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Jeremiah D. Davis
Iowa State University

Ron D. MacDonald
Agviro Inc.

Hongwei Xin
Iowa State University, hxin@iastate.edu

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Keywords
Creep heat

Disciplines
Bioresource and Agricultural Engineering

Comments
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Infrared Thermography Evaluation of Commercially Available Infrared Heat Lamps

Jeremiah D. Davis, Research Assistant

Dept. of Agricultural & Biosystems Engineering, Iowa State University, 3105 NSRIC Bldg., Ames, IA 50011, davisj@iastate.edu.

Ron D. MacDonald, P.E.

Agviro, Inc.,367 Gordon St., Guelph, ON, Canada, N1G 1N1

Hongwei Xin, Professor

Dept. of Agricultural & Biosystems Engineering, Iowa State University, 3204 NSRIC Bldg., Ames, IA 50011, hxin@iastate.edu.

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Abstract. *The objectives of this study were i) to comparatively characterize the radial temperature distribution of six commercially available heat lamps (100W to 250W) at different heights (45-66 cm or 18-26 in) when used with a commercially available plastic lamp fixture and ii) to evaluate the operation of a commercially available power controller used with the 175SYL heat lamp at a 51-cm (20-in) height for three power settings of 100, 125 and 175W.*

Heat lamps with the same power output do not necessarily produce the same temperature profiles along the heated surface. Lamp lens prescriptions greatly affect the shape of the profile. By using a power controller with a given bulb, varying temperature ranges can be achieved while reducing overall energy as compared to varying height with same bulb.

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Introduction

In 2000, 55.5% of all preweaning deaths by producer-identified cause were classified as "laid-on" by the sow (NAHMS, 2002). Producers have traditionally placed a supplemental heat source in the farrowing creep area to attract pigs away from the sow and thus decrease pig mortality from crushing (Hrupka et al., 1998). Infrared heat lamps are commonly used to provide constant localized creep heating in swine farrowing systems, thus meeting the different thermal needs by the newborn piglets (30-32˚C) and by the sow (18-21˚C) in the same room (Xin et al, 1997).

MacDonald, et al. (2000) and Zhang and Xin (2000a) compared heat lamp systems to other creep heating systems. Zhang and Xin (2000a) found that lamp heat was the preferred heat source for the first two days after birth when compared to a heating mat. Others have studied the effects of heat lamp placement on lying behavior and thermal comfort of sow and piglets (Titterington and Fraser, 1975; Zhou et al., 1996; Hrupka, et al., 1998), energy efficiency and radial temperature distribution of heat lamps (Xin et al. 1997) and variable heat lamp output and lamp color (Zhou and Xin, 1999). Zhang and Xin (2000b) measured the maximum contact temperature between piglets and heat mats during a 14-day lactation period and found that the threshold ranged from 44.5 to 46.2˚C and was independent of age. The effectiveness of heat lamps as a local heat source may depend not only on the size of the lamp but also on the spatial distribution of radiant heat. Farrowing crates have become narrow and a suspended heat lamp may cast excess heat over the sow's lying area (Titterington et al., 1975). This may over-heat the sow and encourage the piglets to lie closer to the sow and increase the possibility of crushing (Titterington et al., 1975).

In the past, the 250W R40 (gooseneck) lamp was the conventional choice. However, as producers become more energy conscious, alternative infrared heat lamps have been developed. In the southern states, the choice has been the 125 W R40 lamp due to the lower heat requirements. In a study by Xin et al. (1997), the traditional 250W lamp was compared with an energy efficient 175W (PAR38) Phillips lamp. They determined that the 175W lamp would produce a significant energy savings, 45% lower lamp failure rate, 1.2% reduction in birth-to-weaning mortality and a slightly higher piglet rate of gain.

Zhou et al. (1996) measured the dynamic heat lamp usage rate (HLU) of neonatal pigs exposed to 250W, 175W and 125W heat lamps. HLU is the percentage of the litter having their body within a 45 cm (18-in) radial distance from the projected center of lamp (PCL) of the heat lamp. HLU was greatly affected by heat lamp size with 175W lamp appearing to produce the best piglet resting pattern. There was a consistent circadian pattern in HLU for all heat lamps. Average HLU was 28%, 31%, 39% for 250W, 175W, and 125W, respectively during the day and 13%, 24% and 24%, respectively at night. HLU also declined with increasing pig age. The results suggest that a variable, rather than constant, heat source be utilized to maximize energy efficiency and pig comfort throughout the lactation cycle.

