DOME® by NDSsi

Long-Term Reliability of Factory Characterized LCD Displays

Peter M. Steven, Ph.D.
February 2010

For over a decade, Dome C series and Dome E series LCD displays have been factory characterized for DICOM display calibration as part of the manufacturing process. Characterization is best done in manufacturing where the process can be tightly controlled for ideal circumstances. High-quality, expensive photometers can be used because the cost of their calibration and maintenance is spread across a large number of displays, which is impractical in most end-user settings. The characterization data is then stored individually in each display where it can be recalled in the field for automated DICOM calibration. Due to the precise factory characterization, new Dome LCD displays offer the best DICOM conformance found in the industry without needing to recalibrate in the field. For this method to work over time, however, the LCD displays must maintain the same characteristic curve, so the factory characterization data can be used years later to calibrate the display.

Numerous experts have evaluated LCD technology and have concluded that LCDs are very stable over time. There are many reasons to believe that the characteristic curves of an LCD will not change significantly over its life. Nevertheless, some monitor manufacturers continue to question this stability. This is understandable since many monitor manufacturers have a history building old CRT displays, which undoubtedly affects their view of displays generally. CRT displays were notoriously unstable over time, requiring frequent recalibration to stay DICOM compliant. We can now provide field data to test the stability of LCD displays over time.

This paper analyzes conformance test data collected from a group of 22 Dome displays*. The group included color and grayscale displays at 3 MP and 5 MP resolutions. Dome displays record the actual backlight power-on hours, so we can be very precise about the age of the panels. The displays ranged in age from new with less than 27 power-on hours to nine years old with over 33,000 power-on hours. We evaluated the data to determine how the displays' factory characterization performed over time. The conformance data were collected with an independent external photometer, different from the photometer used for factory characterization or the internal sensor used for display control.

Using the standard DICOM metrics (defined in DICOM Part 14, Annex C), the results were outstanding. The LUM metric — a measure of the standard error of just noticeable difference (JND) intervals — ranged from 0.041 to 0.352. This is well below the recommended limit of 1.000. The slope of the line through the conformance points was less than ±0.0033, where a slope of zero would be perfect. The mean step size is approximately 2.6 JNDs per digital driving level (DDL).

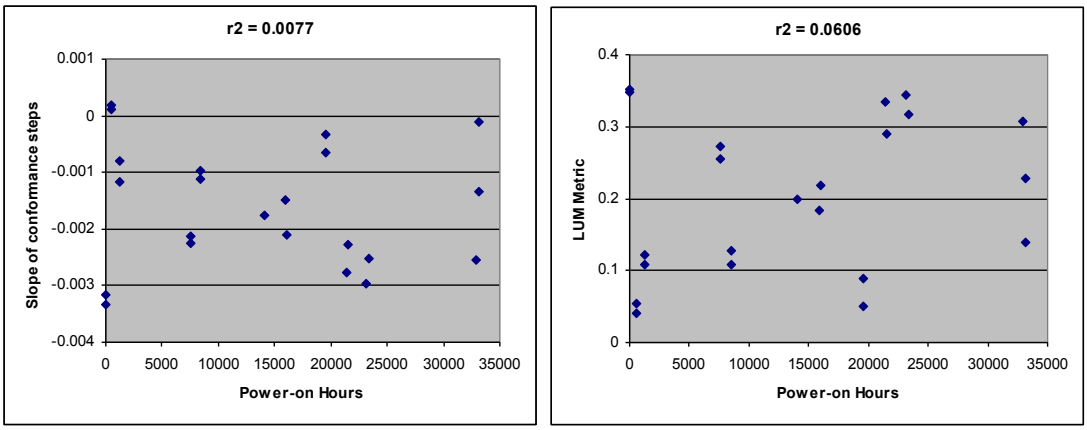
* The data were provided as a courtesy by Jihong Wang of MD Anderson. Dr. Wang did not perform the data analysis, does not necessarily endorse or agree with the conclusions, and was not compensated in any way for providing the data.

The data indicates excellent conformance to the DICOM display function over the life of the products. The results given in the table below are the averages for each grouping. The average slope was calculated using the absolute value to give a consistent deviation from zero.

