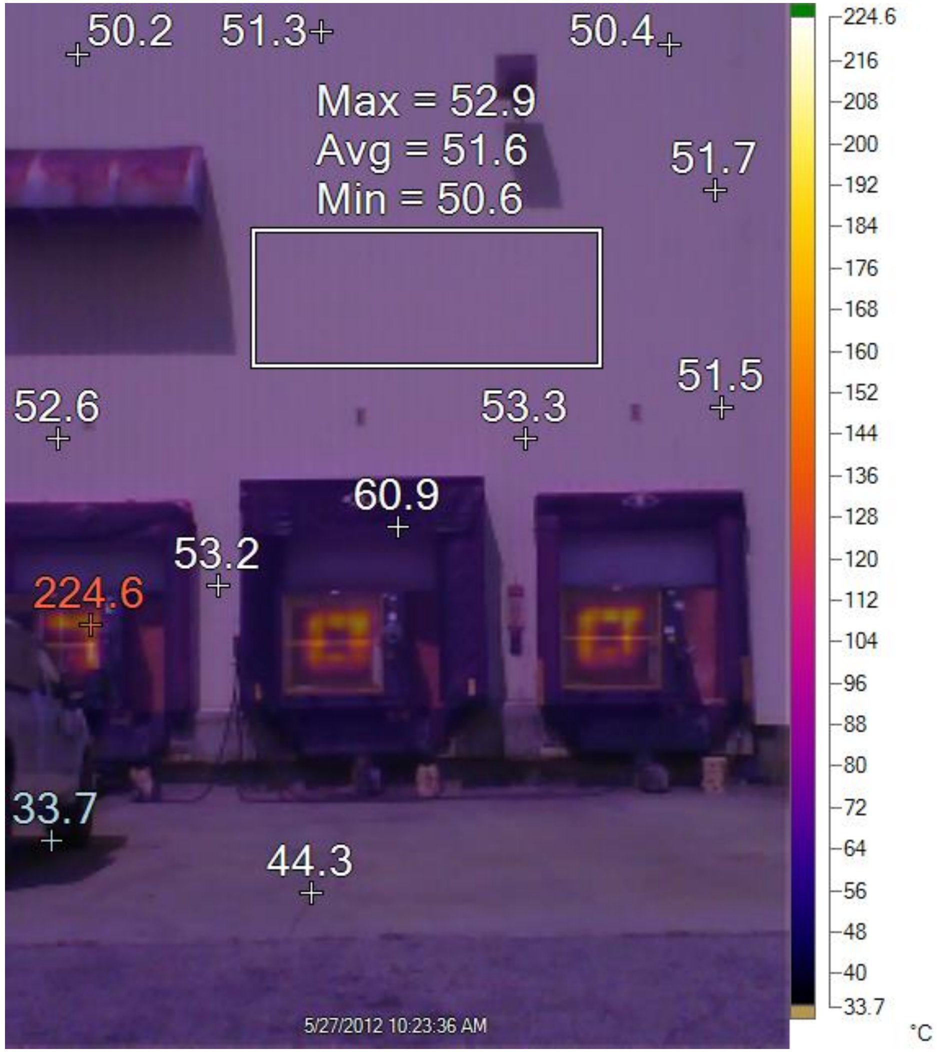
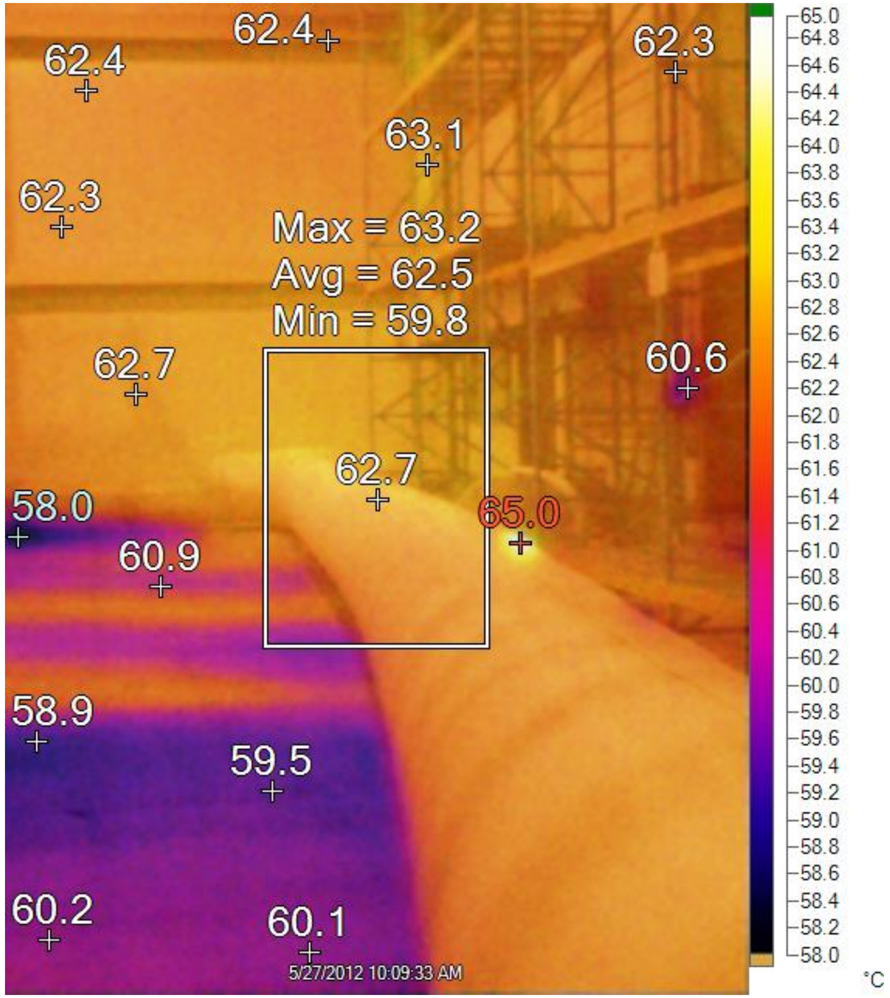
32
29.7
°C

