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Conservation of Cultural Heritage – Specifications for location, construction and modification of buildings or rooms intended for the storage or use of heritage collections

bsi.

National foreword

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A list of organizations represented on this committee can be obtained on request to its secretary.

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Conservation of Cultural Heritage - Specifications for location, construction and modification of buildings or rooms intended for the storage or use of heritage collections

Conservation du patrimoine culturel - Spécifications pour l'emplacement, la construction et la modification des bâtiments et des salles destinés au stockage ou à l'utilisation de collections

Erhaltung des kulturellen Erbes - Festlegungen für Standort, Errichtung und Änderung von Gebäuden oder Räumlichkeiten für die Lagerung oder Nutzung von Sammlungen des kulturellen Erbes

This European Standard was approved by CEN on 20 November 2017.

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European foreword

This document (EN 16893:2018) has been prepared by Technical Committee CEN/TC 346 “Conservation of Cultural Heritage”, the secretariat of which is held by UNI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by August 2018, and conflicting national standards shall be withdrawn at the latest by August 2018.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN not be held responsible for identifying any or all such patent rights.

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Introduction

Cultural heritage collections are intended to be kept for future as well as current generations. Their long-term conservation can only be achieved if the sites and buildings that house them support this goal and do not place them at risk. Building features that are intended to protect collections are primarily structural, involving resilience against external and internal hazards including fire, water, pests, criminal activity and environments that interact with heritage materials.

Environmental considerations for collections are influenced by the nature of their materials, their condition and the uses to which they are put. They are also influenced by policies relating to conservation objectives, such as longevity of collections, and by the nature and costs of energy required to achieve these objectives.

This standard assists custodians of cultural heritage collections by defining the criteria and information necessary to make policy relating to conservation that will in turn influence the outcome of building construction. It is also intended to help them define the specifications necessary for the construction or modification of buildings such that they can safely house collections.

These specifications should be used by architects, engineers and others responsible for the design and construction of new archives, libraries and museums, or modifying spaces within existing buildings for these purposes.

These specifications might not be applicable in historic buildings which may also contain cultural heritage objects, e.g. churches.

1 Scope

This European Standard gives specifications and guidance for the location, construction and arrangement of building specifically intended for internal storage of all heritage collection types and formats.

This standard applies to buildings where collections are housed permanently and can be used as guidance for shorter-term display spaces where appropriate. Throughout the document, where specifications relate exclusively to storage spaces, these are defined as such. Where specifications can also be applied to areas such as display galleries or reading rooms, these applications are referred to explicitly.

Clauses relating to risks associated with security, environmental hazards, fire, water and pests apply to buildings as a whole and to any room in which collections may be held.

Some of the clauses in this standard may be applicable in protected historic buildings that contain collections. In these settings, the scope for any alterations or achievement of conditions suitable for collections may be limited by the historic character of the structure, especially where it is protected by heritage regulations.

NOTE This standard covers the structure of buildings containing heritage collections, whether for storage or use. For a description of technical processing spaces recommended in the design specifically of a storage building open to the public, attention is drawn to EN 16141.

This standard should be seen as complementary to national or local building regulations and specifications.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 1627, *Pedestrian doorsets, windows, curtain walling, grilles and shutters — Burglar resistance — Requirements and classification*

EN 1838, *Lighting applications — Emergency lighting*

EN 12056-3, *Gravity drainage systems inside buildings — Part 3: Roof drainage, layout and calculation*

CEN/TS 16163, *Conservation of Cultural Heritage — Guidelines and procedures for choosing appropriate lighting for indoor exhibitions*

EN 62305-2, *Protection against lightning — Part 2: Risk management (IEC 62305-2)*

EN 60332-1-1, *Tests on electric and optical fibre cables under fire conditions — Part 1-1: Test for vertical flame propagation for a single insulated wire or cable — Apparatus (IEC 60332-1-1)*

EN 60529, *Degrees of protection provided by enclosures (IP Code) (IEC 60529)*

EN ISO 16890-1, *Air filters for general ventilation — Part 1: Technical specifications, requirements and classification system based upon particulate matter efficiency (ePM) (ISO 16890-1)*

3 Terms and definitions

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

3.1
air-conditioning
mechanical system that maintains predetermined control of temperature, humidity, air quality and air distribution

3.2
air infiltration
uncontrolled leakage of air through unsealed points and permeable building materials into a building envelope

3.3
aspirating smoke detector (ASD)
smoke detector, in which air and aerosols are drawn through a sampling device and carried to one or more smoke sensing elements by an integral aspirator (e.g. fan or pump)

Note 1 to entry: Each smoke sensing element may contain more than one sensor exposed to the same smoke sample.

[SOURCE: EN 54-20:2006, 3.1, modified – abbreviation ASD has been added.]

3.4
automatic fire-fighting system
integrated system within a building, designed to control, suppress or extinguish a fire, activated by detection systems

Note 1 to entry: These units can be single- or double-sided.

3.5
Building Management System (BMS)
computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems

3.6
bund
structural upstand that can contain water within a defined space in the event of a flood

3.7
CCTV system
system consisting of camera equipment and/or other image-capture devices, detector(s), monitoring and associated equipment for transmission and controlling purposes

3.8
collection
group of objects having shared or combined significance

Note 1 to entry: The term "collection" is mainly used within "movable cultural heritage".

[SOURCE: EN 15898:2011, 3.1.4, modified – note to entry was shortened]

3.9
conservation
measures and actions aimed at safeguarding cultural heritage while respecting its significance, including its accessibility to present and future generations

Note 1 to entry: Conservation includes preventive conservation, remedial conservation and restoration.

Note 2 to entry: The term “conservation-restoration” is mainly used in the field of movable cultural heritage.

Note 3 to entry: The term “preservation” is also used, e.g. in libraries and archives.

Note 4 to entry: All conservation actions are based on documentary and/or material evidence.

[SOURCE: EN 15898:2011, 3.3.1]

3.10
cooling load
power demand (measured in kilowatts) that is imposed upon an air-conditioning system in maintaining a room at the required level of temperature and RH

3.11
environment
surroundings of an object, some aspects of which may affect its condition

Note 1 to entry: Such aspects could be of human, physical, chemical, biological or climatic origin.

[SOURCE: EN 15898:2011, 3.2.2]

3.12
environmental control
management of one or more factors of the environment

Note 1 to entry: This applies to temperature, relative humidity, light, pollution, etc.

[SOURCE: EN 15898:2011, 3.4.3]

3.13
fire resistance
ability of a building component or construction to withstand the passage of flames and hot gases and temperature rise for a stated period, including load-bearing capacity, integrity and insulation

3.14
monitoring
process of measuring, surveying and assessing the material properties of objects and/or factors of the environment over time

[SOURCE: EN 15898:2011, 3.4.4]

3.15
object
single manifestation of tangible cultural heritage

Note 1 to entry: The term “object” is used in this standard for cultural heritage, both immovable and movable. In specific professional contexts, other terms are used: e.g. “artefact”, “cultural property”, “item”, “ensemble”, “site”, ”building”, “fabric”.

[SOURCE: EN 15898:2011, 3.13]

3.16
pre-action sprinkler
dry sprinkler system or one in dry mode in which the alarm valve can be opened by an independent fire detection system in the protected area

3.17
preventive conservation
measures and actions aimed at avoiding or minimizing future damage, deterioration and loss and, consequently, any invasive intervention

Note 1 to entry: In the field of movable heritage, "preventive conservation" is generally indirect; namely, these measures and actions are carried out within the immediate environment of the object.

[SOURCE: EN 15898:2011, 3.3.5]

3.18
relative humidity (RH)
ratio of the actual water vapour pressure to the saturation vapour pressure

[SOURCE: EN 15757:2010, 3.9]

3.19
remedial conservation
actions applied directly to an object to arrest deterioration and/or to limit damage

3.20
risk assessment
identification, analysis and evaluation of threats that might alter significance, and the probability of their occurrence

Note 1 to entry: Risk assessment is part of the overall process of "risk management" [ISO Guide 73:2009, 3.1.7].

