International Standard

ISO 11799

Third edition
2024-09

Information and documentation— Document storage requirements for archive and library materials

Information et documentation—Exigences pour le stockage des documents d'archives et de bibliothèques

Reference number
ISO 11799:2024(en)

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Foreword

ISO (the International Organization for Standardization)is a worldwide federation of national standards bodies (ISO member bodies).The work of preparing International Standards is normally carried out through ISO technical committees.Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee.International organizations, governmental and non-governmental,in liaison with ISO,also take part in the work.ISO collaborates closely with the International Electrotechnical Commission(IEC)onall matters ofelectrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives,Part 1.In particular,the different approval criteria needed for the different types of ISO document should be noted.This document was drafted in accordance with the editorial rules of the ISO/IEC Directives,Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards,the meaning of ISO specific terms and expressions related to conformity assessment,as well as information about ISO's adherence to the World Trade Organization(WTO)principles in the Technical Barriers to Trade(TBT),see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 46,Information and documentation Subcommittee SC 10,Requirements for document storage and conditions for preservation.

This third edition cancels and replaces the second edition (ISO 11799:2015),which has been technically revised.

The main changes are as follows:

— updated content to reflect ISO standards/technical reports published after the second edition,including ISO/TR 19814 and ISO/TR 19815;

— increased detail and guidance on facility requirements and considerations.

Any feedback or questions on this document should be directed to the user's national standards body.A complete listing of these bodies can be found at www.iso.org/members.html .

Introduction

Archives and libraries are institutions established to collect,preserve and make materials intended for consultation available.

Archive and library collections,wherever they are stored,normally contain a wide variety of materials and formats.These are mainly documents on paper,parchment,palm leaves,papyrus and generally also include photographic,audio-visual documents and digital formats on diverse types of carriers (mechanical, photographic,magnetic,optical).All these materials ideally require specific storage conditions to ensure theirlong-term preservation and access.Note that separation by media type is rarely possible in archive and library storage settings,and that most collections will include a variety of materials.

NOTE See ISO 18934[3 and ISO 189111] on storage of specific materials.

In a number of fields,national or local building regulations can encompass such matters as construction, safety and security for public buildings and buildings in which valuable objects are stored(fire precautions, emergency exits,security against earthquakes,theft,burglary,terrorist acts,etc.),as well as services and equipment in professional use.This document therefore avoids detailed rules and regulations in these fields, except when recommending what can be added to these requirements.

This document presents some facts and general rules to be considered when a purpose-built repository is designed,when an old building originally designed for another use is converted,or when a building already in use as repository is renovated,with respect to energy efficiency and sustainable development.The same applies for underground storage facilities which are intended to function as or are already in use as storage facilities.

This document applies to the long-term storage of archive and library materials.It takes into account that the materials are stored and must allow active usage as well.Note that this document is about the design and construction requirements for archive and libraries storage spaces.ISO/TR 19814[Z] and ISO/TR 198158 serve as companion documents which guide program activities and operations once the physical structure of the store is in place.As such,this document also does not specifically address the design or construction requirements of support spaces to collections storage areas (e.g.supplies storage,receiving areas,and quarantine spaces).Throughout this document,the term"repository"is used to refer specifically to a collection's storage space,as opposed to a broader facility which may include a repository as well as other support spaces.

Depending on the climate and economic situation of individual institutions,it can be difficult to create and maintain optimal conditions for the long-term storage of archive and library materials.In these cases,it is expected that the institution will choose a path that meets the most appropriate compromise given needs and resources.Information that factors into these decisions should be documented with overall project documentation (see 5.3)to inform future professionals as to the decisions made and why.

Information and documentation—Document storage requirements for archive and library materials

1 Scope

This document specifies the required characteristics of repositories used for the long-term storage of archive and library materials.It covers the siting,construction and renovation of the storage facility,and the installation and equipment to be used both within and around the building.

This document applies to all archive and library materials held in repositories,where mixed media can be stored together with paper-based materials.It does not preclude the establishment of separate areas or compartments within individual repositories,where the environment can be controlled to create conditions suitable for the needs of specific archive materials.

This document does not specify exhibition or display guidelines.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document,the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

—ISO Online browsing platform:available at https://www.iso.org/obp

—IEC Electropedia:available at https://www.electropedia.org/

3.1
archive and library material
all types of documents kept in archives and libraries regardless of their physical format,mainly books, manuscripts,files,maps,graphic collections and other documents consisting of paper,but also parchment, papyrus,films,photographic materials,audiovisual recordings,magnetic and optical media,as well as bindings and protective material

3.2
building fabric
materials that enclose the interior of a building,separating the interior from the exterior (walls,floor and roof)and includes a number of different materials that collectively form the external envelope of the building

3.3
document
recorded information or material object which can be treated as a unit in a documentation process

3.4
environmental monitoring
recording and analysis of various environmental conditions -including temperature,relative humidity, light,vibration,or other factors-which impact the long-term preservation of collections materials

3.5
hazard
source of potential harm to collections

Note 1 to entry:Broad examples may include events such as earthquakes,fires,theft,or others.

[SOURCE:ISO 21110:2019,3.7,modified—Collections was specified in the definition;Note 1 to entry was replaced.]

3.6
integrated design
collaborative method for designing buildings which emphasizes viewing the building as an interconnected and interdependent whole rather than an accumulation of its separate components

Note 1 to entry:For cultural heritage,this includes the involvement of collections and facilities specialists as part of the design team.

3.7
life expectancy
length oftime that information is predicted to be retrievable in a system under extended storage conditions

Note 1 to entry:Life expectancy designation (LED)is a rating in years for the life expectancy of records,e.g.,LE-1000, indicates that the records are expected to be usable for 1000 years.

[SOURCE:NISO TR01-1995]

3.8
long-term storage
storage,for a period of undefined length,of material kept for permanent retention

[SOURCE:ISO/TR 19815:2018,3.22]

3.9
maintenance
actions of prevention or correction to support long-term functionality of repositories and the systems that support them.

[SOURCE:EN 13306:2010]

3.10
repository
building,room,or space designed or arranged and used specifically and exclusively for long-term storage of *archive and library materials (3.1)*

3.11
risk
effect of uncertainty on objectives;the potential for damage occurring to collections materials from a particular hazard based on likelihood,frequency,or progress

Note 1 to entry:Adapted from ISO 21110:2019[4]and Preventive Conservation:Collection Storagel51]

4 Sustainability—Collections storage and preservation

4.1 General

Conserving archival and library heritage for generations to come includes sustaining protective storage that presents very low risks to collections.Understanding and minimizing the running costs,energy use and carbon emission potential of maintaining collections in good condition indefinitely is essential to their long-term conservation,in order not to contribute to wider ecological and environmental hazards which themselves would threaten to undermine the practice and purpose of conserving collections.Institutions should strive to invest in building structures that will last for a minimum 100+years,while recognizing that internal systems (mechanical,lighting,sustainable technologies)will by necessity require reinvestment on ~30 year cycles.This reinvestment cycle also allows for the inclusion of new technologies and new scientific knowledge on a periodic basis.

4.2 Specifying storage spaces/conditions

In setting out to design or review the qualities of a storage facility intended to hold archival and library materials,the nature and use of these materials shall be defined and the range of safe storage conditions shall be identified accordingly.Note that recent research has shown that many archival materials can tolerate certain seasonal ranges of environmental conditions without adversely affecting longevity (see Annex B). Using these environmental ranges,in conjunction with proper housing/packaging for materials (such as archival quality boxes,folders,and sleeves where appropriate)can reduce the overall energy consumption, and improve the long-term sustainability,of the storage facility.

Temperature-sensitive materials that profit from or require storage at especially low temperatures (e.g.cellulose acetate film and colour media)and acutely moisture sensitive materials that require dry microclimate packaging (e.g.polyester-base magnetic tape)shall be identified,packaged and stored accordingly in microenvironments so that there is no need for the constant operation of specialized environments throughout the year for the entire archive andlibrary collection.Please note thatthis standard does not address specific design requirements for frozen collections storage facilities,but that envelope and mechanical specifications for these environments will differ from standard storage construction.Frozen storage facilities for long-term preservation shall always be kept separate from frozen environments for quarantine (pests,mould,etc.)purposes.

An organization planning a new or renovated collections storage facility shall explore the potential for designs which incorporate the following characteristics:

— envelope designs and site/facility layouts which mitigate or buffer the majority of external energy loads;

— the possibility for a non-mechanically-controlled 〔or primarily non-mechanically-controlled〕 environment that can maintain appropriate conditions throughout the course of a year (whether in a seasonal or steady climate);

— a high material volume percentage storage design(i.e.,an efficient storage design where the volume of material in the space is significantly higher than free air volume);

— the use ofuninsulated ground-contact floor slabs which provide a heat/energy sink that mitigates energy loads on an upper structure;

— appropriate and effective vapor control layers or seals in allstructural elements.

5 Design planning

5.1 Identify design participants

All construction projects involving the storage of archives and library collections shall utilize an“integrated design”approach that includes:

— the participation of staff from the organization,including preservation and/or collections management staff and facilities/operations staff;

— applicable external experts in the design and operation of collections preservation environments (beyond the general architecture/engineering team);

— relevant architectural and engineering disciplines to the specific project.

This team involvement should initiate as part of predesign and establishment of program requirements and continue through to construction and final building/mechanical commissioning.

The nature and needs of collections storage facilities,whether new facilities,renovation projects,or adaptive reuse,require careful consideration of appropriate design requirements for both collections and sustainable operation;while this standard provides general requirements and guidance,these cannot be applied universally.Relevant staff and external experts,who are intimately familiar with any existing conditions as well as future needs for collections objects,shall be included to inform the appropriate balance between facility design for preservation,sustainability,historic preservation concerns,or other factors.

Note that the design of a storage space is often subject to local regulatory body review and approval.

5.2 Establish design priorities

Design priorities for archive and library storage facilities will vary depending on the institution and its specific needs and resources.Before jointly addressing design specifications as a team,the institution shall carefully define its expectations relative to a series of factors to guide the design and construction process. Those factors should include:

— available budget or budget limitations;

— expected preservation quality/collection longevity;

— need for specialized storage environments (frozen,dry,high security,etc.);

— size/extent of collections to be stored in each storage environment;

— sustainability requirements (including construction materials,operation,etc);

— achievement of target environmental conditions;

— expected building longevity;

— aesthetic architectural requirements;

— occupancy expectations and access requirements(public or staff only,etc.);

— future collections growth requirements;

— disaster risk prevention.

5.3 Establish design specifications

The institution shall,with the assistance of external consultants and designers as appropriate,establish an initial set of design specifications and program requirements to guide the design and construction process. These are to serve as an initial informative document to the broader design team to establish expectations for the finished facility,and should include factors as addressed in Clause 6, including:

— design environmental ranges for storage zone(s);

— any preferred systems or requirements for:

  — building envelope;

  — mechanical systems;

  — lighting;

  — fire suppression;

  — security;

  — flooring;

— storage furniture;

—planned occupancy patterns and storage capacity;

—preferred operational or control characteristics.

Design specifications and program requirements may be updated throughout the course of the design and construction project,based on the findings and decisions of the integrated design team.Original and successive versions shall be preserved as part of the project documentation to record original intent versus the negotiated final design and construction.

