



# Fort Meade is Cool, CALM, and Collected

*By Jeanette Adams*



(Photo by Beatriz B.M. Haspo)

*A view of one aisle in Module 1. The module contains approximately three miles of books and bound periodicals compressed into a footprint of approximately 3000 sq. ft., including the aisle. A person can be seen at the far end of the aisle, which is lit by the warm glow of the high efficiency sodium vapor lights.*

The Library of Congress's off-site archival storage facility at the Fort George G. Meade army base near Odenton, Maryland, is a state-of-the-art satellite facility that epitomizes the mission of the Library: *To make its resources available and useful to Congress and the American people and to sustain and preserve a universal collection of knowledge and creativity for future generations.* The technological infrastructure incorporated in the no-nonsense, high-efficiency, high-storage-capacity design of the modular facility provides for the maintenance and preservation of traditional (books, paper) and visual (photographs, microfilm) collection materials. The human infrastructure incorporated in the logistics of day-to-day storage and access operations ensures retrieval of items when requested by Congress, the American people, and people from all over the world (interlibrary loan, international visitors and scholars).

The Fort Meade storage facility is located on a one hundred acre site, thirty miles northeast of Capitol Hill. The acreage was transferred from the U.S. Army to the Architect of the Capitol in 1993. Construction of Module 1 of the storage facility started in June 1999, and the Library sent its first shipment of books in November 2002. Module 2 opened in November 2005. Construction of Modules 3 and 4, plus four cold-storage rooms, began in October 2006, and they are scheduled to open in March 2009. The facility includes a collections-processing area, an administrative area, an isolation room for quarantining new acquisitions received directly at Fort Meade, and mechanical equipment rooms. In case of emergencies or other contingencies, the facility has its own water tank and pump house for fire control, a storm water management pond, redundant HVAC systems, a blast freezer for water-damaged materials, and a back-up emergency power generator.

Each module and cold-storage room has a specific purpose that dic-

tates its preservation design. Modules 1 and 2 were designed for "cool" storage of traditional library collections: books, pamphlets, and bound periodicals. Modules 3 and 4 were designed for cool storage of traditional materials found in special format collections such as bound volumes, rarer books, manuscripts, prints, drawings, photographs, posters, sheet music, maps, globes, and other three-dimensional objects. Four "cold" storage rooms will be used for analog visual collection materials: photographic negatives, transparencies, color prints, master negatives, microfilm, and microfiche.

#### Fort Meade is Cool: the Science and Technology

The simple statement "no access without preservation" provides added insight into the interrelatedness of the goals in the Library's mission statement. The original items in the Library's vast collection will remain available and useful to Congress and the American people for future generations only if they are sustained via preservation. Many decisions regarding how best to preserve the collections are informed by knowledge obtained from fundamental scientific research in the chemistry and physics of materials.

This research reveals that one parameter ultimately determines the longevities (stabilities) of different types of library collection materials, barring harmful human handling and other types of mechanical damage: How long a material will last is controlled entirely by the rates of the chemical degradation reactions that cause the chemical bonds in the materials to break or otherwise change. If the chemical degradation reaction rates are fast, the materials will deteriorate quickly, and vice versa.

The chemical reaction rates, however, are themselves controlled primarily by three other interrelated factors or variables: (1) the principal chemical components of the collection material, (2) the amounts of chemically

reactive agents either present in the storage environment or inherent in the collection material itself, and (3) the storage temperature. Thus, the greatest technological challenge in an archival storage facility is to reduce the rates of the chemical degradation reactions by minimizing the impact of these three interrelated factors.

#### Challenge: Principal Material Composition

Library materials range from traditional materials to analog audio-visual materials and to digital materials, all of which are significantly different chemically and consequently physically. Early and modern paper-based materials are principally composed of natural polymers such as cellulose and lignin. Twentieth century analog audio-visual materials are instead principally composed of synthetic polymers such as nitrocellulose, cellulose acetate, and poly(ester urethane). Twentieth and twenty-first century digital materials are, generally, principally composed of synthetic polymers, dyes, and other materials.

