Bed Bugs, Heat and Hotel Rooms

Limitations of current bed bug insecticides have fueled interest in non-chemical options, such as heat, to control infestations. Researchers from the University of Kentucky and PCOs from Massey Services put structural heating to the test in this first reported demonstration in hotel rooms.

By Michael F. Potter, Alvaro Romero, Kenneth F. Haynes and Tom Jarzynka

No pest has shown greater resilience to extermination than the bed bug. For hundreds of years, infestations were doused, gassed and sprayed with all manner of insecticides. DDT and other chemicals (e.g., malathion, diazinon) provided relief, but the bugs have since returned with a vengeance. To complicate matters, today's insecticides aren't performing as well as their predecessors, and companies are becoming apprehensive about the amount of pesticide being applied to beds, couches and other indoor surfaces. Consequently, more firms are looking to non-chemical approaches — like structural heating — to battle infestations.

Sections of PVC pipe were used to study bed bug movement between heated and unheated rooms (left). As temperature increased, the bugs became active in their harborage (middle). Bed bugs eventually crawled out of the cooler end of the pipe on the unheated side of the wall (right).

HISTORY OF HEATING. Heat has been used to battle bed bugs for centuries. Boiling water was used to scald bugs residing in bedding, bed slats, springs and other locations since the Middle Ages. Recently some residents have attempted to roast the bugs with cigarette lighters, a more modern take on the former method of using candles and plumbers' torches. In the 1920s and '30s, a larger version of today's portable steamer was used, as were heat-generating lamps plugged into electric outlets *(see "The History of Bed Bug Management," PCT magazine, August 2008)*.

A more comprehensive way of using heat to control bed bugs was adapted from methods developed long ago to de-infest granaries and flour mills. In the early 1900s, investigators showed it was possible to destroy bed bugs in buildings ranging in size from a two-story house to a 350-room dormitory on a college campus. Steam boilers and furnaces were used to elevate the temperature in bed bug-infested rooms to between 110°F and 130°F over a period ranging from several hours to a few days—a process known as "superheating." In the first (1945) edition of the "Handbook of Pest Control," Arnold Mallis also mentioned using superheating to successfully de-bug an animal rearing laboratory. He reported that after eight hours of heating, "the mortality was so terrific, that a carpet of bedbugs covered the floor, and a slight draft through the room piled up windrows of the bugs against several objects on the floor."

Efforts to control bed bugs with heat diminished in the 1940s, due to the ease, economy and effectiveness of DDT. Interest was rekindled in the late-1980s when Drs. Walter Ebeling and Charles Forbes demonstrated the utility of structural heating against drywood termites, wood-boring beetles and cockroaches. Evaluations against bed bugs were not needed at that time, but are of growing interest today, which prompted this study.

THE EXPERIMENT. In November 2007, the University of Kentucky collaborated with Massey Services (Orlando, Fla.) to test the concept of using heat to control bed bugs in hotel rooms. The demonstration was conducted at a large hotel complex in Orlando and involved two side-by-side rooms at ground-level. The common wall between the rooms had a connecting door which made it convenient for monitoring the progression of heating in one room and then the other. Each hotel room had a dimension of 12 by 24 feet, and was constructed of hollow block with sheetrock affixed directly to the block. Ceilings and floors were also concrete with no obvious cracks or openings other than for utilities.

ROOM SET-UP. Prior to heating, air conditioning was turned off to help elevate initial temperature. Fire suppression equipment (sprinkler heads and smoke detectors) did not require deactivation in these particular rooms, but should always be checked by the on-site engineering staff and, if necessary, dismantled or replaced with high-temperature versions before initiation of heating. Electronics such as televisions, phones, clock radios and in-room refrigerators were unplugged but left in place during the heating process. Other heat-sensitive items that often need to be removed or protected (but were not present during our experiment) include computers, oil paintings, musical instruments, medications, vinyl plastics and wax items such as candles.

To facilitate the flow of heated air to all surfaces, in Room 1 furniture was pulled away from walls, headboards were detached, and the perimeter strip of carpet serving as a baseboard was removed. Bedding was stripped and mattresses, box springs and bed frames were placed on edge in the center of the room with enough separation to allow airflow on all sides. Drawers were removed from nightstands and dressers. For experimental purposes, almost no preparation was done in Room 2 except the unplugging of electronic equipment. No effort was made to move items away from walls, dismantle beds, etc., in order to observe what effect such lack of preparation had on the outcome *(see Figure 1 on page 118)*.

