IV. Preservation Issues

9 The Preservation Environment

Paul Conway

> The perpetuation of society as we are accustomed to conceive or idealize it is dependent to a very large extent on the preservation en masse of our accumulated group memories and consciousness stored in the form of the printed and otherwise recorded word or symbol.[1]

A preservation environment is the most cost-effective collection management tool that librarians and archivists have for extending the collective life expectancy of their vast scholarly resources. The preservation environment built in a modern library shelving facility embodies a conscious commitment to preservation and distinguishes such a building from a book warehouse, a book attic, or a typical full-service library. The concept of a "preservation environment" is a complex one that has emerged over nearly a century of concern over deteriorating library collections, several key conceptual breakthroughs in the past 40 years, and focused research in materials science. This chapter reviews how the idea of the library building as a preservation facility has changed over time, how materials science has contributed to the definition of a preservation environment, and how architects, engineers, and librarians designed the Yale University Library Shelving Facility to maximize the building's preservation value. The chapter concludes by identifying one lingering preservation issue that requires further research.

The Library Building as a Preservation Tool

The principal preservation goal in building a high-efficiency, high-density library shelving facility is to extend the useful life of the paper-based and film-based materials held there in comparison to a typically air-conditioned (or, worse, unconditioned) library shelving space. Library collections consist of different types of objects with widely varying rates of deterioration. Books, manuscripts, maps, photographs, films, and magnetic tapes will all last longer when kept in a preservation environment. The concept of "environment" encompasses common factors such as temperature, relative humidity (RH), light, and pollution as well as vibration, exposure to animal pests, insects, bacterial and fungus, and other more exotic agents of destruction. The preservation environment includes security and protection from fire and water damage. A preservation environment is lower in temperature, drier and more stable; is darker; is better sealed; has air freer of particulate matter (dust and dirt) and gaseous contamination; and is more secure than typical library buildings.

Deterioration is in the nature of things, and yet the attempt to cheat death is a part of our human nature. Some 30 years ago, Edwin Williams summed up in one sentence the challenge and the responsibility of library preservation. "Everything in library collections is deteriorating today, was deteriorating yesterday, and will continue to deteriorate tomorrow although we ought to retard the process."[2] This challenge has been with us for some time and it has been common knowledge for at least 175 years that the materials we use to record textual and visual information in published and unpublished form are fugitive and fragile. The problem for libraries and archives, however, is that awareness of a problem and the identification of causes and remedies—most pointedly in the value of the preservation environment—is a relatively recent phenomenon.

Both basic science and actual experience agree that temperature and relative humidity are the primary rate-controlling factors in chemical decay, mechanical damage, and bio-deterioration. All organic materials in collections deteriorate because of chemical reactions that speed up or slow down in response to environmental conditions. Two decades of rigorous laboratory testing have established predictive models of deterioration for materials commonly found in libraries, archives, and museums. These models, which are like maps that relate storage temperature, storage RH, and time-required-for-a-given-amount-and-kind-of-deterioration, show just how long even inherently unstable materials can last under the right storage conditions. They also show the converse—that the wrong environment can doom collections to very short lifetimes.

In the past five years, in particular, corroborative evidence from several laboratories working independently gives library managers new confidence in specifying environmental set points for shelving facilities. These set points are generally 10° cooler and up to 20 percentage points drier than specifications promulgated as recently as 10 years ago. We have a lot to learn about chemical and physical deterioration inside containers (such as a box, bag, or the book itself). We also need to understand more fully the impact of "microenvironments," such as the narrow air spaces surrounding shelved materials. Scientific testing of adhesives and other materials used to construct modern books also leaves too much room for interpretation.

Awareness of Preservation Problems and Solutions

Library materials are by and large organic in character. Deterioration of organic materials—paper, leather, and glue—is a fact of life; as inevitable as the sunrise but nowhere near as predictable. Paper is an amazing substance—strong and flexible when new, friendly to readers, and capable of holding in fixed form printed and handwritten words and images produced with nearly innumerable tools and techniques. Paper and the publishing revolution go hand in hand. Unfortunately, modern machine-made paper and the preservation challenges in libraries and archives are also inextricably linked.

People have been aware for millennia that the materials we use to record facts and ideas deteriorate to the point where they cannot be used for their intended purposes. The *New Testament* (Matt. 6:19) admonishes its readers: "Do not store up for yourselves treasure on earth, where it grows rusty and moth-eaten, and thieves break in to steal it." Book and paper historians report on age-old stories of prohibitions on the use of paper in deeds and manuscripts because of fears it was far more perishable than vellum (Grove, 1964). As early as 1823, alarms sounded in the Western press about the poor quality of writing and printing papers. By the early years of the 20th century, concern for the fragility of modern, machine-made papers reached a state of such frenzy that a search for stable copying methods began in earnest. This search culminated in the development of early standards for paper manufacture and the pursuit of archival microfilm, which remains the preservation strategy of choice when deterioration has undermined the physical integrity of books and papers (Higginbotham, 1990).

Beginning early in the decade of the 1960s, pieces of the preservation puzzle began to fall into place. The puzzle's image portrays the crucial role of environmental forces in exacerbating the deterioration process whose origins are clearly founded in the manufacture of paper, film, and other organic media. And yet the scale of the preservation challenge in research libraries, government cultural institutions, and archival repositories throughout the world, when combined with the significant costs of treatment and copying solutions, preclude addressing comprehensively preservation needs on an item-by-item basis. The recognition of this fact in the latter half of the 20th century has led to consistent and successful efforts to find a collection-based approach to preservation that stands half a chance of buying time for systematic preservation treatment if not solving the preservation problem altogether.

Materials Science and the Scientific Method

A preservation environment has comprehensive impact. All library materials shelved in a preservation environment benefit from increased life expectancy. This is true regardless of the quality of the materials when first manufactured or the condition of the materials when they are placed in the preservation environment. The specification of a preservation environment is based on contemporary understanding of materials science.

Paper and other organic materials deteriorate for a variety of reasons, some of which are related to the source of the material or the way it was manufactured and some of which are related to the way the material is stored or handled. At its most comprehensive, scientific research in materials science considers chemical factors (light, temperature, humidity), biologically induced degradation, and physically induced loss of strength that comes from handling and use. Path breaking materials science and the power of trial and error have fine-tuned the specifics of a preservation environment. The following are the major elements at play in a high-density, high-efficiency shelving facility.

Elements of an Ideal Environment

a) Pollutant-free air
b) Total darkness
c) Constant temperature
d) Constant relative humidity
e) Vibration-free structure and protection against shock and sound waves
f) Absence of all organisms (including humans)
g) A site on high land and a fireproof structure
h) Elaborate emergency back-up control systems
i) Cooperation of the Almighty

Source: Duncan Cameron, "Environmental Control: A theoretical Solution," *Museum News* 46 (May 1968): 17.

