2.4 Protection from Light Damage

INTRODUCTION

When we think of light damage, we think of fading, but fading is only the most recognizable form of damage.

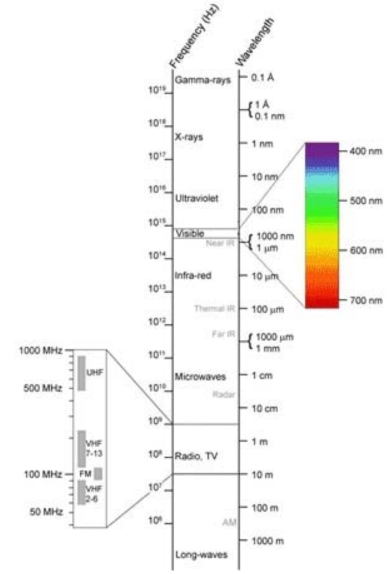
Light is a very common cause of damage to collections. Many materials are particularly sensitive to light: paper, cloth, leather, photographs, and media (inks, colorants, dyes, and many other materials used to create objects and art). Aside from fading, there may be damage to the physical and chemical structure of materials. Light and ultraviolet radiation (UV) provides energy to fuel the chemical reactions that lead to deterioration and while UV is blamed for most of this damage, visible light is also problematic.

Intensity and long exposure times can lead to fading or changing colors in dyes and colorants. Ultraviolet radiation will lead to weakening, bleaching, and yellowing of paper and other organic materials. All of these changes can diminish readability, affect the aesthetic appreciation of artwork, and impact access to the information contained therein. Even if you take a faded photograph down and store it in the dark, it will not return to its original appearance and will continue to fade when taken out again.

Because this damage is cumulative andirreversible, it is important to understand how to protect materials in the first place.

THE NATURE OF LIGHT

Light is the band of radiation that allows us to perceive color and is composed of many different wavelengths that correspond to specific colors. Bookending the visible light spectrum is ultraviolet (UV) and infrared (IR) radiation. Neither UV nor IR is visible, but they are damaging: UV radiation will yellow and weaken materials and IR will cause the surface of objects to heat up. The visible spectrum and UV radiation are of greatest importance for preservation.



Electromagnetic Spectrum

The visible spectrum runs from about 740 nanometers (nm is the form of measurement applied to radiation) to about 380 nm. Ultraviolet radiation lies just below the short end of the visible spectrum (below 380 nm) and infrared (IR) radiation lies just above the long end, but their existence does not affect how our eyes perceive color.

There are two ways we can measure how the human eye responds to light: Color Rendering Index (CRI) and Color Temperature (CT). CRI measures – on a scale from zero to 100 – light quality in relation to the eye's ability to see colors correctly. There is no standard for an acceptable CRI but museum lighting designers suggest 80 - 100 to ensure colors can be viewed properly. Daylight falls at 100 on the CRI scale while many compact fluorescent lamps (the industry term for bulbs) are near 80 and LEDs, while variable, can read as high as 90.

Color Temperature measures the quality of light from cool to warm in units of degrees Kelvin (K). CT can be somewhat confusing since warm light—usually referred to in relation to gold to red tones—has a lower CT than cool light, usually referred to in relation to blue tones. Because fluorescent lamps and LEDs come in a wide range of color temperatures, be sure to check the specifications for each lamp you are considering. Cooler light (3500-5000K) will increase the contrast of objects, which may be desirable but may also alter the appearance of the object. Because of this, warm light (2800K) is preferred by the museum community (when the lux levels are low).

MEASURING LIGHT LEVELS

Visible light levels are measured by a light meter in lux or foot-candles. Lux, simply stated, is the measure of the intensity of light over one square meter. A foot-candle, the old imperial measurement of light intensity, equals about 11 lux. To get the most accurate measure, the meter should be placed where the object will be located and situated just as the object will be when it is on display.


