Section 6
Storage Equipment

6.1 - RATIONALE

Most of the space within archival facilities is dedicated to safely storing collection materials. The challenge is to store and protect collections while still providing access to staff and researchers. A key component for success is the careful planning for shelving and accompanying storage equipment, which can include flat files, cabinets, art racks and other equipment that supports and protects collection material.

Storage equipment is a long-term investment for an archival facility that must be planned to meet the specific needs of the facility and reflect the use, size, types, and quantity of its collections. The choice of a shelving system or combination of systems depends on the following factors.

- Size and quantity of the collections
- Building's size and structure
- Shelving costs and budget
- Archival operations – ease of access and retrieval
- Technical considerations
- User preference

While the largest quantity of storage equipment is located in the collections storage areas, shelving and related equipment is also needed in processing areas, research room(s), the receiving area, and in other areas where collections are temporarily stored. When possible, the same standards for materials, construction, performance, safety, and use should be applied.

As institutions look to improve energy efficiency and lower operational costs, high-density systems such as compact mobile and high bay shelving, are increasingly being considered. Fixed and mobile high bay storage systems are becoming more popular as institutions consider developing purpose-built or off-site facilities on less expensive land with smaller footprints for their collections' storage. Designed as part of energy efficient construction, new or repurposed archival facilities are striving to maximize their storage capacity while incorporating environmentally friendly practices.

Some archival and special collections institutions have installed Automated Storage Retrieval Systems (ASRS) to further increase their square foot storage capacity and incorporate sustainable practices. ASRS provide people-free, stable, and dark environments, which allow for safe and fast retrieval of collections.

6.2 - SHELVING SYSTEMS

The choice of a shelving system depends on a number of factors. These include available space and budget, access, and technical considerations.

- Archival shelving can be either fixed (with static aisles) or mobile (with compactable aisles).
- Ranges in height from 7 feet [2.1 meters] to over 45 feet [13.7 meters] for ASRS systems.
- Based on a typical arrangement of 12 inches [30.5 centimeters] between shelves, the number of shelves can range from 7 to 30 shelves high.

6.2.1 - Fixed or Static Shelving

Fixed shelving requires aisle space between each row of shelving. Heights typically range from 7 feet [2.1 meters] to 12 feet [3.65 meters]. [1]

6.2.1.1 - Advantages Include:

- Less expensive to purchase and install than mobile shelving.
- Requires a lower floor load than mobile or high bay shelving.
- Allows for multiple arrangement of aisles (long and short aisles).
- Shorter retrieval time for staff.
    - If shelving is higher than 8 feet, it requires a ladder or lift for retrieval, thereby slowing down the retrieval time.
    - Depending on the jurisdiction, building codes may require sprinkler heads to be installed within the shelving units when these are over 8 feet tall.

6.2.1.2 - Disadvantages Include:

- Requires a larger building footprint than mobile shelving or ASRS.
- Does not utilize space to optimum capacity.

6.2.2 - Mobile Shelving

Mobile shelving is alternatively known as compact shelving or mobile high-density shelving. It is designed so that the shelving is mounted on track-guided carriages that are moved manually, manual assist, or electrically. Rows of shelving sit next to each other, with no intervening aisle, to provide dense storage. Heights range from 7 feet [2.1 meters] to typically 12 feet [3.65 meters].

6.2.2.1 - Advantages Include:

- Higher storage capacity per square foot than fixed shelving.

[1] Shelving over 12 feet high is considered “high bay” storage under the requirements of NFPA 13.

- Smaller footprint saves on initial building construction costs, and reduced energy and facility maintenance costs.
- Ability to provide dedicated, compartmentalized security to specific shelving bays.
- Electrically operated mobile shelving can be installed with "fire mode."[2]

6.2.2.2 - Disadvantages Include:

- More expensive than fixed shelving.
- Requires a heavier floor load than static shelving and may not be feasible in existing buildings without renovations. See Section 2.4.5
- May increase records retrieval time depending on its configuration and the height of shelves.

6.3.2 - High Bay Shelving

High bay shelving can be either fixed or mobile, with heights ranging from 12 feet to 34 feet [10.36 meters]. Staff retrieve collections using lifts.

