Surface Temperature Distribution of Commercial Electrical Heat Mats for Farrowing Creep Heating

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Summary and Implications

Four commercial electrical mats for localized heating in farrowing creep area were evaluated with infrared (IR) thermal imaging regarding uniformity of the surface temperature distribution and amount of mat area with acceptable temperatures (85 to 105°F). Large variations in these parameters were found among the mats tested. Certain mat configurations or settings are inadequate as the heat source for neonatal piglets. In particular, use of mats without controller (i.e., full power output) produces excessively hot surfaces (>120°F) and thus should be avoided. Mat manufacturers should provide specifications on the operational performance of the mat both for product quality control and for selection and operation of the mat. Swine producers are advised to perform on-farm check or calibration of the actual surface temperature against the controller settings after mats have been installed in farrowing crates.

Introduction

Adequate microenvironment inside farrowing crates is critical for piglets to thrive and to minimize their chance of being crushed by the sow (48% of pre-weaning death loss is caused by sow crushing[1]). Heat lamps have been the primary localized heating sources for piglets, and their use accounts for 62% of the farrowing operation in Iowa according to our recent statewide survey with pork producers. As a result our recent studies have been investigating optimal use of heat lamps to meet the thermal needs of piglets while improving energy use efficiency[2,3].

Meanwhile, some swine equipment suppliers have been promoting electrical heat mats as an alternative heat source for piglets. The potential merit of mats over lamps includes better energy efficiency, more space of warmth for the litter, less maintenance requirement, and reduced fire hazard. Nevertheless, our survey showed that only 25% of farrowing operation in Iowa is using heat mats. The less usage of heat mats primarily arises from the following factors. First, higher initial cost for mats ($40/crate vs. $10/crate for lamp), although the energy savings by mats can offset the extra initial cost in one year. Second, there is a severe lack of technical data on the thermal characteristics of the mats such as temperature uniformity and controllability and operational guidelines. Compared with a gradient surface temperature profile provided by a heat lamp (where piglets can choose their comfort zone), a uniform surface temperature provided by a heat mat could be a potential disadvantage in its own right because a uniformly hot surface would expel the piglets from using it altogether. This mismatch between mat surface temperature and piglet thermal needs has been the cause for some producers who did try to use heat mat to switch back to heat lamps.

The objective of this study was to characterize the thermal performance of commercial heat mats. The results will hopefully help mat manufacturers in their product refinement and swine producers in their selection and operation of heat mats.

Materials and Methods

Four types of commercially available heat mats, representing four manufacturers, were evaluated in this study. They are designated as mat A, B, C, and D. Mats A, B and C were double mats with a single side dimension of 12 x 48 inches and used110VAC power supply. Mat D was a single mat with a dimension of 15 x 48 inches and used 220VAC power supply. All mats were operated through a power controller. In addition, mat A had an option of mat only (no controller). Three or four controller settings were used to cover the temperature range from low to high. Mats A (when used with controller), C, and D used embedded temperature sensors to control the power input, whereas mat B used an external ambient temperature sensor for the power control. There was no power regulation to mat A when used alone.

The test was conducted in a well-insulated room under a draft-free ambient temperature of 70°F. The mats were supported 4 inches off a concrete floor. For each controller setting, the mats were given at least 40 minutes for the surface temperature to stabilize. Once stabilized, thermal images or thermographs of the heat mats were recorded with an infrared (IR) imaging camera (Inframetrics Model PM250) (using $\varepsilon = 0.97$) onto a PCMCIA storage card. The images were later retrieved to a PC for analysis with the accompanying software package (TherMoniotor®).

Variables used to characterize the operational performance of the mats included average surface temperature (T_{avg}), maximum surface temperature (T_{max}), amount of surface area that corresponds to a nominal thermally comfort temperature range of 85 to 105°F, and the percentage of this area relative to the total mat area. The 85 to 105°F temperature range was selected based on a behavioral observation of 3-day-old piglets resting on a heat mat with rather non-uniform heat distribution (Figure 1).