5.4 Risk assessment

5.4.1 General

A risk assessment shall be carried out when deciding where to locate a new building or collection space intended to house cultural heritage collections,whether for storage,display or other use.Existing sites, buildings or rooms,vaults,or caves housing collections shall be re-assessed against risks periodically, particularly when new hazards are known to have emerged.Information and data shall be gathered and assessed in order to formulate site and design requirements to meet applicable environment,security,fire, flood,earthquake,landslide and other protection standards and regulations in any new or renovated facility. As part of the risk assessment,the methodology and steps below shallbe included.The risks set out in the following clauses shall be considered when:

—planning,constructing or adapting the building or collection space (including risks associated with the construction works themselves,in an existing building),

— equipping the building,and

—managing the building once in use.

NOTE For details,consult ISO 21110[4] and ISO 310006.

5.4.2 Hazards to collections

The nature and use of the collections to be housed shall define requirements for the qualities and design of a building or room in which they are to be placed.The organization shall identify the hazards that affect its collections and evaluate the likelihood and impact of those hazards occurring.The following hazards are common to cultural heritage collections and shall be assessed:

—fires;

— water(fresh water supply and wastewater);

— natural events (torrential rain,strong winds,flooding,landslide,snowslide,earthquake,wildfire, lightning,etc.);

—environment (internal and external):unsuitable/inappropriate temperature,humidity,light and pollution including gaseous and particulate (see Annex B and Annex C for examples of guidance information regarding environmental risks and sensitivities of collection materials),

—load-bearing capacity;

—bio-deterioration (pests and mould,endogenous decomposition);

— theft,robbery;

— risk of war or conflict;

— vandalism (including arson).

The hazards associated with the location of a building shall be identified in accordance with local and national guidance (i.e.flood zones,expected sea rise,etc.).The location within a building of activities and services that may create a hazard,e.g.kitchens,laboratories,water storage tanks,oil tanks,combustion equipment,HVAC systems,and electrical switchgear shall be taken into account in the risk assessment. Handwash and sanitary installations within storage areas should be avoided and internal water pipe runs should be avoided.

5.4.3 Site risk assessment

5.4.3.1 Hazards identification

When selecting a site for a new construction or reviewing an existing building (above-or below-ground) a risk assessment shall be undertaken to identify and document the hazards of each potential site and the likelihood of each of the identified hazards causing damage.Specific hazards may include those that result in the sudden loss of,or extensive damage to collections (e.g.the collapse ofthe building,fire,flood orlandslide) or those hazards that can result in damage over time (e.g.insect attack,pollution or climate).

Correlations of individual risks should also be taken into consideration.When selecting spaces within an existing building (whether part or whole)for re-use for heritage collections,a risk assessment shall be undertaken with reference to the strategy outlined in 5.4.1.It is recognised that in many cases natural hazards due to the local climate (e.g.high temperature and relative humidity,risk of hurricanes or cyclones) or geology (e.g.risk of seismic activity)cannot be eliminated and must be accepted and mitigated as far as possible.

Local planning and environmental regulations will always influence where a building is located.No site can be completely free from hazards,but when selecting and planning for a new construction,the probability of the hazards identified causing loss or damage to heritage materials,and the potential cost of mitigation or recovery,is to be assessed and taken into account.

The risk assessment shall include but does not have to be limited to more common hazards associated with the following:

- natural hazards
  - flooding,water penetration (from the sea,rivers and lakes,rainwater and snowmelt),including current and projected water/sea levels/rainfall rates;
  - landslides,avalanches,sink holes,uplift,seismic and volcanic activity;
  - wildfire(from nearby dry vegetation,lightning)
  - hurricanes,tornados or cyclones;
  - solar flares or other events impacting magnetic fields;
  - underground radioactive materials,such as radon.
- human-made hazards
  - road,rail,mining or similar tunnels under or close to the building or elevated roadways,railways orr tramways (e.g.risk of collapse or excessive and regular vibration);
  - sites or areas used for the storage or processing of highly flammable materials (e.g.petro-chemicals, explosives,paint and tyres)at risk from fire or explosions,or at risk from water or chemicals used to deal with such hazards;
  - sites on or adjacent to a place emitting harmful gases,pollutants,smoke,dust,etc.or vibration sources,such as open cast mining,incinerator,cement works,etc.;
  - sites adjacent to a place or activity that will attract rodents,insects and other pests,such as food storage or processing,waste management,landfills,etc.;

— nuclear power stations,plants or other radioactive facilities (including waste and storage sites);

— airports and their associated flight paths;

—high voltage power lines and substations (risk of e.g.collapse or fire);

— defence and other target establishments;

—buildings and places that may become the focus of civil disturbances;

— strong magnetic fields (artificial).

In order to minimize the harmful effects of exposure to sunlight and strong winds that affect air infiltration, careful attention shallbe paid to orientation,landscaping and the site's microclimate.Selection of a new site that is below the 1%(100 year')flood level shall be avoided,if possible.Where a history of springs and underground watercourses exists,these shall be taken into account as heavy and prolonged rainfall may reactivate them.

5.4.3.2 Accessibility of site

In addition to assessing the likelihood and impact of the above,an assessment shall be made of the accessibility of the site to emergency services at all times.The accessibility to the site includes the likely call out time of fire and other emergency services.This is especially important if the building site is remote or accessible only through dense traffic or narrow streets.For example,remote buildings may need additional fire protection measures to allow for additional time for fire service response.The site should include safe and secure transportation spaces,unobstructed access to the building for larger vehicles while at the same time meeting security standards.Sites should have multiple access points;in the aftermath of natural disasters or other events,single-point entry may be blocked,leaving the facility inaccessible.

5.5 Location of repository within structure

For new facilities,the repository location in relation to other aspects of the facility (occupied work areas, receiving areas,etc.)shall ideally be located in one of two areas:

—Central to the facility,surrounded onall sides by other environments/zones which buffer the repository from the exterior environment.Depending on exterior conditions,this can both reduce overall energy loads on the repository,as well as protect it from any failures of the exterior envelope.

— Away from direct sun exposure;in the northern hemisphere this may be on the north side of a facility, with other building programs/elements located on the south side,with the reverse arrangement for the southern hemisphere.While the repository may still have direct exposure to the exterior envelope,thee majority of the heat load will be buffered by other sections of the building.Note that this arrangement may be superseded by other risk factors on the site.

5.6 Subgrade storage considerations

Subgrade storage facilities (underground vaults,cave systems,or larger human-made facilities)can be used to great effect for long-term storage and preservation,and have a number of advantages over above-grade facilities (such as lower and more stable temperature),provided certain risks can be managed.Institutions considering the use of subgrade storage facilities shall specifically account for:

—knowledge of ground-water levels and the likelihood of groundwater rise over time;

—intrusion of surface water;

—in natural vaults/caves,an understanding of the geologic makeup and content of the surrounding strata, specifically as it pertains to preservation risks;

— appropriate water and moisture control,either through envelope design or mechanical intervention;

— the provision of ventilation/fresh air even if the storage environment is not occupied full-time;

—the provision of appropriate fire protection systems;

—the assurance of structural stability(whether natural or man-made);

—multiple paths of ingress/egress.

Using subgrade storage in suitable geographic settings and with the correct design can often provide for appropriate preservation conditions with a minimum of mechanical intervention or energy expenditure, greatly increasing the overall sustainability of the storage solution.Institutions shall consider:

— natural ambient subgrade temperatures,and whether those are suitable for preservation needs without mechanical control;

— designs which strive for overall passive operation;

— unoccupied facilities (no permanent workstations)which require a minimum of ventilation/fresh air.

6 Building materials and assembly

6.1 Building fabric and environmental protection

6.1.1 General

The influence of outdoor climate conditions on indoor environments is partially determined by the construction and quality of the building fabric.The external building fabric of storage areas should be designed to contribute to a stable internal environment appropriate to the preservation of the collection.A new building designed to provide an environment requiring climate control(e.g.heating in winter,or cooling in summer)shallbe capable of maintaining specified conditions in the event of the failure of the equipment for a minimum of 48h or until alternative arrangements can be made.

6.1.2 Insulation and thermal stability(Thermal)

This can be partially achieved by constructing the external walls,roof and floor of the building from materials that,as far as possible,protect the interior from temperatures that are greater or less than internal conditions,and from the impacts of external temperature changes.

The two principal components of this are:

—thermal mass-the capacity of the building fabric to absorb,store and release heat.The buffering effect reduces rapid temperature fluctuations within the storage environment.

—insulation -If allowed to heat or cool from prolonged external conditions the fabric will absorb this energy and release it at aslower rate into the storage environment.Insulation on the external face of thee thermal mass will delay its temperature change when the external temperature is greater or less than that of the thermal mass.

New repository construction shall include sufficient thermal mass/insulation to mitigate external temperature changes to either:

— allow for passive interior environmental control (in the interest of sustainable operation)at acceptable preservation conditions;

— or to minimize thermalloads sufficiently to reduce the mechanical intervention necessary to achieve the selected preservation conditions.

Existing facilities/repositories should strive to retrofit,where possible,by means of addition of insulation to appropriate floor,wall,or roof structures.This process will likely require specialist input into the overall appropriate envelope structure.

External weather conditions should be assessed to evaluate the impacts of temperature on the performance requirements of the thermal fabric.Permanently higher or lower temperatures than the internal conditions will not be stabilised by insulating the thermal mass as it willget heated or chilled over a long duration.

6.1.3 Airtightness

For the insulation to perform effectively the fabric also needs to be protected from air leakage.that is the leaking of controlled internal air to the outside through gaps in the construction and the uncontrolled external air replacing it.

New construction should incorporate an air seal strategy.The air seal membrane may be achieved through products such as paper-based building wrap products or utilizing the vapour seal membrane.Where two storage repositories are connected,or a storage repository links directly to another room or corridor that is not maintained at the same environmental conditions,an air seal shall be used in the wall/zone envelope separating the two spaces.Airlocks may be utilized at entrance points as necessary;the layout of the airlock shall allow for the movement of staff and collections.

Consideration shall be given to the type and position of an airtightness membrane within the wall structure to prevent the risk of interstitial condensation forming within the external fabric of the building[30].

6.1.4 Hygroscopicity/permeability (Vapor)

Fluctuations in humidity are reduced by maintaining an appropriate temperature range but can be further protected by construction practices.

— One option is to provide a hygroscopic face (such as open-textured concrete block finished in water-based paint)to the internal surfaces of the repository,which provides for internal moisture buffering utilizing the structure.This should be used in association with a vapor control layer to mitigate thee passage of moisture vapor between outside and inside.

— Another is to seal the interior surfaces of the repository against moisture absorption,and rely on mechanical intervention to specifically manage interior relative humidity conditions.This may reduce overall moisture content in the structure if that is an overall concern.

Moisture passes through a structure both with and independently of air leakage.Institutions shall identify and implement a vapor control strategy;this shall be considered independently of airtightness.

Vapor permeability is the measure of how quickly water vapor will diffuse through a particular medium from areas of high vapor pressure to low vapor pressure.Building fabric with a high permeability will allow moisture to diffuse through the structure quickly,making it more difficult to keep moisture out and dehumidify in humid environments or to maintain interior moisture levels when humidifying.Envelope structures (whether at the whole-building level or for an interior zone/space)with a low vapor permeability slow the rate of diffusion and make it easier to control and maintain appropriate dew points in collections environments through humidification and dehumidification.For existing structures where the inclusion of the vapor membrane may not be feasible in the original wall structure,application may be achieved through the construction of an interior added wall or surface.The design of this new wall for thermal and vapor control shall be determined by a qualified professional.