Materials science research reveals that differences in the principal chemical components and molecular structures of materials cause them to deteriorate via different bond-changing chemical reactions at different rates. What ultimately determines collection accessibility, however, is the impact these chemical reactions have on the physical and optical properties of the materials. For example, lignin in wood-pulp paper deteriorates to produce organic acids and other compounds that result in discoloration and paper breakage called the "brittle book" syndrome. Cellulose acetate in microfilm deteriorates to produce acetic acid resulting in "vinegar syndrome," which causes the materials to crack and crumble. Degradation of poly(ester urethane) in magnetic tapes results in "sticky shed syndrome" that causes tape squealing, damage to tape heads, and loss of



(Photos by Jeanette Adams)

*Physical manifestations of chemical deterioration reactions that negatively impact access to Library of Congress collections. Deterioration of wood-pulp paper results in “brittle book syndrome”, which makes paper in books, manuscripts, and other collections break when handled. Deterioration of microfilm and other cellulose acetate materials via “vinegar syndrome,” and deterioration of unstable materials in compact discs (CDs) via loss of the reflective layer, causes these collections to be unreadable.*

audio-video signal. Unstable materials in compact discs (CDs) deteriorate to produce pin-hole defects, delamination, and “edge rot” that cause loss of digital data, including audio-video data. The different chemical reactions, and the different physical and optical manifestations of the reactions, indicate that archival storage requirements for the different materials must be different, and, indeed, scientific research confirms this hypothesis.

In addition to the principal chemical components, there are two other important factors that affect the rates of chemical degradation reactions. These factors are the temperature and the presence of chemically reactive agents.

### Challenge: Chemically Reactive Agents

Materials-science research reveals that chemically reactive agents, if present in the storage environment or in the collection materials themselves, can either induce or accelerate the deterioration of what would otherwise be stable materials. There are three general types of environmentally introduced, chemically reactive agents: (1) corrosive airborne pollutants such as sulfur diox-

ide and nitrogen oxides that react with water in the air or in the collection materials to form damaging sulfuric and nitric acids, (2) airborne water vapor that hydrolyzes (breaks) the chemical bonds in materials, and (3) ambient oxygen that, by itself or in conjunction with ultraviolet (UV) light, either oxidizes or photooxidizes chemical bonds in materials. Detrimental changes in chemical bonding can include bond scission (splitting), which can cause materials to become brittle and break; cross-linking, which can cause materials to become stiff; and/or polymerization, which can cause discoloration.

Levels to which environmental chemically reactive agents must be reduced depend both on their inherent reactivities and on their concentrations in the environment. Airborne pollutants such as sulfur dioxide are highly corrosive and thus can pose a threat to collections when present in miniscule parts-per-billion (ppb) levels. In contrast, water vapor is not inherently highly corrosive or reactive. However, water vapor is present in air at a high concentration of 1% (1 part in 100 parts) at 68 °F (20 °C) and a relative humidity (RH) of 50%. Similarly, oxy-

gen is present in air at a concentration of 21% (21 parts in 100 parts). Thus both water vapor and oxygen are, respectively, 10 million and 210 million times more concentrated than the ppb threat-level for sulfur dioxide, which means that hydrolytic (water) and oxidative (oxygen) degradation reactions can pose significant threats to library collections under normal ambient conditions.

To reduce threats from chemically reactive agents, their concentrations in the storage environment must be reduced to acceptable levels. Chemical air-filtration systems and humidity control can reduce threats from airborne pollutants and water vapor. It is critical to understand, however, that polymeric materials in library collections must contain some moisture to retain their molecular structures and thus their physical strengths and durabilities. Consequently, library collection materials should never be stored under RH conditions that are either too low or that fluctuate. In fact, different collection materials have different optimum RH requirements. RH that is too low can lead to shrinkage and cracking of substrates (film, paper, parchment)

and media (inks, binders, photographic emulsions). Conversely, RH that is too high can lead to expansion, curling, and other material distortions, and, in particular, mold infestation. Science has not yet informed us of an acceptable level of oxygen in the storage environment. However, many chemical reactions involving oxygen are *photo*-oxidation reactions, which means that by minimizing UV light, impact from oxidation can be reduced.