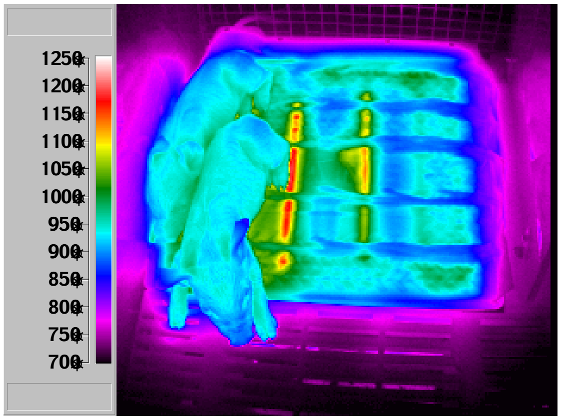

Figure 1. Choice of surface temperature by 3-day-old piglets on an unevenly distributed heat mat.

Results and Discussion

Thermographs of the heat mats at the selected controller settings are shown in figures 2a through 14a. Corresponding to each thermograph is a figure describing the temperature specific and cumulative area distribution profile (single mat basis) (figures 2b through 14b). The measured performance variables are further summarized in table 1.

Table 1. Surface temperature (T) distribution of four commercial heat mats. All mats had one-side dimension of 12 x 48 inches except for mat D that is 15 x 48 inches. Air temperature = 70°F.

Mat ID*	T_{avg} (°F)	T_{max} (°F)	Area (in^2) of 85-105°F	% Total Area
A-No	101	122	478	83
A-85°F	84	93	85	15
A-Hi	85	94	160	27
B-Low	85	91	347	60
B-Mid	94	103	481	84
B-Hi	100	114	362	63
C-85°F	83	91	0	0
C-95°F	91	99	479	83
C-Hi	94	102	530	92
D-85°F	83	90	0	0
D-95°F	90	98	577	80
D-105°F	97	106	657	91
D-Hi	101	110	559	78

* *Mat ID represents the mat type (A, B, C, or D) and controller dial setting ('No' means no controller).*

From the thermographs and the summary data of Table 1, it can be seen that three out of the four tested heat mats – B, C and D have reasonably uniform heat distribution at the surface level. The same mats also show good responsiveness to their controller settings, although the actual surface temperature may deviate from the dial setting on the controller. Such deviation makes it necessary to calibrate or check the controller settings versus the resultant mat surface temperature after the mats have been installed in the farrowing facilities. With proper controller settings, which will depend on piglet age and ambient conditions, mats B, C and D can provide adequate space of warmth for a litter of 10 to 11 piglets during the most vulnerable days (<5 days of age) of the lactation period. Piglets of this age (weighing 4 to 5 lb.) occupy a floor space of 46 to 54 in.^{2} when resting in sternum position ($A = 0.019W^{0.66}$, where A in m^2 and W in kg). Hence, with a 5 to 10°F span in surface temperature, these mats are capable of providing the needed space for the entire litter without causing excessive huddling and thus mechanical stress among the piglets.

In comparison, mat A showed large variations in temperature distribution (Figure 2a). When operating without controller, the mat produces excessively hot regions (up to 122°F) around the heating elements. Consequently, even though the mat seemingly provides a good amount of warmth area (478 in.^{2}, Table 1), the existence of the hot regions greatly reduces the usable area for the piglets for they will avoid contacting these hot spots as shown in Figure 1. Such high surface temperatures would explain why piglets stay off mats, as has been reported by some swine producers and consultants. When operating with the controller, the mat showed significantly reduced but still varying surface temperature (Figures 3a and 4a). Also as shown in Figures 3a and 4b, the controller was ineffective in regulating the power input to the mat. Consequently, there was little difference in surface temperature between the 85°F (medium) and the high controller settings.

The results of this study suggest that heat mat suppliers should provide technical specifications on the mat performance such as the parameters used in the current study. The specifications are essential for both quality control and operation of the mats. The results further indicate the need to conduct on-farm check or calibration of mat surface temperature against the nominal controller settings. Non-contact IR thermometers can be used for this purpose.