Vapor control can be achieved through the use of membranes in the external building fabric;their location is relative to the thermal insulation,typical outdoor conditions and direction of vapor movement to prevent the risk of interstitial condensation forming[30].The penetration of these membranes can result in the loss of local vapor control,and can lead to inappropriate internal microenvironments or damage to the envelope structure.Any penetration through the finished envelope or membrane shallbe well-sealed.

6.1.5 Air pressurization and repositories

All repositories shall be neutral or positively pressurized relative to their surrounding spaces(whether internal or outdoors).Positive pressurization requires the mechanical addition of outside air,which is often a primary source of energy (heat and moisture)and pollutant (particulate or gaseous)load,into the repository.Design and program strategies such as non-occupied repositories and balanced airflow designs intended for full recirculation capacity can reduce the reliance on outside air for reasons other than pressurization,and allow facilities to operate at a closer to neutral condition.

Local regulations might not require small repositories,such as high-security vaults and microenvironment spaces within a larger storage facility to have external air intake;neutral pressurization should be considered for these spaces due to their location within a larger collections preservation environment.

No archive or library repository shall be designed to operate at a negative pressure condition relative to its surroundings.Doing so allows the uncontrolled movement of air,moisture,and pollutants into the repository.

6.1.6 Modelling

All planning and design process for new or renovated storage repositories should undergo a comprehensive modelling process.Assessment of the impact of the external environment on internal conditions will require dynamic thermal and hygroscopic modelling,year-round weather data will be required for the location of the site to determine how normal external weather conditions can affect internal conditions and the building structure designed to remain within required conditions when these changes occur.

The model should also be used to predict the impacts arising from changes in external environment,such as extreme weather conditions so that mitigation strategies can be established.Future climate change can impact the accuracy of modelling based on historic data;modelling processes should include predictive elements of worst-case climate change scenarios based on the expected lifespan of the structure.

When undertaking modelling of the internal environment account should also be taken of the hygroscopic capacity and the thermal mass of the collection,including its packaging and placement within open or closed shelves or furniture.However,if it is not planned to fill the collection store initially the model should reflect the quantity of material that is to be initially stored.

6.2 Building materials and stability

6.2.1 General

Expert advice shall be sought from appropriately experienced building design professionals when the design or re-design of a building is planned.The fire and rescue service,security experts and police authorities should also be consulted to prevent conflict between security and fire protection measures and the safety measures for both people and collections.

6.2.2 Foundations and ground-bearing slabs

An assessment should be conducted to determine whether the potential collection weight/pressure loads imparted by the building and contained collections may be greater than those defined by national/local building standards;where that is the case,institutions should account for the required collection loads.

Materials and design solutions for collections storage facilities should account for the findings of the initial site risk assessment,including:

— the ability to withstand earthquake risks (often even in geographic locations where it may not be required by local regulations);

— suitability of the bearing earth/strata;

— the risk of structural undermining based on groundwater movement;

— the incursion of groundwater.

6.2.3 Exterior

The external fabric of a building (including the roof)provides the primary protection to the internal environment.It shall be built:

— of materials to ensure that no ingress of water will occur from rainfall,ground water or flood,

— to separate internal and external environments,

—to provide mitigation against risks identified in 5.4 such as pollution,pests and dust,

— to prevent the spread of fire into the collection for the duration required,

—to a specification that minimizes reliance on heating,cooling and humidity control,

—to protect the collection from unauthorized access commensurate with the level of risk identified,

— with an appropriate design life.

Institutions should recognize that the role and nature of library and archives storage facilities requires construction materials that have a proven record of stability,structural integrity,durability,and cost-effective maintenance.In many cases,traditional materials and techniques may be preferable to newer technologies and formulations which,while tested and in use in other applications,may not have shown the robustness necessary for a 100+year structure.

Note that structuralglass construction is typically not an appropriate choice for collections storage facilities due to its inherent issues with heat-gain,light exposure,security,and robustness.

6.2.4 Roof

The goalin any design is to prohibit water from entering the facility;designs should accommodate the need to rapidly trace and rectify any incursion.Roofing design and material selection for collections storage facilities may consequently differ from typical practice."Single"depth roof construction (as opposed to external and internal designs)is acceptable provided the construction is able to meet the requirements above.

The roof of a collection store offers greatest protection ifit has separate internal and external roofs offering a cavity to buffer thermal impacts,sun shading and two independent layers of rainwater protection such that leaks can be identified between the outer and inner layers before any water can enter the collection store.Variations on this design,such as a separate external roof over the primary building structure (allowing for improved air circulation between the two layers,and the reduction in heat load on upper parts of the structure),may be particularly viable in various geographic regions.Design should include easy maintenance access to any roof structure where monitoring or maintenance may be required.This is particularly important in situations where other building infrastructure(HVAC,photovoltaics,etc.)may be included on the roof surface.

Critical considerations:

—Internal drainage/water removal shall not be used-note that this may prohibit/limitthe use ofa parapet wall design.

— Green roof designs shall not be installed over collections storage environments.

-Wherever possible,there should not be any penetrations through the roof structure over the collections storage environment.

— Generally,dark-coloured roofs should be avoided from a potential heat gain perspective.Light-coloured finishes are preferred where possible.

— Designs shall not use single rainwater outlets from a roof area-there should be multiple outlets/drains or overflows in any design.

6.2.5 Interior—General

In a shared-use building,interior walls,floors and ceilings are the primary protection against:

— risks such as pollution,pests and dust,

— water ingress,

— spread of fire,

— impacts on the collection from temperature and humidity,

— unauthorized access.

A risk assessment should be undertaken to establish the performance requirements for these elements of construction,consideration shall also be given to the potential for change of use of the adjacent areas in undertaking a risk assessment.

The enclosing walls of a repository may have internal walls,floors and ceilings adjacent to other rooms not under the direct control of the collection storage team.Consideration shall be given to the security,access, fire and environmental strategies in establishing the requirements for the specification of the enclosing fabric of a repository.

False ceilings shall not be used in repositories as they create voids that might harbour hazards such as pests. Where the use of false ceilings is unavoidable in non-storage areas,they shall be constructed of materials of limited combustibility.

Raised access or false floors shall not be used in new repositories as they create voids that might harbour hazards such as pests.See also 6.2.9.1.

No services,such as roof drainage,fresh and waste water,electricity and gas,shall be routed through a repository that do not serve that space.If pre-existing services cannot be re-routed the condition and size shall be considered in establishing an appropriate mitigation strategy such as an alarm.

6.2.6 Interior finishes

Interior finishes shall:

— be low/non-volatile organic compound(VOC)producing;

— not create dust,for example all concrete surfaces shall be sealed;

— avoid creating concealed spaces such as ceiling and floor voids;

— shall not increase the risk of harbouring insects (such as in carpeting,etc.);

— provide appropriate hygroscopic control and thermal mass to contribute to the stability of the internal environment.

— Floor coverings should be light in colour to aid in overall lighting and identifying space issues (pests, damp areas,staining,etc.].

The internal finish may also contribute to the air seal,note that this is different from the vapor seal.For more information see also References [36]and [41].

6.2.7 Off gassing of construction materials

The materials used in interior construction shall be evaluated to determine that they do not emit gaseous pollutants into the interior environment to an extent that would be expected to cause unacceptable irreversible change in the contents of the storage facility.Design teams or the institutions should review materials safety data sheets(MSDS)or other data resources to identify or confirm low-VOC or other low-pollutant options for construction.Any improvements should take into account the recommendations for safe building materials included in various bibliographic resources (see References [65],[53],[52],[36]and

[41]).The project team should agree,as part of the design process,what the specific safe levels of applicable VOCs or other pollutants for the collections environment are,based on the building materials used,cost implications,the specific collections to be housed in the space,and the expected ventilation strategy.

In situations where ultra-low VOClevels may be desired,institutions shall also consider that their collections housing and boxing strategies play a role into the overall reduction of pollutant risk from building off-gassing to materials.In cases where off-gassing of collection materials is the primary risk,reduced sulfur gases and volatile organic compounds generally have higher concentrations in enclosures compared with the external environment.

Materials used should be tested and deemed safe from generating off-gassing pollutants that may be damaging to a collection.Paint,varnishes,coatings,sealants,toppings and coverings that do not emit VOCs shall be used in construction of building components in areas intended to hold collections.Note that certain finish materials may require multiple products (i.e.epoxy finishes);in these cases,MSDSs as well as pertinent manufacturer's instructions for applications and use should be inspected for all products.Any equipment (including filtration)that produces ozone shall not be installed or operated near collections,as ozone can be harmful to heritage materials.

Some products will off-gas initially.Where this applies in the products selected a suitable period,usually 30 days orlonger,shall be allowed prior to the introduction of the collection.HVAC systems,if present,should be operating during this off-gassing period.Where possible,VOC testing can be conducted to determine whether sufficient off-gassing has occurred over a specific time period.

6.2.8 Building equilibration

In the case of newly constructed buildings,drying time for building structure shall be accounted for to enable the internal environment to stabilize before any heritage objects are placed there.Buildings with high thermal inertia are likely to use water for their construction,this may take many months to achieve full drying.Consideration should be given to allow the drying process to begin as soon as the building under construction is weather tight.Specialist advice should be sought over the drying time of the construction. including the finishing screed.Collections should not be moved into the repository until the building has been tested and confirmed as suitable for the ingress of the collection.As a general rule,a minimum 30-day off-gassing period is also recommended before allowing the movement of collections into the space.

Drying time shall not be shortened or omitted in the event of construction delays but shall be incorporated into the project schedule.The environment inside the building shall be monitored during this drying period; collections shall not be introduced until the space/environment is able to be maintained at the determined environmental design condition fora minimum of atwo-week period (this applies whether HVAC/mechanical systems are present or not).

Transfer of collections to a new building can influence the internal environmental conditions (typically in terms of RH control and moisture content);in such instances a further acclimatization period can be necessary before the appropriate performance of the building and any HVAC equipment present can be assessed.

Where a control strategy utilises the collection for stability of the conditions,institutions should account for that influence when assessing the suitability of conditions.

6.2.9 Floors

6.2.9.1 General

Floors in storage spaces and between stores and reading rooms or display galleries shall be level and uninterrupted by steps,door sills,heating grilles or mats,in order to allow the safe passage of collections and moving equipment.Where a change in floor level is unavoidable,an assessment shall be made as to the safest means of transition (ramp or step)for the objects that need to be transported.Where mobile racking is used the rails should be recessed into the floor to provide a level surface.Floor surfaces shall be resilient and be of materials that reduce the built-up of a static charge.False floors should be avoided in new construction and if possible be removed in adaptation schemes.Where this is not possible,a system of pest monitoring and cleaning shall be incorporated.

6.2.9.2 Loading

An assessment shall be undertaken of the loads to be imparted on the floor,and to assess if there is a requirement to design to a greater loading than set out in national standards.

The storage equipment manufacturer will provide guidance on the permissible tolerance in floor level,this will be based on factors such as the type and height of the shelving system,for example a mobile storage system requires a flatter floor to prevent the shelving moving under its own weight.Deflection in the floor level shall be factored into the determination of the levelness of the floor.The mass and distribution of the collection materials,which might be stored,and of static or mobile shelves,shall be calculated.Where the use of mobile shelves is considered,an assessment regarding its suitability for the floor and building structure should be made by a structural engineer in conjunction with the storage equipment manufacturer.

In some floor constructions,the layout ofthe shelving will ffect the structural capacity ofthe floor,therefore it is better to establish the shelving layout early in the design of a building,or when assessing the viability of adapting an existing building.Where a new building is designed for static shelving it is recommended to design in the capacity for future conversion to mobile shelving to increase capacity.