Damage from Light

Among the suite of agents that cause deterioration, sunlight accounts for the most widespread destruction of materials outdoors. Sunlight, or solar radiation, and certain sources of artificial light are important in photochemical and photosensitized reactions because they are the sources of the radiant energy that make the reactions possible. Short wavelength radiation, especially ultraviolet rays, are far more damaging to library materials than either visible light or the longer wavelengths of infrared rays, radio waves and the radiation from high-voltage power lines. Light damage is cumulative; the amount of damage depends upon wavelength and the length and intensity of exposure. Brief exposure under relatively high intensity can be just as damaging as extended exposure to low intensity. Chemical reactions initiated by exposure to light continue even after the light source is removed and materials are put into dark storage (Ritzenthaler, 1993).

Indoors, damage from light is most troublesome on external surfaces such as the spine bindings of books and containers for archives and manuscripts collections. Light speeds up the oxidation of paper and therefore its chemical breakdown. Photo-oxidation of cellulose is accelerated by the presence of pollutants such as sulfur dioxide and nitrogen dioxide. Light is also a bleaching agent; it can cause some papers to whiten and can cause colored papers and inks to fade. Upon exposure to light, lignin reacts with other compounds in paper, causing lignin-containing paper to darken. Newspapers left outdoors for even a day or two provide graphic evidence of this effect.

Researchers discovered the negative consequences of light on library materials well before they zeroed in on other, even more damaging external sources of damage. Technical reports published in 1936 and 1941 pinpointed the damaging power of short wavelength radiation, especially ultraviolet (UV) radiation. Research by the National Bureau of Standards culminated in the extraordinary measures taken by the National Archives to protect the Declaration of Independence while on public display (Calmes, 1988).

By the late 1950s, architects of library buildings began to emphasize the need to build stack spaces without windows and to equip them with light fixtures that filter UV light. The first truly modern library storage facility, designed by Paul Banks and built as an extension to Chicago's Newberry Library, was a windowless cube with a darkened interior lit only to retrieve volumes. The latest thinking on lighting in shelving spaces that will not be browsed by the general public emphasizes limited duration lighting, low-intensity light sufficient to retrieve items, and the use of lighting systems that emit little or no ultraviolet rays. High-pressure sodium lamps, for example, cast a yellow light, but can be used where color rendering is not important. Sodium lights are highly efficient, are low in heat generation and operating costs, and relight quickly after being shut off (Lull & Merk, 1982).

Temperature and Humidity in Theory and Practice

Temperature and relative humidity are inextricably linked in a preservation environment. One of the best ways to grasp the significance of this linkage is by way of the "Isoperm Theory," developed by Don Sebera of the Library of Congress and refined for film and other organic materials by James Reilly of the Image Permanence Institute. The Isoperm Theory is based on a simple idea: the rate of deterioration of water-absorbing materials such as paper is influenced strongly (perhaps even controlled) by the temperature and relative humidity of its surrounding environment. Paper and other organic materials commonly found in libraries, archives, and museums will lose strength with increased temperature and moisture content. Conversely, lowering either or both temperature and moisture content reduces the rate of chemical deterioration and so increases life expectancy. The Isoperm Theory combines and quantifies the preservation effects of temperature and relative humidity and presents the results in a comprehensible graphical form.

An isoperm is a graphical plot of the influence of temperature and relative humidity equilibrium on paper permanence. Underlying the theory is the assumption that temperature and relative humidity act together to speed up or slow down chemical deterioration to more or less the same degree in most organic materials. Figure 1 is a graph of isoperms from Sebera's seminal publication. The predictive power of the graph derives from varying one of the set points (temperature or relative humidity) while leaving the other set point constant. For example, by starting with environmental conditions at 68 degrees temperature and 50 percent relative humidity and then lowering the humidity level to 30 percent, the life expectancy of a collection is increased by a factor of two beyond what it would be if stored at the higher humidity setting. By raising the temperature from 68 to 80 degrees, the life expectancy of the collection decreases by a factor of three. Varying both set points simultaneously can have an even more dramatic impact on collection life expectancy.

Definition of an Isoperm

A line of constant permanence (isopermanence). Consider a paper at equilibrium with some initial considerations of temperature and relative humidity that determine its rate of deterioration and permanence. Now let us increase the relative humidity to a higher value; if the temperature is unchanged, the rate of deterioration will increase. However, if we reduce the temperature by exactly the right amount, the resulting temperature induced rate decrease will exactly compensate for the relative humidity induced increase so the overall deterioration rate (and permanence) is unchanged from that at the initial environmental conditions. We can make another change in relative humidity (or temperature), and another temperature (or relative humidity) can be found that will exactly compensate for the new relative humidity (or temperature) induced permanence change. These paired values, when plotted on a graph of T and %RH as axes, generate a line.

Source: Donald K. Sebera, *Isoperms: An Environmental Management Tool* (Washington, D.C.: Commission on Preservation and Access, 1994), 4.