NFPA 13 restricts the shelving height to 34 feet [10.36 meters] for a maximum of 30 shelves. Additionally, NFPA 13 has specific requirements for fire suppression. In-rack sprinkler installations are not required as long as the high bay shelving system meets specific requirements including: See Section 4.8.

- Designed with "fire park" mode
- Installed with an Early Suppression Fast Response (ESFR) sprinklers
- Specific sized horizontal and transverse flue spaces.
- Solid steel tops over the shelving units
- Fire baffles for mobile systems

6.3.2.1 - High Bay Fixed Shelving

- Higher storage capacity than shorter fixed shelving system.
- Smaller storage footprint saves on initial construction costs and reduced energy and facility maintenance costs.
- Requires lifts for collections retrievals.
    - Requires guide rails or a wire guided system installed in the floor to guide a lift down the aisles for collections retrieval.
    - Eliminates the need for steering and avoid shelving damage and operator injuries.
- Require end of aisle protection barriers.

[2] In electrically operated mobile shelving, upon activation of the smoke detectors, water flow alarm or fire alarm, "fire mode "allows the shelving rows to automatically separate to create minimum 5-inch aisles. This allows the smoke to escape to the detectors and for the water to put out the fire, reducing loss of collections. The electric mobile shelving system can also be programmed to go into "fire mode" when the facility is closed for business.

6.3.2.2 - High Bay Mobile Shelving

- Higher storage capacity than fixed high bay shelving system
- Maximizes floor space.
- Smaller footprint saves on initial construction costs and reduced energy and facility maintenance costs.
- Requires lifts for collections retrievals.
    - Requires guide rails or a wire guided system installed in the floor to guide a lift down the aisles for collections retrieval.
    - Eliminates the need for steering and avoid shelving damage and operator injuries.
- Require end of aisle protection barriers.
- More expensive than high bay fixed shelving.

6.4.2 - Automated Storage and Retrieval System (ASRS)

An ASRS is a computer-controlled system for automatically placing and retrieving collection material to and from storage racks. There are various styles of ASRS, but generally they consist of a mechanized and automated handling system which transports collection material in containers, trays, bins or shelving units from storage vaults to and input/output stations and back again. Sometimes additional conveyance machinery is used for example to transport material to a different room or floor. Bar-coded or RFID-coded containers are retrieved by a robotic crane or a storage and retrieval machine (SRM). Most systems are designed so that no contact is made with the actual archival object or containers, instead the SRM transports the metal tray, bin, or shelving unit on which collection material is stored. ASRS systems can be sized to meet the storage requirement and have been built to storage material as high as 89 feet (27 meters).

6.4.2.1 Advantages Include:

- Highest storage capacity.
- Maximum storage density.
- Fixed or random placement for collections within in the system.
- Smaller footprint saves on initial construction costs and reduced energy and facility maintenance costs.
- Potential for lower long-term maintenance costs than high bay mobile shelving
    - Reduced storage room cleaning costs.
- No lights needed in collections storage for better preservation and energy savings.
- People-free environment.
    - Reduced dust and contaminants may require less air filtration.
    - Ability to store collections in colder environments.
    - Does not require staff to use stairs or operate lifts in collection spaces.

- Faster retrieval than high bay mobile shelving.
- Can operate with or without shelf barcodes.
- Can operate on back-up generator power in an emergency.
- Increased workplace safety than high bay mobile shelving.
- Can be designed with ergonomic input/output stations to reduce physical stress on staff.

6.4.2.2 - Disadvantages Include:

- Highest first-time installation costs than mobile systems.
- Depending on the design of the racking and storage system, manual retrieval of collection material will most likely not be possible. Access to the collection is limited to the number of input/output stations and too few stations could create a bottleneck.
- Retrieval times will be tied to system size, design and performance.
- Planning for moving collections into an ASRS must factor in the expected ‘put away’ times for the ASRS.
- Learning curve for staff as they learn to work with the new system and software.
- Building maintenance staff will have to be trained to maintain the ASRS and respond to faults when they occur.