Acknowledgements

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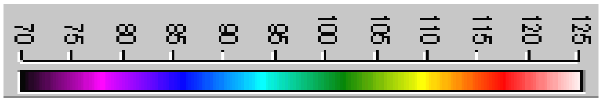
References

1. Tubbs, R. 1996. Preweaning mortality robs potential profits. National Hog Farmer. No. 22, Spring 1996.
2. Xin, H., H. Zhou, and D.S. Bundy. 1997. Comparison of energy use and piglet performance between the conventional and an energy-efficient heat lamp. Appl. Engr. in Agri. 13(1): 95-99.
3. Zhou, H. and H. Xin. 1998. Responses of piglets to variable and constant output heat lamp with clear or red color. ASAE Paper No. 98-4074. St. Joseph, MI: ASAE.



← Color scale of the thermographs

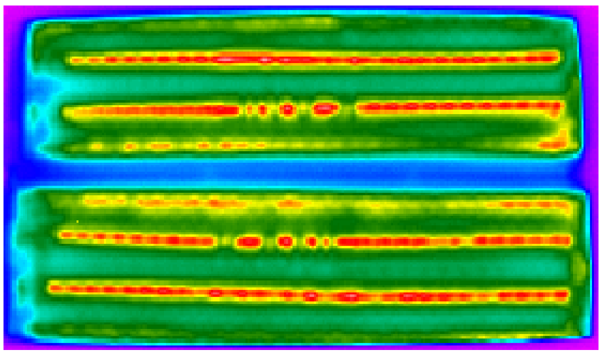


Figure 2a. Thermograph of mat A-No at T_a =70°F.

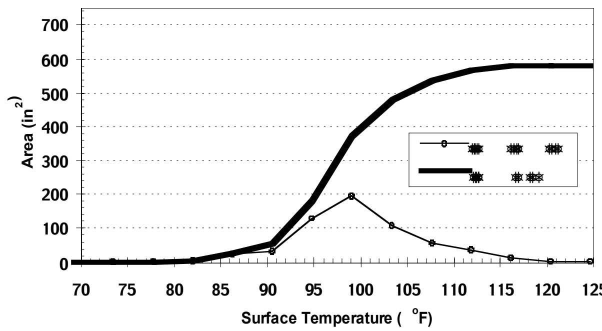


Figure 2b. Temperature specific and cumulative area distribution of mat A-No at T_a =70°F.

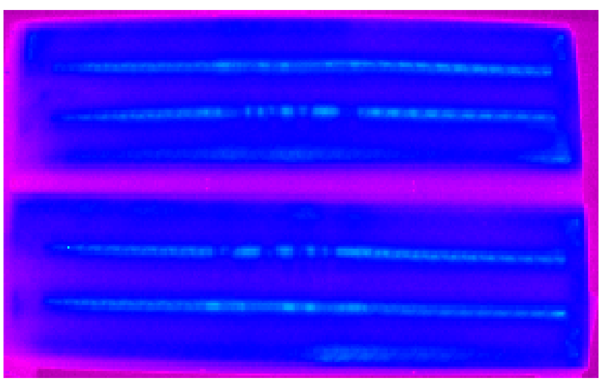


Figure 3a. Thermograph of mat A-85°F at T_a =70°F.

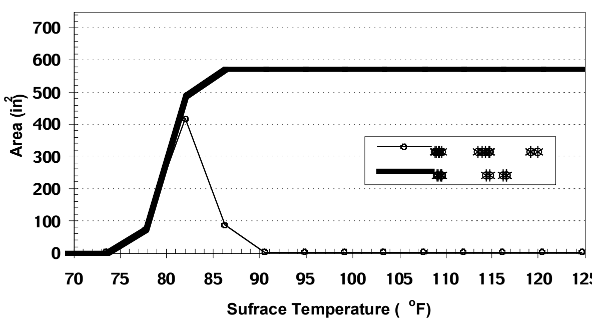


Figure 3b. Temperature specific and cumulative area distribution of mat A-85°F at T_a =70°F.

