Chapter 5 Environmental Agents of Deterioration

A. INTRODUCTION

1. Deterioration of Museum Property

Deterioration of objects and specimens results from adverse environmental conditions. Changes in temperature and relative humidity, and exposure to light, dust, and pollution cause detrimental chemical and physical reactions in objects and specimens. Atmospheric moisture can cause corrosion of metals, warping of wood, and encourage mold growth. Excessive heat may cause certain materials to become embrittled. The visible and ultraviolet components of light can cause many materials to fade. **Although the effect of individual agents of deterioration upon an object or specimen may be devastating, deterioration of material most often results from a combination of agents working simultaneously.**

Objects and specimens continually interact with their surrounding environment. Rates of deterioration are not constant, but vary as they are influenced by a variety of factors. The more unfavorable the environmental conditions, the faster an object deteriorates. However, deterioration is most often a gradual process that occurs throughout the life of an object. The visual effects of such deterioration may become apparent quite slowly, and often escape notice by the untrained eye.

This Chapter addresses the environmental agents affecting museum property: temperature, relative humidity, light, and air pollution. Biological agents, microorganisms, insects, and vertebrate pests, are discussed in Chapter 6.

2. Museum Property Environmental Standard

Monitoring and controlling the environment in spaces housing museum property are key factors in ensuring the long-term preservation of a unit's museum property. Departmental policies and standards for environmental monitoring and control, as excerpted from 411 Departmental Manual, Chapter 2, are included in Appendix A.

NOTE: There are several legal mandates that require Federal agencies to conduct energy programs to reduce energy consumption and costs. The Federal Energy Management Improvement Act of 1988 and Executive Order 12759, April 17, 1991, are the most recent mandates requiring Federal agencies to practice energy conservation. While preservation of museum property should take precedence over energy conservation, it is essential that the decision-making process for controlling relative humidity and temperature support the goals of energy conservation. For example, using well-designed exhibit cases to maintain appropriate environmental levels for museum property is more energy cost effective than attempting to control the environment of an entire exhibit space.

B. TEMPERATURE

The important points to keep in mind about temperature are as follows:

! Generally, the lower the temperature, the better, because the rates of chemical reactions and biological activity decrease as the temperature decreases, and increase as temperature increases. Most chemical reactions double in rate with each increase of 10°C. When relative humidity levels are high, higher temperatures also tend to promote biological activity such as mold growth.

! Temperature can cause structural damage (e.g., waxes may lose their consistency at high temperatures). **Avoid abrupt changes in temperature**. Fluctuating temperatures can be doubly destructive because matter tends to expand and contract as temperature increases and decreases. When an object consists of two or more materials that respond to temperature changes at different rates, destructive strains can develop. Repeated freezing and thawing in objects having high water content also causes damage.

! Temperature changes should be minimized between storage

and
study areas when storing frequently-used museum objects and/or specimens (e.g., natural history collections).

! Temperature is a primary factor in determining relative humidity levels. The temperature affects the ability of air to hold water. The relationship between temperature and relative humidity is discussed in the following section.

C. RELATIVE HUMIDITY (RH)

Humidity (water content in the air) plays a significant role in the various chemical, physical, and biological forms of deterioration of museum objects. Sources of humidity include rain; lakes, rivers, and oceans; broken gutters, leaking pipes; moisture in walls; human respiration; wet mopping; flooding; and cycles of condensation and evaporation. **The key factor in object deterioration is not simply the amount of moisture in the air, but rather the relationship between the air's water content and its temperature. This relationship is relative humidity (RH).**

Temperature determines how much moisture the air can hold. An increase in the temperature causes the molecules in air to spread out, which creates more space for water molecules. A relative humidity reading indicates how close a given volume of air is to being saturated with moisture. A reading of 50% RH means the air contains 50% of the total amount of water vapor it can hold when saturated (i.e., at 100% RH).

The amount of moisture in the air dictates the amount of moisture in the object or specimen. Hygroscopic materials (e.g., wood, textiles, paper, leather, basketry, and bone), are especially sensitive to changes in relative humidity. The term "hygroscopic" refers to the ability of an object to absorb or release moisture to the air. Hygroscopic objects contain water as a constituent, with the amount determined by the RH of the surrounding air. They swell or shrink, constantly adjusting to the environment until the rate or magnitude of change is too great and deterioration occurs. This may be in imperceptible increments, becoming noticeable only over a long period of time, or the breakdown of materials may be sudden.

Relative humidity is one of the most important environmental factors to control. High relative humidity increases the rate of chemical deterioration, such as the fading of dyes and the corrosion of metal. High RH levels cause swelling and warping of wood and ivory, softening and sticking of adhesives, cockling of paper, and slackening of stretched canvas paintings. Mold growth occurs only when RH is above about 70%; insect activity also tends to increase at high RH levels. At the other extreme, low RH levels (below 35%) cause shrinkage, warping, and cracking of wood and ivory; embrittlement of paper and adhesives, tendering of textiles, and the embrittlement of basketry and paper objects. Relative humidity changes should be minimized between storage and study areas when storing frequently-used museum objects and/or specimens.

D. MONITORING AND CONTROLLING RELATIVE HUMIDITY AND TEMPERATURE

1. The Reason for Monitoring

The objective of an environmental monitoring program is to document existing conditions, identify problems that require special actions, and evaluate the effectiveness of previous corrective measures. An ongoing monitoring program is essential for the following reasons:

- to determine whether the museum property collection is threatened;
- to ensure that control equipment is functioning properly;
- to determine environmental trends: daily, weekly, monthly, and seasonally;
- to determine the character of environmental zones within a structure;

- to signal the need for corrective action when a problem is discovered;

- to evaluate the effectiveness of corrective measures that may already have been taken; and,

- to record the effect of extraordinary events (e.g., broken windows, leaky roofs or pipes, long periods of rain, or drought).