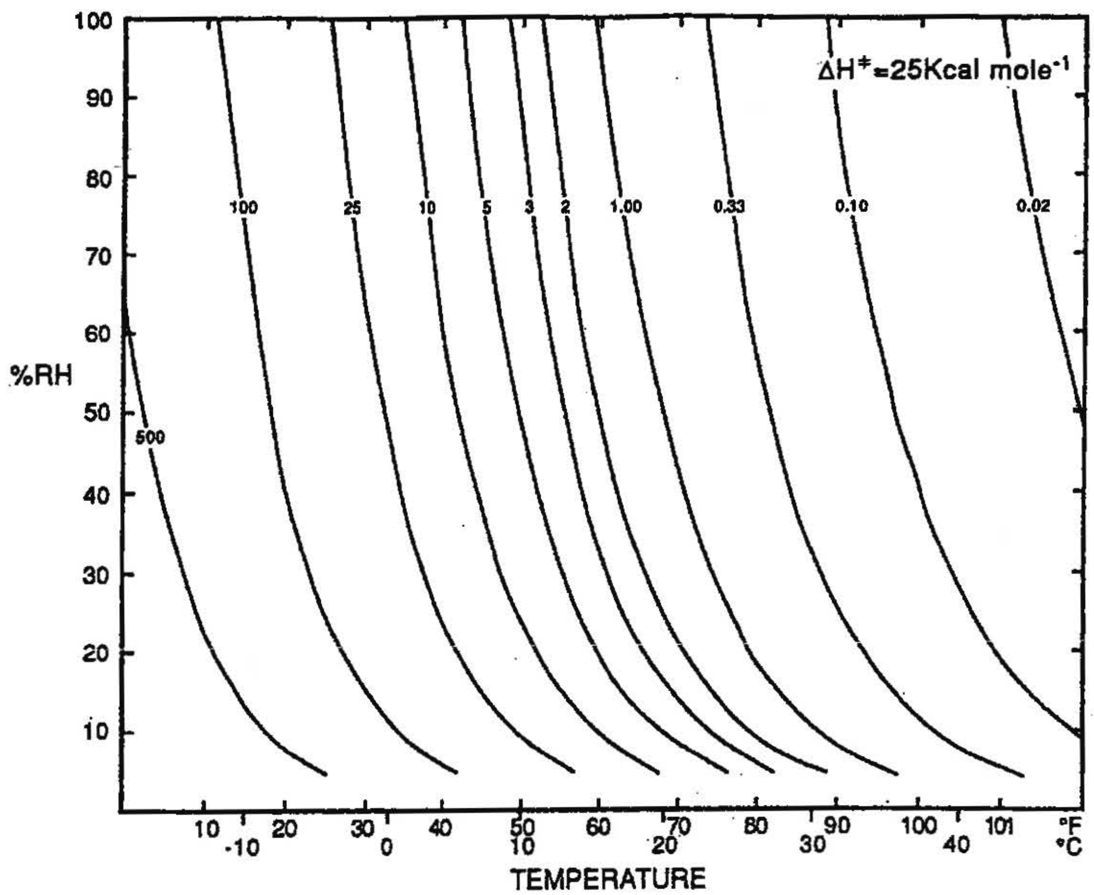

Figure 1. Isoperm Diagram Showing Percent Relative Humidity Versus Temperature

For some, the most confusing aspect of Sebera's Isoperm Theory is that his method is a view of the relative rather than the absolute rate of deterioration—the measure of the relative change in the deterioration rate resulting from the change in environmental conditions. It is the deterioration rate **ratio** that the preservation manager can control through changes in the temperature and percent relative humidity of the collection shelving areas. It is not possible to change nonenvironmental factors such as paper fiber type, fiber length, degree of heating of the pulp, the character of sizing agents, and the like, all of which influence the absolute rate of deterioration of a given paper.

> To illustrate, suppose a certain decrease in temperature and/or relative humidity results in the initial deterioration rate, r_1, dropping to a new lower rate, r_2, such that the r_2/r_1 ratio = 0.5. This ratio carries the implication that all papers subjected to this change in environmental conditions will have their rates of deterioration cut in half. The rate reduction would be the same

> twofold value irrespective if a paper was short or long-lived. A paper which, for example, reached a given state of embrittlement in 45 years under the initial set of conditions would, because its rate of deterioration was halved, attained the same state of brittleness in 90 years under the new conditions. Similarly, a paper with a 200 year life expectancy would see its permanence extended to 400 years.[3]

Under the direction of James Reilly, the Image Permanence Institute at the Rochester Institute of Technology extended the research underlying the Isoperm Theory to predict the preservation value of shelving situations that experience seasonal variation in temperature and/or relative humidity. He derived a time-weighted measure of the impact of environmental fluctuation on collection life. Reilly and his colleagues, with the support of the National Endowment for the Humanities, summarized the measure in a report published in 1995 by the Commission on Preservation and Access. The following is a description of the measure taken from the report.

> The Preservation Index (PI) is a means of expressing how ambient temperature and RH affect the chemical decay rate of collections. PI has units of years and gives a general idea of how long it would take for vulnerable organic materials such as poor-quality paper to become noticeably deteriorated, assuming that the temperature and RH did not change from the time of measurement onward. PI helps us to quantify how good or bad the environmental conditions are at that moment for chemical deterioration of the collections. The "years of life" aspect of IP values was chosen deliberately to reflect the behavior of relatively short-lived materials. PI is *not* meant as a predictor of the useful life of any particular object. It is simply a convenient measure of the effect of current environmental conditions on the overall life expectancy of the collection, using shorter-lived materials as a yardstick.[4]

The research of the Image Permanence Institute, when combined with the recent research at the Smithsonian Institution argues strongly for consistent set points within reasonable limits, erring on the side of cooler and drier as much of the time as possible. The Smithsonian research, controversial because of its suggestion that significant seasonal cycling has no negative impact on the mechanical properties of library materials, nevertheless does not undermine the value of a cool, dry environment for slowing or stopping deterioration from chemical reactions (Erhardt & Mecklenburg, 1995).

Pollution and Particulates

Airborne contamination takes two forms: gaseous pollution and particulate matter. The damage from gaseous pollution is not well understood. Mechanisms for controlling pollution inside a shelving facility are prone to uncertainties. Wessel (1970) reported at great length on the variety of pollutants and their possible effects on library collections without reaching meaningful or practical conclusions. In the intervening 30 years, little consensus has been found on the maximum allowable levels of atmospheric pollution in a preservation environment. The obvious conclusions that levels should be (a) as low as possible (or affordable) and (b) well below the recommendations of the Environmental Protection Agency for outdoor air quality are not particularly helpful for establishing design parameters.

The report of the National Research Council (1986) cautioned against the hasty establishment of indoor pollution levels based on suspended molecules in a mass of air. "Unless a more sophisticated definition of particulate air quality is adopted than one based solely on total aerosol mass concentration, there is a danger that ventilation systems will be designed that will lower mass loadings without achieving a proportionate reduction in damage potential." Nevertheless, when pressed for specific recommendations to guide the design and construction of a new building for the National Archives and Records Administration, the group relied on expert opinion rather than scientific evidence of pollution damage. The resulting recommendations of less than 0.4 parts per billion (ppb) for sulfur dioxide, less than 1.0 ppb for ozone, and "best available technology" for nitrogen dioxide exceed by a large degree the detection limits of continuous monitoring equipment.

William Lull and Paul Banks (1995) and William Wilson (1995) recognize the inherent uncertainty of pollution control and recommend maximum levels that, while well below EPA recommendations, are within the range of common detection devices. Lull and Banks describe succinctly the complexity of the gaseous pollution challenge. "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." The theory, which is not yet subjected to rigorous scientific analysis, is that collections have lower tolerance than human occupants of a given space because the human body is living and can effect repairs to itself, while collections have no such self-renewing mechanism.

The level of particulate matter in the air may not appear to be a pressing preservation problem, in the sense that particulates may not be a direct cause of deterioration. Nevertheless, once a collection of library materials shelved in a high-density shelving facility becomes dirty, it is virtually impossible to clean. The spaces between materials shelved by size and the shelves themselves typically averages one inch or less. The sheer volume of materials housed in a room with shelving systems stretching 35 feet in the air precludes moving collections for general maintenance. Additionally, infestations of insects, rodents, and biological agents such as mold spores are extraordinarily challenging to halt in a high-density facility. The most prudent preservation strategy is to prevent infestations from the start. Without a doubt, extraordinary attention to cleanliness of the facility (through rigorous custodial activity) and to cleanliness of the collections (through cleaning routines applied uniformly) is a vital preservation concern.

Preservation at the Yale University Library Shelving Facility

The Yale University Library Shelving Facility (LSF) was completed in November 1998 following a two-year process that encompassed programmatic planning, physical and operational design, and construction. The LSF consists of an 8,000-square-foot processing area and a single shelving module of 12,500 square feet (inside dimensions). The module is outfitted with a single tier shelving system arrayed in six aisles. The capacity of the module is approximately 2.3 million volumes. The site of the facility is large enough to accommodate six shelving modules and should provide for collection growth over the next 50 years.

Although a number of libraries and museums have installed cold rooms for the storage of archival films, at the present time, the LSF is the coldest and driest building designed for the shelving of general library collections. The decision on environmental set points was not an easy one. Making it involved balancing a number of assumptions about what types of materials would and would not be shelved in the facility over its life, circulation rates from the facility, and costs of construction and operations.