Heritage collections are generally in place for many years,and it is therefore important that the long-term behaviour of the building is considered.Suspended floors experience long-term deflections (creep)that can exceed the calculations for the initial floor deflection.This means that a floor that was initially acceptable could become unacceptable over time.This can be a particular problem if mobile storage is adopted.

Future expansion space should be incorporated in all collections that accept acquisitions.Shortterm growth requirements for a number of years may be included in the initial building design,but a strategy should also be developed within an overall facility or site design for further expansion through physical extension or adaptation of the building/facility.

6.3 Mechanical/HVAC systems

6.3.1 General

Mechanical or heating,ventilating,and air-conditioning(HVAC)systems can contribute to many aspects of environmental control for archives and library storage facilities,including control of temperature and moisture,air circulation and ventilation,and filtration of particulate and gaseous pollutants.Mechanical systems should not be presumed to a be a necessary feature of every storage facility;certain storage environments may be capable of operating passively or with a minimum of mechanical intervention depending on the preservation quality and set point goals established during the design priority and design specification stages,the geographic region and typical weather patterns,and the construction of the facility envelope.When any of these factors do not align to allow for appropriate control of environmental conditions for long-term storage and preservation,institutions should engage in planning for HVAC/mechanical infrastructure.For further detailed information,see Reference [35].

6.3.2 Equipment location

Mechanical infrastructure shall be housed in a different area from the repository and separated by fire-rated construction and curbed construction to prevent any water leaks from escaping the mechanical room. Rooftop system applications may be considered;where possible units should not be located directly above collections storage areas.In-room equipment,such as computer-room air-conditioning(CRAC)units,are not recommended;if selected,they also should be located in a separate area,with air ducted to and from the repository.Plug-in standalone equipment,such as room air conditioners and dehumidifiers,shall not be used except in emergency/disaster recovery situations due to the risk of electrical fire and/or flooding.

6.3.3 Design considerations

6.3.3.1 General

Design of mechanical systems to serve repositories shall account for the following potential needs and factors.

6.3.3.2 Zoning

Repositories are considered unoccupied zones and should not have permanent staff workstations;occupancy should be limited to the retrieval and reshelving of collections materials.This allows for minimal use of outside air and improved sustainability.

6.3.3.3 Sustainable operation

Sustainable operation strategies such as reduced outside air,seasonal set point conditions,reduced fan speeds,scheduled system shutdowns shall be considered,accounted for in the design process,and tested for feasibility[38].

6.3.3.4 Sensible temperature control

Systems shall be sized adequately and with the appropriate equipment to achieve sensible heating and/or cooling as required by the preservation goal,building envelope,and geographic/climate region.Different technologies may be considered,however,the institution shall carefully consider the risks and performance capabilities of any technology proposed or adopted.

6.3.3.5 Dehumidification

In situations where the removal of moisture is necessary to maintain appropriate RH conditions at the target temperatures,systems shallbe capable of dehumidification.Common design options to consider include:

— subcool/reheat designs;

— desiccant dehumidifiers/energy wheels.

6.3.3.6 Humidification

In situations where addition of moisture is necessary to maintain appropriate RH conditions at the target temperatures,systems shallbe capable of humidification.Water used for humidification should ideally be filtered via reverse osmosis/deionization(RODI).In steam systems,direct building steam shall not be used due to the descaling chemicals used for maintenance of the overall system.Softened water shall not be used due to the risk of salts deposits on collections materials.Common design options to consider include:

— adiabatichumidification:evaporation-based technologies,includingultrasonic,misting,and evaporative pad systems;

— isothermal humidification:steam-based technologies,including electrode canisters,infrared,and steam-to-steam systems.

6.3.3.7 Outside/Fresh air

Outside/fresh air quantities shall be designed to provide the minimal volume necessary for unoccupied environments.Economizing/free-cooling designs (use of outside air for free interior conditioning)rarely work in collections settings due to the dual temperature and RH control requirements.In situations where an economizer control is being considered,control shall be based on dew point conditions rather than sensible temperature or enthalpy (see also 6.1.4 for discussion on fresh air impacts on pressurization).

Note also that the amount of outside air directly influences the levels of gaseous and particulate pollutants that enter a building;limiting outside air is the easiest way to reduce overall filtration loads for both particulates and gaseous pollutants(including hydrogen sulfide,sulfur dioxide,nitrogen dioxide,ozone,and others).

6.3.3.8 Air circulation and balancing

All repository areas served by mechanical systems shall be designed with adequate supply and return air volumes,equalized to allow for operation in recirculation mode (no outside air)when appropriate without pressurization implications.Design should strive to avoid risks of short-circuiting the air path by placing supply diffusers and return intakes at an appropriate distance from one another.All repositories shall undergo initialtesting and balancingfor airflowatthe time ofconstruction orrenovation,and should consider undergoing periodic retesting or rebalancing whenever issues with circulation or microenvironments occur.

6.3.3.9 Filtration

All mechanical systems serving collections space shall be equipped with a minimum of MERV 13(~85 % arrestance of particles 1μm to 3μm in size)equivalent or better filtration,which equates to ISO 16890>50% for PM1,>65%for PM2,5 and>80%for PM10.The inclusion of gaseous filtration should be determined based on energy implications and assessed need (factors include levels of exterior pollution and style of collections housing-boxed or unboxed).Note that if gaseous filtration is selected,potassium permanganate should no longer be used due to the risk of released dust leading to oxidation of collection materials and furnishings.For further discussion,see also References [50]and [64].

6.3.3.10 Downstream equipment

All mechanical conditioning work (sensible temperature and moisture control)should be performed at the primary unit(s),away from the repository.Downstream equipment,most commonly downstream reheats or humidification for subzone control,should still be physically located outside of the repository.Variable-air-volume(VAV)boxes or other dampers to control air volumes are allowable.

6.3.3.11 System control

Primary control of the system shall be based on sensors based in the physical storage zone;if the design is a single-zone system,a return air sensor may also be used as the primary control.Other control points may vary based on the specific operation.

—For dehumidification,control should be based on achieving the appropriate dew point.This may be controlled from a space sensor,but is more often driven by a leaving condition from the specific component-for example,a leaving air temperature from a chilled water or refrigerant coil,or a leaving dew point condition from a desiccant wheel.

—For humidification,control should be based on either the space sensor RH reading,or the RH reading at the return air in a single-zone system.

In most applications,preferred control shall be through a building management system(BMS)that allows for programming of sustainable operation strategies,remote access,and trending data including air conditions and component operation(valves,dampers,fans,etc.).

6.3.3.12 Maintenance and planned reinvestment

Mechanical designs for storage facilities shall take into account the availability of repair professionals to service the equipment selected;technologies for which no repair technician is readily available should be avoided.Likewise,if institutions are to rely on external contractors to perform regular preventive maintenance,it shallbe ensured that those contractors have experience with the technologies selected.

Institutions shall maintain a supply of typical consumable components for the systems.These may include, among other items:

— filters;

—fan belts;

—electrode canisters for humidification.

Appropriate preventive maintenance shall be performed on a periodic basis.Note that certain tasks,such as filter replacement,may need to be completed more often depending on external factors such as seasonal particulate pollution or general geographic location.

Institutions shall recognize the need for periodic capital reinvestment;expected performance life will vary depending on the system or component.Institutions should be prepared reinvestment ranging from~10-15 years for certain package units to~25 years for larger component-based systems.Controls installations should aim to calibrate all sensors at least every 5 years,with full controls upgrades or replacements after ~10 years.

6.4 Security

6.4.1 General

Collections shall be rigorously protected against theft,vandalism,unauthorized alteration and casual damage or disturbance caused by inexpert or careless handling.Unauthorized and unsupervised access to any room in which collections are stored shall be forbidden.An overall security strategy based on a risk assessment shall therefore be implemented that includes the site/premises,the building,its contents and its use.The strategy shall be informed by advice from security experts.

Where a storage facility is not part of a larger building,and is located on a stand-alone or island site consideration should be given to restricting access around the whole perimeter which should be security gated and fenced.It should be clearly illuminated in the hours of darkness,and vegetation and shrubbery on the site,which obscure visibility,shall be removed.This should be considered the datum for security that other layouts need to match through other measures.

For a building holding collections that forms part of a larger building,a security hierarchy (spaces and access)shall be put in place taking account of all users such as staff,visitors,cleaning and maintenance workers.

On an urban site where it is not possible to have a fenced zone of restricted access to the perimeter,the security provided by the construction including walls,roofs,doors,windows and service entry points shall be commensurate with the protection offered by a stand-alone facility as described above.

6.4.2 Protection against intruders

The building shall be secure against theft,burglary and vandalism,and be resistant to terrorism and other criminal acts.An intruder alarm system linked by secure phone line to an alarm-monitoring centre shall be provided.It is essential that the building is protected against intruders,whether the building is open or closed to the public.This shall not be compromised during emergency evacuation procedures.

6.4.3 Doors and circulation routes

Doors,frames,mountings and hardware shall be constructed to resist unauthorized entry.The resistance class shall be established based on a risk assessment,which shall take into account the value of heritage objects in the collection.Locks shall open from the inside without a key.No door of a high security area (such as a repository)shall be used as an external door of the building or open into any part of the building to which the public has normal access.Emergency exit doors from secure areas of the building shall be alarmed and designed to open only from the inside and shall open onto an escape route.

A hierarchy of master and sub-master keys ("lock suiting")shall be configured to ensure that only authorised staff can access repositories,for example to ensure that even normal maintenance staff for the building can enter only under supervision.No part of a space in which archives or library materials are permanently or temporarily stored shall be used as a corridor or emergency exit serving a non-storage area.Doors into or between secure areas shall be lockable.

There shall preferably be only one entrance for visitors to a building in which collections are situated.A separate secure,controlled area should be provided for the vehicular transit of documents for acquisition, rescue work in case of emergencies,etc.

6.4.4 Services

To minimize unnecessary access to the building,services related to it shall be designed to be independently controlled and isolated.Wherever practicable,air conditioning plant,heating,electricity,water supplies or drainage,including rainwater pipes,shall be situated outside the collection spaces of a building or preferably outside the building itself and shall be accessible and controllable without entering the collection spaces to reach them.Gas,oil,water supplies and drainage (including water pipes and sewage),shall not pass through a storage repository.

6.4.5 Windows

Wherever practicable,an existing storage space shall not have windows and no new storage space shall be designed to incorporate them.Where windows are present in display or reading areas or in historic or existing storage buildings,in the interests of security these windows shall be un-openable (note that the rooms shall comply with sufficient number of escape routes in case of fire),barred and glazed with security glass.One-way glass may be used,where necessary,to prevent people looking into the building.Roof lights shall never be installed in a secure storage space.

7 Furniture and lighting considerations

7.1 Furniture

7.1.1 General

Storage furniture is fundamental for preventive conservation.It can significantly minimize a large number of risks to collections,including mechanical and microbiological damage,chemical degradation,and physical losses due to theft or disaster events.To ensure this,it should allow for logical organization of the collections and be appropriate to their specific storage requirements as well as to the operational processes in the repository.When in doubt,collection-and process-related criteria,such as appropriate protection and ease of safe access,should be given priority over efficient use of space by the storage furniture.

7.1.2 Material requirements

For typical library and archives collections materials (bound materials,boxed archives,etc.),storage furniture in a new facility shall be made of stable materials that have inert coatings-powder-coated steel is a common example.They shallbe non-combustible,nonabrasive,and anti-static,have no sharpedges,and shall be physically rated to handle the weight of the proposed collection material.

