AARDENBURG IMAGING
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On the Use of Data Loggers in Picture Frames (And Other) Micro Climates

Data loggers are used in a variety of applications at Aardenburg Imaging & Archives. They monitor storage and display environments at the historic Hyde House in Lee, Massachusetts. They log accumulated exposure in our accelerated light fade test units, and they record light, temperature, and relative humidity in the micro climates of the picture frames deployed in our real world digital print research studies. There are numerous low-cost data loggers available today for temperature and relative humidity monitoring, but the choices for tight-budget projects narrow dramatically when light intensity measurements are also required. Other factors must also be considered. For example, the Aardenburg Digital Print Research Program requires:

1) Extended field deployment time equal to or greater than one year with absolutely no maintenance or human intervention required of the project's participants.

2) A light measuring range from less the 50 lux to greater than 50,000 lux (three orders of magnitude is a common occurrence when considering print viewing locations in typical home and office environments).

3) Small size and low weight that facilitates direct installation into a conventional picture frame (comprised of glazing, frame, typical matting, and mounting materials).

4) A data logging hardware solution that costs less than $250 per picture frame unit.

The technical overhead associated with data loggers is generally not a large burden for trained museum, library, or archives staff, but the AaI&A digital print research project had to consider the

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consequences where participants may be "technology challenged". More and more remote site measurement solutions are being offered by data logger vendors, yet none appeared to meet our cost constraints or the "no human intervention" ease of use we were looking for. Remote site installations require human interaction from time to time, if for no other reason than to reset a misbehaving internet or phone/modem connection. Yet the ultimate reason for AaI&A to use an annual "swap and replace" data logging solution for the field work is that we also need to reclaim the environmentally monitored prints from time to time in order to analyze color, tone, and other physical properties of the actual prints in the study. So, extended and sustainable field operation of the data loggers and data downloads coinciding with the retrieval of the framed prints became an important consideration in determining which data logger to use for the project.

In fact, no single data logger in the market today appeared to meet all of the project design criteria, but the use of two Hobo U12-012 data loggers did meet the project design goals. Of course, two units per picture frame doubled the data logger capital and operating costs, yet the total price still met the target cost per picture frame unit. On the upside, the use of two data loggers also doubled the memory capacity, and by splitting temperature, RH, and light measurement intervals between the two data loggers, a one year unattended monitoring period with adequate sampling frequency was achieved. One data logger is set to record low to moderate light levels, temperature, and RH every 39 minutes while the other is set to log moderate to high light intensity levels every 13 minutes. The seemingly odd time increment of 13 minutes accomplished two objectives, namely, to log environmental data continuously for over one year before requiring data download, and second, to avoid unwanted time frequency synchronization with nominally recurring environmental events such as HVAC programmed set points or seasonal sunrise and sunset times. Lastly, by adding a neutral density filter in front of one of the Hobo light sensors, and by establishing an efficient calibration routine at AaI&A, we achieved an approximately 20 to 80,000 Lux recording range from each pair of Hobo light sensors.

Micro Climates Fundamentally Differ from Macro Climates

It is well-known that micro climates exist within larger macro climates and that their very presence is defined by the environmental differences that exist between them and the greater surrounding macro climate. Most data logger projects relate to macro climate monitoring not micro climate monitoring. For example, monitoring an indoor gallery space, a museum storage room, or an outdoor agricultural site all present a relatively abundant supply and movement of air over the surface of the data logger sensors. However, micro climates exhibit a very common condition of limited ventilation and subsequently static air qualities. Combine the static air with the natural moisture absorbing properties of hygroscopic materials like wood, paper, and textiles, and micro climates often exhibit significantly more steady-state environments than their surrounding macro climates. Micro climates can be specifically implemented to reduce the deleterious effects of light, heat, and humidity, and air pollutants within an indoor storage or display environment. However, an additional consequence of the limited airflow and the effective moisture buffering by the hygroscopic materials is that the response of the data loggers placed in these micro climate environments must be interpreted with much greater care. Data logger sensors have their own thermal mass and sensor surface response that depends on air flow to maintain real-time responsiveness to a change in the environment. The sensors are often located within the data logger's case or housing of some kind. Reduced air flow to the sensing unit then creates another micro climate within the data logger case that lags behind the micro climate which one intends to measure.