Table 6-1 Archival Storage Systems Access and Operation

Storage System[3]	**Access Method**	**Operation**
Fixed, 7 shelves high	Ready access or with footstool/small ladder	
Mobile, 7 shelves high	Ready access or with footstool/small ladder	Manual, Manual Assist, Electric
Fixed, 8-11 shelves high	Ladder Access	
Mobile, 8-11 shelves high	Ladder Access	Electric
High Bay Fixed, 12-15 shelves high	Tall ladder or lift	
High Bay Fixed, 16-30 shelves high	Mechanical lifts	
High Bay Mobile, 12-15 shelves high	Tall ladder or lift	Electric
High Bay Mobile 16-30 shelves high	Mechanical lifts	Electric

[3] Based on 12 inches [30.5 centimeters] between shelves.

6.3 - MATERIALS AND FINISHES

Steel is the most commonly used shelving material in archival facilities.

- Steel finished with a factory finished electrostatically applied polyester epoxy hybrid or equivalent finish.
- Solid steel shelves and end panels with smooth, non-abrasive finishes that are resistant to chipping.
- Be free of sharp exposed edges and protrusions, such as exposed nuts and bolts, that are hazardous to staff and collections.
- Other shelving options:
    - Chrome plated steel.
    - Anodized aluminum.
    - Perforated shelves and end panels are available but solid is preferred for fire protections
        - Perforated features are sometimes where extra circulation is desired or to accommodate specific accessories like shelf dividers.

6.4 - PERFORMANCE

Archival shelving units and their shelves must support the weight of the collections without failure.

- Be braced to protect against seismic forces as outlined by the applicable building codes.
    - Bracing should not obstruct frontal access to shelves.
- Shelving units - braced and secured to prevent deflection, leaning or collapse when all shelves are full.
- Capacity of the uprights strong enough to support the shelving units such that they can be installed and loaded to full capacity in any sequence (such as from top down or bottom up or from any location vertically).
- Shelving supports - strong enough to prevent bending or warping when shelving units are full.
- Shelves – no permanent deflection under fully loaded conditions
    - For paper-based materials: 16 by 40 inches [41 by 102 centimeters] shelf should have a minimum load bearing capacity of 200 pounds [91 kilograms] per shelf.
    - For paper-based materials: 32 by 40 inches (81 by 102 centimeters) pass-through shelf should have a minimum load bearing capacity of 300 pounds per shelf.
    - For specialized storage equipment such as cases and cabinets: the shelves should be rated for a minimum of 50 pounds of load carrying capacity for each cubic foot of storage space provided.
- Specifications for the design and testing of shelving are based on ANSI MH28.2, Shelving Manufacturers Association (SMA).

6.5 - CONSTRUCTION

Whether fixed, mobile or ASRS, the archival storage equipment should have similar construction and performance requirements.

- Uprights and bracing: minimum 18-gauge steel.
- Provide top canopy shelves on all shelving units.
- Provide base closures or kick plates on all shelving units.
- Provide metal end panels.
- Minimum height for the lowest shelf is 3 inches off the floor [8 centimeters].

6.5.1 - Shelves

- Shelf thickness: 18 to 22 gauges depending on the requirements of the collections.
- Solid steel with a smooth surface.
- Fully adjustable in 1 to 1 ½ inch increments
- Optimal space utilization uses independently adjustable double-faced shelves (back-to-back) or pass-through shelves.
    - Typical size for paper records is two 16” shelves back to back or one 32” shelf.
    - Do not use cross bracing and metal dividers between double faced shelving units to allow pass thru storage for oversized materials.

6.5.2 - Mobile Shelving Rails

Mobile shelving moves on wheeled carriages over low-profile steel rails. Regardless of installation method, it is critical that the rails be level to prevent drift or movement of the carriages.

6.5.2.1 - New construction

- Recess rails into concrete floor

6.5.2.2 - Existing or remodeled facilities

- Rails are installed over existing concrete floor.
- Platforms are installed that are built up to track levels.
    - Recommended: platforms made of steel or aluminum
    - Not recommended: platforms made of plywood
    - Install to allow carts to be easily wheeled over the rails and to prevent staff from tripping over the rails.

6.5.3 - Mobile Shelving Carriages

Construct the carriages of a mobile shelving system with a sufficient strength-to-weight ratio to prevent binding, racking and misalignment.

- Minimum structural deflection as determined by structural engineer.

    - Carry the specified weight of collections stored on it without distortion and should evenly transfer the weight onto the wheels.
- No fasteners that can loosen or break.
- Balanced wheels for a smooth operation of carriages.