HEATING PROCEDURE. Various forms of equipment are available for use in heat treat-

Surface temperature readings were taken periodically using digital infrared thermometers.

ments. Propane-powered heaters generate large volumes of heated air blown in through flexible ducts from outside the building. While propane heaters are efficient, they are not always able to force hot air to the upper levels of multi-story buildings. Heating with propane also can be obtrusive, limiting use in hotel settings. Furthermore, propane is prohibited in some municipalities due to risk of fire and explosion. This study utilized Massey Services' heat remediation procedure, which operates on custom-built electric forced air heaters manufactured by Chromalox (Pittsburgh, Pa). Two portable heaters stacked one on top of the other were used to treat each hotel room. While the electric heaters can run on the building power, this experiment used a 20 kilowatt generator instead.

Operation of heaters in Room 1 commenced at 9:30 a.m. and concluded at 4:30 p.m. for a total of seven hours. Room 2 received a shorter period of heating from 5:00 p.m. until 9:15 p.m., totaling 4.25 hours. The abbreviated duration of heating in the second hotel room deviated from the company's usual treatment protocol, but provided findings that were nonetheless useful.

MONITORING TEMPERATURE. When performing a heat treatment, ongoing monitoring of air and surface temperatures is essential. If conditions become too hot too quickly, items can be damaged — on the other hand, the infestation will persist if the treatment does not achieve lethal temperatures wherever bed bugs are hiding. To monitor the progression of heating, temperature probes (sensors) were placed in several locations (24 in Room 1; 12 in Room 2) and connected via wires to digital data recorders. Selection of sensor placement was based on sites where bed bugs are likely to frequent, including mattresses, box springs, bedding, drapes and furniture. We also drilled and inserted temperature probes into wall cavities such as where headboards were mounted, and the hard-to-heat wall void area at floor level. Additional sensors were placed in a suitcase filled with clothing, and inside an insulated test wall installed in the doorway entering the bathroom. Other sensors were placed out in the open to continuously monitor ambient air temperature in the room. Surface temperature readings were also taken at various times in each room (32 separate locations in Room 1; 13 in Room 2) with a digital infrared thermometer.

Temperatures were recorded throughout the experiment. Based on Massey Services' corporate heating protocol, the target (desired) temperature for ambient air in the room was 130 °F to 140 °F and 113 °F for voids and surfaces — the approximate thermal death point for bed bugs — maintained for at least three hours. The progression of heating was monitored to prevent surface temperatures from rising faster than 15 °F per hour, since some items (such as wood laminates) run a greater risk of damage if heated too quickly.

ASSESSING EFFECTIVENESS. Logistical constraints prevented us from treating established infestations of bed bugs in this hotel. Instead we used bed bugs and eggs from field-collected colonies maintained at the University of Kentucky. Four bed bugs (adults and older nymphs) were placed in 2- by 2-inch paper envelopes, which were then placed in 32 different locations in Room 1 and 13 locations in Room 2. Examples of where the bugs were placed included: on or within mattresses, box springs, blankets and pillows; behind headboards, pictures, wall outlets and carpeting; and inside nightstands, dressers, fire alarms and a suitcase filled with clothing. Four locations also were provisioned with small Petri dishes containing about 100 eggs each that were laid on cardboard during the previous four days. Bed bugs and eggs not subjected to heating served as untreated controls.

Once the envelopes and dishes were installed, heating was initiated. While the majority of test insects were subjected to the entire heating period, some were removed after a few hours and observed for mortality or subsequent lethal effects. Adults and nymphs

SUPPLIERS OF HEATING EQUIPMENT

Various manufacturers of heating and monitoring equipment are available to pest management firms interested in the technology. Three of the leaders include:

- **Chromalox**, Pittsburgh, Pa., 800/443-2640, www.chromalox.com
- **Temp-Air**, Burnsville, Minn., 888/838-4035, www.thermal-remediation.com
- **ThermaPure**, Ventura, Calif., 800/375-7786, www.thermapure.com

HOT ENOUGH FOR YA?