In addition to environmentally introduced reactive agents, all collection materials themselves can inherently contain—and through chemical degradation reactions produce—reactive chemicals that can also cause the degradation of an otherwise stable material. For example, some paper is inherently acidic because it is manufactured using alum-rosin size, which is added to the paper to prevent ink from soaking into the paper and “feathering” during writing and printing. Unfortunately, the acid introduced from alum-rosin size accelerates the degradation of otherwise stable cellulose. However, all paper will decompose naturally to produce damaging organic acids that can then accelerate further degradation. In addition, some of these naturally formed acids are volatile enough to enter the general storage environment and thus accelerate the degradation of adjacent materials.

Consequently, the impact of reactive chemicals that are inherent in collection materials—the “inherent vice” of the materials—must be reduced to minimize their degradation. This can be accomplished by using collection housing materials that absorb reactive agents and by controlling the third important factor that impacts the rates of chemical degradation reactions: the temperature.

#### Challenge: Temperature

The third and perhaps most important factor that impacts the rates of chemical degradation reactions is temperature. Higher temperatures exponentially speed up some degradation

reactions and vice versa. Reducing storage temperature by 18 °F (10 °C)—or from 68 °F to 50 °F—may cut at least in half the rate of a chemical degradation reaction. However, decisions regarding temperature reduction must be tempered with the knowledge that reduced temperature can negatively affect the physical, as opposed to chemical, stability of some collection materials. Consequently, some materials should never be stored long-term under sub-freezing conditions, whereas others are best stored at such temperatures.

#### Meeting Preservation Challenges at Fort Meade

All of the kinds of challenges to the long-term preservation of Library collection materials that I have identified have been addressed in the technological design of the Fort Meade storage facility. This design includes the segregation of collections based on their principal chemical components, an air filtration system that reduces corrosive airborne pollutants, control of relative humidity to reduce hydrolysis reactions, appropriate lighting to reduce photooxidation reactions, housing materials to absorb volatile organic acids and other reactive chemicals emitted by the collections themselves, and temperature reduction to decrease the rates of all chemical degradation reactions.

The collections at Fort Meade are stored in either cool modules or cold rooms. Collections are segregated by material type, and stored at levels of relative humidity and temperature appropriate for each kind of material. The cool modules, which are for storage of traditional materials, are maintained at 50 °F (10 °C) and 30% RH. The four cold rooms, which are for storage of visual materials such as fiche, film, and photographs are designed in accord with standard ISO 18911 of the International Organization for Standardization and are thus maintained at either 35 °F (2 °C) or 25 °F (- 4 °C). The three cold rooms kept at 35 °F and 30% RH are for storing black-and-white photographs, microfilm, and

microfiche. The one cold room kept at 25 °F and 25% RH is for storing photographic negatives, transparencies, and color prints. To prevent condensation of water on materials when they are being retrieved from the cold rooms, all items are placed in an acclimatization area at 50 °F and 30% RH before being moved to ambient temperature (70-75 °F) and relative-humidity (40-55%) conditions.

In addition to temperature and humidity control, care has been taken to reduce reactive airborne pollutants and photooxidation reactions. Interior building materials meet stringent specifications regarding the release of volatile compounds that might harm collections. High-efficiency chemical and particulate air filters remove airborne pollutants from both return air and outside air, which is introduced at a minimum to meet ventilation requirements. Having no windows and using energy-efficient, low-pressure sodium vapor lights, which emit a soft yellow color and eliminate 99% of UV radiation, minimize photooxidation reactions.