6.5.4 - Automated Storage Retrieval Systems

ASRS systems have the same requirements for construction stability, durability, reliability, material and finishes, and safety for collections and staff as the other types of storage. Additional requirements are:

- ASRS racking must be floor mounted and free standing. It must not support the building structure.
- ASRS controls are capable of receiving and processing instructions from the institutions' collection management software system.

6.6 - LAYOUT

Shelving comes in a variety of sizes. Develop a shelving plan to identify:

- The various sizes and quantities of shelving and storage equipment needed.
- Optimal aisle spacing.
- Efficient layouts for the stacks that take into consideration columns, doors, and access requirements.
- Comply with OSHA, state, and local regulations to ensure the best possible access and safety compliance.

6.6.1 - Configuration

Arrange shelving in configurations that make maximum use of floor space while still conforming to fire and life safety regulations. Shelving is usually arranged in rectangular blocks with one or more main transportation aisles. ASRS will have a transportation aisle for each required storage and retrieval machine (SRM).

6.6.1.1 - Avoid

- Locating under water pipes.
    - If under pipes, see Section 2 for mitigation measures, including containment piping or drip pans.
- Locating against un-insulated exterior walls.
- Locating against heat sources.

6.6.1.2 - Interior walls

- Install shelving units or other storage equipment at a minimum of 1 inch from any interior wall in a collections storage area.
    - To avoid heat and cold radiation.
    - To protect collections from any water running down the walls from overhead leaks.

6.6.1.3 - Exterior walls

- Install shelving units or other storage equipment a minimum distance of 18 inches [45.7 centimeters] from any exterior wall in a collections storage area.
    - To avoid heat and cold radiation.
    - To protect collections from any water running down the walls from overhead leaks.
    - Allows for air circulation and inspection and repair of exterior walls without relocating the collections.
    - The impact on usable storage space is reduced if the circulation aisles are located along the exterior walls.

6.6.2 - Width of Main Aisles

The widths of main aisles in collections storage differ depending on the type of shelving system used:

- Fixed or mobile shelving - main aisles should be at least 48 inches [1.2 meters] wide.
- Fixed or high bay mobile shelving - main aisles should be at least 12 feet [3.7 meters] wide to allow space for lifts and retrieval equipment.
- ASRS – main aisle dependent on size of the storage and retrieval machine (SRM).

6.6.3 - Width of Stack Service Aisles

The widths of the service aisles between ranges of shelving are different depending on the type of shelving system and/or the size of the collections being stored:

- Standard stack service aisles - minimum of 36 inches [91 centimeters] wide and 42 [x centimeters] is preferred.
- Oversized records - the service aisles may need to be wider to safely access oversized materials.
- High bay shelves that require the use of lifts are a minimum of 54 inches [137 centimeters] for a narrow aisle lift and larger for other kinds of lifts. Consult with the high bay shelving provider for appropriate aisle size.

6.6.4 - Length of Stack Aisles

The maximum length of the stack aisles for any archival facility will be dictated by:

- Footprint of the facility.
- Location of entrances and exits.
- Codes for egress and life safety.
- Type of shelving system.
- Accessibility requirements.

6.6.4.1 - Long aisles

- Long aisles provide greater collections storage density within a stack.
- Longer stack aisles require more time it takes for staff to retrieve records.
- Consult the life safety codes for the maximum length of a storage room aisle.

6.6.4.2 - Mobile storage systems

- Manual systems - are limited to ranges measuring up to 45 feet [13.7 meters] in length.
- Electric systems - standard lengths are up to 81 feet [24.6 meters], but they can be as long as desired by the user within code restrictions.

6.7 - DIMENSIONS

6.7.1 - Height of Shelving Systems

6.7.1.1 - Standard

- Traditionally, the height of shelving in an archival facility was set so that the average person could reach the top shelf without the aid of a footstool or ladder.
- Standard shelving height - 84 to 90 inches high [2.1- 2.3 meters].
    - Provides 7 shelves with 12 inches between shelves [30 centimeters].

6.7.1.2 - Taller Than Standard

It is increasingly common to install taller shelving to increase density because of the higher costs for land, construction, operations, energy, and maintenance.

