DISTRIBUTION AND STRATIFICATION OF TEMPERATURE IN PROCESSING PLANTS DURING HEAT STERILIZATION

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Heat sterilization for insect management in cereal grain processing plants has been used effectively since the early 1900s. Facilities that use steam to process cereal grams already may have sufficient capacity for heating production areas to temperatures lethal to insects. Target temperatures currently used by industry are 50-55°C for 20-30 hours. The amount of time necessary to conduct a heat treatment about 48 hours, is comparable to the time necessary to fumigate with methyl bromide. Presently, temperature and the length of time that a facility is heated are dictated by structural limitations and production schedules rather than by scientific examination of the impact of heat on insect pests. Heating an entire processing facility to a specific temperature for a set length of time is difficult and will result in isolated pockets where insects might escape the heat and be a source of reinfestation. The objective of this study was to examine the distribution and stratification of high temperature in processing plants during a heat treatment

Methods. The flour mill in Shellenberger Hall at Kansas State University has used heat sterilization for insect management since January 1995. The working flour mill is designed for research and teaching and contains a variety of equipment commonly used in commercial flour milling. The mill occupies five floors with about 120 m^2 per floor, has 4.25 in high ceilings, and one sub floor area of about 50 m^2 and a ceiling height of about 1.2 m. The building is made of concrete blocks and faced with native limestone. The floors are poured concrete with steel I-beam supports and the sub floor rests directly on earth. The north and east walls border hallways of the building. The south wall divides the flour mill from the grain-cleaning house that is not heated but fogged with a synthetic pyrethroid after the null has been heated. The west wall is the only exterior wall of the null and has windows on all floors that start about 2 m above the floor and goes to ceiling level.

For this study, only the sub and first floor levels were examined because of previous difficulties in attaining high temperatures for adequate insect management in these rooms. The first floor area contains ten roller nulls with associated ducting coming from the second floor and continuing though the equipment to the sub floor below, where it is pneumatically elevated back into the system. The first floor also has a few pieces of packing equipment The sub floor contains the ducting from the first floor and pneumatic return lines as well as the electrical motors to run some of the roller mills. In the first floor area, heating is accomplished through the existing air ducts for the building and no additional heaters have been installed to increase heat output. Forced hot air enters the first floor through a duct in the northwest comer. An 30 cm flexible hose is attached to the duct and exhausted near the middle of the room. The sub floor area is heated with a steam coil heater located in the northwest comer of the room.

Temperatures were recorded at 10-minute intervals throughout the heat sterilization procedure using HOBO® TEMP temperature loggers (OnSet Computer Corporation, Pocasset, MA). Temperatures were monitored on the floor and ceiling levels and 1.5 to 2.5 in above the floor at 37 locations at each level on the first floor of the flour mill. In the sub floor area, temperatures were monitored at 10 locations each at floor and ceiling levels. The location of each sensor was identified on (X, Y, Z) coordinates. The resulting temperature data was plotted on contour maps that were generated using Surfer Contour and 3D Surface Mapping software (Golden Software, Golden, CO). The target temperature and time was to hold 50°C for 24 hours.

Ten red flour beetles in cages were placed at 69 locations with temperature sensors in the sub floor and first floor areas to determine if the time x temperature combination was adequate to kill insects. Any cages containing surviving insects after the heat sterilization procedure were held for one week then examined for final mortality.

Results. The heat sterilization procedure reported here was conducted 3-7 July 1997. Outside of the null, daily high temperatures were 32 to 35°C and overnight low temperatures were 20 to 23°C. The heating was turned on at 12:00 on 3 July and turned off at 9:00 on 6 July and allowed to cool without forced ventilation. The average temperature measured at floor level in the sub floor and first floor areas never reached the target temperature of 50°C during the procedure (Fig. 1). The average temperature: measured at the ceiling of the sub floor and first floor areas and at midlevel on the first floor were above 50°C for 70, 44, and 24 hours, respectively (Fig. 1).

The hours that the temperature was above 50°C, as well as the maximum temperature attained, were variable from floor to ceiling as well as within each level (Fig. 2). As expected, the ceilings of both areas (Fig. 2b and 2e) were hotter than the floors (Fig. 2a and 2c) and the maximum temperatures attained at the ceiling level (Fig. 3b and 3e) were greater than that at the floor (Fig. 3a and 3c). The variability in temperature distribution was due to poor air circulation within the rooms. While some parts of the floor -never attained the target of 50°C for 24 hours, most of the mid level and the entire ceiling in both areas exceeded the target for time, temperature, or both time and temperature. On the west side of the mid level, the temperatures measured next to the windows were lower than those measured 0.2 m from the windows.

All insects placed in the sub floor area were dead after treatment even though the temperature never reached 500C on most of the floor surface. In the first floor area, mortality was 100% at all locations at the ceiling and mid level and at the floor level except along the south and east walls. Where insect mortality was not 100% at floor level, the mortality ranged from 0% to 80%.

To improve the efficiency of heat sterilization of the first floor of this facility, it would be useful to add fans to direct the heat toward the walls and floor-wall Junctions. Although 100% mortality occurred in the sub floor area, it also would be advisable to circulate the air in this area to assist in increasing the floor temperature.

