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ABSTRACT

These guidelines are intended to orient the library/archives professional in New York to the common issues, language, pitfalls, and opportunities involved in dealing with the built environment and its impact on the conservation and preservation of a valuable collection. Although developed for the climate typical in New York State, many aspects will be applicable to institutions in other regions. The guidelines cover general collection environment criteria, assessment, monitoring, and goals for an improved conservation environment. General building environments and building systems that can create a good conservation environment are described, including various possible compromises. Typical interim and low-cost measures for improving an environment are suggested. Common phases of design and construction projects are also described for both new designs and environmental renovation, including planning steps and guidelines for selecting the design team. The appendix offers definitions of common terms used in the design and construction of building systems, references and suggested readings, and guidelines for selecting manufacturers. (MAB)

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Conservation Environment Guidelines For Libraries And Archives

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The New York State Program for the Conservation and Preservation of Library Research Materials

Conservation Environment Guidelines For Libraries And Archives

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CONTENTS

Summary: This document discusses general collection environment criteria, assessment, monitoring and goals for an improved conservation environment. General building environments and building systems are discussed that can create a good conservation environment, including various possible compromises. Typical interim and low-cost measures are suggested to improve an environment. Typical phases of design and construction projects are described for new design and environmental renovation, including planning steps and guidelines for selecting the design team. The appendix offers definitions of common terms used in design and construction of building systems, references and suggested readings, and guidelines for selecting manufacturers. Although developed for the climate typical in New York State, many aspects will apply to institutions in other regions.

INTRODUCTION

The purpose of a library, archives or any other cultural institution is to preserve and provide access to information and artifacts from the past. The value and meaning of these collections are diminished if they have been embrittled, warped, stained by mold or soot, faded, or are too fragile to be handled. Such damage often comes from exposure to extremes in humidity, excessive light levels, gaseous and particulate pollutants, water damage, and other environmental offenses. Where a collection has high artifactual value, or otherwise commands special concern for its preservation, then the collection environment must be considered.

Many of the objects in a collection may have survived for centuries in an unheated chapel, or under a sheet in an old shed. When they are taken under the special care of a cultural institution these objects are usually offered a new home in a building with dry heating in the winter, and high humidities in the summer. They are often placed on display under bright lights or under a bright window, and are exposed to urban pollution and modern corrosive chemicals in the air. Without the proper environment, collections can be quickly damaged and may reach a condition much worse than if left undiscovered.

For an institution to meet the responsibility of preserving a collection, a good environment is the only strategy that can help preserve entire collections all the time. Repair and conservation treatment of items in a collection have little value if the items are returned to an environment which causes the damage to recur.

In practice, it is often hard to reconcile the need to preserve a library or archives collection against the constraints of politics and money. The collection is expected to pass through this generation's relatively brief stewardship, and continue to be available for centuries or millennia. Unfortunately, short-sighted planning and limited budgets often do more damage to a collection in a few years than it has suffered in the last hundred.

Part of this problem is a lack of understanding of the mechanisms that attack and destroy collections. This is being addressed through many research and education programs, and has led to studied criteria for collections use, for collection conservation, and for conservation environments to preserve collections. Unfortunately, more is now known about what a safe collections environment is than how to achieve it. This does not mean that it cannot be achieved with the technology available, but that any number of factors can cripple or destroy the conservation merits of the environment ultimately provided for the collection.

When a collection environment is identified as deficient, other solutions to the problem should be considered before selecting major retrofit or renovation of the building environment. There is nothing more disruptive to an institution than a construction renovation project. First, the collection can be exposed to unprecedented threats of damage from the construction process and activities. Second, the new environment may initially be quite unstable, causing dramatic environmental changes and resulting damage to the collection. Third, in all too many instances, the final "new and better" environment may be no better than the original, and may be even more damaging to the collection.

One of the reasons major environmental renovation should be a last resort to address environmental problems is that the institution must work through others, as intermediate instruments, to achieve environmental goals. Unlike many other improvement projects in which the institution staff can directly purchase, approve, install, and supervise items with complete control, a contract construction project puts many decisions in the hands of outsiders.

Although a primary purpose of a library or archives and its environmental control system is to create an environment that will preserve the institution's collection, unfortunately that may not be a goal of all those involved in the project design. To achieve a safe and satisfactory built environment for a collection, the larger and universal motivations of politics and money must be considered in addition to environmental criteria. An environmental design must meet the budget and political capabilities of the institution, the limitations of any existing construction and infrastructure, and must be consistent with the institution's ability to operate and maintain the system.

When "climate control" is asked for, any number of things can happen in design, even with the best intentions. When clear criteria for the environment are stated to the people who are charged with responsibility for the design, the criteria are sometimes not understood, are rejected out of hand as impractical, or, unbeknownst to the institution, are simply ignored. The architect may share the collection conservation goals in spirit rather than action, developing an architectural design style at the expense of conservation goals. The engineer designs from his previous knowledge and experience, based on commercial office environments, trying to meet human comfort and energy conservation goals. The engineer can fall into habits that expedite design rather than tailor it to collection preservation needs. Conservation professionals may be called in to review the design too late, and then often cannot identify problems in the design documents they are given to review, and may be unable to express concerns in a manner that is understandable and credible to the design team.

Further barriers to achieving a good environment come in construction execution, operation and maintenance. Execution of the design is hampered by cost-practical construction concerns which tend to refine and redesign the project through processes removed entirely from the original conservation environment goals. Operation of the systems may be deficient due to a lack of initial commissioning and setup, inadequate or missing operating manuals and instructions, poor design for on-going service and operation, postponed or ignored maintenance, modifications to save energy, and attention only to problems with human comfort. The small library and archives is faced with the further problems of limited budget, limited space, and limited existing building systems to support a proper environmental system, but has no less a need for a safe environment for its collection. These needs and limitations can be met by a proper complement of balanced compromise criteria, smaller environmental systems, "low-tech" solutions, and design sensitivity to the smaller facility.

This document is intended for the overwhelmed preservation administrator, the hesitating archivist in a multi-departmental bureaucracy, and the director of a historical society who is scrambling to interpret design drawings and plans. It cannot hope to cover all the complexities of a heating, ventilating and air conditioning (HVAC) system or present a comprehensive renovation design program; it cannot substitute for five years in architecture school and twelve years of professional practice in building design and construction; and it cannot substitute for study in a conservation training program, apprenticeship and professional experience in conservation treatments. It is, however, intended to provide an unprecedented comprehensive document to orient the library/archives professional to the common issues, language, pitfalls, and opportunities in dealing with the built environment and its impact on conservation and preservation of a valuable collection. It can assist in environmental assessment and monitoring, in setting environmental goals, and in introducing environmental standards. With it, library/archives professionals should be able to better understand and communicate their needs to and make better use of conservators, architects, engineers, contractors, and other consultants.

While these guidelines are intended for library and archives professionals, many aspects will apply to historical societies, museums and other institutions interested in the basic information to pursue an improved conservation environment. Although developed for the climate typical of New York State, many issues and recommendations will be applicable to institutions in other climate regions.

Throughout this document, whether or not it is stated explicitly, it is important that each situation be addressed with its own opportunities and constraints. It is essential that, when needed, appropriate professionals be called in, be they conservators, environmental consultants, architects or engineers. This document is a supplement to, and not a replacement for the services of qualified professionals, who can address the specifics of a particular project and institution.

SYNOPSIS. Rather than following topics, this document is organized to follow the typical flow of an environmental improvement project. The first part gives the basic factors and ideal criteria for a conservation environment ("The Conservation Environment"), then the basics on how to assess an environment for those factors ("Collections Environment Assessment and Monitoring"), followed by typical compromises that might be considered to reconcile the ideal against measured conditions ("Compromises for Conservation Environment Goals") and how to set practical goals for a renovation with a limited budget. This is followed by three sections, each discussing issues, options and guidelines for HVAC, lighting and fire protection ("Achieving Conservation Environments"), followed by a section that discusses what can be done by the institution on a very limited budget ("Interim and Low-Cost Environmental Improvements"). The last section ("The Design and Construction Process") is a discussion of the typical design and construction process for an archives or library project outlining the steps an institution might take on a project, with special notes on small-scale projects. The Appendices give general supporting information to the discussions in the body of the document. This includes a list of abbreviations used in the document, a lexicon of design and construction terms, a list of references and suggested readings, plus other information.

THE CONSERVATION ENVIRONMENT

Library and archives collections often consist of different types of objects, including books, manuscripts, maps, photographs and films, and may be housed with historical collections containing a variety of museum objects as well. Almost all objects will last longer when kept at lower temperatures, stable relative humidity, and in air free of particulate and gaseous contamination. However, some classes of objects are more sensitive—will deteriorate faster—under a particular set of environmental conditions, compared to other objects. For example, mold can form on paper in high relative humidity, photographs are particularly sensitive to damage from gaseous pollutants, and a low humidity that suits silver-gelatin microfilm would cause permanent damage to vellum. The mix of different components of a collection, and each component's relative value to the institution, will determine the best environment. It may also indicate possible segregation of the collection to provide different environments for different groups with different needs.

RELATIVE HUMIDITY

Most paper-based collections need a stable 40 to 45% relative humidity (RH). Film collections generally last longer at a lower humidity of about 30% RH, although the best humidity for a particular collection can vary with the film type and housing. Fluctuations in relative humidity can cause more damage to collections than stable humidities that are moderately high or low. Relative humidity in a building may fluctuate dramatically over the period of a day, particularly if heating or cooling is turned off or changed at night. Over a year, the relative humidity in a building may range from nearly 100% in summer if no dehumidification is provided, to as low as 10% in winter if heating is provided without humidification. The humidity of a conservation environment should not fluctuate, but should be as stable as possible.

TEMPERATURE

Other things being equal, most objects would last longer at low temperatures. Higher temperatures of 60 or 70°F are usually needed for human comfort, but not for the benefit of the collection. In almost all collections, the lower the temperature the better, with 65 to 68°F a good compromise with human needs and other practical concerns. Due to their particular sensitivity to temperature, every attempt should be made to segregate any important photographic and film collections, particularly color, and keep them at temperatures below 55°F.

However, stable temperature should generally be subordinated to stable relative humidity, since a stable humidity is more important than stable temperature. One of the factors that directly effects relative humidity is the temperature of the air.

At times, depending on the collection, low temperature may need to be subordinated to low humidity needs. For example, when air is at 60°F and 65% RH, it would typically suit most paper-based collections better to have the air warmed to 68°F, so that its humidity will drop to less than 50% RH. This is the technique used at some major research libraries on moist, cool days to reduce relative humidity in their stacks.

LIGHT

All visible light can damage objects; it is a common misconception that only the ultraviolet or infrared components of light cause damage. This is why it is important to keep light levels themselves as low as possible. Although a collection may contain some objects which can tolerate higher light levels, and some materials may be stored in opaque boxes, their segregation in storage or display cannot be assured. Generally, almost all collection storage areas need to be kept at minimum light levels appropriate for the most sensitive objects in the collection.

While light levels of 30 to 60 footcandles (330 to 660 lux) may be needed in reading or inspection areas, light-sensitive collections should generally be displayed for limited periods at levels of 5 to 15 footcandles (55 to 165 lux), and stored at light levels of 1 to 5 footcandles (11 to 55 lux). Although this sounds low, a stack area lit at 2 footcandles (22 lux) of vertical illumination at the book spines is not uncommon, and is a quite effective light level for collection access. Higher light levels, often found at the top of unevenly-lit stacks, can often be the cause of differential fading, depending on where an item is shelved.

ULTRAVIOLET EXPOSURE. The damaging effect of light can be increased if there is a large component of ultraviolet (UV) radiation, radiation just above the visible spectrum. This radiation does not improve the visual experience, is more damaging than visible light, and can be readily filtered out of light. Electric light sources can also be chosen that have little or no UV output. In all cases, the amount of UV radiation in the light should be less than 75 microwatts per lumen (μW/L), or roughly less than 2 to 4% of the energy emitted from the light source.

INFRARED LIGHT EXPOSURE. The damaging effect of light can be increased if there is a large component of infrared (IR) radiation, radiation just below the visible spectrum. This radiation does not improve the visual experience, and can cause damage to the collection through radiant heating, thermal expansion and spot desiccation.

It is important to note that UV and IR only increase the damaging effect of light. Removing UV and IR, even through a perfect filter, would not prevent light from damaging light-sensitive objects.

PARTICULATE CONTAMINATION

Particulates can be anything from a nuisance to a clear danger to collections. The most common particulate contamination is a soft brown dust generated by the collection itself. This dust has relatively large particles (usually paper fibers), is generally no more abrasive than the collection materials themselves, and is easily removed through dusting or vacuuming. The HVAC system can become contaminated by this dust and can spread it throughout a building, which is why effective filtering is desirable.

The particulate contamination that causes the most problems is the fine black soot found in urban and industrial areas. It is found on window sills and as black stains on HVAC grills and ductwork. This soot comes from combustion of organic compounds, typically from automobiles, boilers, furnaces, and fossil-fuel power plants. It is very small, usually less than 1-micron in diameter, and easily stains objects. It is not easily removed, since dusting seems to spread it, working it into the surface of objects. It is so small that it is not easily picked up by a vacuum cleaner, and passes through the filters of conventional vacuum cleaners and typical HVAC filters. It requires special filtration to prevent contamination of the space and HVAC system and to prevent spreading it throughout a building.

GASEOUS CONTAMINATION AND AIR POLLUTION

The damage from gaseous pollution is only now being understood and quantified. The gaseous contamination may come from pollution in outdoor air, from contamination by off-gassing from the building's construction or cleaning materials, from building occupants, or from the collection itself. Harmful compounds include sulfur dioxide, oxides of nitrogen, hydrochloric acid, ozone, and many volatile organic compounds (VOCs), such as formaldehyde and acetic acid. Standards have been set for acceptable conservation levels for pollutants (see References 1 and 2), but these are not easily measured or achieved. Generally, contaminants should be limited to levels which reduce or eliminate the threat of damage to the collection. In most cases this is removal of almost all airborne contaminants and pollutants to levels well below outdoor levels, and well as below levels deemed "safe" by environmental protection agencies.

When discussing gaseous contamination or pollution levels, specific numbers should be checked. Table 1 compares the collection conservation criteria for sulfur dioxide (SO_2), oxides of nitrogen (NO_x), and ozone (O_3), from References 1 and 2, to typical "safe" threshold levels for gaseous pollutants as promulgated by the United Stated Environmental Protection Agency. Note that "safe" gaseous criteria for the collection are very low levels, often less than 1/100th of acceptable EPA or "human" levels. This means that a nominally "safe" level of gaseous pollution for people, or air treatments that satisfy EPA or "odor control" goals will usually not be safe for the collection.

Part of the reason the collection has a lower tolerance than human occupants of the same space is that the human body is living and can effect repairs to itself--the collection has no such self-renewing mechanism. The collection is also expected to have a longer life and exposure period, hopefully several hundred or thousand years, which means that even a low level of gaseous pollution will have a significant cumulative effect.

Table 1 - SUMMARY COMPARISON OF CONSERVATION AND US EPA CRITERIA FOR GASEOUS POLLUTION

	Range of Conservation Criteria	US EPA Levels*			
		Long-Term		Short-Term	
	$\mu g/m^3$	$\mu g/m^3$	period	$\mu g/m^3$	period
SO_2:	1 to 10	80	1 yr	365	24 hrs
NO_x:	5 to 10	100	1 yr	---	---
O_3:	2 to 25	---	---	235	8 hrs

* As described in ASHRAE Standard 62-1989

Table 2 summarizes the criteria for conservation environments. For further information on conservation environment criteria consult References 1, 2, 3 and 4.

Table 2 - SUMMARY OF CRITERIA FOR THE CONSERVATION ENVIRONMENT

RELATIVE HUMIDITY
- Paper: 40-45% RH
- Film: generally 30% RH, but can vary with material

TEMPERATURE
- Paper: 60-65°F for storage
  65-70°F for occupied areas
- Film: Same, or lower if possible

Temperature goals should generally be subordinated to humidity goals and stability.

LIGHT
- Storage: 1-5 Footcandles (11-55 Lux)
- Display: 5-15 Footcandles (55-165 Lux), the lower the better
- Reading/Work Areas:
  30-60 Footcandles (330 to 660 Lux), but only short exposures for paper and other light-sensitive materials
- UV Content: <75 microwatts per lumen, <2 to 4% UV
- IR Content: Limit with light levels or dichroic reflector lamps

PARTICULATE CONTAMINATION

Remove problem particulates, where soot is present, filter to remove better than 50% of 0.5 micron particles.

GASEOUS CONTAMINATION

R[illegible] of Conservation Criteria based on References 1 and 2:

	$\mu g/m^3$	ppb
Sulfur Dioxide (SO_2):	1 to 10	0.38 to 3.8
Oxides of Nitrogen (NO_x):	5 to 10	2.5 to 5.0
Ozone (O_3):	2 to 25	1.0 to 12.8

COLLECTIONS ENVIRONMENT ASSESSMENT AND MONITORING

An important foundation to achieving a good conservation environment for a collection is evaluation of the collection's needs, the collection's general condition, and existing environmental conditions.

To properly assess the environmental needs, condition, and environmental indications of a specific collection, a trained conservator should be consulted. If the institution does not have a staff conservator, or the staff conservator is not familiar with a particular type of collection, a consulting conservator may be called in. The Division of Library Development of the New York State Library, or the New York State Conservation Consultancy may be able to assist in locating and securing the services of a consulting conservator familiar with a particular type of collection.

The needs of a specific collection should be characterized by a trained conservator. However, as a starting point, an environment can always be assessed against general guidelines for relative humidity, temperature, light exposures, particulate and gaseous contamination noted in the previous section.

GENERAL ENVIRONMENTAL OBSERVATIONS

Almost anyone can make a few basic observations to get some general indications of the condition of a collection. These observations can help orient the institution to the collection and collection environment, and help in discussing possible conservation environment problems with others.

1. *GENERAL MATERIALS SURVEY.* Identify the general type of materials in a collection, although differentiation within types of objects (types of paper, types of film, types of bindings) may not be possible without training.

2. *INDICATIONS OF DAMAGE.* Inspect the collection for obvious indications of environmental problems, such as accumulations of dust or black soot, discolored "halos" at the exposed edges of older books, and general embrittlement and deterioration of paper and book bindings. Photographic films may show separation of the emulsion from the substrate, or wrinkling. Stains may indicate high humidity, water or mold problems. Insect carcasses or patterns of granular particulates beside objects may indicate an active insect infestation. Some of these observations, under certain conditions, may be old damage or inherent vice, while others may be clear evidence of a deficient collection environment.

3. *THE BUILT ENVIRONMENT.* Survey the built environment, i.e., the building and building systems which house and protect the collection. Look for windows that allow strong daylight to reach the collection; fluorescent lamps without UV filters, or lamps located too close to collections; particulate staining at HVAC grills; radiators or lights that overheat parts of the collection; and, water staining or other evidence of leaks or condensation.

It will also be helpful to know how the collection is generally stored, and the rough square footage of each collection space. This will help in discussing the scope of the project with others unfamiliar with the institution.

For the untrained eye, these observations should not be used to draw any direct conclusion, other than there is the need to undertake further investigation with the help of a conservator.

ENVIRONMENTAL MONITORING

In assessing an existing collection environment, consistent and reliable measurements and monitoring can be invaluable. This will not only allow conditions to be compared to ideal goals, but will establish possible causes for past and current collection problems, and may often lead to clear diagnosis of problems with building systems.

TEMPERATURE/HUMIDITY INSTRUMENTATION. Equipment for monitoring can range from simple spot measurement equipment to continuous recording devices, to automated and computerized systems.

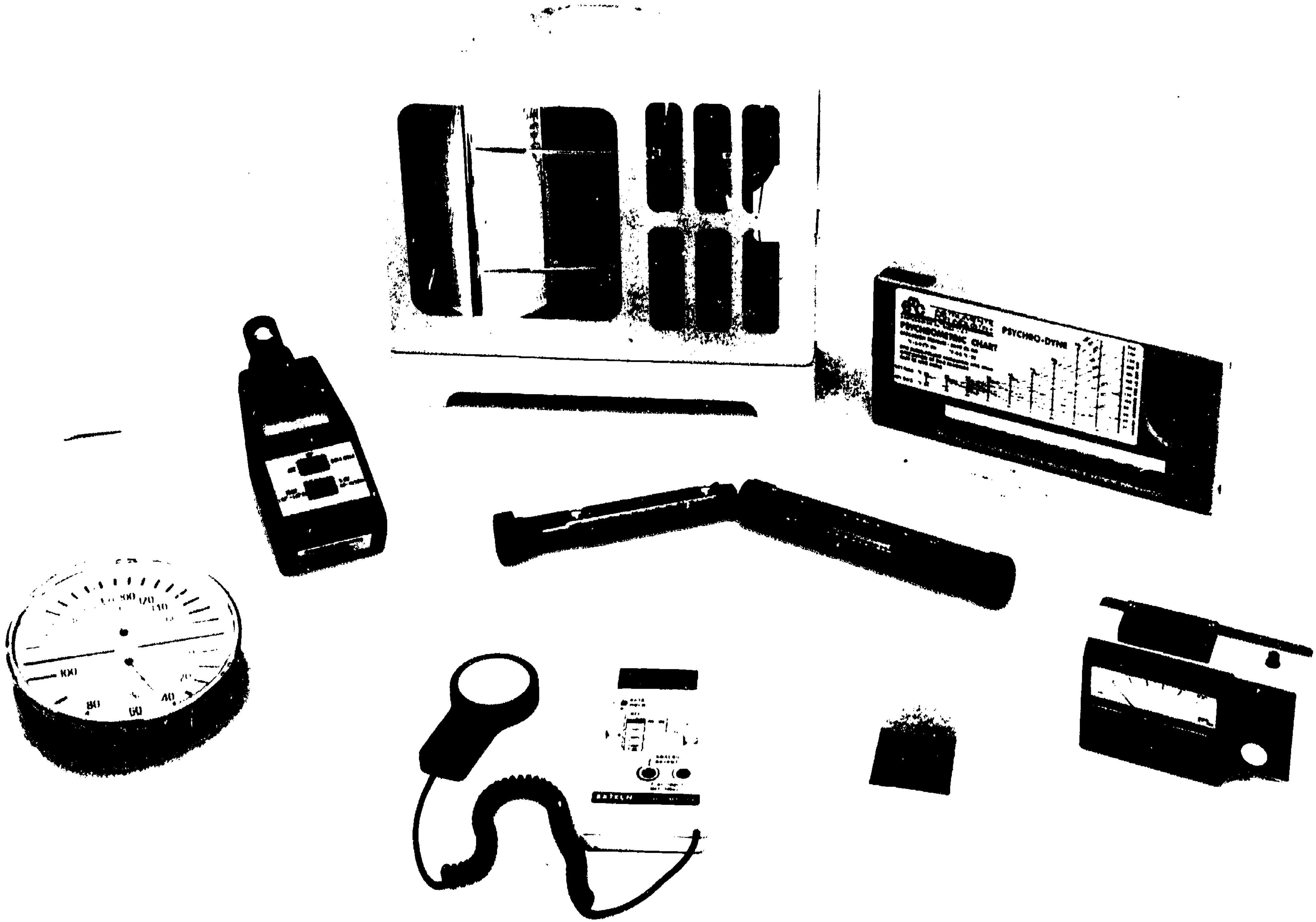
Spot measurements are of value, but provide only the most basic information. They can be made with thermometers and relative humidity color cards (less than $10), high/low thermometers (less than $50), more expensive sling and aspirating psychrometers ($40 to $200), or electronic temperature/humidity meters ($180 to $1,000+).