2. Establishing Environmental Parameters

The success of a monitoring program depends on planning. Each structure and museum property collection represents a special set of problems. The needs of the structure and the needs of the collection should be carefully evaluated. Any corrective measure that is too narrowly focused or unrealistic can have an adverse impact on one or both. The questions to ask when establishing environmental parameters for museum property are:

- What is the appropriate environmental range for each type of material represented?

- What is the character and significance of the structure in which museum property is housed?

- What is the environmental norm for the region of the country where the unit is located?

- What is the realistic target range that can be achieved for the structure and the museum property collection?

It is important to remember that environmental conditions vary from floor to floor in a structure, and even within a room. For example, localized heating is possible when direct sunlight shines into a room, and condensation may occur near cooler exterior walls in the winter. In some regions it is not feasible to maintain a constant environmental range throughout the year. Allowances need to be made for seasonal variation. There are usually several appropriate actions which might be taken to correct a given environmental problem, including the transfer of sensitive objects and specimens to an acceptable environment.

Follow the steps below to establish acceptable ranges and limits of relative humidity for spaces housing museum property:

a. Identify the Nature of the Museum Property

Note the material makeup of objects and/or specimens housed in each space (e.g., organic materials such as paper, wood, textiles, and natural history specimens or inorganic materials such as metals, ceramics, and glass). Describe the types of materials and approximate percentages of each type. Identify climate-sensitive objects and specimens, and, if appropriate, levels of importance for the objects and specimens.

NOTE: This information is needed to develop a house-keeping plan for spaces housing museum property. Refer to Chapter 7. It may be helpful to gather the data simultaneously.

b. Determine Acceptable Relative Humidity Levels

Refer to Figure 5.1 to determine acceptable relative humidity levels for various materials and types of objects. Most museum property collections are mixed, perhaps necessitating minor compromises in providing a suitable environment. Some objects and specimens, however, may need exact environmental conditions to ensure long-term stability. An appropriate environment for these objects and/or specimens can be created in a cabinet, room or space separated from the rest of the museum property collection.

Aside from the RH level or range optimum, one should also consider an object's history and previous acclimation to another RH level. For example, the optimum range for plant fibers is 40-60%. Sandals worn in the arid southwest by the Anasazi a thousand years ago, however, have become acclimated to a much lower RH. The stable level for these museum objects is the lower RH to which they have become accustomed.

c. Determine Environmental Conditions

Determine the environmental conditions in spaces housing museum objects. A year-round record of relative humidity and temperature is necessary.

Archeological Materials	
! Negligible Climate-Sensitive Materials	30% - 65%
! Climate Sensitive Materials	30% - 55%
! Significantly Climate-Sensitive Materials	30% - 40%
Natural History Materials	
! Plant, insect, and bird specimens, mammal skins and taxidermy mounts, specimens in preservative fluids (keep at higher level to lessen evaporation), bone and teeth (keep above 45%)	40% - 60%
! Paleontological Specimens (keep pyritic fossils at low RH level)	45% - 55%
Paintings	40% - 65%
Paper	45% - 55%
Wood, Leather, Textiles, Ivory, Bone	45% - 60%
Photographs/Films	30% - 40%
Metals	0% - 35%
Ceramics, Glass, and Stone	40% - 60%

Figure 5.1. Relative Humidity Optimum Ranges for Various Materials Housed in a Unit's Museum Collection

(See NPS Museum Handbook, Part I [Rev. 9/90], Curatorial Care Appendices I-S for guidance on RH parameters for specific types of materials.)

d. Consider the Structure That Houses Museum Property

Consider the requirements and capabilities of the structure that houses museum property. For example, in colder climates excessive humidification can cause deterioration of outside walls by moisture buildup, unless the building is designed and constructed to prevent this problem. Gather and record the following information for each facility housing museum property:

1) **Type of structure**

Work with facility maintenance staff to gather information about the structure (e.g., construction, material makeup, and unit function).

2) **Physical location of the structure**

Describe the structure's location (e.g., unusual environmental circumstances such as high water table, snowbelt, floodplain; exposure and surrounding terrain; nearby bodies of water; presence of surrounding vegetation; rural or urban setting; and proximity to an industrial area or a road).

3) **Condition of the structure**

Note the structure's condition (e.g., leaky roof, poor or no insulation, or wet basement).

4) **Historic structures**

If museum property is housed in a historic structure, consult with historical architects, engineers, and facility maintenance staff about legal or preservation restrictions regarding installation of systems in the building to control relative humidity.

5) **Exhibit and storage spaces**

Study specific exhibit or storage spaces within each structure. Prepare a floor plan of each space. Refer to Appendix G for a sample floor plan. Answer the following questions:

- Are there any external walls?
- Are the walls and ceilings insulated?
- What are the dimensions of the space?
- How many doors and windows are in the space?
- What are the existing means of controlling the relative humidity and temperature (e.g., heating, cooling, humidification, and dehumidification)? Are back-up systems in place?
- Are the objects exhibited in open areas or in cases?
- Are the objects stored in cabinets, drawers, or on open shelving?

e. Consider the Specific Climatic Zone and Seasonal Variations

Relative humidity levels that are desirable and maintainable in temperate areas of the United States may not be appropriate in arid areas. As a general rule, stable RH levels are obtained with less expense and less complicated engineering by working within existing local conditions and attempting to buffer rapid fluctuations through various means (e.g., insulation, use of hygroscopic building materials, and judicious temperature control). In arid areas the resulting RH level, if maintained with minimal fluctuation, will be appropriate for most museum objects already acclimated to a low level.