[SOURCE: EN 15898:2011, 3.4.5]

3.21
sprinkler system
system of water pipes fitted with sprinkler heads at set intervals and heights, designed to detect, control or extinguish a fire by the automatic discharge of water

3.22
storage
designated area where objects are housed providing the necessary conditions required for preservation, safety and security while not on display

Note 1 to entry: The term "repository" is used in archives and libraries.

[SOURCE: EN 16141:2012, 3.8]

3.23
T_g – Glass transition temperature
reversible transition in amorphous materials (or in amorphous regions within semicrystalline materials) from a hard and relatively brittle "glassy" state into a molten or rubber-like state, as the temperature is increased

Note 1 to entry: Examples of cultural heritage materials sensitive to temperatures that influence T_g include gelatine photographic emulsions and waxes.

3.24
UVA
ultraviolet radiation of wavelength 315 nm to 400 nm, which is present in sunlight and some artificial light and is damaging to many heritage collection materials

3.25
Whole Life Cost (WLC)
total cost of ownership over the life of an asset, in this context a building

Note 1 to entry: Typical costs include planning, design, construction, operation, maintenance, renewal, eventual demolition, build cost and depreciation.

4 Principles and strategies

4.1 Sustainability

As cultural heritage collections are intended to be preserved indefinitely, buildings intended to house them shall be designed to have a long life. Whether planning a new building or the refurbishment of an existing building, the Whole Life Cost (WLC) shall be evaluated and used as a basis for decision-making. The projected energy use, water consumption, carbon emissions and maintenance costs over the life of a building shall be included, in addition to capital costs.

Planning for any new or refurbished building or space shall be directed at determining whether collections can be protected through passive or low energy means wherever possible. Wherever a collection requires ongoing energy use (e.g. heating, freezer storage), the use of renewable energy sources should be explored in the first instance. Since the success or otherwise of a passive climate building design strategy over time may not be predictable at the planning stage, options for retro-fitting controls in the future shall be taken into account.

Consideration of a site shall also take account of the potential energy consumption of users travelling to the location. For example, a remote location may be low risk but it may increase energy consumption, so the balance of risk over ease of accessibility should be assessed.

Assessment of costs associated with construction shall comply with ISO 15686, Parts 1 and 5.

4.2 Risk management

4.2.1 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, as defined under Clause 5 below. Existing buildings or rooms housing collections shall be re-assessed against risks periodically, particularly when new hazards are known to have emerged. Information and data need to be gathered and assessed in order to formulate a policy for the intended environment, security, fire and flood protection inherent in the building design or its continued use. As part of the risk assessment, the methodology and steps below shall be included. The risks set out in the following clauses shall be considered when:

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

b) equipping the building, and

c) managing the building once in use.

4.2.2 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 assess the likelihood and impact of those hazards occurring. The following hazards are common to cultural heritage collections and shall be assessed:

a) environment (internal and external): temperature, humidity, light and pollution including gaseous and particulate (see Annexes B to E for examples of guidance information regarding environmental risks and sensitivities of collection materials);

b) bio deterioration (pests and mould);

c) theft, robbery;

d) vandalism;

e) fires;

f) water (fresh water supply and wastewater);

g) natural events (torrential rain, flooding, landslide, earthquake, etc.).

The hazards associated with the location of a building shall be identified in accordance with 5.1. The location within a building of activities and services that may create a hazard, e.g. kitchens, laboratories, shall be taken into account in the risk assessment.

4.3 Environmental strategy

4.3.1 General

An environmental management strategy for the collection shall be developed, based on an assessment of the needs of the collections. The strategy shall include a statement of the expected collection lifetime and the energy demand arising from the environmental conditions needed to achieve this, taking into account the sensitivity, significance and use of individual collection items.

The strategy shall make clear the balance the organization intends to aim for between conservation requirements, collection use and energy economy.

4.3.2 Collection information

As a minimum, the information relating to the collection shall include the following:

a) the significance of the collection or collection items therein;

b) the current and expected usage of the collection, including display, handling, transit and loan;

c) the condition of the collection, its structure and component materials;

d) the past environment of the collection and its sensitivity (to RH, temperature, light and pollutants) as detailed in any existing records, noting in particular changes over time (see also Annexes B to E);

e) the expected growth and development of the collection.

4.3.3 Specifications for environmental protection

Any environmental specification has to be set with the aim of preserving the collection concerned. Environmental specifications shall be established after a review of:

a) the preferred collection lifetime and associated energy demand;

b) the risk assessment of environmental hazards conducted in 4.2.1 a);

c) the information collected in 4.3.2;

The environmental specifications for collections shall include:

1) the permissible upper and lower limits for temperature and a desired seasonal average;

2) the permissible upper and lower limits for RH and a desired seasonal average;

3) the permissible upper limit for light exposure, upper limit for illuminance and upper limit for UV to light ratio if relevant;

4) pollutants expected to cause unacceptable risk;

NOTE See also 5.4.3.2.

Environmental specifications shall be set for general storage, cooled storage, cold storage, display and transit, as appropriate based on the collection type. Separate environmental specifications shall be set for any microclimates.

4.4 Environmental monitoring strategy

4.4.1 General

An understanding of how well a collection will be protected and preserved can only be achieved by continuous monitoring of the environment in which material is held. All spaces intended for future installation of collections shall be monitored before installation in order to understand how the spaces behave and how they may need to be modified. Monitoring shall also be carried out in existing locations that already hold collections, in order to understand the present state of the collections, particularly if they are to be moved to a new location. The information derived from monitoring shall be reviewed regularly and the implications of trends in RH, temperature, light and, where necessary, atmospheric pollutants shall be interpreted by a conservator or other specialist with knowledge of the collection and the building and its infrastructure. 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 and to rectify the situation or plan for improvements.

4.4.2 Methodology

Monitoring devices for environmental hazards shall be provided and used within collection space, whatever the method of environmental control. Monitoring of temperature and RH should typically be carried out continuously (e.g. a minimum of 1 datum per hour). Even if a building management system (BMS) is in use, independent monitoring devices shall be used to verify its correct operation. Monitors and their sensors shall be situated to provide readings that represent the typical conditions in which collections are held or will be held but account should also be taken of extreme or abnormal conditions that could occur, for example near outside walls or close to a source of heating or ventilation. For comparative purposes, the outdoor temperature and RH shall be monitored and pollutants where necessary.

NOTE 1 Because indoor pollutant concentrations rarely change abruptly, seasonal monitoring will be sufficient unless pollutant-related damage is observed or if furnishings or building features change substantially.

Where collections are packaged, monitoring the room environment will not provide sufficient information about the environment around objects. Sensors should also be placed inside selected packages.

Monitoring data shall be inspected regularly, at least once a week if they are being relied upon to establish how an uncertain environment is behaving, or for known environments and longer-term analysis at least once every three months. Data shall be retained indefinitely in a retrievable form. 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 calibrated according to the manufacturers' instructions. They may also be checked against independent devices such as a hand held digital hygrometer, in case they require calibration or develop a fault.

NOTE 2 Even electronic sensors tend to drift and need recalibration from time to time, which is why some independent monitoring is desirable. It is advisable to carry out calibration in a laboratory equipped for that purpose.

NOTE 3 Attention is drawn to EN 15757 and EN 15758.

4.5 Facilities management strategy

Facilities management strategy shall reflect the nature, purpose and use of the building and the operations and collections that are housed within. Where used, Building Management Systems (BMS) shall incorporate continuous environmental monitoring and control of the BMS and its ongoing development shall be undertaken in close partnership with collections specialists. Environmental and energy data generated by BMS shall be archived in a retrievable form.

If a BMS is in use it is also recommended to have some independent monitoring devices, e.g. for inside packages, showcases and for back-up monitoring. BMS can be set up to provide multi-location monitoring.

NOTE Inspiration on facility management issues can be found in the EN 15221 series.