Overall,storage furniture materials should be selected with an awareness of their ability to withstand long-term decay or disaster situations.Decomposition in the event of fire,water exposure or sprinkler discharge, and natural aging of materials should not release harmful substances or impact the structural integrity of the furniture-note that wood or plastic composites should be avoided wherever possible.

Collection materials should not come in contact with storage furniture or shelving that may chemically decay or off-gas over time.Ifnon-stable materials must be usedin an existing facility-for example wooden or fibre-board shelving-all shelving should be lined with inert material(such as corrugated polyethylene board)to separate collections objects from direct contact with potentially degrading or off-gassing materials.Inert shelf-lining material may also be required on some oversize storage furniture,such as warehouse or pallet-racking.Be aware that use of shelf lining materials may increase other risk factors,such as pest activity or risk of off-gassing in a fire.

7.1.3 Furniture configuration in the repository ambient conditions

To ensure stable environmental and overall storage conditions,furniture and objects shall not be placed too close to exterior walls or directly on the floor.Note also that furniture configurations shall be designed in conjunction with fire protection and suppression,lighting,air distribution and other critical systems to ensure proper visibility and fire suppression capability.Potential issues that shall be considered when designing and siting furniture within the repository include:

— avoiding stagnant microenvironments-this is most likely a risk along exterior walls,although may be present on interior walls that separate different environmental zones;

—necessity(or lack thereof)for cleaning between furniture and a wall;

— the potential for leaks or other moisture presence (condensation,diffusion),either from overhead or along a wall (interior or exterior);

—the potential risk of materials falling into a gap or space between furniture and a wall;

—the existence of non-visible pest pathways along room edges;

—the risk of physical movement due to seismic activity or other vibration;

— a minimum distance of 150 mm shall be ensured between the floor and any objects,primarily for protection against potential flooding.This should remain the practice even if physical floor drains are present in the space;

—for static shelving/furniture along interior walls:no minimum distance between the wall and shelving is required.Institutions may choose to allow a gap for cleaning purposes or other concerns.Note that microenvironments may still be a concern if the wall separates different environmental zones;

—shelving uprights should be strong enough to support the bay load,and the shelf clips or bearers should be strong enough to support the loading capacity of a shelf;

— shelving uprights and shelf bearers should not obstruct the withdrawal or replacement of objects or their containers.

Primary concerns institutions should consider when siting furniture along an exterior wall include:

—for static shelving/furniture along exterior walls:no holdings shall be stored in close proximity to an outside wall.There should be a distance of at least 200 mm between items and wall;

—risk of temperature or relative humidity microenvironments between the object and the wall;

—there is no required minimum distance between the actual furniture and walls,although institutions may want to consider a space of at least 530 mm if the ability to clean between furniture and the wall is desired.

For mobile shelving in the "parked"position,institutions should ensure that gaps between carriages are sufficient to allow the following:

— effective deployment of the fire suppression system.This spacing should be informed by the shelving manufacturer and by a fire prevention engineer;

— adequate airflow for normalenvironmental conditions.Gaps of not lessthan75mm should be considered for this purpose.

See also ISO/TR 19814[Z]for additional guidance on shelving design and configuration.

7.1.4 Types of storage furniture

Depending on structural requirements,scope,type and nature of the collections to be stored,both an open form of storage with shelving in the form of upright shelves and mobile shelving systems,dollies and pallets, and a closed form with cabinets and plan/flat-file cabinets can be used.

In open storage,there is a significantly higher susceptibility to nearly all potential hazards.Provided that it is a modular storage system,appropriate components can be combined with each other in a space-saving and flexible way.In the planning process,planners should be precisely informed about the weight,volume and sensitivity of the collections.

Objects of similar size and similar conservation requirements should be grouped together if possible.Placing objects next to each other according to collection-related criteria or current catalogue number can cause damage to materially incompatible objects over time.

7.1.5 Mobile shelving systems

Mobile shelving systems are used to save space when storing library and archival collections by minimizing aisle space.Modularly assembled mobile shelving systems are also suitable for storing a wide range of collections.The length of the trolley depends on the floor space and design constraints of the shelving system itself.

The tracks should be set flush in level and hard floor with sufficiently high load bearing capacity.Concrete floor surfaces should be sealed beforehand to prevent dust.If flushness is not possible due to structural limitations,a composite floor,which excludes voids that may harbour pests,can be partially installed up to track height and combined with ramps to avoid tripping hazards.Bumpy running of the mobile units on the tracks,which can cause damage to the system itself and objects carried,shall be avoided.

When calculating the mobile shelving system and the load capacity of the floor surfaces,the volume and type of collections,its packaging and the weight of the shelving system itself should be carefully considered. With respect to older buildings,a building survey is required for this purpose.It may be helpful to contact manufacturers early in the design process regarding test setups of mobile shelving systems.

Deflection of floors and the associated safety risk to users and collections shall be avoided.If necessary, structural support can be provided overall or in specific areas of higher load,such as an additional steel grid that supports the rails and transfers the load from the floor to the building frame.This is known as an adjustable carrier rail system and can be adjusted under load as needed over the usefullife of the installation.

The system layout,including aisle widths and drive type,is based on specifics of the repository,the force required to move the racks,the frequency of retrieval and repositioning,and specifics ofthe objects to be stored.

Depending on their dimensions and the load to be moved,mobile shelving systems are equipped with either mechanical or electrical drive.They should be able to be operated with one hand.The motors of electrically driven equipment should be either low voltage(DC)motors or fully enclosed AC motors[20].From the point of view of fire safety and energy sustainability,electric mobile shelving systems should be avoided wherever possible in favour of mechanical drives.

The size of objects should correspond at most to the depth of the compartments and shall not protrude beyond the shelves.They should not be at risk of falling out when the rolling shelving system is moved.In the case of sensitive collections,electrically operated systems should also be equipped with a shock-absorbing start and stop function.

It is not recommended that runs of mobile shelving back onto each other unless there is a clearance of a minimum of150mm between them.On electrically driven systems,the minimum clearance should be 500 mm.

7.2 Lighting

7.2.1 General

Most archival and library materials are sensitive to light exposure.Exposure to UV which is present in natural and in artificial light sources may result in chemical changes (e.g.the fading of inks)or physical changes (e.g.the loss of mechanical strength)to collection materials.Organic materials are more vulnerable than inorganic materials.High sensitivity materials may show noticeable fading after only a few days exposure to sunlight,whereas medium sensitivity materials may show noticeable fading after a few weeks. For example,high sensitivity materials may include exposed objects,such as:

— dyed or coloured leather or cloth book bindings;
— wood pulp papers containing lignin (such as newsprint or dust-jackets on bound volumes),
— watercolour pigments and other artwork on canvas or paper.

The damage caused by exposure to light is cumulative,and depends upon intensity,duration,and the spectral distribution of the light.The total damage also depends on the light's proximity to collections and the vulnerability of the material that is exposed.It is advisable to measure and control the total amount of light exposure.

Avoiding ultraviolet (UV)radiation exposure,which can cause both fading as well as impact the overall rate of chemical decay in sensitive materials,is the most critical.As the wavelength of radiation increases, the associated energy decreases,as does the rate of photochemical damage that it can cause.Filtration or blocking of UV and other light exposure from natural and artificial light sources in locations where collections are stored may be achieved through various means including filtering films,UV-protective glass, and storage of archive and library collections in boxes or cases.If permanent staff workstations are not present,there is no need for lighting storage areas beyond what is required for retrieval and emergency purposes.

7.2.2 Repository

7.2.2.1 General

The repository should be designed and/or equipped to avoid direct exposure of collections to sunlight. Lighting requirements within the repository will vary based on the type of materials housed (packaged or not),the shelving design and arrangement,and the height of the space,among other factors.

7.2.2.2 General principles

Institutions shall:

- select lighting solutions which do not emit UV radiation,or which can be installed so as to emit as little UV as possible;
- keep storage areas unlit when not in use with user-activated or timed lighting;
- measure and monitor light levels to assess risk of light damage to the collections;
- where possible,keep collections stored in individual boxes,cases,or under covers;
- maintain the minimum level of lighting needed for tasks and employee safety.

7.2.3 Artificial light sources

Photometric studies to determine light levels at various locations and levels should be conducted as part of lighting design for storage repositories.Like all electrical equipment or parts thereof,light sources shall be checked for safety before and during use.

- Technology options:
  - Light-emitting diode(LED)technology is the preferred application due to the absence of UVlight and reduction in heat and energy consumption.
  - Fluorescent:while still commonly used,fluorescent fixtures introduce the risk of UV exposure and will contribute heat load to the repository environment.Where possible,institutions should replace fluorescent fixtures with LED fittings to reduce risk and promote sustainability.
  - Incandescent and high-pressure mercury lamps:shall not be used due to the significant heat gain, energy consumption,and fire risks.
- Illumination levels:
  - Recommended lighting levels at the lowest storage shelf should be greater than or equal to 100 lux, with a maximum light level of 300 lux at the highest storage shelf level.

—The ultraviolet content of the lighting source in the repository shall be less than 75 μW/lm.Lamps with UV radiation exceeding 10 μW/lm shall be fitted with an effective ultraviolet filter(discussed in mitigation strategies).

— Physical design/installation considerations:

- — The positioning and operation oflamps should be so planned that aisles,when in use by staff,are not left in shadow.
- — Typically,luminaires should be perpendicular to the shelving direction.
- — Lighting circuits shall not be mixed with other electrical circuits such as sockets/plugs.
- —There should be a minimum distance of 50 cm between a lamp and the nearest collection materials.
- — There shall be separate switches for the illumination of each of the sections or zones that the repository is naturally divided into.Repositories shall be zoned to limit the number of fixtures controlled by a single switch in order to limit light exposure to currently occupied areas.Lights should be switched off either manually or automatically when not required.
- — Motion sensors may be used on a zone basis to automatically illuminate occupied areas in the repository.Lights should automatically turn off after a set period oftime without activityin the zone.
- — Indicator light outside of the repository may be used to show whether interior lights are still on.
- — The repository shall be equipped with emergencylighting as appropriate.
- — Code/municipal requirements will vary based on location.Institutions may choose,based on occupancy patterns and local law,to eliminate permanently-on emergency fixtures in certain repositories to reduce light exposure.
- —For instances where permanently-on emergency fixtures are required,institutions may considerr locating boxed or other protected materials near these fixtures.
- — The points at which any wiring,trunking,etc.enters and leaves the repository should be fire-stopped,and sealed against vermin and insects as well as against air infiltration and dust.

7.2.4 Natural light sources

Storage repositories shall not have sources of natural lighting,whether windows or skylights,due to difficulty in light control and the potential impact of both UVand infrared (IR)radiation.

For repositories with existing windows,penetrations shallbe blocked (whether permanently or reversibly) to eliminate light incursion.Where blocking is not possible,other mitigation strategies,such as light filtering shades or blackout shades should be utilized.

For repositories with existing skylights or other roof penetrations for natural light,these shall be blocked to eliminate light incursion,either at the roof level or at the interior ceiling location.In institutions or repositories that make the conscious choice to include natural daylighting for sustainability or other purposes (such as ventilation),windows are recommended over skylight applications.Where possible, windows/glazing should be double-glazed and insulated,with built-in UV protective coating.Shades (light-filtering and blackout),shutters,or louvres should also be applied to provide some control of light incursion throughout the course of a day.