Zhou and Xin (1999) concluded that heat lamps with a variable output (VO) from 175W to 100W appeared more suitable for creep heating than a constant output (CO) system across a 21-day lactation period. The VO system presented 21% energy savings as compared to the CO system and slightly higher average daily gains.

The objectives of this study were i) to comparatively characterize the radial temperature distribution of six commercially available heat lamps (100W to 250W) at different heights

(45-66 cm or 18-26 in) when used with a commercially available plastic lamp fixture and ii) to evaluate the operation of a commercially available power controller used with the 175SYL heat lamp at a 51-cm (20-in) height for three power settings of 100, 125 and 175W.

Materials and Methods

A new Retroliter® Hang Straight™ plastic heat lamp fixture (RetroLite Corporation of America, Hatboro, PA - fig. 1) was suspended at four heights - 45, 51, 56 or 66 cm (18, 20, 22, or 26 in) from the heated rubber mat (0.91m x 0.91m; 36in x 36in) placed on plastic slat flooring inside an environmentally controlled test room (fig. 2). The height was measured from the mat surface to the lamp face. The new heat lamp fixture was designed to improve heat distribution when used with the companion heat lamp. For comparison with the plastic fixture, a conventional metal fixture was used and evaluated for the 51-cm (20-in) height. The room ambient temperature was held at 21±1˚C (70±2˚F) throughout the tests.

Six commercially available incandescent infrared heat lamps were used in this study. Lamp size, brand and lamp lens prescription are described in Table 1 and illustrated in Figure 3. Three replications of each type of lamp were individually installed and allowed to stabilize before acquiring the thermographs using an infrared (IR) camera (0.06˚C or 0.1˚F sensitivity, model PM250, FLIR, Inc., North Billerica, MA) positioned 1.6 m (64 in) directly above the mat. The thermograph of heated mat surface was taken instantly following removal of the heat lamp. The rubber mat was cooled down convectively using a fan before the thermograph for the next lamp height or replication was taken.

A Retroliter® CZ20 Dual Power Controller (DPC) (RetroLite Corporation of America, Hatboro, PA - fig. 4) was evaluated with the plastic lamp fixture using 175SYL lamp at the four heights with full power setting (175W n=3) and a reduced power setting of 125W (n=1) or 100W (n=1).

The thermographs were analyzed using the companion Thermonitor® software of the IR camera to determine mat surface temperatures and distribution. Average 2D radial temperature profiles were constructed using eight (45˚ apart) temperature profiles extending 40.6 cm (16 in) from the PCL of the heated mat area (fig. 5). These measured profiles represented 0.52 m^2 (804 in^2) mat area.

RESULTS AND DISCUSSION

Example thermographs of 100SYL, 125HOG, 125SLI, 175SYL, 175PLP and 250SLI lamps using the plastic lamp fixture at the 51-cm (20-inch) height are presented in Figures 6a-11a, respectively. Each thermograph has a 0.91-m (36-inch), 2-D temperature profile through the PCL of the heated area to illustrate the variation in mat surface temperature for each bulb. The thermographs demonstrate spatial variation near the center due to the heating element for the clear lens lamps (125HOG – fig. 7a, 125SLI – fig. 8a and 250SLI – fig. 11a). The 175PLP lamp exhibited the largest radial temperature gradient of approximately 59˚C (106˚F) while the 100SYL and 175SYL lamps displayed more uniform radial profiles. The 100SYL and 175SYL lamps have evenly distributed lenticels along the inner surface to uniformly distribute heat whereas the 175PLP has a clear hexagonal center surrounded by evenly spaced lenticels (fig. 3).

The thermographs were compiled into 2D radial temperature profiles (fig. 6b-11b) for each lamp at all heights. The 100SYL (fig. 6b) and 175SYL (fig. 9b) lamps demonstrated a relatively constant radial temperature within a 25-cm (10-in) radius with temperature profiles converging at approximately 35 cm (14 in) from the center. Outside of this convergent radius the lamp height does not have a significant effect on temperature distribution. The 175SYL is called the 175W Comfort Zone 20™ by the manufacturer because it provides uniform heat over a 20-in diameter at a 20-in height. The thermographs shown in figures 6b and 9b demonstrate temperature profiles that are consistent with such a statement. The 175PLP profile (fig. 10b) had the highest temperature gradient with mat surface temperatures nearing 85˚C (185˚F) at the center (45-cm height), resulting in rippling of the mat. The 175PLP profiles converge between 20 cm (8 in) and 25 cm (10 in). The clear surfaced 125HOG, 125SLI, and 250SLI had highest temperature measurements between a 10 cm (4 in) to 15 cm (6 in) radius corresponding to the heating element and their heated areas converged at approximately a 30-cm (12-in) radius for all heights.

