Bed bugs are a growing problem throughout the U.S.

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HOT HOUSE

Can lower prescribed heat be used effectively to control bed bugs and their eggs? Researchers at the University of California, Berkeley, wanted to find out.

For more than five decades bed bugs (*Cimex lectularius*) have been scarce in the United States due, in part, to the historical use of DDT and other currently banned products. However, with increased international travel, more species-specific pest control methods, and a general lack of understanding and awareness by the public, bed bugs have rebounded. Bed bugs are difficult to control given their cryptic nature. With a growing number of chemical substances (carbamates, organophosphates, etc.) no longer available and an increasing threat of pyrethroid resistance, eradicating bed bugs in a structure is a difficult task.

Many claims have been made regarding the use of heat to eradicate bed bugs and their eggs in a structure. Historically, heat has been well documented in successfully killing insects such as stored product pests and termites in both laboratory and field settings, but little is available on killing bed bugs in a structure. Buildings heated with ThermaPure® are considered "successfully controlled" for bed bugs when the infested area has been heated and held for either three hours at 130°F or two hours at 140°F. However, many questions still exist. Namely, is it possible to decrease the temperature requirements, extend the treatment time, and still achieve lethal temperatures in the structure to kill bed bugs and their eggs?

The objective of this demonstration was to test the efficacy of ThermaPure heat on adult bed bugs and their eggs by heating a single structure at a lower temperature and for a longer period of time than the current label specifications (140°F for two hours or 130°F for three hours).

STRUCTURE PREPARATION. The test was conducted on June 11-12, 2007, on a single-story, 2,000 square-foot, ranch-style home *(see Fig. 1 on page 99)*. The home was built in 1970 and is located in Ojai, Calif. The construction details include wood frame studs with drywall interiors and a crawlspace. The entire structure was heat treated, except the attached garage. The home contained furniture including bed frames, mattresses, dressers, and various clothing and linens. Precision Environmental, a licensee of ThermaPure, provided the on-site technical expertise and equipment during testing. Prior to the arrival of UCB entomologists, the structure was prepared by removing any potentially damageable items as recommended by ThermaPure (list available at www.thermapure.com).

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The structure was divided into two treatment sections (Fig. 1). Section 1 consisted of the master bedroom, bathroom, closet, vanity and sitting room; and Section 2 included the remainder of the house including a bedroom, bathroom, kitchen, dining, living room and an office. The two sections were separated from each other by closing the master bedroom door.

Two types of treatments using heat were tested: infrared heaters in Section 1 and heat exchangers in Section 2. In Section 1, a total of 15 infrared heaters were installed; 10 in the master bedroom, two in the vanity area, two in the sitting room and one in the bathroom. In Section 2, five heat exchangers were used; one each in the office, dining room and kitchen, and two in the living room.

Temperature sensors were placed in both sections of the house to measure and record the temperature of the treated area over time. Section 1 received seven temperature sensors while Section 2 received 20 sensors. Care was taken to place sensors in "cold spots," including some inside wall voids, at window frames and doorframes. Once the temperature sensors were installed, fans were strategically

TABLE 1. SURVIVORSHIP AND TEMPERATURE RESULTS FOR BED BUGS AND EGGS TREATED WITH HEAT TECHNOLOGY

Dish	Dish contents	Location in structure	% surviving 4 hours into treatment	Temperature 4 hours into treatment (°F)	% surviving 16 hours into treatment	Temperature 16 hours into treatment (°F)	% surviving 2 weeks post treatment
SECTION 1: INFRARED TREATED AREA							
A	100 bed bug eggs	Master bedroom closet	*	115	*	130	0
B	100 bed bug eggs	Master bathroom	*	116	*	133	0
C	100 bed bug eggs	Sitting room	*	132	*	123	0
1	10 bed bugs	Master bedroom wall void	100	120	0	129	0
2	10 bed bugs	Master bedroom: between mattress and box spring	0	122	0	130	0
3	10 bed bugs	Sitting room	0	122	0	140	0
SECTION 2: HEAT EXCHANGE TREATED AREA							
D	100 bed bug eggs	Living room	*	98	*	145	0
E	100 bed bug eggs	Bedroom	*	93	*	140	0
F	100 bed bug eggs	Hall closet	*	90	*	135	0
4	10 bed bugs	Dining room: in a cabinet	100	135	0	150	0
5	10 bed bugs	Living room: under couch cushion	50	98	0	145	0
6	10 bed bugs	Bedroom: under mattress	90	69	0	125	0
7	10 bed bugs	Hall closet	100	98	0	130	0
UNTREATED BED BUGS AND THEIR EGGS							
G	100 bed bug eggs	Taken to the lab for observation	*	N/A	*	N/A	100
H	100 bed bug eggs	Taken to the lab for observation	*	N/A	*	N/A	100
I	100 bed bug eggs	Taken to the lab for observation	*	N/A	*	N/A	100
8	10 bed bugs	Taken to the lab for observation	100	N/A	100	N/A	100
9	10 bed bugs	Taken to the lab for observation	100	N/A	100	N/A	100
10	10 bed bugs	Taken to the lab for observation	100	N/A	100	N/A	100

