Producing Uniform High Illumination Large Area Backlight Systems with Long Life

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Abstract

Establishing and maintaining optimum lamp operating temperature is critically important in backlight systems for large area displays. The information presented in this paper is based upon work completed for a tiled 37.5" AM LCD, plus projections for a 37.5", 42" & 50" monolithic display. Due to the size of the units, a requirement for highly collimated light and a requirement for high brightness, >550 nits at the display surface, significant wattage is required which generates high heat levels in the backlight display assembly and potentially, at the display rear surface. Uniformity of illumination becomes an important element in the system design because of the large area involved.

1. Introduction

In the design and operation of a backlight system for an AM LCD display, it has been known that there are several very important factors that affect the performance of the system. These factors include, lamp design and lamp operating parameters, reflections and optimum utilization of the generated light, and the electronic drive parameters of the system. When operating a backlight assembly for a large area display, an additional factor becomes critically important: that is the optimization and control of the temperature of the lamps. Control of this parameter determines the maximum light being generated, the uniformity of illumination, the life of the backlights and the life of the electronic drive mechanism.

This paper will discuss the affect temperature has on the performance of the display system, as well as prove the importance of optimizing all of the elements of the display system.

2. Size, Power and Efficiency of the Backlight System

Adequate control of a backlight system becomes more problematic as the size of the display system increases. Table 1 shows the dimensions and areas for three different large area displays as compared to a 20" display. As can easily be seen, the increase in area is substantial which translates into an increase in the magnitude of the issues.

Table 1. Display Area by Format

Display Size	Format	Horizontal	Vertical	Area (in^2)	Area (cm^2)
20"	4 x 3	16"	12"	192	1239
37.5"	16 x 9	32.75"	18.5"	605	3903
42"	16 x 9	36.6"	20.5"	760	4903
50"	16 x 9	43.5"	24.6"	1071	6910

Due to the requirement for highly collimated light, we needed to generate approximately 30K nits of light at the lamp surface in order to have >550 nits at the display surface for large area displays. To generate this level of light, you need 200-250 watts of power for the multiple lamps needed. This translates into a requirement to generate close to 90 lumens per watt. To operate at this brightness and efficiency level, HCFL (hot cathode fluorescent lamps) are used because they are significantly more efficient than CCFL (cold cathode fluorescent lamps) at high brightness levels. Using all of these criteria, table 2 shows the expected performance measurements for the sizes of display shown.

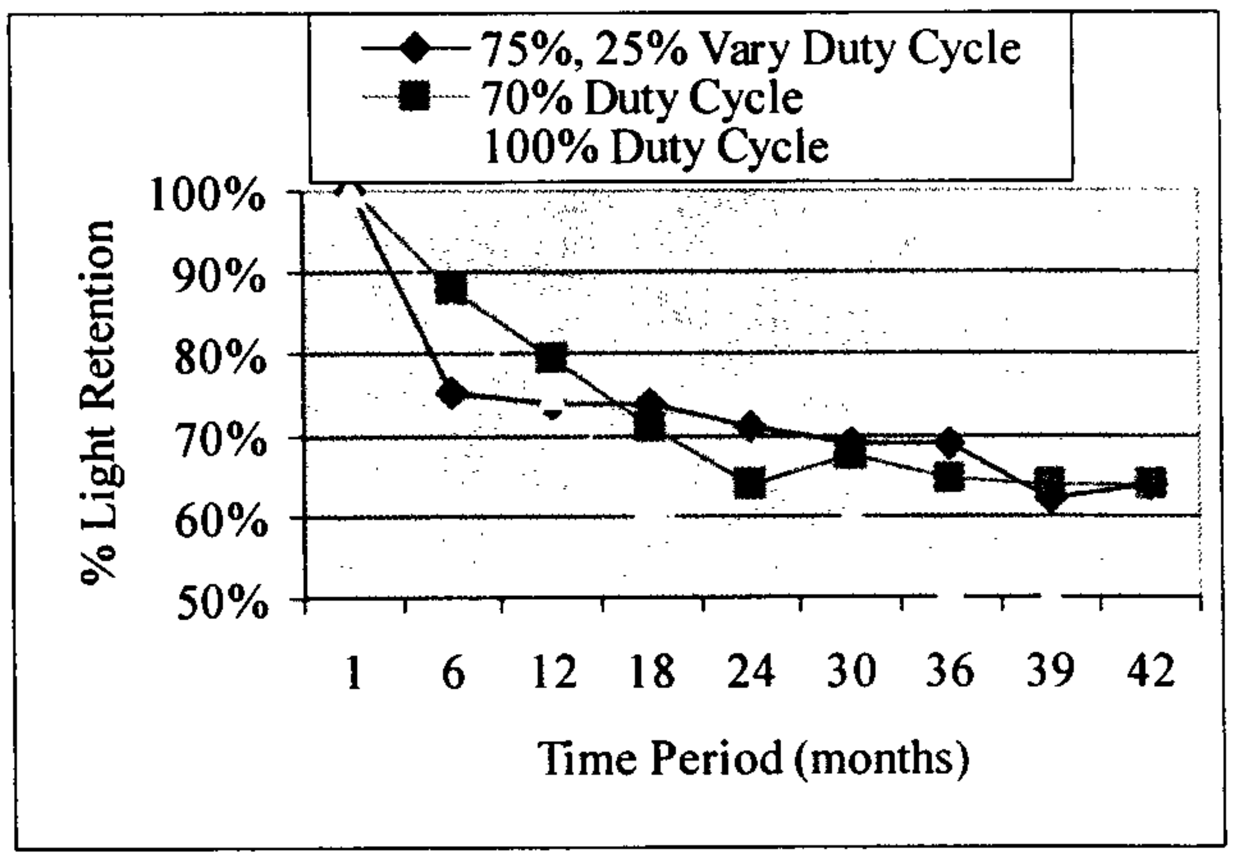
Table 2 Performance Measurements

Display Size	Brightness (K nits)	Power (W)	Life-Time (Hours)	# of "U" Lamps
37.5"	550	200	45K	3
42"	550	240	45K	3
50"	550	200	50K	4