Seasonal adjustments in set points for RH are not harmful if the changes are not abrupt. A gradual shift from the low end of the desirable range in winter to the high end in summer probably will save money, as well as reduce the chance of damage to the building by condensation in winter.

Obtain local climatic information from Weather Bureau publications, local newspapers, and, if established, unit weather stations. Obtain from the Weather Bureau a copy of the publication Local Climatological Data, Annual Summary with Comparative Data, 1985 prepared by the National Oceanic and Atmospheric Administration. This publication provides the average high and low daily temperatures, daily precipitation, percentage of sunshine, monthly averages for precipitation for the last 30 years, monthly and annual temperatures for the last 30 years, snowfall, wind, and relative humidity.

3. Monitoring Equipment

Four commonly used instruments for gathering and recording data on relative humidity and temperature levels are: thermohygrometers, hygrometers, hygrothermographs, psychrometers, and data loggers. Refer to Appendix J for sources of monitoring instruments.

a. Characteristics of Thermohygrometers

Portable thermohygrometers are easy to use instruments that provide readings of temperature and relative humidity by means of a probe that can be extended into exhibit cases or other limited access spaces.

b. Characteristics of Hygrometers

Hygrometers are used to measure relative humidity levels in exhibit cases and in spaces not monitored by a hygrothermograph. When using a hygrometer, it is important to also use a thermometer to measure the temperature. The two types of hygrometers are dial hygrometers and electronic hygrometers. An electronic hygrometer may be used to calibrate other instruments in place of a psychrometer. When a dial hygrometer would be too conspicuous, paper strips impregnated with cobalt salts (called humidity indicator strips) may be used. **NOTE**: hygrometers are less accurate than other equipment available, and are often difficult to calibrate.

c. Characteristics of Hygrothermographs

Hygrothermographs record relative humidity and temperature levels continuously over a period of 1, 7, 31, or 62 days. Hygrothermographs are accurate within ±3% to ±5% RH when properly calibrated. They are most accurate within the range of 30-60% RH.

NOTE: All hygrothermographs require calibration at least quarterly (preferably once a month). Calibration is especially important after exposure to sudden extremes of humidity. Refer to Appendix F for instructions on calibrating hygrothermographs.

Hygrothermographs are delicate instruments and are easily damaged by improper handling. Follow these recommendations:

! Keep the instrument clean, and free of dust.

! Locate the instrument in an area that minimizes vibration.

! Do not touch the relative humidity sensor.

! Replace the relative humidity sensor when the instrument requires frequent RH adjustments during calibration.

! Keep the pens clean and free flowing.

! Use only the glycerine based ink supplied with the instrument. Alcohol based inks for felt tipped pens do not work in metal pens. **NOTE**: Cartridge (felt-tip) pens are available for hygrothermographs and are easier to use. Cartridge pens help to eliminate ink blotted charts and stained hands. However, these pens have a shorter shelf life. If properly maintained, the metal pen points with ink are more cost-effective.

! If your instrument requires winding, do so before placing the chart on the instrument's drum. If your instrument is battery operated, replace the battery at least annually and follow the replacement with calibration.

! Before placing the chart on the instrument's drum, date the chart, and record the instrument's number and location.

d. Characteristics of Psychrometers

A psychrometer is the most reliable instrument for determining relative humidity and temperature. There are two types of psychrometers: the sling psychrometer and the aspirating psychrometer. The advantages of the sling psychrometer are its simple design, low cost, and portability. The sling psychrometer, though simple and reliable, can be incorrectly used; however, with proper instruction and practice, the user can become adept at accurately measuring relative humidity levels. The aspirating psychrometer is a mechanized unit, compact and easily transportable. Advantages of the mechanized device are accuracy and less chance for procedural error. It is useful in confined areas that lack sufficient space to whirl a sling psychrometer.

e. Characteristics of Data Loggers

Data loggers are compact sensors that are usually used in areas where larger monitoring equipment either cannot fit or would be intrusive (e.g., HVAC ducts or exhibit cases). After data loggers record environmental readings for a specified period of time, staff collect the instruments which are then plugged into an IBM-compatible computer. The computer prints out the information in a number of formats, facilitating evaluation of environmental conditions. Their portability, and the fact that the computer can collate data faster than unit staff, make data loggers particularly useful for units that have a number of sites to monitor. Most small units that have only one or a few areas to monitor will find that data loggers are not cost-effective.

4. Reading and Interpreting Hygrothermograph Charts

There are many variables that contribute to unusual hygrothermograph readings. Some of them are as follows: the nature and the condition of the structure in which the collection is housed (sometimes referred to as the envelope); staff activity; public visitation; HVAC equipment performance and failure; barometric pressure; weather; the condition of the monitoring equipment and its accuracy; and unusual sources of moisture such as curing concrete, underground cisterns, and clogged gutters.

Although it is impossible to explain all of the patterns which are encountered in a monitoring program, Figure 5.2 illustrates a pattern that is commonly encountered. The recorded pattern clearly illustrates the relationship that exists between temperature and relative humidity. As the temperature decreases, relative humidity increases. And as the temperature increases, relative humidity decreases. This pattern appears most often in enclosed spaces with minimal human activity (e.g., storage space). (A large number of people congregating in a room might cause an increase in both relative humidity and temperature.)