Collection management staff and other staff working in the building (e.g. security, maintenance of technical systems, general building service, cleaning) shall be involved in the planning of a new building.

5 Building specifications

5.1 Building location

5.1.1 Hazards identification

When selecting a site for a new construction or reviewing an existing building 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. When selecting spaces within an existing building for re-use for heritage collections, a risk assessment needs to be undertaken with reference to the strategy outlined in Clause 4. The risk assessment shall include an evaluation of whether preventive measures can be implemented to minimize the risks identified and whether after measures are put in place the level of risk is likely to be acceptable.

NOTE 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 certain hazards causing loss or damage to heritage materials is to be assessed and taken into account.

When selecting a site, a risk assessment shall take account of hazards that result in the sudden loss of, or extensive damage to collections (e.g. the collapse of the building, fire, flood or serious contamination resulting in the site becoming inaccessible) and those hazards that can result in damage over time (e.g. insect attack, pollution or climate).

The risk assessment shall include hazards associated with the following:

a) road, rail or similar tunnels under or close to the building or elevated roadways, railways or tramways (e.g. collapse or excessive and regular vibration);

b) landslides, sink holes, uplift, seismic and volcanic activity;

c) flooding, including current and projected water levels;

d) 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;

e) 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.;

f) sites adjacent to a place or activity that will attract rodents, insects and other pests, such as food storage or processing, waste management, etc.;

g) nuclear power stations, plants or other radioactive facilities;

h) airports and their associated flight paths;

i) high voltage power lines and substations (e.g. collapse or fire); or

j) defence and other target establishments.

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 investigation.

5.1.2 Natural hazards

In order to minimize the harmful effects of exposure to sunlight and strong winds that affect air infiltration, careful attention shall be 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. Where a history of springs and underground watercourses exists, these shall be taken into account as heavy and prolonged rainfall may reactivate them.

5.2 Site capacity

5.2.1 General

In planning a new heritage collection building, the projected growth of collections according to the obligations of the institution shall be assessed and additional capacity for this shall be included. Wherever practicable, the site of a new building shall be large enough to allow for subsequent extension.

5.2.2 Self-containment

Where a self-contained unit within a larger structure is selected for housing collections, any additional risks imposed by the larger building shall be assessed and mitigated as much as possible, so that the collection unit's security, structural integrity and fire protection are not compromised. Risks shall be regularly reassessed, particularly if the nature of activity undertaken in the larger building changes.

5.3 Building structure and environmental protection

5.3.1 General

This clause covers specifications for the construction of a purpose-built new building intended to provide a protective environment for cultural heritage collections and should also be used when planning to remodel an existing building or room in order to improve its qualities sufficient for it to be used for collections.

It should be noted that the changes needed to achieve these environmental specifications may be prohibited in a protected historic building. Where an historic structure already houses heritage collections, such as an historic library, archive or house, a detailed risk assessment shall be carried out to determine its capacity to provide a protective environment.

NOTE Collections integral to a protected historic interior can need to remain *in situ* unless the environment has become damaging to them (e.g. where a local water table has risen, causing water to penetrate).

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 shall also be consulted to prevent conflict between security and fire protection measures and the safety measures for both people and collections. The different parties involved might have different priorities and it is essential that discussions take place at the outset of the building construction. Building constructions shall be compliant with 6.3.

The scope and nature of a collection, as defined following 4.3.2, shall be used to determine the kind of environments that a building or space should provide. If an appropriate environment can be achieved by passive means, these shall be adopted. Some sensitive collection materials may require additional mechanical control such as freezer storage or heating.

5.3.2 Construction materials

Walls, floors and ceilings shall be made of materials that conform to the specifications in 5.3.4 and 5.4.3. Internal finishes shall not impede the function of the thermal and hygroscopic capacity of the building to stabilize conditions and shall not produce dust.

5.3.3 Building acclimatization

In the case of newly constructed buildings, drying time for building structure and off-gassing of internal finishing, paint and varnishes shall be calculated and this drying time incorporated in the construction schedule to enable the internal environment to stabilize before any heritage objects are placed there. This 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 and only when the specified conditions are achieved shall heritage materials begin to be introduced.

NOTE 1 Where two or more diverse forms of constructions are to be used in a building, it is particularly important that the construction schedule takes drying times into consideration. A wet form of construction, intended to provide high thermal inertia (for example, *in situ* cast concrete floors, masonry walls) takes longer to dry out than, for example, a lightweight prefabricated dry form of construction that can be used for public and staff facilities.

NOTE 2 Transfer of collections to a new building can influence the internal environmental conditions and in such instances a further acclimatization period can be necessary. This can have a short-term negative effect on the performance of any air-conditioning plant if it is used. Movement of heritage materials also creates dust and so it is important to check the condition of ductwork, filters and other equipment after the move.

5.3.4 Passive or low-energy environment structures

5.3.4.1 General

Most collection types can be stored and used in an environment (RH and temperature) that changes gradually over an annual seasonal cycle, which can be achieved through passive means. The maxima and minima in an annual cycle shall be determined by the allowable specifications for collection types. If a new building or the renovation of an existing room is being planned, it shall not be assumed that mechanical environmental control systems are required without a full investigation of all available options to achieve specified conditions.

Dynamic thermal and hygroscopic modelling shall be used to determine how changes in external environment, such as extreme weather conditions, could affect internal conditions and the building structure designed to remain within required conditions when these changes occur. The specification for the building structure (insulation and hygroscopic properties) shall also take account of the length of time that it will take for the environment to go out of the required range following failure of any control equipment (e.g. heating in winter).

The insulation and hygroscopic properties of a new building designed to provide an environment requiring climate control (e.g. heating in winter) shall be capable of maintaining specified conditions in the event of the failure of the equipment for a minimum of 48 h or until alternative arrangements can be made.

5.3.4.2 Storage spaces

Environmental stability in a storage space shall be achieved by a location and construction that ensures that the temperature inside the space is not rapidly or substantially influenced by the temperature outside, has low air infiltration rates, has a barrier to prevent moisture penetration from outside and incorporates hygroscopic materials on the inside to moderate internal RH fluctuations. Heating infrastructure (pipework) that is not intended for the storage space shall not pass through or under the space. Any such pipework in an existing room that cannot be removed as a part of the modifications shall be insulated in order to minimise thermal gain and avoid excessively dry conditions in winter.

A new storage building or space shall be built to maximise air tightness. Air infiltration shall be less than $0{,}5 m^3$ per square metre per hour at 50 Pa. A storage space within an existing (not historic) building should meet the same standard and if necessary shall be improved in order to meet it.

Tests intended to assess the air infiltration rate of a proposed storage space shall not involve the sealing up of likely air passage locations such as doors and ductwork since these, if they are not to be changed or removed, will continue to affect the rate of infiltration once the collection is in place.

NOTE 1 In passive controlled storage environments the annual indoor temperature pattern will be similar to the outdoor pattern but at different levels. In practice, it is possible to keep the annual temperature variation in an above ground structure within a 10 °C variation, while this variation will be greatly reduced (i.e. improved) in below ground structures. Because it is more difficult to eliminate air infiltration in above ground structures, some dehumidification can also be necessary in summer months. Achieving a low air infiltration rate reduces energy use by reducing the dehumidification load.

The extent of internal hygroscopic characteristics shall be informed by the hygroscopic nature of the collections held within and the ratio of space to the collections. The construction type and building fabric chosen, with low air infiltration and high thermal stability, shall not cause condensation to occur within it or on its surfaces. Passive microclimate packaging should be used for RH sensitive collection materials to further reduce the rate of change to the object contained.

NOTE 2 Hygroscopic organic materials respond to changes in RH which in turn cause changes in dimensions and mechanical properties. The response time of collection items to RH change depends on the materials and varies according to thickness and permeability. Packaging and buffered frames and display cases slow the response time of a collection item, depending on the air-tightness and buffering capacity of the enclosure.

A policy of encouraging regular open storage visitor access is incompatible with the successful maintenance of some passive storage climates.