Most collections are re-housed in custom-designed containers that contribute to the physical and chemical protection of the collections. The re-housing containers provide protection for long-term storage, transit, and use while simultaneously helping to absorb volatile chemically reactive compounds that arise from the collections themselves. Books and bound periodicals are packed in corrugated board boxes that have an alkaline reserve, and pamphlets are placed in buffered envelopes that conform to Library of Congress Preservation Directorate specifications. The boxes are not sealed but have side slits that are open to the general environment, which prevents reactive compounds from reaching high concentrations inside the containers. The re-housing containers also provide protection against stray light and water damage in case of fire.

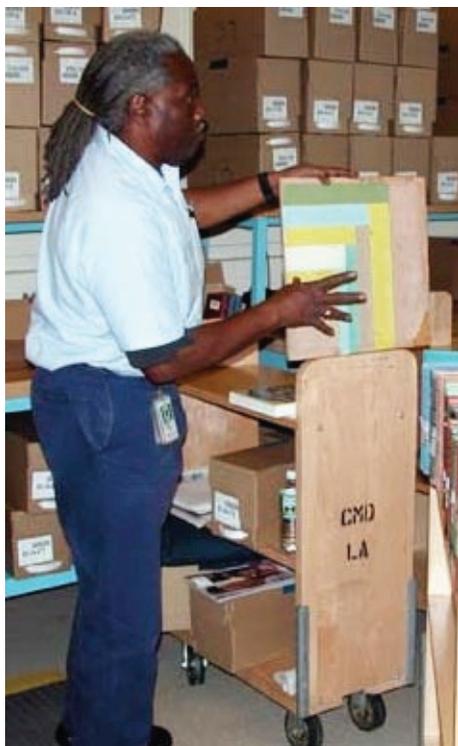
In addition to reducing chemical risks to the collections, the Fort

Meade facility also minimizes and/or eliminates physical risks. These include damage from excessive human handling, mechanical damage from inappropriate storage shelving or similar structures, water damage from leaking pipes or poor roofs, insect and mold infestations, damage from poor house-keeping (dust, dirt), and collection loss through security breaches. Storage at Fort Meade addresses all challenges, chemical, physical, and mechanical.

### Fort Meade is CALM: the Human Side

The technological design and day-to-day operation of the storage facility would not be possible without continued support from Congress and the collaborative efforts of staff members from multiple divisions in Library Services (LS) and Integrated Support Services units of the Library of Congress, and also from the Architect of the Capitol's office, the U.S. Army Corp of Engineers, and contractors. Staff members from the Preservation Directorate continue to provide time and expertise in preservation and materials science and in evaluating internal building materials to ensure that they meet preservation standards. Staff members from almost all of the Collections and Services Directorate's divisions, the Law Library, Photoduplication Services, and the Preservation Reformatting Division have spent innumerable hours selecting and preparing detailed lists of the estimated thirty-three million collection items to be moved to Fort Meade. Over the last six years, a team of more than two dozen preservation specialists has spent, and is spending, tremendous numbers of hours working with the Conservation Division to aid the other divisions in assessing the condition of the collections, stabilizing them, and re-housing them, which includes designing unique housing containers, ordering massive quantities of supplies, and helping to plan collection moves. The lead in this massive effort, including significant numbers

of person-hours devoted to the intricate planning details and day-to-day operations of the facility, has come from staff members in the Collections Access, Loan, and Management Division (CALM) of LC's Collections and Services Directorate.



(Photo by Beatriz B.M. Haspo)

*Ronald Burton, CALM staff, measuring books against templates to determine which size container to use for storage.*

Intricate planning is required because the overall design of the modules is based on the high-density book-storage facility at Harvard University. For example, multiple books are stored together in boxes, all of which are organized by book size instead of specific collection, which enables 125,000 cubic feet of items to be placed into a "footprint" of 12,000 square feet. To accomplish such high-density storage, a laboriously detailed and intricately exact map—a "planograph"—is made before any shelving is designed and assembled. This map shows exactly where the storage box containing each separate item will be placed. For Modules 3 and 4, which will contain objects of different shapes, planning began in 2004 when divisions determined the items to be transferred to Fort Meade

and the size of containers that would be needed. It then took two years for CALM staff members to make the planograph, which requires a zero margin of error so that shelf dimensions and spacing fit exactly into the modules with all shelves filled to capacity. The design of Modules 3, 4, and the cold rooms has involved exact placement of approximately one million storage containers.

