

PD 5454:2012



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PUBLISHED DOCUMENT

Guide for the storage and exhibition of archival materials

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Foreword

Publishing information

This guide is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 31 March 2012. It was prepared by Technical Committee IDT/2, *Information and documentation*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This Published Document supersedes BS 5454:2000 and PD 0024:2001, which are withdrawn.

Information about this document

This is an amalgamation and full revision of BS 5454 and PD 0024, and introduces the following principal changes.

- This Published Document follows a different structure from BS 5454:2000. The PD starts with detailed guidance on the nature of documents and best practice for their storage and use and this is followed by guidance regarding a new repository building.
- An update of the types of environment that protect archival materials has been provided, based on research available at the time of publication and in line with requirements specified in PAS 198.
- The guidance has been adapted to recognize a different approach to environmental management. This allows for environmental fluctuations to occur within recommended parameters, such as can occur with seasonal changes, instead of a tight level of stability and control being recommended around set points for temperature and RH.
- Explicit recognition has been made of the needs of archives and library collections managed in historic buildings and other existing repositories.
- A new distinction has been made between the needs of mixed traditional archival materials, where sensitive documents cannot be separated, and those of specialist archival materials, providing four different environmental recommendations.
- More detailed guidance has been given regarding the interaction between the storage environment and reading room and display conditions. A clause containing new guidance for reading room environments has also been included to take into account those documents taken out of storage.
- An emphasis on low energy solutions, first outlined in PD 0024, has been given within the guidance for achieving a suitable environment for archival material.

Use of this document

As a guide, this Published Document takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Any user claiming compliance with this Published Document is expected to be able to justify any course of action that deviates from its recommendations.

Presentational conventions

The provisions in this Published Document are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a Published Document cannot confer immunity from legal obligations.

In particular, attention is drawn to the following regulations which may be amended from time to time. The commentary in this Published Document reflects the state of the regulations in 2012.

- The Dangerous Substances and Explosive Atmospheres Regulations 2002 [1];
- The Dangerous Substances and Explosive Atmospheres Regulations (Northern Ireland) 2003 [1];
- The Copyright, Designs and Patents Act 1988 [2];
- The Data Protection Act 1998 [3];
- The Building (Amendment) Regulations 2011 [4];
- The Building Regulations (Amendment) Act (Northern Ireland) 2009 [4];
- The Work at Height (Amendment) Regulations 2007 [5];
- The Work at Height (Amendment) Regulations (Northern Ireland) 2007 [5];
- The Equality Act 2010 (Disability) Regulations 2010 [6];
- The Manual Handling Operations Regulations 1992 [7];
- The Regulatory Reform (Fire Safety) Order 2005 [8].

0 Introduction

Archival storage is intended to prolong the existence of documents and books of all kinds through conservation measures (both preventive and remedial), on the understanding that people will have access to them if necessary. In planning the construction of a new archive repository (whether a new-build or within an existing structure) or reviewing the qualities of an existing location in which archives are held, custodians need to start by understanding the nature of the collections in their care. Different types of archival material can require quite different storage environments and no matter how secure and physically well protected collections are, if the environment in which they are held is unsuitable (too damp, hot, dry, cold or polluted) they will suffer over time, becoming increasingly unusable.

A single archive might contain a wide range of materials having different physical and chemical characteristics. Commonly, an archive can be composed of both modern and ancient documents in good and bad condition, including papers, parchments, wax and resin seals, leather and cloth covered books, plasticized folders, plastic and paper photographs, chemically produced copies (architectural plans, letter books, etc.) and magnetic and optical machine-readable formats. Many documents are themselves made of composite materials and structures, such as books of all kinds; large rolled surveys with booklets sewn to them; albums or scrapbooks with manuscript, photographic and printed items affixed to their pages; video and audio tapes, CD-ROMs, etc. Some of these materials require specialized environments if they are to survive even for a few decades, while many (often older) formats can remain stable for centuries as long as they are protected from damp or careless handling. It is therefore important that custodians consider whether to separate some formats and materials from others and provide different environments most suited to the preservation of each.