Figures 12 and 13 illustrate the variation in heat distribution for all six lamps at 45-cm (18-in) and 66-cm (26-in) heights, respectively. The two dashed lines represent the maximum contact temperature range (44.5 to 46.2˚C) between piglets and heat mats measured by Zhang and Xin (2000b). The area within a 17-cm (7-in) and 20-cm (8-in) radius would be used only in short durations if applying the maximum contact temperature range for 175PLP and 250SLI at 45-cm (18-in) height, respectively. In viewing fig. 13, by raising the height to 66 cm (26 in), only the area within a 13-cm (5-in) radius of 175PLP would exceed the maximum threshold. Heat lamps with the same power output do not necessarily produce the same temperature profiles on the heated surface.

A comparison between the plastic fixture and the conventional metal fixture is displayed in fig. 14 for 175SYL (PAR38) and 250SLI (R40) at 51-cm (20-in) height. Though the temperature distribution profiles are similar, the metal lamp has a slightly higher temperature profile (1.5˚C and 1.6˚C) along the length of the 175SYL lamp and a 15-cm radius for the 250SLI lamp.

Figure 15 shows the temperature profiles of the 175SYL lamp at each power setting 100W (n=1), 125W (n=1) or 175W (n=3) for the 51-cm (20-in) height. Temperatures were linear and increased with increasing power and/or decreasing height. This VO system provides the potential for the producer to achieve a higher HLU and should translate into increased energy efficiency and possibly decreased crush losses.

A comparison of the 175SYL, using the plastic fixture and DPC, and equivalent lamps shows the utility of this system. The 175SYL lamp can operate equivalent to 100SYL by varying the DPC from 175W to 100W (fig. 16). The combination of 175SYL lamp and DPC at 125W setting provides a more uniform temperature profile than the 125HOG or 125SLI lamps (fig. 17). A given temperature profile of the heated area may be achieved by adjusting the height of the same heat lamp or by varying the power input to the heat lamp while keeping its height. The latter will lead to energy savings.

The plastic fixture provided more visible light in the room than the metal fixture. This can allow additional energy savings since supplemental lighting is not required except for work activities (piglet processing, cleaning, etc.). The lamp bulb within the plastic fixture tended to hang straighter due to the flexible mounting whereas certain bulbs tended to hang off-center because of variations in screw terminals in the metal fixture. The plastic fixture also appears to provide a cushion from mechanical damage, which should extend lamp life.

Conclusion

From these thermographs and 2D radial temperature profiles we can conclude that:

- Heat lamps with the same power output do not necessarily produce the same temperature profiles along the heated surface. Lamp lens prescription greatly affects the shape of the profile. Lamp fixture design impacts output marginally between the plastic and conventional fixtures.
- By using a power controller with a given bulb, varying temperature ranges can be achieved while reducing overall energy as compared to varying height with same bulb.

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Table 1: Incandescent infrared heat lamps.

	Symbol	Brand	Type	Power (W)	Lamp Lens Prescription
1	100SYL	Sylvania	PAR 38	100	Fully textured
2	125HOG	Hog Slat	R40	125	Clear
3	125SLI	SLI Lighting	R40	125	Clear
4	175PLP	Philips	PAR 38	175	Textured/clear hexagon center
5	175SYL	Sylvania	PAR 38	175	Fully textured
6	250SLI	SLI Lighting	R40	250	Clear

Figure 1: Conventional metal fixture and Retroliter® Hang Straight™ plastic fixture.

Figure 2: Experimental setup showing the PM250 IR camera above the plastic fixture at 51-cm (20-in) height.

Figure 3: Lamp surface treatment (l to r) for a) 125HOG, b) 125SLI and 250SLI, c) 100SYL and 175SYL and d) 175PLP.

Figure 4: Retroliter® CZ20 Dual Power Controller (DPC) with three settings (100W, 125W and 175W) paired with the plastic fixture.