Yale's decision about life expectancy was informed by the state of research on environmental control, but influenced most directly by the research findings of the Image Permanence Institute. Working with IPI data (Figure 2), the LSF planning committee identified the PI values for five combinations of temperature and relative humidity that satisfied combinations of criteria.

	Temperature (°F)												
% RH	32	37	42	47	52	57	62	67	72	77	82	87	92
5	2634	1731	1147	767	516	350	240	165	114	80	56	40	28
10	2234	1473	979	656	443	302	207	143	99	70	49	35	25
15	1897	1255	837	562	381	260	179	124	86	61	43	30	22
20	1613	1070	716	482	328	224	155	107	75	53	37	27	19
25	1373	914	613	414	282	194	134	93	65	46	33	23	17
30	1170	781	525	356	243	168	116	81	57	40	29	21	15
35	998	668	451	307	210	145	101	71	50	35	25	18	13
40	852	572	387	264	182	126	88	62	43	31	22	16	12
45	729	491	333	228	157	109	76	54	38	27	19	14	10
50	624	421	287	197	136	95	66	47	33	24	17	12	9
55	535	362	247	170	118	82	58	41	29	21	15	11	8
60	459	312	213	147	102	72	51	36	26	18	13	10	7
65	394	269	184	128	89	62	44	31	22	16	12	9	6
70	339	232	160	111	77	54	39	28	20	14	10	8	6
75	292	200	138	96	67	48	34	24	17	13	9	7	5
80	251	173	120	84	59	42	30	21	15	11	8	6	4
85	217	150	104	73	51	36	26	19	14	10	7	5	4
90	187	130	90	63	45	32	23	16	12	9	6	5	3
95	162	112	79	55	39	28	20	15	11	8	6	4	3
	PI Values, in Years												

Figure 2. Preservation Index (PI) Values (showing predicted lifetime, in years, of short-lived organic materials at various combinations of temperature and relative humidity conditions)

The planning committee then asked consulting engineers to estimate the impact of these combinations on the cost of building and maintaining the preservation environments. The five combinations investigated, the reasoning behind the choices, and utility cost estimates in 1997 dollars, included:

1. 68°/40%RH (PI=58 years)
   Conditions in newly renovated Sterling Memorial Library
   No special dehumidification system required
   Lowest RH without special equipment
   Readers and library materials together
   Est. $1,724 per month electric costs

2. 60°/30%RH (PI=131 years)
   Emphasis on RH; compromise on temperature
   Less concern for transitions to and from the LSF
   Est. $2,708 per month electric costs

3. 50°/40%RH (PI=217 years)
   Emphasis on cool temperature, compromise on RH
   Appropriate for art, rare books, natural history collections
   Est. $3,998 per month electric costs

4. 50°/30%RH (PI=275 years)
   Coolest conditions for nonspecialized clothing for staff
   Overengineered for relative humidity control
   Appropriate for paper, film, and tape that does not circulate
   Est. $3,998 per month electric costs

5. 45°/40%RH (PI=300 years)
   Push limits on human working conditions
   Emphasis on temperature; compromise on RH
   Explore limits on operating costs
   Est. $8,152 per month electric costs

The decision to establish set points of 50°F and 30%RH was based on these assumptions, which were developed after much discussion and debate in the planning committee.

- The LSF is not intended to serve as a shelving space for art objects or natural history collections. Research suggests that these types of materials, not commonly found in quantity in research libraries, benefit from humidity levels that are higher than optimum for paper- and film-based library collections.

- A key planning assumption for the LSF is that annual circulation rates will not exceed 3 percent of the contents. For example, if the LSF contained an average of 500,000 items in a given year, that no more than 15,000 items would be retrieved by patrons. The assumption of low use allowed the Yale planners to de-emphasize the need for and the cost of special procedures that mitigate the adjustment of materials to higher temperatures and different humidity levels that exist outside the LSF during transportation and use of the materials.

- A key design assumption was that the environmental control system should be overengineered. A control system designed and built to hold cooler and drier conditions than are typical in shelving facilities today would permit future adjustments downward or upward as new scientific understanding emerges on the impact of environments on library collections. Over the past decade, the science has pointed clearly toward cooler and drier. Yale wanted to build the capacity from the outset to adjust conditions as needed or recommended.

- The cost assessment undertaken during the design phase demonstrated that there was no difference in either construction or operating costs of an environmental system overengineered to produce relative humidity set points below those in the typical library shelving facility.

Ultimately, the decision on temperature and relative humidity set points turned on the desire of the planning group to maximize the useful life of the collections shelved there, while making it possible for staff to operate in the shelving module without special clothing and equipment.

The Harris Box

The preservation environment in the Library Shelving Facility is a turnkey system designed, constructed, and installed by Harris Environmental Systems, Inc. under terms of a sole-source contract.[5] Harris Systems is one of the country's oldest and largest manufacturers of specialized environments. In business since 1939, the company has concentrated for the past 40 years on environmental rooms, clean rooms, dry rooms, cycling test chambers, and archival storage vaults. Harris builds its rooms in a factory and then installs the rooms and associated equipment on site using its own mechanics and carpenters. Since 1995, the company has installed more than 1,000 environmental rooms. Recent library and museum customers include The Art Institute of Chicago, J. Paul Getty Center, the Smithsonian Institution, Kansas State Historical Society, and the Harvard University Depository.

The Harris system is essentially a giant refrigerator built to fit a cinder block and concrete box 197 feet deep, 69 feet wide, and 38 feet high (outside dimensions). The walls and ceiling of the single room are lined with 3-inch-thick, metal-clad, polyurethane insulated panels. The wall and ceiling panels have an insulation value of R23.8 at +30°F. Under the wall panels is a double-layer, high-density, polyethylene vapor barrier with a perm rating of 0.045. Under the shelving module's concrete slab is a flexible sandwich of high-density polyethylene and aluminum with a perm rating of 0.0142.

The daily-use doors into the shelving module (as opposed to the emergency exits) are single leaf, horizontal sliding, and power operated. The doors are insulated with an R-value of 28 at 40°F and are equipped with reinforced polyester gaskets all around.

Temperature and Relative Humidity

The shelving module holds a temperature of 50°F ±2°. Humidity levels in the module are maintained at 30%RH ±2%. Both the temperature and relative humidity levels are held constant at all times of the day and night, every day of the year. The Harris system is engineered with the potential for seasonal variation of both temperature and humidity levels. Yale has chosen to keep both levels flat until research findings settle the issue of the costs and benefits for collections of seasonal variation.

Potential heat gain in the module is an issue. The design of the mechanical systems assumes that access doors will be opened no more than 10 times per day and that only two people will be working in the module at a given time. The system exchanges air in the shelving module at the rate of 2.2 times per hour (12,000 cubic feet per minute). Make-up air from outside the module is limited to 10 percent of the total air exchanged.

The principal cooling device is an air-cooled condensing unit with a 78-ton capacity. Manufactured by Technical Systems (a RAE Corporation), the system features redundant independent refrigerant circuits for increased reliability (Figure 3). Effectively adding humidification to an air stream without creating wetness in the system is critical to maintaining a healthy environment, free of conditions that foster mold growth. Humidification, when needed, is provided by an electric steam system manufactured by DRI Steam Humidification Co. The systems capacity is 12 lbs/1.4 gal/5.4 kg.