3. Summary of Life Test Results

Figure 1 shows the light output of three backlight systems over a time period of 42 months (>30K hrs), with varying duty cycles, but each had very good control of the lamp temperature. A duty cycle is defined as the brightness level the lamps are operated at, during the time period noted. One unit was operated at 100% duty cycle, while a second unit was operated at 70% duty cycle and the third unit varied the duty cycle between 25% and 75% each day.

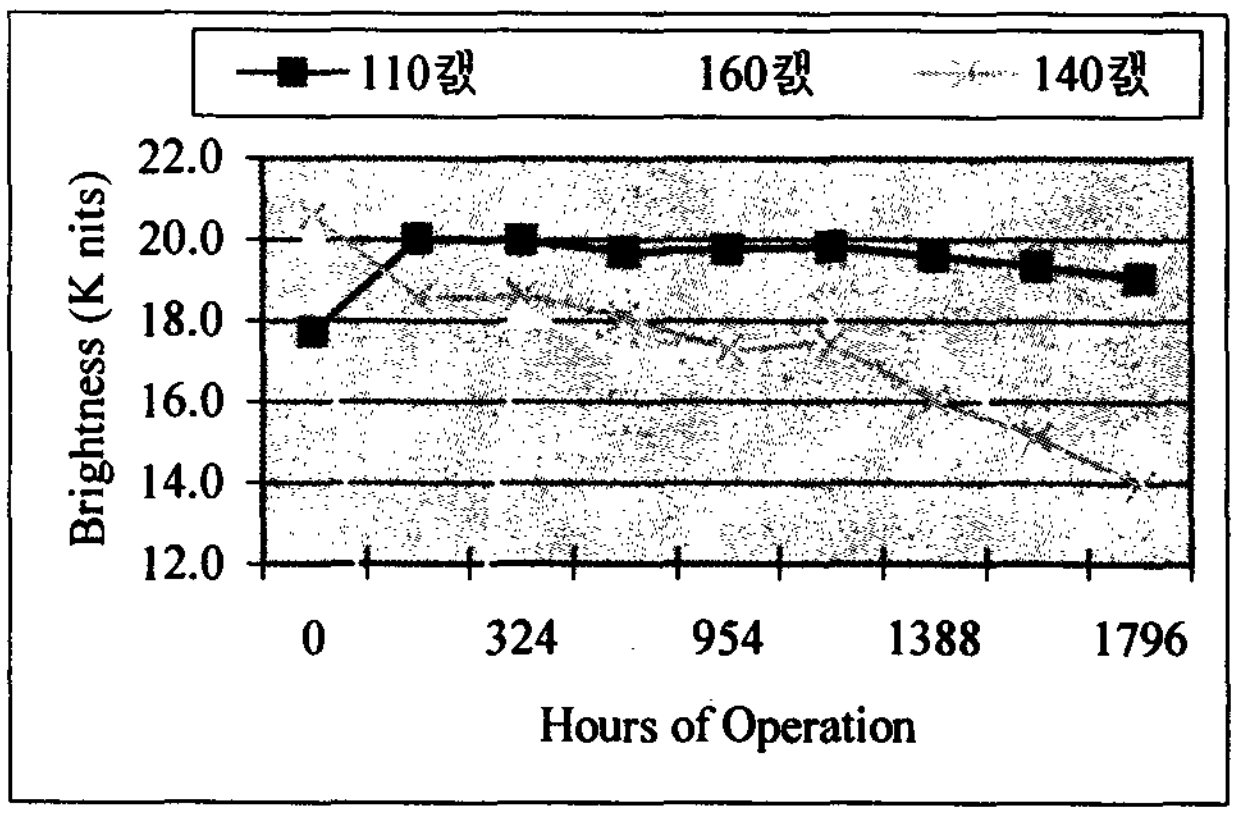
Figure 1 Lamp Life with Different Duty Cycles



The test results show that the unit which was operated at 100% duty cycle through the entire test, reached end of life (defined as 50% of the original brightness) at 39 months (28K hrs.). The two units, which operated at lower duty cycles, each show almost 65% of the original light output after 42 months (>30K hrs.). This figure extrapolates into >45K hrs at the defined end of life. In each of these test units, the cathode and lamp surface temperatures were closely controlled.

The affect of over-temperature on the lamp surface is summarized in Figure 2. In each of these tests, the cathodes temperature was closely controlled, while the lamp surface temperature was maintain at three different levels, 110°C, 140°C and 160°C. Each test consisted on four (4) straight-legged lamps mounted horizontally in a test rig. The temperature was measured at three points of each lamp and then averaged for that lamp. The averages of each of the four lamps in each test was then averaged again to get the results for that test, as is shown in Figure 2. These tests were conducted over 1800 hrs of continuous 100% duty cycle run time. The rapid decline in the average brightness of the lamps in the 140°C and 160°C tests, are readily apparent, as compared to the relatively stable brightness readings @ 110°C.