In addition to planning the exact location of each collection item, CALM staff members provide day-to-day logistical support for the use of the facility. There is a crew of three and an on-site manager at Fort Meade. On Capitol Hill, a six-member team shifts sections of books, moving approximately 4,800 books per day into empty spaces that are left after books are transferred to Fort Meade. A team of approximately forty handles the transfer and retrieval of items to and from the Fort Meade facility. This includes transferring approximately 3,000 items per day to the facility and retrieving approximately 15,000 items per year. Retrieval requests are delivered twice a day from Fort Meade to Capitol Hill.

Fort Meade has been able to fill 100 percent of all requests. This perfect record is a result of the redundancy and logical design of the process used by CALM to track collections that are moved to Fort Meade. For books, this process essentially consists of seven general steps: (1) when a book goes to Fort Meade, its entry in the Library of Congress Integrated Library System (LC ILS) bibliographic database is first checked to ensure it includes a complete item record and a collection barcode, and then the entry is updated to reflect the change in location of the book to Fort Meade; (2) the book is vacuumed, measured against templates to determine the appropriate container size, and then placed into an 18-inch-deep, bar-coded storage box with similarly sized books; (3) the ILS barcode of the book and the barcode of the box is "wanded" into a custom tracking database using a wand barcode scanner

so that the book's ILS barcode is linked to the barcode on the storage box; (4) all data are independently verified one more time; (5) filled storage boxes are placed into specially designed metal book carts that are delivered to Fort Meade in an air-conditioned truck, which unloads all containers onto an air-conditioned loading dock; (6) the book carts are moved by an electronic forklift, and the containers are placed into their permanent locations on bar-coded shelves in the storage facility, and the barcodes of the storage boxes are linked to the barcodes of the shelves using a hand-held portable data terminal (PDT); and (7) the PDT data are finally uploaded into the database, which is backed up at least once a day. Retrieval then simply involves receiving a request and tracking the bar-coded links between book, storage box, and storage shelf.

#### Fort Meade is "Collected": the Collections

CALM's 100 percent retrieval record is truly remarkable considering the vast number and types of collections stored at Fort Meade, and the fact that the items stored in each module are stored by size and not specific collection. When Modules 3 and 4 and the cold rooms are filled, there will be an estimated thirty-three million items at Fort Meade stored in a volume the approximate size of five Olympic swimming pools, on shelving that would cover approximately ten football fields and would stretch seventy-two miles from Washington, D.C., to Culpeper, Virginia.

The organization of the shelving of each module is designed to contain different types of items. Modules 1 and 2 are designed to contain books and bound periodicals. Module 1, the smallest module, stores 1.6 million books and bound periodicals from the African and Middle Eastern Division, Asian Division, General Collection (agriculture, medicine, and literature collections), Humanities and Social Sciences Division, Law Library, and



(Photo by Jon W. Netherton)

*The emergency power generator being placed in its permanent location in June 2008. The generator provides 1500 kW of power with a 48-hour fuel capacity.*

Music Division. Module 2, which is 50 percent full, will store 2.2 million items from the General Collection, the Law Library, the Music Division, and the Rare Book and Special Collections Division. Items for storage in Modules 1 and 2 were selected primarily because they were either less used, available digitally through subscription databases, not generally used to answer reference questions, or second copies.