UV meter

In general, light meters only measure visible light; to measure the proportion of UV radiation in light, a UV meter must be used. UV meters, however, can be expensive: if a meter is not available, it is best to assume that sunlight, fluorescent lamps, and quartz-halogen lamps will read above the recommended maximum of 75 µW/lm (microwatts per lumen) and that displays in this light will require filtering. Manufacturer's information is available about UV emissions for the various lamps that are on the market: checking the manufacturer's website will generally provide you with the specific information you need.

If no light or UV meter is available, it is possible to estimate the damage that might result to an artifact from particular intensities of light and lengths of exposure. This can be done using the ISO' Blue Wool standard cards, available from a number of conservation suppliers.
More than other measurements, the Blue Wool cards visibly demonstrate the destructive powers of light. Because these cards provide a standard against which subsequent fading can be judged, they can be used to convince skeptics that light really is a problem. Each Blue Wool standard contains eight samples of blue-dyed wool. Sample 1 is extremely light sensitive, while sample 8 is the most stable dye available (although not permanent). Sample 2 takes twice as long to fade as sample 1, sample 3 takes twice as long as sample 2, and so forth. For more information, see "Light, Ultraviolet and Infrared" by Stephan Michalski in Resources.

To demonstrate the degree of fading caused by the intensity of light in a particular location, cover half of the card with a light-blocking material to protect it completely from light damage (or cut the card up into strips reserving one as a control). Note the date and set out the Blue Wools in the desired location. Check periodically (every couple of weeks) to determine how long it takes the various samples to fade. Since the sensitivity of the first few samples on the card corresponds to light sensitive materials such as watercolors and textiles, the results will give you a general idea of the amount of damage you might expect if materials were exhibited for the same period of time at the current ligh level in that location.

In most cases, a general correlation between the sensitivity of the artifact and the Blue Wool standard's scale will be sufficient to allow informed decision-making.

SOURCES OF LIGHT

There are two sources of light: sunlight and electrically produced light. As a primary light source, sunlight is not recommended. It is too intense, causes extensive fading, and has a high UV component, which also causes damage at the chemical level. Different types of electrical lighting may be required for storage, staff, public, and exhibition spaces within libraries, museums, and archives. It is helpful to understand the available options and characteristics to select the best option for lighting these spaces. The most common lamps found, especially in storage and exhibit spaces, are:

Blue Wool Card

caption

- **Incandescent lamps**
  - **Tungsten lamps** produce light when an electric current is passed through a tungsten filament. These lamps convert only a small percentage of the electrical current into light; the rest is given off as heat. The traditional tungsten lamp is being phased out and will be difficult to obtain after 2014.
  - **Quartz tungsten-halogen lamps** are a variation on the traditional incandescent lamp; they contain halogen gas inside a quartz bulb, which allows the light to burn brighter and longer. Quartz tungsten-halogen lamps are often used in exhibition lighting; examples include the Halogen Parabolic Aluminized Reflector (PAR) and the Multifaceted-Reflector (MR) lamps. These lamps give a very good light spectrum overall but emit a lot of heat. The casings get very hot, and the lamps have been known to explode.

- **Fluorescent lamps** contain mercury vapor inside a tubular glass lamp whose inside surface is painted with white fluorescent powder. The lamp can come as a tube in multiple lengths and diameters, in compact tubes (CFT), and in various shapes to screw into traditional incandescent fixtures (CFL). Fluorescent lamps are inexpensive to use but the commonly available versions emit significant UV radiation. Manufacturers do make low UV versions of all of these lamps so check the manufacturer’s website for accurate information on specific lamps.
- **Light Emitting Diodes (LEDs)** are semiconductor devices (materials with electrical conductivity) that can emit a specific spectrum (color temperature) of light depending on the semiconductor material used. LEDs do not emit UV or IR radiation and the light does not generate heat (although the conductor box does). They can supply light for a lower energy cost and have a longer lifespan than other light sources. There is a wide variance in color temperature and CRI and the intensity of the light can diminish over time.

For more information on lamps for libraries, archives, and museum spaces, see Michalski, “Light, Ultraviolet and Infrared.”

