HISTORY

Since early 2005, Massey Services and Chromalox have been investigating the utilization of heat remediation as a method of controlling bed bugs. Our studies and research of bed bugs indicate that heat impacts physiological processes and behaviors of the bed bug. The use of heat in controlling pests is not new. History indicates that heat treatments were used in the United States as early as 1911. Some records indicate that heat treatments were used to protect grain in France as far back as the 1700's. The Kansas State University Department of Grain Science has been conducting heat treatment research since the mid 1990's and has held three conferences specifically addressing the use of heat in controlling stored product pests.

Effects of Temperature on Insects

Zone	Temperature	Insect Response
Lethal	120°F to 140°F	Death in minutes
Lethal	110°F to 115°F	Death in hours
Sub-optimum	95°F to 100°F	Development stops
Optimum	75°F to 90°F	Maximum development
Sub-optimum	65°F to 70°F	Development slows
Sub-optimum	55°F to 60°F	Development stops
Lethal	35°F to 45°F	Death in weeks
Lethal	-5°F to 10°F	Most insects die
Lethal	-20°F to -10°F	Death in minutes, insects freeze

University researchers have documented that significant change in bed bug body temperature causes decay of cellular functions, changes endocrinal functions, and increases metabolism. The principal mode of action (cause of death) when using heat for insect control is desiccation. Heat also affects denaturing of protein and kills Wolbachia, a symbiont bacteria.

As the environment is heated, there is an increase in insect metabolism that includes the opening of spiracles associated with respiration. The heating process creates a drop in atmospheric relative humidity within the treatment area. As the relative humidity of the atmosphere within the room and wall voids decreases, the moisture within the insect's body is gradually lost through the open spiracles. The insect dehydrates as the dry air pulls moisture out of its body. A physical change also occurs with the introduction of heat into an insect's environment. This is the breaking down of the cuticle of the exoskeleton. This waxy layer contributes to the retention of water; its breakdown also aids in the dehydration of the insect.

Changes in insect behavior due to heat stress has been verified, as the normally cryptic bed bug has been observed moving from its hidden harborage by our technical staff during the heating process. During Massey Services' field tests of the heat remediation process, bed bugs were often observed moving out of harborage areas and climbing up walls and furniture after temperatures reached 105ºF. The surfaces the bed bugs moved to were consistently hotter than the areas

vacated by the pest. This suggests that they were not moving to cooler areas to escape the heat but rather were moving due to the overall stress of heat exposure. In related studies of bed bug behavior Dr. Michael Potter of the University of Kentucky observed, similar movement when steam was utilized against bed bugs in infested mattresses and furniture. Bed bugs thrive in environments with 75% to 80% relative humidity and temperatures of 83º F to 90º F. Temperatures just 10º F above this range do not kill healthy adults but do stress the insect, change their behaviors, and negatively impact their ability to reproduce. Temperatures above 105ºF produce death in a percentage of the population but many insects appearing near death recover when temperatures return to the normal state. Bed bug mortality rates increase by holding the elevated temperature longer at lower relative humidity.

According to Mallis Handbook of Pest Control the thermal death point for bed bug adults and nymphs is 111º F -113º F with an exposure time of 15 minutes. Eggs are killed when held at this temperature for 60 minutes. Our own field tests conducted in August 2005 produced similar results. Our research led us to set our target zone for ambient air temperature at 140°F to 145°F. This high limit also refers to surface temperatures of walls and furniture. Limiting surface temperatures to this level will allow us to safely raise temperatures in hidden harborage areas above the lethal range of 111º F -113º F while minimizing risk of physical damage to the structure, wall coverings and furniture.

Our Process

The Massey Services bed bug elimination process utilizes specially designed portable electric high temperature forced air heaters to heat the air space within the treated room. The TRMX heaters are unique and adaptable to function with the various power configurations typically encountered in residential and commercial structures. As air is heated and circulated throughout the treatment area, heat energy is absorbed by all objects and surfaces within the room, furnishings, walls, ceilings, and floors. The heat energy absorbed by these surfaces and objects is continuously recharged by the TRMX heaters until the ambient temperature reaches temperatures between 140ºF-145ºF. The voids of walls, ceilings, and floors within the treatment area must reach a minimum temperature of 120ºF. **The target temperature of 120ºF is maintained within the void spaces for a period of 4 hours**.