Figure 2 Lamp Temperature Affecting Life Time



If we look at the results of the reading on the individual lamps in each test, we can see that the position of the lamp does have some affect on its performance. In each test lamp #1 was positioned at the top of the unit, while lamp #4 was at the bottom.

Figure 3 Lamp Life @ 110°C

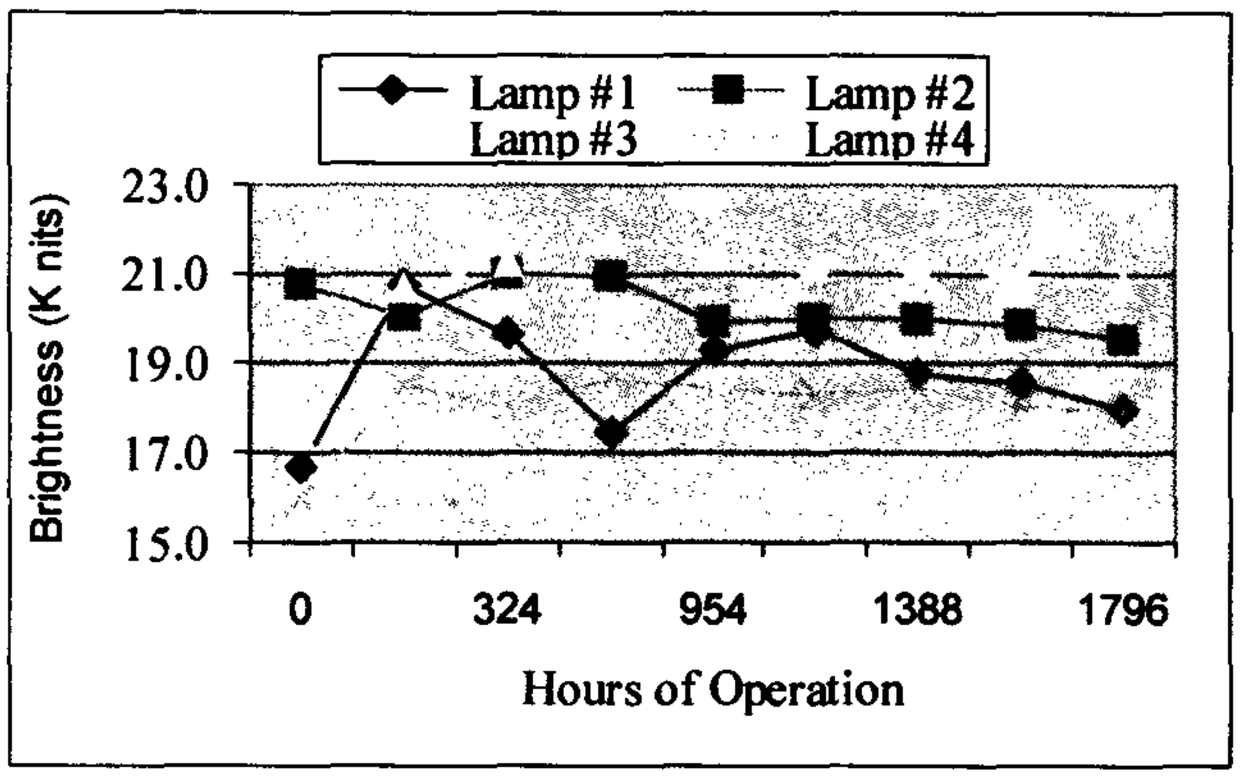
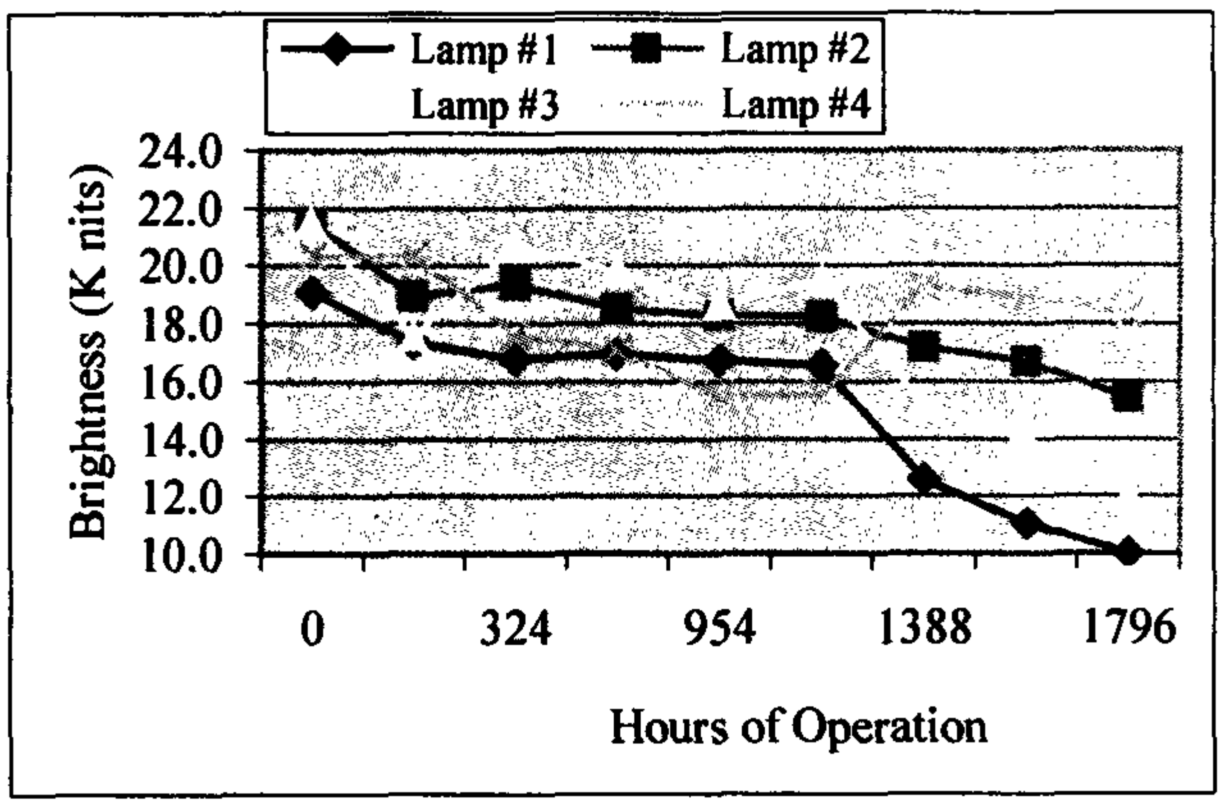