Dial hygrometers are not recommended, since they are often wrong by a considerable amount: in a recent situation, several dial hygrometers read 60 to 70% RH when the true relative humidity was 35%. Although dial hygrometers often use the same human hair sensing element found in more expensive and more accurate hygrothermographs, the hair in the dial hygrometer is often too short for reliable readings. An exception are the "animal membrane" dial hygrometers, which use a more accurate patented sensing element.

While daily spot readings are better than nothing, even hourly spot readings cannot fully characterize the environment, and are usually not made at night, when the harmful fluctuations are most likely to occur. Meaningful monitoring does not require a conservator or dedicated technician, but does require instruments which make continuous records, training in their use, and some regular attention.

HYGROTHERMOGRAPHS. By far the most common monitoring device is the hygrothermograph (typically $400 to $900 each), which continuously measures and records temperature and relative humidity. The hygrothermograph should be a linear chart type (also called a strip or drum type), rather than the circular type. A linear strip chart is much easier to interpret and make further use of.

The relative humidity part of the hygrothermograph should be recalibrated when first set up, whenever moved, and weekly or monthly when in use. Without regular recalibration, a hygrothermograph can be off by 10 to 20% RH, usually giving readings that are falsely high. For continued accuracy and performance it should be "rehydrated" no less than once a year, following manufacturer's instructions.



Photograph 1 - ENVIRONMENTAL MEASUREMENT EQUIPMENT. Center: Sling Psychrometer. Clockwise from top: Hygrothermograph, Aspirating Psychrometer, UV Meter, Blue Wool Fading Card, Light Meter, Dial Hygrometer/Thermometer, Humidity Measurement Color Cards, Electronic Humidity Meter. Photo by P.A. Hutchins, Minneapolis, MN.

A meaningful hygrothermograph measurement program should cover at least two consecutive seasons, preferably a year, before full conclusions can be drawn. A good monitoring program will be based on the thoughtful use of one or more hygrothermographs, training in setup and calibration, and a device to recalibrate the hygrothermograph's relative humidity reading, usually a sling psychrometer, an aspirating psychrometer, or an electronic temperature/humidity meter. A member of the staff should be designated to regularly check the equipment, change charts, and recalibrate. Although less than ideal, if charts cannot be changed weekly, then a hygrothermograph with a monthly chart rotation should be used.

When the number of hygrothermographs are few and the spaces to be monitored are many, a well-planned program for rotating the available equipment through different spaces is essential for adequately characterizing an institution's environment. For large institutions, the effort of managing a program with too few hygrothermographs may actually cost more in labor and missed information than the cost of the additional hygrothermographs.

CENTRAL COMPUTERIZED MONITORING SYSTEM. For very large institutions, a large number of hygrothermographs can present a problem. In these cases a computerized monitoring system often provides the best solution, trading recurring labor costs for a relatively high capital cost system. Such a system should be based on high-quality electronic relative humidity sensors, and not on typical HVAC control humidity sensors or humidistats, although the monitoring system might be part of an HVAC direct digital control (DDC) system. In order to assimilate the computerized environmental data, and to provide a meaningful alternative to hygrothermographs, the system must provide a linear graphic output, the computer equivalent to a linear hygrothermograph chart. The system should also be periodically checked and recalibrated against independent measuring devices, much as one would check hygrothermographs.

DATA LOGGERS. These devices are usually a type of small electronic hygrothermograph ($400-$1,000+), often about the size of a pack of cards, using internal or external electronic temperature and humidity sensors. They do not provide the character of continuous information or immediate information that comes from a hygrothermograph, and require the use of a computer system and special software to extract data from them.

Their advantage is that they are usually more rugged than a hygrothermograph and are well-suited for data acquisition and reduction from remote locations where local expertise to recalibrate or protect a hygrothermograph would not be available. Since they are not designed to provide immediate information on a casual basis, they usually do not suit most institutional monitoring applications as well as hygrothermographs, or a centralized monitoring system as part of a building's HVAC DDC system. For large institutions they can often effectively combine most of the *bad* characteristics of using hygrothermographs and a DDC monitoring system with few of the benefits.

LIGHT LEVELS. Unlike temperature and relative humidity, which are best measured continuously, light levels can often be effectively measured with selected spot readings at typical and at the brightest collection locations. In situations where daylight varies the light levels, the highest daylight level should be measured, since the maximum light level will usually indicate the level of damage. Remember that in some locations direct sunlight may come in before or after usual opening hours, and daylight entry may differ depending on the season.

Light levels can be measured with light meters, ranging in cost from less than $50 to over $200. The meter should provide accurate readings in the range from 5 to 250 footcandles. The lower cost meters are often only effective in measuring very rough light levels below 20 footcandles, but are adequate to identify badly over-lit conditions.

A camera with a built-in light meter can be pressed into service as a crude light meter. Set the camera's ASA to 400, the lens to f/5.6, and point the camera at a white sheet of paper located where the light level is to be measured. With the white paper filling the field of view, read the camera's shutter speed (1/8, 1/15, 1/30, 1/60, etc.). The denominator (8, 15, 30, 60, etc.) will indicate the rough light level in footcandles.

UV EXPOSURES. In contrast to visible light levels, UV exposure, or the percent of UV in illumination, is much harder to measure. Some older-design UV meters in the $500-$1,500 price range are not adequately sensitive to all UV frequencies. If they indicate a problem UV exposure situation, then one exists; however, if they indicate a safe level, UV overexposure may still exist. New-design meters in the $3,000-$5,000 price range are more effective in accurately detecting high UV exposures.

In practice, UV levels can usually be evaluated based on the light source, comparing it to the goal of less than 75 μW/L of UV, or less than 2 to 4% of UV radiation. Table 3 may be helpful in this analysis. When evaluating illumination in a conservation environment, consider both the UV component and the light level. Be aware that lamp UV output may vary between manufacturers, and between specific lamp products. The manufacturer should be contacted for the specific UV output of a lamp.

NOTE. This document follows the manufacturing and construction industry nomenclature for lighting, using the term "lamp" to describe the luminous light source the layman often calls a "light bulb," and using "light fixture" or "fixture" to refer to what the layman might call a "lamp."

The standard UV criteria is specified as a proportion or ratio of the illumination at proper conservation levels, and would need to be revised to a lower level if illumination levels should exceed the specified conservation light level. That is, if lighting is above the recommended level, then 75 μW/L would be too high.

For example, given the goal of 10 footcandles at less than 75 μW/L: lighting at 30 footcandles should be less than 25 μW/L to meet UV criteria; lighting at 100 footcandles should be less than 7.5 μW/L to meet UV criteria; and lighting at 5 footcandles need only be less than 140 μW/L to meet UV criteria.

Table 3 - SUMMARY OF UV CHARACTERISTICS FOR VARIOUS LIGHT SOURCES

Light Source	Typical UV µW/L	Typical %UV
Sunlight		
Direct or South	400	10%+
Overcast or North	800	20%+
Blue Sky	1600	40%+
Incandescent		
Standard	60-80	4%
Tungsten-Halogen	130*	8%
Low-Voltage	60-120	4-8%
Florescent, General	40-250	2-12%
Special Low-UV	<10	<0.5%
High Intensity Discharge		
Mercury Vapor	400+	10-20%+
Metal Halide	400+	10-20%+
Sodium Vapor (LPS & HPS)	<10	<0.5%

* With glass filter.

(Table developed from Reference 2, pages 168 and 175; and from table provided by Edward K. Robinson, March 1981.)

CUMULATIVE LIGHT EXPOSURE. The true test for light exposure is damage to the collection. Blue wool sample cards have been developed for testing the long-term fading effects of light exposure. These cards, available from conservation supply sources for less than $5, have sample pieces of material which progressively react to light damage. The typical sample is prepared by making a light-shielded strip to allow quick comparison of the faded sample to its original condition.

OTHER ENVIRONMENTAL MEASUREMENTS. Relative humidity and light are two of the most important environmental factors, and, along with temperature, can usually be effectively addressed with a good hygrothermograph program and a general light level survey. Other environmental aspects, such as particulate and gaseous contamination, require more sophisticated and expensive equipment, usually in excess of $10,000 for each measurement instrument, which often require special technicians. Even the largest institutions have found regular or continuous measurement of particulates and gasses not feasible, although simpler and cheaper methods are under development.

PARTICULATES. Presently, particulate contamination is most easily evaluated by direct observations, such as with a white glove. More sophisticated particulate measurements can be made by an environmental testing lab, but are rarely used.

GASEOUS CONTAMINATION. Since one source of gaseous contamination is air pollution, local pollution records from federal, state or local government agencies can be helpful; however, many instances of gaseous contamination come from internal or site-specific sources, which would usually not be reflected in local of regional data. Meaningful measurements of gases must generally be sensitive to levels as low as 1/100th of the acceptable EPA or OSHA "threshold value levels" (TVLs) and "permissible exposure levels" (PELs), which can be quite expensive and involved.

When discussing gaseous pollution levels be sure to check specific numbers for the contamination level, usually expressed in micrograms per cubic meter ($\mu g/m^3$) or parts per billion (ppb). Do not accept the patent characterization that "our pollution levels are safe"—this usually means that you are below the EPA levels which may still mean you are ten to one hundred times the recommended criteria for your collection. (See Table 1.)

Gaseous contamination can sometimes be evaluated if a conservator can make tests to trace collection damage to gaseous contamination. Copper and silver "corrosion coupons" may also be used to test for certain gaseous contaminants, but true electrolytically-stripped laboratory coupon tests can cost up to $300 each.

SETTING UP A MONITORING PROGRAM. An environmental monitoring program should gather meaningful data on humidity, temperature, light, and other important factors of the institution's environment, as outlined above. A regular monitoring program is important not only when an environment is suspect, but when an institution believes a good environment is being maintained. Clear and reliable monitoring information can provide concrete evidence and lay the basis for convincing arguments for improving poor environmental conditions. Continuous monitoring can also identify transient or progressive problems with building systems to provide early warning of threats to the quality of the environment, and to the safety of the collection.

For institutions that do not have access to a trained conservator, it may be advisable to obtain the services of a consultant to set up an environmental monitoring program, helping determine the need for special testing and the scope of prudent continuous monitoring. The program could then be carried out by the regular institution staff.

For further information on conservation environment assessment and monitoring consult References 2 and 5.

COMPROMISES FOR CONSERVATION ENVIRONMENT GOALS

Without the proper environment, collections are eventually damaged on a wholesale basis. On the other hand, environmental goals can be set which are unrealistic, impractical or too expensive to achieve in light of the real limitations on many projects.

The following discussion is intended for the consideration of compromises in meeting environmental goals, when a compromise system is required due to overall budget limitations, or to protect the fabric of an historic building. *If a first class system is needed and can be supported by the project budget, then these compromise goals should not be considered*! These compromises should be a last resort, and should not be used to subordinate the environmental goals to the capricious desire to spend money on more tangible but ephemeral building amenities in a renovation project.

LIMITATIONS AND PRIORITIES. One of the more important aspects of providing a conservation environment is to work within existing limitations to provide an improved environment that is balanced in its goals and better for the collection than alternative improvements that would cost the same. With the advice of conservators trained to evaluate the various parts of a collection, one should consider priorities and compromises based on the specific needs of the collection, balanced against the different levels of protection that can practically be provided by the institution's budget and the building's environment. The compromises mentioned here are representative but are certainly not all-encompassing. As with any attempt to cover the complex issue of environmental goals and building systems, any given collection may have requirements that are not covered here, or may require substantial modifications of these suggestions.

RELATIVE HUMIDITY

Stable relative humidity is the most important environmental goal which must be met. Rather than simply specifying a constant 45% RH, or 42% ±2% RH, it may be necessary to consider the merits to the collection of the different aspects of humidity control, and how easily each aspect might be achieved. This can help set achievable intermediate goals on limited budgets for improved but less-than-ideal conditions.

LOW RELATIVE HUMIDITY. For most paper collections, very low humidities may cause temporary or permanent embrittlement which will lead to damage upon handling, contraction and deformation of the fibers in paper, or differential shrinkage which can cause delaminations. While stable 45% RH is often the ideal goal, the major damage for many objects comes from humidities below 35 or 30% RH in winter. When compromises are needed, consider lower, more easily achieved levels near 30% RH in winter. Compromises may be indicated from costs or environmental system limitations, but most often are the result of a building envelope which will be damaged by higher humidities in winter. Among the exceptions to such a compromise is vellum, where a 30% RH compromise may cause permanent embrittlement and damage, even if the object is not handled.

A typical possibility is the case of a collection with vellum in an historic building which cannot tolerate 35% RH in winter. Treating the building to make it tolerant of enough humidity to protect the vellum might be entirely too expensive, and might damage its historic character. So long as the amount of vellum is limited, the vellum parts of the collection might be segregated and stored in special storage boxes, cabinets or rooms which could have their humidity separately kept at the proper level for the vellum, yet protecting the balance of the building from the higher humidity within.

HIGH RELATIVE HUMIDITY. High relative humidity can cause acceleration of deteriorating chemical reactions, expansion of some materials, and can support mold growth and insect infestations. Stable conditions around 45% RH are desirable, but in compromise situations there may be considerable merit in reducing mold and insect growth by keeping the level below about 60% RH as much as possible in the humid seasons. Specific collateral actions, such as providing good air circulation and protecting from initial insect contamination, will often determine how effective a compromise will be in protecting the collection.

LOW HUMIDITY/LOW TEMPERATURE COLLECTIONS. In some cases, part of a collection can be identified and segregated for a special environment with low relative humidity and low temperature, most commonly the archival storage of photographs and microforms. Depending on the value of the collection, priority may need to be placed on summer cooling and dehumidification to the appropriate level, often to 30% RH at 60°F, or below. Such control can be a considerable challenge. The merits of the more easily achieved level of 60 or 50% RH at 65°F should be considered where compromises are needed.

For valuable master negatives which the institution need rarely access, consider arranging off-site storage at a special storage facility for film.

TEMPERATURE

Temperature does not usually present as much of a threat to collections as relative humidity and it is usually more of a one-way problem: the temperature is too high. Lower temperatures in winter can also allow easier and less expensive humidification.

HIGH TEMPERATURE. A high temperature limit is a reasonable goal, and consistent with human comfort. Unless there are aspects to the building which cause severe thermal loads, such as large expanses of glass or roof, or excessive heat from lights, cooling to 70 or 75°F should be a reasonable expectation for a typical HVAC system.

LOW TEMPERATURE. A low temperature goal has the general benefits of slowed chemical reactions and a longer life for the collection. However, low temperatures, below 60 or 65°F, can cause other problems. People become uncomfortable, even with supplemental clothing, and objects at lower temperatures can gain damaging moisture through condensation when they are quickly brought into warmer humidified spaces. Temperatures below 60 or 65°F during the cooling season will generally require specialized HVAC systems that are an added cost and that many

HVAC engineers cannot easily design. At temperatures much below 55°F there can be problems with damage to the building systems, and special precautions may be required.

HUMIDITY vs. TEMPERATURE CONTROL. In most cases temperature should rightfully take second place in priority to relative humidity, but, unfortunately, stable temperature control is more easily achieved (often by HVAC processes that effectively modulate the environment's relative humidity to maintain that stable temperature). Proper systems for conservation environments should allow temperature to fluctuate in favor of stable relative humidity.

PARTICULATE CONTAMINATION

To be of value, HVAC filtration should remove as much of the particulate contamination as possible. Compromises include the use of containers and covers to protect the collection from particulates as they settle. Proper cleaning can also help, so long as it removes particulates, rather than just stirring them up and spreading them around, as classically happens with a feather duster.

GASEOUS CONTAMINATION

SOURCE REDUCTION. One method to reduce gaseous pollution levels is to limit the internal generation of pollutants. This is not easy. All interior finish materials, particularly paints, carpets and processed wood products must be considered as possible sources of gaseous contamination that need to be controlled. All compounds regularly used in the building, particularly cleaning supplies, should also be considered as potential sources.

COLLECTION CONTAINMENT. In some instances the collection may be stored or displayed in closed containers, closed furniture or display cases. This limits the exposure to pollutants because of reduced exchange of air with the ambient building environment. These contained environments may be designed to include compounds which can remove some of the pollutants that enter, or can be made from materials that can serve as buffers against airborne pollutants. In most collections this type of treatment will not suit all parts of the collection, but is most commonly used for storage of photographic film and prints, and archival records. This will work so long as the portion of the collection that needs this protection is limited, or extensive access is not needed; for open-shelved library stacks, containment is virtually impossible.

LOCAL FILTRATION. Similar to collection containment, specific areas can have gaseous pollution control added, rather than treating all the collection areas. This should generally be done for the most sensitive parts of the collection. In cases where there is an acute source of gaseous contamination within the building, such as a lunch room or smoking lounge, it may be appropriate to filter the offensive space rather than the collection space.

LIGHT EXPOSURE

While the design of sophisticated HVAC systems may require moderation in the expectations for relative humidity, particulate or gaseous performance to meet budgets, there is little excuse for overlighting a collection. UV filters are relatively inexpensive, and are usually easily applied to windows and lights. In general, less light improves the environment, reduces capital costs, and reduces operating costs.

Light levels can be easily reduced through window shades, blockout panels, tinted glazing, dimmers, de-lamping, or replacement of lamps with lower-wattage alternatives. In the worst case, new light fixtures and windows may be needed, but these and other costs are often paid for by reduced lighting and cooling bills from the lower-level lighting.

ACTING ON COMPROMISES

Although compromises may be needed to have balanced achievable goals, any compromises should be developed with advice and evaluation from a trained conservator. The items mentioned here are only concepts—they should not be applied to any situation without further consideration. Compromises should be avoided where a collection warrants a first class environment—that is why the original criteria were developed.

ACHIEVING CONSERVATION ENVIRONMENTS: HVAC

The purpose of the heating, ventilating and air conditioning (HVAC) system is to establish and maintain relative humidity (add and remove moisture), maintain temperature (add and remove heat), filter the air (remove particulates and offending gases), and perform these tasks evenly throughout the space.

While HVAC systems are the main determinants for actively maintaining the conservation environment, an effective conservation environment involves more than just the HVAC system. The basic architectural design (such as windows and vapor barriers) and building operation (24-hour operation and availability of heating and cooling sources) must complement these purposes and not pose impractical challenges to the HVAC design.

PRIMARY FUNCTIONAL COMPONENTS OF A CONSERVATION ENVIRONMENT HVAC SYSTEM

The following are the primary functional components and basic features of an HVAC system that provides a good conservation environment for an archives or library. These are highlighted in Diagram 1.

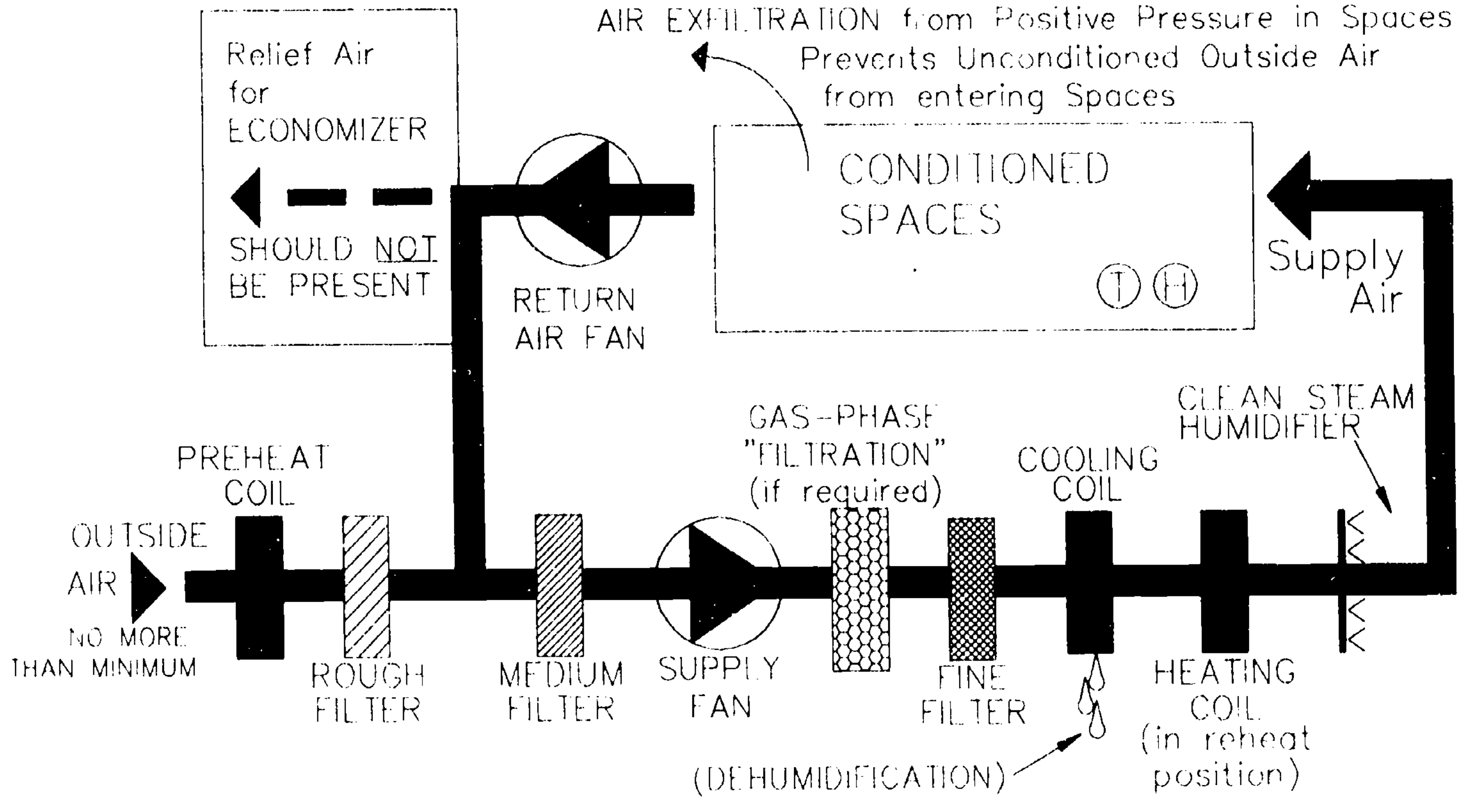
CONSTANT AIR VOLUME. Archives and libraries rely on mechanically assisted air flow to filter and control humidity for the collection, not just for cooling or heating. Air should be constantly circulated at full volume, regardless of space tempering needs, and should have good circulation throughout the collections space.

COOLING AND HEATING. The system should provide the necessary cooling and heating, but must subordinate temperature control, particularly heating, to the need for stable relative humidity.

PARTICULATE FILTERS. To avoid particulate buildup and cleaning problems, air filtration should be effective down to the typical contamination particle size. In most cases this will require two or three sets of filters. The rough or prefilter is intended to remove the large particulates, and is the type of filter used in virtually all HVAC systems. Medium and final filters are used to remove the smaller particulates. The reason of this staged filtration (rough/medium/final) is for the upstream filter to protect the downstream filters from premature loading with large particulates.

GAS-PHASE FILTRATION. Where new construction materials, interior contamination, or outdoor pollution present a gaseous pollution threat to a sensitive collection, gaseous contamination control equipment should be used. Although the word "filter" is often used, this equipment does not mechanically filter the air; it chemically adsorbs and absorbs contaminants from the air.

OUTSIDE AIR. Since an archives or library is trying to maintain a stable indoor environment, outside air presents a potential problem. It is almost always at other-than-desirable temperature and relative humidity, and varies in this respect



PRIMARY FUNCTIONAL ELEMENTS
OF A CONSERVATION ENVIRONMENT HVAC SYSTEM

DIAGRAM 1

throughout the day. It can introduce particulate and gaseous pollution from the outside. An "air economizer," in which large amounts of outside air is used for "free" cooling, should be avoided. Outside air should usually be at a minimum amount, to provide the necessary fresh air for occupants, and to pressurize the collection spaces. Pressurization is desirable to cause exfiltration at leaks in the building envelope, rather than allow infiltration of untreated outside air.