- The optimum height of the shelving in archival facilities is determined by the building's ceiling heights and the fire suppression system.
- With higher ceilings, archives planners may opt to install shelving that is taller than 90 inches [2.3 meters], thereby providing more storage space per square foot for records.
- Generally, each addition of another shelf above seven feet [2.1 meters] increases the total storage capacity of a storage room by more than 14 percent.

6.7.1.3 - High Bay Fixed or Mobile Systems

- Shelving heights at maximum 34 feet high [9.1 meters].
- Example: high bay mobile storage at the Zhang Legacy Collections Center at Western Michigan University is 32 feet high [9.75 meters].

6.7.1.4 - ASRS systems

- Can be installed at heights greater than 34 feet [10.36 meters].
- Example: the ASRS at the Utah State Archives is 45 feet tall [13.7 meters].

6.7.2 - Height of Bottom Shelf above the Floor

Minimum height of the lowest shelf in a shelving installation is 3 inches [7.62 centimeters] off the floor to prevent damage to the collections from flooding.

6.7.3 - Vertical Storage Space between Shelves

Shelves are typically spaced 12 inches [30.5 centimeters] apart for textual records stored in archives or cubic-foot boxes (records center type boxes).

- Provide a minimum of 11 inches [28 centimeters] of clear vertical storage space between each level of installed shelves for textual records and collections stored in cubic foot boxes.
- Provide adjustable shelves so that adjustments can be made for non-standard sized boxes, books, ledgers, oversized materials, and special media records.

6.7.4 - Shelf Size

Maximize storage capacity by using shelf sizes that efficiently store the collections with little wasted shelf space. There are preferred shelf sizes that accommodate the use of archives boxes, cubic foot boxes, and some special media records.[4] Additionally, there are commonly used shelving sizes for efficient book storage. Large volumes, oversized materials, and special media records require specialized shelving sizes or other kinds of shelving equipment.

6.7.4.1 - Archival shelving uses single or double-sided deep shelving units.

- Generally, archives shelve boxes using single sided shelving units.
- Records Centers and some archives increase the storage density and shelve using double-faced, double deep shelving units.

6.7.4.2 - Measurements

- Standard sized archives boxes or cubic foot boxes: the most common shelf size measures:
  - 40 inches long by 16 inches deep [41 by 102 centimeters] for single faced shelves.
  - 40 inches long by 32 inches deep [81 by 102 centimeters] for double faced shelves.
  - Allows for storage of standard boxes and oversized items.
- Book Collections: the typical library shelf measures
  - 36 inches long by 10 or 12 inches deep [91 by 25 or 30 centimeters] for single faces shelves.
  - 10-inch deep shelves are the most common for standard sized book collections.
- Other effective shelf size options can be considered depending on stack size and configuration, access requirements, frequency of use, size of the collections, and the budget.
  - Shelving boxes double deep requires different shelving sizes.
  - ASRS shelving may have different shelving sizes to accommodate trays, bins or containers used in the retrieval process.

6.7.4.3 - Shelf length:

- The 40 inches [102 centimeters] shelf length should provide at least 38 inches [97 centimeters] of clear horizontal storage space.
  - A 40-inch-long shelf will house 7 archives boxes or 3 records center boxes.
- An efficient high bay shelf length for cubic box storage is a 50 inch [127 centimeters] long shelf.

[4] An archives box, also knows as a flip top box or a Hollinger box, holds folders containing paper documents stored vertically. It comes in letter size (12 ¼" W x 10 ¼" H x 5" D) and legal size (15 ¼" W x 10 ¼" H x 5" D). A cubic foot box, also known as a records center box, holds approximately one cubic foot of records and is designed to hold either legal or letter size files (12" W x 15" L x 10" H). Some Canadian institutions use a typical box that is greater than a cubic foot.

    - A 50-inch long shelf will house 4 records center boxes.
- For many manufacturers, their standard shelving lengths are a 36 inch [91 centimeters] library shelf and a 42 inch [107 centimeters] “archives” shelf.
    - A 42 inch [107 centimeters] shelf will hold 8 archives boxes or 3 records center boxes.
    - With a 42 inch [107 centimeters] shelf there is some loss of efficiency if storing record center boxes.