CONTROLLING LIGHT DAMAGE

Light damage to leather binding

Molecules, the basic chemical building block of all materials, are in constant motion. On the electromagnetic spectrum, as the wavelengths get shorter, the

potential energy increases. When this energy is introduced to the molecules, they vibrate more quickly (they get “excited”) and begin to spread out. Thus, wavelengths that are short (e.g., those from the ultraviolet portion of the spectrum) will increase the vibration of the molecules and encourage them to expand, then cleave, and bond again, which leads to the deterioration of plant and animal fibers. In addition, this re-bonding can change the way that visible light interacts with the material, causing a change in the wavelength of the light and, as a result, we are shown a different color. For example, a book with a dyed leather cover sits in the sunlight at the end of a shelf, over time, the light causes the molecules in the dye to vibrate more quickly, bump into each other like a demolition derby, and change their shape. The light hitting and reflecting off these new molecules changes the speed of the wavelength and thus the color the eye perceives in relation to the dye changes. The general term for this process is photochemical deterioration.

Along with fading, another of the primary photochemical reactions is oxidation, in which the “excited” molecule transfers its energy to an oxygen molecule, which then attracts other molecules to initiate damaging chemical changes including embrittlement and yellowing. While the reactions can be extremely complex, the result is always deterioration.

As wavelengths become longer—toward the infrared end of the spectrum—they have less energy and reduced capacity to “excite” molecules. However, the energy absorbed from infrared radiation can increase an object's temperature. High temperatures are another form of energy that increases molecular vibrations and speeds up the damaging chemical reactions. For more information on temperature and its effect on collections, see NEDCC leaflet 2.1: *Temperature, Relative Humidity, Light, and Air Quality: Basic Guidelines for Preservation.*

Since UV radiation is the most energetic, and thus the most destructive, it is easy to assume that if UV radiation is eliminated, damage will cease. Unfortunately, this is not the case; visible light also causes damage. While exposure to U can be eliminated from exhibit and storage areas (and diminished in public spaces with filtering and lamp selection), reducing visible light requires different strategies.

In storage areas, strategies to control the damage caused by light and UV radiation include:

- putting light sensitive items into boxes;
- keeping the lights off when no one is retrieving materials or installing motion sensors on the lights (this step also saves on electricity costs);
- filtering tubular fluorescent lights with UV blocking sleeves (no filters exist currently for compact fluorescents); and
- covering windows with shades.

There are a number of ways to control light in combined storage and staff or public spaces:

- Cover windows and skylights with UV blocking film and shades which should be closed during the most intense light of the day.
- Filter tubular fluorescent lights with UV blocking sleeves (no filters exist currently for compact fluorescents).
- Keep collections off of top shelves and away from direct contact with windows.
- Protect any materials that may be particularly susceptible to light damage, such as framed color photographs or watercolors, by displaying away from any direct light (sunlight and spotlights) and glazing with UV blocking glass or Plexiglas or by displaying good quality facsimiles.
- Keep lights off when spaces are not occupied, especially after hours.

Filtering Ultraviolet Radiation

As mentioned, UV radiation can be filtered. UV-filtering films for windows, exhibit cases, glass fronted cabinets, etc., are flexible and adhere to glass, acrylic, or polycarbonate. Filters vary in the wavelengths of UV radiation they block, as well as the amount they are able to block. Filters can be clear or tinted (filtering visible light as well) and many can act as insulation from solar heat gain. UV-filtering film is most effective if it covers the surface it is placed on completely so that all light passes through it. For information on acceptable window films and how they age, as well as many helpful charts of the different manufacturers' films, see "UV-Blocking Window Films for Use in Museums – Revisited" in the Western Association for Art Conservation (WAAC) Newsletter, listed in the Resources.

If film is not an option, acrylic panels that have built in UV blocking capabilities can be used. The acrylic can be used:

- in place of window glass (if fire regulations allow);
- mounted as secondary glazing on existing windows; or
- mounted inside the window from hooks, magnets, or a separate frame (the panel must be cut larger than the window glass, so that all light passes through it).