Creating an environment that is comfortable for people to use archives is also a consideration for many repositories, even though this might not be the most protective storage environment for the archives themselves. Understanding how archives react to different environments can help custodians to balance the long term survival of archives with their use. Digital copying is an important consideration for custodians in planning the preservation of archives. Such surrogacy will maximize the accessibility of archives in demand and reduce their time out of a protective storage environment.

In addition to preventing a storage environment from jeopardizing the long term survival of an archive, it is important that a repository is able to protect the collection from a variety of natural and man-made hazards, the most common of which are fire, flood and theft.

The recommendations in this guide have been designed to help create and maintain appropriate conditions for document storage and use, and to enable a repository for archives to be built or converted to a high standard. They can be used where an archive is located in a mixed use development and can also be used as guidance for custodians of collections in historic buildings, defining best practice for archival materials while recognizing that best practice for the conservation of a building might require a compromise, based on a risk assessment. They have been developed to cover the United Kingdom's common geological and atmospheric conditions, i.e. fluctuating island weather conditions in a temperate climate, as distinct for example from tropical, alpine, desert or mid-continental climates.

Since the first publication of BS 5454 (the standard on which this publication was based) in 1977, new materials have entered archival collections (e.g. magnetic and optical storage media) and there have been advances in the understanding of the vulnerability of some heritage materials and of the relative stability of others. It has also been recognized that the long term conservation of archives and other heritage collections is not to be achieved at the expense of the earth's environment or through unrestrained energy use. This guidance has been produced in the light of these changes in scientific knowledge and the awareness that a protective environment needs to be achieved sustainably by passive means, wherever practicable.

1 Scope

This guide gives recommendations for the storage and exhibition of documents, including books and other library materials. These recommendations apply to permanent and temporary storage of documents, and equally apply to material which is subject to restricted access or is on display.

The guidance is for use by archivists, librarians, conservators, museum curators, architects, facility managers, contractors, engineers and those concerned with the planning, construction, equipment, maintenance and working of storage repositories and their associated search-rooms, reading rooms and display areas. The recommendations in this guide apply to archives of all traditional archival materials and formats, such as paper and parchment documents, books, maps and plans, and also cover guidance on photographic media common to archives and on more modern machine-readable media.

2 Normative references ¹⁾

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.

BS 1153, *Recommendations for the processing and storage of silver-gelatine-type microfilm*

BS 1449-1 (all sections), *Steel plate, sheet and strip – Part 1: Carbon and carbon-manganese plate, sheet and strip*

BS 4737-4.3, *Intruder alarm systems in buildings – Codes of practice – Part 4: Code of practice for exterior alarm systems*

BS 4971:2002, *Repair and allied processes for the conservation of documents – Recommendations*

BS 5266-1, *Emergency lighting – Part 1: Code of practice for the emergency escape lighting of premises*

BS 5699-1, *Processed photographic film for archival records – Part 1: Specifications for silver-gelatin type on cellulose ester base*

BS 5699-2, *Processed photographic film for archival records – Part 2: Specifications for silver-gelatin type on poly(ethylene terephthalate) base*

¹⁾ This clause, which contains standard wording used for all European and international standards, is intended to identify all other documents to which reference *might* need to be made in the application of this standard. In practice, it might be possible to apply this and many other standards without recourse to all or any such external references.