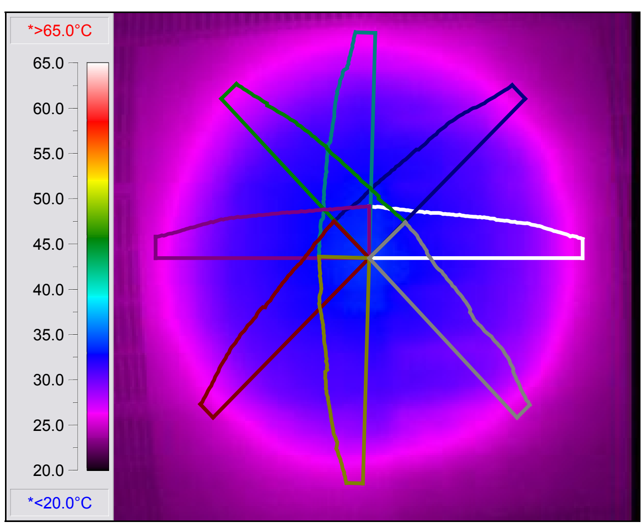

Figure 5: A thermograph of rubber mat surface heated by 175SYL lamp at 51 cm (20 in) height illustrating the eight radial temperature profiles used to generate the average 2D temperature profile for each lamp.

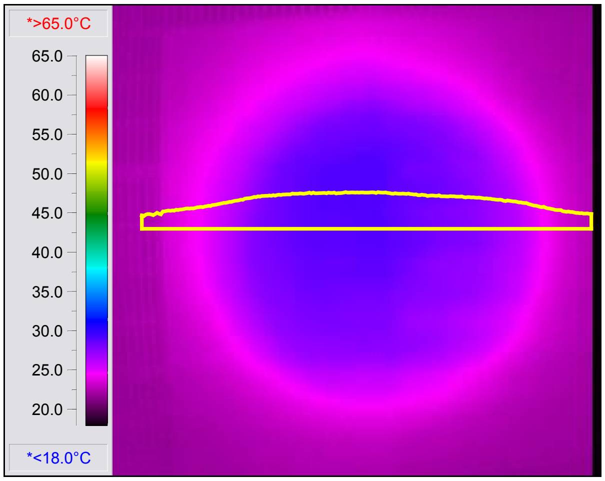

Figure 6a: A thermograph of 100SYL lamp in plastic fixture at 51-cm height with 0.9m (36-inch) 2D temperature profile.

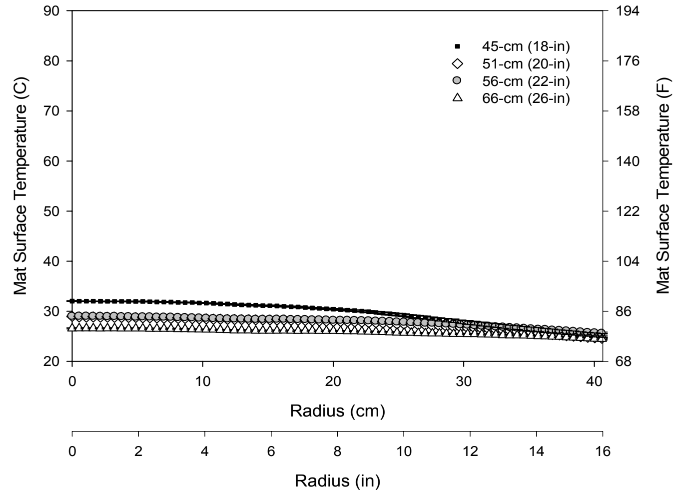

Figure 6b: Temperature distribution of rubber mat heated by 100SYL lamp in plastic fixture at each height (n=3).

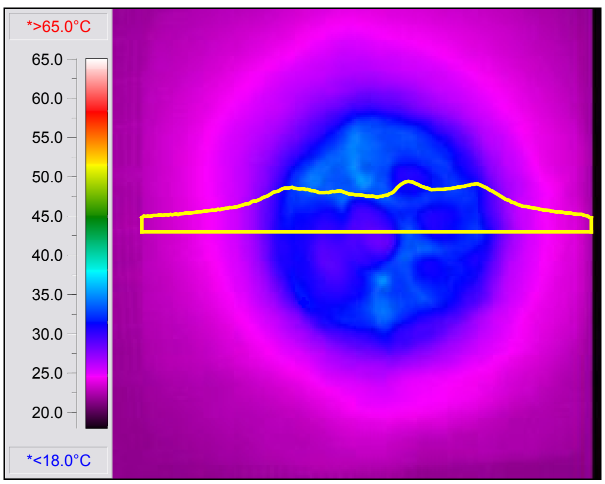

Figure 7a: 125HOG lamp in plastic fixture at 51-cm height with 0.9m (36-inch) 2D temperature profile.