HUMIDIFICATION. Humidification should be provided by clean steam introduced in the air system. "Spray" or other systems which introduce water mechanically without heating it to its vapor phase should be avoided.

HVAC CONTROLS. The HVAC controls, the components that modulate the various components in an HVAC system, are a critical aspect of a good conservation environment. Sensors, thermostats and humidistats, must be located in the collection space itself, not in the return air stream. In all cases, a variation in temperature is preferable to a variation in humidity. This has strong implications for HVAC controls design, since conventional controls treat temperature as the primary goal and humidity as supplementary.

DEHUMIDIFICATION. To dehumidify, moisture is usually removed from the air by a cooling coil, usually the same coil which also cools the supply air for space cooling.

REHEAT. The air system should have "reheat" capabilities so that dehumidification can occur when space cooling is not required (which is most of the time). This means that the system must cool the air to remove the moisture, and then heat it back up to reduce the relative humidity of the cooled air. The reheat is also to prevent over-cooling of the space. In many cases the reheat may be provided by having the normal heating coil in the "reheat position," downstream of the cooling coil. (A portable dehumidifier combines both cooling and reheat in a single system. Cooling comes from a small cooling compressor, and the heat comes from the condenser heat produced by the compressor.)

DESICCANT DEHUMIDIFIERS (not shown in Diagram 1). An alternative to dehumidification with conventional cooling is a dehumidification system using desiccants, which are usually required to maintain low humidities at low temperatures. Such systems pass the air to be dehumidified through a desiccant bed, which absorbs moisture from the air and increases the air temperature. The desiccant bed is then moved to a regenerative air stream, usually as a wheel, and exposed to hot air which drives the moisture from the desiccant and into the regenerative air which is exhausted. These systems are not common in most HVAC designs, are almost always in addition to conventional cooling, and are unfamiliar to most maintenance personnel. They should be avoided unless absolutely necessary. If required, they should be carefully selected for easy maintenance, and to prevent contamination of the collection by abrasive and chemically-active particulates shed by the desiccant bed.

TYPICAL HVAC SYSTEMS

HVAC distribution systems were created to provide temperature control inside buildings. This is usually achieved by addressing discrete areas—spaces or groups of spaces within a building. These areas, or environmental control "zones," are typically tempered by delivering varying amounts of heating or cooling, through the delivery of water or air. For their application in libraries and archives, these systems must also provide humidification and dehumidification for each zone, as well as other features, and in these goals they differ significantly from typical systems designed primarily for human comfort.

Most distribution systems can generally be categorized by their medium of providing zone tempering. The descriptions here are predicated on systems that must provide basic humidity control for each control zone.

ALL-AIR. These systems deliver only air to condition the spaces served, delivering air that is warm or cool, moist or dry, to maintain space conditions. These systems primarily or exclusively use ducts rather than piping, which can eliminate the HVAC system as a water source in collection areas. In general, all-air systems provide the best environmental control, with little or no piping or maintenance activities required in the collections spaces.

AIR-WATER. These systems deliver a combination of air and water, through a combination of ducts and pipes, to condition the spaces served. They may also require steam piping or local steam generators. In general, air-water systems require piping and maintenance activities in the collections spaces, a clear disadvantage.

ALL-WATER. These systems use hot or cold water, through pipes, to condition the spaces served. In general, all-water systems require extensive piping, require regular maintenance activities over or in collection areas, and can rarely provide the features needed to meet conservation goals.

LARGE SYSTEMS. Conservation needs have been best met by constant-volume all-air systems with central air-handling stations, with filtration, humidification, maintenance and monitoring at a central location, avoiding possible leaks from water piping above collection areas.

A typical application of such a full-feature central HVAC system is shown in Diagram 2. From a central location, it serves several spaces with individual humidity and temperature control. A boiler burns oil or natural gas and produces steam for humidification, and for use in a heat exchanger to produce hot water for heating and reheat. A chiller uses electricity to produce chilled water for cooling and dehumidification, rejecting the heat to the outside through a cooling tower. The system shown also incorporates the other primary functional components of a conservation environment system.

SMALL SYSTEMS. A large central HVAC system is not always required for effective environmental control, although it may be the best choice for larger facilities. For small areas, or for a decentralized HVAC treatment, complete environmental systems can be found as small package systems, combining some or all of the key conservation aspects needed for a small library or archive. Typical are small package environmental systems made for computer rooms, and for allergy and health clinics. If used, they should be located in separate spaces or closets, with any piping and maintenance activities separated from the collection space as much as possible.

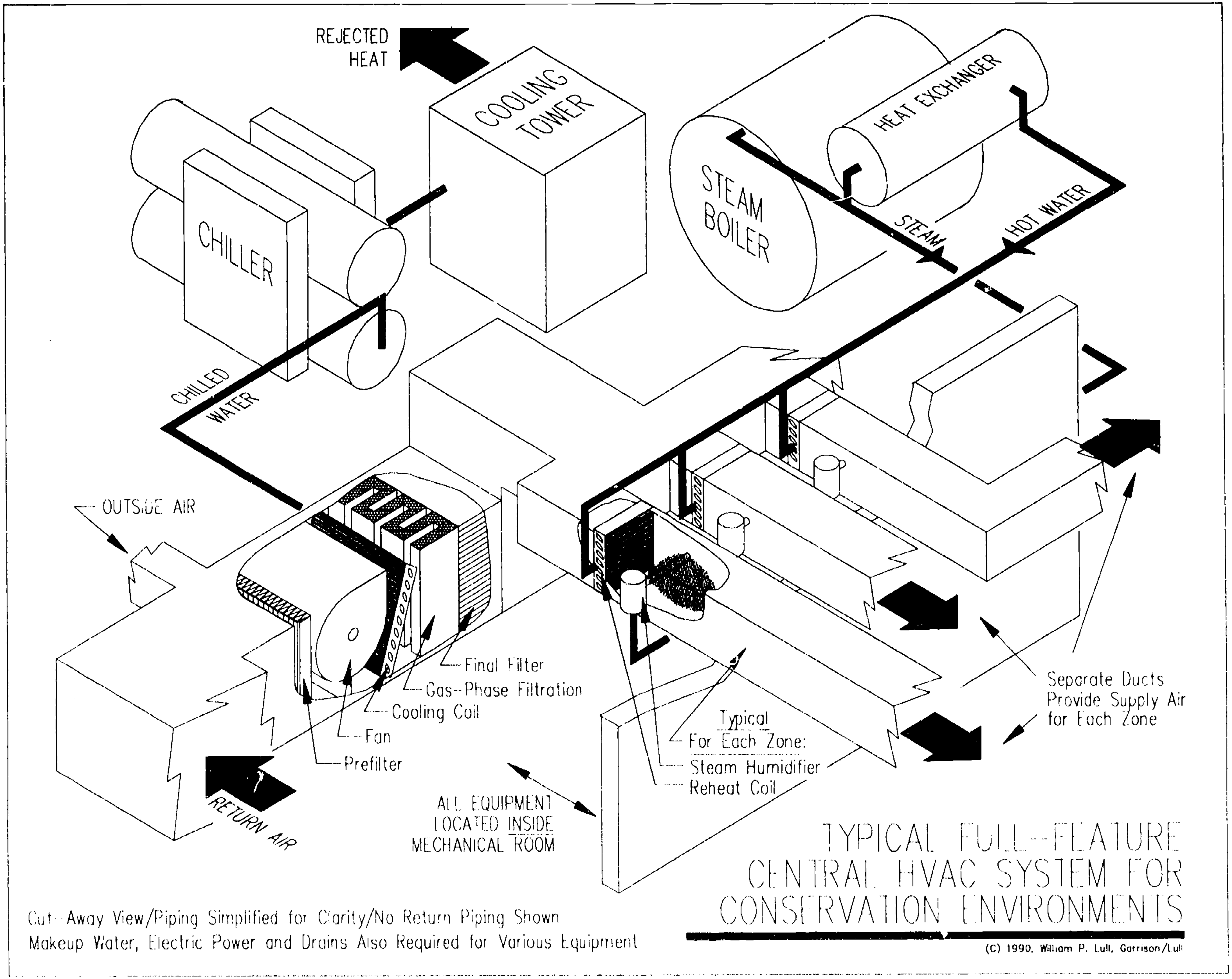

REJECTED HEAT
COOLING TOWER
CHILLER
STEAM BOILER
HEAT EXCHANGER
STEAM
HOT WATER
CHILLED WATER
OUTSIDE AIR
RETURN AIR
Final Filter
Gas-Phase Filtration
Cooling Coil
Fan
Prefilter
ALL EQUIPMENT LOCATED INSIDE MECHANICAL ROOM
Typical For Each Zone:
Steam Humidifier
Reheat Coil
Separate Ducts Provide Supply Air for Each Zone
TYPICAL FULL-FEATURE CENTRAL HVAC SYSTEM FOR CONSERVATION ENVIRONMENTS
Cut-Away View/Piping Simplified for Clarity/No Return Piping Shown
Makeup Water, Electric Power and Drains Also Required for Various Equipment
(C) 1990, William P. Lull, Garrison/Lull

DIAGRAM 2

A typical application of such full-feature small systems is shown in Diagrams 3 and 4. The system in Diagram 3 uses existing chilled water and hot water systems, as may be available in large buildings, along with a new steam generator for humidification. (Before considering the use of an existing chilled water/hot water system, confirm that the hot water and chilled water are available 24-hours throughout the year as needed.) The system in Diagram 4 uses only the basic services of electric power, water and drains, and requires an exterior condenser for heat rejection. It combines a package cooling system (with built-in condenser reheat) and a supplemental filtration system, since the package system did not provide the gaseous control and level of particulate filtration needed.

HVAC SYSTEM PERFORMANCE ISSUES

Any given system, as applied in any given project, may have one or more of the primary functional components and desirable characteristics identified earlier for an HVAC system serving conservation environments. Key aspects to consider when evaluating any system are discussed below.

HEATING/COOLING. Tempering air should be supplied through ducts. Baseboard and radiant heating are excellent for human comfort but present an environmental disaster for collection environments. They introduce dry heat with no chance of concurrent humidification, inviting spot desiccation, and provide no duct system for recirculation and destratification, general air circulation and particulate filtration.

HUMIDIFICATION. Be sure the system has a method to effectively add moisture to the air in each zone. In many systems, without a zone humidifier, the system may be substantially compromised and may provide unstable humidity control in winter.

HUMIDIFICATION STEAM. Humidification steam should be clean and free of additives. The steam should ideally come from a separate boiler or steam generator using clean or deionized tap water. Most central steam heating systems are a poor source for the steam since they are most always treated with compounds to protect the boiler and steam piping from corrosion. If central steam must be used, the concentration of the any treatment compounds must be carefully monitored and kept at minimum levels.

For further discussion of problems with steam treatment consult Reference 6.

DEHUMIDIFICATION. While many systems provide cooling which can usually perform dehumidification, without zone "reheat" for dehumidification, the system may be substantially compromised and provide inconsistent humidity control. Some chilled water systems may not be able to reliably deliver chilled water that is sufficiently cold, or may have cooling coils too shallow for dehumidification to occur at the cooling coil.

FILTRATION AND FAN HORSEPOWER. Some systems have inherently limited fan horsepower and air pressure, which prevents adding good particulate and gaseous control, either initially or as a retrofit.

PIPING. Pipes carrying water or steam over and in collection areas always present the possibility of leaks. While some systems can provide full control without running any piping to the zones, other systems require anywhere from two to six pipes to be

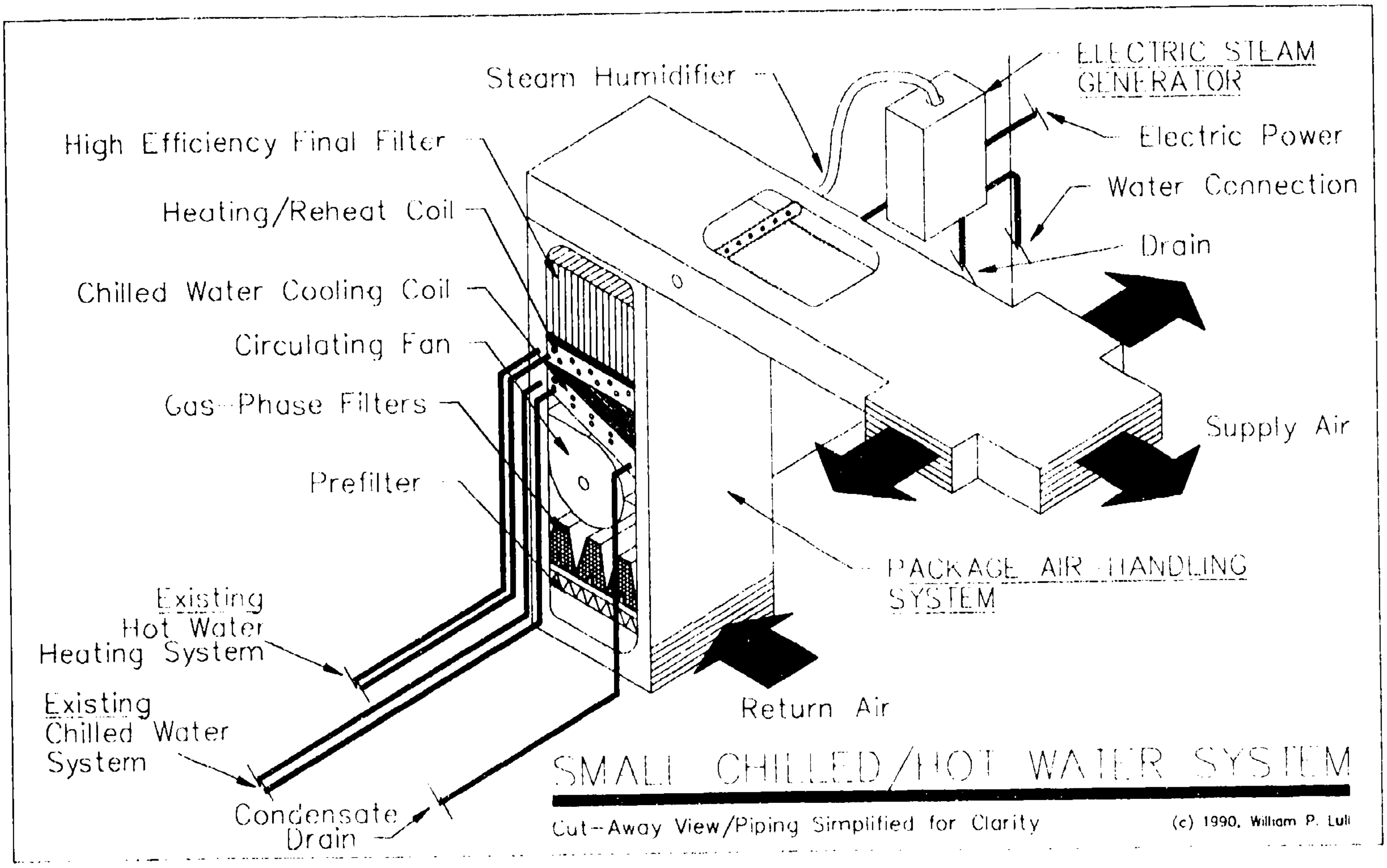


DIAGRAM 3

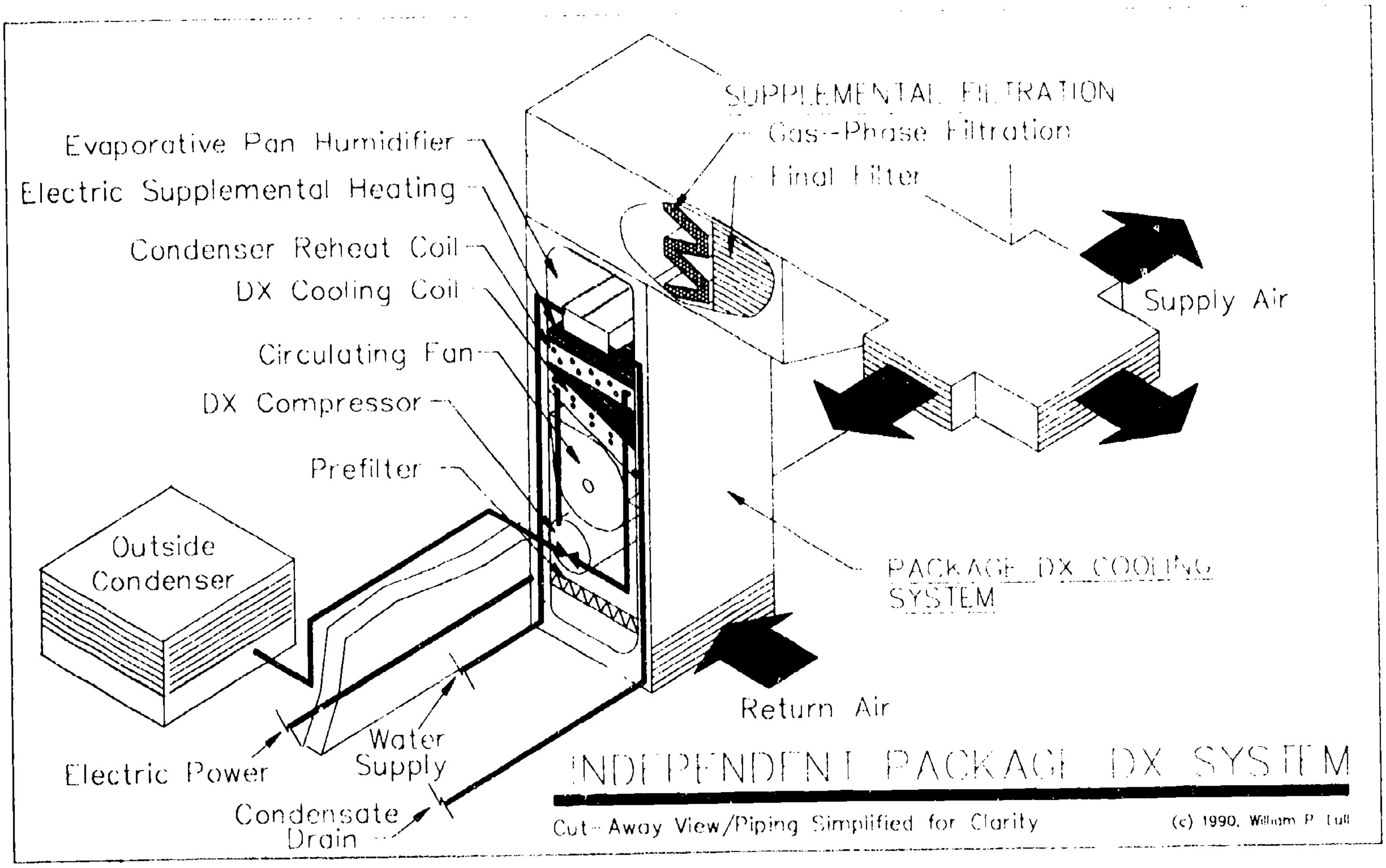


DIAGRAM 4

run to each zone. These pipes must almost always be run over or in collection areas.

OUTSIDE AIR. This should not only be at a minimum amount as required for safe ventilation of the building; air economizers should not be used. The outside air intake should be located away from any potential sources of outside contamination; it should be away from street level and away from any exhausts or flues.

MAINTENANCE AND EASE OF OPERATION. A common failing in many modern system designs is poor consideration of on-going operation and maintenance expectations. Most designs will work if properly adjusted and maintained, but many institutions find they do not have the staff, budget or expertise to give the system the attention it needs. The regular maintenance required for any system should be matched against the institution's manpower and staff capabilities.

VAV SYSTEMS. Variable-Air Volume or "VAV" systems have become very popular since the energy crisis of the 1970s. In a VAV system cool air is delivered to each zone, and the amount of air is varied by the amount of cooling needed in the zone. They save in the capital cost of the fan and chillers, fan energy, the operating cost of reheat, or the capital cost of a multizone distribution. They are an efficient solution to the problem of conditioning office buildings and many other commercial applications where flexibility and varying internal loads are primary concerns.

However, they are not effective in maintaining stable humidities since their basic function is temperature-dependent. When VAV systems are used in archives and libraries, as a rule, they generally have problems in holding stable winter or summer humidity, do not maintain adequate air flows for filtration and consistent space conditions, and have a general lack of flexibility to meet more stringent environmental criteria. They pose a threat to the collection from the overhead reheat water and steam piping which must be added to make the system control humidity.

Sometimes a VAV system is recommended due to "space and budget constraints." In virtually every case, the cost and space required for the properly designed VAV system (full filtration, local humidification, local reheat, minimum air volume settings, well-planned piping, well-planned maintenance access, and extremely well-documented operating instructions) gives no observed advantage over the more conservative, less problematic, and easier to maintain multi-zone, dual-duct or other constant volume systems. While a VAV system can be made to save energy compared to the constant-volume alternatives, it does so at the expense of the institution's collection.

HVAC SYSTEM COMPONENT OPTIONS

Individual situations will vary, and in some cases only partial aspects of the functional HVAC system goals can be achieved in an existing situation. It may be helpful to independently consider the separate functional goals of environmental control systems. Each has its own range of components and component capabilities to strive for that goal.

In the following sections, some component options for each functional HVAC goal are listed from lowest cost compromises with most modest performance expectations, to the best available to meet uncompromised conservation environment goals. These may or may not be applicable in any given situation. Other options not listed may be indicated in a particular situation.

**Relative Humidity--
45% RH Goal**

The following options for relative humidity control can be considered, up to the best available to hold to the exact 45% RH goal.

1. Humidify with a drain-through pad, wetted belt or wetted drum humidifier, permanently piped with makeup water. This will only provide modest performance, will require no less than monthly maintenance and cleaning, and should be upgraded to a steam system for a long-term solution.
2. Humidify with clean steam to prevent relative humidity from dropping below 30% RH, with a high-limit cutoff.
3. Using the previous system, add dehumidification to hold below 60% RH with cooling and reheat, or with unit dehumidifiers equipped with permanent drain capability.
4. Using the previous system, boost humidification to 45% RH with improvements to the building envelope, if necessary, to make it tolerant of the higher humidity.
5. Using the previous system, add sensitive controls and system capacity to hold humidity within the desired 40-45% or 45-50% RH band, using humidification and dehumidification as required, and provide alarms for off-normal events.

**Relative Humidity--
low humidity goal**

The following options for levels of humidity control can be considered for the "low humidity" goal, such as for archival film storage.

1. Dehumidify to below 60% RH with typical cooling and reheat or unit dehumidifiers equipped with permanent drain capability.
2. Dehumidify to 35 or 30% RH with special cooling and reheat or dehumidification system, possibly requiring use of a desiccant system, in a room or building envelope sealed to prevent entry of humid air in spring, summer or fall.
3. Using the previous system, add sensitive controls and system capacity to hold relative humidity within 30-35% RH or other desired band, and provide alarms for off-normal events.

Temperature

The following gives options for achieving a range of capabilities for temperature control. Note that since the collection is damaged primarily by heat and extremes in relative humidity, heating itself is not a priority at lower levels of control, although it may be required in winter for occupant comfort, safety, or stability of building systems.

1. Ventilate the space to remove heat buildup.
2. Mechanically cool the space to below 80 or 70°F.
3. Using the previous system, add capability to heat the space to 55°F, but only if sufficient humidification is provided to keep the relative humidity above 30% RH.

4. Using the previous system, hold temperature within 60-65°F for storage spaces and 65-70°F for occupied spaces, adding insulation and other envelope modifications, as required, to efficiently maintain conditions.