NOTE 3 For example a building constructed exploiting low winter temperatures to maintain cool conditions inside a store will not support the additional warming, moisture and air infiltration caused by regular flows of visitors.

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, airlocks shall be used. The layout of the airlock shall allow for the movement of staff and collections.

5.3.4.3 Display and reading spaces

Air infiltration rates and temperature in a display gallery or reading room will inevitably be higher than in a storage space, especially if they are to be comfortable for users. When planning to use collections in any building, the relationship between building orientation, weather patterns, sunlight and the intended collection use shall be considered. In display spaces that do not provide hygroscopic stability, buffered cases and frames shall be used to protect RH sensitive collections.

Lighting installations shall be in accordance with 5.8.3 and produce minimal heat.

Any heating infrastructure (pipework) that has to pass through or under the space but is not intended to warm the space shall be insulated in order to minimise thermal gain and avoid excessively dry conditions in winter.

Windows shall have filtration to block UVA radiation and have blinds fitted or other means of reducing or removing direct sunlight and solar heat gain. Localised heating shall be fitted with manual controls. The seasonal pattern of sunlight in display spaces should be modelled or recorded and the use of collections adjusted accordingly to avoid risk of light damage.

NOTE Attention is drawn to EN 15999–1.

5.4 Air quality

5.4.1 General

Existing buildings and sites intended for collections shall be assessed for pollution risks. New buildings shall be constructed using materials that do not emit pollutants harmful to collections. Collections should be assessed to identify their different sensitivities to pollutants and whether they themselves produce internal pollutants.

5.4.2 External pollutants

In planning a new building, published data on local outdoor gaseous pollutant concentrations shall be examined to determine which pollutants, if any, need also to be monitored indoors. Collection items shall be evaluated to identify materials known to interact with outdoor generated gaseous pollutants. If an outdoor gaseous pollutant concentration is high, and sensitive collection items are held on display, pollutants shall be monitored indoors to guide action to mitigate any risks identified. If risks of pollutant/material interaction are identified, collection items shall not be installed until pollutant levels have been reduced and/or risks eliminated.

NOTE External pollutants of most concern include ozone, nitrogen oxides, sulphur dioxide and dust. For supplementary information on external pollutant interactions and sensitivity of collections, see Bibliography for further reading.

Air intakes (e.g. for ventilation) shall not be located close to sources of pollution, excessive moisture or heat. Where external air pollution levels entering through ventilation systems are high enough to place collections at risk, air intakes should incorporate chemical filtration. Dust entering the building via air intakes shall be collected through a coarse filter in accordance with EN ISO 16890-1 and a fine filter in accordance with EN ISO 16890-1.

5.4.3 Internal pollutants

5.4.3.1 Building materials

Collection items held in passive storage spaces or furniture shall be evaluated to identify materials sensitive to gaseous pollutants generated within or by the building materials, surfaces, storage enclosures or cases.

NOTE 1 Pollutants such as acetic acid (ethanoic acid), formic acid (methanoic acid), formaldehyde (methanal), reduced sulphur gases and volatile organic compounds generally have higher concentrations in enclosures compared with the external environment. Pollutant interactions with heritage materials are promoted by high RH and temperature levels.

The materials used to construct enclosures and display cases shall be evaluated to determine that they do not emit gaseous pollutants to an extent that would be expected to cause unacceptable irreversible change in the contents of the enclosure. Any improvements should take into account the specifications in EN 15999-1.

Paint, varnishes and coatings that do not emit volatile organic compounds shall be used in construction of building components in areas intended to hold collections. Any equipment (including filtration) that produces ozone shall not be installed or operated near collections, as ozone can be harmful to heritage materials.

NOTE 2 Emissions from surfaces and coatings can continue for years after application, especially in a well-sealed, low air-exchange space. Gum, gelatin, casein and silicate paints can be used for brickwork, masonry and concrete as safe alternatives.

Paints, varnishes and sealants can emit pollutants at high concentrations while maturing after application. Collection items shall not be brought near maturing coatings until emissions have fallen below thresholds.

NOTE 3 For examples of internal pollutants and their sources see Annex D.

NOTE 4 Pollution emission from building and storage enclosure materials can be reduced by the application of barrier materials and/or protective coatings or lacquers.

5.4.3.2 Emissive collections

Some collection materials emit volatile compounds of a nature and volume that place themselves and other collections at risk. An assessment shall be made to establish the level of risk of any emissive collections and where these are deemed sufficiently high, ventilation shall be incorporated into storage and display. In mechanically ventilated systems carbon filtration shall be placed on recirculated air to absorb these pollutants. Dedicated storage spaces shall be constructed or used for highly emissive collections to ensure that people and other collections are not harmed. The selection of which ventilation system, whether natural or mechanical, shall be determined by factors including safety and energy consumption.

NOTE Emissive collections likely to require compliance with 5.4.3.2 include: spirit stored natural history specimens, radioactive specimens, large collections of cellulose acetate and nitrate cine film.

5.4.4 Ventilation

The building shall have a controllable means of ventilation in order to change air that has become polluted or following a change in atmospheric conditions resulting in high internal RH or temperature. Methods of ventilating that do not use electro-mechanical equipment shall be specified in order to allow for ventilation when no power is available, e.g. natural ventilation systems, and shall be blocked off when not in use.

NOTE 1 Natural ventilation, either wind driven or buoyancy (stack) effect, uses naturally occurring pressure differences to reduce the cost and environmental impact of energy costs.

Ventilation using external air shall incorporate filtration to reduce external pollutant concentration levels to conform to 5.4.2. Fresh air intakes for ventilating shall not be located close to sources of pollution, excessive moisture or heat. Materials used for filters shall not be damaging to heritage material. Filter performance should be regularly monitored and filters should be maintained according to manufacturers' instructions. Any filtering equipment that produces ozone shall not be used, as this can be harmful to heritage materials.

Ventilation shall provide even distribution so that all areas of the space are reached. Air diffusers used to distribute air evenly shall be located inside a storage space such that they allow for air circulation around loaded shelves.

NOTE 2 Ventilation systems can be used to distribute and balance air across spaces where conditions in localized zones are temporarily outside the required ranges, but are not be used as a permanent environmental control strategy.

The sides and backs of both fixed and mobile shelves shall allow the free circulation of air. There shall be a sufficient distance between the floor and the lowest shelf, as well as between the ceiling and the average line of upper edges of objects stored on the top shelf. There shall also be a sufficient distance between the top of the highest object on each shelf and the bottom of the shelf above.

Where a ducted air distribution or control system is to be installed, account shall be taken of the space required for the ductwork connected to the plant. Plant shall be situated outside storage spaces. An alarm system shall be installed to alert staff to any malfunction in the plant.

NOTE 3 See also 5.12.

5.5 Mechanical environmental control

5.5.1 General

Environmental control shall be achieved through building design or building improvements that meet the specifications in 5.3 and the use of packaging and buffered display cases and frames, etc. For collections that require specific environments that cannot be achieved by building structure alone (e.g. cold storage) mechanical control equipment such as air conditioning can be installed.

Sources of damp, excess air infiltration or weaknesses in insulation in an existing structure shall be identified and remedied first before considering the use of mechanical means of control.

Plug-in mobile dehumidification units, humidifiers, heaters or other electrical equipment can increase the risk of fire or flood. Such equipment should only be used temporarily where no other means can be found of bringing an existing space within suitable RH or temperature ranges and in conjunction with suitable safety cut-out equipment in the event of a malfunction and whenever possible should be switched off when the building is closed. A new storage repository shall not be designed to incorporate plug-in mobile electrical units to be placed within it as a means of controlling the environment.

5.5.2 Air conditioning for storage repositories

The decision to include air conditioning to control conditions inside a storage repository shall be based on a decision that the specified environment for collections cannot be achieved and maintained without it.