Figure 5.2. Hygrothermograph Chart Illustrating the Relationship Between Temperature and Relative Humidity

NOTE: For an accurate analysis of temperature and RH in a space housing museum property, more than one hygro-thermograph may be needed. This is especially true of a historic structure located in the temperate zone where summers are hot and humid and winters are cold and dry.

One suggested method for organizing relative humidity and temperature data from the charts of each hygrothermograph is to record in a table format the following information over a period of time (e.g., 4 to 6 weeks): maximum high temperature, minimum low temperature, maximum diurnal (24 hour) temperature change, maximum high relative humidity, minimum low relative humidity, and maximum 24 hour relative humidity change. If for example, a unit operates a hygrothermograph in each of two museum collection storage spaces, a suggested format for data record from the weekly charts is illustrated in Figure 5.3. Refer to Appendix F for additional guidance on organizing data from hygrothermograph charts.

Chart Date	Data	Storage #1	Storage #2
5/18/87- 6/15/87	MAX. HIGH TEMP	28°C (84°F)	28.3°C (83°F)
	MIN. LOW TEMP.	20.5°C (69°F)	18.8°C (66°F)
	MAX. 24 HR. TEMP. CHANGE	+4°F -	+4°F -
	MAX. HIGH RH	54%	56%
	MIN. LOW RH	45%	46%
	MAX. 24 HR. RH CHANGE	4%	3%
	# OF DAYS RH EXCEEDED 55%	0	4

Figure 5.3. Sample Chart for Summarizing Hygrothermograph Data

5. Controlling Relative Humidity

a. General Considerations

The goal of controlling the climate surrounding museum property is to provide a stable environment that eliminates rapid fluctuations and extremes in relative humidity and temperature. The data represented by the hygrothermograph charts provides an opportunity to approach an environmental control problem in an objective manner. There are several correct responses that could be employed to resolve problems revealed by hygrothermograph charts. It is important to include all appropriate disciplines in the decision-making process, including curatorial staff, property management specialists, conservators, maintenance staff and historical architects. In developing a strategy to control relative humidity and temperature, several general points should be kept in mind. The below list produces a discussion of these general points.

! Because units of the Department of the Interior are in many different climatic zones, acceptable ranges and limits of relative humidity should be established individually for each unit based on: the local climate (e.g., tropical, temperate, or arid), the nature and condition of the materials constituting the museum property collection, the nature and condition of the structure housing museum property, as well as any other relevant factors. There is no general solution to a control problem. A program to control relative humidity is site-specific.

! An effective control program requires information about the structure, the museum property collection, and data about the surrounding environment. **A unit should record data for one**

year before establishing acceptable ranges and limits.

- Strategies for controlling levels of relative humidity and temperature should include energy costs.

- Controlling the climate includes both active and passive methods. Where possible, solutions to controlling relative humidity and temperature should explore simple modifications to a structure or space and employ the use of localized or portable mechanical equipment (e.g., humidifier, dehumidifier, heater, or air conditioner).

- Once control strategies have been put into effect, continue the ongoing monitoring program to evaluate the effectiveness of the corrective measures.

b. Assess the Building Envelope

Obtain assistance in examining the structure and/or spaces within the structure that house museum property for possible sources of moisture that may be causing high levels of relative humidity (e.g., leaking roofs, ceilings, and windows; leaking plumbing in an adjacent space; damaged gutters and downspouts; drainage problems; or wet walls and foundations). Eliminating sources of moisture by repairing the structure or correcting drainage problems is essential to controlling interior conditions.

c. Employ Passive Methods

1) **Maintain HVAC settings**

In spaces housing museum property, avoid turning heating and cooling equipment on during the day and off at night. This practice causes rapid fluctuations in RH levels.

2) **Adjust controls to compensate for fluctuations**

a) The presence of large groups of people in a room raises the temperature and lowers the relative humidity. Control the number of visitors in furnished historic structures and exhibit spaces to prevent overcrowding. It may be necessary to lower the set point of the heating equipment to counteract a reduction in the relative humidity or to open

and close interior doors to change the circulation of air.

b) Conversely, large groups of people in a room may raise the relative humidity. This most often occurs in social situations such as receptions where people are talking or drinking. Raise the set point of the heating equipment to counteract a reduction in the relative humidity or open and close interior doors to change the circulation of air.

3) **Protect sensitive objects and specimens**

In exhibit and storage spaces place sensitive objects and specimens away from spotlights, windows, exterior walls, air vents, and entrance doorways.

4) **Utilize structural features**

Increased temperatures caused by the sun can be controlled by using existing blinds, curtains, filtering materials, drapes, or exterior shutters.

5) **Make seasonal adjustments to HVAC system**

In temperate zones, reduce temperature levels during the winter. (Lowering the set point of the heating equipment by several degrees raises the interior relative humidity.) It is important to gradually reduce the interior temperature level over a period of weeks. In the spring, gradually raise the temperature back to the appropriate set point.

6) **Create micro-climates**

Controlling relative humidity levels for sensitive objects (e.g., metals, textiles, paper, pyritic mineral, and fossil specimens), may require the creation of a micro-climate. This can be achieved by using a properly sealed museum storage cabinet or exhibit case with a buffering material (e.g., a desiccant).

Silica gel, a high capacity moisture absorbent, is a porous granular, chemically inert material that can absorb 30-40% of its dry weight in water. Properly conditioned, this material stabilizes relative humidity by maintaining (increasing or decreasing) moisture levels in the air surrounding museum objects. Ideally, a conservator should be consulted to determine the proper quantity of silica gel to apply in specific situations.