Particulate Filtration

Particulate filters are rated in their ability to remove particulates by "efficiency." More and smaller particles are removed as the particulate efficiency increases, but with higher efficiencies come higher pressures (see the pressure drop discussion below). The level of filtration required for any particular collection depends on the type of particulate contamination that must be removed.

The most common filtration found in HVAC systems is the open-weave panel or "furnace" filter. It provides virtually no value for protection of any collection situation, protecting only the air-handling equipment from gross fouling.

Better filtration comes from at least a 1-inch or 2-inch thick pleated panel filter. At time of replacement, it is important to note that the lesser-quality open-weave filters, which cost about $1 each, are often substituted for pleated filters, which cost about $5 each, causing a major loss in efficiency.

Even a good pleated filter will let most of the smaller particulates pass through, providing very little protection from typical urban black soot. Most systems need the addition of high performance "final" filters, usually 6 or 12 inches deep, which can remove most of the smaller particulates which do the most damage to the collection.

PRESSURE DROP. As filter efficiency increases, usually the fan pressure and motor horsepower required to move the air through the filter increases, although this can be mitigated somewhat if the size of the filters is increased. This pressure is called the filter's "pressure drop." In most cases the filter's efficiency and pressure drop increase as it becomes loaded with particulates.

Most fan systems can be adjusted or easily modified to move air through a 1- or 2-inch pleated filter. High efficiency final filters will usually require a higher pressure fan system, or significant modifications to an existing fan system.

ELECTROSTATIC FILTERS. Electrostatic air cleaners help remove particulates by exposing the air to a high-voltage electrostatic field, causing smaller particulates to coagulate into larger particles more easily filtered. Such cleaners which consume electricity will generally create ozone and should not be used to filter collection spaces. To achieve much of the same electrostatic coagulation effect of electrostatic cleaners without ozone or ionization, passive electret (permanently charged) plastic filters can be used, where no electricity is used by the filter media.

Gaseous Control

Based on the sensitivity of the collection, evidence of previous damage, pollution records or measurements, and supplemental or alternative treatments, consider the degree of gaseous pollution control needed in the HVAC system.

MEDIA TYPE. Water washes can be somewhat effective in controlling gaseous contaminants, but few institutions can give the virtually constant maintenance they require. Most options for gaseous contamination control involve the use of impregnated media or granular beds. Carbon is a good general adsorbent of gaseous contaminants, and can be supplemented with special chemicals to enhance its effectiveness on certain contaminants. Potassium permanganate in alumina pellets is favored in many situations for its ability to oxidize certain contaminants, particularly sulfur dioxide and volatile organic compounds. The pollution control media must be kept relatively clean and *must be changed when depleted*, usually at least once a year.

OPTIONS. The typical gaseous contamination control equipment ranges from particulate filters impregnated or coated with carbon, to panel filters filled with carbon or potassium permanganate, to "V" cells with carbon and/or potassium permanganate, to vertical chamber systems, to deep-bed scrubbers. They range from virtually no long-term protection with little pressure drop penalty, to long change intervals and large pressure drops.

GASEOUS POLLUTION REMOVAL PERFORMANCE. The ability of a system to remove gaseous contaminants depends on how fast the air flows through the media, the amount of media in the air stream, and the amount of air that bypasses the media and is not effectively treated.

ENERGY AND OPERATING COSTS

In many cases the energy costs for operating a conservation environment can be a significant consideration, but for the long-term protection of a valuable collection, the annual energy costs of a good environment are a wise expenditure. Many aspects of a good conservation environment, including low light levels and limited window areas can, in many cases, more than compensate for the additional energy used by the HVAC systems. For the institution with a small or limited operating budget which simply cannot afford a major increase in annual energy costs, some compromises might be warranted, or some initial capital investments might be made in systems to offset recurring annual costs. Most of the higher operating costs for conservation environments come from humidity control: humidification and dehumidification. The following two options can be considered to control these costs.

COMPROMISE HUMIDIFICATION SOURCE. Although a considerable compromise, a drain-through, wetted pad or wetted drum humidifier might be used for humidification. These will not give the performance or life of a steam humidification system, but will provide modest humidification at low annual operating cost. If a wetted pad or wetted drum humidifier is used it should be carefully cleaned every few weeks.

DEHUMIDIFICATION REHEAT SOURCE. A good long-term and efficient method of providing reheat for dehumidification is to use the heat rejected by the cooling system which provides the dehumidification. This is exactly what a portable dehumidifier does. In a permanent installation a cooling/dehumidification system can use the heat generated by its condenser for reheat. This removes the need to have a boiler or electric system provide the heating. This can be a more expensive system to install than electric or boiler reheat, but it has virtually no energy cost, entirely saving the cost of electric or boiler reheat, and works even if the boiler is off. In some cases this is easily done by selecting the proper cooling equipment initially, and can be part of both smaller direct-expansion (DX) systems and larger chilled water systems.

For further information on HVAC systems consult References 7, 8, 9 and 10.

HUMIDITY-TOLERANT BUILDING ENVELOPE

Winter humidification should be the first priority of a conservation environment in a heated building in New York State, but the building's ability to tolerate the humidity must be considered. In many instances, the building envelope, the walls, roof and windows, will have problem condensation at 45% RH in winter, either on single-glazed windows, on window frames, or inside the exterior wall or roof. Under certain circumstances this condensation can cause cosmetic or substantial damage to the building. In such cases two alternatives present themselves: 1) the winter humidity must be kept stable and below the point where problem condensation will occur; or, 2) the building envelope must be retrofitted to tolerate the higher humidity.

Depending on the humidity level that can be maintained without problems, a collection may require that the envelope be modified to support a higher humidity. In most projects where modification of the building envelope is required to tolerate higher winter humidities to support a collection within, there is a considerable design challenge and expense. The expense of such a building-wide envelope retrofit can be as much as all other environmental modifications combined, and should not be undertaken lightly or without proper professional advice and evaluation by a licensed architect and/or professional engineer.

As noted under the compromises for relative humidity, if the collection needing a higher humidity does not consist of the entire building contents, but only a manageable minority, separate humidified storage containers, cases, cabinets or rooms are an alternative. These must be carefully sealed to preserve their internal environment and to protect the building envelope from the damaging moisture.

LIMITATIONS AND PRIORITIES

Even when the conservation goals for the building's environment are clear, there is often not enough money to provide the ideal system. Certainly there are cases where simply too little money is available, and the project should be postponed until further funding is found. All too often, when "something is done about the environment," the decisions are made without a good understanding of realistic conservation goals and of how different elements of the building and the HVAC systems affect them. Ill-conceived compromises may result in an environment that is no better for the collections than before, possibly worse. Instead, a balance should be struck between what funding can support and achieving meaningful and realistic compromise goals.

In creating a built environment there are always alternatives. These should be matched against the identified and prioritized needs of the collection and the various constraints of capital funds available, existing building structure and systems, and annual operating budgets.

This may have first been considered by Keyes Metcalf in his 1965 book, *Planning*

Academic and Research Library Buildings (Reference 11). On page 83, he lists the following:

Alternative Environmental Systems:
a) Heating only, not recommended for most libraries
b) Minimum recommended installation: heating and ventilating with air filtration
c) Comfort installation: heating, ventilation, air filtration and cooling. This is recommended if the library is open to the public during hot and humid periods
d) Conditioned installation: heating, ventilation, air filtration, cooling and humidity control. This is recommended...if the collections have rare and irreplaceable books and manuscripts
e) The ideal installation: heating, ventilation, air filtration, cooling and humidity control, all within specified narrow limits in order to maintain ideal conditions of temperature and humidity the year around, regardless of outside conditions.

While this is a good start, it is intended to meet the needs of a working library environment which may not necessarily "have rare and irreplaceable books and manuscripts," where comfort may, at times, be the only concern. It fails to be properly balanced when a conservation environment is considered as the initial goal, it does not fully reflect conservation priorities, it does not respond well to the practical opportunities and limitations inherent in HVAC design, and it does not give particularly usable guidelines for the archives or library professional in setting working goals for their HVAC project.

BASIC PRIORITIES. A reconsideration of the basic priorities for a conservation environment should be focused on a balanced protection of collections from harm. Consider the following basic priorities for a paper-based library or archives collection:

1. The first priority for a heated building should be concurrent humidification throughout the winter, since a clear and present danger is from a too-dry environment.
2. The second priority should be protection from high-humidity damage, usually in spring, summer and fall.
3. Next comes protection from high temperatures, possibly subordinated to the need to address particular problems with particulate and gaseous contamination.

Although fundamentally correct, these priorities over-simplify the issues, and do not consider how often the goal may be met, how consistently, with what practicality, and at what expense.

Taking Metcalf's "Alternative Environmental Systems" as a lead, a composite listing is needed to consider the basic conservation environment priorities, interrelated to the various issues and character of the variety of typical collection environments.

LEVELS OF CONTROL ("Putting it all together")

Few institutions have an ideal conservation environment. In setting goals for improvement, it is important to characterize the various level of environmental control an institution may currently have, and to compare it with situations that might be closer to ideal. This helps an institution identify higher goals it might prudently set for improvements, when it cannot necessarily afford a first-class system.

The following "Levels of Control" for conservation environments are based on typical and practical opportunities and limitations of HVAC systems, building situations, conservation priorities, and budgets.

UNACCEPTABLE: Heating only, without humidification. This will lead to very dry winter conditions, often less than 20% RH in cold climates such as New York State.

ALSO UNACCEPTABLE: Ventilation with open windows. This allows totally unfiltered air to enter the space, and can lead to practical problems of what may enter (vermin, rain, dust) through an open window. This system is in all probability doing more damage to the collection than if the collection were kept in an unheated warehouse or shed that was safe from the weather.

A typical unacceptable situation might be a building heated with radiators, where windows are used for summer ventilation. Simply adding a few window air conditioners, the most common "next step" (primarily for occupant comfort) does not remove the building from the "unacceptable" category. Unless the air conditioners are left on 24 hours a day, and they allow windows to be left closed which would otherwise be opened, they might do more harm than good. More importantly, they do not address the first priority: winter humidification. The money for the air conditioners would be better spent on the more appropriate next step: adding winter humidification.

Note that the typical unheated storage area, which might be considered "Level Zero" but above "Unacceptable," is better than the same space with heat but without humidification. It should be clearly understood that *adding heating without sufficient humidification can lead to a worse environment.*

LEVEL ONE: Heating with 24-hour winter humidification, ventilation, and particulate filtration. This level of control should keep the relative humidity above 30 or 35% RH in winter, and should allow sufficient filtered ventilation to remove heat buildup (keeping the temperature at a level close to outside conditions).

This might be the same radiator-and-window building where unitary humidifiers and filtered ventilation have been added, or a building with a forced-air furnace where humidification, better filters and ventilation are added.

LEVEL TWO: Winter heating 24-hours, 24-hour summer cooling with reheat for dehumidification, 24-hour winter humidification, 24-hour air flow and improved particulate filtration. This is considered relatively typical "full environmental control" (sic) for commercial and institutional buildings. When cooling is added, dehumidification comes easily as part of the initial installation with the addition of reheat from existing heating sources or from the cooling system's own condenser heat. Cooling and dehumidification may not always be available in the "non-cooling" season. This level of control should keep the relative humidity above 30 or 35% RH in winter, and below 60% RH in summer. Separate "low humidity" collection areas for film or metal objects cannot usually be provided.

Note again that window air conditioners themselves do not achieve Level Two; they almost always do not provide reheat or adequate air distribution and filtration. They might be used in combination with a separate filtration system and a reheat source or a dehumidifier, so long as winter humidification has already been provided.

LEVEL THREE: Heating, cooling, dehumidification, humidification and superior particulate filtration, available 24-hours a day in any season, in a humidity-tolerant building envelope. This is basically an improved Level Two system, with environmental controls available in any season as well as at any hour, with closer tolerance HVAC controls, and usually a greater heating and cooling capacity. At this level the building envelope is either originally designed, or has been modified, to tolerate a higher winter humidity of 40 to 50% RH without condensation problems. For any separate "low humidity" collection areas, such as for film, dehumidification to 30% RH in summer should be provided, preferably with lowered temperatures.

LEVEL FOUR: Level Three system plus the addition of gaseous pollution control, cooling-heating-humidification-dehumidification capacity to hold close-tolerance environmental conditions at all times, and better "industrial" grade controls. The controls system should provide monitoring to call attention to any spaces where conditions fall off-normal, or where leaks or other problems present a threat to the collection.

An acknowledgement of variations in levels of control avoids the over-simplified characterization of an institution's environment as either "good" or "bad," since the "bad" label might discourage the pursuit of a better environment, might discount the good aspects which are there, and might discourage donations or loan exhibits. Identifying its relative level will allow an institution to know where it stands, to see what goals have been achieved, and to identify the next steps toward improvement.

ACHIEVING CONSERVATION ENVIRONMENTS: LIGHTING

Lighting in a conservation environment requires careful selection of the light source, the lighting treatment, and a proper design rationale.

LIGHT SOURCES

The best method of establishing proper lighting for a conservation environment is the proper selection of light sources. The ideal source would emit a constant level of only visible light, devoid of infrared and ultraviolet components. For display, the ideal source should additionally be able to provide point-source direct illumination, as well as diffuse fill illumination. Unfortunately, the ideal source does not exist. The sources available are:

DAYLIGHT. Daylight has a high content of infrared (IR) and ultraviolet (UV) radiation, and extreme variations in intensity. Because of these variations, daylighting for illumination at low light levels requires complex control schemes. Useless at night, daylighting also requires an auxiliary electric lighting system in addition to UV filtration. Rather than attempting to filter, control and supplement daylight, it should be avoided as a significant illumination source in conservation environments.

Where daylight is a predefined source of daylight, such as in period display areas of an historical building, the daylight should be heavily filtered to reduce its intensity.

INCANDESCENT LAMPS. Incandescent lighting, also known as tungsten lighting, provides a pleasing continuous spectrum, with little UV content (about 4%). Common screw-base lamps used in homes are tungsten lamps.

Tungsten-halogen lamps, sometimes called quartz-iodine, are tungsten lamps with a special halogen gas inside and a special quartz bulb, which allows the tungsten to burn hotter and brighter. These lamps can expose collections to significant amounts UV since their higher temperature generates more UV, and their quartz bulbs absorb less UV than glass bulbs. These lamps can have twice the UV of regular tungsten lamps (about 8% compared to less than 4%) and must usually be filtered for UV if used.

When compared to other light sources, all tungsten lights are relatively inefficient, generating many times more heat for the same amount of light. This inefficiency and heat gain may cause problems in cooling and in annual energy costs if they are used extensively in a facility. Another drawback is their associated lamp costs, because of their short lamp life—they commonly last only a tenth to a thirtieth the life of other sources.

DICHROIC REFLECTOR LAMPS. At high light levels tungsten lamps may be a significant source of infrared heating, and may cause damage to lit objects. Although more expensive, "dichroic" reflector lamps should be used if tungsten spotlights are used to achieve high light levels and infrared damage is a suspected problem. The dichroic reflector prevents the tungsten spotlight from focusing the infrared energy from the lamp into the light beam. They are sold under trade names such as "cool-beam" and "cool-lux," and must usually be used in fixtures with porcelain sockets, rated for the use of such lamps.

FLUORESCENT LAMPS. Fluorescent lights use a luminous gas to create a bright-line emission spectrum, only certain colors of light, usually heavy in UV. This bright-line spectrum is absorbed by the phosphor coating on the inside of the bulb, which glows or fluoresces to create light. Because they depend on UV to create their light, these lamps range from 1/2% to 12% in UV output, so they must be chosen carefully. Often the "energy efficient" lamps will have more UV. When using a special lamp to control UV take care in the purchasing and stocking of replacement lamps since it is easy to intentionally or unintentionally substitute a standard lamp. Before a major purchase, contact the lamp manufacturer to confirm the UV output of the selected lamp, as they may change their phosphor mixture—and change the resulting UV emission—without changing the product designation. The manufacturer is responsible for a given lamp having a specific wattage and basic light output, not a specific UV emission.

Sleeve filters are often used on fluorescent lamps to reduce UV output, but are not as good as selecting a low-UV lamp. If the sleeve filter is miscut or misfitted, UV leaks can occur. This scheme can be hampered by damaged or lost sleeves, or by poorly-fitted filters or gaskets at the ends of the lamp, where most UV emission occurs. Four-foot fluorescent lamps generally come in two varieties, the old standard diameter T-12 lamp and the new, thinner T-8 lamp. Filters intended for the T-12 lamps will fit very loose if at all on the thinner T-8 lamps, while thin filters will not fit on the older lamps unless they are slit open to leave half the lamp unfiltered. In either case, UV leakage will occur if filters are mismatched.

MERCURY AND METAL HALIDE HID LAMPS. The high-intensity discharge (HID) mercury and metal-halide lamps are bright-line sources using phosphors to generate much of their light (like fluorescent lamps), and are usually too intense and too strong in their UV output for anything but an indirect treatment. In fact, when the outer envelopes of some of these lamps are broken, those without an expensive self-extinguishing feature emit levels of UV which are an established health hazard to human skin. Even in an indirect application, the UV exposure may be too high and, with the lamp's high intensity, use of UV filters is problematic.

SODIUM HID LAMPS. The high and low-pressure sodium HID lamps produce very little UV due to their inherent emission spectrum. The most efficient of all lamps available, they are low in heat generation and operating cost. Low pressure sodium (LPS) lamps are too orange in color, but high pressure sodium (HPS) lamps can be used where the color rendering is not important, such as in a storage area. Since it is a high-intensity lamp, indirect lighting is suggested, usually by bouncing light off the ceiling. This ensures low illumination levels and allows large wattage lamps to be used. This is a decided advantage in lowering initial and ongoing lamp costs. Unlike mercury and metal halide HID lamps, which take 3 to 10 minutes to relight after being shut off, HPS lamps usually relight in less than a minute. (For details on an application of HPS for storage see Reference 12.)

In general, UV filtration is needed for daylight, most fluorescent lamps, and some tungsten-halogen (or quartz-iodine) lamps. Some low-UV fluorescent lamps need no filtration, although the use of UV filters is good insurance. Tungsten lamps, when providing illumination at or below conservation levels, usually require no filtration.

TYPICAL LIGHTING PROBLEMS

In evaluating a current or proposed luminous environment, there are several common problems. Although not directly conservation environment issues, these problems can be symptoms of an over-lit environment, or they can be inappropriately addressed through additional lighting. Properly addressing these problems should reduce light levels in the collection spaces, and will reduce the tendency to overlight the collection to otherwise offset the problem.

VEILING REFLECTIONS. This is where the object to be viewed is obscured or "veiled" by a reflection on an intervening surface, such as display case glass, or reflection from the object itself. The problem comes from the orientation of the light source and the object being viewed and/or the position of the viewer. Typical situations are where a light is reflected in the glass of a display case, light coming from above and in front of a reader casts a veiling reflection on a glossy page, or light from a window in front of the viewer casts veiling reflections on the spines of shelved books or boxes.

The solution is to change the position of the light source, object or viewer, or to reduce the brightness of the light source, not to increase the light level. In only rare cases is it possible to anticipate exact positions of light sources and viewers, or to change the layout of a typical shelving stack. The solution is to reduce the brightness of the light source, such as shading or blocking out a window. The way to do this without having a reduction in light level (assuming the light level is already at the recommended conservation level) is to increase the size of the source of the illumination. This means using a larger light fixture with a larger reflector but the same or less lamps, or an indirect lighting scheme where the entire ceiling becomes the dimmer but larger light source.

CONTRAST GLARE. This is where a very bright area in the field of view, almost always a window or light fixture, prevents the viewer from seeing the less bright objects of interest. A bright window in the field of view in a dimly lit interior display area make viewing the collection very difficult, particularly for older people. This also comes from a bright window at the end of a dimly lit stack aisle. Most people prefer no more than a 3-to-1 ratio from bright to dark, and most cannot tolerate more than a 10-to-1 ratio. This tolerance reduces with the age of the viewer.

Consider that the bright surface causing the glare is not the object of interest, and the object to be viewed would usually be better appreciated if the ratio was 1-to-3 rather than 3-to-1, with the object of interest being the brighter.

Shading or blocking windows, improved artificial lighting (such as using a larger light fixture with a larger reflector or using indirect lighting), and brighter environmental finishes in the field of view can reduce severe contrast glare in most environments.

DISCOMFORT GLARE. This is where the absolute brightness of an object causes discomfort, and almost always is accompanied by contrast glare. This typically happens when a bright window or light fixture is in the direct field of view.

The solutions are similar to the solutions for the other problems. Shading or blocking windows, improved artificial lighting with better aiming or "glare control" fixtures, and indirect lighting can reduce or eliminate discomfort glare in most environments.

UNEVEN LIGHTING. This is most commonly found in a typical stack aisle where books and boxes on the top shelf are lit to 90 footcandles while objects on the bottom shelf, usually in shadow, have less than 1 footcandle of illumination. This uneven lighting leads, technically, to contrast glare for the person trying to read the book spines or box labels. This is usually due to a bright light source located near the top shelf, usually a bare-lamp fluorescent fixture.

The difference in illumination is due primarily to light drop-off with distance from the light source, and a change in the angle that the light strikes the object illuminated. These properties of light cannot be changed; the location of the light source, its character, and the brightness of surrounding surfaces can be changed.

Solutions include moving the light source higher away from the top shelf (usually not that effective), changing the light source to provide a larger luminous area so that light drop-off with distance is reduced (such as using a larger light fixture with a larger reflector or using indirect lighting), and brighter environmental finishes to increase the reflected component of the light on the objects on the shelves (lighter-colored shelves, boxes and book spines).

TYPICAL SOLUTIONS FOR COMMON PROBLEMS. For different reasons the same characteristics of a good lighting environment for reading rooms and stacks emerge: shade or block-off windows, use a light fixture with a large reflector or indirect lighting, and use brighter environmental finishes (lighter-colored shelves, boxes and book spines).

LIGHTING TREATMENTS

The lighting treatment determines the way the chosen light source is used. A treatment should try to avoid the problems just cited, and provide illumination at or below conservation light levels while providing an effective working environment.

STACKS AND STORAGE. Stacks and storage spaces are usually best lit with low-UV fluorescent lamps, designed to provide 2 to 5 footcandles of vertical illumination. For small or confined areas several common tungsten lamps may be a good choice. Avoid daylit, and direct mercury and metal-halide lighting treatments.

For good design of stack lighting, the lighting designer should perform "point illumination calculations" to check the maximum, typical and minimum vertical footcandles of illumination on the objects in storage.

To improve collection illumination under low lighting, shelving, particularly the underside of shelves, should be white.

INDIRECT LIGHTING. Most lighting is direct, where light shines directly from the lamp or fixture to the task or illuminated object. In indirect lighting the light from the lamp or fixture first shines on a large environmental surface, such as the ceiling, and the luminosity of the ceiling provides the effective illumination within the space.

This can provide very satisfactory lighting at relatively low light levels. For economy in capital and operating costs, fluorescent or HPS lamps are usually required for indirect lighting. If possible, an indirect scheme should be used in storage areas. It further reduces UV if the bounce surface is painted with titanium dioxide paint, while providing even illumination and improved vertical illumination and general visibility. Bounce or indirect lighting requires high ceilings, generally over 9 feet high, with space below for the light fixtures. In some cases the fixtures can be mounted to shelving or walls with ceilings as low as 7 feet.

Large storage spaces with high ceilings should use an indirect HPS scheme. Where higher color-rendering is needed in an indirect treatment, the lighting can be with a combination HPS/ metal-halide light fixture.

READING AREAS. Reading areas should be designed for 30 to 60 footcandles of illumination at the reading task area. A good solution for providing this is with general illumination to a level of about 15 footcandles, supplemented with task lights at the reading desks. This reduces the overall exposure to the collection, yet provides the high light level where needed. For the general illumination, an indirect treatment can provide a pleasing lighting environment with high task contrast and low veiling reflections, leading to a very good reading environment at light levels at a fraction of conventional direct illumination treatments.