6.7.4.4 - Shelf depth

- A 16 inch [41 centimeters] shelf depth ensures that standard archival boxes will not extend beyond the face of the shelf.
    - When installed as double-faced units, without cross bracing or dividers, the depth of the back-to-back or through shelves is a minimum of 32 inches [81 centimeters].
- High bay fixed shelving may use two 32-inch-deep shelves [81 centimeters] back-to-back with a 6-inch [15.2 centimeters] longitudinal flue space in between the shelves and a 3-inch [7.6 centimeters] transverse flue space between the shelving units.
    - This allows the user to stack boxes two deep on a shelf thereby increasing capacity.
    - This is especially useful for storage areas that have collections with low retrieval rates.
- For many manufacturers, their standard shelf product measures 15 inches deep [38 centimeters].
    - On fixed shelving, archives boxes will extend beyond or hang over a 15 inch [38 centimeters] shelf thereby risking box damage.

6.8 - ACCESSORIES

Accessories are available that help maintain the collections on the shelves or help staff when referencing and retrieving collections. Accessories include:

- Book supports to keep books/volumes upright on the shelf.
- Pull out work shelves (also known as sliding reference shelves) to aid staff reviewing materials in the shelving aisle.
- Multi-media shelves to provide efficient storage of videos, cassettes, and other media type materials.
- Back stops or back panels for shelving against interior walls or as needed to protect materials from falling off back of shelf.
- Dividers
- Signage
    - Includes card holders, range finders, custom sign holders

6.9 - OVERSIZED AND SPECIAL STORAGE

Oversized collections and three-dimensional materials (3-D) require the use of specially sized shelving, flat files, cabinets and racks. The guidelines for the materials, construction, performance, safety and use of oversized shelving are the same as those for more standard sized archival shelving.

6.9.1 - Oversized Textual Collections

There are several options for the safe storage of oversized textual collections such as maps, plans, posters, unframed art, etc. Oversized textual collections should be stored when possible unrolled and unfolded in oversized folders in flat files. Other options:

- Oversized boxes fabricated to size.
- Storing rolled plans in bags or tubes on open shelving.
- Storing rolled plans on brackets fastened to the wall.

6.9.1.1 - Flat Files/Map Cases

- Flat files can be stacked 3 to 5 high.
- Flat files can be stacked and installed on mobile shelving carriages.
- Size the aisle width between rows of flat files wide enough to accommodate a fully opened drawer and for a staff member to safely retrieve oversized materials.
- Drawer specifications
    - Open and close smoothly, reducing vibrations to items.
    - Include stops to prevent them from falling out of the cabinets.
    - Include dust covers or rear hoods to prevent items from damage when opening or from bulging at the back of the drawer.
    - Size of drawers in flat files are maximum two inches deep [xx]
        - One inch [xx] and two-inch [xx] drawers are both popular.
        - The deeper the drawer, the greater the weight on the items, and the more difficult it is to remove an oversized document from the drawer.

6.9.1.2 - Racking systems

Racking systems, also known as art racks or art screens, are used to safely and efficiently store framed items. Racks come in a variety of installation options:

- Interior wall mounted racks/screens.
- Ceiling supported pull out racks.
- Floor supported lateral pull out racks.
- Floor mounted pull out racks.
- Modular, free standing pull out racks.
- Carriage mounted racks on mobile carriages.

6.10 - COLD STORAGE SHELVING

Open, through-style chrome plated stainless steel wire shelves or racks are recommended for boxed material housed in cold storage areas, usually those with temperatures below 50 degrees Fahrenheit [10°C].

- Chrome shelving provides good air circulation and prevents condensation from gathering on containers.
- The recommendations for the materials, construction, performance, safety, and use of cold storage shelving are the same as those for more standard sized archival shelving.
    - The guidelines in 8.3 and 8.4 also apply to the cold storage shelving.

6.11 - CABINETS

Cabinets provide closed storage for materials that require extra protection or security.

- Cabinets can be ordered with specially sized shelves or drawers.
- Cabinets for the storage of artifacts are available with gasket seals to protect against dust and contaminates.
- Filing cabinets are used for the storage of textual collections.
- The recommendations for the materials, construction, performance, safety and use of cabinets are the same as those for more standard sized archival shelving.
    - The guidelines in 8.3 and 8.4 also apply to cabinets. for guidelines on shelving and cabinet materials and finishes.