	Temperature (° F)		
Location	2 hrs	4 hrs	6.5 hrs
Bathroom wall surface	119	123	134
Bathroom wall void	105	117	130
Headboard wall surface	113	113	126
Headboard wall void	98	112	121
Box spring surface	119	124	135
Mattress surface	125	131	145
Mattress interior	99	126	138
Suitcase exterior	108	114	129
Suitcase interior	112	117	126
Pillow surface	120	129	131
Pillow interior	99	107	115

Table 1. Temperature recorded in various areas of Room 1 at progressive times after initiation of heating.

subjected to the abbreviated period of heating were monitored for five additional days and egg hatch for three weeks.

Another important question with respect to heating is whether bed bugs are likely to move to a cooler location as temperature increases — such as to an adjoining room or apartment. To begin studying this question, a portable wall was built to fit the door opening connecting the two hotel rooms. Holes were cut and foot-long sections of PVC pipe were inserted through the false wall, extending into both the heated and unheated room. The pipe ends extending into the heated room were capped whereas those on the unheated room side were left open. Folded paper tents (serving as harborages) provisioned a few days earlier with six adult bed bugs were placed at the ends of the tubes extending into the room to be heated. As heating progressed, activity and movement of bed bugs inside the tube was observed from the unheated side of the wall.

TREATMENT OUTCOME. The progression of heating in representative areas of Rooms 1 and 2 is shown in Table 1 (right), and Figures 2 and 3 on page 120. In Room 1, all 32 locations where surface temperature was monitored exceeded the thermal death point (111°F to 113°F) for bed bugs, and ranged from 114°F to 145°F after 6.5 hours of heating (Table 1). Lethal temperatures (119° to 143°F) also were attained in the 24 locations where probes were inserted into wall voids, mattresses, etc. Figure 2 shows the progression of heating in six of these areas plotted by the data recorder. Lethal temperatures were not achieved, however, in seven of the 12 sensor-monitored locations in Room 2, which was heated for only 4.25 hours and received no prior preparation to facilitate heat transfer. Figure 3 shows the progression of heating in six of these areas,

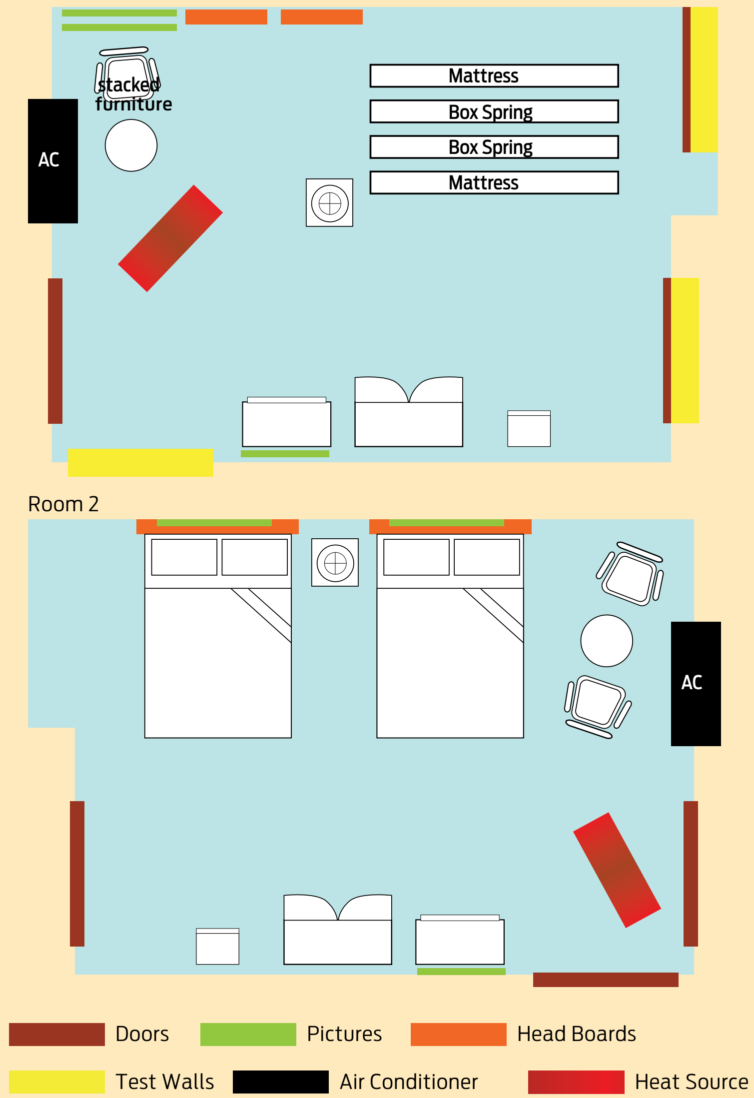

Figure 1. Layout of Rooms 1 and 2 at initiation of heating.