*All treated and untreated Petri dishes were held in the laboratory for two weeks post treatment to observe adult survivorship and egg hatch.

placed in both Section 1 and 2 to facilitate the movement of heated air throughout each test area.

INSECT PLACEMENT. Live bed bugs and their eggs were obtained from ICR Laboratories in Baltimore, Md. A total of 10 covered Petri dishes (seven treated and three untreated) were prepared with 10 live adult bed bugs each, and nine Petri dishes (six treated and three untreated) were prepared with approximately 100 bed bug eggs in each *(see Table 1 on page 98)*. The treated and untreated Petri dishes were kept at room temperature for two weeks post treatment to observe adult survivorship and egg hatch.

Petri dishes containing the live adult bed bugs or eggs were distributed throughout the structure. In some cases, the location of a sample was undisclosed to Precision Environmental in order to simulate unknown locations of an infestation. In addition, locations were chosen to simulate not only a single family residence, but similar locations in a hotel room, i.e., areas with limited air flow, closets, cold spots because of crawlspaces or adjacent rooms.

For Section 1 (Table 1), bed bugs (Dish 1) and a temperature sensor were placed inside a master bedroom wall void that shared a common wall with the untreated garage. Bed bugs were also placed in the middle of the master bedroom between a box spring and mattress (Dish 2) and in the adjoining sitting room under a mattress placed directly on the floor (Dish 3). Bed bug eggs were placed in the master bedroom closet (Dish A), bathroom (Dish B) and sitting room (Dish C).

For Section 2 (Table 1), bed bugs were placed in a dining room cabinet (Dish 4), between the cushions of the living room couch (Dish 5), between the floor and a mattress on the floor in a bedroom (Dish 6) and in the hall closet (Dish 7). Bed bug eggs were placed on the floor in a corner of the living room (Dish D), in a particularly cold spot on the floor in a bedroom (Dish E) and in the hall closet (Dish F).

After placement of the Petri dishes, the heating process was initiated. The infrared heaters were powered on and the temperature was set to 140°F and monitored for stability. The heat exchangers were then connected by hoses and powered from a central (water) heater. The temperature on the heat exchangers was set to 170°F and monitored for stability.

RESULTS. After four hours of heating, we entered the structure to take initial observations. Although hot inside, we were able to spend about 15 minutes inspecting the condition of household items left in the home and observe Petri dishes containing bed bugs. Items of particular interest, due to their suspected vulnerability to heat, were plastic cups still in their thin plastic sleeves and telephone wires from the wall to the phone. All inspected items did not appear to be affected by the raised temperature of the building.

In Section 1, four hours into treatment, all bed bugs were dead in Dishes 2 and 3 (Table 1). In Dish 1 (Table 1) all bed bugs were still alive, but clearly agitated. Observing the temperature sensors in Section 1 indicated a temperature range from 115° to 132°F (Table 1). In Section 2, all bed bugs were alive except in Dishes 5 (50 percent alive) and 6 (90 percent alive). Some of the live bed bugs in this section appeared to be agitated, while others showed no observable change in behavior. The temperature sensors in Section 2 indicated a range of 69° to 135°F (Table 1) at four hours into treatment.

Sixteen hours into the treatment, all bed bugs for all Dishes and sections treated were dead. In Section 1, temperature sensors ranged from 123° to 140°F, and the temperature sensors in Section 2 ranged from 125° to 150°F (Table 1).