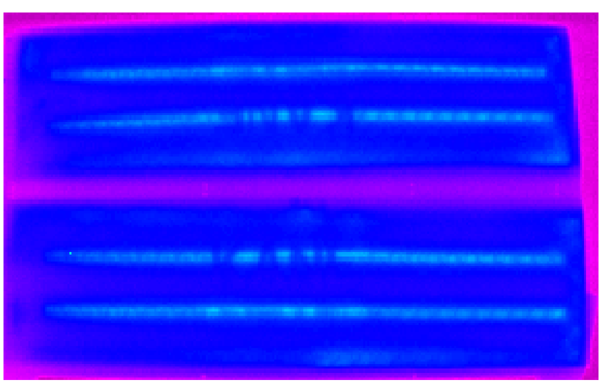


Figure 4a. Thermograph of mat A-Hi at T_a =70°F.

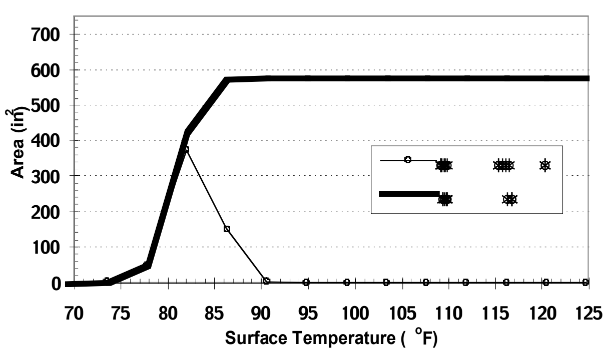
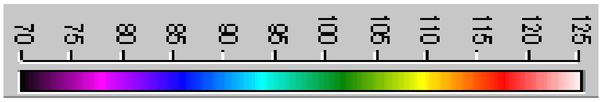


Figure 4b. Temperature specific and cumulative area distribution of mat A-Hi at T_a =70°F.



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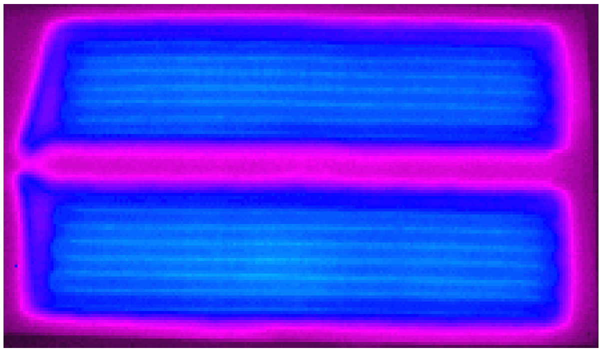


Figure 5a. Thermograph of mat B-Low at T_a =70°F.

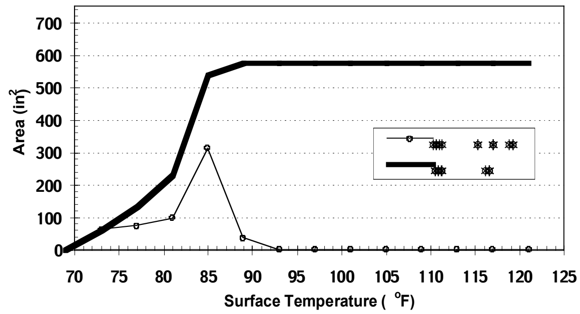


Figure 5b. Temperature specific and cumulative area distribution of mat B-Low at T_a =70°F.

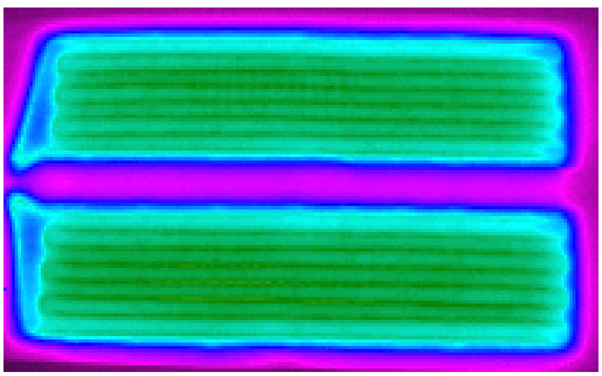


Figure 6a. Thermograph of mat B-Mid at T_a =70°F.