Ambient air, surface, and wall void temperatures are measured by thermocouple sensors and thermocouple probes placed strategically within the treatment areas. Temperatures are monitored and recorded over the duration of the treatment with a laptop. This laptop provides remote real time monitoring of conditions within the room without unnecessarily continuously exposing technicians to high temperatures and releasing heat when entering and exiting the room. Once lethal temperatures are recorded in all target areas and maintained thereafter continuously for 4 hours the heat equipment is turned off and the temperature slowly returns to normal. All data is stamped and archived for post treatment analysis.

The process requires that all furniture, headboards, mattresses, box springs, and other furnishings are moved away from the walls of the room and positioned so that the heated air can flow evenly around the item. Heat energy will move three dimensionally through room contents, into wall structures and voids. Heat is effective in killing all life stages of the bed bug.

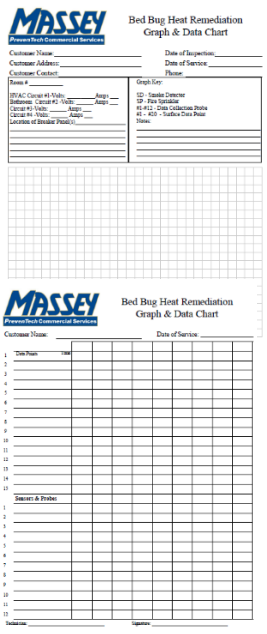
HEAT REMEDIATION PROCEDURES

Room Prep

Prepare the room by removing heat sensitive items. Arrange furniture, bedding, etc. by using stacking crates to elevate the bed frame, box springs and mattresses horizontally. Elevate dressers, nightstands, and other furniture 2 to 3 inches off the floor as well. These steps allow heated air to flow between the layers and under the furniture. Assure all furniture is moved away from walls leaving no items along walls. Place the heating unit and position heat deflectors and monitoring probes in a manner that will allow air to flow throughout all items.

While performing heat remediation services temperatures are to be monitored in at least the following 6 points:

1) Heater air intake – check the read out on the control panel of the unit.
2) Ambient air locations should be approximately 6 feet from floor.
3) Mattress.
4) Two different furniture items.
5) wall void locations within the wall supporting headboard
    a. high
    b. low



The computer program records the progress of the heat application. This monitoring is supplemented by scheduled entry into the treated area to make observations and record surface temperatures with a handheld infrared thermometer. Typically, numbers are written on 20-25 adhesive dots or painter's tape. These numbered dots are placed on wall surfaces, furniture and bedding identifying sites that will be monitored through the course of the service. Locations may include multiple wall surface locations, mattress and box springs, furniture surfaces, and curtains. These recordings are to take place each hour until the target temperature is achieved then every two hours thereafter. Painted and laminated surfaces should not experience increases in temperature of more than 15°F per hour. Document the service by noting the locations of the dots on a graph of the room being serviced. Record the temperatures on a thermal remediation log sheet.

Place picture frames flat on the floor. You should direct heat away from potentially sensitive items that cannot be removed from the room with

welder's blankets or reflective insulation. Three to five mil plastic sheets can be used effectively to insulate sensitive areas or section a large room into smaller spaces.

Ideally, room heaters or air conditioners is to be set to 85°F for a period of 12-24 hours prior to beginning the heat remediation service. Setting the thermostat to 85°F allows the temperature of all items and surfaces to rise and will reduce the time to attain lethal temperatures when conducting the heat remediation service. Starting at higher temperatures decreases the potential for damage to wall coverings and room contents. Do not allow room temperatures to exceed 88-90°F prior to beginning the heat application. Doing so may stress the population at sublethal temperatures and result in bed bugs relocating prior to the beginning the heat remediation service.

Following the initial inspection and room preparation a heat treatment of a bed bug infestation begins with the following steps:

1. Physical removal of bed bug nymphs, adults, cast skins, and eggs with a HEPA-filtered vacuum. Bed bug eggs are deposited with cement like material, so it is important to vigorously brush the surfaces of the item being vacuumed. The cracks and crevices around the seams of mattresses, bed frames, baseboards are extremely important focal points. Surfaces and grooves should be brushed toward the vacuums inward airflow to prevent distribution of bed bugs and eggs to other areas.