The rate of air circulation designed to be delivered by air conditioning plant shall be determined from the cooling load to maintain the required temperature and RH in the repository. In order to prevent unregulated air from being drawn in and thereby undermining the intended control over RH and temperature, positive pressure shall be maintained by including sufficient fresh air make-up into the airflow ahead of the air conditioning unit and by operating return fans at a slower rate than supply fans. Storage repositories have low human presence and do not need standard office fresh-air make up. Fresh-air make-up in stores shall therefore be no more than is necessary to maintain positive pressure; typically less than 5 %.

Where an air-conditioning unit is designed to use a chiller battery to remove moisture, the control system shall always give priority to humidity levels and not to temperature levels, in order to prevent dehumidification cooling from being switched off when the required temperature level of room air is reached. Off-coil air shall be re-heated when dehumidification cooling takes it below the specified room temperature levels, followed by controlled re-humidification when resulting conditions require it.

Return-air temperature, RH and internal pollutant sensors linked to the air conditioning controls shall be incorporated, in order to regulate the room environment. Return and supply ductwork passing through spaces outside the repository shall be insulated to reduce changes of temperature affecting sensors used for controlling air conditioning units, especially if sensors are located in return ductwork.

Air conditioning and ventilation controls shall be designed so that, when sensors determine that temperature, RH or pollutant levels are within the required conditions, fans and controls shall switch off automatically and remain off until conditions start to go outside the required conditions. Air conditioning control strategy shall not result in rapidly and widely fluctuating RH for collections that cannot be readily packaged and are susceptible to fluctuation, e.g. of 10 %.

During installation, an inventory of critical replacement parts (such as fan belts, filter bags, heater elements and humidification bottles, electronic fuse and switching modules etc.) shall be identified and acquired as stock to be kept on site at all times so that the failure of such parts does not result in periods of down-time while replacements are sourced. Heritage materials may be at risk of damage in high or low temperatures and RH. Mould can rapidly spread if RH is above 65 % for periods of a week or more, so equipment failure down-time should be avoided.

Air-conditioning installations shall be kept clean and in good working order and this shall be taken into account in their design.

5.6 Prevention of infestation by pests and mould

Vegetation shall not be incorporated into the structure of a new building or against external walls. 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.

The level of pest activity inside and around a building shall be monitored and assessed in accordance with EN 16790 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.

NOTE 1 See EN 16790.

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 shall be 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. Areas of damp penetration or poor insulation shall be identified and improvements made in order to prevent the risk of mould or moisture damage. Where the physical or mechanical deficiencies causing damp penetration or condensation in an historic structure cannot be remedied, collections shall be kept away from the area affected. Storage equipment such as shelves and drawers shall be placed to allow for a gap between heritage materials and the surface of walls.

NOTE 2 A colder zone in a storage space could give rise to RH conditions that are higher than the ambient conditions in the rest of the space. This can cause condensation and a higher moisture content within collections, promoting the growth of mould.

NOTE 3 If mould is germinating, specialist advice is to be sought about the health risks and the spread of mould spores.

5.7 Protection against water

5.7.1 Design and materials

Rooms where moisture is penetrating through the walls, floor, ceiling or openings shall not be used for collections. Buildings or rooms intended to hold collections shall be designed, and the materials for their construction chosen, such that the risk of damage to the collections from water is reduced to a minimum.

Where an assessment indicates a high risk of external water ingress, such as in below-ground accommodation, forms of protection shall be used, for example waterproof coatings or the construction of a bund. Equipment for removal of ingress of water such as sump pumps shall be installed and checked frequently. Leak detection with an alarm shall be installed.

NOTE See 5.5.1.

5.7.2 Rainwater discharge systems

Rainwater discharge systems shall conform to design rainfall rates in accordance with EN 12056-3. The design shall include a provision for sufficient weir overflows to prevent water entering a building when an outlet is blocked. Rainwater discharge systems shall be located outside of the building and floor drainage systems shall discharge away from walls. Rainwater gutters and pipework systems shall be designed to enable regular and easy access for clearance.

5.7.3 Drainage and piping work

Storage spaces, display or collection spaces shall not be constructed with water supply or drainage running through them. Provision shall however be made for the controlled rapid removal or exit of any water that might accumulate in a building during firefighting or sprinkler operation, for example. There shall be no obstructions to the dispersal of floodwater via drains. The lowest level of a storage compartment (shelf or drawer) shall be at least 150 mm above the floor.

Drains in non-collection spaces (or in existing spaces used for storing or using collections) shall be fitted with one-way valves to prevent water backing up into the building and shall be designed and located to prevent the risk of flooding or providing a means of entry for polluted air or pests. The need for emergency pumping systems, either as an alternative or as a supplement to drains, shall be assessed. Drainage access points, pipe-work or other sources of water shall be regularly monitored and fitted with flood sensors and alarms that are audible outside the building.

5.8 Windows and lighting

5.8.1 General

Exposure to light can damage objects. The level of the light reaching a surface (illuminance), the exposure (duration) and the spectral distribution of the light source shall be controlled, especially in display areas and reading rooms.

5.8.2 Glazing and light levels

Windows and roof-lights shall not be incorporated in new storage spaces (see 7.7). In other new spaces intended to house heritage objects, windows shall be at least double glazed, with a UVA filter incorporated in the glass or provided as a screen. In addition, shutters, louvres or blinds shall be used wherever practicable to control light levels and in the interests of security.

NOTE 1 See also Clause 7.

Windows in existing storage spaces shall be blocked up. Windows in other areas shall include a UVA filter or be covered, e.g. with blinds. UVA filters should be tested at least once a year and replaced when internal UVA transmission is detected.

NOTE 2 It cannot be permissible or practical to place UVA filtering on historic glazing. In these circumstances alternatives such as the use of blinds are to be considered.

5.8.3 Artificial lighting

Lighting for exhibition and display areas shall conform to the specification in CEN/TS 16163. Guidance information about light sensitivities of collection material is given in Annex E.

The following specifications shall be observed when designing lighting services for storage spaces:

a) lighting shall be installed such that it can be switched off either manually or automatically when not required. Large storage spaces in particular shall be divided into separate lighting zones;

b) lighting shall be fitted along the length of each aisle and gangway and at right angles to mobile shelf runs, unless integrated into the mobile shelf system. Lighting shall not obstruct access to the shelves;

NOTE Lighting can be attached to storage equipment. For mobile shelves or screens, lighting can be arranged to switch on and off as individual aisles are opened and closed.

c) any potential hot spots (see also 6.3.7.3) shall be identified in any lighting scheme plans and wherever possible these are avoided;

d) the heat output of the lamps and the effect on the thermal environment shall be assessed and wherever possible heat output reduced in scheme design and equipment specification.

5.8.4 Lamps

Lamps should not emit UVA radiation (i.e. of wavelength below 400 nm). Lamps or bulbs located in existing spaces shall be tested and replaced if found to emit UV radiation. Fluorescent lamps emit UVA radiation and shall not be installed in new constructions. The energy efficiency of lamps shall be identified and low energy lamps specified and installed.

Light levels in storage spaces shall be determined by national health and safety regulations but should be designed to switch off when not in use.

Lighting for exhibition and display areas shall be in compliance with CEN/TS 16163.

NOTE See also 6.3.7.

5.9 Emergency electrical supply

Batteries or other secondary generation equipment shall be installed to support emergency lighting and any environmental control systems in the event of electrical supply failure. An emergency lighting system conforming to EN 1838 shall be provided.

5.10 Ceilings

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

The minimum internal height of a storage space shall take account of the racking height and the service zones above, in compliance with 5.12.

5.11 Floors and load distribution

5.11.1 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. Floor surfaces shall be resilient be of materials that reduce the built-up of a static charge.

NOTE 1 Attention is drawn to EN 13813 and EN 1081.

NOTE 2 Heritage collection loads are generally in place for many years and it is therefore important that the long-term behaviour of the building is considered. Suspended concrete and timber floors experience long-term deflections (creep) that could exceed 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.

5.11.2 Calculation of floor loads

A high degree of accuracy is necessary for floor load calculations, particularly in storage spaces and where mobile shelves are to be installed. False floors should be avoided in new constructions. The mass and distribution of the heritage objects, 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.