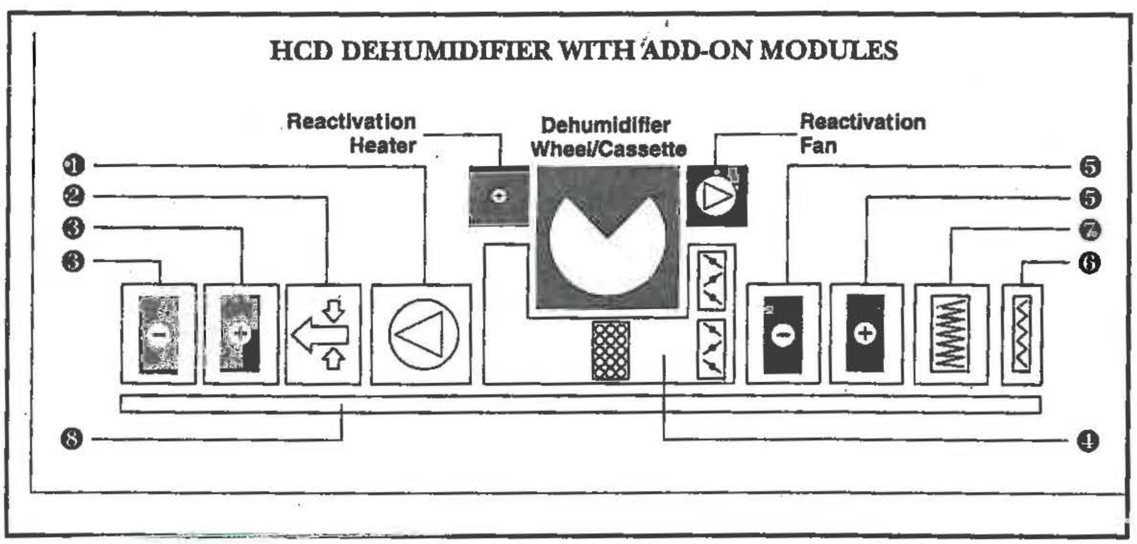

Figure 3. Schematic Diagram of Typical Mechanical System of a Preservation Environment. (1) Process Air Blower Plenum; (2) Mixing Plenum; (3) Post-Heat/Cool Coil Plenum; (4) Pre-Heat/Cool Coil Plenum; (5) Face and Bypass Plenum; (6) Filter Plenum, 30%; (7) Filter Plenum, High Efficiency; (8) Skid

Courtesy Cargocaire Division—Munters Corporation.

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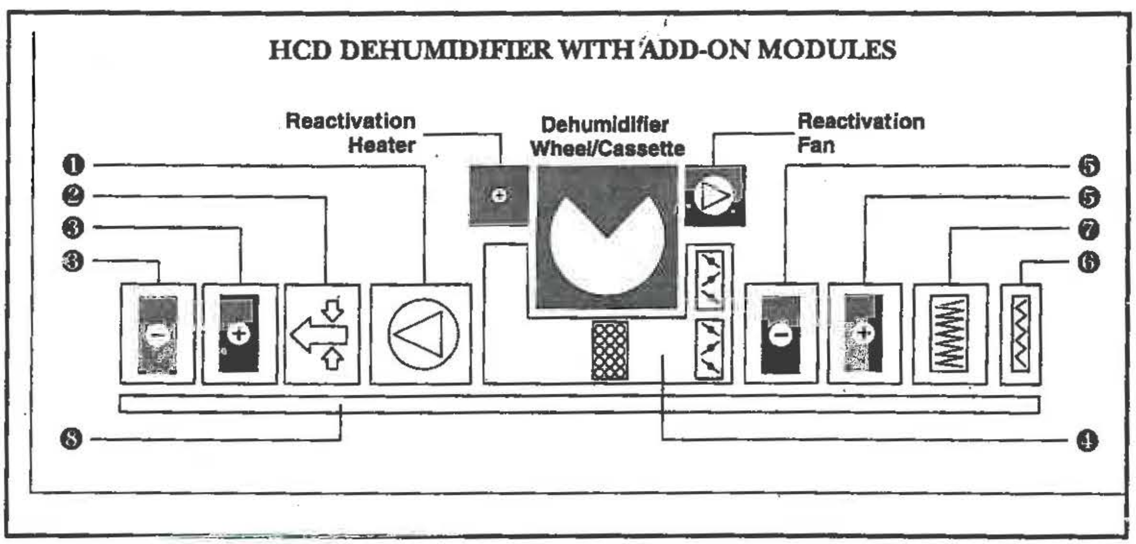

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Courtesy Cargocaire Division—Munters Corporation.

The particular combination of constant temperature and relative humidity that Yale has chosen to hold in the shelving module cannot be accomplished without the assistance of a desiccant dehumidification system. The Cargocaire desiccant system features a large rotating wheel filled with a lithium chloride desiccant, which is a nontoxic and nonmetallic compound. Dehumidification is accomplished by forcing cooled air through the wheel across the desiccant materials. As the wheel rotates, natural gas–heated air flows over the moisture-laden desiccant to release water, which is drained away, and restores its drying properties. The system can remove up to approximately 50 pounds of water per hour.

Temperature and relative humidity values in the shelving module are detected and transmitted to a central control panel. The sensors are mounted on the walls of the shelving module. They detect room temperature with an accuracy of ±0.5°F. The sensors detect humidity levels with an accuracy of ±1%RH. Linearized output signals are provided for transmission over a length of cable. The sensors are low-maintenance models and need calibration once every two years.

Continuous recording of temperature and relative humidity readings is provided on a 10-inch circular chart. Digital data from sensing devices is translated to analog traces by two disposable fiber-tip ink pens. Stepper motors controlled by a microprocessor drive the chart and the pen to help insure precise, maintenance-free operation. Since the speed of the chart is configurable, users can record environmental readings with variable levels of granularity. At Yale, one chart records a single week of continuously plotted temperature and humidity readings.

Air Filtration

The air handling unit for the shelving module contains a four-stage filtration system. The four stages include a pre-filter for large particulate matter, a rigid filter for fine particulates, and two chemical filters that have the adsorptive properties of activated carbon combined with the chemisorptive properties of chemically treated media. One of these filters is designed to control diesel exhaust drawn into fresh air intakes and to trap gasses released from compounds used in the building construction, such as adhesives, sealants, and paint. This filter system absorbs toluene, formaldehyde, nitrogen dioxide, and ozone. The second carbon filter is designed for airborne pollution from outside air and compounds released during the process of organic deterioration. The filter is highly effective against sulfur dioxide, nitrogen dioxide, high molecular weight volatile organic compounds, chlorine, ozone, and many other oxidizable materials.

Harris engineered the Yale filtration system to function at 95 percent efficiency for particulate pollution. The system has the capacity to reduce levels of sulfur dioxide, nitrogen dioxide, ozone, and other gaseous pollutants to less than 10 parts/billion/volume. The actual level of particulate and gaseous pollution in the LSF depends in large measure on the quality of the outside air and the long-term maintenance of the filtration system. Harris recommends annual air quality measurements as part of the system's maintenance contract. The LSF is too new to determine the overall effectiveness of the pollution filtration system.