7) **Create an independently-controlled storage area**

While ideal, it is often not possible to store all museum property in a space with a strict climate-controlled system. A more practical method for controlling relative humidity and temperature for large collections of sensitive objects and/or specimens (e.g., biological specimens in solution, climate sensitive archeological objects, or photographic film), is to create a separate space within or adjacent to the existing storage facility to meet the special needs of these materials. In some situations, a superinsulated prefabricated building equipped with an environmental control system, specifically designed to maintain the appropriate RH and temperature levels, is one approach to creating a separate space. Refer to Appendix G for information about such a structure.

d. Employ Active Methods

A stable, environmentally secure space for housing museum property may be created by installing a properly designed heating, ventilating, and air conditioning (HVAC) system. The system should establish and maintain appropriate levels of relative humidity and temperature, and filter particulates and gases from the air. Installing an HVAC system that achieves the above requirements is not easy and, often, is not a practical or feasible corrective measure. The design process, especially with a historic structure, should consider architectural and historical concerns (e.g., integrity of the building fabric and the impact of vapor barriers, glazing, and ducts and vents on the fabric), operation (e.g., performance and energy costs), and maintenance.

In many instances, it may be more practical and less costly to use localized or portable humidifiers, dehumidifiers, heaters, and air-conditioners to control temperature and humidity. Use only humidifiers and dehumidifiers that are controlled by humidistats. A humidistat, functioning like a thermostat on a heater, automatically switches on the equipment when necessary. When properly located and maintained, humidifiers and dehumidifiers can help to prevent dangerous conditions.

1) **Use humidifiers**

Humidifiers are designed to quickly add moisture to the air in a controlled manner. This equipment may be used in spaces housing museum property to counteract the drying effect of a heating system. It is recommended that only unheated evaporative humidifiers be used. This type of humidifier does not disperse minerals into the air. Also, if the humidistat malfunctions, this type of humidifier will not raise the RH level above 65-70%.

When using a humidifier, it is important to ensure that the humidified air is well-circulated. It may be necessary to place fans in specific locations to eliminate any pockets of stagnant or overly damp air. The size and number of humidifiers needed depends on the size of the space, the air exchange rate, the differences between conditions inside and outside the building, and the number of persons passing through or working in the area.

2) **Use dehumidifiers**

Use a dehumidifier for short periods of time to lower high levels of relative humidity. This equipment should not be used as a permanent corrective measure to control high RH levels.

The two types of dehumidifiers are: desiccant and refrigerant. The desiccant type forces air through a dry material (e.g., lithium chloride), to reduce moisture. Use a desiccant dehumidifier in cold climates. The refrigerant type, which works on the same principle as a refrigerator, should be used in warm climates. Remember: the use of dehumidifiers requires an appropriate drainage system or procedures.

E. LIGHT

Light has the potential to be the most damaging of the environmental agents to museum objects. The materials most sensitive to light are textiles, watercolors and other works of art on paper, dyed leather, photographs, natural history specimens (e.g., furs and feathers), and other organic material whose surface color is important. The most obvious sign of light damage is the fading or bleaching of materials. Another sign that may not be as easily detected is embrittlement -- the actual progressive breakdown of molecular bonds that causes materials to lose strength and eventually become powdery. Even small amounts of light, well within the acceptable range, cause damage. Damage to museum property caused by exposure to light is cumulative and cannot be reversed.

1. The Nature of Light

Light (electromagnetic radiation) can be divided into three categories: ultraviolet, visible and infrared.

Ultraviolet (UV) radiation is the most damaging segment of the light spectrum. All forms of lighting (e.g., daylight, fluorescent lamps, tungsten [incandescent], and tungsten-halogen lamps) emit varying degrees of UV radiation. Daylight is the strongest source of ultraviolet radiation in most units although most fluorescent lamps emit higher than acceptable levels. Ultraviolet radiation should be eliminated to the greatest extent possible.

Visible light is that part of the electromagnetic spectrum that is visible to the human eye, from violet through blue, green, yellow, and orange to red. The strength of the lighting is referred to as the illumination level or "illuminance" and is measured in units called lux (1 lumen per square meter) or foot-candles (1 lumen per square foot). One foot-candle is equivalent to about 10 lux.

The rate of damage caused by light is directly proportional to the illumination level multiplied by the time of exposure. To reduce damage to objects from visible light, it is important to reduce the amount of light and the duration of exposure. A 200 watt bulb does twice as much damage as a 100 watt bulb of the same type in the same length of time. A 200 watt bulb does twice as much damage in 10 hours of exposure as it does in 5 hours of exposure. It is important to keep this "reciprocity law" in mind: low light levels for extended periods cause as much damage as high levels of light incur during brief periods. Damage as a result of light can be arrested totally only by placing a museum object in dark storage.

Infrared radiation, also invisible to the eye, causes heat buildup in objects. The distance of the light source from a museum object is a factor that should be considered. Incorrectly used spotlights, the ballasts of fluorescent fixtures, and direct sunlight are common sources of infrared radiation.

Lighting in spaces housing museum property must be controlled to protect objects from excessive visible, and any ultraviolet, radiation. Adhere to recommended levels when exposing museum property to light for any extended period of time.

2. Monitoring Light Levels

a. Light Monitoring Equipment

Measure light levels using a combination of a light meter and a UV monitor. Measurements should be taken seasonally, especially if any ultraviolet filters are in use. If lighting fixtures or equipment change in an area housing museum property, measurements should be taken at that time to ensure that the light stays within the recommended levels. If daylight is present in the room, light measurements should be taken both in the morning and the afternoon to record the change in sunlight as the sun moves across the sky.