7.2.5 Collection-level mitigation strategies for reducing light exposure in existing repositories

— Exterior window applications such as shutters or louvers

— UV film on windows or other external light sources.Note that applied films will lose efficacy over time and will require replacement based on observed/monitored UV levels

—Packaging,including boxing of collections or individual enclosures for sensitive bound volumes

— The use of enclosed storage furnishings such as cabinets or drawers

—Interior window shades(light-filtering and blackout)

— Light-blocking curtains

— Motion-detection or timed control of light fixtures

—Fluorescent tubes shall be fitted with sleeve UV filters.Note that these filters will lose efficacy overtime and will require replacement based on observed/monitored UV levels.

8 Environmental monitoring

8.1 General

Environmental monitoring is the process of measuring,collecting,and analysing the environmental conditions of a given storage environment in support of the long-term preservation strategy.Continuous monitoring is required for effective management of the storage environment and cost-effective achievement of the conditions required to preserve library and archival collections.This data should be maintained permanently forlong-term tracking and comparison of preservation quality and environmental performance.

Monitoring alone does nothing to improve preservation conditions;it is essential to respond to evidence from monitoring that shows conditions are or will be outside recommended ranges (see Annex B) and to rectify the situation or plan for improvements.

Environmental monitoring may include the gathering of such data as temperature,relative humidity, light,atmospheric pollutants,or vibration.These data should be regularly reviewed by conservators or other specialists with knowledge of the collection,building and infrastructure.Data analysis will identify immediate risks to collections,as well as longer-range trends that show whether conditions are stable within recommended ranges or trending out of range to allow an effective and planned response.

Monitoring of spaces under consideration for collection storage will provide data on current conditions. Data of current storage locations can be used to understand the present state of the collections and any considerations if they are to be moved to a new location.Short-term monitoring of specific locations may also be used for measurement and diagnosis of suspected problems or microenvironment conditions.

8.2 Methodology

8.2.1 General

Monitoring devices independent of building management system(BMS)or other climate control equipment sensors should be used within the collection storage space.This allows for the specific location of dataloggers or other instruments near the actual collection or wherever data-gathering is required.

8.2.2 Equipment

The choice of monitoring equipment depends primarily on the objective of the monitoring,but may also be influenced by security or other considerations.For new or renovated library and archival storage facilities, institutions should use electronic/digital datalogging devices,which allow for the continual gathering of data over long periods of time.These data are easily viewed and evaluated with analytical software packages, many of which will provide initial preservation quality assessments,such as rate of chemical decay or risk of mould growth.Many of these systems also allow for alarm notifications when conditions are outside of the allowable environmental range.

8.2.3 Deployment and sample rates

The devices should be situated to provide readings that represent the typical ambient conditions in which collections are held,as well as areas with potential microclimates and extreme or abnormal conditions such as near outside walls or close to a source of heating or ventilation.As a minimum general approach,at least one datalogger should be deployed in each room/space where collections are stored or used;in many facilities conditions may change distinctly from one space to another based on airflow,envelope conditions, occupancy,and other factors.Based on the size of the space,multiple dataloggers may be necessary to monitor environmental differences due to mechanical zoning(different air handlers serving the same space), storage layout,height differences,or other factors such as limited airflow in compact storage configurations. Data sampling rates should be continuous;every 30 min to 1h is typically appropriate for most settings.

Dataloggers or other devices may also be required in potential microenvironment situations,such as inside display cases and specialized storage equipment such as cabinets,where the conditions may be buffered by the furniture or packaging.Microenvironment monitoring may also be desired for particularly sensitive formats or items.

In addition to interior environments,the outdoor conditions at the specific site should be monitored and recorded.Data are ideally collected by sensors onsite at the facility,but may be obtained for a local area from a national service,especially for information regarding atmospheric pollutants,which may not be monitored at a building level.This information is essential to understanding the natural risks to long-term preservation as well as informing the necessary operation of the facility envelope and/or any mechanical systems.It is also useful for storage spaces with exterior walls and locations with concerns over external pollutants.

8.2.4 Data retention and analysis

Data shallbe retained indefinitely in a retrievable,neutral format.Data should be collected and evaluated regularly;best practice is monthly,but spaces that have shown stable operation may extend this to quarterly.For spaces where there are suspected problems,data should be retrieved and evaluated weekly until conditions have improved.An annual analysis is recommended to document seasonal conditions and longer-term trends.

Where readings show that conditions are outside those selected,the reason for any discrepancy shall be investigated and plans made to remedy any identified problems.Monitoring devices shall be regularly calibrated according to the manufacturers'instructions.They may also be checked against independent devices such as a hand-held digital unit with appropriate sensors,though caution should be taken when comparing device displays to ensure that the sampling rates align.

8.2.5 Other data sources

Spot measurements (using handheld devices such as infrared cameras,temperature sensors,light sensors, or other tools)can be used to identify risks in the environment at short notice,but should not be used in place of long-term environmental monitoring.Any single reading at a specific location will be unique to that moment and may reflect a variation in operation based on time of day,external conditions,suboptimal operation or other factors,and is most useful as a means of discovery or in diagnosing specific examples of an immediate concern or longer trend.Care should be taken to account for the accuracy of readings based on the calibration of the instrument and its equilibration to the space in question.

There are different systems for monitoring environmental conditions related to building control,which are based on different objectives and are therefore not interchangeable.Building management systems(BMS), including those for HVAC,are intended for the safe and energy-efficient operation of plant,and are most often used in applications for controlappropriate to human comfort.The data generated,including humidity and temperature as well as other variables,can be considered to identify interactions between buildings and collections in combination with monitoring data collected from a conservation perspective.BMS data shall be made accessible to both facilities and collections staff in order to encourage communication regarding operation and controls with observed conditions in the collection storage environment.

9 Building-related hazards to collections

9.1 Pest considerations

The level of pest activity inside and around a building shall be monitored and assessed and,where necessary, a programme of pest management initiated.Areas shall be kept clean and unused space shall be accessible for cleaning.Materials and activities that could provide a food source for pests for example food and drink, pot plants and wool carpets,shall never be introduced into a storage space.

Vegetation or other installations that may encourage pest activity shall not be incorporated into,onto or against the structure of a new building.The exterior of existing buildings shall be kept free of vegetation wherever possible.Cracks and holes in existing structures shall be sealed to prevent pests migrating into the building.The points at which any new wiring or trunking enters and leaves the building shall be sealed against pests,as well as against air infiltration and dust.Ventilation or air-conditioning supply and extract vents shall be fitted with filters or screens to prevent the entry of pests into the building.Doors shall be installed and seal tightly in their frames.

Heritage objects shall not be brought into the building until they have been checked for pest or fungal contamination and treated where necessary.A separate area shall be provided for this purpose and precautions shallbe taken to confine contamination to it.

Damp objects shall never be placed into an otherwise dry store as localized damp conditions promote the growth of mould.Rooms with cold or damp walls or unregulated air vents shall not be used to store collections.Existing buildings or spaces intended for conversion to use as collections spaces shall be surveyed and any structural weaknesses remedied before collections are installed.Storage equipment such as shelves and drawers shall be placed to allow for agap between heritage materials and the surface of walls.

9.2 Water considerations

Appropriate water controlaround the facility and the site is critical to the long-term maintenance of both the structure and the interior environment.Factors to consider throughout the siting,design,and construction process include the following.

—Site grading shall be directed away from the facility on all sides.Where this cannot be accomplished due to hillsides or other factors,appropriate swales,drainage systems,or other strategies shall bee incorporated to keep precipitation and runoff away from the structure.

-Vegetation shall be kept well away from the building structure to allow for adequate air circulation and drying.

— All roof drainage shall be directed to underground piping or routed well away from the building slab/ foundation.

—Location ofall natural springs,streams,or other natural water features on the site shall be documented and accounted for during the design process.

—Water evacuation systems (drainage,sump pumps) shall be included as necessary in the design, particularly in subgrade storage environments.

—For subgrade storage designs,institutions shall consider the addition of an interstitial space/corridor with appropriate drainage to isolate the collections environment from the exterior envelope and any water intrusion.

9.3 Fire protection and prevention

9.3.1 General

In most jurisdictions,national and local regulations require a fire strategy to be developed for any new or refurbished building which may include fire risk assessment,structural fire protection,means of escape and fire extinguishing.In the case of libraries and archives,this shall include specific measures relating to the protection of the collections in addition to those standard provisions relating to human safety.Fire precautions shall be designed to protect the contents and structure of the building both from the fire itself and from damage caused by firefighting operations,as well as protecting staff.The fire strategy for collections shall be designed with the advice and support of fire experts (see References [5] and [2]).

Library and archive collections are made of combustible materials and therefore should be kept away or protected from all sources of flame such as smoking or hot working.The probability of fire occurring shall be reduced to the minimum level practicable by a combination of design and management.

Fire risk assessment and plans involving the collections as part of a wider disaster recovery plan shall be drawn up in collaboration with the local fire and rescue service and fire insurers in order to provide the fire and rescue service with information in the case of an emergency.The fire risk assessment and plans shall include a warning that the indiscriminate use of extinguishing agents used by fire services,for example water,can cause serious damage to the collections.

9.3.2 Fire risk assessment

A fire risk assessment shall be undertaken to inform the fire strategy for the building and its contents and to ensure that adequate provision of the necessary fire prevention and protection measures are in place.This shall be undertaken by a qualified and experienced fire engineer or other professional with the necessary experience and competence in protecting cultural resources from fire.

The assessment shall be performed:

— at the design stage of a new build including the site selection;

—at the design stage of an alteration of an existing building;

— when planning any modification of a collection building and its contents;

— when changes that occur externally to the collection building might increase the risk of fire.

The fire risk assessment shall establish a hierarchy of risk,for example distinguishing between higher risk spaces such as publicly accessible rooms,medium risk areas such as staff spaces and the most fire-resistant spaces such as the repository.

9.3.3 Structural fire protection

9.3.3.1 General

The following subclauses relate to the means of incorporating fire resistance into an existing or new structure.

Fire precautions,including limitations on distance of travel for means of escape,are the subject of national legislation,which may be supplemented by local legislation.Fire precautions shall be discussed with the fire and rescue service and insurers.Experts such as fire engineers,fire consultants and insurers shall be asked to advise about particular problems or risks.The aim is not only to minimize the possibility of a fire breaking out within the building itself,but also to make collection spaces as impregnable to fire as is practicable in the event of a fire originating in areas adjacent to,above or (in a building of several storeys) beneath the collection space.For this reason,it is recommended to carry out an overall fire risk assessment at the design stage (see 9.3.2).

9.3.3.2 Structural fire resistance

The elements of structure of the building or collection space shall be designed to minimise the spread of fire.Construction shall provide a level of fire resistance against a fire occurring outside a collection space appropriate to the findings of a risk assessment.Fire resistance,particularly for collection stores,shall be against both heat transfer through walls,floors and ceilings and collapse of these elements.For new storage buildings or rooms,no wall,floor or ceiling of the store shall form a partition between the heritage collection institution responsible for the contents of the store and another organisation not under the management of the collecting institution.

Fire risk assessments shall cover adjacent premises (e.g.shared buildings or neighbouring buildings with a party wall)to assess conformity with the fire resistance specification (see also 5.1).If the risk assessment, including fire-fighting response times,indicates a likelihood of fire spreading from outside a storage space, the structure shall be designed to achieve 4-hour fire resistance.

NOTE Attention is drawn to the classes of fire resistance of building elements set out in the EN13501 series [12]–[17].