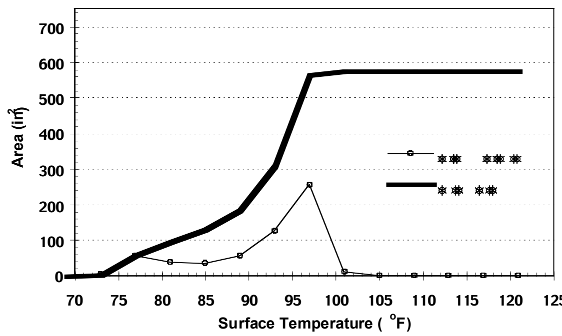


Figure 6b. Temperature specific and cumulative area distribution of mat B-Mid at T_a =70°F.

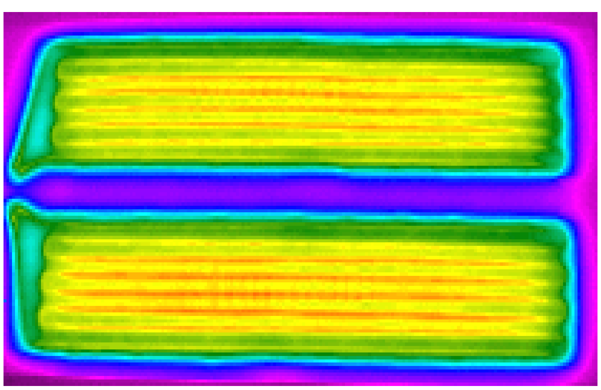


Figure 7a. Thermograph of mat B-Hi at T_a =70°F.

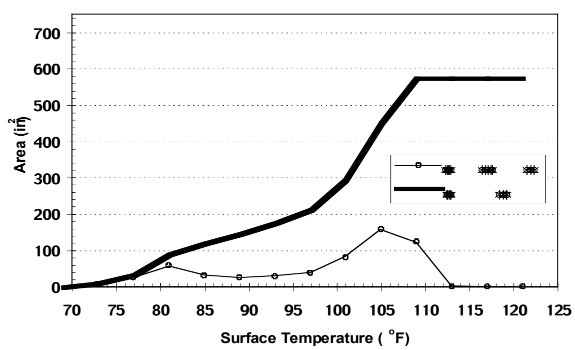
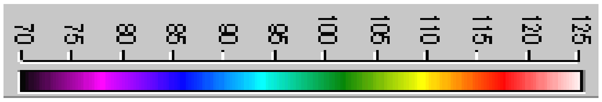


Figure 7b. Temperature specific and cumulative area distribution of mat B-Hi at T_a =70°F.



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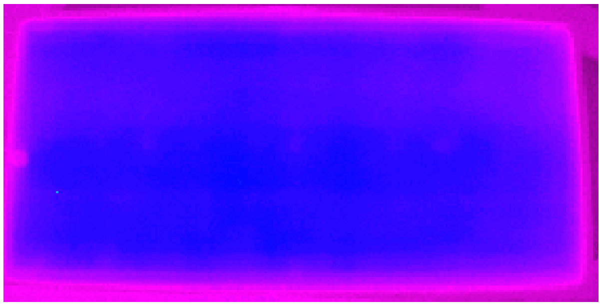


Figure 8a. Thermograph of mat C-85°F at T_a =70°F.

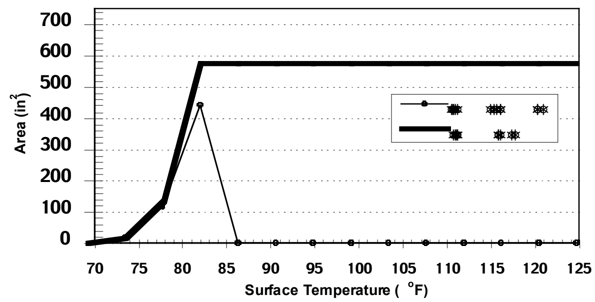


Figure 8b. Temperature specific and cumulative area distribution of mat C-85°F at T_a =70°F.