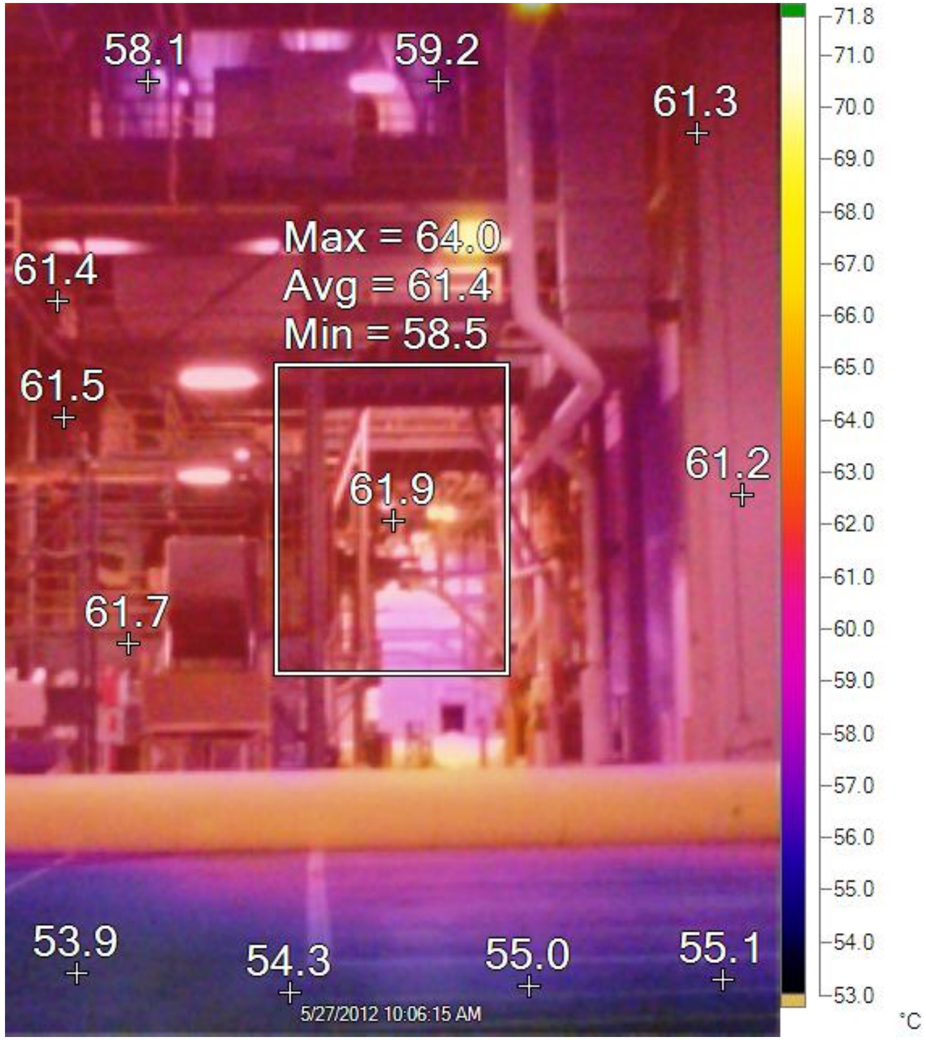

50.2
51.3
50.4
Max = 52.9
Avg = 51.6
Min = 50.6
51.7
51.5
52.6
53.3
60.9
53.2
224.6
33.7
44.3
5/27/2012 10:23:36 AM
224.6
216
208
200
192
184
176
168
160
152
144
136
128
120
112
104
96
88
80
72
64
56
48
40
33.7
°C

Thermal Print Inside & Height


57.5
57.4
57.5
57.5
63.4
57.8
57.7
57.6
57.6
56.8
57.4
57.3
56.7
52.3
52.8
5/27/2012 9:53:50 AM
67.8
67.0
66.5
66.0
65.5
65.0
64.5
64.0
63.5
63.0
62.5
62.0
61.5
61.0
60.5
60.0
59.5
59.0
58.5
58.0
57.5
57.0
56.5
56.0
55.5
55.0
54.5
54.0
53.5
53.0
52.5
52.0
51.5
51.0
50.2
°C


62.4
62.4
62.3
63.1
62.3
Max = 63.2
Avg = 62.5
Min = 59.8
62.7
60.6
62.7
58.0
65.0
60.9
58.9
59.5
60.2
60.1
5/27/2012 10:09:33 AM
65.0
64.8
64.6
64.4
64.2
64.0
63.8
63.6
63.4
63.2
63.0
62.8
62.6
62.4
62.2
62.0
61.8
61.6
61.4
61.2
61.0
60.8
60.6
60.4
60.2
60.0
59.8
59.6
59.4
59.2
59.0
58.8
58.6
58.4
58.2
58.0
°C

Temperature Profile from ground to a height of 80 feet (25 m)



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