Lighting

The lights in the shelving module are 250 watt sodium vapor bulbs suspended in a heavy-gauge aluminum reflector designed to provide a long and narrow distribution of the light. Two parallel internal panels reflect the light at high angles to provide high vertical illumination on the stacks. Two additional panels provide uniform illumination up and down the aisle. Each light (spaced at 30 feet) casts approximately 11 foot candles along the stacks and at the floor level. Lighting is free of UV rays. Lights in the shelving module are off when the building is not in use.

Fire Protection

The entire Library Shelving Facility, including the shelving module, is equipped with a wet-pipe sprinkler system conforming to the standards of the National Fire Protection Association (Artim, 1999). A wet-pipe system has automatic sprinklers attached to a piping system containing water and connected to a water supply so that water discharges immediately from sprinklers when they are opened by fire. All sprinkler heads are UL-listed Quick Response Commercial heads designed for ordinary hazard application. Piping for the sprinkler system extends into the shelving system in two horizontal tiers at 15 and 25 feet above the floor. Sprinkler heads are located approximately at eight-foot intervals and heads are staggered on the two tiers so that every shelving segment has one sprinkler head associated with it.

Extending Preservation Through Care and Handling

The Yale University Library Shelving Facility, by the mere existence of its environmental conditions, is a state-of-the-art preservation program. The ways in which materials are chosen, prepared, and handled as part of the transfer process from campus collections to the off-campus LSF extend the preservation value of the facility. The processing of library materials from their campus libraries to the LSF is guided by one overarching goal: do no harm. In practice, the accomplishment of this goal requires that the entire processing system—from the point of pulling an item from a shelf in a campus library to placing the item in the shelving module—ensures the transfer of materials as quickly and efficiently as possible without damaging items or exacerbating damage that may already have occurred due to age or past use. It is important to reiterate that the goal of inserting preservation sensibilities into the processing procedure is to make sure that items are transferred without damage, rather than to facilitate collection care or other preservation activities, either now or later.

The premise of low use drives much of the preservation planning at the LSF. As a general rule, less than 3 percent of the total collection can be expected to circulate in a given calendar year. This rule is derived from decades of cumulative experience of the Harvard Depository and a dozen other high-density facilities. The low-use premise stands in stark contrast to typical circulation rates in full-service research library collections, which may range from 15 percent per year to well over 100 percent per year. The low-use premise shifts the focus of care and handling procedures from those governing active use to those governing transfer to the facility initially.

Beyond the past and expected use of the collections transferred to a high-density shelving facility, preservation procedures must be informed by the overall condition of collections slated for transfer. A study conducted at Yale while planning the LSF suggested that no more than 11 percent of Yale's collections would require special preservation handling during the transfer process. A study undertaken at the University of Kansas for completely different reasons supports the findings of the Yale study (Baird, 1997). This relatively low rate of fragility may come as a surprise to preservation administrators more commonly accustomed to the daily routine of broken and brittle materials circulated by readers. Procedures for handling materials that need be handled only one time under controlled circumstances may be more forgiving than general care and handling procedures for general circulating collections used repeatedly by the general public.

Transfer Risk of Low-Use Materials: A Survey

In planning the transfer of library materials from their current locations to the new Library Shelving Facility, one of the factors considered was the physical condition of the material to be moved. Differing opinions among selectors suggested that from 35% to 50% of all material might need extra care before safe transportation is possible. The path breaking and highly influential Yale condition survey from 1986 suggested that 40% of the Library's collection was in brittle condition. Decades of seasonal changes between humid summers and the hot, dry steam heating of winter, combined with fossil fuel pollutants from New Haven's industrial past produced brittle books with imprint dates as early as 1800, fifty years earlier than the acknowledged beginning of the "brittle books era." Given the possible fragile condition of much of the collection, it was conceivable that significant damage could be caused by the handling and processing required to meet the expected 2,500 volume per day production quota. Also, if the level of fragility in the transfer collections was as high as suspected, it would be virtually impossible to provide item-level conservation treatment to transferred items and still achieve the daily transfer quota. The purpose of the survey was to gain information about the transferability of material and determine the preservation impact of filling the LSF with low-use but possibly badly deteriorated library.

(Continued)

The preservation aspects of the LSF processing system are based on the following assumptions:

- Selectors or their delegates (including, perhaps, Preservation Department, Access Services, or LSF staff) retain responsibility for identifying items needing special handling.
- All flags, printouts, and other objects placed in items during the transfer process that have any chance of remaining with the item on the LSF shelf will be constructed of archival quality paper.
- Processing efficiencies derive from batch processing, wherever possible.
- Efficient processing routines mitigate preservation concerns in many domains.
- The proportion of materials transferred to LSF that will require special handling of any kind will not exceed 10 percent overall.

In the course of planning the processing routines for Yale's LSF, the Preservation Department derived a set of rules and guidelines built around six transfer principles. See the appendix for details on the implementation of the transfer principles at Yale.

The principal study question was "What percentage of the total material within selected subject domains would need to be excluded from transfer to the LSF due to its present condition?" To answer this question, Preservation Librarian David Walls examined the physical condition of six hundred volumes from six subject areas of the collection. Additional data on imprint date, last circulation date, and whether the item had a barcode were also collected. Large serial sets were skipped to increase the variety of material surveyed. Items were examined in call number order as they stood on the shelves. Data were recorded in a spreadsheet designed to calculate simple percentages for each class surveyed.

The findings of the survey suggest that the vast majority of the low-use material scheduled for transfer to the LSF could be safely sent without causing further damage. About 11% of the material will need to be handled with extra care to ensure safe transfer. This activity could be targeted at the point of selection during the move, barely slowing the daily transfer rate, if at all. While some pamphlets were found to be adequately housed for safe transport, all of the material disqualified from immediate transport, 7%, consisted of brittle pamphlets or pamphlets housed in brittle or nonsupportive enclosures. These pamphlets may be divided into three readily recognizable categories: brittle pamphlets housed in brittle or soft covers; brittle pamphlets housed in envelopes; and pamphlets housed in oversized boxes. In the survey no formats other than pamphlets were identified as being at risk during transport.

(Continued)

Transfer Principle No. 1: Every item transferred to LSF must have a container that is intact or secured.

Transfer Principle No. 2: Every container transferred to LSF must have a bar code associated with it, unless the container can't or shouldn't accept a bar code.

Transfer Principle No. 3: Specially designed tubs should be used to transfer containers from the campus library to the LSF.

Transfer Principle No. 4: Dual processing streams separate containers needing special care from those that can be processed routinely.

Transfer Principle No. 5: Information about the condition of an item transferred to LSF is best retained in the LSF inventory database, rather than in the online catalog.

Transfer Principle No. 6: Every container will be cleaned at LSF prior to processing and shelving, even if it appears to be clean.

It is important to recognize that the condition survey addressed only whether an item is physically capable of being sent to the LSF with a reasonable degree of safety. A brittle volume with a history of low use demands little intervention as long as it is housed within an appropriate environment. If this same volume were suddenly added to a course reading list, for example, immediate intervention would be required to preserve its integrity.