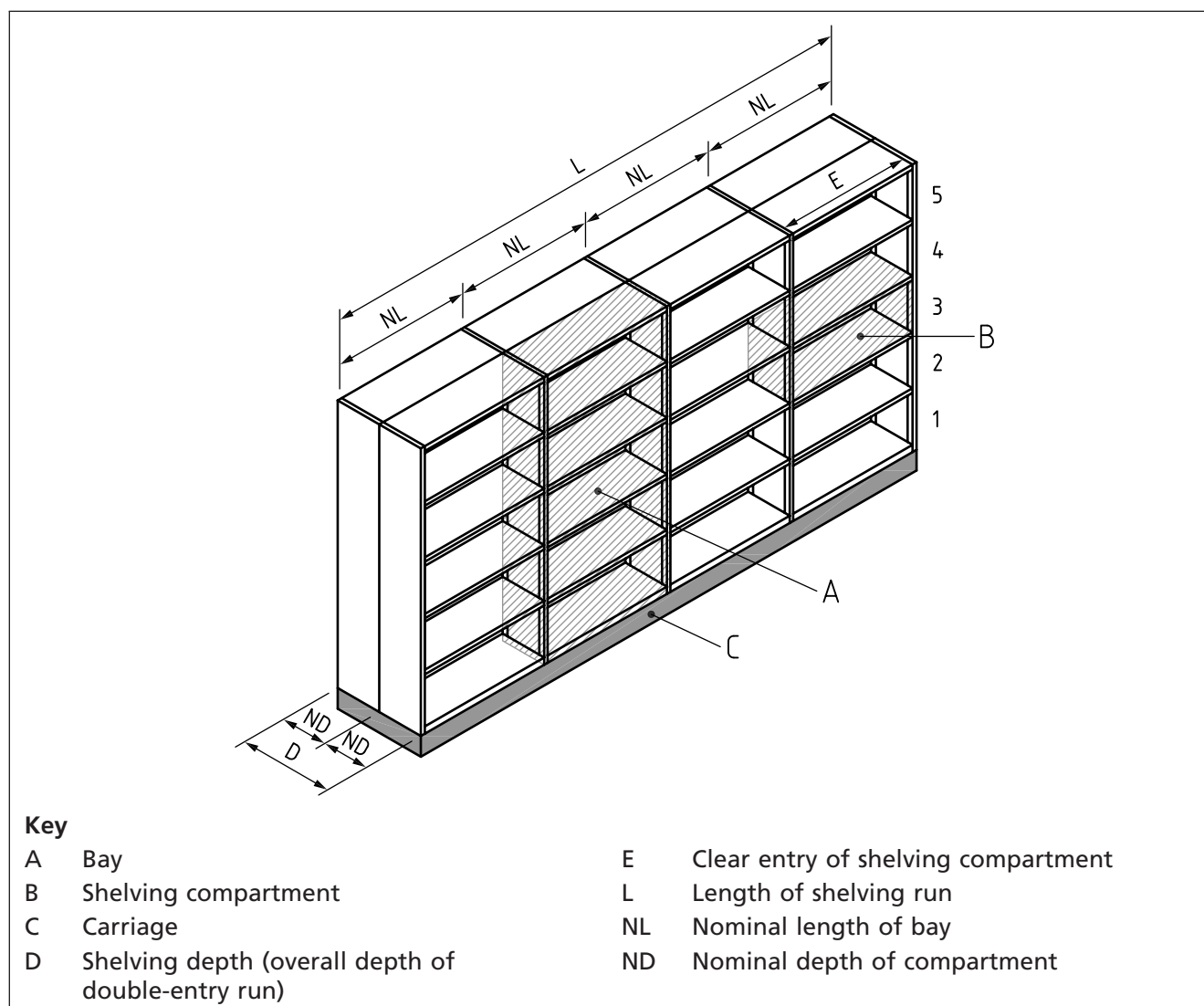
- BS 5720, *Code of practice for mechanical ventilation and air conditioning in buildings*
- BS 5839-1:2002+A2:2008, *Fire detection and fire alarm systems for buildings – Part 1: Code of practice for system design, installation, commissioning and maintenance*
- BS 7671, *Requirements for electrical installations – IEE Wiring Regulations – Seventeenth edition*
- BS 9990, *Code of practice for non-automatic fire-fighting systems in buildings*
- BS 9999, *Code of practice for fire safety in the design, management and use of buildings*
- BS EN 3 (all parts), *Portable fire extinguishers*
- BS EN 356, *Glass in building – Security glazing – Testing and classification of resistance against manual attack*
- BS EN 779:2002, *Particulate air filters for general ventilation – Determination of the filtration performance*
- BS EN 1627, *Pedestrian doorsets, windows, curtain walling, grilles and shutters – Burglar resistance – Requirements and classification*
- BS EN 1838, *Lighting applications – Emergency lighting*
- BS EN 1991-1-1, *Eurocode 1 – Actions on structures – Part 1-1: General actions – Densities, self-weight, imposed loads for buildings*
- BS EN 12056-3:2000, *Gravity drainage systems inside buildings – Part 3: Roof drainage, layout and calculation*
- BS EN 15095, *Power-operated mobile racking and shelving, carousels and storage lifts – Safety requirements*
- BS EN 20534 (ISO 534), *Method for determination of thickness and apparent bulk density or apparent sheet density of paper and board*
- BS EN 60332 (all parts), *Tests on electric and optical fibre cables under fire conditions*
- BS EN 60529, *Specification for degrees of protection provided by enclosures (IP code)*
- BS EN 62305 (all parts), *Protection against lightning*
- BS EN ISO 9706, *Information and documentation – Paper for documents – Requirements for permanence*
- BS ISO 18902, *Imaging materials – Processed imaging materials – Albums, framing and storage materials*
- BS ISO 18906, *Imaging materials – Photographic films – Specifications for safety film*
- BS ISO 12606:1997, *Cinematography – Care and preservation of magnetic audio recordings for motion-pictures and television*
- BS ISO 18916, *Imaging materials – Processed imaging materials – Photographic activity test for enclosure materials*
- PAS 198, *Specification for managing environmental conditions for cultural collections*