NOTE See Annex F for further information on uniformly distributed loads based on a storage height of up to 2,3 m.

5.12 Storage space arrangements

The shape, dimensions and layout of a storage space shall be determined by the need to provide maximum capacity and ease of withdrawal and replacement of heritage objects. For new constructions, it is recommended that the structural solution, in particular the column grid, should allow for the most efficient storage equipment layout. Wherever practicable, areas shall be designed to be free from obstructions especially if, for example, high-density mobile shelves and drawer chests are to be used.

NOTE 1 It is inadvisable to store items or containers so tightly on shelves that they cannot be removed easily, so space is to be allowed for to ensure ease of retrieval.

Openings of doors through which loaded trolleys or other handling equipment are to pass shall be adequate for the collections housed within. Space around doorways and ends of storage equipment shall allow for manoeuvring the largest objects. Where mezzanine floors or galleries are incorporated within a storage space, easily accessible straight flight stairs only should be provided to give access to the upper spaces. Gangways and stairs shall be wide enough to allow the largest heritage objects stored to be removed and replaced without difficulty. Suitable manual or mechanical means of transferring items to a mezzanine gallery shall be provided appropriate to the collections being housed.

NOTE 2 Attention is drawn to EN 16141.

Ceiling height in storage spaces shall be designed to provide sufficient clearance between the highest shelves and the ceiling or lowest suspended element (including lamps or ducts, etc.) to permit the safe placement of items onto the shelves (see also 5.4.4).

NOTE 3 High bay storage will require ceiling clearance sufficient for safe use of mechanical lifts and their occupants.

6 Fire protection and prevention

6.1 General

A fire strategy shall be developed in any new or refurbished building or space where heritage collections will be held that includes 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.

Most heritage objects are made of combustible materials and therefore should be kept away 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 heritage 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 heritage collections.

6.2 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:

a) at the design stage of a new build;

b) at the design stage of an alteration of an existing building;

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

d) 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 storage spaces.

6.3 Structural fire protection

6.3.1 General

The following clauses 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 advice 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 6.2).

6.3.2 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 hours fire resistance.

NOTE Attention is drawn to the classes of fire resistance of building elements set out in the EN 13501 series.

6.3.3 Lightning conduction

The need for a lightning protection system shall be determined in accordance with EN 62305-2. Lightning conductors shall not run within a fire compartment, particularly inside a display area or storage repository.

6.3.4 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 6.3.2.

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

6.3.5 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.

NOTE See 7.5 and 6.4.2.

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.

6.3.6 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 or dampers and doors of material with an appropriate fire resistance.

6.3.7 Minimizing fire hazard in an electrical system

6.3.7.1 Cables

Cable insulation should be flame retardant conforming to EN 60332-1-1 and be of low smoke zero halogen (LS0H) to minimize the emission of harmful fumes in the event of fire. The points, at which cables enter and leave a storage or display space or pass through intermediate walls, shall be fire stopped in order to maintain the fire resistance of the walls. Electrical circuits shall not pass through a storage repository unless they serve it.

6.3.7.2 Master switches

Except for those switches providing fire detection and protection or emergency lighting, there shall be a master switch or switches outside storage and display spaces to isolate electrical 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.

6.3.7.3 Electrical fittings

Electrical fittings should have an index protection rating of at least IP20 in accordance with EN 60529.

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.

NOTE See 5.8.

6.4 Minimizing fire hazards in ventilation plant and equipment

6.4.1 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.

6.4.2 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.

6.5 Fire detection and firefighting

6.5.1 General

Where practicable, automatic fire detection, alarm and automatic fire-fighting systems shall be consolidated into one continuous system that detects a fire, sounds an 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 6.3.4).

6.5.2 Detection and alarm systems

A higher sensitivity smoke detection system shall be installed in collection spaces. 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 6.3.3). If an ASD is selected for a passive climate storage space, the air extracted for sampling should be returned to the room in order to avoid creating negative pressure in the space.

NOTE 1 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.

NOTE 2 Further information regarding aspirating smoke detectors can be found in EN 54–20.

6.5.3 Monitoring

The central automatic fire detection system control panel shall provide a facility to monitor all components of the system, 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.

6.5.4 Automatic fire-fighting systems

A fire risk assessment shall be carried out both inside and outside a space or building holding heritage collections to determine whether an automatic fire-fighting system (also known as fixed fire-fighting systems) should be installed in the collection space. 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 spaces 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.

NOTE 1 See Annex A.

NOTE 2 Where an existing historic building is being adapted for use for the storage or display of collections, it cannot be possible to install gas or oxygen reduction systems for fire suppression as any attempt to reinforce the building to make it gas tight could cause damage to the heritage fabric. For historic spaces that are not accessed by the public, modular storage can be installed inside which a suppression system can be used.

6.5.5 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.

6.5.6 Protection of areas adjacent to collection spaces

Where a collection space is part of a larger building, firefighting equipment that uses water shall be provided outside the space and in accordance with the advice of the local fire and rescue service. Portable fire extinguishers shall also be provided in accordance with 6.5.5.

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

6.5.7 Smoke extraction

It is important to remove the products of combustion from a collection space 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 collection space.

6.5.8 Fire control and mobile shelves

To assist fire control in a storage space, 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.

NOTE See 6.3.4.

7 Security specifications

7.1 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 building, its contents and its use. The strategy shall be informed by advice from security experts.

7.2 Security risk assessment

The security strategy shall be informed by a security risk assessment. The assessment shall be undertaken to determine the levels of prevention and protection necessary to protect the heritage collections from theft, burglary and wilful damage, in compliance with 4.2.

7.3 Site security

Where a new building is not part of a larger building, wherever practicable it shall be on a stand-alone or island site with restricted access around the whole perimeter. The perimeter shall be clearly illuminated in the hours of darkness, security gated and fenced. Vegetation and shrubbery on the site, which obscures visibility, shall be removed.

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.

7.4 Protection against intruders

The building shall be secure against theft, burglary, vandalism, terrorism, other criminal acts, and an intruder alarm system linked to the police or 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 or during emergency evacuation.

All security systems installed, such as external intruder alarms and closed circuit television (CCTV) should conform to EN 50131-1 Grade 4. In historic buildings Grade 4 may be unachievable so the highest level possible shall be sought.

7.5 Entrances

Means of access to a building, such as doors, lifts, stairways, windows and ventilation risers, shall be designed to exclude the possibility of entry by unauthorized persons and to ensure that even normal maintenance staff for the building can enter only under supervision. No part of a building in which heritage material is permanently or temporarily stored shall be used as a corridor or emergency exit for non-storage area. There shall preferably be only one entrance for visitors to a building in which collections are situated. Doors into or between secure areas shall be lockable.

7.6 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 outside the building itself and shall be accessible and controllable without entering the building to reach them. Gas, oil, water supplies and drainage (including water pipes and sewage), shall not pass through a storage repository.

7.7 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, barred and glazed with security glass in accordance with EN 1627. 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.

NOTE See 5.6, 5.8 and 7.4.

7.8 External doors to the building

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. The resistance class for secure areas of buildings shall be a minimum of RC4, in accordance with EN 1627. Locks shall open from the inside without a key.

No door of a high security area (such as a storage 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 shall be alarmed and designed to open only from the inside and shall open onto an escape route.

NOTE See 5.3.4, 6.3.5 and 7.5.

Loading bay doors shall be of a resistance class defined by the security strategy. If loading areas lead into other secure parts of the building, these internal routes shall also be protected by the specified resistance class door-sets.

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 heritage collection 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

Heritage collections often represent a significant quantity of combustible material (e.g. library and archive collections), 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 heritage 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 and further guidance in relation to the actuation and control of pre-action sprinkler systems can be found in BS 7273-3. Heritage objects 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 agent suppression systems

There are different types of gaseous fire-fighting system used to protect repositories, including those using an inert gas like argon, and those using halocarbon agents such as heptafluoropropane (HFC-227), which are often known as chemical agent gases. These systems are actuated automatically by an associated smoke detection system. Guidance relating to such systems can be found in the EN 15004-1 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. Gaseous suppressant systems are designed to delay a full inflammation occurring for enough time to allow the source or seat of a fire to be investigated and rendered safe. A high-sensitivity detection system also assists in this respect and addition of a gaseous suppressant 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).