Source: David Walls, "A Condition Survey of Six Subject Classes of Low-Use Material," unpublished study report, Yale University Library, October 1997.

Cleaning Items Prior to Shelving

The Yale University Library Shelving Facility is the first library building of its kind to incorporate into the design of the building and into the processing workflow the systematic cleaning on site of all items shelved there. Four arguments drove the cleaning plan.

- Most items transferred from campus libraries exhibit some level of visible dirt and grime.
- Dirt is a carrier of and a breeding ground for mold spores and can be an important source of acidic and corrosive compounds that exacerbate the deterioration of library materials.
- Once lodged in the shelving module, dirt and dust is almost impossible to remove, due to the low rate of air exchange and the high-density shelving system.
- Most libraries from which materials are transferred do not have sufficient space to clean items systematically and efficiently.

Yale's planning team inspected existing library shelving facilities during the early design phases. In the process the team convinced itself that particulate matter (from paper and cellulose, as well as from brake pads of order-picker equipment operated in the shelving module) should be minimized by cleaning all accessioned items and through rigorous building and equipment maintenance.

The final design of the cleaning facility was completed while the building was under construction. Consultations with Yale's Office of Health and Safety as well as creative brainstorming by an ad hoc planning group clarified key design issues, such as efficient processing, ergonomics, and the preservation handling of library materials. Personnel from the construction management team mocked up a prototype cleaning apparatus, which was tested using representative examples from the library stacks. Additionally, the planning group received valuable advice on mechanical system design from Professor Peter Kindlmann of Yale's Electrical Engineering Department. The net result of this work was a clarification of the goals of the cleaning program and an outline of the specific requirements for the layout of the cleaning room, the design of the cleaning system, and the capabilities of auxiliary equipment and supplies.

The following is an outline of the capabilities of the cleaning facility as built at Yale.

Room Capability

- Four identically outfitted workstations
- Continuous work surface along one wall
- Redundant vacuum systems; one per cleaning station
- Negative pressure in the HVAC system associated with the cleaning room to improve the overall cleanliness of the LSF
- Cleaning process and equipment stations combined to accommodate at least 2,000 items per day, every day
- Vacuum machinery located outside the work area to minimize noise, heat, and dust inside the work area
- Cleaning room exclusively dedicated to the cleaning of library materials.

Cleaning Station Design (specifications for each station)

Work Surface

- Continuous, smooth surface
- Nonstatic
- 36 inches in height

- 36 inches in depth
- 68 to 72 inches of surface allocated to each station

Vacuum System

- Remote location, yet easily serviced and emptied
- Outside venting to eliminate need for HEPA filters
- Capability to support brush-on-hose cleaning and fixed cleaning head
- Left- and right-handed hose attachment flush with surface
- Cleaning head assembly mounted flush with surface
- Ability to switch from hose to head cleaning with little difficulty
- Produces 200 to 500 cfm at cleaning surface with capability to adjust and monitor airflow
- Special catch filter in clear plastic housing that prevents pieces from particularly fragile items from being drawn into the vacuum.

Cleaning Head Assembly

- Modular design (component parts, removable, interchangeable)
- Simultaneous brushing and surface vacuum
- Bristle assembly is removable for easy replacement
- Assembly can accommodate bristles of different material (natural or synthetic) and length

Auxiliary Equipment and Supplies

A certain level of harmonious design and selection of carts and other equipment is needed to support the efficiency of the overall cleaning process.

Carts

- Function fluidly with tubs chosen for transfer
- Position top rim of tub of materials to be cleaned at 36 inches, preferably through some sort of adjustment mechanism
- Top of carts should be smooth and without lips, flanges, or handles to facilitate the movement of oversize materials

Chairs

- Seating at processing workstations is not used in many shelving facilities for accessioning work. Following an ergonomic review of the Library Shelving Facility, the operations manager decided that all cleaning operations would be undertaken while standing

Health and Safety Equipment

- Cushioned pads for standing at cleaning station
- Appropriate dust masks and aspirators for special circumstances
- Task lighting at each cleaning station (if appropriate)

Continuing Controversy

In spite of an emerging consensus on the components of a preservation environment, forged from almost two decades of experience with high-density shelving facilities, at least one major technical issue remains unresolved. This has to do with the need for rigorous temperature and humidity set points throughout the year and the related concern over the possible negative impact on library materials when they are moved out of the shelving facility temporarily to be used.

Researchers at the Smithsonian Institution have focused attention on the issue of seasonal cycling (Erhardt and Mecklenburg, 1995). The heart of the matter is the cost of maintaining the preservation environment in the facility once it is built. The argument of the Smithsonian researchers is that materials can withstand seasonal variation without physical damage and that allowing seasonal variation in temperature and relative humidity set points can save many dollars in utility costs. The Smithsonian research focuses on mechanical damage to materials based on extreme changes in temperature and humidity over varying time frames. Their work is not necessarily concerned with chemical damage that occurs when temperature and/or humidity levels climb even for short periods of time. Only rigorous scientific inquiry and rigorous investigation of the assumptions outlined in the Smithsonian Institution research will resolve the controversy. The present state-of-the-art argues that stable temperature and humidity levels are the foundation of a true preservation environment. Just because library collections can withstand temperature changes without mechanical damage does not mean they should be put at risk of chemical damage through cycling.

The concern about the impact of physical stresses when library materials move from cool-dry conditions of a shelving facility to the warm-humid conditions of a reading room on a summer day derives from the Smithsonian research findings. No systematic research has been carried out on this issue. Yet informal commentary exchanged among facilities designers and operational staff suggests that there is little need for concern when paper is the principal medium being shelved. For film, however, a period of acclimatization is needed between the transfer from a preservation environment to a normally conditioned (or unconditioned) environment. The LSF handles this by transporting films in picnic coolers and recommending a 24-hour adjustment before films are viewed.

Conclusion

Yale University's Library Shelving Facility, along with nearly all such facilities built within the last 10 years, is a first line of defense against the deterioration of library materials. There may always be room to improve upon the basic model. And yet, these facilities go a long way toward satisfying the core criteria of an effective preservation program articulated by Gordon Williams some 35 years ago.

> A preservation program must preserve all books of significant value; it must preserve the maximum amount of information carried by the original books; it must provide for the longest period of preservation practicable with present technology and compatible with the other requirements; it must provide for the continuous and ready availability of the preserved materials to anyone who needs them; and it must avoid unnecessary duplication of effort and expense.[6]

Notes

1. Guy Petherbridge, ed., *Conservation of Library and Archive Materials and the Graphic Arts* (London: Butterworths, 1987), 10.

2. Edwin E. Williams, "Deterioration of Library Collections Today," in *Deterioration and Preservation of Library Materials*, ed. Howard W. Winger and Richard Daniel Smith (Chicago: University of Chicago Press, 1970), 3.

3. Donald K. Sebera, *Isoperms: An Environmental Management Tool* (Washington, D.C.: Commission on Preservation and Access, 1994), 4.