2. Apply Cimexa dust formulations under and behind all baseboards, doorframes, electrical outlets, and within the hollow voids of all bed frameworks. Assure an even placement of the material into wall voids and along carpet baseboard crevices. The best practice for treating along room edges with carpet is to pull it back from the wall, dust under the tack strips, and resecure it.

3. No liquid residual treatment on the day of heat treatment. Aprehend treatment will be done the next day.

4. Do not apply any residual pesticide materials to the surfaces of the mattress or box springs where people or pets could contact the treated area. All surfaces, folds, and tufts are to be thoroughly brushed and vacuumed to remove insects, cast skins and eggs. Treatments of non-residual contact insecticides labeled for mattress use may be applied after vacuuming (Sterifab).

5. Bite proof and escape proof mattresses should be provided (as a separate charge or if included in the quoted price) to prevent surviving insects and bed bugs that hatch from viable eggs following the service from gaining access to a host and moving to other parts of the room. Encasements are both escape proof and insect bite proof. The use of encasements will also prevent bed bugs introduced into the room in the future from directly infesting the mattress.

6. Make sure all items that will be removed from the room are bagged and sealed before they leave the room to prevent a second infestation in another part of the building. If the items are to be thrown away, be sure they are clearly marked and defaced/damaged to prevent/discourage someone from taking the infested items to their home.

7. Adjoining rooms in homes, guest rooms in hotels and rooms of adjoining apartments are to be inspected and serviced to prevent bed bugs from moving through wall voids and into these areas. The minimum level of service should include a thorough inspection, application of Cimexa into wall voids shared with rooms with confirmed bed bug activity and crack & crevice applications to headboards, bed frames and box springs with material listed on the interior material rotation chart. Record completion of this step in the Heat Service Checklist and Customer Service Report.

ITEMS TO COMMUNICATE TO THE CUSTOMER

1. All bed linens, spreads, covers, pillows, etc. **must be sealed in plastic bags prior to removal from the room.** All items should be placed in a dryer and heated at high temperatures (120°F to 140°F) for a minimum of 40 minutes prior to regular laundering. Launder in hot, soapy water and dry. Dry cleaning may be appropriate for some items.
2. In hotels, if a guest and their belongings are to be relocated to another room, inspect, and provide a complete material service of the second room using Cimexa Dust and with residual material on the interior material rotation program prior to beginning service of the infested room.
3. If there is evidence of infested clothing or belongings, these items can be heated in a dryer for a minimum of 40 minutes. All hard goods (suitcases, bags, carts) must be inspected, brushed, and vacuumed prior to being removed from the room. Treatments using labeled, non-residual contact insecticides may be applied after vacuuming (Steri-Fab).

4. The room(s) must remain vacant until all remedial services are completed and the room has been cleaned, reassembled and the “day after” follow up inspection and service has been completed.

5. If the customer chooses to discard the infested furniture, **moving the furniture must occur AFTER treating the infested items and area(s).** Items to be thrown away must be clearly marked and defaced/damaged to prevent/discourage someone from taking the infested items to their home. Inspect and treat replacement furniture in the storage area prior to placement into the affected guest room.

At the time of sale and prior to performing heat remediation treatment, the TRMX Heat Preparation Checklist must be reviewed with the customer. Some items in the space to be heated may be sensitive to elevated temperatures. The most significant include:

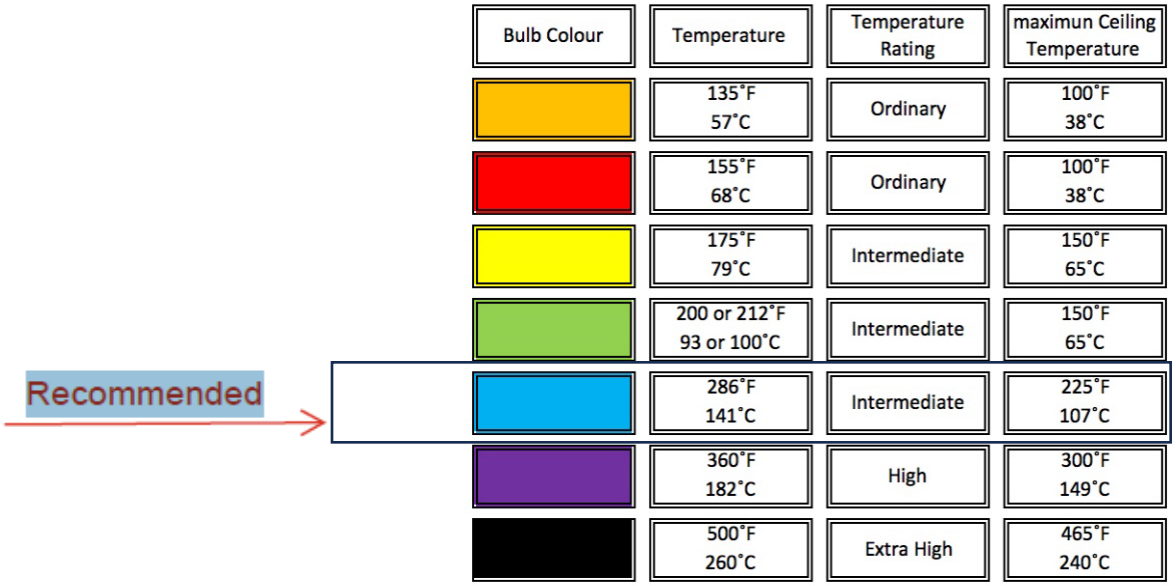
- sprinkler heads, fire protection system
- smoke detection devices
- electronic devices (unplugged all electronics)
  - computers
  - television
  - radio
- Refrigerators (plugged in and powered)
- Composite doors
- Uncured paint (latex < 6 months old)
- Cosmetics
- Antiques
- Musical Instruments
- Any vinyl plastic
- Anything made of soft plastic
- Horizontal plastic blinds

It is recommended to remove the following from the treatment area after inspection:

- Medications (remove or place it in refrigerator)
- Wax items such as candles/crayons
- Live plants
- Hot-glued items such as picture frames
- Firearms and ammo
- Oil paintings
- Musical instruments that cannot be removed must be inspected and then wrapped in welder's blanket or reflective insulation.

FIRE SUPPRESSION/SPRINKLER SYSTEM

Fire suppression systems are very complicated. Operation and maintenance is regulated by state laws and regulations. Federal and state statues cover fire prevention and control. The sprinkler heads in most consumer sprinkler/deluge systems are classified as "**ordinary**". Metal link and glass bulb fused sprinklers that are rated to activate at temperatures ranging from 125°F to 150°F cannot be exposed to temperatures exceeding 100°F. The fusing mechanism begins to breakdown well before the intended release temperature. A sprinkler head that has been exposed to temperatures more than 100°F is less sound than one that has not. It is required that local fire codes are followed. **At minimum this may require the customer to arrange to have the system drained and the existing sprinkler heads in the treatment area removed and replaced with intermediate class (175-225°F) sprinklers. The entire system must be active during the heat treatment**. Note: Fire codes and manufacturer specifications prohibit exposing **Intermediate** class sprinkler heads to temperatures exceeding 150°F. **High Temperature** sprinkler heads are prohibited from being exposed to temperature of 225°F or higher. The Bed Bug Service Agreement includes a clause related to fire sprinkler responsibilities and must be reviewed with the customer prior to scheduling a heat remediation service.



Bulb Colour	Temperature	Temperature Rating	maximun Ceiling Temperature
	135˚F 57˚C	Ordinary	100˚F 38˚C
	155˚F 68˚C	Ordinary	100˚F 38˚C
	175˚F 79˚C	Intermediate	150˚F 65˚C
	200 or 212˚F 93 or 100˚C	Intermediate	150˚F 65˚C
	286˚F 141˚C	Intermediate	225˚F 107˚C
	360˚F 182˚C	High	300˚F 149˚C
	500˚F 260˚C	Extra High	465˚F 240˚C