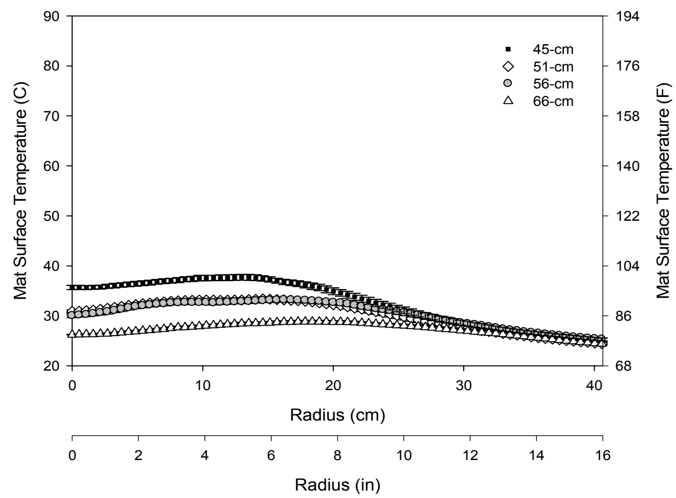

Figure 7b: 125HOG lamp in plastic fixture at each height (n=3).

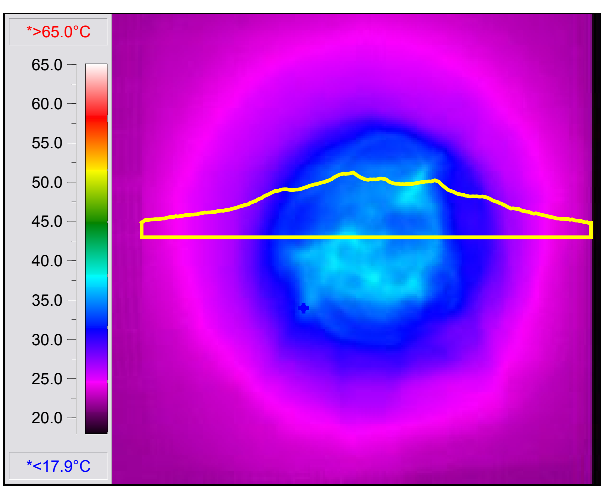

Figure 8a: 125SLI lamp in plastic fixture at 51-cm height with 0.9m (36-inch) 2D temperature profile.

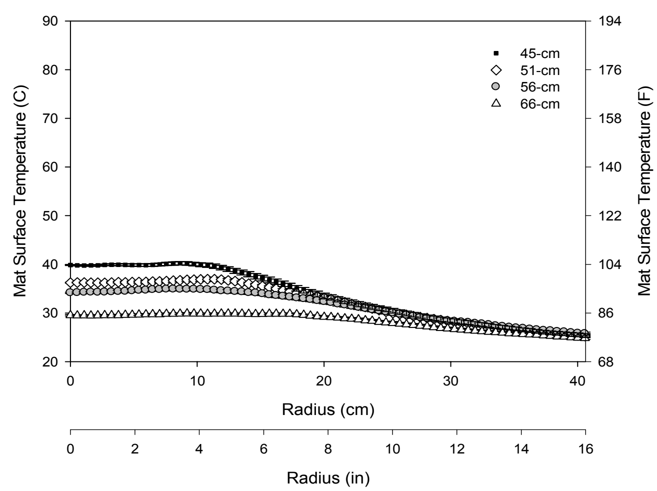

Figure 8b: 125SLI lamp in plastic fixture at each height (n=3).

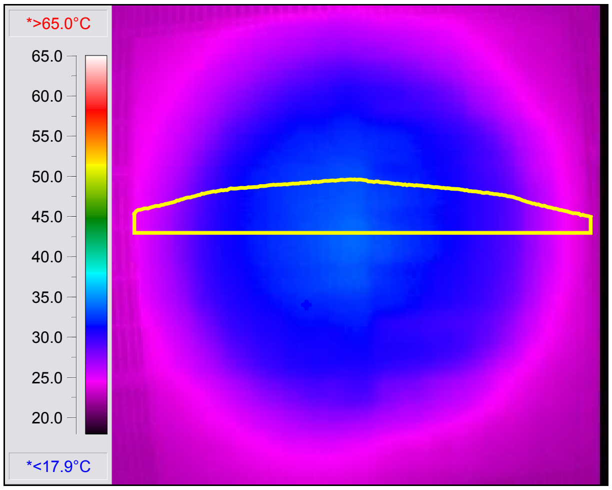

Figure 8a: 175SYL lamp in plastic fixture at 51-cm height with 0.9m (36-inch) 2D temperature profile.