4. James M. Reilly, Douglas W. Nishimura, and Edward Zinn, *New Tools for Preservation: Assessing Long-Term Environmental Effects on Library and Archives Collections* (Washington, D.C.: Commission on Preservation and Access, 1995), 4.

5. Harris Environmental Systems, 11 Connector Road, Andover, MA 01810, (978) 470-8600; Web site: http://www.harris-env.com

6. Gordon Williams, "The Preservation of Deteriorating Books," *Library Journal* 91 (January 1, 1966): 51–56, and (January 15, 1966): 189–94.

Appendix: Transfer Principles

Transfer Principle No. 1: *Every item transferred to LSF must have a container that is intact or secured.*

Examples of containers include:

- binding
- slip case
- phase box
- Paige box (for archival records)
- document case or envelop (for loose pamphlets or archival materials)
- microfilm box

At the point of selection from the shelf, each item should be inspected quickly for the integrity of the container—with one question in mind: can this item be transferred to LSF and processed without damaging it? If the answer is "YES," pull it. If the answer is "NO," the selector or delegate must decide to secure it for transfer or leave it on the shelf. Visual signs of condition that may indicate a container is NOT OK to send as is include:

- One or both covers/boards loose or falling off
- Spine loose, separated from boards/covers
- Many pages loose, leaf loose
- Pages crumbling from very advanced brittleness
- Leather, vellum, etc. bindings are rotting, rubbing off, crumbling
- Leather, vellum etc. bindings are cracked, splitting in solid pieces
- Spills, stickiness obvious anywhere on container
- Pest (worms, etc.) obvious to eye
- Container appears wet/damp, verified by touch
- Container has been seriously mutilated/is torn, cut in some way
- Heavy smell of mildew

The manager of the LSF will return an item to a sending library that cannot be handled routinely or processed to the LSF shelf without causing damage to the item.

Transfer Principle No. 2: *Every container transferred to LSF must have a bar code associated with it, unless the container* ***can't*** *or* ***shouldn't*** *accept a bar code.*

- A container **can't** accept a bar code because of its **physical condition** (e.g., rotting leather, very soiled surface, very rough or mottled surface, etc.)
- A container **shouldn't** accept a bar code because of its **artifactual value** (e.g., rare, valuable, or decorated bindings; rare or unique item; highly valuable item, etc.)

When in doubt, a bar code should be placed on the surface of the container. The Processing Group recommends that containers that cannot or should not be affixed with a bar code should be wrapped or placed in an acid-free envelope with the bar code attached to the wrapper or envelope.

Transfer Principle No. 3: *Specially designed tubs should be used to transfer containers from the campus library to the LSF.*

The risk of damage to items transferred on book trucks is simply too great. Damage will likely occur when trucks spill or are jostled during transfer to and from the van, to and from the home library loading areas, and while in transit. Over-packed book trucks will damage an item as it is loaded on or taken from the truck. The risk of damage from book-truck transfer far exceeds the risk of damage from transfer in and out of tubs, particularly if a subset of tubs can be identified and marked "Fragile—Handle with Care." Tubs are cheaper, more durable, and more flexible to transport than book trucks.

The following are some of the specifications for transfer tubs:

- Distinctive from other library portables for quick identification
- Dimensions: 23" x 15.5" x 8.5" (l x w x d)
- Maximum 50 lbs. capacity when full
- Snap-down lid with channel drainage for water resistance
- Stackable when full up to five high
- Nested when empty
- Constructed of high density polyethylene
- Sides labeled for easy sorting (as needed)

Transfer Principle No. 4: *Dual processing streams separate containers needing special care from those that can be processed routinely.*

Since no more than 10 percent of the containers (more likely 5 percent) received at LSF will require special handling of any sort, the overall efficiency of the LSF program depends upon the routine and efficient processing of containers that do not need special handling. Those that do should be processed as a batch as time permits during a given week, rather than integrating preservation handling procedures into the normal workflow. Wrapping for preservation handling can and should be handled centrally at the LSF, especially if fragile containers arrive in specially marked tubs. A wrapping workstation must have the capacity to provide for the wrapping, bagging, enveloping, and/or securing of fragile containers and the attachment of bar codes where necessary and appropriate.

Transfer Principle No. 5: *Information about the condition of an item transferred to LSF is best retained in the LSF inventory database, rather than in the online catalog.*

Condition information will facilitate safe retrieval and transfer from LSF to the campus library. Additionally, a record of poor condition is an investment improving the possibility that fragile items shelved at the LSF can be retrieved in the future specifically for batch preservation processing. The LSF inventory database must provide a data field in which preservation condition or value codes will be entered; up to five codes identify specific conditions. Parallel processing of preservation items will greatly facilitate the consistent and efficient entry of condition/value codes.

Transfer Principle No. 6: *Every container will be cleaned at LSF prior to processing and shelving, even if it appears to be clean.*

Thorough cleaning of every container is essential to the long-term cleanliness of the LSF shelving environment. Only in exceptional circumstances, and with the prior approval of the LSF manager, are containers to be processed without cleaning. Items inside containers (e.g., pamphlet in envelope, book in a box, fully wrapped periodical volume) need not be cleaned separately if the container is new. Items wrapped by the home library prior to transfer will require surface cleaning only.

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Library Off-Site Shelving

Guide for High-Density Facilities

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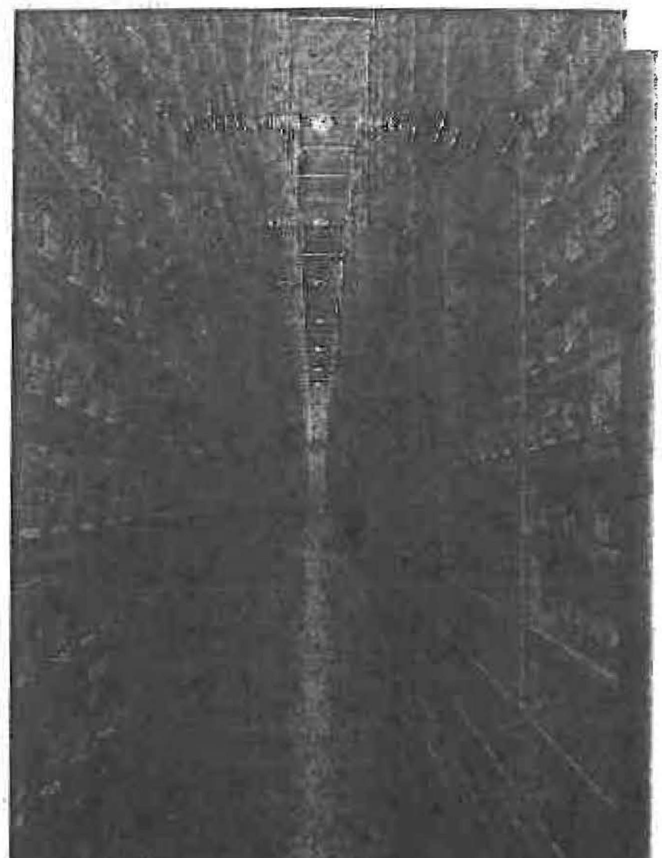

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