3 Terms and definitions

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

- 3.1 air-conditioning system**
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 aisle**
subsidiary passageway between runs leading from a gangway enabling access to shelves for the removal or replacement of documents
- 3.4 archive**
collection of documents intended for long-term preservation
- 3.5 archival material**
type(s) of matter of which a document in an archive is composed
- 3.6 aspirating smoke detection system**
automatic fire detection system in which a sample of the atmosphere in the protected space is drawn by a fan or pump into a fire detector which may be remote from the protected space
[BS 5839-1:2002+A2:2008, 3.4]
- 3.7 automatic fire-fighting system**
integrated system within a building, designed to control, suppress or extinguish a fire, activated by detection systems
- 3.8 bay**
unit of shelving consisting of horizontal shelves between a pair of uprights or upright frames
NOTE 1 See Figure 1.
NOTE 2 These units may be single- or double-sided.
- 3.9 bay load**
total allowable weight of all the unit loads in a bay not including unit loads which might be stored on the floor of the bay
[BS EN 15878:2010, 3.2.9]
- 3.10 buffer**
- 3.10.1 alkaline buffer**
alkaline content of a packaging material, which reacts with volatile acids to protect the contents of the package
- 3.10.2 hygroscopic buffer**
hygroscopic material that tends to react against changes in the ambient RH by releasing water vapour when the RH falls and absorbing it when the RH rises
- 3.11 bund**
structural upstand that can contain water within a defined space in the event of a flood

Figure 1 Shelving arrangement

**3.12 CCTV system**

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

NOTE This might be used for the surveillance of a defined secure area.

[BS 8418:2010, 3.1.5]

3.13 conservation

measures and actions aimed at safeguarding cultural heritage (including documents) while respecting its significance, including its accessibility to present and future generations

3.13.1 preventive conservation

indirect measures and actions aimed at avoiding and minimizing future deterioration, damage and loss

3.13.2 remedial conservation

actions applied to an object to prevent or arrest damaging processes

- 3.14 cooling load**
load (measured in kilowatts) that is imposed upon an air-conditioning system in maintaining the repository at the required level of temperature and RH
- 3.15 custody**
responsibility for the care of documents based on their physical possession
- 3.16 deflection limit**
maximum permissible degree of bending in a shelf under the imposed load, usually expressed as a ratio of measured deflection to compartment length
- 3.17 document**
combination of a medium and the information recorded on or in it that forms an item in an archive
- 3.18 drop-spine box**
single-piece book box with its lid and spine-wall hinged at the base allowing access to the bound volume from the spine side
NOTE A drop-spine box can also be used for the storage of the same sized paper manuscripts/documents. See BS 4971 for further information.
- 3.19 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
- 3.20 gangway**
principal route in a storage room providing people and trolleys with access to aisles with free space
NOTE The gangway is measured as the narrowest space between any protruding surfaces, including hand-cranks or hand-wheels on mobile shelving.
- 3.21 hydrolysis**
chemical reaction in which a compound is changed by interaction with a water molecule
NOTE An example of hydrolysis in archival material is the gradual breaking of bonds in cellulose molecules of paper, leading to embrittlement.
- 3.22 medium**
material on or in which information is recorded
- 3.23 membrane**
single skin, or part of a skin, of parchment or vellum
- 3.24 molecular sieve**
microporous crystalline material that absorbs and traps other chemical species, incorporated into packaging material to remove off-gassing compounds
NOTE This is often referred to as a pollutant scavenger.
- 3.25 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
- 3.26 preservation**
retention and protection of different formats of archive and library materials and/or their information content in order to maximize their useful life