Many types of light meters are available for measuring visible light. Refer to Appendix J for sources for light monitoring equipment. When choosing a light meter, it is important to use a meter that is sensitive to light levels as low as 25 to 50 lux with a reasonable degree of accuracy (10% or better). Light meters are available that measure light in lux or foot-candles. Using an ultraviolet monitor, measure ultraviolet levels in spaces housing museum objects to make sure that ultraviolet filtering materials remain effective.

When taking light readings with either the light meter or the UV monitor, follow these standard procedures: Eliminate shadows from the hand or body.

For two-dimensional objects (paper, paintings, and photographs), the sensor should be parallel to the surface. For three-dimensional objects, aim the sensor toward the light source. Take light readings at various points on the object if it is larger than approximately 1 foot.

b. Establishing a Light Monitoring Program

The strategy for establishing a light monitoring program is as follows:

1) **Gather data**

It is important to obtain and record the following information:

a) Daily light variations

Determine how the sunlight moves about the room in the course of the day. Determine the effect of artificial lighting used to supplement natural light or to highlight certain objects on exhibit.

Unlike temperature and relative humidity which constantly vary, light variations occur quarterly at approximately the same rate and time every year as long as other factors (e.g., shrubbery, film, or windows) remain the same. Establish seasonal light variations over a one-year period. Once measures for controlling light levels have been introduced, continue to monitor to ensure their effectiveness.

b) Past lighting conditions

In a historic structure, determine historic lighting conditions by studying the history of the structure.

c) Types of fixtures and filtering material

Note the characteristics of existing lighting fixtures and filtering materials.

d) Space usage

Note the frequency of one-time events (e.g., the filming of a documentary film in a historic structure).

2) **Monitor light levels**

a) In each space, identify museum property that is most susceptible to light damage.
b) Identify sources of light within each space.

c) Establish monitoring sites. Each time measurements are taken, use the same sites and the same procedures. Old sites can be abandoned and new sites established as conditions warrant. Prepare a floor plan that indicates the location of each monitoring site.

d) Record all light and heat measurement data. A sample chart is illustrated in Appendix F, Section C.

e) Note any corrective actions taken (e.g., curtains drawn, historic awnings replaced, UV filtering film installed over windows and/or fluorescent tubes, electric voltage stepped-down because of historic wiring resulting in dimmer lights, or light fixtures replaced).

3) **Evaluate data from light monitoring program**

Identify areas and objects that exceed Departmental standards. Determine how long light sensitive objects have been exposed to elevated light levels. Determine whether or not those objects show signs of light damage. Remember, not all damage can be detected by visual inspection; it may be necessary to consult a curator and/or a conservator.

Corrective actions must be taken to lower light levels that exceed standards. Incorporate monitoring the results of those actions into the light monitoring program. For example, if UV filtering film is installed on glass window panes, monitor the UV radiation passing through the film and compare it with previous readings without the film. Does the film filter UV radiation? How much UV radiation has been eliminated? By installing UV filtering film on windows, how has visible light been affected? Does the visible light level exceed the standard?

In historic structures or settings, compare existing light conditions with historic lighting conditions. For example, do objects on exhibit receive more or less light than they did historically? Does reducing light levels in historic houses improve interpretation of the structures and the museum objects as well as being a beneficial preventive conservation measure?

Data collected by monitoring provides an important basis for any request for change or removal of threatened objects. Keep a permanent file of all light monitoring data.

3. Controlling Light Levels

All light must be controlled in spaces housing museum property.

a. Visible Light

Visible light, whether natural or artificial, should be maintained within recommended light levels (refer to Figure 5.4). These levels can be obtained using a variety of control methods.

- Control natural light coming through windows by using window coverings (e.g., blinds, shades, curtains, shutters, or exterior awnings). Close these devices whenever possible to prevent entrance of light into spaces housing museum property.

- Use dustcovers to cover light sensitive objects (including floor coverings). Use materials such as cotton muslin or Gortex® that block visible light and are air permeable, allowing objects to "breath." Dustcovers are particularly useful in storage areas and in furnished rooms that are closed to the public part of the year.

- Place tinted light filters (films or varnishes) on windows or over artificial lighting to lower visible light levels (e.g., plastic solar control film for windows, UV filtering film or sheet for windows or picture frames, and filter sleeves for fluorescent tubes). When these filters are affixed to window glass, leave a thin line of glass along the edges uncovered to allow for the expansion and contraction of the materials. (This unfiltered area is not considered to be damaging because the natural light coming in would reflect onto the window molding and frame.)

  Many of the tints available (such as the dead bronze or silver reflecting shades) diminish the integrity of historic structures, thus negatively impacting the historic scene. Choose tints that are unobtrusive.

- Reduce artificial light levels by lowering the wattage of the incandescent bulbs, using fewer light fixtures, using flood light bulbs instead of spots, and turning off artificial lighting when people are not present.

- Electrical switches can be used in exhibit areas that activate lighting in specific areas only when a button is pressed or a circuit is interrupted by a physical presence. A timer can be attached to the switch so that the light stays on for only a specific period of time.

> 50 lux (5 foot-candles) for especially light-sensitive materials (e.g., dyed and treated organic material, textiles, watercolors, tapestries, prints and drawings, manuscripts, leather, wallpapers, natural history specimens such as botanical specimens, fur and feathers, and certain types of photographs [e.g., films such as albumen and cyanotypes]).
>
> 200 lux (20 foot-candles) for undyed and untreated organic materials, oil and tempera paintings, and finished wooden surfaces.
>
> Generally, other materials are less sensitive to light and may be exposed to higher levels, up to a maximum of 300 lux. However, when these materials are housed with light-sensitive materials, light levels must be controlled at levels appropriate for the most sensitive materials.
>
> Except for short durations required for access or housekeeping, no light is acceptable for museum property in storage.