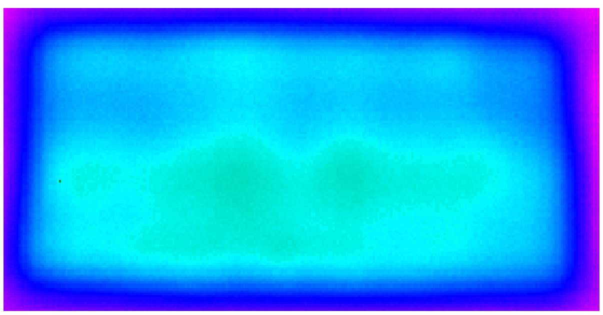


Figure 9a. Thermograph of mat C-95°F at T_a =70°F.

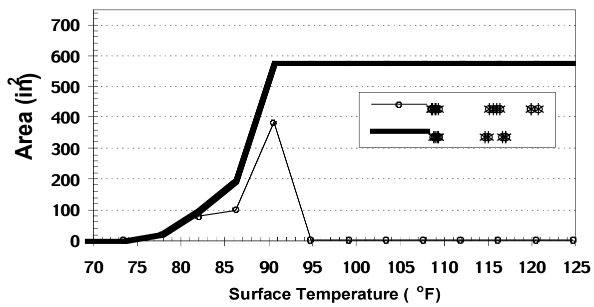


Figure 9b. Temperature specific and cumulative area distribution of mat C-95°F at T_a =70°F.

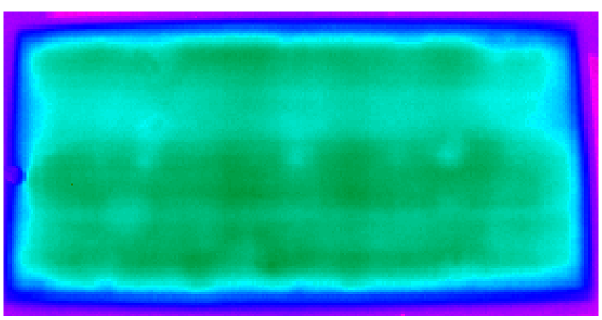


Figure 10a. Thermograph of mat C-Hi at T_a =70°F.

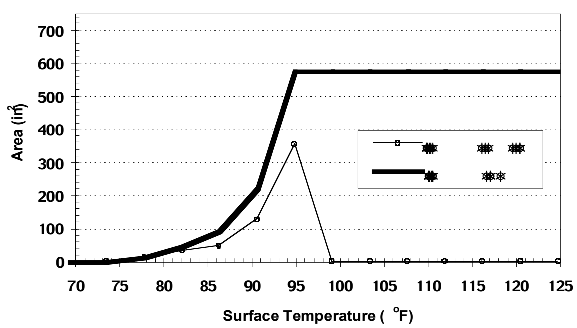
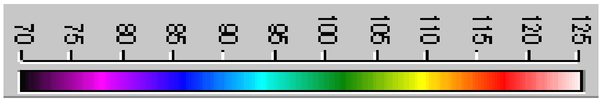


Figure 10b. Temperature specific and cumulative area distribution of mat C-Hi at T_a =70°F.



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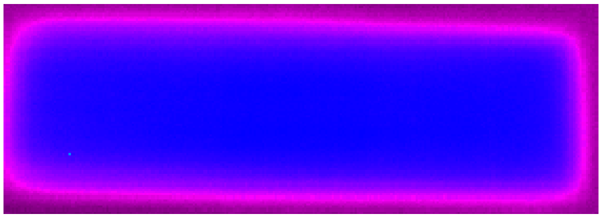

Figure 11a. Thermograph of mat D-85°F at T_a =70°F.