If the environment that the logger "sees" is merely lagging behind the environment that one is attempting to monitor, then the transient condition is simply a delayed recording of the actual environmental response. However, at times a transient response can be unlike the actual conditions occurring within the micro environment that one is attempting to evaluate. Figure 1 illustrates this point. A picture frame was located inside one of Aa&A's light fade units. The surrounding macro climate (actually, another micro climate) is designed to maintain 60%RH ± 5%RH. The temperature at the sample plane is largely controlled by building HVAC, the light fade unit only being cooled by additional forced-air fan ventilation when needed. The light fade unit also creates two light/dark cycles every 24 hours, so the lamps turn on between 9:00am and 5:00pm and then again between 9:00pm and 5:00am. Meanwhile, the building HVAC during this time of the season uses a temperature setback at night, and the sluggish response of the baseboard heating system to the 7:00am HVAC call for more heat leaves the temperature inside the picture frame at a lower temperature value at 9:00am than at 9:00pm when the HVAC temperature set point is still calling for a higher temperature. Now, observe the effect of the light cycle. When the lamps turn on, the temperature in the picture frame begins to rise. The goal is to achieve an approximately 75˚F sample plane temperature during the lamp "on" cycle. During the initially rapid rise

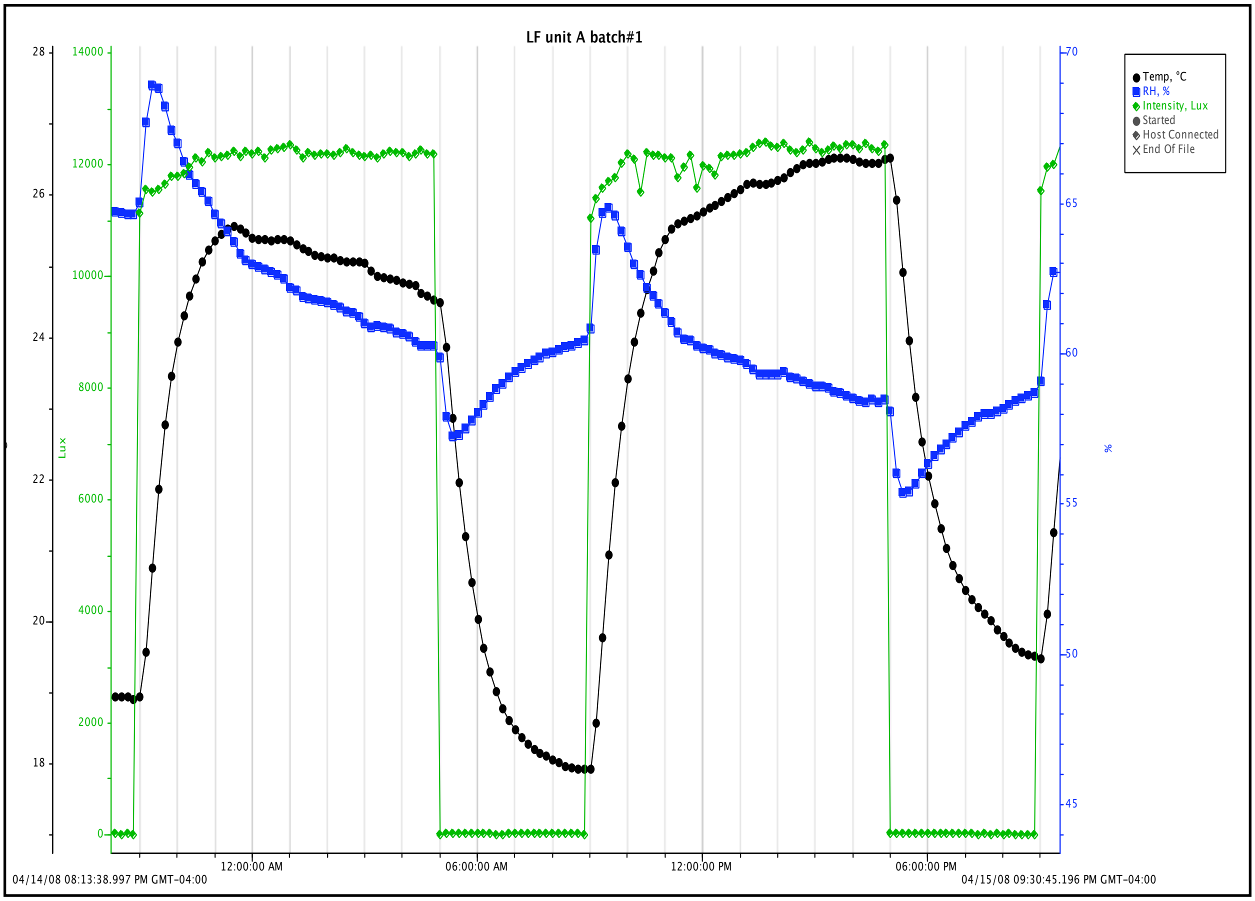

Figure 1. Micro climate Response of a Picture Frame Located in an Accelerated Light Fade Chamber