- 3.27 record**
document created, received or generated in the course of a transaction and forming part of that transaction
- 3.28 relative humidity (RH)**
ratio, defined as a percentage, of the existing partial vapour pressure of water to the vapour pressure at saturation
NOTE It is usually, but not always, equal to the percentage of the amount of moisture in the air to that at saturation.
[BS ISO 18934:2011, 3.13]
- 3.29 repository**
building, part of a building, or area(s) within a building designated for the long-term storage of documents
NOTE The term repository is not intended to embrace other associated functions such as reading rooms and offices within the same building.
- 3.30 risk assessment**
identification, analysis and evaluation of hazards
- 3.31 run**
two or more connected bays of single-sided or double-sided shelving joined end-to-end
NOTE See Figure 1.
- 3.32 shelving compartment**
shelf space for storing archival materials
NOTE See Figure 1.
- 3.33 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
- 3.34 thermal inertia**
characteristic of building materials with high heat capacity to absorb and hold heat to maintain a stable room temperature
NOTE Dense materials maximize this effect.
- 3.35 watermist system**
distribution system connected to a water supply, with atomizing media where required, that is fitted with one or more nozzles capable of delivering watermist intended to control, suppress or extinguish fire
NOTE Watermist systems can discharge water or a mixture of water and some other agent or agents, i.e. inert gases or additives.
[DD 8489-1:2011, 3.2.7]

4 The storage environment for archival materials

4.1 Background and general recommendations

The storage environment chosen for an archive should be based on the range of archival materials that it contains. Although no single set of environmental conditions will be ideal for storing every type of archival material, an emphasis on keeping the temperature low and the RH moderate will slow the rate of decay of all archival materials. Some unusually unstable materials might need to be put into cold storage (see 4.3.3). For this reason, a survey of the archival materials, including the format that they are in, their condition and the extent and quality of their physical protection should be undertaken prior to selecting a storage environment. Details of environmental vulnerability and risks for a wide range of cultural heritage materials can be found in PAS 198. Where necessary, some materials might need to be removed from a mixed archive and a separate environment provided for them, if they are to be preserved. Clause 4 is divided into recommendations for the storage of traditional archival materials (including books, parchment and paper) and separate recommendations for photographic, audio-visual and electronic media.

An unsuitable storage environment is one of the commonest causes of damage to archives. Different archival materials have different optimum environments for their long term preservation, and the length of time over which a document can be expected to last also depends on how often it is taken out of a protective storage environment and handled (unfolded and re-folded, unrolled and re-rolled, opened and closed, etc.) and the type of environment in which handling or display occurs (see 4.10).

Damp conditions encourage the growth of mould which is damaging to paper, parchment and other archival materials and can represent a health hazard. Very dry environments can preserve archival materials but can also make some archives, such as folded, rolled and multi-membrane documents, acid-decayed papers and adhesive book structures more inflexible. In a desiccated and inflexible state, these documents are more likely to resist opening and might tear or break when used.

Chemical changes happen in all archival materials over time and can be considered to be part of the natural ageing process. Archival materials such as some wood-pulp papers, 19th and 20th century book leathers, plasticized adhesives and coatings, photographs and photographically reproduced drawings, and some inks are more chemically unstable than, for example, handmade rag papers and parchment. Unstable materials change at a quicker rate as the temperature rises, leading to more rapid ageing. A practical approximation, as given in PAS 198:2012, for all organic materials, including archives, is that reaction rates double with each 5 °C rise. Likewise, high RH can also induce or accelerate chemical change (for example acid hydrolysis of paper and iron gall ink corrosion). Chemical change is often revealed by discolouration or by brittleness and tearing caused by breaks in the molecular chains (polymers) that make up paper and other fibres. Atmospheric pollutants (man-made pollution such as sulphur and nitrogen oxides and natural agents such as ozone) can advance the chemical decay of most archival materials. Some archival materials, such as plastics and some photographic copy papers, can contribute to this decay as they emit gaseous compounds, which, if contained, affect the materials around them and speed up their own decay. All of these factors should be taken into account when determining the storage environment for archives.