Inert gas systems release a gas that is not harmful to heritage collections. Halocarbon gas agents produce break-down products on contact with fire. These products can be harmful to organic materials often found in heritage collections and the chemical agents themselves may be harmful. It is advisable to consider this when selecting the gaseous agents to be used in automatic fire-fighting systems. Where the repository has air distribution ducting and an external exhaust, prompt ventilation after a gaseous discharge may be used to minimize this effect. However, in rooms that are controlled without air distribution, such rapid ventilation might not be possible.

A.4 Overpressure

All gaseous systems generate overpressure when discharged into a space (initially there will be both the air in the space and also gas to the same volume). Prior to procurement of a gaseous 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 (all parts).

A.5 Reduced oxygen systems

Reduced oxygen (hypoxic air) systems can be installed to protect heritage collections but these are not as well established as gaseous suppressant systems. 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. Such systems are less well established than sprinklers or gaseous suppressant systems. At the time of publication, there is no test protocol for configurations of stored materials found in repositories, and the effect of mobile storage equipment on water-mist dispersion is likely to be more pronounced than on 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.

NOTE See Bibliography for further reading on suppression and extinguishing systems.

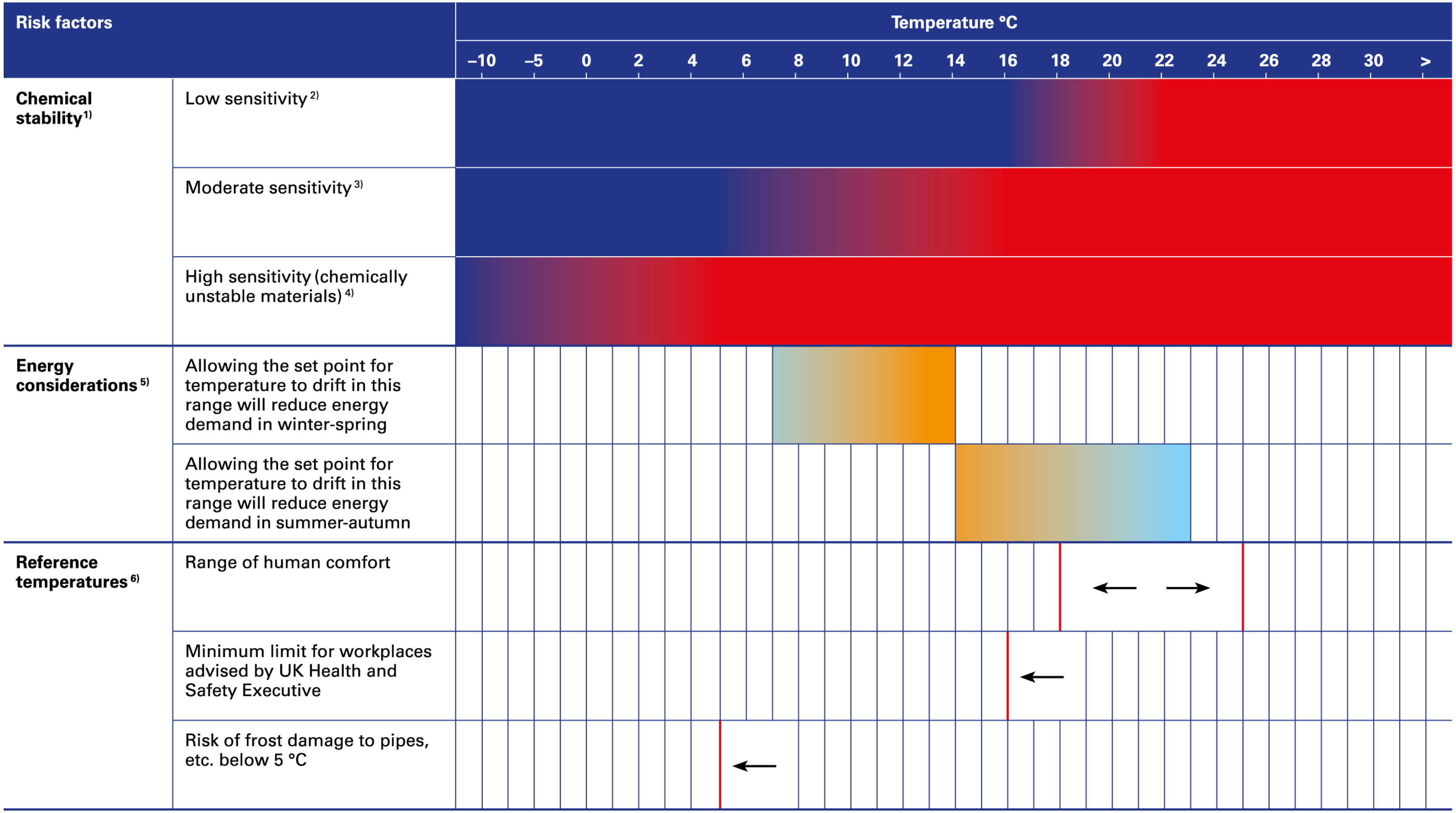
Annex B
(informative)

Relative risk of damage and deterioration due to temperature [1)]

An example of a visual representation of the relative risk of damage and deterioration due to temperature including alongside the relative energy demand associated with maintaining a particular temperature. Advice shall be sought from a collection specialist when identifying the temperature stability of specific heritage materials.

[1]This table was first published by British Standards Institution in PAS 198:2012 *Specification for managing environmental conditions for cultural collections.*

Table B.1 — Relative risk of damage and deterioration due to temperature



Key

1 Low sensitivity: materials with reaction rates less affected by temperature, e.g. ceramic, glass (but not enamels).

2 Moderate sensitivity: materials with reaction rates moderately affected by temperature, e.g. paper.

3 High sensitivity: materials with reaction rates highly affected by temperature, e.g. plastics, film.

4 Chemical stability: these ranges show higher temperatures leading to accelerated degradation rates, indicated by the gradation from blue to red.

5 Energy considerations: these ranges show the energy demand, with the light blue indicating lower demand and the orange higher demand. Local climate will affect energy considerations and achievement of safe RH ranges for the collection.

6 Reference temperatures: reference temperatures are included for the purposes of comparison. The human comfort range may for example be considered to be between 18 °C and 25 °C. There is no lower limit for exhibitions that take place in conditions outside the human comfort range. Below 0 °C, there is an increasing risk of frost damage to the building structure, frozen pipes, etc., so a 5 °C limit is a precautionary lower limit based on expectations of spatial and temporal variation.

NOTE 1 If the period of exposure is sufficient for thermal response (minutes to hours for most collections), there is no difference in the potential for physical damage between short and long periods of low temperature, except in a few special cases such as migration of plasticizers from plastics or of lubricants from magnetic tape.

NOTE 2 Many ethnographic and decorative arts collection items have been observed during exposure to −30 °C in collections in cold countries or following the use of low temperature pest control. The consensus is that no visible damage beyond a few small fractures has occurred to the great majority of items.

NOTE 3 Low temperatures can cause embrittlement due to a T_g change and can cause harm to some materials e.g. video and audio cassettes.

Annex C
(informative)

Relative risk of damage and deterioration due to relative humidity [2)]

An example of a visual representation of the relative risk of damage and deterioration due to relative humidity, including the relative energy demand associated with maintaining a particular temperature. Advice shall be sought from a collection specialist when identifying the RH stability of specific heritage materials.

[2] This table was first published by British Standards Institution in PAS198:2012 *Specification for managing environmental conditions for cultural collections*.