All adult bed bug and egg samples were removed from the structure and transported back to the laboratory where they were observed for two weeks. None of the bed bugs in Dishes 1-7 survived the heat treatment in either section. However, all untreated bed bugs (Dishes 8-10) remained alive at the two week visual observation period. Bed bug eggs (Dishes A-F) exposed to the heat treatment did not emerge at the two week observation period. The untreated bed bug eggs (Dishes G-I) hatched and emerged at two weeks post-treatment.

CONCLUSIONS. Given the results that all bed bugs and their eggs were killed after 16 hours of treatment at temperatures (in many cases) below the recommended 130° to 140°F suggests the question: What are the benefits of slowly raising the temperature when treating a structure? One obvious benefit is limiting any potential damage to building components. Paper cups in thin plastic sleeves, telephone cords, picture frames, etc., all withstood temperatures without damage during this trial. With an extended treatment time of 16 hours, an advantage to the structure is the ability for interior walls and wooden beams to have a longer "baking" time and potentially more time to eliminate the offending pest.

The infrared heaters were of particular interest during this trial since this was the first time they have been used in a structure to test their effectiveness on bed bugs. The heaters, although hot to the touch, did not burn. Additionally, if the heaters should fall over during heating they would automatically shut-off. One drawback noted was the large number of infrared heaters used during this test; however, with further research it is feasible that fewer heaters might accomplish

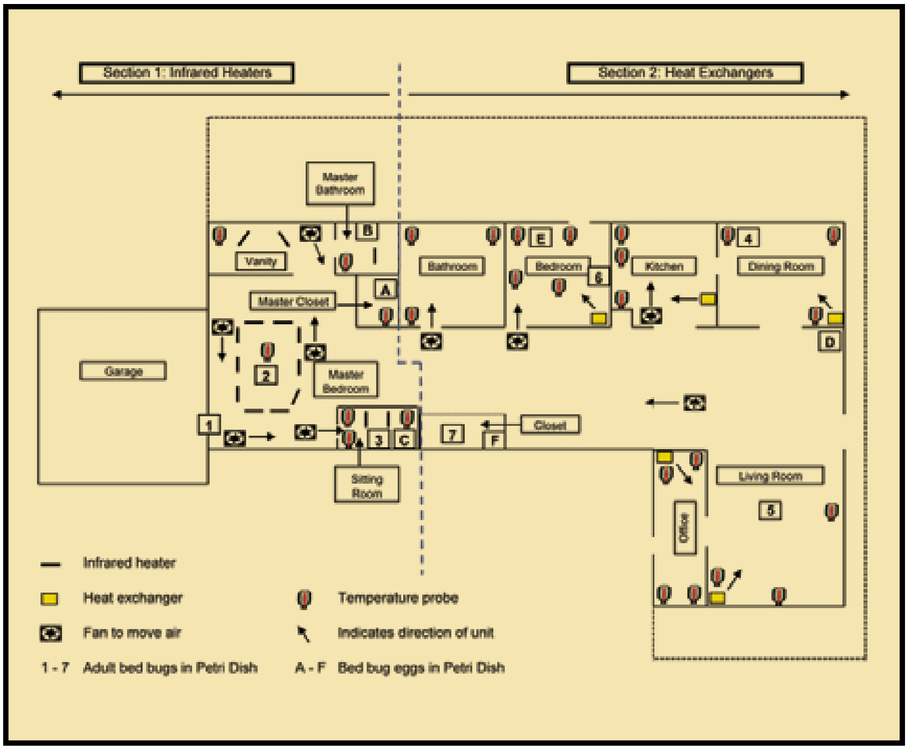

Figure 1. Plot map of the treated structure and locations of heaters, temperature probes and bed bugs for a heat demonstration in Ojai, Calif.

the same or better results.

The infrared heaters show greatest promise when used for structures where they can be set up overnight and dismantled and removed the morning after treatment. Hotels, schools, day care centers, office buildings, vacation homes and homeowners that are not opposed to moving out for the night, would all be potential beneficiaries of this technology.

In conclusion, we were impressed with the use of heat and ThermaPure technology for the control of bed bugs and their eggs in a structure and look forward to additional field research at a larger scale. Infrared heaters should be considered as another tool available for pest management professionals.

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Areas of the ranch style home were treated with heat to control bed bugs.

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