Figure 5.4. Maximum Acceptable Illuminance Levels for Light-Sensitive Materials

b. Ultraviolet (UV) Radiation

Eliminate as much Ultraviolet light as is possible.

If the UV radiation level exceeds 75 microwatts per lumen, it must be controlled. Some techniques recommended for controlling visible light are also effective in controlling ultraviolet light. When installing UV filtering material between the light source and museum property, keep the following points in mind:

! install filtering material on all except incandescent lighting fixtures;

! always place ultraviolet filtering material over fluorescent tubes. (**NOTE**: Fluorescent tubes are now available that have been coated with an ultraviolet filtering chemical); and,

! periodically monitor UV radiation to ensure that filtering material is effective. Materials (e.g., mylar or plastics) to which the chemical filtering coating is attached tend to breakdown faster than the filter. Replace filters whenever they begin to breakdown physically (e.g., turn yellow or crack), as well as when the ultraviolet filtering chemical ceases to be effective. Refer to Appendix J for sources of filtering materials.

c. Heat

The distance of the light source from the museum object is also a factor that should be considered. Lighting that is too close to an object raises the temperature of the object, resulting in damage to organic materials. This increase in temperature also lowers the relative humidity level of that object(s). Heat that is generated by natural or artificial lighting should also be controlled to prevent rapid changes in relative humidity and the possible risk of fire.

1) **Heat produced by natural light**

Heat generated by natural lighting can be controlled through use of window coverings, window filters, and good air-circulation systems (e.g., fans or air conditioners).

2) **Heat produced by artificial lighting**

Heat produced by artificial lighting can be controlled by using light filters, good air-circulating systems, and by physically separating lighting fixtures from the section of exhibit cases that contain museum property.

! If the light fixtures for an exhibit area are in an enclosed box, this box should be well vented to the general exhibit area to prevent heat buildup. Dimmers that operate light bulbs at a lower level when the heat buildup becomes excessive should be used.

! Strong flood lamps for professional photography can be a serious heat problem. Control heat in these situations by using heat-absorbing light filters and making sure the area in use is well-ventilated with fans or air conditioners. The strong lighting should stay on only when actual filming is taking place and be turned off in between shots and during rehearsals. If rehearsals with lighting are necessary, use dummy objects.

! Do not allow spotlights to throw a concentrated beam of light on an object or part of an object.

F. DUST AND GASEOUS AIR POLLUTION

1. Types of Air Pollutants

Air pollutants are classified into two types: gaseous and particulate.

a. Gaseous Pollutants

Gaseous pollutants include ozone and acidic compounds of sulfur and nitrogen. These pollutants can cause silver to tarnish, bright copper to discolor, lead to become coated with a white powdery encrustation, and leaded bronze to grow crystals, frequently accompanied by structural deterioration. Some of these pollutants attract water, thus facilitating harmful chemical reactions (e.g., weakening cellulose materials in paper and textiles, discoloring dyes, and deteriorating varnish and oil paints). Metals, stone, and several organic materials (e.g., paper, textiles, and leather) are particularly susceptible to gaseous pollutants.

b. Particulate Pollutants

Particulate pollutants include dirt, dust, soot, smoke, hair, skin cells, and pollen. Particulate pollutants vary enormously in size, and are especially dangerous to objects because they attract moisture and gaseous pollutants.

- Composed of minute mineral particles (e.g., silica and iron oxide), dust can be an abrasive agent. Removing dust involves washing, wiping, or shaking, all of which accelerate deterioration and increase the risk of physical damage to a museum object.

- When water condenses around particulates, some of them become active chemical agents that directly attack museum objects.

- Dirt attracts insects and is often acidic.

- In coastal areas, the air contains chloride salts that are often highly corrosive.

- Ground soil is a particular concern for archeological objects. Water soluble salts (e.g., sodium chloride, sulfates, phosphates, and nitrates) contained in the soil tend to infuse ceramic and other porous materials. After removal from the ground, these salts may crystalize on the surface, eventually destroying the physical structure of the object.

c. Relationship Between Gaseous and Particulate Pollutants

Particulate matter plays the following three basic roles in relation to gaseous pollutants:

- it is a source for sulfates and nitrates. (These particles can readily become acidic on contact with moisture);
- it provides a catalyst for the chemical formation of acids from gases; and,
- It is an attractant for moisture and gaseous pollutants. (When particles absorb moisture from the surrounding air, they may also attract sulfur dioxide or nitric dioxide).

2. <u>Sources of Indoor Pollutants</u>

a. Building Materials

Dust from building materials may include minute alkaline particles from unsealed concrete and formaldehyde resins used in plywood, particle board, adhesives, and glues.

b. Pollutants Introduced by HVAC System

Outdoor pollutants are brought indoors in large quantities through a structure's heating, ventilation, and air-conditioning system (HVAC), making pollution filtration systems important in controlling the amount of pollution found within a structure.

c. Museum Property

Some museum objects pollute indoor air because they are made up of materials that emit gases. Examples include celluloid and other unstable plastics, cellulose nitrate and diacetate negatives, and pyroxylin impregnated cloth used in twentieth century book binding. Objects treated with a fumigant (e.g., ethylene oxide) may also emit gases.

d. Exhibit and Storage Materials

Unpainted or unvarnished woods can give off acidic vapors that damage organic materials, particularly if the organic materials are enclosed in cases or cabinets constructed of these untreated woods. Some types of paints (e.g., acrylics) and varnishes emit damaging gases. Oak and Douglas fir produce more volatile organic acids than other types of woods and therefore are the most unsuitable types to use for construction. Polyvinyl acetate (PVA) emulsions are also unsuitable because they cause lead objects and to a lesser extent zinc and bronze objects to deteriorate. Silver objects and many photographic negatives and prints may be damaged by sulfides emitted from certain glues, paints, textile finishes, and rubber products.