NOTE Published research and information can be found in the further reading section of the bibliography regarding the nature and deterioration of archival materials.

4.2 Temperature and RH for traditional archival materials

4.2.1 General

The temperature and RH levels and stability that can be achieved in a repository depend largely on the form and era of its construction. Subclause 4.2 gives guidance on the levels that can, if maintained consistently, prolong the life and usefulness of archival materials. It is focused on what is safe for the materials wherever they are held, not on the building construction itself, for which further information can be found in Clause 6.

For some archival materials, the levels of temperature and RH suitable for permanent storage can be mutually dependent; that is, one temperature range can require a specific RH range to avoid moisture content becoming too high or too low. The environment chosen for a mixed collection of materials should be based on protecting the most sensitive documents within it. Some very sensitive archival materials (such as cellulose acetate photographs and moving image film) require different conditions from most other traditional archival materials and so should be placed separately in the storage environments defined in 4.3. A survey should be undertaken to determine the full range of materials in an archive in order to determine and specify the appropriate storage conditions. Documents having significantly different temperature requirements might need to be housed separately from other archival material, but small numbers of documents that have specialized RH requirements may be placed in microclimate enclosures (for example, using conditioned silica-gel) within a general repository. Any separate housing of such material should be recorded so that its provenance is not lost.

Most repositories, especially those housing traditional archival materials, do not yet have the resources for purpose-built storage (or additional separate cold stores). For some repositories, such as those in historic settings, the environmental conditions might never be optimum for their archives, but the responsibility to preserve the collection remains. For those people responsible for these repositories, it is especially important that guidance is available to help them obtain the best available conditions in buildings that cannot provide the perfect storage environment. The environmental recommendations given in Clause 4 start with those that can apply to a wide range of traditional materials in a single setting, and are further refined for separate specialized collections. Recommendations for a new repository are covered in Clause 6.

NOTE For more detailed examples of archival material requirements see PAS 198.

4.2.2 Mixed archives

Archives having documents created during the past thousand years might contain archival materials which are not removable from their context but which are more sensitive to the level of temperature and RH in which they are held than those archival materials around them. The most sensitive of these items are wax seals appended to parchment and paper documents, and gelatine emulsion photographs (e.g. within mixed albums). Beeswax seals are affected adversely by temperatures below 13 °C, which make them more brittle and precipitate their natural alkane plasticizers into surface crystals. For stability, gelatine photographs require a higher RH minimum at higher temperatures and conversely low RH maximum at lower temperatures. In addition to these sensitive items, some modern colour ink-jet printed documents are vulnerable to colour change in RH below 30% and parchment stored below 35% can be too inflexible to avoid damage when handled.

NOTE 1 For information regarding material damage and deterioration and risks associated with temperature and RH, see PAS 198:2012, Table E.1 and the further reading section of the bibliography.

The level at which mould generally begins to reproduce is around 65 %RH, although this is also dependent on a number of other factors (see PAS 198:2012, 5.2.2) and so a precautionary maximum for mixed archives, to avoid the risk of periods at this dangerous level, is 60 %RH, recognizing that brief periods (e.g. less than one day) between 60 %RH and 64 %RH represent only a slightly increased risk.

The following ranges of RH and temperature are recommended as a means of preventing even sensitive archival materials referred to within 4.2.2 from being compromised when stored alongside less critically sensitive archival material:

- 13 °C to 20 °C;
- 35 %RH to 60 %RH.

The anticipated longevity of materials decreases as temperature rises. For this reason it is recommended that storage temperatures are kept as low as practicable and for the longest time achievable, recognizing that a very stable environment all year round might not be feasible in anything but a purpose-built repository. The guidance given in 4.2.4 should be used with regard to fluctuation within these recommended ranges.