9.3.3.3 Lightning conduction

The need for a lightning protection system shall be determined by the design team.Lightning conductors shall not run within a fire compartment,particularly inside a display area or storage repository.

9.3.3.4 Fire compartments

For reasons of fire safety,the building shall be divided into compartments with the advice of relevant experts. Internal/external walls,floors,ceilings and doors between single rooms and compartments and between collection spaces and other areas of the building shall be constructed in such a way that fire,water and smoke are prevented from spreading into a neighbouring unit.The fire resistance of storage compartments in particular should conform to 9.3.3.2. Where the 4-hour fire resistance is deemed insufficient for particularly valuable and sensitive materials consideration should be given to placing them in a secondary fire protection enclosure,such as a fire certified safe.

NOTE Fire compartments can have an impact on the internal environment and this can be especially significant in a storage space.

9.3.3.5 Doors and other openings

Openings including ducting in fire-resisting walls shall be protected to prevent the movement of smoke and be fire resistant to the same level as the walls that contain them.Doors shall be self-closing in the event of a fire.

If overpressure vents are fitted in a storage repository to allow for installation of a gaseous fire-fighting system,these shall be sealed and not compromise the environmental stability,security and air infiltration standards of the repository.

Where a specific firefighting requirement is identified within the fire strategy the access doors and emergency break-out provisions shall be fully integrated in the design.

9.3.3.6 Vertical openings

Stairways,lift shafts,ventilation risers and other vertical openings that might act as flues for fire,smoke,or toxic gases shall be enclosed by walls,partitions,dampers,doors or curtains of material with an appropriate fire resistance.

9.3.4 Minimizing fire hazard in an electrical system

9.3.4.1 Cables

Cable insulation should be flame retardant and be of low smoke zero halogen (LSOH)to minimize the emission of harmful fumes in the event of fire.The points at which cables enter and leave a repository or display space or passthrough intermediate walls shall be fire stopped in orderto maintain the fire resistance of the walls.Electrical circuits shall not pass through a storage repository unless they serve it.

9.3.4.2 Master switches

Except for those switches providing fire detection and protection or emergency lighting,there shall be a master switch or switches outside storage repositories to isolate all lighting circuits out-of-hours.The master switch shall be labelled and secured against vandalism and tampering and shall be fitted with a warning light to indicate when the power is on.

9.3.4.3 Electrical fittings

Electricalfittings should have an index protection rating of at least IP20 in accordance with EN60529.Where fluorescent lamps and systems are fitted these shall be replaced with LEDs to reduce fire risk associated with heat from ballast units.Electrical light fittings selected shall not create a concentration of heat (hot spots)which might present a fire risk.

9.3.5 Minimizing fire hazards in ventilation plant and equipment

9.3.5.1 Ductwork

No ventilation or other ductwork system for a storage repository should at any point connect with ducts serving premises outside the repository,nor should ducts serving other premises pass through the repository.

9.3.5.2 Dampers

Where a collection space is served by ducted ventilation,ducts shall be installed with fire and smoke dampers.Fire and smoke dampers of a rating to match the compartment fire rating shall be installed,for example,where the ductwork passes through fire compartment walls or floors.An automatic fire detector of the smoke sensitive type shall be installed at the outlet side of the fan.

9.3.6 Fire detection and firefighting

9.3.6.1 General

Where practicable,automatic fire detection,alarm and automatic fire-fighting systems shall be consolidated into one continuous system that detects afire,sounds an alarm or activates visual alarm,allows a set time for people to check whether the alarm is genuine and to leave the building,and then sets off any automatic fire-fighting system.Automated fire-fighting systems should operate independently (see 9.3.6.4).

9.3.6.2 Detection and alarm systems

A higher-sensitivity smoke detection system shall be installed in repositories.This can be either an aspirating detection system (ASD)or high sensitivity point detectors.The system shall be supported by an appropriate level of monitoring (see 9.3.6.3).If an ASD is selected for a passive climate storage repository, the air extracted for sampling should be returned to the room in order to avoid creating negative pressure in the space.

NOTE ASD systems can be particularly useful for historic interiors,if an automatic fixed fire-fighting system cannot be installed,as long as sampling points and pipe runs can be concealed from view.

9.3.6.3 Monitoring

The central automatic fire detection system control panel shall provide a facility to monitor allcomponents of the system via a secure line,visually display the status of the system and transmit a signal to a remote monitoring centre.Panels shall be located in a convenient central location that is either continuously staffed or is at least staffed while the facility is occupied or open.Where the panel location is not the most likely fire and rescue service entry point,a supplementary or repeater panel shall be provided for use by the fire and rescue service.The operation of an automatic fire-fighting system shall be monitored both locally in the collection space and remotely at an alarm-receiving centre.

9.3.6.4 Automatic fire-fighting systems

A fire risk assessment shall be carried out both inside and outside a repository or building holding heritage collections to determine whether an automatic fire-fighting system (also known as fixed fire-fighting system)should be installed in the collection repository.Risk includes emergency services response time.

Depending upon the type of system employed,these systems can act to suppress,control or extinguish fires, both those starting within the repository and those starting outside in adjacent spaces.A system should not be one that will cause damage to the heritage collections in the event that it is used.Space and infrastructure constraints,sustainability and maintenance costs shall also be considered.

Where an existing historic building is being adapted for use for the storage or display of collections,the use of suppression systems that require a room seal must be evaluated in terms of risks to the historic building fabric,as well as their feasibility,costs,and long-term maintenance.For historic spaces that are not accessed by the public,modular storage can be installed inside which a suppression system can be used.

NOTE See Annex A.

9.3.6.5 Portable fire extinguishers

Portable fire extinguishers provide the opportunity for the rapid extinguishing of small fires;however, a risk-based approach shall be used to select the extinguishing agents and to choose their placement and purpose within the building,including the nature of the collection protected.The risk assessment shall include risks to the collections as well as to humans.

9.3.6.6 Protection of areas adjacent to collection repositories

Where a collection repository is part of a larger building,firefighting equipment that uses water should be provided outside the repository and in accordance with the advice of the local fire and rescue service. Portable fire extinguishers shall also be provided.

Wherever possible,all collection spaces,including storage,display galleries and reading rooms,shall be protected from surface water run-off from adjacent areas.Repositories and adjoining rooms shall be fitted with a fire-fighting-water drainage system.

9.3.6.7 Smoke extraction

It is important to remove the products of combustion from a repository after a fire to minimise damage to the collection.Where a natural venting or mechanical smoke extraction system is installed,it shall be integrated with any fire-fighting system,and shall be designed to avoid water entering the repository from the exterior of the building.

9.3.6.8 Fire control and mobile shelves

To assist fire control in a repository,the spines of double-sided mobile shelf runs shall be separated by solid metal partitions placed at every five or six runs.Where an automatic firefighting system is installed, the runs of any mobile shelves shall be set apart by not less than 25 mm when the storage repository is unoccupied in order to assist the penetration of the firefighting agent to all parts of the room.

9.4 Seismic

In areas of noted seismic activity,certain precautions shall be made based on the specific risk to collections facilities.Note that certain human activities such as oil and gas exploration have been shown to cause seismic activity in areas where it was not previously noted;institutions shall strive to take these factors into account,and may choose to design/construct a seismically resilient facility even if not required by regulations.Specific considerations for seismic protection in collections repositories shall include:

— consideration of safe shelving height;

— appropriate bracing of shelving,whether stationary or mobile;

—installation of strapping or guards on individual shelves to keep collection materials from falling during a seismic event.

9.5 Power/Emergency power

9.5.1 General

Individual wires/cables should be properly encased.The lighting circuit shall be laid with copper core insulated conductors through conduits.

There should be a master switch or switches outside the repository to isolate all circuits except those providing fire detection and protection or emergency lighting.The switches should be secure against vandalism and tampering and should be fitted with a warning light to indicate when the power is on.

9.5.2 Emergency power

In settings where power outages are a known risk (whether due to natural disasters,weak infrastructure, or other factors)facilities shall be equipped with an emergency power generator(s)capable of powering emergency circuits/systems for a minimum of one week.Considerations in the design of this system shall include:

—Siting:emergency generators and fuel storage tanks shall be located exterior to the collections storage facility to minimize overall risk and avoid heat gain in the facility.

—Accessibility:the generator and fuel tank shall be easily accessible for maintenance and refuelling.

— Testing:emergency generators shall be tested regularly to ensure response in a power outage.

—Circuits:typical emergency circuits will only include critical building operations such as basic lighting and security.Institutions may consider whether to include mechanical systems serving preservation environments to emergency circuits;ideally the goal would be to achieve an envelope design capable of buffering exterior conditions without requiring mechanical operation.

10 Facility records and maintenance

10.1 Facility records

All design and construction documentation and drawings shall be retained by the institution as a permanent record of the process.Process documentation,such as design specifications,documentation of various design phases,etc.,shall be maintained and updated by the collections team as part of the institutional archives,available for research but not expected to require regular access.A minimum of two print copies of final as-built specifications,drawings,and operational manuals shall be maintained,one with the facilities/ operations department for regular use and consultation,and one with the Collections department as permanent documentation;at least one paper copy shall be kept off-site for consultation in case of disaster on site.Alternatively,digital versions of the as-built specification and drawings may be provided as the regular use copy for both departments.

10.2 Maintenance

A sustainable approach to all future maintenance shall be taken with forward planning,including funding, to address the building's maintenance requirements as it ages.There shall be regular and high-level dialogue between the building's users,usually in form of its facility managers or similar,and the specialists who provide maintenance services.Certain maintenance tasks may have specific deadlines while others are dependent on the state of the building after survey and assessment.Communication and a flexible approach will serve the most sustainable methods of maintenance.

The institution shall continuously monitor the condition and changes of the repository site,spaces and surroundings.Appropriate action shall promptly be taken to restore protection if changes impair the archive and library premises protection level.Besides complying with legally-required regular inspection intervals, shorter intervals may be necessary,if the storage conditions are prone to special risks.

All installations in the repositories shall be maintained and checked for proper function and any shortcomings shall be corrected.Function checks and actions taken shall be promptly documented.The data shall be accessible to responsible facilities and collections staff.

Examples of functional checks are regular check of air temperature and relative humidity in the repositories, inspection of fire alarms,fire damper,smoke extract fans,smoke hatches,fire extinguishing equipment, moisture alarms,burglar alarms,automatic door closers,lighting equipment,water supply and wastewater systems and electricity,electronic devices.

The institution shalldevelop and adopt internal procedures and rules for the use of the repositories.These rules shall be announced and regularly repeated to facilities and collections staff.In order to meet changing requirements due to new regulations or approved expert findings on storage or collection conditions, altered risk situations,or best available technology and materials,institutions should keep up with expert knowledge and interdisciplinary skills.This goal may be achieved by regular information exchange among staff of the institution and within the expert community as well as by reading relevant publications.

Annex A
(informative)

Automatic fire-fighting systems

A.1 General

Automatic fire-fighting systems are most commonly specified for the preservation of human life (in offices and shops,for example)and consequently water sprinkler systems are most frequently selected for populated locations,since these have a long record of reliability in extinguishing fires.In library and archive repositories it has been common to specify inert gas suppressant systems,including systems that maintain a permanently reduced oxygen environment (hypoxic air systems)because the release of these gases is safe for organic material collections and is unlikely to cause collateral damage in areas beyond the seat of a fire or cause major clean-up and restoration expense.