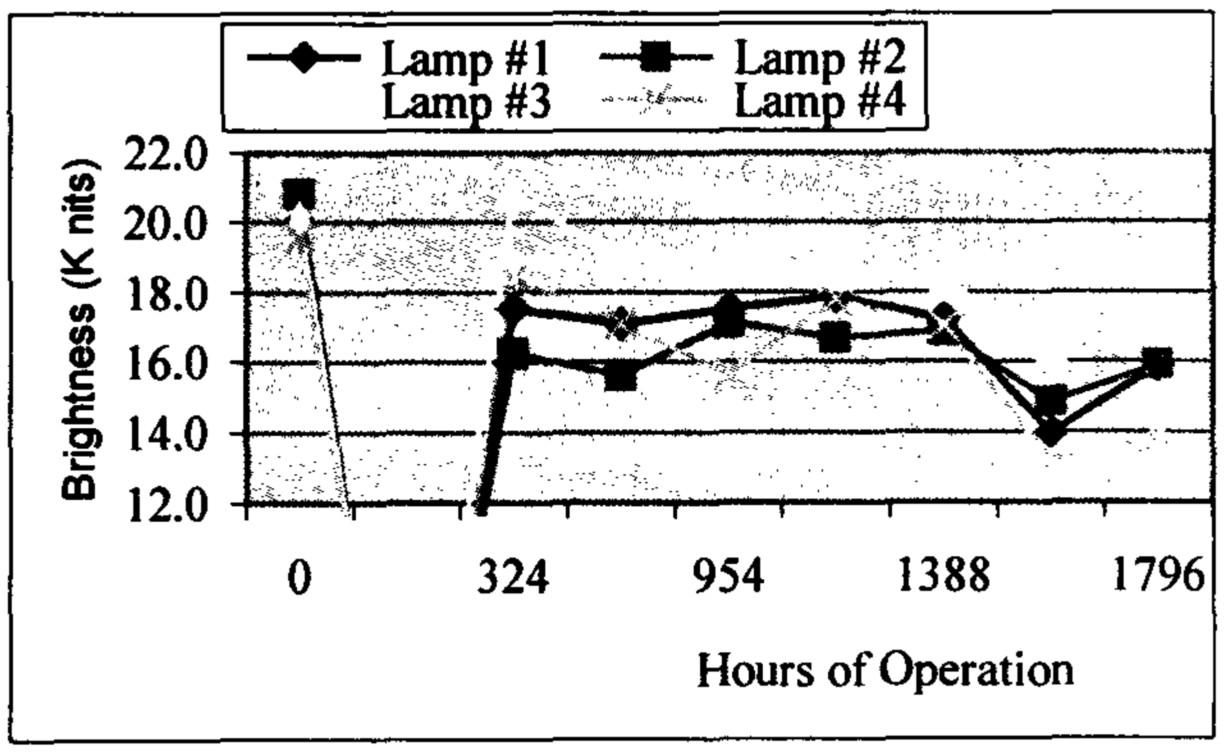
Figure 3 shows the results of the 110°C temperature, with the exception of lamp #1, the brightness readings over the time period are essentially flat. Lamp #1 was in the top position, and we did not attempt to have temperature control on individual lamps. We were monitoring the overall temperature of the test rig only.

Figure 4 Lamp Life @ 160°C



In the 160°C test rig, it is very apparent that the slope of the brightness is downward during the entire test. Lamp #1 reached E.O.D. (end of life) in a little over 1800 hrs. Lamp #3 is very close behind, with EOD being only a few hundred hours away.

Figure 5 Lamp Life @ 140°C



While the slopes of the brightness readings in the 140°C, as shown in Figure 5, are not as dramatic as the 160°C, it is very clear that these lamps will be failing within the next few thousand hours. The only conclusion one can make is that the temperature along the surface of the lamp has an impact on the life of the lamp. Based upon this information, one needs to determine what is the optimum lamp surface temperature for maximum lamp brightness.