Additional research is planned or presently being conducted in other facilities to study heat distribution and penetration of heat into milling equipment and electrical boxes.

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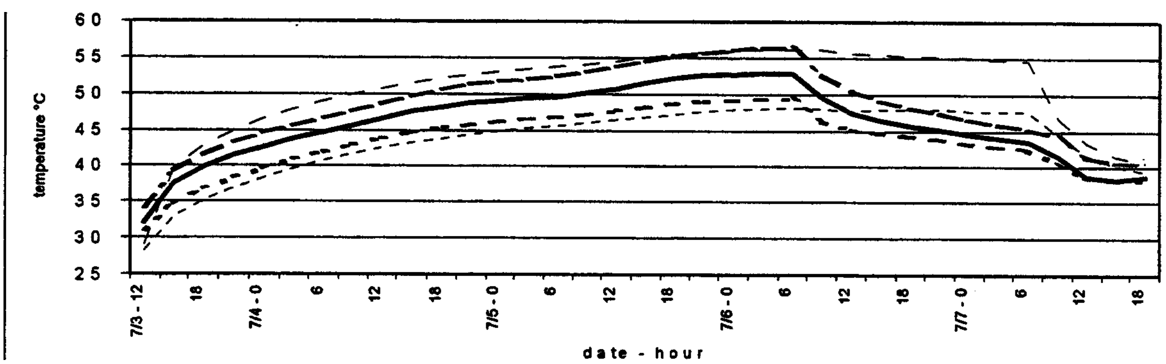

- - - - - subfloor ceiling - - - - floor -------Midlevel ----- - - ceiling

Figure 1. The average temperature at hourly intervals recorded in the sub floor and first floor areas of a flour mill. Mid level is 1.5-2.5 m above the floor.