A.2 Combustible materials

Library and archive collections often represent a significant quantity of combustible material with the potential for a deep seated Class A fire,as defined in EN 2.Water sprinklers are a proven method of effectively controlling such fires and limiting the extent of fire damage but the effects of water damage on the collections should be considered.There is also potential for water damage from inadvertent or accidental operation.It is possible to use pre-action sprinkler systems to obviate this risk although the added complexity and cost of such systems should be considered before selecting one.Guidance on the design of sprinkler systems can be found in EN 12845[10] and further guidance in relation to the actuation and control of pre-action sprinkler systems can be found in BS 7273-3[32].Books and documents in repositories that use a water-based extinguishing system should be boxed or otherwise enclosed for protection in the event of water discharge.

A.3 Inert gas and chemical and clean agent suppression systems

There are different types of gaseous fire-fighting system used to protect repositories,including those using inert gas mixtures (e.g.argon/nitrogen/CO_2)which reduce the concentration of oxygen below that required for combustion(15%)and those using free-radical recombination agents which interfere with the chemical reactions taking place in a fire.These systems are actuated automatically by an associated smoke detection system.Guidance relating to such systems can be found in the EN 15004-1[9] and other parts of this series. Further guidance in relation to the actuation and control of gaseous systems can be found in BS 7273-1[31]. Gaseous suppressant systems are designed to deliver a sufficient quantity of the agent into a space in order either to reduce the oxygen concentration below 15%or to delay a full inflammation occurring for enough time to allow the source or seat of a fire to be investigated and rendered safe.As such they can only be used successfully in comparatively small spaces.A high-sensitivity detection system will add to the likely time available should the source of a fire not be established promptly following an alarm triggered by detectors (for example at times when the building is closed and not occupied).Clean agent systems are comparatively new.They have the advantage of not requiring the pressure release openings that inert gas systems require. Long-term viability of clean agent suppressants is constantly evolving,with several products no longer in production (or in the process of being phased-out)due to HFC/HCFC composition and ozone depletion concerns and other products under consideration for discontinuation due to their classification as"forever chemicals."

A.4 Overpressure

All gaseous systems generate overpressure when discharged into a space.Prior to procurement of agaseous system,the structure of the repository should be assessed by a structural engineer to establish whether it is able to withstand this pressure.If overpressure vents need to be fitted,these should not compromise the environmental stability,security and air infiltration standards of the repository.Duct-work leading to a plant-room outside the repository can have vents included so that they act as a route for the escaping air. Inert gas systems should conform to EN 15004-1[19].

A.5 Reduced oxygen systems

Reduced oxygen (hypoxic)systems can be installed to protect heritage collections.When selecting such a system,care should be taken to consider the implications for the safety of those working in the repository as the required oxygen level required to reliably prevent or suppress fire development might be lower than that permitted for unrestricted access.Such systems require constant replenishment of the atmosphere in the room with nitrogen or pre-mixed,reduced oxygen air.There are,therefore,continuous energy costs associated with such systems that should be considered as part of whole-life costing.

A.6 Water-mist systems

Water-mist systems can be designed with automatic nozzles,similar to an automatic sprinkler system,or be designed as deluge system,where all nozzles within the protected space will distribute water simultaneously. The main advantage of water-mist systems over water sprinkler systems is that less water is used.The effect of mobile storage racking,particularly when closed,on water-mist dispersion is likely to be more pronounced than with sprinklers.Water-mist systems designed to flood the whole space on activation of an aspirating smoke detection system can be more effective,but with the result that all surfaces are wetted.

See BS 8489[33]and EN 14972[18].

Annex B
(informative)

Recommended climatic conditions for the long-term storage of archive and library materials

Environmental conditions for the long-term storage of archive and library materials should include defined parameters for both temperature and relative humidity(RH).These conditions should enable the collections life expectancy to be achieved taking into account the materials and structures of collections items and their sensitivity to temperature,RH,and changes in both conditions.Note that every collection is unique;design parameters must address the needs of a specific collection,construction,and location; outdoor environments in specific regions (temperature and moisture contents)should be accounted for.In geographic regions with favourable exterior conditions (i.e.a cold region or season),interior environments that take advantage of these conditions(i.e.cooler interior temperatures)may be beneficial.For example, long-term preservation may be improved by seasonal fluctuation to cooler conditions (provided that appropriate RH can be maintained),compared to maintaining a constantly warmer temperature throughout the year.For detailed guidance on determining appropriate design parameters,see ISO/TR1981581.

The safe temperature and relative humidity conditions of a particular environment,and thus its overall preservation quality,are primarily determined by the moisture content (dew point)present.At any given dew point,temperature and relative humidity have aninverse relationship;as temperature rises,RH will all, and as temperature falls,RH will increase.High dew point environments will make it difficult to maintain cool conditions at moderate relative humidity,while low dew points create challenges in ensuring materials do not become too dry in warm or human comfort conditions.Passive or non-mechanized environments will typically mimic the exterior dew point of the location/region.For mechanically-controlled environments, moisture control is the key design consideration for long-term preservation of collection materials.For further information on the relationship between temperature,RH,and dew point,and the impact on preservation quality,see the Image Permanence Institute's Dew Point Calculator(www.dpcalc.org)38.

The rates of many deterioration mechanisms (chemical,biological and physical)increase as temperature increases.Changes in temperature within a collection space can also cause deterioration.Generally, for concerns of chemical degradation of organic materials,the goal is to maintain as cool a temperature as possible at moderate relative humidity conditions.Relative humidity(RH)influences the rate of many deterioration mechanisms:chemical,biological,and physical.Changes in RH can also cause deterioration; generally,ranges between 30-55%are safe for a broad selection of collection materials.Note that higher RH conditions contribute to an increased rate of chemical decay.Generally,for most library and archive collections,reducing the rate of chemical decay through temperature control is the most significant aspect of risk mitigation.

Attempts to establish a universal safe zone for all collections items by providing conditions required only by sensitive collections items can result in harmful conditions for other collections,as well as leading to unjustifiably increased use of energy.Where only small numbers of sensitive items are present in an otherwise less sensitive holding,it is simpler and more cost effective to package them individually or together in a microenvironment with a controlled temperature or relative humidity,or where larger numbers are concerned,in a climate-controlled cabinet or separate store room.Note that in collections that primarily consist of sensitive media (e.g.cellulose acetate film materials),the entire store may need to be designed to more stringent conditions or parameters.As a rule,chemical reactions accelerate exponentially as temperatures rises.A practical approximation for moderately stable organic materials is that reaction rates (degradation)double with each 5°℃ rise.RH levels also impact the rate of chemical degradation in organic materials;research has shown that reaction rates double with a rise of 20%RH(i.e.degradation rates doubles at 50%RH compared to 30%).

For some groups of documents on modern materials,there are standards for long-term storage,e.g.for photographic documents of different kinds,audiovisual and sound records.For documents made of more traditional materials like palm leaves,various paper types,papyrus,parchment,and others used for records around the world,no International Standards on their storage exist.For an example of a standard for a specific media type,see ISO 18911[1].

Note that Tables B.1 and B.2 are based on guidance provided in ISO/TR 198158 .This annex can be used as a general guide,but it is strongly recommended that ISO/TR 198158 and other publications on this topic are consulted for more details about areas of application,alternative storage conditions for different purposes, specific materials,geographical varieties,etc.

Table B.1—Temperature ranges for long-term preservation and storage

Temperature range ℃	Risk/Benefit considerations
19 and above	Elevated risk for chemical decay for most materials.As noted above,rate of chemical degradation doubles for every 5℃ increase in temperature.In general,conditions above 19° ℃ are not recommended as appropriate long-term preservation storage environments for most sensitive organic materials. —Increase in biological activity(mould and pests)in damp conditions
11 to 18	Cool temperatures slow the rate of chemical decay —Good for most materials except film and color photographs —Exercise caution with certain media including wax seals/ materials.
1 to 10	Good for most materials Beneficial to slow degradation rates for acetate/nitrate film and color media collections. Exercise caution with certain media,including oil and acrylic artwork and wax seals/materials. Must consider glass transition temperatures of specific materials
Below 0	Necessary for some materials such as degraded colour media and acetate/nitrate films in order to stabilize the rate of chemical degradation. Recommended for nitrate media to protect against combustion risks. —Must consider glass transition temperatures of specific materials.

Table B.2—Relative humidity ranges for long-term preservation and storage

Relative humidity range %RH	Risk/Benefit considerations
70 %and above	—Significant risk for mould growth in most settings/collections.
65-69%	—Increasing risk for mould growth Above 65%-significant risk for mechanical deformation.
56-64%	Note that higher RH conditions contribute to an increased rate of chemical decay. Above55%begins risk of corrosion/oxidation reactions for metallic components, including silver-based film/photographic materials. Above 55%introduces risk of iron gall ink degradation. Above 60%increased risk of mechanical deformation of some materials.
30-55%	Good for most materials. Minimal risk to most books, paper documents, photographs, and museum-type objects that may be found in broader archives/library settings. Some materials such as vellum and parchment may be safer at RH conditions of 40-55%.
Below 30%	Generally safe for most inorganic materials Increased risk for dimensional (physical) change due to moisture loss. Inappropriate for particularly sensitive materials, e.g. vellum, parchment, and film/photographic materials.

Annex C
(informative)

Environmental transitions for materials

C.1 Transition between different environmental conditions

Care should be taken when moving collections from one environmental condition area to another,as rapid and large changes in either temperature or relative humidity can have severe detrimental effects on some materials.Risk is most often incurred in either:

—The movement of materials from a warm,moderate dew point environment into a cold/frozen environment;or

— The removal of materials from a cold/frozen environment into a room-temperature setting,such as a workspace or research environment.

For the former,specific recommendations exist on how to properly package materials for cold/frozen storage,particularly in cases where the RH is not adequately controlled.For example,movement back into a cold store from a warm reading room may cause condensation on the inside of polyester sleeves or other impermeable encapsulation if appropriate mitigation strategies are not used.For the latter,the primary risk is in moving materials at a cooler equilibrated temperature into an environment with a higher dew point temperature (e.g.moving a 10°℃ object into a 15°℃ dew point condition).This crossover incurs a risk of condensation on the cold object.

Depending on the variations in environmental conditions between two spaces,and particularly the RH control of the cold/frozen environment,it may be necessary to package collections before moving between environments.Acclimation chambers between the two environmental conditions are an option,but if RH is properly controlled in both settings,simply bagging or otherwise packaging cold materials may be sufficient to protect against condensation on objects until the temperature is fully equilibrated.

C.2 Time out of storage—Chemical degradation risk

If the organization is considering the inclusion of frozen storage environments for acetate film,colour media,or other materials,the intended programmatic usage of those materials is a key consideration in the potential long-term preservation value of the storage condition.The intention should be for materials to be permanently stored in the frozen environment with minimal retrieval to human-comfort environments. There is no advantage to very low temperature cold storage if the object is retrieved frequently to room temperatures.Cold storage does not reverse the decay that progresses during warm periods.Temperatures for cold storage should be designed considering the expected retrieval pattern.

Data exist that illustrate the influence of "time-out-of-storage"on materials,specifically on where the retrieval pattern has cut the potential of the cold temperature by one-half.Lower temperature storage will not significantly improve remaining life expectancy unless retrieval time also diminishes (see also Reference [35]).

Keep in mind that the time out of storage concept should not be used as justification not to freeze certain sensitive,at-risk materials.Frozen storage may still be used for temporary stabilization of at-risk media until migration or reformatting is possible.

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