3. Establishing an Air Pollution Monitoring Program

Measurements of pollution levels requires sensitive and expensive instruments. If observations indicate that air pollution may be causing damage to museum property, contact the bureau's museum property program manager for assistance in obtaining measurements. There are several steps that can be taken by the museum property staff to monitor air pollution levels:

a. Inspect Storage Spaces

Record the time frame for build-up of dust between dustings (e.g., on floors, open shelving, and the tops of cabinets and tables). Look for increased insect activity; such activity is often associated with an unacceptable accumulation of dust.

b. Inspect for Active Corrosion

In coastal areas watch for chloride pollution by inspecting metal objects for active corrosion. Chlorides attack painted iron or steel objects. Inspect all bronze objects for evidences of "bronze disease" - a pale green, powdery corrosion.

c. Gather Data

Some units may already have recorded information through ongoing research on air quality. Contact the Environmental Protection Agency (EPA) to obtain information on the levels of ozone, sulphur dioxide, nitric dioxide, and particulates recorded in the unit. These data assist curatorial staff in identifying potential pollutant problems.

d. Monitor Relative Humidity

Because the presence of water accelerates the effects of particulate and gaseous pollutants on objects, relative humidity data being recorded in spaces housing museum property is essential to an air pollution monitoring program.

e. Analyze the Space Housing Museum Property

Observe and record the nature of internal air control systems and the nature of the structure housing museum property. Adobe and unsealed concrete walls are sources of high levels of dust. Air intakes, not properly filtered, may convey high levels of pollutants into a space housing museum property. Exhibit cases, storage cabinets, shelving made of untreated wood or painted with improper paints, may outgas at increased levels. In addition, observe how much dirt and dust is brought into spaces by staff and visitors.

4. Methods for Controlling Air Pollution

Eliminate gaseous and particulate pollution to the lowest practical level. There is no minimum acceptable level of pollution. Suggested methods for controlling air pollution in spaces housing museum property are as follows:

a. Institute a Preventive Conservation Program

In storage spaces, keep floors, tops of cabinets, and work surfaces clean to minimize particulate accumulation. Incorporate dust control into the housekeeping program.

b. Separate Functions

Separate office and museum property staff work space from museum property storage space.

c. Prevent Pollutants From Entering the Space

Upgrade and maintain seals and weather stripping around doors and windows.

d. Use and Maintain Appropriate Storage Equipment

Store all sensitive objects in appropriate museum specimen cabinets. Maintain gaskets on all storage cabinets. Replace old gaskets with neoprene gaskets.

e. Use Dustcovers

Use dustcovers to protect objects on open shelving. Dustcover material should be chemically and physically non-damaging and provide as complete a dust seal as possible while allowing easy access.

- Use clear plastic (polyethylene) sheet or unbleached cotton muslin material. The plastic sheet and the cotton muslin each have advantages and disadvantages. Plastic sheet is an impenetrable barrier to dust and moisture and is clear, thus, facilitating inspection of objects without having to open the covering (thus destabilizing the microclimate). The disadvantages of the plastic sheet are that it is not flameproof and can lead to condensation in improper environments. Cotton muslin may be made flameproof but does not allow viewing of the artifacts without opening the covering.

Two new non-woven materials: Tyvek® (style 1621C), a spun polyethylene sheet and Gore-Tex® 1.3 oz. Barrier, a laminate of a teflon membrane with a polyester backing, may be used as dustcovers. Both materials are flexible, dustproof, waterproof, opaque, and allow air circulation. A disadvantage is that neither material is flameproof. Another disadvantage of Gore-Tex® 1.3 oz. Barrier is its high-cost.

! There are a number of methods for attaching the covering material to the shelving. Two methods currently in use are affixing the covering to the steel shelving with small magnets or clipping the covering to shelves and uprights with spring clips. Velcro, the hook and loop fabric fastener, may also be used. Caution should be used in removing covers to prevent damage to covered objects or specimens.

f. Segregate Objects that Outgas

Some objects may generate gaseous pollutants through a process called outgassing. Segregate objects that outgas (e.g., cellulose nitrate negatives and diacetate negatives) from all other objects. Store them in appropriate cabinets to meet standards developed for these types of materials (e.g., freezers).

g. Use Appropriate Cases

Store, exhibit, or transport objects in appropriate cases that do not release damaging gases.

5. Air Conditioning

Filters in an air-conditioning system may reduce air pollution levels. Effective control of gaseous pollutants by air-conditioning requires highly specialized design and engineering. Such systems may use water sprays or activated charcoal filters to remove gaseous pollutants. Except in the most rigidly designed system, it is not practical to eliminate all particulates because high pressures are necessary to force air through the paper filtering system.

Filtering systems work best when air is filtered at two points in the air flow system. The first filter should be a "viscous filter." This filter is placed near the air intake to the structure. These filters use a liquid such as oil to trap coarse particulates. The next filter should be a "fabric filter" (layers of fabric). These are more efficient in removing particulates. Remember: to be effective, filters need to be routinely cleaned or changed.

An air-conditioning system for museum property storage spaces should be independent from other systems in the structure. Never use "electrostatic precipitators" in a space housing museum property. These precipitators, though effective, generate ozone.

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