EXHIBIT OR DISPLAY. Display lighting should usually be based on tungsten light sources for a high degree of control, and should be based on a mix of direct and diffuse or "fill" light. Direct lighting will give color saturation and its shadows will give modeling detail to the objects on display. Fill light, either reflected from other objects, from general illumination, or from spill from adjacent lights, lessens the contrast of the direct light's shadows. (For more information on display lighting see Reference 13.)

HEAT GAIN AND ENERGY

A major problem, particularly for old buildings with existing cooling or duct systems, is control of heat gain from lighting. Lighting can easily cause inadvertent heating of the collection spaces, leading to heat gains in excess of the capacity of the cooling system in summer, or heating in winter leading to reduced space humidity. Where appropriate, a maximum lighting power budget, in watts, should be established, in addition to a maximum conservation light level.

Reduced lighting levels from reduced wattage has the additional benefit of reduced electric usage, reduced cooling, and reduced energy costs. Even in winter, the reduced heat gain will, if necessary, be made up from the main heating system, which is usually more efficient and less costly than the heat from lights.

RETROFITS

High light levels can be addressed through the replacement of lamps with lower wattages, installation of dimmers and removal of lamps and blocking or shading of windows. For IR exposure control, tungsten light sources can be chosen that have integral dichroic filters to reduce the IR exposure. For UV exposure control, UV filters can be used on windows, fluorescent and tungsten-halogen lamps.

For further information on lighting conservation environments consult References 12 and 13. For further information on lighting consult References 14 and 15.

ACHIEVING CONSERVATION ENVIRONMENTS: FIRE PROTECTION

Unlike HVAC or lighting systems, fire protection systems do not have an active daily impact on a conservation enviroı ment for libraries and archives, but their features and function can be critical to the safety of the collection. The following issues, options and types of systems are common, and may be among the considerations for a given situation.

AUTOMATIC vs. MANUAL SUPPRESSION. In some instances, fire codes may allow the option of manual suppression, such as fire extinguishers and water hoses, rather than automatic systems, such as sprinklers. The institution should seriously consider the damage that a high-pressure water hose, which can literally cut through drywall partitions, may do to the collection. In many instances the threat posed by a well-designed automatic sprinkler system is more manageable than the threat posed by a manual system in the course of fire suppression.

There are two basic options for distribution of sprinkler water for typical library/archive applications: wet-pipe and pre-acting.

WET-PIPE SPRINKLER SYSTEM. The wet-pipe sprinkler system is the most common and least expensive sprinkler system. In this type of system a fire causes a sprinkler head to open and discharge water from sprinkler piping that is always filled with water (hence, "wet-pipe").

PRE-ACTING SPRINKLER SYSTEM. The pre-acting sprinkler system is a more expensive system which controls the water in the sprinkler piping. In these systems, water is not present in the sprinkler piping until several conditions, such as smoke, fire, heat and/or the opening of a sprinkler head, have called for the release of water into the system. Water is not actually discharged into the space until a sprinkler head has been opened by space temperature, and after the smoke and/or heat conditions have triggered the "pre-action" of releasing water into the piping. If a major threat is from leaking or frozen sprinkler piping, then pre-acting distribution is a solution. A pre-acting system is more expensive than a wet system and, due to its complicated sensors and controls, requires more maintenance while providing a slightly lower level of fire safety.

In non-storage collection support areas, such as offices and lab/work areas, the more reliable wet system is usually an easy choice. However, in or above collection areas, there is a perceived threat of water damage from accidental discharge of a wet system, although the actual probability of this is typically much less than the chance of fire.

For areas where the collection has a primary enclosure, such as closed cabinets and plastic film cases, sprinkler discharge should be a minimal risk, and a wet system might be indicated. For open display and storage areas, the institution must assess the risk of exposure of the collection to a modest amount of water, weighed against the cost and maintenance premiums of a pre-acting system.

ON-OFF SPRINKLER HEADS. As an alternative to the typical fused-link sprinkler head for wet or pre-acting sprinkler systems, on-off ("flow-control" or thermostatic shut-off) sprinkler heads are an option. These heads shut themselves off once the space temperature drops after a fire is extinguished, which reduces the threat to the collection from excess water discharge. Although a significant cost premium over the conventional fused link head, if a major threat to the collection is from prolonged water discharge, then the on-off heads should be considered.

PRIORITIES AND FIRE PROTECTION. When considering fire protection design, it is important to remember that the first priority for design is life safety, and that will be the primary and possibly exclusive goal of the local fire code official. In many cases the fire protection codes are intended to slow the spread of fire, and not necessarily to protect the contents of the building. The goal is often time, rather than protection of property.

This is why on-off heads and other features that provide additional protection to the collection are necessary in a library or archive. For example, the fire-fighters will usually place the lowest priority on shutting off the sprinklers, since they are decidedly working in the fireman's favor—the on-off head will automatically limit water discharge once the fire is extinguished.

GAS FIRE SUPPRESSION. For decades, fire protection of sensitive and confined spaces has been done with introducing a gas into the space where the fire is, rather than using water. In such systems a gas such as Halon, nitrogen or carbon dioxide is introduced at a high enough concentration to cause combustion to stop. The concentration needed varies with the type of gas used. Gas fire suppression is attractive, since it promises to extinguish a fire without the introduction of water. By their nature, gas suppression systems must work in a confined space to hold a sufficient concentration of the gas to maintain fire suppression. To reduce the impact of an accidental discharge, and to improve the efficacy of the gas suppression system, the areas protected should be broken into small suppression zones with sealed and fire-rated partitions between.

A problem with gas suppression is that it may protect the objects from a fire generated within the suppression zone, but may be ineffective against fire from adjacent spaces breaching the zone. This can allow the gas charge to escape or to not reach the required concentration, allowing the fire to consume the contents of the zone. Another problem is that gas suppression systems usually suppress combustion but do not necessarily remove the conditions which caused the fire. If combustible materials and the ignition source remain after the gas dissipates, the fire may re-ignite. This is rarely the case with water suppression, since the water can effectively remove combustible materials and usually cools the ignition source.

Halon, the most popular gas suppression agent in the past, is very expensive, and its manufacture is being reduced due to concern for the damage it may do to the earth's ozone layer.

If gas systems are used, pre-occupancy and periodic testing are essential to ensure efficacy. In almost all cases, there are original construction leaks or user modifications which allow the gas to leak from the suppression zone, preventing it from reaching the required concentration for suppression.

Thought should always be given to a water sprinkler system as a backup to a gas system, depending on the construction and spaces adjacent to the zones. The additional sprinkler coverage may cost less than suppression gas reserves, which may be required to provide continuous protection after a false discharge. In most cases the collection will be exposed to water even if a sprinkler system is not used, since most fire regulations require the fire department to wet down any area where there has been a fire suppressed only by a gas system.

Whenever fire protection is involved in a project, the institution should retain the services of a qualified fire protection consultant for proper consideration of fire protection issues and designs.

For further information on fire protection for conservation environments consult References 16 and 17.

INTERIM AND LOW-COST IMPROVEMENTS

The following items can be considered for improving a conservation environment at very low capital costs. Use common sense and consult a trained conservator for the relative merit of these measures for a given collection and situation; under certain circumstances some measures may not be advisable, applicable or feasible.

NOTE: In the following discussion measure designated by an asterisk (*) are among the few collections conservation measures that might also reduce energy use, and may be funded as an "energy conservation" activity, and/or may have energy cost savings which can help cover the modest cost.

HVAC

When the cost of a small-scale environmental renovation is out of the institution's reach, or where a space is only to be used for a short period, interim and absolute low-cost improvements can be considered. These are often of a very temporary nature and may require much more attention from the staff for effective performance than an HVAC system with even basic automatic controls.

Even though these measures are small-scale, they should still respond to the basic priorities for an improved conservation environment: humidify first (whenever heating is used), and dehumidify second. Then seek to control particulate and gaseous contaminants, and provide cooling.

Low Humidity Problems

The following systems can address low winter humidity problems.

PORTABLE HUMIDIFIER. The first priority for a heated space is to provide humidification in winter. This is most easily accomplished with a portable humidifier, as one might buy from a local department store for the home. However, for a library or archives application, additional care should be taken in its installation and operation.

INSTALLATION. Since a portable humidifier can run out of water, it presents a risk to the collection of an abrupt drop in humidity if it should run dry over a weekend or holiday. To be effective a portable humidifier should be piped into a constant water source, with a float/refill valve installed. In this way it can always have water. This water connection need be no more complicated than installing water for an icemaker in a refrigerator.

OPERATION. The system should be operated throughout the winter, whenever the humidity begins to drop. Most portable dehumidifiers have a humidistat which will control the humidity fairly well. The unit should be cleaned every month, and a new pad installed at least every year. The drawback is that the system has low capacity, very poor performance, and will cease to function unless regularly checked and maintained.

COST. The humidifier should cost from $150 to $300, and the water installation from $50 to $150, for a total of less than $500.

CENTRAL HUMIDIFIER FOR FORCED-AIR HEATING SYSTEMS. Although not a long-life system, a drain-through evaporative humidifier will significantly reduce energy costs if a good steam source is not available. This system allows a steady stream of water to drain down through a rigid pad over which warm supply air is blown. Water at the bottom of the pad is discharged to waste and is not recirculated—there is no standing pool of water. This system is lower-maintenance than the portable wetted-pad type of humidifier, since this unit's water pad is self-cleaning.

This system is a considerable compromise, and should only be used on a temporary basis or where operating cost, lack of steam and only modest humidification performance is expected. Since this type of humidification does not use heat, the humidified air is always cooled as it is humidified, which can considerably confuse the operation some control systems. This system is very inefficient in water use, discharging about 5 to 10 quarts of water to waste for every quart of water evaporated. The water waste only occurs when the system is in operation—when humidification is needed—and should not pose a problem in most situations.

INSTALLATION. This is usually installed near the furnace or air-handing system, and where water and drain connections will be convenient. It needs both a water and drain connection. This system can be controlled by a humidistat in the space humidified, which will control the valve that lets the water run over the pad.

OPERATION. The system should be operated throughout the winter, whenever the humidity begins to drop. The unit should be cleaned at least once a year.

COST. The humidifier should cost from $250 to $500, the water installation from $50 to $150, and the drain from $50 to $250, for a total of less than $1,000.

Spray, fog, spinning disk, and ultrasonic humidifiers can all force contaminants from the water into the air, and/or can allow the build-up of contaminants in pans of standing water. *These systems are not recommended for conservation environments.*

Dehumidification/ High-Humidity Problems

The following measures can help with high-humidity problems, either by reducing the humidity, or reducing the possibility of humidity damage to the collection.

PORTABLE FAN FOR AIR CIRCULATION. One or more portable fans can help reduce the chance of mold in humid collection areas. These cost about $25 to $75 each, and should be used with 20-amp extension power cords, where required. The cords should be strung above head height, or securely taped to the floor. The fans should run at all times.

PORTABLE DEHUMIDIFIER. A portable dehumidifier can provide effective dehumidification, depending on the size of the space and the moisture load.

INSTALLATION. The dehumidifier is of little use if it quickly fills and shuts off, or regularly shuts off at night, weekends or holidays. To be effective the dehumidifier should be equipped with a small pump, usually called a condensate pump, to pump the accumulated water from the dehumidifier bucket to a drain or to the outside.

OPERATION. The dehumidifier should be turned on as soon as the humidity begins to rise in spring and left in continuous operation until fall. Its built-in humidistat should be effective for control.

COST. The dehumidifier should cost less than $400 and the pump less than $150, for a total of less than $600.

Supplemental Filtration Systems

The following equipment can improve the filtration for particulate and/or gaseous contamination control.

FIRST-CLASS CENTRAL FILTRATION. An add-on filtration system, providing first-class high-efficiency particulate filtration and good gaseous contamination control, with its own booster fan, can be added to existing forced-air heating or cooling systems and cost of less than $3,000, for the equipment to serve 1,000 to 2,000 square feet. Often the institution can provide the labor for installation—little or no ductwork is usually required, and only modest 120V/15A electric service is usually needed. Contract labor to install the system might cost up to $500.

COMPROMISE CENTRAL FILTRATION. Residential particulate filters are available as add-on filtration systems, providing good particulate filtration but no gaseous contamination control. These are deep-pleated filters, in a plastic frame, providing about a 60% dust spot performance. Their pressure drop is generally so low they can be added to existing furnace or fan systems. The systems cost less than $200, and may cost another $200 to install.

ROOM FILTRATION. Smaller portable filtration systems can be used on a room-by-room basis, and cost from $400 to $1,000. They usually contain a good-to-excellent particulate filter, and can also contain gaseous media.

Window Air Conditioner

Window air conditioner can provide some improvements, generally as a third priority for a conservation environment. It will lower the space temperature, it can permit windows to be kept closed that would otherwise be opened, thus reducing pollutants, and it can do occasional dehumidification as cooling loads permit. It should preferably be used in combination with a complement of the previous items: humidification, dehumidification and filtration.

INSTALLATION. The air conditioner should be securely installed in the window, and all windows in the space(s) to be conditioned should be closed and locked. These windows must not be opened no matter how nice a day it is.

OPERATION. To do more good than harm, the unit must be operated continuously so that it does not cause daily fluctuations in temperature and humidity. This means that as soon as it becomes warm in the space to be conditioned, the air conditioner is turned on, generally until fall. The unit can be controlled by its thermostat, but the thermostat setting should be at a fixed value and not be turned up or down for occupant comfort.

IMPROVED DEHUMIDIFICATION. The dehumidification performance of window air conditioners can be improved if fans are set to "low," so long as the unit's compressor is still cooling at full capacity. At the lower air flow the unit will do more dehumidification and less total cooling. Not only will the system do more moisture removal while the compressor runs, but the compressor will usually run longer since it has a reduced total cooling capacity.

Although this is also how to "turn the unit down" without changing the temperature setting, this modulation to a lower fan setting should be done in response to a rise in space humidity, as might be indicated by a humidity card or hygrothermograph. This low-fan technique is good for dehumidification but bad for energy efficient operation.

Be warned that a window air conditioner on 24-hours a day will have significant operating costs throughout a summer season, usually at least twice the cost of a unit operated only during office hours, and the institution must be prepared to pay this bill. If the operating costs are too high, and the unit is operated intermittently, the fluctuating temperature and humidity may very well do more harm than good.

Refrigerator *cum* Film Vault

Depending on the volume of material to be stored one or two commercial or residential refrigerators or freezers might be used as a film vault. For stability and reduced maintenance, this film storage should be locked with very limited access. To control humidity, they will need to have a passive humidity control system which will require regular maintenance. This will likely involve the use of silica gel, recharged on a regular basis. The exact maintenance interval of the passive system will need to be investigated with the use of a hygrothermograph and testing of various maintenance procedures and periods.

REMOVING OBJECTS FROM COLD STORAGE. Due to their temperature, the objects in the refrigerator, or any objects stored below about 55°F, may form condensation when abruptly moved into the general ambient environment. To protect from this, store the object in an air-tight container, or while still in the refrigerator, place the object into a plastic bag or other vapor-tight container. Then remove the sealed object to the normal room conditions and allow it to reach room temperature *before opening the sealed container.* This warming may take several hours to several days, depending on how large the object is, and how much insulation the vapor-tight container provides. (This is why plastic bags are often used, since they allow quicker warming of the object within.)

LIGHTING

Several low-cost measures may be taken to reduce light levels, reduce heat gain and reduce UV exposure. These are among the few conservation environment measures that reduce energy use, and some or all of the cost of these may be funded as an "energy conservation" activity.

BLOCK OFF WINDOWS IN STORAGE AREAS. Use gypsum wallboard covered with plastic sheets to block off windows. This will prevent light from entering storage and should also reduce moisture loss and infiltration of relatively dry winter air. To reduce the temperature in summer, use aluminum foil or white foam-core boards against the existing window before application of the wallboard to reflect solar gains away from the storage space.

ADD UV ACRYLIC PANEL FILTRATION. Adding acrylic plastic ("Plexiglas") panels as secondary interior storm windows can preserve the views through a window while reducing UV and light levels, but installations can be expensive. However, if the thermal benefits are not required (i.e., there is already double glazing, or UV control is more important than thermal control), simply hang the panels just inside the windows. Get Rohm and Haas "UF3" Plexiglas, Continental Polymers "UF7" Acrycal, or an equivalent product, BUT BE SURE IT IS EQUIVALENT IN UV FILTRATION—not just any acrylic sheet will do. (General Electric's Lexan acrylic sheets evidently do not come in a UV filtering model, only "UV resistant." Spectral filtering curves from each manufacturer show Lexan sheets are passing over 70% of the UV at 400 nM, while "UF3" Plexiglas and "UF7" Acrycal pass less than 10%.)

Cut the acrylic sheet to be about 1/2" smaller than the window opening but larger than the "glass" part of the window, making it smaller than the window frame but larger than the transparent part of the window, so that all light must pass through the acrylic sheet. Then hang the acrylic sheet just inside the window, one or two inches from the inside of the window, hung from two hooks, or eyelets and wire, running through two holes in the top of the acrylic sheet. This "hung" sheet is much more easily installed, can look more attractive, and is much easier to clean. Be sure to use recommended acrylic sheet cleaning products to prevent abrasion and scratches.

* In most cases light darkening is also needed, so consider using tinted acrylic sheets, which might reduce solar loads and reduce energy use in a mechanically cooled building.

LIGHT AND DUST COVERS FOR SHELVES. Survey collection storage spaces and consider hanging muslin sheets over the front of the shelves to reduce light levels and reduce particulate contamination. This will not only better protect the collection in storage on the shelves, but will increase the effective lighting on adjacent shelves when the covers are opened for collection access, due to the higher light reflectance of the covers.

* *LOWER LIGHT LEVELS.* In storage as well as display areas, use fewer lamps of smaller wattage to reduce light levels. This will reduce heat gain and keep spaces cooler. Try a standard household lamp in place of reflector lamps in track and socket lights—this will reduce the intense "spotlight" illumination, and dramatically reduce the cost of lamps

* *TURN LIGHTS OFF.* Wherever possible, turn lights off. In storage, install timers to reduce the time lights are on. In display areas, consider installing commercial

motion detectors or infrared sensors (less than $40 at most hardware stores) to turn on display lighting only when visitors are near.

USE STANDARD FLUORESCENT LAMPS SELECTED FOR LOW-UV. Select a "standard" fluorescent lamp with low-UV (less than 2% UV output) for use *throughout the institution*, even in non-collection spaces. This will mean that, even with misapplication of filters and lamps, the UV exposure will always be limited.

Recent 1987 tests available from General Electric indicate "Deluxe Warm White" lamps to be the lowest in UV output among the various general fluorescent lamps available from GE, with their special "SP" lamps substantially higher in UV. (As of March 1990, GE reports that the lamp phosphors have not changed, and that the 1987 tests are still valid.)

FIRE AND WATER PROTECTION

PORTABLE EQUIPMENT (Fans, dehumidifiers, etc.) Beware of the added fire risk the motors in these devices might pose. Check the equipment regularly for abnormal noises or erratic operation which might indicate a problem or failing motor.

AREAS WITH WET SPRINKLERS. Discharge from wet sprinklers can present a threat to a collection. Damage can not only come from wetting by the water, but the first few gallons of water from any sprinkler will usually have considerable contamination, primarily iron oxide. This can badly stain some objects, so protection of the collection from sprinkler discharge should be considered.

a. *STORAGE.* In storage areas consider the strategic use of containers or sheets of polyethylene over the face of shelving to keep the possible discharge from the sprinklers off sensitive objects.

b. *DISPLAY.* Consider the safety of objects on display. Where possible, use plexiglass displays or other means to to keep the possible discharge from the sprinklers off sensitive objects.

PREVENTIVE "DISASTER PLANNING" FOR WATER LEAKS. Survey collection storage spaces and identify past and possible future leak areas from pipes or other water sources, such as a rest room above. Install 6 mil plastic sheets (such as "Visqueen" or "Frost Queen"), aluminum flashing, or metal sheets to catch potential leaks and direct them away from the collection. Use duct or packing tape for the plastic sheets, and pop rivets and pipe tape (metal stripping with holes) to support the flashing and metal sheets. Try to route any water accumulation to existing drains or areas where the water will not do much damage. Avoid blocking any sprinklers or smoke detectors.

The institution should also have a written formal disaster plan, which would include a general building hazard survey inside and out. For further information on disaster planning, consult the *Disaster Preparedness Planning Resource Packet* available from the New York State Library.

ACTIVE PLUMBING IN HISTORIC STRUCTURES. Where there are unnecessary or unused bathrooms in an older building, the institution should reconsider its water use requirements, since active plumbing can cause serious damage if leaks or mischief occur. Consider installing isolation valves on each plumbing riser in the basement, and shut off all non-essential plumbing at the basement level.

GENERAL ENVIRONMENTAL IMPROVEMENTS

When considering these improvements, be sure not to compromise any other environmental or life-safety aspects of the building operation, such as air grills, emergency egress, smoke detectors or sprinklers.

* *REDUCE WINTER HEATING.* Be sure heating in winter is as low as possible without damaging the building or the institution's program. If overheating occurs, the heat must be turned down--windows should not be opened. This is typically a problem in buildings heated by radiators, and installation of new steam control valves may be required. If the temperature is around 65 to 70°F and occupants feel it is too cold, ask them to wear sweaters, etc. However, be sure not to turn the heat off at night, since this will cause fluctuations in humidity.

* *SEAL WINDOWS.* Use plastic sheets and tape to seal off windows in winter. This should reduce moisture loss and infiltration of relatively dry winter air.

* *KEEP OUTSIDE DOORS CLOSED; ADD WEATHERSTRIP.* In winter leaky doors, like open windows, allow relatively dry outside air to enter. Be sure doors are not left open and are effectively weatherstripped. Test them with a strip of paper to be sure they are sealed: a 1" wide strip of writing paper should not slide from side to side when closed in the door gasket. No light should be visible through the gasket with the door closed.

24-HOUR EQUIPMENT OPERATION. Some of the most acute short-term damage that has occurred to a collection has resulted from the shut-down and restarting of the environmental systems. It is important not to shut off the HVAC system at night or on weekends as this will usually cause fluctuations in humidity which can cause significant damage. This includes window air conditioners in summer and particularly heating in winter (but be sure the heating is at a constant low level). Be sure any humidifiers or dehumidifiers are also left on. If humidifiers need to be filled, or dehumidifiers need to be emptied, be sure they are on and adequately filled/emptied to maintain constant conditioning overnight or over weekends and holidays. It is better to reduce the humidity control than to have it shut down and restarted many hours later. (For example, reduce the humidifier setting so that it does not run out of water before it can be filled again, or increase the dehumidifier RH setting so it can be emptied before it shuts off from too much water. This of course does not apply to humidifiers with piped water supplies or dehumidifiers with pumps and piped drains.)

Although 24-hour conditioning usually requires little or no capital investment--it simply uses the existing equipment--it will almost always increase annual energy use costs if the equipment is currently being turned off daily.

BLOCK RADIANT GAIN FROM RADIATORS. If there are radiators in collection spaces, protect the collection from "line-of-sight" transmission of heat from the radiators by using barriers of wallboard and reflective foil.

USE AVAILABLE SPACES BEST WAY; SEGREGATE COLLECTION FOR BEST STORAGE. Survey the storage spaces available. Consider whether the current use of spaces can be modified to better suit the collection. Survey the collection and its environmental needs. Consider whether the collection can be practically and programmatically segregated into groups of different or varying environmental requirements, and store the groups in the most appropriate spaces. This may also reduce the size of any new improved conservation environment spaces.