HEAT REMEDIATION PROTOCOL

- Inspect the rooms to be heated using the Heat Remediation Prep Checklist.
  - Ensure all steps are followed on the Heat Remediation Prep Checklist
  - Check for sprinkler heads. If present, ensure they have been changed to at least and intermediate head. System MUST be in operation, NOT capped.
  - Ensure all items that are heat sensitive are removed or are not in the heated air flow.
  - If customer missed an item during their prep, remove it for them.
- Vacuum items to remove live bed bugs, eggs, and cast skins
- Prep the room arranging furniture so there is airflow around and under each piece of furniture. NOTE: Furniture and cabinets made of laminated components must be heated slowly over several hours to prevent the laminated surfaces from expanding faster than the core material and breaking the adhesive bonds. **DO NOT PLACE THESE ITEMS IN FRONT OF HEATER AIR FLOW. **
- Place heater(s) in room.
  - Object to heat is to get the headboard wall void to 120ºF+ degrees while getting the rest of the room and all items to 120ºF+ degrees. You will need to adjust the heaters to get the proper air flow throughout the room.
- Plug in heaters.
  - Typically, you can only plug 1 plug into 1 circuit. Plugging 2 plugs into 1 circuit will cause the breaker to blow. So, plug 1 plug into each room. If you run out of outlets, check the breaker box to see what rooms have multiple circuits. You may also have to move plugs to other outlets to in order find other circuits. Plug the 240V plug into

the Dryer or Oven/Stove outlets. If the Oven/Stove outlet is 50amps, you can plug our breaker box into the outlet and then plug 2 of the 240v plug into the box. In hotels, connect the motor control plugs to the bathroom GFSI.

- Turn on laptop.
    - Connect the receiver to the USB port on the laptop. Open the app (MESH NET or AGI) on the desktop. Turn on air sensors and probes to ensure they are connected.
- Place air sensors and probes in room(s) being heated.
    - Using the Heat Remediation Graph and Data Chart to list and show where each air sensor and probe are located.
- 20 – 25 Data Points
    - Using the Heat Remediation Graph and Data Chart to list and show 20 - 25 data monitoring spots throughout the room.
- Turn the FAN toggle switch on.
- Turn the toggle switch on for heat. NOTE: the heaters will not heat without the fan being on. This is a safety feature.
- During the first hour, pay attention to the laptop chart. Look for drips in the line graph. This indicates a drop in temperature, which usually means that a breaker could have blown. Adjust plugs and heater positions until everything is running smoothly.
- Every hour record temperatures onto the Heat Remediation Graph and Data Chart for all air sensors and probe through the entire heat process.
- Every hour record temperatures using an infrared temperature gun of the 20 – 25 Data Points. Once temperature has reached 120ºF, record temperatures every 2 hours till the heat process is completed.
- Once temperatures of 120ºF have been reached, you're on the clock. Hold at 120ºF or higher for at least 4 hours. If the room(s) you're heating have high activity, it would be in your best interest to hold the temperature longer than 4 hours just to be safe. It's easier to hold the temperature longer vs having to reheat.
- During the heat application conduct the inspections and required services for surrounding rooms. In a hospitality/healthcare situation this will include the 8 rooms above, below, and adjacent to the affected room. In a multiunit housing scenario this includes the apartments above, below, and adjacent to the affected apartment. These areas may be treated with applications of residual materials to cracks crevices and voids where bed bugs may move from one location to another.
- Once you have reached the end of the holding time, turn the heat switch off on the heater. Let the fan continue to run so it cools the heating coils.
- Unplug all unneeded extension cord and cables and roll then up. DO NOT unplug the fan plug, this is the last thing you do.
- Retrieve all air sensors and probes and place in carrying case.
- Place the computer and receiver in carrying case.
- Remove stacking crates from room.
- Turn fan switch off on the heater and remove it from room.

- Instruct customers not to turn A/C on to the heated rooms, the temperature needs to come down naturally. The heated room cannot be used till the next day after being cleared.
- Day after follow up inspection and service.
    - Inspect the entire room for bed bug activity.
    - Vacuum any found bed bugs
    - Apply Aprehend in a two-inch band around the areas with bed bug activity. These areas can include but are not limited to box spring, end tables, headboards, nightstands, picture frames, chairs and other areas with bed bug activity. Do not apply to furniture, upholstery or mattresses where prolonged contact with humans will occur.
        - Apprehend to interior voids and cracks/crevices and outer surface areas of the box springs, not the mattresses. Focus on seams, fabric folds and structural elements that could be bed bug harborage sites
    - After treatment has dried, the room can be released to be used.
- One week follow up inspection and service.
    - Inspect entire room
    - Vacuum any bed bugs found
    - Apply Aprehend as needed to areas of activity found that were not previously treated.

All inspection/services are to be documented on a Customer Service Report and reviewed with the customer.