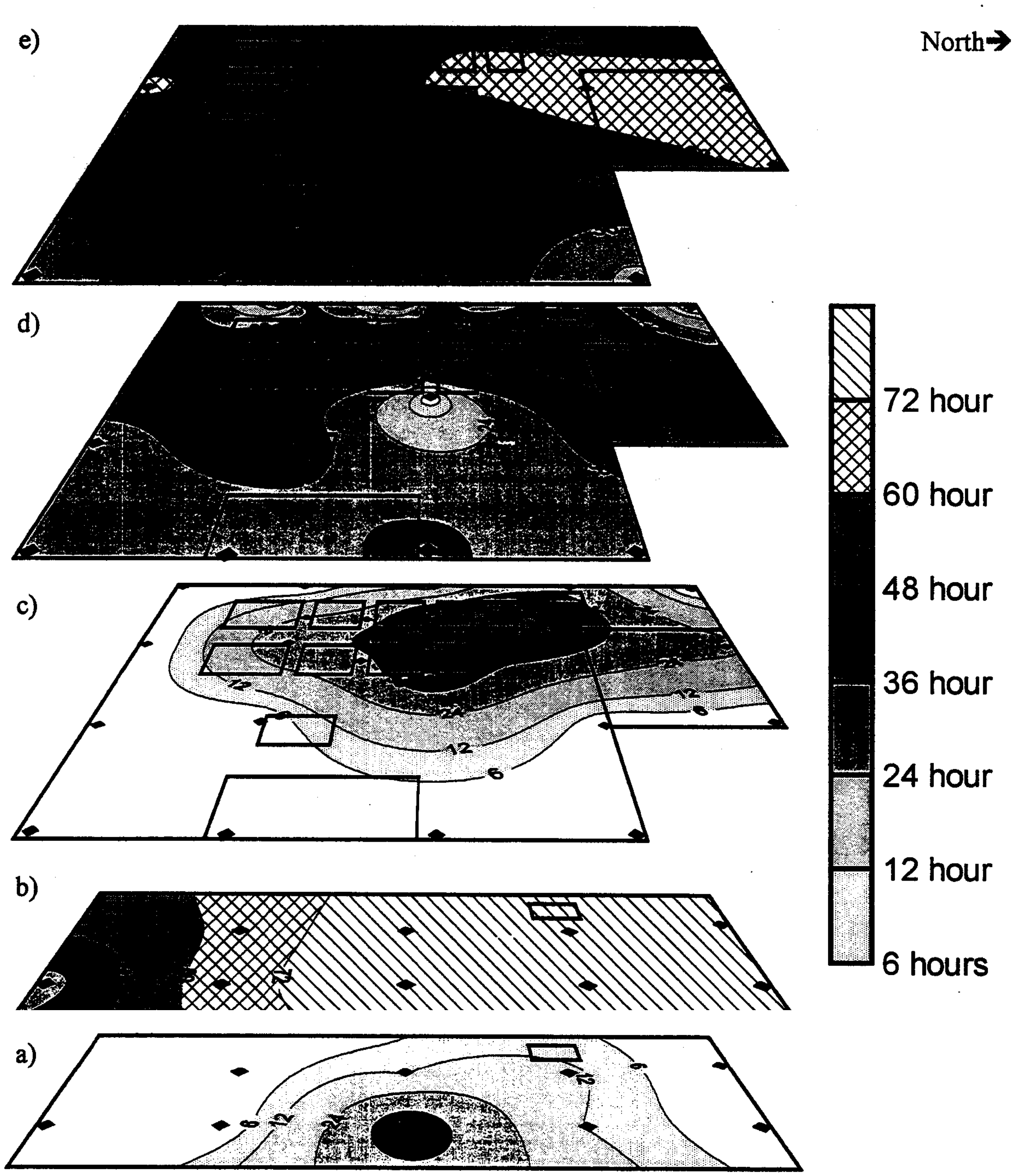

Figure 2. The length of time (hours) that the temperature was in excess of 50°C at the (a) floor and (b) ceiling of the sub floor area, and at the (c) floor, (d) 1.5-2.5 m above the floor, and (e) ceiling level of the first floor during heat treatment of the Kansas State University flour mill July, 1997; u indicate locations of temperature sensors.

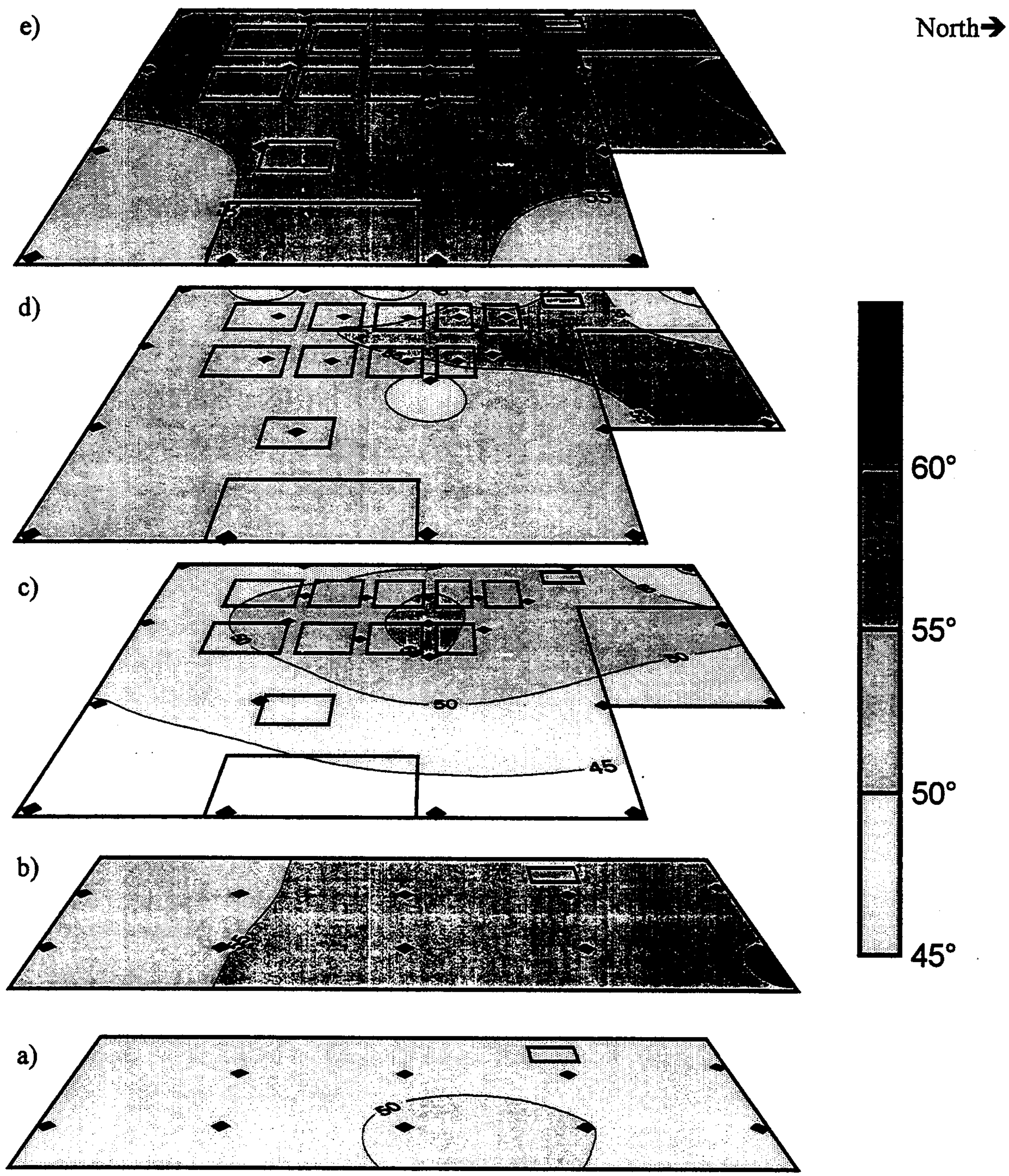

Figure I The maximum temperature (°C) attained at the (a) floor and (b) ceiling of the sub floor area, and at the (c) floor, (d) 1.5-2.5 m above the floor, and (e) ceiling level of the first floor during heat treatment of the Kansas State University flour mill, July, 1997; u indicate locations of temperature sensors.