For example, a hot, dry attic might provide ideal storage for metal objects. A cool, moist basement might be too moist for storage of paper and other objects, but film or other very small objects which do not need regular access might be safely stored there. Objects that can be sealed in air-tight containers could be carefully sealed in polyethylene containers inside polyethylene boxes with silica gel. A brightly-lit sun room in an historic house might be a good home for silver, metal, ceramic and porcelain objects tolerant of light. Before adopting any of these examples, they should be approved by a conservator based on a particular institution's collection.

MAJOR MANUFACTURER BACKUP ON EQUIPMENT. Wherever possible, consider pursuing problems with the manufacturer responsible for the equipment which is causing problems. Although they may not offer direct redress, they may offer suggestions and expertise, usually at no cost, to help you solve the problem. To properly tap this resource, you must usually first contract the local dealer or distributor who provided the equipment. If they do not provide a satisfactory response, as often is the case, then call the home office of the manufacturer and ask to speak with customer service or the engineering department. Outline your problems and they should be able to give suggestions for alternate operations, maintenance, or other systems which may be causing or contributing to the problem.

FLOORS. To control ambient dirt particulates, hard floors (concrete, vinyl, tile, terrazzo, etc.) must be damp-mopped or vacuumed regularly, no less than once every 48 hours in high traffic areas, to control particulate build-up. A dust mop or broom will not be adequate and will stir up rather than control dust and dirt. Vacuum cleaners should have special high-efficiency filters (typically found on vacuums designed to handle copier toner, or designed for use in allergy clinics) to prevent smaller particulates from being blown back into the room. The floor should be waxed as it becomes dull in traffic areas to prevent the floor from holding dust. Carpet should be vacuumed several times a week in high traffic areas.

STORAGE CLEANING. Storage area shelves, cabinets and floors must be regularly cleaned to reduce general particulate contamination (such as dirt stains when an object brushes the floor) and to help detect particulates that might indicate an active insect infestation.

OFFENDING SPACES AND ACTIVITIES. Certain spaces will have activities, processes or equipment which will pose a threat to the institution's collection. This includes ozone from xerographic equipment, laser printers and dry mount presses; smokers; food stuffs; and workshop or lab areas. The solution for these contamination problems is to provide designated areas for these activities—generally making sure that "office" activities do not in any way occur in "collection" spaces. A physical separation is needed to contain most of the contaminations noted, and the area should be on an HVAC system separate from collection spaces.

MATERIALS. Before using any commercial material that is not designed for conservation environments, such as plastic sheets, shades, or sheet construction material, confirm that the material has no significant off-gassing: check for an obvious odor when opening the package or store the material, or take a small sample of the material and place it in a sealed odorless container (such as a mason jar) for a week, then open the container and sniff for solvents. If necessary, let the material air-out for weeks or months, away from collections, with spacers to facilitate air flow, as necessary, before using. Avoid plywood and composite wood products which do not use exterior glues or do not have an American Plywood Association (APA) trademark label; avoid letting any collections touch wood surfaces. Avoid oil, alkyd and solvent-based paints; seek acrylic, water-based, and two-part epoxy paints.

THE DESIGN AND CONSTRUCTION PROCESS

Before making changes to the building environment, either through retrofit or expansion, an institution must be aware of what is involved in the renovation process. The institution should know what will be expected of it, and what to expect from others in the design and construction process. Extending beyond "design and construction," careful attention must be paid to planning, selection of the design team, management of the design team services, and occupancy.

Table 4 is a summary of the typical phases in the design and construction process. The issues involved in each part of the process are discussed at length in this chapter.

SMALL RENOVATION PROJECTS

Almost all of the basic activities in a large project are undertaken in a small renovation project. Major differences include the character of the design team and the number of phases in design.

THE DESIGN TEAM (see section I.4, below). Where required by local ordinances or state law, an architect and/or engineer may be required to design a project of a certain size, cost or character. The selection of the design team should be the same as for larger projects, although much less involved.

Where allowed by law and consistent with local practice and the institution's past experience, a contractor can be hired directly to provide both design and construction, providing a design-build service. In such a case the contractor becomes the design team, and is responsible for all the activities noted for a larger project, including preparation of design drawings and documentation.

DESIGN PHASES (section II, below). Due to the limited size and scope of a small environmental renovation project, there are generally not as many options to be considered in planning and design. This usually indicates fewer stages in the design and a shorter design period. For example, for a small renovation the "Interview and Select the Design Team," and "Program Update, Inspection by Design Team" steps might be combined into a visit and interview with a prospective design-build contractor.

The design should generally have two phases: preliminary design, and construction documents. The preliminary design would combine the aspects of preliminary and schematic designs described for a large project, and should be followed by a very studied review for its conservation merits. After the preliminary design, final construction documents are usually prepared. These documents should have at least a very thorough bid-set review. For a somewhat complex project, or where the design may have been extensively flawed in the first preliminary design, an additional pre-bid review may be prudent.

In application, a given project can fall somewhere between the small and large project, and a blending of the two processes should be considered.

Table 4-SUMMARY OF PROJECT PHASES FOR NEW CONSTRUCTION EXPANSION OR MAJOR RENOVATION

I. PLANNING AND THE DESIGN PROGRAM

1. Define Scope and Goals of the Renovation
2. Prepare a Formal Renovation Design Program
3. Project Costs
4. Interview and Select the Design Team

II. THE DESIGN PROCESS

1. Program Update, Inspection by Design Team
2. Conceptual or Preliminary Design, (often combined with Schematic Design)
   a. Preliminary Design Review
3. Schematic Design
   a. Schematic Design Review
4. Design Development
   a. Design Development Review
5. Construction Documents
   a. Pre-Bid or "Quality Assurance" Review
   b. Bid Set Review

III. THE CONSTRUCTION PROCESS

1. Bidding
2. Contract Award or Negotiation
3. Construction
   a. Pre-Construction Meeting
   b. Construction Inspections
   c. Substantial Completion
   d. Punch List
   e. Independent Test and Balance
   f. Commissioning
   g. Stable Performance Test Period
   h. Final Acceptance
4. Systems Documentation
5. Training of Operating Staff

IV. OCCUPANCY

1. Move into Non-Collection Spaces
2. Purging of Collection Spaces
3. Orientation and Training of Professional Staff
4. Trouble Shooting of Environmental Irregularities or Events.
5. Preparation of Collection Spaces
6. Move into Collection Spaces

V. OPERATION AND MAINTENANCE

I. PLANNING AND THE DESIGN PROGRAM

Faced with the considerable challenge of achieving an improved collection environment, it is essential that the institution undertake deliberate effort to plan and place bounds on the design. The following steps should be followed, in sequence, to develop firm limits on the scope and goals for the renovation or expansion.

1. Define Scope And Goals Of The Renovation

The institution should define the needs and possible scope of the renovation, preferably before using outside design consultants or architects. Environmental renovations to any existing spaces should be based on the results of a monitoring program. Have the collection surveyed for indications of environmental problems, using consulting conservators, if necessary, to accurately characterize the environmental goals.

Develop a written outline of the space and environmental needs, drawing on the curatorial and conservation resources of the institution. If there are existing problems with the HVAC systems, consider having the system evaluated by an environmental consultant or engineer. In some cases a "test and balance" report may need to be prepared if much of the existing system may be reused in the renovation.

From these investigations, consider the different possible scopes of renovation, rough costs, and possible funding. Settle on the general scope and budget for the improvements to the facility.

2. Prepare A Formal Renovation Design Program

Based on the decided scope and budget, the institution should take several steps to formally state the goals for the new environmental design. These will lead to what is called the "design program," a formal document describing the areas to be renovated and their environmental goals and criteria. This should describe the requirements, guidelines, rules and budget for the subsequent design and construction process, whether it is a simple renovation or a major expansion. The institution should prepare this program itself, usually through consensus with a designated "building committee," with possible help from consultants.

The building committee should include representatives from the collections management staff, at least the librarian and/or archivist, and should include any registrar and curators on staff. While the "building and grounds committee" of a board of directors or board of trustees may set overall goals and review the building committee's work, the substance of the program should come primarily from the full-time collections staff.

If revision of the institution's layout and space use is needed, then an architect or architectural programming consultant may be required. If used at this stage, architects or programming consultants should not be allowed a free hand to define needs—they should only help interpret needs. These consultants should preferably *not* then go on to prepare the design; rather, they should be available to review subsequent designs to be sure they are consistent with the original goals. When working with a consulting firm that also does design, such intentions on the scope of services should be made clear up front.

ENVIRONMENTAL CRITERIA. Collections environment criteria may be set from any number of reference sources, but using published sources is not a substitute for an informed inspection of the collection by a trained conservator, identifying special needs and particular indications. As outlined earlier in this document, a conservator should evaluate the collection for evidence of, or susceptibility to damage from: high or low humidity, heat, light or UV radiation, particulate buildup, and gaseous pollution. Based on these observations, the environmental criteria should be set, using the published references (including this document and the references listed herein) as guidelines for improvement of the environment.

Criteria should cover lighting, temperature, relative humidity, particulate filtration, and gaseous filtration. They should be expressed or translated into a form usable by the architect and engineer, such as particulate filtration efficiency rather than micrograms of particulate per cubic meter. Formal environmental criteria for a renovation should, but rarely do, cover the basic types of building systems that are preferred, based on past experience at other institutions.

CONSERVATION ENVIRONMENT CONSULTANT. Consider using a conservation environment consultant to clearly define the goals and expectations for the renovation environment. In many cases such a consultant may help in defining the environmental criteria, in interpreting conservator recommendations into construction issues, in giving clearer working guidelines for subsequent design, and in supplementing the overall design program. The conservation environment consultant can also be instrumental in explaining to the institution the implications of design options and alternatives. Based on successes and failures at other institutions, a good consultant will give clear directions for the issues and options involved in selection of building systems, and will enumerate system characteristics that are essential to achieving the institution's goals.

SPACE USE AND ENVIRONMENTAL NEEDS PLANNING. Before any major renovation, space reorganization, building expansion, or master planning is undertaken, the institution should develop a space use plan. The space use plan should be based on an inventory of space needs for storage, reading, display, and office/support areas to support the collection and the institution. For each, list the current and future space requirements in square footages, and the current and desired environmental conditions. These space requirements should be further broken down into the feasible types of conservation environments for collection spaces, possibly including general storage (usually 65°F and 45% RH), low temperature and low humidity (usually 45 or 55°F and 35% RH) such as for films, and any small special-conditions spaces. This environmental space breakdown, as square footage and as a relative percentage, should guide any major space planning effort.

Where at all possible, the program should plan for keeping office areas separated and apart from collection areas.

The result of all these investigations, and space and environmental requirements should be summarized in a specific and fixed document, "the design program." It must be understood and backed by all involved, and should be incorporated into the subsequent design contract with the architect and engineer. Using a series of memos and letters instead of a formal program is a proven way to guarantee that the new environment will not work.

3. Project Costs

In the planning phase of a project costs or budgets should be developed to balance against funding sources and possible phasing of improvements. There are any number of aspects of a construction or renovation project which will be major determinants to the project cost. The following are the major "cost drivers" most common on conservation environment projects. Actual costs cannot be offered here since they will vary widely based on location, specific conditions, available utilities, existing heating and cooling sources, the quality and merits of the design, availability of equipment, and the economic environment at time of construction. The institution should be able to get rough cost estimates on a particular project, working from a clear renovation program, from local contractors, architects and engineers. When doing so, *be sure they have taken the following cost drivers into account.*

HUMIDITY TOLERANT BUILDING ENVELOPE. Since adequate humidification is usually the first priority in a conservation environment, most projects must consider the limitations on winter humidification if the building envelope (the walls, roof and windows) cannot tolerate 40 or 45% RH without problem condensation. The cost of retrofitting an existing envelope can be considerable, often as much as, if not more than, all the other modifications and improvements to the environment. Since this renovation often involves new interior finishes (furring, insulation, vapor barrier, drywall, and interior storm windows), this is even more expensive when the interior has rich details to be preserved.

UTILITY SERVICE INFRASTRUCTURE. For most environmental system renovations, HVAC equipment often depends heavily on utility services such as electric power, natural gas, water and drains. (See Diagrams 3 and 4: power, water, drains and other systems are required for even the smallest system.) If these services are available at or very near the location of the equipment, with sufficient capacity available to serve the equipment, then costs are primarily for the new equipment itself. If new primary electric service, natural gas service, flue and drains must be run to a new location in a building to serve a small environmental system, the new services can cost many times more than the equipment itself. For example, installing a portable wetted-belt humidifier and dehumidifier in a storage room with a sink can be very easy. The sink can provide a constant water supply for the humidifier, and a drain for discharge of the dehumidifier's condensate. However, if limited electric service is available (such as only a 15 amp circuit which already was heavily loaded) then there may only be enough power to connect the small motor in the humidifier—the additional power required for the motor in the dehumidifier's compressor might require adding a new electric circuit.

PRIMARY SOURCES FOR HEATING AND COOLING. As with adequate utility services, a renovation project can be less expensive if there is chilled water and hot water or steam available, since most HVAC systems require heating, cooling or steam to perform their function. Where there are existing boilers and chillers, with available capacity, distribution service, and the right operation schedule, they can significantly reduce the cost of installing a new HVAC system.

DUCT OR DISTRIBUTION INFRASTRUCTURE. In many cases a major investment to support a good environment will be a ducted air distribution system to support an all-air HVAC system. If the building already has a serviceable duct system most of that cost can be avoided, but in a building with only radiators a major cost of the project will be installation of the ductwork. Similarly, if steam piping is needed to supply humidifiers throughout a building, a building with existing piping will cost less to renovate than one without.

EXAMPLE COSTS. The following are some very rough 1989 example costs to develop a feel for the cost of various renovation expenses.

1. Costs for a typical small renovation project, such as the installation shown in Diagram 3 (see page 25), serving a 1,000-2,000 square-foot storage area, might range as follows:

Small HVAC System (3 Ton)	$5,000
Uses central chilled water and hot water	
Controls and Ductwork	$1,000
Electric Steam Generator/Humidifier	$1,000-$2,000
Electric Service	$100-$2,000
Drain/Water Piping	$100-$2,000
General Construction/Finish Work	$100-2,000
Contractor Markup	$700-$2,000
Total	$8,000-$16,000

These costs assume a tie-in to an *existing chilled water and hot water system* (which can provide all-season/24-hour heating and cooling), and electric services already in the building with sufficient capacity to serve the new system. This also assumes convenient locations available for water and drains.

The cost would be higher if electric service needs to be brought into the building, or if a gas-fired boiler was chosen to avoid the high annual electric cost of electric humidification, or if other site specific conditions complicated the project. The system might not be applicable if the chilled water/hot water system were not available, or if they did not operate all year long.

2. Costs for a similar small renovation project, such as the installation shown in Diagram 4 (see page 25), serving a 1,000-2,000 square-foot storage area, might range as follows:

Small HVAC System (2 Ton)	$6,000
electric humidified, compressor & reheat	
Supplemental Filtration	$3,000
Controls and Ductwork	$1,000
Outside Condenser	$2,500
Condenser Refrigerant Piping	$100-$1,000
Electric Heating	$500
Electric Service	$100-$2,000
Drain/Water Piping	$100-$2,000
General Construction/Finish Work	$100-$2,000
Contractor Markup	$1,600-$3,000
Total	$15,000-$23,000

These costs, substantially higher than the previous example, assume a major tie-in to only existing electric service with sufficient capacity, and convenient locations available for connecting water, placing drains and for location of the outside condenser.

The cost would be higher still if electric service needs to be brought into the building, if a gas-fired boiler was chosen to avoid the high annual electric cost of electric heating and humidification, or if other site-specific conditions complicated the project.

The total cost of such a system could reach $50,000 if a high-quality computer room HVAC system was used, the filtration system was built up from conventional filtration components rather than a specialty filtration system, and if the project is in New York City.

Note: These examples might not apply at all to any particular situation.

HIDDEN COSTS. For many libraries and archives where contracting for construction is performed by a local government agency, the standard contracting procedures and requirements may increase the cost of a small project dramatically. For example, a $1,000 humidifier might cost over $3,000 if the local government requires short notice at-risk completion guarantees, $1,000,000 liability insurance, or places other onerous constraints on the contractor. On a larger project this cost might not be noticeable, but in this example the institution should see if contract provisions can be waived, or else the institution should consider installing the modest equipment in this example without an outside contractor.

OPERATING COSTS. The institution must also consider how much it is willing to commit for an operating budget. This should include both energy and maintenance costs. For a large project or expansion, the institution may need to hire additional staff for building operations and custodial care.

Several options in the project will have an impact on annual energy and maintenance cost, and maintenance effort. The institution should be prepared to carefully consider the long-term implications of recurring annual costs, and be sure there is annual funding commitments or endowment to support the operation of critical environmental systems. It is not uncommon for critical systems to be shut down, or to fall into a state of disrepair, because of annual funding constraints.

There will also be capital/annual cost tradeoffs. The institution should be prepared to discuss the value of capital against annual costs. For example, a piece of equipment or feature that costs $10,000 more might save $2,000 in annual costs. In such a case it is easier for the institution to: a) raise the $10,000 lump sum initially; b) raise the added $2,000 annually to avoid spending the $10,000 initially; or c) raise additional endowment to provide an extra $2,000 annually?

Once the costs have been developed, the institution is better equipped to set realistic goals and possibly reconsider the scope of the renovation, based on funding limitations.

4. Interview And Select The Design Team

In most cases the institution must work through a design team, consisting of at least a registered architect and a professional engineer, licensed to practice in New York State. Not only is this design team not going to perform the actual construction work, but often the architect prefers to have the engineers and consultants who will design the HVAC, lighting and other systems work through the architect, rather than for the institution. If this is the case, an engineer, now once-removed from the client, designs a system and produces drawings and specifications. This design is usually built by a general contractor, who hires HVAC and electrical construction firms as sub-contractors. These sub-contractors may do most of the actual work, but a critical part of the HVAC system, the controls, are often designed and installed by yet another separate temperature controls contractor or manufacturer. With construction work executed this many levels removed from the actual librarian, archivist, conservator or administrator, it is a surprise if the institution gets anything it needs which is out of the ordinary.

Since the institution will be working through the design team as their principal agents in the design and construction administration process, careful selection of the design team is essential. Using the program document prepared in the previous step to describe the project, the institution should solicit proposals or letters of interest and credentials from architects and engineers. When finally making the contract for services with the design team, seriously consider making the program a part of the contract.

The architect and engineer selected must recognize the goals of a proper conservation environment and should understand that this is not a conventional office or residential space. If possible, they should be able to qualify their capabilities with success on similar library, archives or museum projects. When selecting design professionals of any kind, call the library or archives professionals and conservators involved with their recent projects and find out the successes and failures of their previously built environments. Even if they have never designed a library or archives before, call their previous clients to find out what their clients would have done differently in working with them.

THE ARCHITECT. The architect is responsible for designing the architectural systems, including the walls, floors, roof, windows, fixtures and finishes of the building or renovation project, and providing a built environment to protect the general public's health and safety. In most cases this is certified by the architect's stamp on the construction documents. By convention, the architect also will usually manage the overall project, and generally act as the agent for the "owner," in this case the institution. This management role for the architect is sensible when there is an existing relationship between the architect and the institution so that the architect has been able to develop a feeling for the institution's operations, goals and particular needs. This relationship should be with a specific person in an architect's office, preferably one of the principals.

The well informed institution should take the lead with their relationship with the architect, not just blindly follow. Be warned that a recent editorial in *Architectural Record* encouraged, "If a work of architecture is to transfigure the commonplace, the architect must begin by keeping a critical distance with regard to the client's initial program, being none too ready to fulfill its requirements." This attitude may lead to wonderful and monumental architecture but it often shows benign neglect for the environmental goals, if not actually robbing the environmental systems to pay for architectural expression.

Planning Academic and Research Library Buildings, (Reference 11) offers some good guidelines for "selection of the architect." On page 87, Keyes Metcalf, n library consultant, observed "there has been an unfortunate tendency in recent years (reversing the trend of the first decade after the Second World War) on the part of some of the more capable and better-known architects to attempt to attract attention by glamorous and exciting buildings which subordinate function to other features. They ignore the fact that most academic institutions must choose between a building which is primarily functional, and quarters that will be more expensive, quickly outgrown, and be difficult to explain a generation hence when it will require an addition or even a replacement."

The institution should seek an architect who can merge and if necessary subordinate subjective aesthetic goals to the functional requirements of environmental goals. The most valuable architect will help the institution undertake the initial master planning so critical to developing a clear architectural space program and to prudent fund-raising.

THE HIGH-PROFILE DESIGN ARCHITECT. If the institution is undertaking major expansion or design of a new building and feels the need for a "high-profile" design architect, consider both the benefits and problems of such a choice. While the well-known architect may help the institution raise building funds, there will almost always be an increased construction budget to support the (hopefully) award-winning design. As a rule, without the additional money, the design will not suffer but the collection environmental goals will.

Consider that if the use of a well-known architect helps raise 20% more money, but designs a 30% more expensive building, the institution has had a net loss, almost always at the expense of the conservation environment. A design better suited to the local community and more sensitive to local construction practice will often come from a more practical local architect.

In all cases a studied review by the institution of the design and budget breakdown in the early phases of the design process are critical to be sure an adequate amount is being budgeted to support the environmental goals.

DESIGN COMPETITIONS. In some cases the institution may consider a design competition to select the architect or design team. This should only be done if fund-raising or political constraints require such a process for project success. If the competition is intended to attract a high-profile architect, then the same caveats apply to the construction budget. Since an obligation to a winning competition design is common, the competition must be based on a clearly defined program, possibly developed with the help of an architectural programming consultant. It is absolutely essential that the competition be judged based on each design's fulfillment of the program, with active participation in the judging by the curators, conservators and conservation consultants, just like a preliminary design review. In all too many instances a blue-ribbon panel, almost entirely removed from the institutional, collection and conservation concerns, has selected a winner based purely on architectural merits, saddling the institution with an impractical, inefficient and problematic design concept.

THE ENGINEER. The engineer is responsible for designing the mechanical, electrical, plumbing and/or structural systems for the building or renovation project, and assuring that these systems are consistent with good engineering practice and the general public's health and safety. In most cases this is certified by the engineer's stamp on the construction documents prepared. In the balance of this discussion, primary interest is in the mechanical (or HVAC) and electrical engineer who designs the systems that actively create or maintain the conservation environment.

The HVAC engineer is usually the design team member who is the most concerned with, and has the most direct influence on the quality of the collection environment. Unfortunately, most engineers who design mechanical systems are not extensively trained in the deductive and developmental principles of system design, rather, they are trained by inductive experience: they do what they have done before. If they have not designed a library, archives or museum recently, or correctly, then the design may not be what is needed. The engineer's resources, primarily in the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) handbooks, present little meaningful help in library and archives design. In the absence of library experience and specific environmental systems criteria, the engineer may develop a typical office building environment, entirely ill-suited to preservation of the collection. Strong environmental goals, guidance and information beyond the ASHRAE handbooks is needed. It is the responsibility of the institution to develop these, with the help of consultants if necessary, and to express them to the engineer, usually in the design program.

Choose the particular engineer based on a balance among competency, proximity and interest. Since a conservation environment renovation distinguishes the institution from the majority of HVAC clients—there are specific expectations for humidity, temperature and other aspects of the environment, and the results will be measured—the engineer should understand this before being hired. The engineer should prove past success in design of this character of building, a willingness to provide on-site services to discuss the design with the institution, to perform thorough on-site construction inspections, and to provide on-site services, after construction if necessary, to make the system work.

Most engineers rely on designing with new equipment, which has clear, catalogued performance factors. In some cases a renovation project has a significant amount of existing equipment which could be reused in the renovation, such as existing ductwork concealed behind historic finish work, or an old multi-zone system which needs minor repairs rather than replacement. In such cases the engineer should be carefully chosen for a willingness to work with the older existing equipment, often including taking extensive field measurements to produce the information needed for design.