Bed bugs and eggs were placed in several locations — including fire detectors, box springs and behind insulation.

Room 1

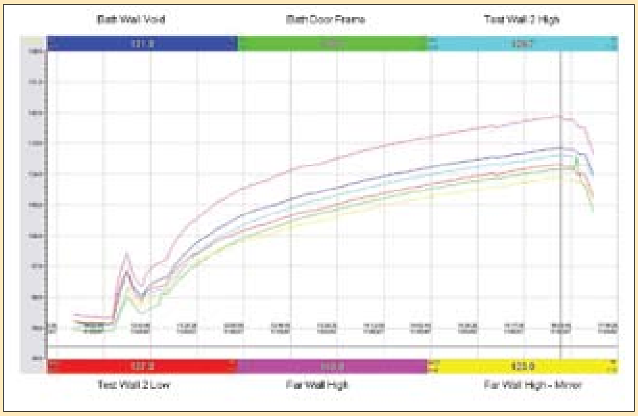

Figure 2. Progression of heating in six locations of Room 1, plotted by a data recorder. The decrease in temperature about an hour into heating was due to a temporary malfunction of the generator. The vertical line to the right is when heaters were turned off.

Room 2

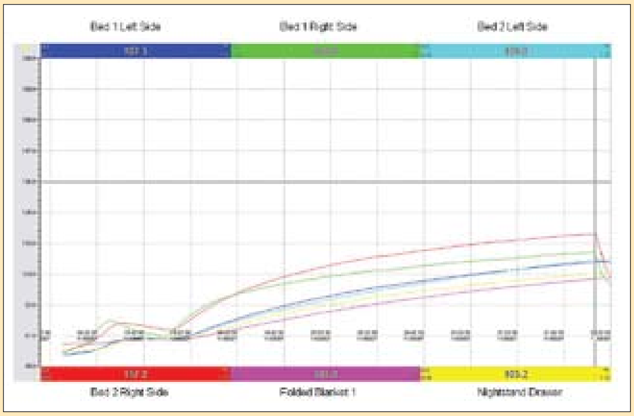

Figure 3. Progression of heating in six locations of Room 2, plotted by a data recorder. Only one of the six locations reached the thermal death point for bed bugs.

only one of which reached a lethal temperature for bed bugs.

Mortality of bed bugs and eggs correlated with the temperatures to which they were exposed. In Room 1, almost all bed bugs (96 percent mortality, 25 of 26 envelopes, four bugs per envelope) were dead after seven hours of heating—yielding end temperatures of 123˚F to 154˚F where the bugs were placed. The only location where four adult bed bugs survived the full period of heating was behind a section of carpeted baseboard left in place to observe the outcome. (As mentioned previously, the rest of the carpeted baseboard was removed as per Massey's corporate heat treatment protocol.) While the final surface temperature of the carpet in this location registered 118˚F, the temperature behind the baseboard near the concrete floor may have been lower, enabling the bugs to survive. All bed bug eggs exposed to seven hours of heating situated in a location where the final temperature reached 154˚F did not hatch.

Survival was notably higher when bed bugs and eggs were exposed to abbreviated periods of heating. Nearly a third of the adults and nymphs (31 percent, seven different locations) were still alive when removed from Room 1 after 1.5 to 2 hours of heating — and only 16 percent of these died within the next five days. One group of 100 eggs removed after two hours of heating hatched normally while the other did not. All surviving bugs and eggs were located in areas where the temperature at time of removal had recently reached about 120˚F — underscoring the fact than temperatures exceeding the lethal threshold for bed bugs must still be maintained for a sufficient period of time. No bed bugs or eggs survived the abbreviated period of heating in places where the temperature had risen to 128˚F to 134˚F.