Metric	< 1000 hrs	1000 - 5000	5000-10,000	10,000-20,000	20,000-30,000	> 30,000 hrs
n of displays	4	2	4	5	4	3
LUM metric	0.19864	0.11453	0.19062	0.14787	0.32160	0.22513
Slope	0.00170	0.00099	0.00162	0.00126	0.00263	0.00133
JND/DDL	2.63199	2.51976	2.57358	2.62652	2.77804	2.54559

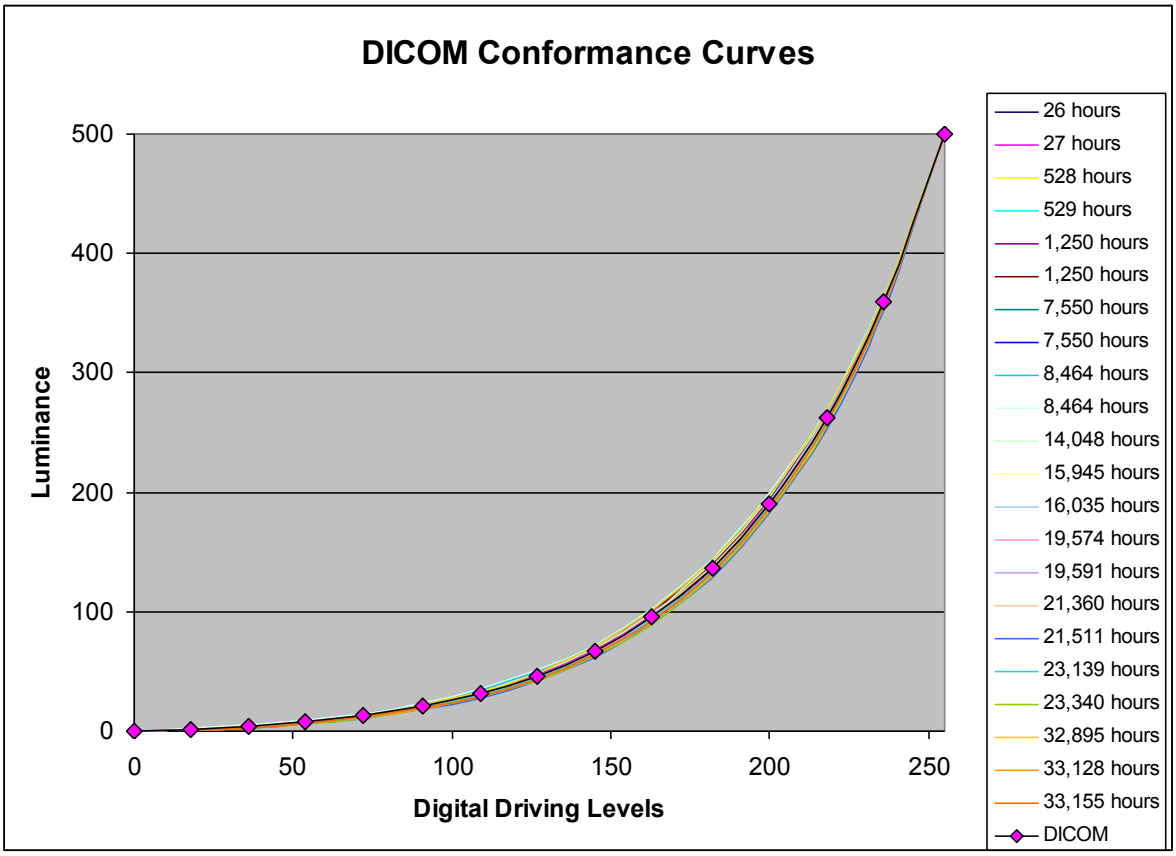
These results are consistent with every evaluation of Dome displays we have conducted in the past. This demonstrates that careful characterization as part of the manufacturing process remains an effective and unobtrusive method for automatic calibration.

We next tested the correlation of the power-on hours of the display to the conformance statistics to see if there was an aging trend. Again, the results here were quite compelling. The correlation coefficient, r^2, ranges from zero to one and indicates how closely related two measurements are. In our case, we compared power-on hours to both the slope and the LUM metric. The correlation in both cases was well below 0.1 suggesting no statistically significant relationship between the conformance results and the age of the panel. The data, plotted below, show the scattered, random appearance of two unrelated measures.



The data are a powerful demonstration of the remarkable stability of the Dome display characterization over time. Even after 9 years, the original factory characterization accurately represents the display's behavior.

Finally, we include that plots of the DICOM conformance curves. We have normalized the maximum luminance for this plot to make the results comparable. The 22 display conformance plots are virtually indistinguishable from the DICOM target response curve regardless of their age.



Characterizing medical displays in the most careful controlled environment possible with the most precise calibration equipment available is the ideal. Dome's method of factory characterization closely approaches this ideal performed under carefully controlled conditions, with an industry-standard, high-performance photometer. This method has significant advantages over making less accurate and less well-controlled measurements in the field, particularly when using sensors intended for gross validation, not precise calibration. Our factory photometers are regularly calibrated to the National Institute of Standards and Technology (NIST) standard and have certified NIST-traceability. Sensors mounted in the display cannot be calibrated and have no traceability to the NIST standard. The data here demonstrate not only the accuracy of our factory characterization, but the remarkable stability of the LCD response function over time.