With all these expectations, be prepared to pay the engineer higher fees than for a typical building design, because a good conservation environment requires much more of the engineer than a typical building.

Remember that the engineer should hold primary allegiance to the institution and discharge a fiduciary trust in its needs. Be wary of the engineer who may hold a primary allegiance to the architect. The engineer should work to the ends of the institution, not in deference to an architect in anticipation of future work. Although it is not common, and it may displease the architect, the institution can contract with the engineer directly for services, without going through the architect.

If the majority of the project is renovation of the mechanical systems, plan on contracting for services from a mechanical engineer, not an architect. If some architectural work is involved, let the mechanical engineer sub-contract that work to an architect, particularly if the architectural work is primarily treatment of the building envelope to support a conservation environment. Despite this, it is often done the other way around, generally with added expense and more compromises in environmental performance.

DESIGN-BUILD CONTRACTORS. Many institutions have found that the right "design-build" contractor, with a local practice, can provide a direct and efficient path to achieving environmental goals. These contractors, usually for the HVAC systems, will join the design team in a design capacity as the HVAC engineer. They will, however, design based on their considerable experience in installing systems and making them work, and based on their considerable preference for the equipment and manufacturers with which they have standing relationships. While the particular manufacturer of HVAC equipment is not usually critical for a satisfactory system, since most system components have multiple vendors, there can be problems when the design-build contractor shows a preference for inappropriate equipment. If they can provide good references, and will offer an extended service contract for several years, at a low cost, to show an on-going obligation to satisfactory performance, and can otherwise meet the requirements for a good engineer, a design-build contractor can be a good choice.

For a small HVAC renovation project, the design-build contractor may be the entire design team as well as the primary contractor.

ENERGY-CONSCIOUS DESIGN. Be wary of anything or anyone who wants to "save energy." With obvious exceptions (such as low light levels, minimum areas of windows, efficient motors), a good conservation environment has a tendency to use energy to save the collection. Reheat for dehumidification and heating humidification steam are just two examples of "wasted" energy which are essential parts of a stable conservation environment. Most energy conserving systems save energy at the expense of the collection. The "energy crisis" of the 1970's caused many conservation environment disasters, such as high-UV "watt-mizer" fluorescent lamps, VAV systems, air economizers, and indiscriminate daylighting.

OTHER DESIGN CONSULTANTS. In addition to the architect and engineers for mechanical (HVAC), electrical, plumbing, and structural disciplines, the design team may also enlist the services of other consultants for fire protection, security, lighting, transportation (elevators) and other design disciplines.

OWNER CONSULTANTS. Some consultants, such as the conservation environment consultant or cost consultant, who provide a review capacity but no design services, often provide the best service if they are hired directly by the institution. By working from the "owner" side of the table, they can give more objective evaluations of a design.

The institution should plan on periodic meetings with the "owner" consultants throughout the design process. These meetings may or may not include the formal design team, as appropriate.

PROJECT MANAGER. In some larger projects the institution may obtain the services of an independent or institutional project manager (not to be confused with the architect's "project manager"), to supervise the design and construction process. This person should work directly for the institution and should be brought in early. They can help the institution manage many of the design process problems and control the budget, although the project manager should not have primary technical involvement on the environmental design. Beware of contractual agreements for project management services where there is an incentive to save money, as they may save money at the expense of the collection environment. If such a clause is kept, then it should be entirely subordinated to the achievement of environmental goals: if goals are not reached, as verified by independent tests (not the least of which should be a year of hygrothermograph readings in the completed environment), none of the incentive will be paid.

II. THE DESIGN PROCESS

After the program is completed, and the design team is selected, the design may begin. The institution should remind the design team that the program, prepared in the previous phase, is the primary working document to communicate their needs, and that the design should always be based on that context.

REVIEWS. As the design is developed, regular planned reviews should be made by the institution at the completion of each specific design phase. The earlier reviews are where timely, concise and effective feedback is required. For smaller projects the preliminary and schematic reviews may be combined into a single "preliminary" review. It is essential that the construction documents not proceed until all environmental design issues are resolved. A review before the start of construction documents must always be required, and is critical in checking the design, since the construction document review is generally too late to make major changes. This is not to minimize the construction document pre-bid or final review, where small but often critical changes are made.

As the project progresses, the institution must keep in mind that any design project has two mechanisms working against each other: as time passes the design becomes more clear, and at the same time less flexible. Changes cost less the earlier they are identified. This is why it is important to require the early development of the principal features of the conservation aspects of the design, and not let them be "worked out later." Later they will cost more to implement, particularly if they are flawed. It is often the very systems and details that the design team wants to put off, the ones with which they are least familiar, that require the earliest and longest work for satisfactory and efficient solution.

The reviews should be of a complete set of design documents for all systems; a review of only a "presentation" by the design team is not sufficient. Lack of review of hard design drawings and system descriptions is a good way to lose control of the design. For early reviews where some systems are not fully developed, there should be a narrative description of systems, not simply an "outline specification." The narrative must express the intent of the design to be developed, not just the materials to be used.

The design team's submittal for each review should be a clear cadence in the design process. Submissions where they "have supplied all the information presently available and will continue to supply information as it is finally developed" (quote from an actual letter), is not acceptable for a meaningful design review. This "smearing" of the design submissions over time has lead to major gaps in system designs and systems installed without critical features which might have cost little or nothing if requested before bid or before equipment was ordered.

DELIBERATE PROCESS. Projects often acquire a life of their own, and often acquire a false sense of urgency from the time-is-money habits of the design team, who work so often with commercial clients. Remember that to delay, suspend or cancel a project in the design stage is usually less than one tenth as expensive as building the wrong building. Skipping or abbreviating a review simply to keep a project on schedule may make sense for a commercial project where a late project delivery can cause major problems, but for most cultural institutions it is foolish and usually causes a waste of limited funds. A good environment and good investment in new systems requires a slow and deliberate process.

The architect and engineer are usually at legal risk for their designs, and ultimately have the option to withold their stamp from the design, generally preventing the construction of that design. However, remember that the design professionals work for the institution, not vice versa. The building does not belong to the design professionals, and it is not intended to meet their expectations for expediency and economy.

UNDERSTANDING EACH DESIGN PROPOSED. The institution must clearly understand the design proposed by the design team at each design phase. This does not mean that the institution must understand each line and symbol in a design drawing or the specific operation of each piece of equipment. This means that the institution should have a conceptual understanding of what is happening in the building and with the building systems. This means that the institution must have an operational explanation of the performance, operation and maintenance of the systems.

The institution staff should make the design professionals explain every aspect of the design, and should object to any part or expense that is not understood or is not what was intended or programmed.

A recent dialog about the critical topic of basic capability for humidity control that took place during a renovation project provides a helpful example:

Owner:	"I see your submission says you will maintain 50% RH. That's very good. How will you do humidification?"
HVAC:	"We have an electrode canister steam generator."
Owner:	"How much will that cost me to operate?"
HVAC:	"I thought you wanted a least-cost system?"

Owner:	"How much would a more expensive system cost, and how much money would it save me each year?"
HVAC:	"I don't know--more, but it will cost about one-third as much per year for humidification." [It will also be more work to design.]
Owner:	"Can you get back to me with my options? Now, how will you do dehumidification?"
HVAC:	"The cooling coil will do dehumidification for you."
Owner:	"All the time?"
HVAC:	"Almost all the time."
Owner:	"How much of the time?"
HVAC:	"Most all the time."
Owner:	"How about on a cool, damp spring day?"
HVAC:	"How often does that happen?"
Owner:	"Often enough."
HVAC:	"Well, we could add an electric reheat coil--that wouldn't cost much."
Owner:	"How much will that cost me to operate?"
HVAC:	"I though you wanted a least-cost system?"
Owner:	"How much would a more expensive system cost, and how much money would it save me each year?"
HVAC:	"I don't know--more, but it will cost about one-third as much per year for humidification." [It will also be more work to design--seems to be getting familiar?]
Owner:	"Can you get back to me with my options?"

The technique for understanding a design is quite simple: ask questions, and keep asking questions until you feel as comfortable proceeding with the design as you might if you were buying a new car. (You may not understand how to change the spark plugs, but you want to know how often it must be done, who will do it and how much it will cost.)

Ask relatively simple questions about the system, if it will do what you want it to do, and if you can afford to operate and maintain it. Questions should be based on the obvious, and the issues, criteria and guidelines contained herein. Consult the "HVAC System Performance Issues" section for specifics.

The institution should write everything down that is unclear or needs to be resolved, be sure everyone gets a copy, and make unresolved issues the first order of business at the next meeting. This is in addition to the design team's "meeting minutes." Do not rely on the meeting minutes to achieve this.

COLLECTION ZONE PLANS. One of the most powerful and clear documentations of a project where only part of the building will hold collections is a set of floor plans showing the "Collections" and "Non-Collections" areas. Such plans graphically indicate the "Collections" areas--the areas that will enjoy the application of the conservation environment criteria. With these, the institution can quickly and unquestionably see the design team's intended scope of collection spaces.

CONDENSATION AND VAPOR BARRIER. A major problem with many conservation environments is inadequate condensation control and vapor barrier design. Unfortunately the resolution of the problem is in the hands of the architect and his design, but the understanding of the issues lies in the engineer's domain.

There is rarely any coordination or resolution to this aspect of the design if any attention is given at all. The institution should push for a specific report from the architect and engineer on how exterior window, wall and roof condensation has been addressed in the final design.

WATER CONTROL. The most common problem in all forms of construction is keeping the rain out. A collection space should have a conventional, reliable roof system. Problems have been encountered with new or special roofs, or collection areas below grade (underground) with a "walkable" outdoor area. For collection areas below grade, check the water table to be sure no special site drainage is needed to keep the collection area dry; simply sealing below-grade walls to keep out water does not work.

CONSERVATION ENVIRONMENT SYSTEM BUDGETS. A common problem in design is meeting the budget. Often a single budget figure is used for a complex project; unfortunately, this does not express the priorities in the design. If a design is developed without a clear budget for the conservation environment, and then cost cuts are needed, the cuts will most likely come from the "hidden" features such as the HVAC system. It is not uncommon to make the mistake of cutting systems and features at the last minute to meet the budget, and then find that virtually none of the environmental goals are met.

On any project that involves more than an environmental renovation, set early budgets for the HVAC system and other aspects of the design critical to the conservation environment, such as the humidity-tolerant envelope. The budget breakdown can be set out in the program, or can be developed with the independent project manager or a cost consultant. Interestingly enough, a good design team will often be able to have a good idea of the cost of critical conservation environment systems, such as HVAC systems, so long as the institution is clear on the goals and general systems to be used in the project. If the project budget is reduced, then reduce the size and scope of the project, or exercise cost control contingencies planned well in advance.

BUDGET CUTS AND CONTINGENCY DESIGN. There can always be a problem with meeting construction budgets and this should be anticipated from the outset of the design. A design should have a well-documented budget contingency plan, allowing parts of the project to be deleted to reduce costs.

Where conservation environment systems are involved, the systems should not be critically compromised by a planned deletion. For example, following the Levels of Control suggested earlier in this document, never delete humidification; rather, delete gaseous pollution control equipment or high-efficiency filters, leaving future space and fan pressure capabilities, with the intention that the deleted systems be obtained later. For small systems, equipment features can often be deleted so that they can be added later. Problems have been encountered with substitutions of inappropriate equipment, features or systems, such as VAV or air economizers, to meet the project budget.

DESIGN CHANGES AND FEES. It is important to note that it is only reasonable for the design team to be paid more in fees if there are changes to the design. This is why the institution should clearly develop the project program and a description of expected services for the benefit of the design team before they are hired, so that the full scope of services needed are contracted for.

TYPICAL DESIGN PHASES

The following are typical design phases for environmental projects, listed in order of occurrence. While a specific institution or design team may have phases and plans that differ somewhat from these, it should be clear how these activities occur in any alternative plan. Under no circumstances should combining reviews or postponing involvement of the archives or library staff on the project be allowed, although for small projects some design phases may be combined.

1. Program Update, Inspection By Design Team

In preparation for actual design, the design team, primarily the architect, may wish to develop a new design program. This, of course, must be based on the design program prepared by the institution, but may qualify and elaborate on areas the architect feels needs further definition or development. It will usually include interviews with selected members of the staff and any consultants.

This "updated" program should be carefully reviewed by the institution and any original consultants used by the institution. The original program should not be set aside; rather, the updated program should complement it.

FACILITY INSPECTION BY DESIGN TEAM. In preparation for design of renovation projects, the design team should perform an on-site inspection of the facility. This should allow the design team to have a clear understanding of the scope, constraints and challenges of the project, and to gather information to support a design for minimum disruption of the building and collection, and maximum reuse of existing systems. In some cases the design team may wish to prepare a set of "as-built" drawings, documenting the existing conditions before design begins.

2. Conceptual Or Preliminary Design

This is the design phase in which the design team develops drawings that describe the overall concepts and very rough general layout of how the design concept will meet the program needs. In many projects this is combined with the schematic design phase.

The design team should prepare and submit a preliminary design and budget for review by the institution and by any programming consultants used by the institution. The design should demonstrate that the spaces needed are provided and are of appropriate size, and that there are not any problematic aspects to the space arrangement. This is the time to comment on any conceptual problems in the way the system is planned, and to be sure the design team is planning to meet the environmental goals.

3. Schematic Design

This is the design phase in which the design team develops drawings, preliminary calculations and descriptions of systems. These describe the general scheme of a design, demonstrating basic layout and feasibility, without details or full development of the design.

The design team should prepare and submit a schematic design package of drawings, a narrative description of systems and schematic budget for review by the institution and by any programming consultants used by the institution. The design at this stage should show all the spaces used and required for the renovation, including space for major ducts, and where the system will connect to existing building systems, such as for power, drains, condenser or chilled water, and hot water or steam. Do not accept an "architect's" plan for execution of the building systems; at this point the engineer should be on board, and should have prepared drawings. Drawings should show at least a "single-line" drawing of the connections on a scaled floor plan drawing of the existing construction, showing preliminary routing of the ducts and pipes and primary location of equipment. Review the design with attention to areas of possible leaks and equipment access for service—these should be out of the collection areas so that leaks and service operations will not disturb or contaminate the collection. The narrative description of systems should describe the general treatments and types of systems to be used. If there are problems in the design, be sure to quickly document the problems to the design team in writing, and be sure the design team knows that the institution expects solutions to be developed.

Check the budget to make sure sufficient funds are allocated to support the conservation environment systems.

4. **Design Development**

At this phase in the design the design team develops the full substance of the goals of a design, demonstrating all but the details required for construction.

As in schematic design, the design team should prepare and submit a design package of drawings and a narrative description of systems, plus an outline specification and construction budget, for review by the institution and by any programming consultants used by the institution. The design at this stage should be reviewed for the same issues identified for the schematic design, for resolution of any problems previously identified, and for merit of the new details developed in the design.

5. **Construction Documents**

At this phase the design team develops the final drawings and specifications describing the detailed design of the project, suitable for use in executing construction.

PRE-BID OR "QUALITY ASSURANCE" REVIEW. The design team should prepare and submit a pre-bid or "quality assurance" design at 70 or 80% of completion of the design, including a construction estimate, for review by the institution and by any programming consultants. The design should show details for all major parts of the design, and should clearly show resolution of all outstanding issues identified in the previous design phases. The construction estimate should show that the design team has a balanced development of the systems, and has not set up the conservation environment features and systems for last-minute cost cuts. This is the last chance to try and make any substantive changes to the design.

BID SET REVIEW. The bid set is the set of documents intended to be sent to contractors to solicit cost bids for the construction described. The design should be complete at this stage, and should be reviewed by the institution and by any programming consultants before the bid sets are sent out. The design should show all details of how the renovation will be done. Only very minor items can be efficiently changed at this point, since virtually all systems have been set, and the design fees have been spent. However, the design fees are still less than the upcoming construction cost, and if there are critical inadequacies now evident in the design a redesign may be required. Note that minor changes can be made, even after the project has been put out to bid, with "addenda" or "bid bulletins," which can change a design for a period of time before a final bid is accepted.

FINAL CONSTRUCTION DOCUMENTS. The final result of design is the construction documents, a set of drawings and specifications (narrative description of the construction materials), which should have been extensively reviewed to confirm their suitability for the intended conservation environment. The drawings and specifications may be sent out for bids or negotiated contract, or used directly for construction by the institution.

III. THE CONSTRUCTION PROCESS

Construction is when the new environment--conceived, programmed and designed--is finally built. Construction should be closely supervised by the design team, and, if used, the institution's independent project manager. The contractor will need to offer refinements to the design, some required, such as contractor designs and shop drawings, others, change-orders, which may or may not be in the best interest of the conservation environment. Some refinements to the design details are called "shop drawings," and will cover small parts of the design not determined in the design documents, such as details of the ductwork. For other systems, such as the temperature controls, or refrigerated rooms, the design may be left entirely up to the contractor or his subcontractors. The contractor will inevitably wish to change the design, or substitute different equipment for that called for in the design. Changes, unless specifically allowed in the construction documents, must be official and in the form of change orders.

Contractor designs, shop drawings, and change-orders must be approved by the institution or their representatives, and must be closely reviewed, with the same deliberation and competency as used in the design phase, to assure consistency with the environmental design goals.

The following are typical construction phases for environmental projects, listed in order of occurrence. While a specific construction project may differ somewhat from these, it should be clear how these activities occur in any alternative plan.

1. Bidding

The construction documents are issued to solicit bids from contractors who are interested in doing the work. Contractors may have questions, request clarifications, or suggest alternatives.

2. Contract Award Or Negotiation

Among the interested contractors who tender bids, the institution may select the low bid, middle bid, or may negotiate with one or more bidders for a final contract. For government projects, the selection is often required to be the low bidder. (In the more realistic real estate development market, preference is often given for the middle bidder, who, unlike the low bidder, probably did not miss anything in his bid.)

3. Construction

After the contract is awarded, the construction phase begins. Many issues that arise in construction—issues which are only temporary nuisances for normal construction projects—are issues which can cause considerable short-term damage to the collection and long-term compromises to the conservation environment.

Where construction is near or in spaces with collections, special precautions are required to protect the collection as the considerable disruption of construction can pose a considerable threat to a collection. Simply covering objects with plastic sheets or drop cloths is unacceptable—it is essential that the collection be located entirely in another part of the facility or be removed to another location for protection from construction harm's way. Special precautions may also be required to isolate the construction activities, disruptions and contaminations from any collection areas.

The following are some of the typical events during construction, usually in the order shown.

PRE-CONSTRUCTION MEETING. This is a "kickoff" meeting where special aspects or changes to the design are discussed.

CONSTRUCTION INSPECTIONS. The design team, primarily the architect and engineer, usually provide several regular inspections of the construction while it progresses. These are not only to confirm that the design is being properly executed, but often are used to check on the extent of project completion for authorization of interim payments from the institution to the contractors.

SUBSTANTIAL COMPLETION. At this stage the construction is more or less complete (usually less). All the major parts and systems of the project have been installed.

PUNCH LIST. After substantial completion, the owner (the institution), prepares a "punch list" describing all the aspects of the construction which are incorrect or deficient. This can cover anything from a missing electrical outlet to poor workmanship on a new roof. The formal punch list is usually prepared by the design team; however, the institution should take an active interest in the punch list, making sure all important aspects of the conservation environment design are properly executed. The institution should consider having any programming consultants assist in the punch list preparation.

INDEPENDENT TEST AND BALANCE. As the HVAC system is completed, it should be tested and balanced. This is best done by an independent certified test and balance engineer, preferably not by the design engineer. The design engineer should review the test and balance report as an audit of the quality of the HVAC subcontractor's work.

COMMISSIONING (Optional Service). The term commissioning has long been used overseas to describe the construction follow-up services by an engineer, where the engineer works with the system, contractor and owner to make sure the building operates as designed. Although not a legal "authorization to operate" as it is in some countries, this service can often mean the difference between an HVAC system simply operating, and operating properly.

STABLE PERFORMANCE TEST PERIOD (Often omitted). The new conservation environment should be tested for a period of time to assure that it operates properly, and that it does not pose a threat to the collection it was intended to protect. This includes not only the HVAC system, but the piping, roof, drains and other systems which, if they failed, might cause considerable damage to the collection. The importance of this cannot be over-emphasized—it is very common to find construction errors or deficiencies, such as broken humidistats, clogged drains, missing roof flashing and other problems, which are discovered only after a system failure.

During the test period the new environment should be monitored with hygrothermographs and other appropriate devices. The length of this period is debatable, but should certainly extend over a rain storm and a change in season, typically 90 to 180 days.

This test period should be clearly noted in the construction contract before the project goes to bid, including the minimum acceptable performance expected. If the design team or contractor do not agree to the test period, then consider if someone else can be found who will agree.

FINAL ACCEPTANCE. In final acceptance the institution or other designated agency "signs off" on the project. Once this is done, warranties, guarantees and promises not withstanding, the contractor often has lost considerable interest in solving any problems, since the final acceptance usually releases a 5 to 20% "retainage" of the total project monies. This is why it is very important that the institution recognize this event in the project timeline. When the construction contract is written, it is a good idea to specify the grounds for withholding of final acceptance (final payment), preferably including satisfactory operation of all systems for the specified stable performance test period. When the library or archives is part of a larger institution or local government, beware of standard contracting procedures where someone not directly concerned with the performance of the project may quickly sign off on final acceptance before thorough testing.

4. Systems Documentation

At the completion of construction the institution is usually left with copies of the shop drawings and a set of service manuals or operating instructions for all equipment on the project. These are usually just a compilation of manufacturer's information on the pieces of equipment installed, insufficient for satisfactory building operation. These are almost always lost, misplaced or never forwarded to the institution.

Not only should all contractor submittals be carefully gathered and maintained, but the institution may also wish to require the design team to prepare additional systems documentation These can include day-to-day detailed technical operating instructions and manuals on the HVAC systems, and as-built drawings to document what was built (rather than the design drawings which only show what was intended to be built).

5. Training Of Operations Staff

The institution's operating staff should be thoroughly trained in the operation of the new building systems. This should include training by the contractors and suppliers of equipment, as well as the design team, although the latter is rare. In the case of a smaller institution where contract maintenance will be used, the institution should gather as much written information as possible on operation of the systems for future reference, even if the maintenance organization says they have it already or do not need it.

IV. OCCUPANCY

This very important stage is often not addressed in most project planning, except for simple move-in. The following steps are suggested, in order, for occupancy of a new conservation environment. As noted, some of these may overlap with other final construction activities, and some may not.

1. Move Into Non-Collection Spaces

When otherwise appropriate, the non-collection spaces may be occupied. These are usually the offices and non-collection support spaces.

The institution should consult with legal council to check if a partial move-in can be considered to be "beneficial occupancy," and how it might compromise the institution's ability to compel the contractor to fulfill any obligations relating to the other aspects of occupancy outlined below. This and other aspects of the occupancy process may need to be clearly specified in the construction contract.

2. Purging Of Collection Spaces

New materials and finishes may give off gaseous chemicals (off-gas) for an extended period of time, and paints and other coatings may give off gases as the cure. Although often not done, the collection spaces should be purged for construction off-gassing, construction particulates and construction moisture. This may be done in conjunction with a stable performance test period, but must be done after *all* construction is completed. All environmental surfaces of the collection spaces should be washed or mopped, not just dusted or brushed.

Conservatively, once the "new" smell disappears when you first walk in each morning, the space is safe.

3. Orientation And Training Of Professional Staff

Apart from any operating staff, the institution's professional staff, librarians, archivists, curators, conservators and such, should be trained in the basic operation of the new environment. This would typically be an extra service for an extra fee, and might include what not to touch, where sprinkler cut-off valves are, how environmental alarms are signaled, what adjustments can be made directly or by others, and how the system can be expected to operate. The last is very important since having expectations consistent with performance is critical to overall success.