Modules 3 and 4 have been designed to hold traditional collections that include books plus other items that require more specialized housings, shelves, and cases. They will hold 890,000 bound volumes and books; 2,100,000 pieces of sheet music; 10,000,000 manuscripts; 2,300,000 items of art on paper; 542,000 maps; 500 globes; and 1,800,000 more items in various formats. There will be 4 million photographs stored either in the modules or in the cold rooms as appropriate for the specific photographic materials. These 22 million items are from eight LS divisions (African and Middle Eastern; Collections Access, Loan, and Management; Geography and Map; Manuscript; Music; Prints and Photographs; Serial and Government Publications; and Rare Book and Special Collections), and from the American Folklife Center and the Law Library.

The cold rooms will house 11 mil-

lion analog visual items. These will include 6,500,000 photographic negatives, transparencies, and color prints; 205,000 microfilm master negatives; 500,000 microfilm reels; and 4 million microfiche. These items are from the Music Division, Photoduplication Services, Prints and Photographs Division, and the Preservation Reformatting Division.

Like items stored in Modules 1 and 2, many items from the traditional and special format collections are being moved from Capitol Hill to Modules 3 and 4 because the items are used less than others. However, some items from Capitol Hill are selected to go to Fort Meade primarily to take advantage of the cool preservation environment of the modules. Items selected by the Rare Book and Special Collections Division for Fort Meade storage include a comprehensive run of archival Dell paperback books. These are important because they provide documentation of American taste and cover art, and because they are highly prone to deterioration, having been published using acidic wood-pulp paper.

The Dell paperback books were chosen also because of another criterion for determining the types of traditional collections being stored remotely at Fort Meade: The Dell books were published generally in the twentieth century and later. Thus, Manuscript Division

items include writings, journals, and personal correspondence about Eric Sevareid, Johnny Carson, Henry Ward Beecher, and Bayard T. Rustin. Music Division items include performing-arts production materials, songbooks, music manuscripts, and other visual materials about Leonard Bernstein, Bob Fosse, Gwen Verdon, Jascha Heifetz, Danny Kaye, Sylvia Fine, and others. American Folklife Center items are in various formats and include items from the Aaron Ziegelman Foundation, the Paradise Valley Folklife Project, the Robert W. Gordon Songsters, and the Land's End All-American Quilt Collection.

Traditional items from LC's Geography and Map Division include international collections of nautical charts, in particular the Bruce Heezen-Marie Tharp Collection, which contains the first comprehensive maps of the ocean floor that revealed the Mid-Atlantic Ridge, a discovery that significantly contributed to the evolution of plate tectonics theory. In addition to maps, Module 3 will also contain twentieth-century globes and plastic raised-relief models, which will be stored in housings especially designed to protect these unusually shaped objects.

The cold rooms will store visual items that are being moved from non-ideal storage conditions on Capitol Hill and poor conditions at LC's Landover storage facility to take advantage of the preservation environment at Fort Meade. Prints and Photographs Division items include negatives from the Farm Security Administration-Office of War Information Collection, slides from the Charles and Ray Eames Collection, and color photographs and transparencies from numerous collections. Collections at Fort Meade from the Photoduplication Services and Preservation Reformatting Division include preservation microfilm master negatives, microfilm rolls, and microfiche.

The master plan for the Fort Meade site includes an expansion of the current four modules to a total of thirteen. The plan is designed to accommodate the Library's storage needs through the year 2027. Details of the plan are not, however, restrained by the technology of 2008. Over the next twenty years, the science of preservation can be expected to provide new information regarding how best and most efficiently to preserve library collection materials.

With this new information may come alterations in design and perhaps technological refits of the current facility to improve it.

Over the next twenty years, what will not change is the requirement for the human infrastructure. It is this infrastructure that performs the research in preservation science, designs the storage facilities on the basis of current science, selects which objects should be stored remotely, assesses the condition of and re-houses the collection items, and maintains the databases to ensure that the collections are accessible. It is this human infrastructure that will continue to provide stewardship of the vast resources of the Library of Congress for the U.S. Congress, the American people, and the world.

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Modules 1-3 as of April 2007. Module 4 and the cold rooms have now been added to the left of Module 3. (Photo by Jon W. Netherton.)