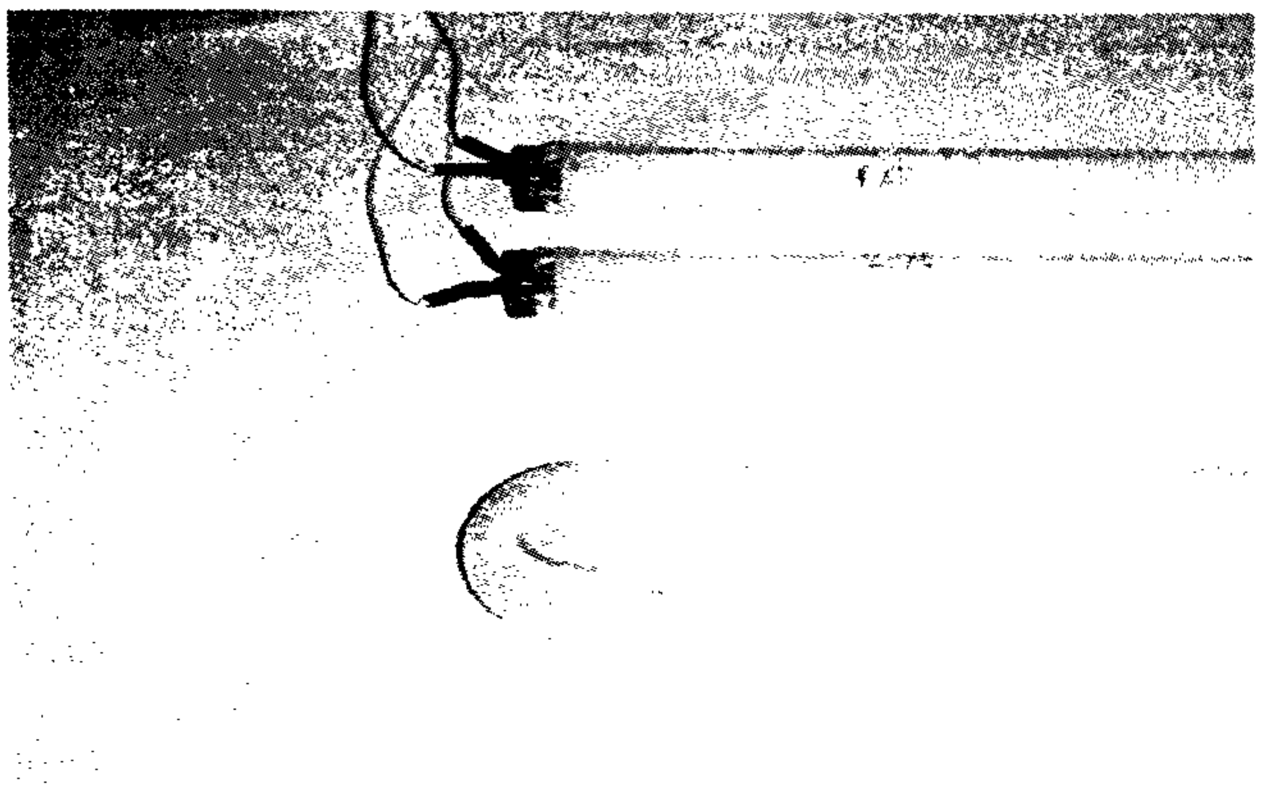
4. Cathode Temperature Control

The pictures shown below compare the lamps from a backlight system using straight-legged lamps vs. a backlight system using "U" shaped lamps. The advantages of using "U" shaped lamps are:

a. Fewer terminations than two straight-legged lamps, therefore, it is more efficient. (4 terminations vs. 8 terminations)
b. It is easier to control all of the cathodes, since they are in the same area of the backlight system.

Figure 6 Right End of Lamps

Figure 7 Left End of Lamps



From a wiring point of view, using the "U" shaped lamps provides for a cleaner assembly, since all lamp terminations are in one area of the backlight system, as can easily be seen when comparing figure 8 and figure 9.