4. Test Period And Trouble Shooting Of Environmental Irrregularities Or "Events"

During purging and a stable performance test period, constant attention should be given to identifying and correcting any problems with the environment. As the hygrothermograph shows any off-normal conditions, the exact time should be noted in an "events log" and the contractor and/or commissioning engineer should clearly explain what caused the event. Unexplained events should not be accepted, since they may recur later when it is harder to bring attention to bear on the problem.

5.	**Preparation Of Collection Spaces**	Before the collection is moved in, the collection spaces should be prepared. All HVAC equipment should be checked; all shelves and other furnishings should be installed. There should be no activities remaining that might put the collection at risk.
6.	**Move Into Collection Spaces**	After the institution is convinced that the new environment is the one expected--that it will not harm the collection, either from acute system failures, or an unstable environment--the collection can be moved in. (The late move-in for the collection applies to small and large projects alike. Some of the most regrettable and needless damage to collections has come from a premature move into an unstable or incomplete space. In some instances, the collection has been used by construction crews as props and sawhorses to support construction of the final finishes.)
V.	OPERATION AND MAINTENANCE	Based on the training and information provided by the contractors, equipment manufacturers, and design team, it is a good idea to set up a regular preventive maintenance program. This should include regular filter inspections and changes, regular lubrications, pre-season checkouts of boilers, chillers, humidifiers and other important equipment, and other recommended procedures. A weekly and/or monthly checklist can be prepared for follow up on these important tasks. For further information on the design and construction process for libraries consult Reference 11.

Appendix 1

SUMMARY OF ABBREVIATIONS

The following abbreviations are used in this document, and may also be found in common usage in the building industry.

APA - American Plywood Association
ASHRAE - American Society of Heating, Refrigerating and Air Conditioning Engineers
DDC - Direct Digital Control (for HVAC)
°F - Degrees Fahrenheit
DX - direct-expansion (cooling)
EPA - Environmental Protection Agency
HID - High Intensity Discharge (lamp)
HPS - High Pressure Sodium (lamp)
HVAC - Heating, Ventilating and Air Conditioning
IR - Infrared (light)
LPS - Low Pressure Sodium (lamp)
NO_x - Oxides of nitrogen
O_3 - Ozone
OSHA - Occupational Safety and Health Administration
PEL - Permissible Exposure Level
ppb - Parts Per Billion
RH - Relative Humidity
SO_2 - Sulfur dioxide
TVL - Threshold Value Level
UV - Ultraviolet (light)
$\mu g/m^3$ - Micrograms per Cubic Meter
$\mu W/L$ - Microwatts per Lumen (UV content of light)
VOC - Volatile Organic Compound

For further information on specific terms consult the following lexicon and the index.

Appendix 2

LEXICON OF DESIGN AND CONSTRUCTION TERMS

The following design and construction terms and abbreviations may arise in discussions concerning design, construction or building systems. Their definitions are offered below for edification of non-construction professionals.

Addendum (or Bid Bulletin) - information or changes to a project currently out for bids, issued by the building owner or his representative before final bids are accepted, to reflect a change in the project design.

As-Built Drawings - drawings prepared after construction is completed, showing the building and building systems as they have been built, since this is always different from the building as represented in the design drawings.

ASHRAE - American Society of Heating, Refrigerating and Air Conditioning Engineers, the primary professional society for HVAC engineers.

Balancing - usually the measurement and adjustment of the actual flows against the intended design flows in an HVAC distribution system, such as balancing the air flow in ducts or water flow in pipes.

Bid Bulletin - see Addendum.

Bid Set - the documents, usually the construction documents or "working drawings and specifications," which are issued for bids from contractors.

Building Envelope - generally, the exterior walls, windows and roof of a building; "weather envelope" is the outside of the building envelope which resists weather.

Built Environment - an architectural buzz word meaning the building and building systems, used to differentiate the structure creating the building environment from the natural outside environment.

Bulb - the glass or quartz envelope of a lamp that surrounds the filament or gas, and is fastened to the lamp base. See lamp.

CFM - cubic feet per minute, a common measure of air flow quantity.

Chase - vertical spaces in a building for ducts, pipes and wiring.

Chilled Water - water at around 42 to 55°F, circulated in a building to provide cooling. Chilled water must usually be at 42 to 44°F to provide effective dehumidification.

Chiller - a piece of equipment which usually chills water, which is then used to cool the inside of a building; heat is rejected by either an exterior condenser, or through the use of condenser water. Most chillers, such as reciprocating, centrifugal and screw chillers, create their cooling effect through vapor compression (see compressor); some are absorption chillers, which create a cooling effect through the use of a heat source, such as steam, hot water or hot gas.

Compressor - 1) the part of the cooling system which compresses the refrigerant to allow it to move heat from the evaporator to the condenser; 2) the part of the pneumatic control system for HVAC systems which provides the compressed air for pneumatic operation.

Conceptual or Preliminary Design - a design stage which describes the concepts and general layout of how the design will meet the program needs. Comes after the "program" and before "schematics," usually merged with schematics.

Condensate - the result of a vapor condensing to a liquid; this is either the result of steam giving up its heat (such as in a radiator or heating coil), or the result of humid air blowing past a cooling coil which causes some of the air's moisture to condense on the coil as condensate.

Condensate Drain - piping which allows cooling coil condensate (the result of dehumidification) to safely drain to sanitary or storm drains, or to simply be discharged to the outside.

Condensate Return - piping which returns steam condensate to the boiler for reheating back to steam.

Condenser - the part of a cooling system which rejects heat, usually to the outside.

Condenser Water - water which is used to reject heat from a cooling system; it is usually pumped to a cooling tower where it is cooled.

Constant Volume Reheat System - an HVAC system in which all environmental control zones are served by a single common cool air duct from a central air handling system, and each zone is tempered by variable heating of the air as it is delivered to each zone; requires a hot water, steam or electric "reheat box" for each zone.

Construction Documents - the drawings and specifications describing the detailed design of a project suitable for use in executing construction. Follows "design development" and precedes "bidding."

Convectors - HVAC terminal equipment which heats a space by inducing convective air flows around its heating elements.

CSI - Construction Specification Institute, a professional society which has organized construction specifications into a standard numbered system.

DDC - Direct Digital Control, in which microcomputers directly control environmental systems; may also work to articulate and supervise other control systems, such as pneumatic or electric.

De-Lamping - removing lamps from light fixtures to reduce light levels and energy consumption; usually done to multiple-lamp fluorescent fixtures.

Desiccant - a chemical compound which tends to attract and hold moisture from surrounding moister air, and liberate moisture in the presence of dryer air.

Design Development - the stage in project design in which the full substance of the goals of a design is demonstrated but the details required for construction have yet to be developed. Follows "schematics" and precedes "construction documents."

Design Drawings - drawings of the intended design, as opposed to as-built drawings.

Destratification - reducing the natural tendency of air in a tall space to stratify into hot and cold layers, with hot at the top.

Dew-Point - the temperature at which water vapor in air at a given moisture content and pressure will reach saturation (100% RH) and condense.

Diffusers - HVAC terminal equipment which introduces air into a space with the purpose of mixing or diffusing the air into the space without blowing it directly on people or objects.

Dry-Bulb Temperature - the temperature sensed by a typical thermometer, as opposed to wet-bulb.

Dual-Duct System - an HVAC system in which a central air handling system provides a set of common hot and cold ducts to serve the environmental control zones, in which a zone is tempered by introducing a variable mixture of warm and cool air from the ducts, requiring a "mixing box" for each zone.

DX - "Direct Expansion" cooling system, similar to a residential air conditioner, in which refrigerant is used to cool the air, and then reject the heat directly to the outside air; an intervening liquid is not used for cooling.

Economizer - a device which provides cooling by using cool outside air. Air-side economizers do this by bringing in large amounts of cool outside air; water-side economizers do this by exposing building cooling water to cool outside air.

Electric Controls - an HVAC control system which uses low-voltage wiring and components, usually simple switches and relays or silicon-controlled rectifiers (SCRs), to control equipment operation.

Electronic Controls - an HVAC control system which uses low-voltage wiring and components, usually semiconductors, integrated circuits and SCRs, to control equipment operation.

Enthalpy - total heat content of air; the sum of sensible and latent heat.

Envelope - see Building Envelope.

Evaporator - the part of the cooling system which absorbs heat and provides cooling; usually a coil which has air blown across it.

Exfiltration - air which escapes from a conditioned space to the outside, usually through small cracks and openings in the building envelope.

Fan-Coil Unit - a type of HVAC terminal device, usually part of a "two-pipe" or "four-pipe" HVAC system, in which each environmental control zone has a fan coil unit which circulates the zone air over one or two water coils which can provide heating or cooling, and in which the water is heated or cooled by a central boiler or chiller.

Feet-Per-Minute or "FPM" - a common measure of air flow velocity.

Footcandle - the density of light striking an object; an english system measure of illuminance at a point on a surface, equivalent to about 11 lux; the result of one lumen striking one square foot.

Halon - a chemical gas compound used to extinguish fires by chemically suppressing the combustion process so long as an adequate concentration of the gas remains. Halon 1301 is the gas used in typical "Halon systems" and is nontoxic at usual working concentrations; Halon 1211 is a more toxic type of Halon used in hand-held fire extinguishers. Halon is a trademark for fluorohalocarbons manufactured under license by Allied Chemical, but is in general usage as a generic term.

Heat Pump - a reversible mechanical refrigeration device which can switch evaporator and condenser functions at will, allowing the device to do either heating or cooling.

Hot Water - water circulated in a building to provide heating.

Humidistat - a control "thermostat" which senses relative humidity instead of temperature.

HVAC - heating, ventilating and air conditioning.

Hydronic - the use of circulating piped water for tempering, usually in reference to hot water "hydronic" heating systems.

Hygrometer - an instrument for measuring relative humidity, usually using a human or animal hair to sense relative humidity levels. Most dial hygrometers have limited accuracy even when new and are rarely meaningful for environmental monitoring, since they are so inaccurate. Electronic hygrometers are more accurate.

Hygrothermograph - an instrument for continuously measuring and recording humidity (hygro-) and temperature (-thermo-) on a chart (-graph), usually using a hair hygrometer and bi-metallic strip thermometer which each cause ink pens to move on a paper chart. The chart is usually cylindrical or circular, rotating once each day, week or month.

IES - Illuminating Engineering Society, the primary professional society for lighting designers and engineers.

Infiltration - air which enters a conditioned space from the outside, usually through small cracks and openings in the building envelope.

Interstitial Space - literally the space between two other things, usually interstitial space in construction refers to the space between a dropped ceiling and the floor structure above.

Lamp - the removable part of a light fixture that generates the light, often referred to as the "light bulb" by the layman; in building design and construction "lamp" does not mean the fixture. (If you get a copy of a manufacturer's "large lamp catalog" you will find nothing in it but "light bulbs.") Also see bulb.

Latent Heat - heat associated with a change in moisture content of the air, as opposed to sensible heat. It is heat that is there thermodynamically but is "latent" or not measurable by a simple dry-bulb thermometer.

Louvers - the opening of a duct or plenum, usually to the outside for bringing air into, or discharging air from a building.

Lumen - a measure of the amount of luminous flux or light energy, such as the light output of a lamp.

Lux - the density of light striking an object; a metric system measure of illuminance at a point on a surface, equivalent to about 0.09 footcandle; the result of one lumen striking one square meter.

Makeup Air - air provided to a space or system to make up for air lost through exhaust or leakage.

Makeup Water - water provided to a system to make up for water lost in the system's operation, such as a humidifier or boiler.

Multi-Zone System - an HVAC system in which each environmental control zone is served by its own duct from a common central air handling system, in which cool or warm air is provided in the appropriate duct to temper each zone.

Outside Air - air drawn from the outside environment for use in an HVAC system, usually to replace air that is exhausted, to pressurize a space, or to dilute contaminants. In many library and archive applications, the outside air may actually be a source of contamination, such as particulates and gaseous pollution, and may contribute to unstable humidity in the conditioned space.

Plenum - in HVAC, a space used to collect or distribute air among many different spaces or ducts, effectively a very large duct; often the interstitial space between a dropped ceiling and the floor structure above.

Pneumatic Controls - an HVAC control system which uses a network of small tubing with modulated air pressures to control equipment; one of the oldest control systems.

Potassium Permanganate - $KMnO_4$, a chemical compound used to remove impurities through oxidation.

Principal Design Features or "PDF" - a stage in government design projects, usually between schematics and design development, in which a project design is evaluated to consider if the project should proceed.

Program - the narrative description of the purpose, concepts and goals for a construction project, prepared before design begins.

Psychrometer - an instrument for measuring relative humidity, usually consisting of two thermometers, one of which is covered with a wetted cotton wick, where wet-bulb and dry-bulb readings are made after air is forced over the two thermometers. The concurrent wet-bulb and dry-bulb readings indicate the relative humidity. A "sling psychrometer" forces air over the thermometers by swinging it for several minutes in a circular fashion in the air. An "aspirating psychrometer" usually has a small battery-operated fan to blow the air over the thermometers.

Psychrometrics - the particular properties of air relating to heat, temperature and moisture content; most commonly estimated graphically with a psychrometric chart.

Refrigerant - a chemical compound which is compressed and then allowed to expand to move heat from one place to another, usually a chlorofluorocarbon, such as one of the Freon compounds made by DuPont.

Rehydrate - adding moisture back into a hygroscopic material, such as the human hairs in a hygrothermograph. This usually involves sealing the equipment in a moist container for a day or so - for further information consult the equipment manufacturer. Most human-hair hygrothermograph equipment, which is the typical type of equipment used, must be rehydrated on a regular basis, at least annually.

Relative Humidity - the relative amount of moisture in air expressed as a percentage of the total amount of moisture the air can hold, varies with the temperature and pressure of air.

Retainage - an amount of the construction contract amount, usually 5 to 20% of the total project monies, which is retained by the owner until final acceptance of the construction by the owner.

Retrofit - adding, modifying or correcting an existing part of a building or building system; going back (retro-) and putting something in (-fit); as opposed to "renovation" which usually is a removal and replacement, again (re-) making new (-novation).

Return Air - air drawn from a space or zone and returned to the air-handling system, usually used as supply air after it is filtered, tempered, and mixed with fresh air.

Risers - vertical distribution elements of a building system, such as a piping riser to feed water, or a duct riser to feed tempered air up through a building.

Runouts - lateral or "to point of use" distribution elements of a building system, such as piping runouts to feed water to the point of use, or duct runouts to feed air to diffusers.

Schematics - drawings which indicate the general scheme of a design, demonstrating basic layout and feasibility, but without details or full development of the design. Usually follows the "program" or "concept/preliminary" stage, and precedes the "design development" stage.

Sensible Heat - heat that causes the air to change its temperature, as opposed to latent heat. Has nothing to do with the common usage of "sensible" as "rational;" rather it is heat that can be "sensed" by a simple dry-bulb thermometer.

Sepias - full-size transparent copies of drawings which can be used to generate other full-size copies.

Setpoints - the specific temperature or relative humidity settings in an HVAC control system.

Single-Zone System - an HVAC system in which each environmental control zone is served by its own air handling system which provides cool or warm air as needed to its zone.

Split System - a DX cooling system in which the compressor and condenser are usually located outside, and the refrigerant cooling coil and fan are located inside.

Steam System - steam distributed in a building to provide heating.

Supply Air - air delivered to a space or zone to control conditions within, usually treated and tempered.

Terminal Equipment - the part of an HVAC system which is used to serve a temperature control zone, including diffusers, boxes, convectors, radiators and fan-coil units.

Vapor Barrier - a material, usually 6-mil polyethylene sheeting, used to prevent the flow of air and water vapor, usually to prevent it from reaching a cold surface where it might reach dew-point and condense.

VAV - Variable Air Volume system. Environmental control zones are served by a common duct system providing cool air, in which each zone is tempered by introducing a varied volume of cool air from the system; requires a "VAV box" for each zone.

Ventilating - usually, providing outside air to a space to carry away heat or to dilute contaminants.

VOCs - volatile organic compounds, including formaldehyde. Usually associated with discussions of off-gassing.

Water Source Heat Pump System - an HVAC system in which the environmental control zones are served by a circulating loop of water, and each zone has its own heat pump (consisting of a compressor, evaporator, condenser, circulating fan, filter and controls) which can heat or cool the zone by running the heat pump compressor to either cool the air and heat the water loop, or heat the air and cool the water loop.

Wet-Bulb Temperature - the temperature read by a thermometer whose sensing bulb is covered with a wetted wick and exposed to the evaporative cooling effect of moving air. The reading, compared to an unwetted dry-bulb, indicates the amount of moisture in the air, since that affects how much the water can evaporate from the wet-bulb.

Working Drawings - see Construction Documents.

Zone, Environmental Control - the space or group of spaces within a building with separate capabilities for tempering and humidity control, which are served by the HVAC system; usually each zone has its own thermostat and humidistat.

Appendix 3

REFERENCES AND SUGGESTED READINGS

The following publications are referred to in the body of this document, or are otherwise of interest in learning more about conservation environments for libraries and archives.

1. "Air Quality Criteria for Storage of Paper-Based Archival Records," National Bureau of Standards, 1983, NBSIR 83-2795. Criteria for paper and system recommendations, developed by consensus of a select panel of consultants during intensive workshops at NBS in 1983.

2. *The Museum Environment*, by Garry Thomson, second edition, Butterworths, 1986. Written from the museum perspective with good guidelines. Little advice on the details of equipment, applications, on project management or on how to get things done. Some advice on HVAC, particularly "VAV" systems, will get you into trouble. About $60.

3. *Preservation of Historical Records*, National Academy Press, 1986. The recommendations are based on a moderation of NBSIR 83-2795 (Reference 1), and are the basis for the environmental standards for the new National Archives Building.

4. "American National Standard for Photography (Film)--Storage of Processed Safety Film," ANSI Standard PH1.43-1985, American National Standards Institute, Inc., 1439 Broadway, New York, NY 10018.

5. "Environmental Controls for Local Government Records," by Patricia A. Morris, PhD., NICLOG *Technical Leaflet 111*, American Association for State and Local History, 1989. This has some excellent discussion of environmental monitoring programs and equipment, collections storage and management, and effective procedures to follow in working with staff. Some of the final conclusions on criteria and HVAC equipment discussions and recommendations may be inconsistent and at times misleading or ill-advised.

6. "Volatile Amines Used as Corrosion Inhibitors in Museum Humidification Systems," Paula Volent and Norbert S. Baer, Conservation Center, Institute of Fine Arts, New York University; submitted to *The International Journal of Museum Management and Curatorship*, 6 July 1985.

7. *Environmental Systems Technology*, by W. David Bevirt, National Environmental Balancing Bureau (NEBB), 1985. Of the several books on HVAC systems, this is the only one we know of that provides both meaningful theory and application information, with the added benefit of historical discussions as a preface to each chapter. It is written not only for new system design but for evaluation of existing systems. It does have some gaps, and may provide more information than you need in other areas, but is better balanced than many others. Recently priced at $78 for 768 pages.

8. *The ABC's of Air Conditioning*, Carrier Corporation. Pages 1 to 17, 23 & 24. This is a good introduction to HVAC concepts.

9. *The Armstrong Humidification Handbook*, Bulletin HB-500-C, Armstrong Machine Works. Pages 1 to 11. Good concepts and recommendations for reliable humidification.

10. *The Dehumidification Handbook*, Cargocaire Engineering Corporation. Pages 4 to 13. Good concepts but much is skewed toward their own desiccant systems which are uncommon in typical building applications, require higher maintenance, and are usually only used when trying to hold low humidities at low temperatures.

11. *Planning Academic and Research Library Buildings*, originally by Keyes D. Metcalf in 1965, second edition by Leighton and Weber, American Library Association, 1986. Although this book is focused on libraries, the discussions of the planning process are helpful on any project. The book is not organized as a reference so it must be read from cover to cover. The discussion of lighting is good but lengthy; the discussion of HVAC is well-intentioned but misleading, and fortunately is relatively short. The first edition by Metcalf may actually be better than the recently revised second edition.

12. "Lighting for Storage of Museum Collections: Developing a System for Safekeeping of Light-Sensitive Materials," by William P. Lull and Linda E. Merk, *Technology and Conservation*, Summer 1982. Same source discussions as article above, but addresses storage lighting with indirect high-pressure sodium lighting.

13. "Preservation Aspects of Display Lighting," by William P. Lull and Linda E. Merk, *Electrical Consultant*, November/December 1982. Discussion of the concepts of lighting sources, systems and treatments. Suggested sources, wattage and mounting distances are given.

14. *IES Lighting Handbook*, Illuminating Engineering Society of North America, updated bianually. This is the authoritative handbook on lighting, although it is intended for the lighting designer and engineer. Nonetheless, information it offers on isolated topics is often quite useful.

15. *Lighting Manual*, N.V. Philips' *Gloeilampenfabrieken*, Third Edition, 1981. A basic and practical manual from the Philips lamp manufacturer for lighting and lighting applications, although it uses the metric system. Many discussions are disjointed, and some topics are inadequately covered. However, it is often handier to use and more practical than the IES Lighting Handbook.

16. "Protecting the Library from Fire," by John Morris, *Library Trends*, Vol 33, No. 1, Summer 1984 (and Fire Journal, March 1986). An excellent discussion of past fires, fire protection systems, and risk.

17. "Fire Fighters," by J. Andrew Wilson, *Museum News*, November/December 1989. An authoritative discussion of fire protection systems by the Smithsonian's chief of fire protection.

Appendix 4

SELECTING MANUFACTURERS

Carefully identify and evaluate manufacturers of environmental control equipment for conservation environments. Leads to manufacturers can come from professional contacts, and industry registers, such as the *Thomas Register* (Thomas Regional Directory Co.) and the *Sweets' File* (McGraw-Hill). Periodicals are also good sources, particularly *ASHRAE Journal*, and the IES's *Lighting Design and Application*. Each of these is more or less intended for use by those in the industry, and using them efficiently may not be as easy as one might like.

Look in product literature for a manufacturer's formal expressed interest in meeting the special needs for archives and library environments; do not go just by verbal or unpublished written information provided by a dealer or local representative. Concepts and performance should preferably be published in established and juried professional periodicals, such as *ASHRAE Journal*.

Reputable manufacturers should exhibit at established engineering trade shows, such as the national ASHRAE/ARI show held each winter, and may also exhibit at library, archives or conservation group meetings. The manufacturer should participate in the technical work of professional societies, such as ASHRAE and IES, and should follow established standards for testing their equipment's performance.

Go by reproducible tests of performance rather than endorsements. Testimonials only have merit if they are for your same application, and if the source can be contacted and the endorsement confirmed.

Equipment intended to solve the problems of temperature and humidity in computer rooms may suit conservation needs, but may not. While these systems focus on stable humidity and temperature, they may expect high sensible (dry-only) cooling loads, with little attention to latent (wet, dehumidification) loads, heating or adequate filtration.

Some manufacturers may offer special or unique products that deserve special consideration, but beware of systems which are unusual and which will require specially-trained maintenance or hard-to-find parts. Try to select equipment that uses conventional components in innovative ways, allowing use of established maintenance techniques and parts.

Environmental control equipment is usually sold, installed and serviced by a local dealer who may do a good job or be completely incompetent. The manufacturer may not know or may not be candid with you as to how good a job the equipment or dealer will do.

Finally, be sure to ask for a list of satisfied customers with projects *similar to yours in goals and budget*, with specific names and phone numbers. Call at least three people on the list and confirm the quality of the product and service. Sometimes the dealer or manufacturer will give you a list of "unsatisfied" customers, betting you will not contact them.

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