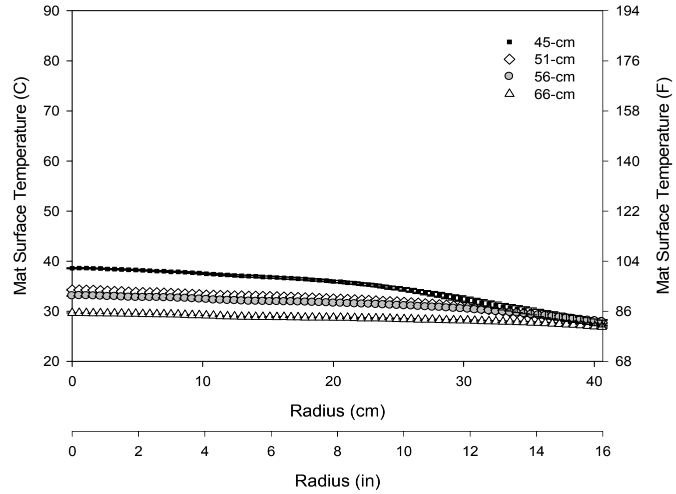

Figure 9b: 175SYL lamp in plastic fixture at each height (n=3).

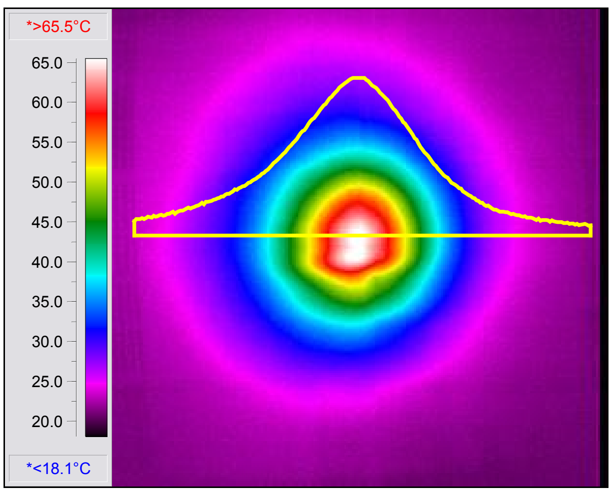

Figure 10a: 175PLP lamp in plastic fixture at 51-cm height with 0.9m (36-inch) 2D temperature profile.

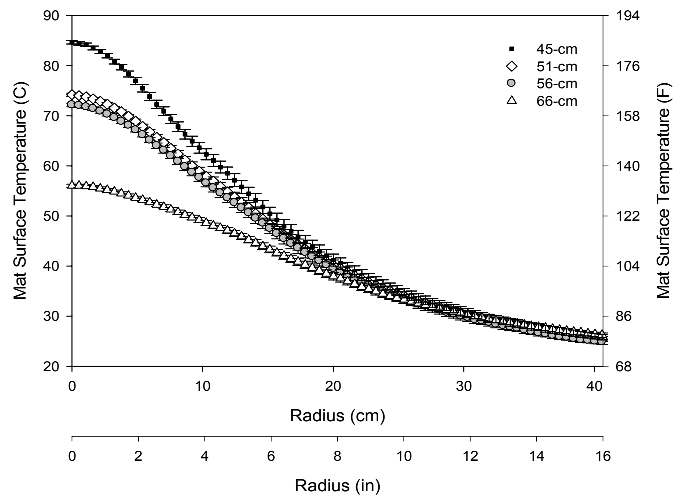

Figure 10b: 175PLP lamp in plastic fixture at each height (n=3).

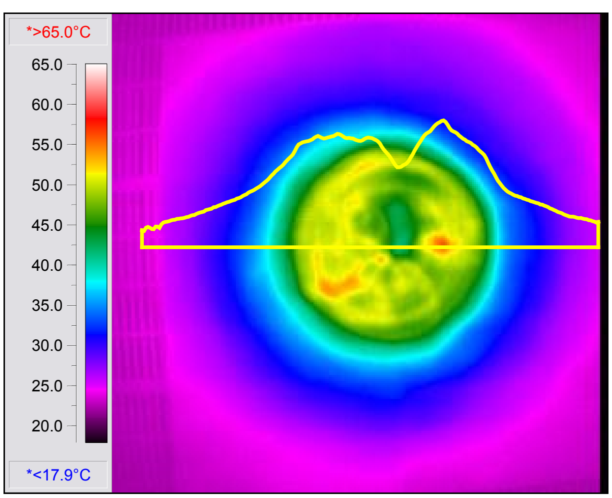

Figure 11a: 250SLI lamp in plastic fixture at 51-cm height with 0.9m (36-inch) 2D temperature profile.