Figure 8 Backlight Assembly using Straight Legged Lamps

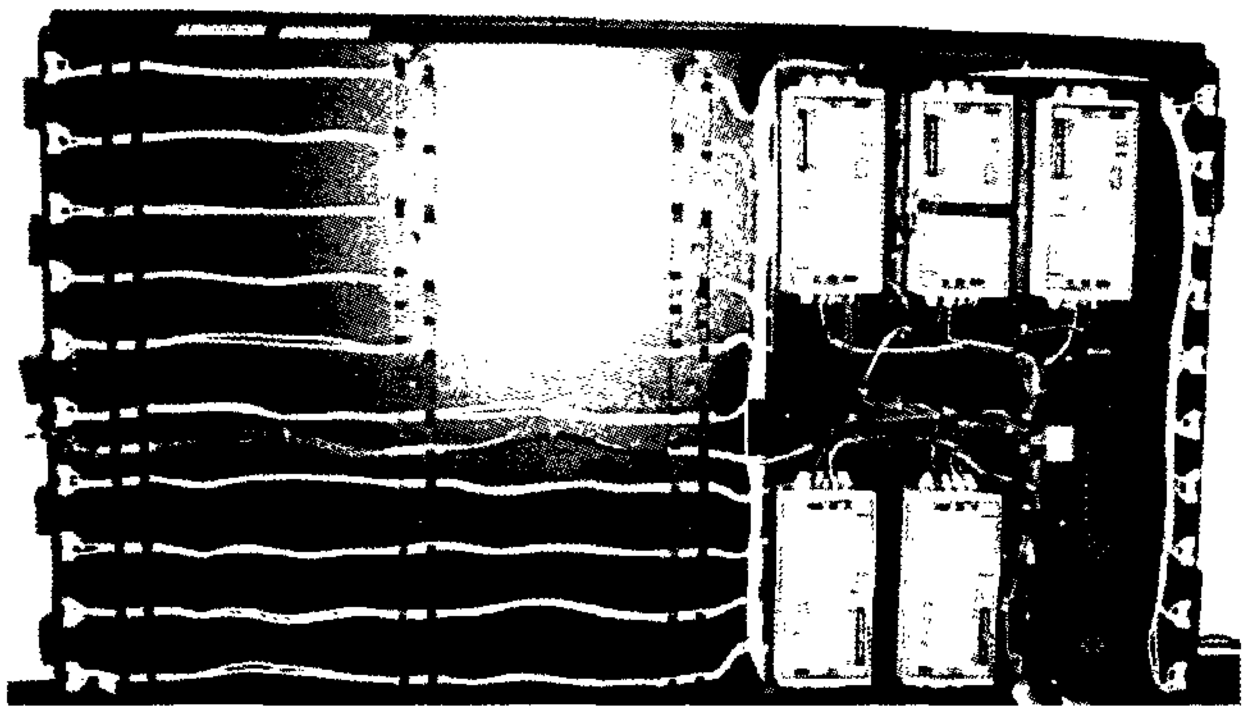
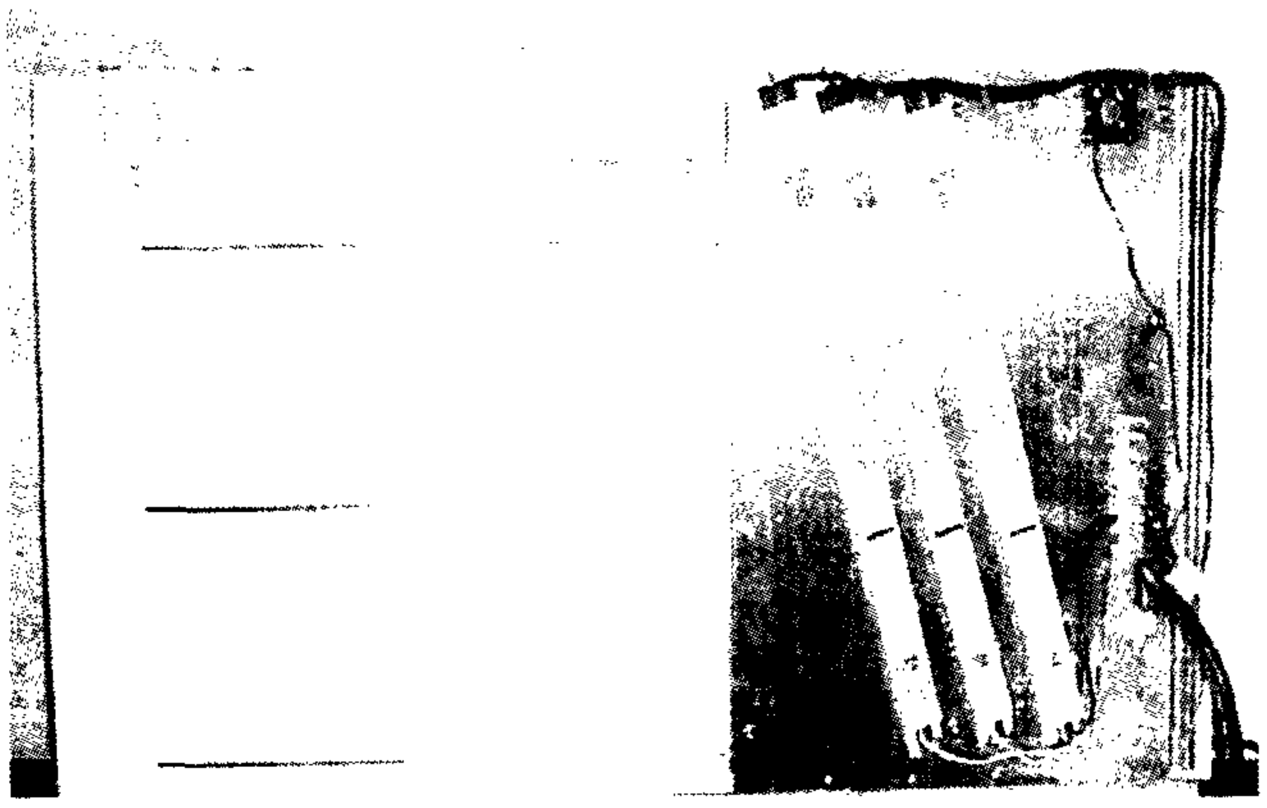


Figure 9 Backlight Assembly using "U" Shaped Lamps



The advantages are readily apparent. Not only have we reduced the wires carry high voltages from the ballast to the lamps (helping to minimizing EMI & RFI), we also have all of the cathodes located along the right side of the unit, where one simple heat sink can maintain uniform temperature control across all of the cathodes. Uniform cathode temperature control is one of the critical factors, which affects the life of the lamp and optimum brightness.

With all of the cathodes along one plane, we can now utilize a temperature sensor mounted to the heat sink to control the temperature of the cathodes. Additionally, we have created a secure mounting structure for one end of the lamps, while only a semi-rigid, inexpensive mounting scheme is required at the "U" end of the lamp.

5. Lamp Wall Surface Temperature Control

The brightness along the length of a lamp is influenced by several factors, including lamp properties such as phosphor thickness uniformity, internal pressure and mercury content. Ballast properties, which control the current through the length of the lamp, also are very powerful influence on the lamp brightness readings. In this test rig, we had a "U" lamp which we measured the temperature and the brightness at 6" intervals along its entire length, as is shown in figure 10.