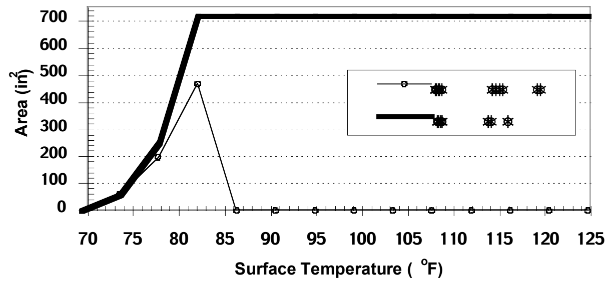

Figure 11b. Temperature specific and cumulative area distribution of mat D-85°F at T_a =70°F.

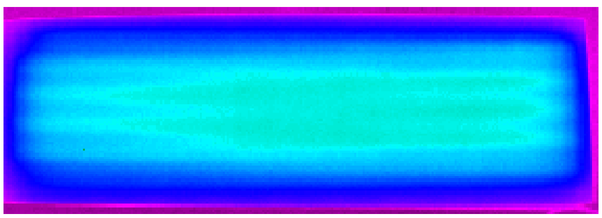

Figure 12a. Thermograph of mat D-95°F at T_a =70°F.

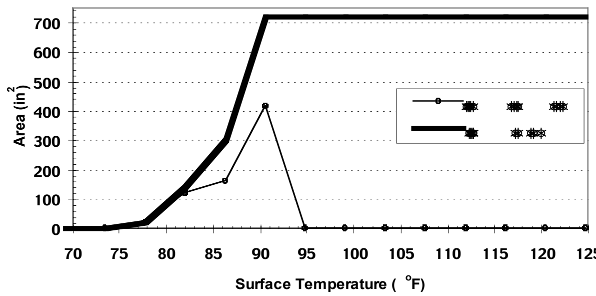

Figure 12b. Temperature specific and cumulative area distribution of mat D-95°F at T_a =70°F.

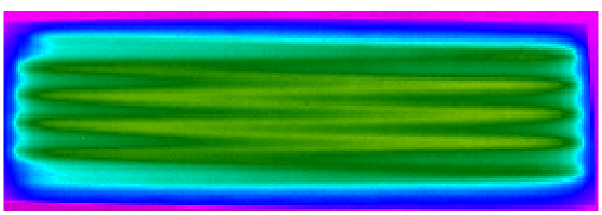

Figure 13a. Thermograph of mat D-105°F at T_a =70°F.

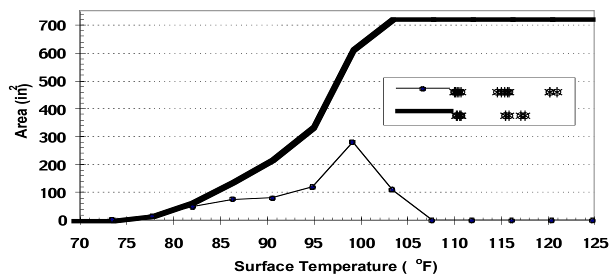

Figure 13b. Temperature specific and cumulative area distribution of mat D-105°F at T_a =70°F.

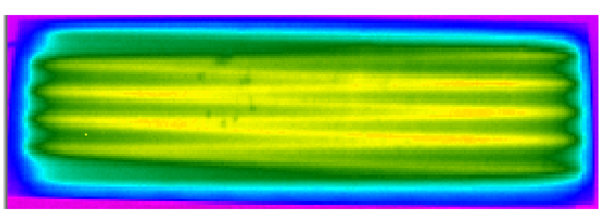

Figure 14a. Thermograph of mat D-Hi at T_a =70°F.

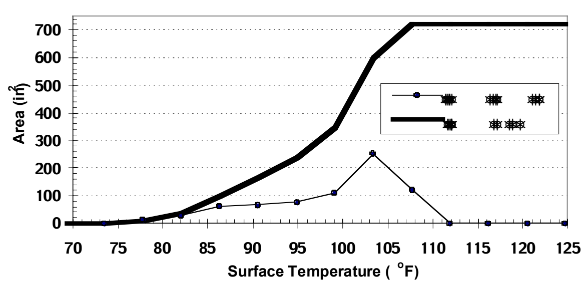

Figure 14b. Temperature specific and cumulative area distribution of mat D-Hi at T_a =70°F.