In Room 2, heated for 4.25 hours without preparation to aid heat transfer, bed bugs survived (26 out of 28) in seven of 13 locations with none of the insects exhibiting delayed mortality. In all but one of the locations, the final temperature was below the lethal threshold. Eggs located under the television stand also hatched and nymphs survived. Some bed bugs in Room 2 *did* die in locations where the final temperature was somewhat below (107˚F to 110˚F) the published thermal death point for bed bugs. Early investigators also observed lethality at somewhat lower temperatures when humidity is high and the period of exposure is lengthened.

In respect to movement, adult bed bugs placed at the end of PVC tubes extending into Room 1 remained within their harborages for the first hour or so of heating. As the temperature in the tubes reached the mid-90s, some of the bugs became active and eventually crawled toward the cooler end, exiting on the unheated side of the wall. The remaining bugs followed a similar pattern of movement as temperature at the heated end of the tubes increased. The last bed bug exited at 110˚F. The period of time from when the first bug exited the tube to when the last one did was about four hours.

LESSONS LEARNED. Results of this study reinforce what others reported nearly a century ago: superheating can be an effective means of controlling bed bugs. Nearly complete extermination of bed bugs and eggs was achieved in Room 1, which was prepared, treated and monitored according to Massey Services' heat remediation protocol. The lone group of bed bugs persisting behind the strip of carpeted baseboard intentionally left in place showed that some areas are harder to heat than others, and if bugs or eggs happen to be there the problem may persist. The intentional lack of preparation and shortened regimen of heating in Room 2 resulted in several groups of bed bugs and eggs surviving.

Mortality correlated well with the temperatures to which bed bugs were exposed, and reinforced the need for diligent monitoring throughout the heating process. Higher temperatures killed bed bugs quickly whereas those at or near the lethal threshold (111˚F to 113˚F) took somewhat longer. Delayed mortality was observed in a small number of individuals following an inadequate heating time, suggesting such effects should not be relied upon, i.e., if bed bugs are alive after treatment they likely will live to bite another day.

The question of whether some bed bugs are likely to escape treatment by moving to a cooler place (such as an adjoining room or apartment) has not been fully answered. As temperature in our study increased, bed bugs vacated harborages and moved through a hollow tube from the heated to unheated side of the test wall. The chances of them escaping in a more complex environment are harder to predict, and likely would depend on the proximity of the bugs to unobstructed routes of escape. Bed bugs hiding near baseboards, carpet edges and utility openings, for example, seemingly would be more prone to escape than those harboring in more interior locations like beds and couches. Likelihood of escape would also depend on type of construction and whether it permitted movement from one room to another.

During Massey Services' commercial utilization of the heat remediation process, bed bugs have been observed moving out of infested furnishings and climbing up walls and furniture after temperatures reached about 105°F similar to what was observed in our study. In rooms bed bugs may often encounter more stressful conditions as they leave hidden harborages to more exposed areas. Based on Massey's retreatment records, movement of bed bugs to adjoining units may not be a common occurrence. Only 4.2 percent of correctly prepared heat jobs (166 total), performed in 2007-08 required retreatment, and re-services have declined further in recent months. To help limit the spread, pre-emptive use of desiccant dusts or other materials under baseboards and in utility openings may be prudent. Concurrent heating of adjoining rooms has also been suggested.

Perhaps the most important lesson from this study is that heating a room is not such a simple process. The approach requires a significant expenditure in time, effort and equipment. High-capacity heaters and temperature monitors designed for such purposes are fairly expensive, and a good bit of training is needed for safety and success. It takes practice to predict the flow of heat in a room. The manner in which the room is prepared and heaters are positioned can greatly affect the efficiency of heating. Several hours are usually needed to achieve lethal temperatures, especially in hard-to-heat places such as near floors, inside walls and within fabrics and other insulating materials. Success may come easier in less cluttered environments like hotel rooms than in homes or apartments although recent studies by other investigators have shown that de-infestation of bed bugs can be successful in these environments also *(see "Hot House," PCT, February 2008)*.

Heat treatment of trailers and other enclosures containing bed bug-infested materials is another promising approach being used by a small but growing number of companies. Considering the limits of the current bed bug management arsenal, use of heat may become increasingly important in the future. **PCT**

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Massey Services' Tom Jarzynka prepares to power up the dual electric heaters used in the study.

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