Figure 10 Measurement Points Along the Lamp

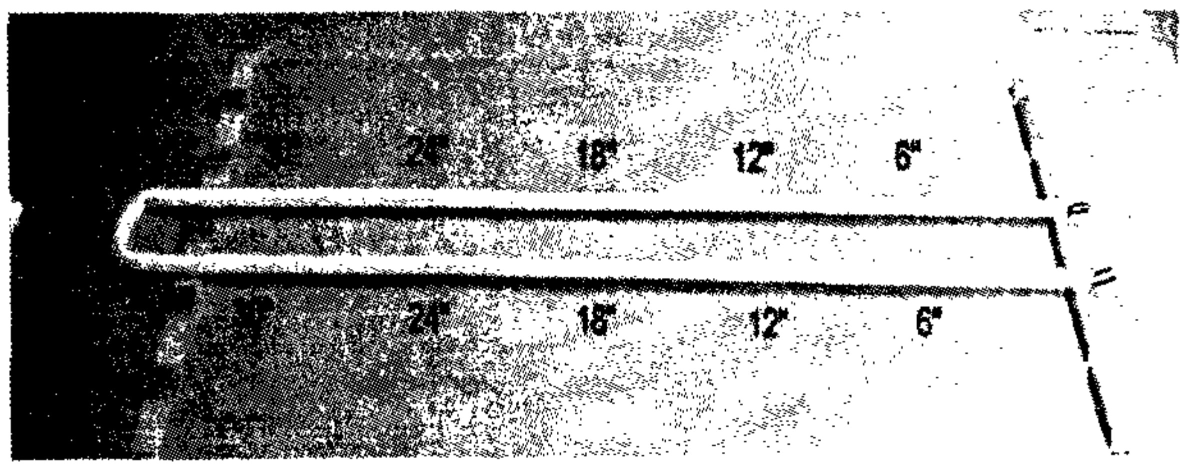
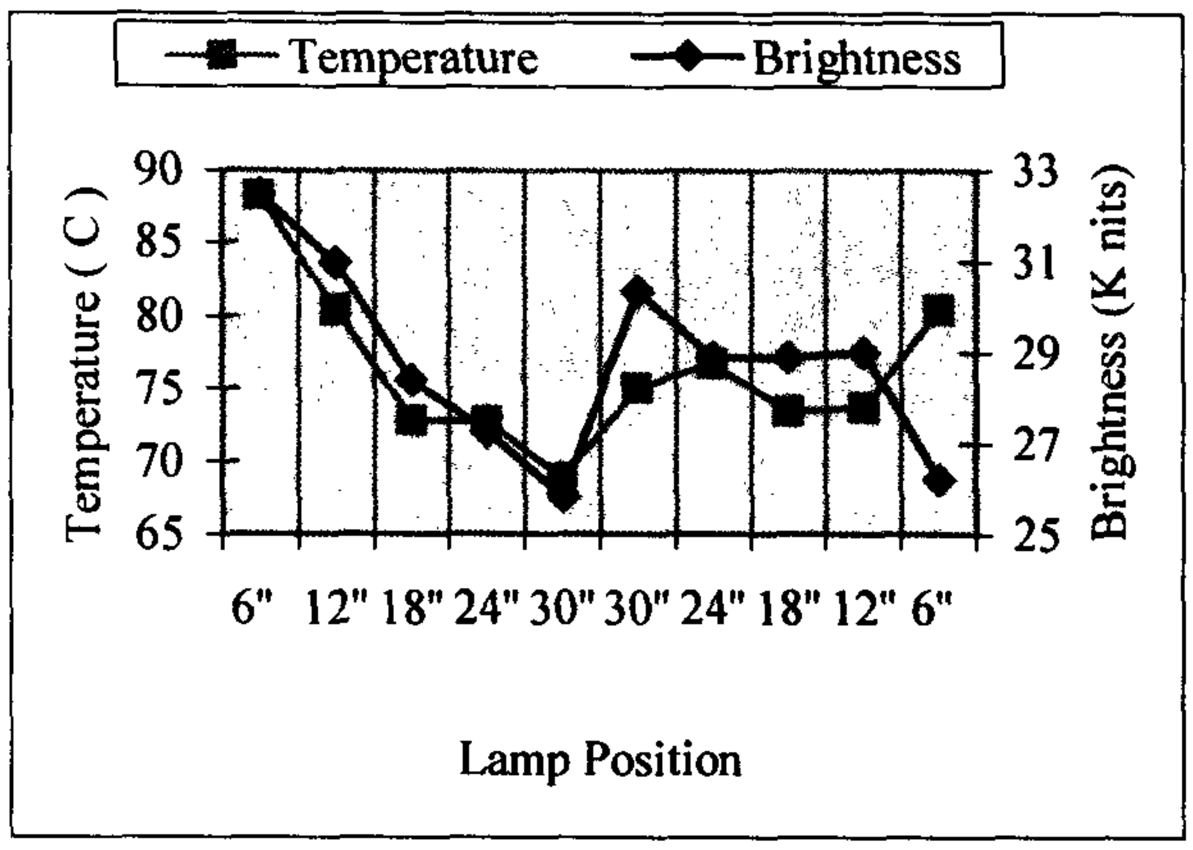


Figure 11 illustrates the temperature of the lamp surface along its length, as well as the corresponding brightness, when a lamp was measured in a test rig.