NOTE 2 The ranges given in 4.2.2 are based on published research into the characteristics of a range of archival materials including some temperature or moisture sensitive materials such as parchment, wax seals, paper-based gelatine photographs and modern colour digital printing inks. The research used in compiling this guidance is set out in the bibliography and a more detailed list of sources related to materials and risks can be found in PAS 198.

4.2.3 Paper records storage

Collections that consist only of boxed paper records and which are rarely handled (for example in remote stores) can safely be stored in a wider range of conditions. The temperature in this kind of repository can range between 5 °C and 25 °C and the RH between 25 %RH and 60 %RH. It should be noted that the average temperature across an annual cycle will help to determine the rate of change of papers: the lower the temperature, the slower the rate of chemical deterioration. Likewise, lower RH will reduce the rate of hydrolytic change that can cause deterioration of paper and inks.

4.2.4 Temperature and RH fluctuation

Temperature fluctuation, particularly within the ranges given in either 4.2 or 4.3, does not itself pose a threat to archival materials but periods of high and low temperature have a different influence on different materials. High temperature accelerates the deterioration of some papers, inks and photographic materials and low temperatures can change the nature of seals made of beeswax (see 4.2.2). Furthermore, temperature fluctuation can cause a corresponding fluctuation in RH, which in turn causes changes to the moisture content of hygroscopic materials such as parchment, paper, cloth, gelatine adhesives and photographic emulsions. These materials expand and contract as they absorb and lose moisture.

Some fluctuation in the RH of the air in a repository can comfortably be accommodated by most materials, especially if documents are densely packed on shelves or in boxes and are less likely to have immediate contact with RH fluctuations in the air. Equally, the effects of atmospheric fluctuation when documents are static in storage for long periods are less of a hazard than the physical changes caused by handling when documents are desiccated or rapidly losing moisture. However, the long-term effects of expansion and contraction of the documents in storage are cumulative, especially where these changes are wide-ranging and frequent. Over time this can weaken bonds between different materials such as: photographic emulsions on paper, glass or plastic; gilding and pigments or inks on the surface of parchment; or resin seals applied to papers. In some cases, such as linen-lined paper maps, one layer might contract in an environment with high RH while the other expands, thus causing the layers to separate. Depending on the nature of the repository building, maintaining a safe range of moisture content might require measures to control RH, either within a store or where the environment in a store is significantly different from that in its associated reading room (see 4.10.2).

Gradual change in the RH and temperature from the upper limit to the lower limit (or vice versa) given in either 4.2 or 4.3, for example as a result of seasonal change, may be considered acceptable if it occurs over a period of a month or more. Even a gradual change of this extent that occurs over a single week in response to weather changes, for example in an historic building with low thermal inertia, can be safe for archives, especially if they are packaged. However, a continuous weekly cycle up and down the ranges will cause a gradually increased rate of deterioration of most archival materials when compared with this rate of change in a very stable environment. While it is preferable to maintain a stable annual average by means of design of the collection space and building structure, it is also safe to allow seasonal movements in RH and temperature in order to improve energy economy, as long as the conditions remain within the ranges given in 4.2.2 or 4.2.3.

In a well-sealed repository room, heavily insulated against external temperature changes, with very low air infiltration and full of archives, RH and temperature change are unlikely to be in opposition to each other, because the hygroscopic nature of archival materials will dominate the RH conditions inside the room. However, in a repository that has little or no insulation and that is rapidly changed by varying external factors such as direct sunlight (for example a repository in an historic building), the RH and temperature will rapidly cycle in opposition to each other. In a repository falling into these extremes (for example those having irregular thermal buffering and air infiltration, areas where damp can penetrate and/or heating pipes which influence local conditions) the environment will vary and fluctuation of both RH and temperature might be rapid and uneven. In this context the packaging for all documents should be the first consideration in order to protect against the conditions experienced by the archives, along with measures to address the weaknesses in the building and its infrastructure. Fluctuations in RH caused by air conditioning systems can also be protected against by packaging. Air conditioning systems should be set up so that they do not produce a rapid fluctuation or cycle (see 4.6).

NOTE 1 For small temperature differences ($\pm 5^\circ\text{C}$ or less) in a room at about 20°C , a useful approximation is that RH will change by $\pm 3\%$ for each 1°C change (a rise in RH for a drop in temperature, and vice versa).