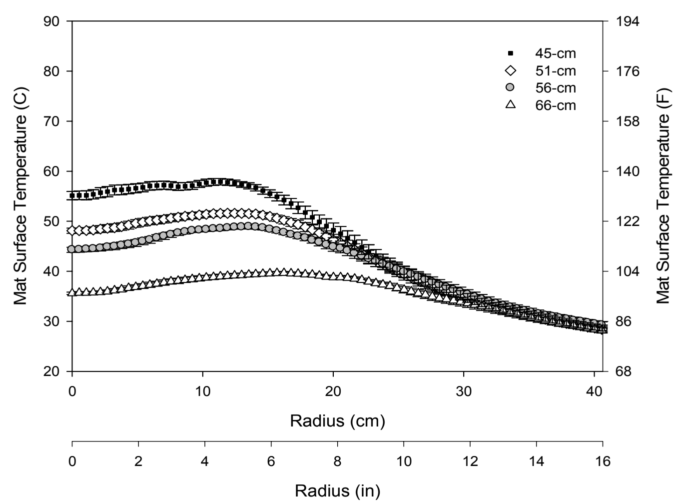

Figure 11b: 250SLI lamp in plastic fixture at each height (n=3).

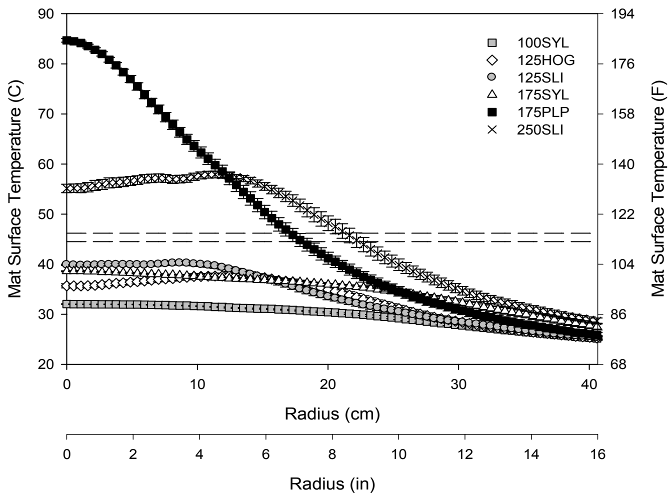

Figure 12: Radial temperature profiles of all lamps (n=3 each) in plastic fixture at 45-cm (18-in) height.

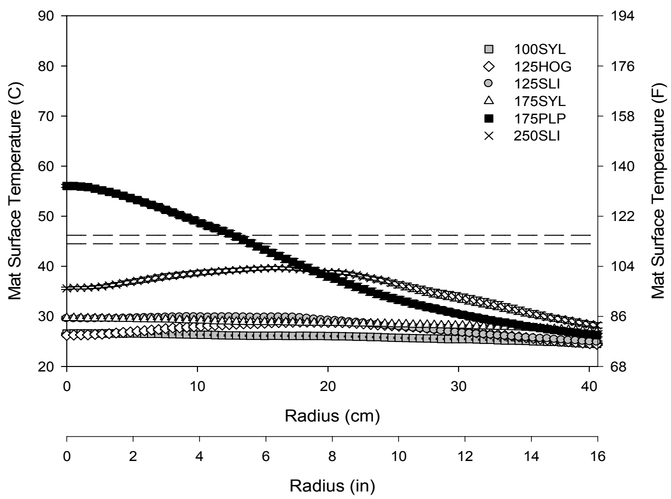

Figure 13: Radial temperature profiles of all lamps (n=3 each) in plastic fixture at 66-cm (26-in) height. Illustration of maximum contact temperature range (---).