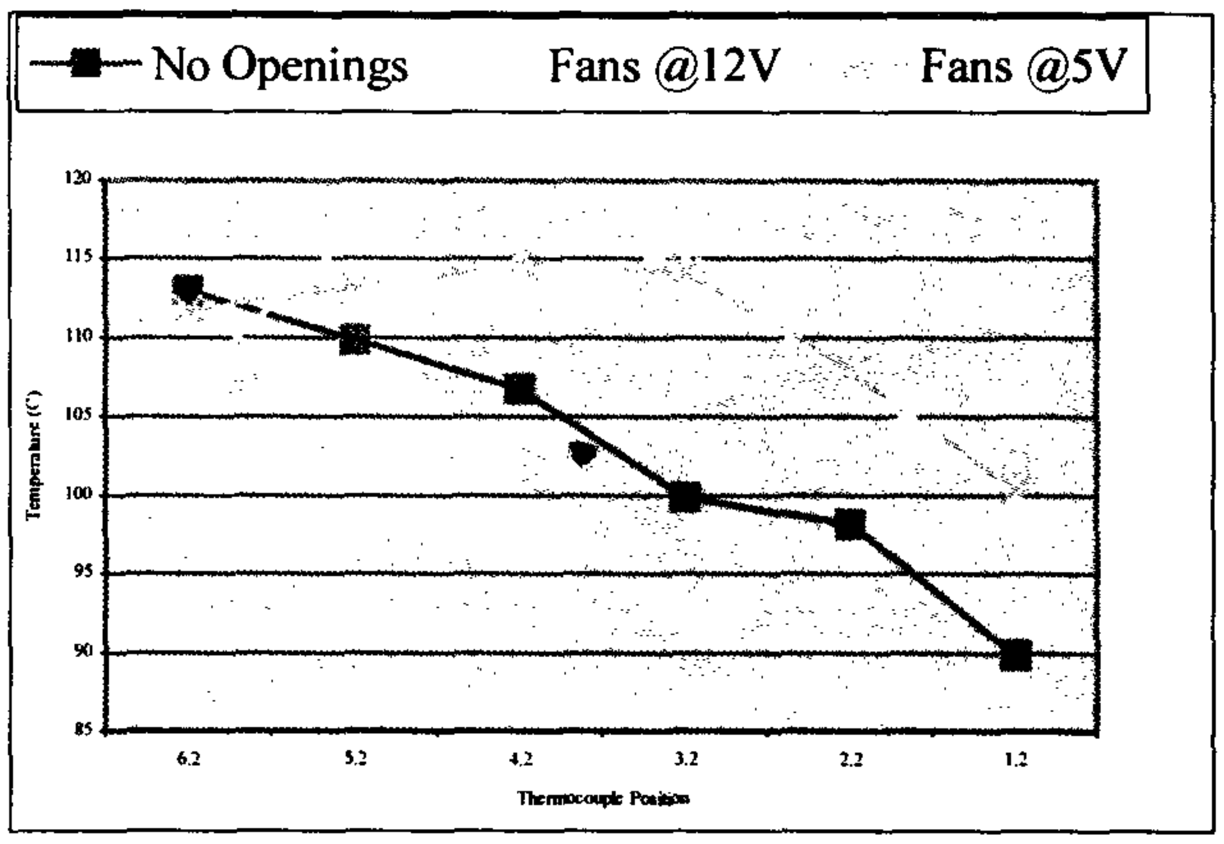
Figure 11 Lamp Brightness & Temperature in a Test Rig



The lowest temperature and brightness reading were measured near the "U" bend, which is not surprising, since this is the greatest distance from the cathode point, combined with variables from the coating process. During this test, the lamp was laid flat in the test rig, with the cathodes mounted in a heat sink. There was no attempt to control the lamp surface temperature. It is clearly apparent that lamp spot temperature affects lamp spot brightness.

In a backlight assembly for a large area display, the affect of having multiple lamps arrayed in a horizontal pattern, leads to a thermal control issue. The requirement is to control the temperature of all of the lamps, so that you can obtain the maximum uniformity. This generally requires that the lamp in the lowest position be allowed to heat up as much as possible, while the lamp near the top of the assembly, need to have positive control of the air around the lamp surface. In figure 12, we measured the mid-point on each leg of three "U" shaped lamps in a complete backlight assembly.

Figure 12 Lamp Temperatures in an Assembly



It is interesting to note that with the addition of the fans, at either 7V or 12V, the overall temperature of the lamps increases as well as uniformity.

6. Air Insertion and Brightness Control

The complexity of obtaining uniform lamp surface temperature is dependent upon several factors, including:

1. Size of the backlight system
2. Brightness required
3. Number of lamps
4. Spacing between the legs of the lamps
5. Maximum power being used

Equally important at high brightness levels is the ability to control the temperature of ballasts, plus maintaining a control air curtain between the backlight assembly and the rear surface of the LCD panel.

Through our experimentation, we have determined that pulling air in up through the backlight area provides the most reliable means of obtaining uniform lamp illumination. While some of the lamps in the backlight assembly will not require air-flow to maintain uniform brightness, other lamps will require air insertion across specific sections of the lamp.

Additional control of lamp surface temperature can be gained by the use of a feedback system for fan speed and having the ability to vary individual lamp current. Our experience has shown that adequate uniformity can be obtained with just temperature sensing and fan speed control.

7. Conclusion

We have demonstrated some of the key issues, which need to be addressed in order to produce high brightness, uniform backlight systems for large area displays. Of equal importance to this effort is the optics assembly, which is placed between the backlight and the LCD panel. Recent development work has produced a new enhancement technique, which aids in producing uniform illumination, in addition to reducing the power required, thereby making the control task easier.

8. Acknowledgements

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9. References

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