Table C.1 — Relative risk of damage and deterioration due to relative humidity

Risk factors		Relative humidity % (0 – 100)
Chemical stability[1)]	High sensitivity to hydrolysis [2)]	
	Medium sensitivity to hydrolysis [3)]	Some inorganic materials, such as metals, will benefit from relative humidity below 30%
	Low sensitivity to hydrolysis [4)]	
Mechanical stability [5)]	Safe range for most non composite, non constrained hygroscopic items to avoid mechanical damage	Organic materials can become less flexible, increasing the risk of damage mainly by mishandling; Above 70%, stability decreases in some materials, e.g. wood
Risk of mould [6)]	Risk of mould germination at 20 °C	
	Risk of mould growth	
Energy considerations [7)]	Reduced energy demand for humidification in winter-spring	
	Reduced energy demand for dehumidification in summer-autumn	

Key

1 High sensitivity to hydrolysis: materials with a relatively high presence of hydrolysis-sensitive chemical groups within the polymer chain, e.g. leather and textiles previously acidified by pollution, cellulose acetate and nitrate film.

2 Examples of inorganic materials that need lower RH levels than organic materials include for example archaeological iron, copper and lead, historical steels,

copper alloys, zinc, tin, pewter, lead, salt laden stone, salt laden ceramics, stone with expanding clay materials. These may need dry stores or microclimate packaging.

3 Moderate sensitivity to hydrolysis: materials with a relatively moderate presence of hydrolysis-sensitive chemical groups within the polymer chain, e.g. some wood pulp papers.

4 Low sensitivity to hydrolysis: materials with a relatively low presence of hydrolysis-sensitive chemical groups within the polymer chain, e.g. rag paper, polyester film.

5 Chemical stability: these ranges show higher relative humidity leading to accelerated moisture-induced chemical degradation rates, indicated by the gradation from green to red.

6 Mechanical stability: the area shown in yellow indicates the range within which the risk of physical damage is higher, whilst the area shown in green indicates the range within which the risk of physical damage is lower. In the area below 30 % RH, the risk of damage to organic materials by mishandling is increased despite the reduced rate of chemical degradation. In the area above 70 % RH, for some materials e.g. wood, mechanical stability decreases.

7 Risk of mould: the areas shown in grey indicate a precautionary upper limit of 65 % RH to avoid mould germination at 20 °C. The gradation to darker grey indicates increasing risk of mould growth and faster germination times. Note also that mould germination and growth are also temperature dependent.

8 Local climate will affect energy considerations and achievement of safe RH ranges for the collection.

Annex D
(informative)

Examples of internal pollutants and their sources

Table D.1 — Examples of internal pollutants and their sources

Pollutant	**Example sources**
Acetic acid (ethanoic acid), solvents	Acrylic and nitrocellulose paints
Acetic acid (ethanoic acid)	Cellulose acetate collection items, cellulose triacetate film
Camphor Formaldehyde (methanal)Nitrogen	Cellulose nitrate collection items and photographs
Acid vapours	Plastics, rubber
Reduced sulfur gases	Polyisoprene rubber (carpet backing), vulcanized rubber, wool and certain sulfide minerals
Acetic acid (ethanoic acid)	Poly(vinyl acetate)
Hydrochloric acid	Poly(vinyl chloride)
Acetic acid (ethanoic acid), formic acid (methanoic acid), solvents	Resins / coatings
Acetic acid (ethanoic acid) Formic acid (methanoic acid)	Wood
Formaldehyde (methanal)	Wood-based panels (sealed with urea-formaldehyde or phenol-formaldehyde resins)

NOTE See also Bibliography.

Annex E
(informative)

Light Sensitivity - Sensitivity of coloured materials to light

Table E.1 — Light sensitivity - Sensitivity of coloured materials to light

No sensitivity	**Low sensitivity**	**Medium sensitivity**	**High sensitivity**
Materials that do not change colour due to light. (These materials may change colour due to ageing or pollutants.) Most but not all mineral pigments. The "true fresco" palette, a coincidence with the need for stability in alkali. The colours of true glass enamels, ceramics (not to be confused with enamel paints). Many monochrome images on paper, such as carbon inks, but the tint of the paper and added tint to the carbon ink are often high sensitivity. Paper itself should be cautiously considered low sensitivity. Many high-quality modern pigments developed for exterior use, automobiles.	Materials rated ISO Blue Wool #7, #8 (and higher). Artists' palettes classified as "permanent" (a mix of truly permanent AND low-light sensitivity paints, e.g. ASTM D4303 Category I; Winsor and Newton AA). Structural colours in insects (if UV blocked). A few historic plant extracts, especially indigo on wool. Silver/gelatine black-and-white prints (not resin coated paper) assuming all UV blocked. Some b/w gelatine printing out papers can fall into the medium or high sensitivity; type needs to be identified Many high-quality modern pigments developed for exterior use, automobiles. Vermilion (blackens due to light). Red lead (lightens or darkens). Polyester	Materials rated ISO Blue Wool #4, #5, or #6. Alizarin dyes and lakes. A few historic plant extracts, particularly madder-type reds containing primarily alizarin, as a dye on wool or as a lake pigment in all media. It varies throughout the range of medium and can reach into the low category, depending on concentration, substrate, and mordant. The colour of most furs and feathers. Iron gall inks Most colour photographs with "chrome" in the name, e.g. Cibachrome, Kodachrome. Orpiment, realgar. Buckthorn, weld, broom. Wools, cellulosic materials which do not contain lignin, e.g. cotton	Materials rated ISO Blue Wool #1, #2, or #3. Most plant extracts, hence most historic bright dyes and lake pigments in all media: yellows, oranges, greens, purples, many reds, blues. Insect extracts, such as lac dye and cochineal (e.g. carmine) in all media. Most early synthetic colours such as the anilines, all media. Many cheap synthetic colourants in all media. Most felt tip pens including blacks. Most red and blue ballpoint inks. Most dyes used for tinting paper in the 20th century. Most colour photographs with "colour" (or "color") in the name, e.g. Kodacolour, Fujicolour. Some B/W printed out photographs e.g.matte gelatine bromide Many alcohol-preserved zoological speciemns and certain mineral specimens e.g. realgar, silver halides Silks, nylon, lignin-containing cellulosic materials, e.g. jute, severely degraded linen with a 'bleached' appearance, wood-pulp papers, newsprint, etc.

NOTE Table derived from Michalski, S. (2010) Light, ultraviolet and infrared, Table 3. Canadian Conservation Institute website.

Annex F
(informative)

Recommended maximum loads

The below-mentioned recommendations are based on EN 1991-1-1.

The following values are recommended for uniformly distributed loads based on a storage height of up to 2,3 m:

Static shelves: 4,0 kN per metre of height having a minimum of 12 kN;

Mobile shelves: 4,8 kN per metre of height having a minimum of 15 kN.

In all cases, the floor is likely to be subjected to localized (point) loads either directly from the shelf unit uprights or from the wheels used for mobile carriages. In addition to the uniformly distributed load, the floor should be checked for point load effects. The following point loads are recommended:

Static shelves: 2,6 kN per metre of height having a minimum of 7 kN;

Mobile shelves: 3,0 kN per metre of height having a minimum of 10 kN.

Large objects might require higher kN values.

NOTE 1 Point load effects are particularly important when a suspended concrete floor is considered.

NOTE 2 Wet loads, for example in the event of a fire or flood, exert considerably greater force than dry loads. It is expected that such a situation will be short-term and can be considered as an accidental load case. It is possible to consider wet loads as a long-term load situation; however, this will lead to a more expensive design for the storage equipment and, possibly also, for the building.

NOTE 3 Attention is drawn to EN 15635.

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[4] EN 1991-1-1, *Eurocode 1: Actions on structures — Part 1-1: General actions — Densities, self-weight, imposed loads for buildings*

[5] EN 12845, *Fixed firefighting systems — Automatic sprinkler systems — Design, installation and maintenance*

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[8] EN 15004-1, *Fixed firefighting systems — Gas extinguishing systems — Part 1: Design, installation and maintenance (ISO 14520-1:2006, modified)*

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[11] EN 15635, *Steel static storage systems — Application and maintenance of storage equipment*

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