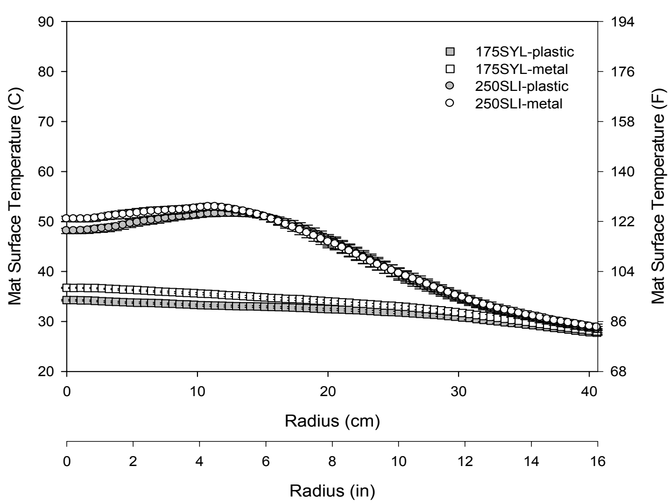

Figure 14: Comparison of plastic and metal lamp fixtures for both the 175SYL (n=3) and 250SLI (n=3) at 51-cm (20-in) height.

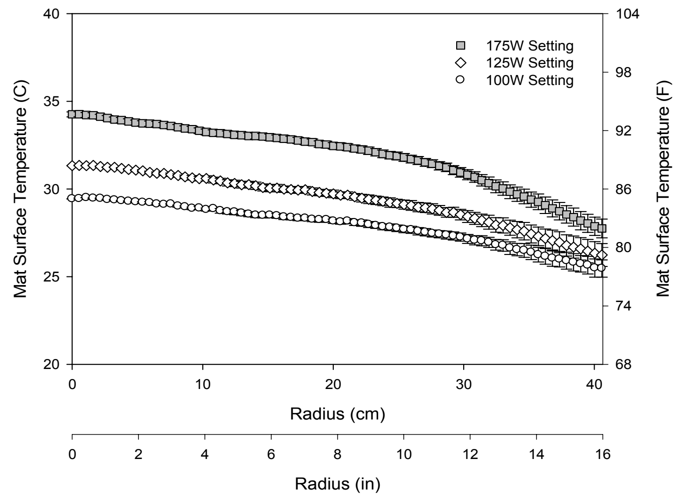

Figure 15: 175SYL lamp with plastic fixture and DPC at 51-cm height (notice y-axis scale change).

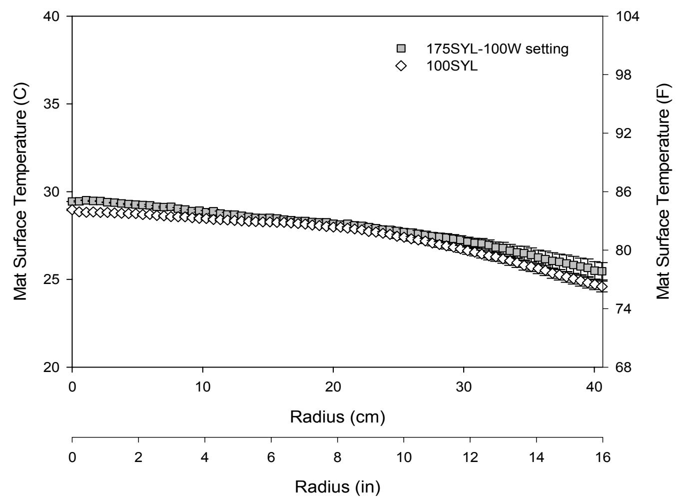

Figure 16: Comparison of 175SYL with DPC (100W setting, n=1) and 100SYL lamp (n=3) using plastic fixture at 51-cm height (notice y-axis scale change).

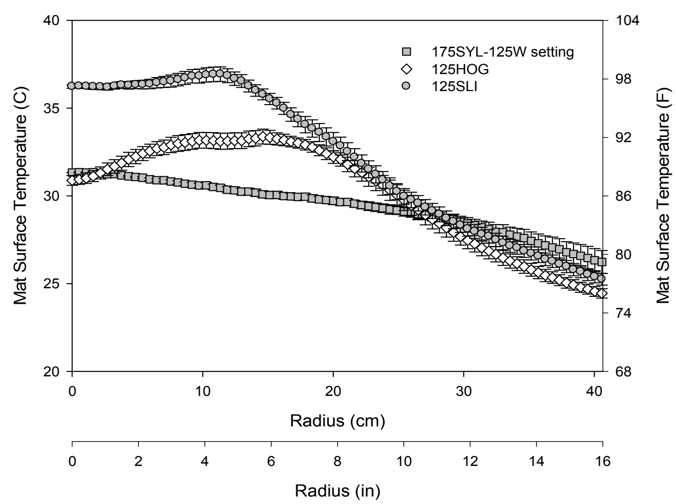

Figure 17: Comparison of 175SYL with DPC (125W setting, n=1) and 125HOG and 125SLI (n=3 each) using plastic fixture at 51-cm height (notice y-axis scale change).