Filters for tube-shaped fluorescent lamps are available in the form of soft, thin plastic sleeves and hard plastic tubes. Filters are not yet available for non-tubular fluorescent lamps. While the hard plastic tubes are generally much more expensive than the thin sleeves, they are also much less likely to be accidentally discarded with the old bulb, as they are more conspicuous. Both filters should fit the tubes but, if necessary, two thin sleeves can be overlapped to form a longer sleeve for oversize fluorescent tubes. No specific guidelines exist for when to change these filters, but their useful lifetime ranges between 5-10 years.

Some fluorescent lamps produce less UV than others. If a low-UV fluorescent lamp is chosen (check the product literature for UV emissions in microwatts per lumen), UV filters may not be necessary, but would be an added benefit.

If fluorescent lights are housed in fixtures completely covered by a plastic shield (no open holes), sleeves may not be required for the lamps. The plastic shields often provide a moderate level of UV filtering but if the fixtures are in storage areas with unboxed collections materials, a layer of UV blocking polyester film on the inside will help improve filtering.

EXHIBITION LIGHTING

While on exhibit, collections are most susceptible to light damage and care should be taken to protect these materials. The intensity of light and the length of time the materials will be on display are the primary factors and need to be considered together.

Most collection materials can be on exhibit for three to four months at 50 to 150 lux and show no fading. A level of 50 lux is similar to the lighting in a home living room in the evening. For comparison, standard office lighting is around 400 lux and direct sunlight measures 30,000 lux. Lower light levels are necessary for light-sensitive materials such as watercolors, photographs, leather, textiles, and prints. Materials without color (printed text, black and white photographs, carbon black ink manuscripts, etc.) can be exhibited at up to 150 lux. It is acceptable to adjust the intensity of light up or down within this range depending on the sensitivity of materials. Very sensitive or fragile materials should be displayed with care or only displayed as facsimiles. No paper, wood, leather, textile, or other organic object should ever be on permanent display.

If the light levels are to be higher than 50-150 lux, the length of time on exhibit needs to be decreased accordingly. When making the decision about time on exhibit and light levels, be aware that low light levels for extended periods of time cause as much damage as high light levels for short periods. We can measure the damage to materials in direct proportion to the light level multiplied by the time of exposure, measured in lux hours (lx h). For example, an object lit for 10 hours a day at 50 lux for 100 days would have a light dosage of 50,000 lx h. Ideally, light-sensitive materials would only have an annual exposure of 50,000 lx h, regardless of whether they will be displayed annually or not. When considering how much and how often an item is to be on display, always keep in mind that light damage is cumulative and irreversible.

Using lux hours to track light exposure provides useful and concrete information on how bright exhibition lighting can be by clearly showing that the same amount of expected damage occurs with brighter light and short time as dimmer light and long time. In order to use this principle effectively, good records of exhibition durations and actual light levels must be kept.

Ultimately, every institution must decide on an acceptable upper limit of exposure (i.e., a certain number of lux hours per year) for exhibited objects, which may differ for different parts of the institution's collection. When establishing limits on exhibition times, factors to consider include:

- the amount of time the lights are turned on in the exhibit space (this figure is not always as straightforward as simply noting exhibition hours, since lights are often turned on for housekeeping or other purposes when the exhibit is closed to the public);
- the sensitivity of the items being exhibited;
- the desired lifespan of these items;
- the levels requested by a loaning institution; and
- the importance of aesthetic concerns in exhibition.

Finally, where possible, spotlights should not be trained directly on an object; if spotlights are necessary, appropriate filters must be used. Indirect and low lighting will spare the object, and will require less adjustment of the eye from areas of intense light to those of relative darkness, allowing the use of lamps with a lower wattage throughout exhibit spaces.

Labels explaining the reason for low light levels in the exhibit can be used to educate visitors and actually increase their understanding of the value of the collection.

CONCLUSION

All light is energy and the energy that light provides fuels destructive chemical reactions that contribute to the deterioration of collections in libraries, archives, and museums. Light also damages bindings, photographic emulsions, and other media, including the inks, dyes, and pigments used in many library and archival materials.

While all sources of ultraviolet light should be filtered, and the exposure of collections to visible light should be strictly controlled, the guidelines in this leaflet will allow institutions to take these factors together and make informed decisions reconciling the needs of their collections and their exhibitions.

RESOURCES

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