in temperature, the data logger is also recording a spike in the relative humidity. This spike is a transient data logger response which is not actually occurring at the print sample plane. What is really happening is that the print paper and mat board are more quickly rising in temperature than the data logger temperature sensor housed in the body of the data logger. Their rise in temperature drives some moisture out of these paper materials, but the picture frame glass prevents this moisture from being released into the surrounding environment of the light fade unit. Rather, the extra moisture follows the temperature gradient path to the cooler air behind the mat board which is also where the temperature and RH sensor cavity of the data logger is located within the picture frame. The RH sensor dutifully records an increase in RH in this location within the picture frame. It is a consequence of the moisture migration from the print sample plane and the temperature gradient within the picture frame. A similar inverted spike occurs at the beginning of the lights "off" period. If one ignores these spikes and looks at the overall light and dark cycle trends in RH, a more accurate interpretation of the actual RH at the print sample plane is made. Thus, correct interpretation of the sample plane RH requires understanding that the print sample plane is being slightly desiccated not humidified when the lamps are on. During the lights "off" dark period the print sample and mat board begin to recover some of the lost moisture and the total environmental cycle repeats itself the next day in test. The macro climate controls the long term average temperature of the system, but the short term micro climate response reveals the light-induced temperature gradients and moisture migration occurring within the picture frame. Note, also, the subtle influence of the building HVAC on the temperature response of the picture frame during the light exposure in the evening hours versus the light exposure during the daytime hours in test.

Data logger Software, Interpretation, and Advanced Filtering in Excel

My final remarks concern data logger software and interpretation of results. Data logger software is usually very basic, allowing one to view and plot the data but not much more. Often the supplied software uses auto scaling, and I've seen some software packages where auto scaling cannot be turned off. The user therefore has little to no control over the scaling used to generate graphs of the data. This situation in turn can lead inexperienced users to an unwarranted sense of concern when looking at plots that appear to show very large oscillations in temperature, RH, etc. I recall once listening to a presentation at a preservation conference where the speaker expressed great dismay that a valuable historic textile was being subjected to severe temperature cycles in the museum gallery where it was being displayed. He showed a data logger graph with very large roller coaster peaks and valleys in the plot to underscore his point. However, he had failed to consider the auto Y scaling that the data logger software had utilized to amplify the graph between minimum and maximum temperature values. The gallery was holding temperature to 21˚C ± 1˚C, but the full-height temperature swings looked very alarming to the untrained researcher and his audience! It is helpful to have data logger software where one can override auto scaling behavior and apply more rational scaling values when circumstances require it.

The Hoboware Pro software is very good, but ultimately one needs to be able to filter and analyze data beyond the simple scaling, averaging, and sub setting of the data that is provided by most vendors' software. Vendors understand this requirement. I've never seen any data logging software that doesn't allow one to export the data as a comma or tab delimited text file that can then be read by spreadsheet software such as Microsoft Excel. Excel allows one to conveniently filter, scale, and analyze data as necessary. It also enables calibration control over the sensors when a calibration option isn't provided by the vendor. For example, in our real world print monitoring research AaI&A calibrates the Hobo U12 light sensors by importing the raw data into Excel and applying corrective calibration curves for three illuminance ranges, 20–200 lux, 200–1000 lux, and 1000–20,000 Lux. The corrective equations are determined by comparing the Hobo readings to measurements made with a NIST traceable instrument grade radiometer. The corrective equations also include the neutral density filter attenuation that prevents saturation of the Hobo light sensors in direct or nearly direct sunlight situations where illuminance levels can reach 60,0000 to 80,000 Lux.

The need to perform special filtering of the data is particularly important for micro climate evaluations due to the transient responses of the data logger sensors as illustrated in figure 1. For example, in the light fade test data, we want to sort temperature and RH results during the "lights on" time periods from the "lights off" time periods. We may also want to isolate and remove the spikes that aren't representative of the print sample plane. In real world studies, we want to look at temperature gradients associated with high light levels greater than 1000 lux, for example, to analyze the solar heating load on a picture frame exposed to direct sunlight streaming though a window during the day. Excel performs these types of analyses easily and routinely.

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