NOTE 2 Dramatic temperature variations within a collection space are usually caused by the situation of documents next to an exterior wall or floor without sufficient space for air circulation, or situating them close to heaters, air-conditioning equipment or air vents, or in direct sunlight.

NOTE 3 A useful approximation for a space maintained near 50 %RH is that condensation will develop on any surface more than 10 °C colder than the temperature at which the RH is 50%. Precise calculations can be made using a standard psychrometric chart.

4.3 Temperature and RH for photographic, audio visual and electronic media

4.3.1 General

Most photographic and machine-readable media require more precise control over moisture content and fluctuation in RH and temperature than older traditional archive materials. They are usually composite materials, often with layers of hygroscopic media embedded in or on other forms of substrate, making them vulnerable to deterioration caused by different expansion and contraction rates. Most audio visual formats (audio tape, moving image film, video tape, etc.) and photographic negatives and transparencies are constructed from plastic materials, many of which shrink or decay over time and cause distortions that interfere with or prevent access to the sound and/or image they carry. Because they are prone to decay over a shorter time than older materials such as parchment or handmade paper, they can benefit from colder conditions that slow or even halt this decay. Some formats, such as cellulose acetate based materials, should be frozen if the image or information they carry is to be preserved on its original carrier.

All of these formats will degrade faster if they are regularly played or viewed in a normal reading room environment. For this reason, it is recommended that such collections are copied and the originals are stored in a cool or cold (freezing) environment for as much time as possible while the copies are played or viewed instead. With the exception of optical discs (CDs and DVDs) all of these formats will be preserved for the longest time if stored frozen, but most can also have their life extended by cool storage as long as RH and moisture content are managed within the recommended ranges (see 4.3.2).

Wherever practicable, a separate room or rooms should be provided for these documents, following the recommendations given in 4.3.2 and 4.3.3. Where separate storage rooms are not available and documents are stored in the conditions referred to in 4.2.2 for mixed traditional archives, they should be individually packaged in a micro-climate designed to provide a different RH environment from the surrounding store (see also 4.3.2). Photographic, audio visual and electronic media should never be stored in the environment defined in 4.2.3, which is intended for paper archival materials only.

Alternatively, photographic, audio visual and electronic media should be transferred to a collecting organization with specialized facilities for storing the relevant media.

For magnetic media, an assessment of the risk of magnetic interference should be carried out in accordance with BS ISO 12606:1997, 4.9.9 and 4.9.10 and a suitable storage location should be identified.

NOTE 1 See 3.17 regarding the definition of document.

NOTE 2 Cellulose nitrate sheet and moving image film can explode in a fire and cannot readily be extinguished. Further guidance on this can be found in guidance from the Health and Safety Executive, The Dangers of Cellulose Nitrate Film, HSE 2010 [9].

NOTE 3 Detailed guidance on the environment for all of these media formats can be found on the Image Permanence Institute website. ²⁾

²⁾ The Image Permanence Institute website: <https://www.imagepermanenceinstitute.org>

4.3.2 Cool storage

Cool storage is defined within this Published Document as temperatures falling between 5 °C and 18 °C.

A cool storage environment will slow the rate of decay of the document formats listed in this subclause but will not be as effective as cold storage in achieving this (see 4.3.3). Cool storage requires less energy than cold storage and at the highest temperature in the range can allow use of the stored documents without acclimatization. At the lowest temperature in the range, documents intended for use should be acclimatized by being placed inside a sealed enclosure for 24 hours until they have reached the same temperature as the reading room, in order to avoid condensation forming.

The RH should be maintained within the range of 30 %RH and 50 %RH in order to be suitable for a cool storage environment. This RH can be achieved in one of two ways: either through the design and management of the storage room itself or through packaging the relevant documents and thereby creating microclimates.

Cool storage may be used for:

- black and white polyester base photographic sheet film negatives and transparencies (including microfiche and aperture cards);
- black and white polyester base moving image film and microfilm;
- black and white photographic glass plates (e.g. gelatin dry plate and collodion wet plate negatives and collodion positives);
- black and white collodion ferrotype sheets (tintypes or melainotypes) and daguerreotypes;
- black and white photographic paper prints of all types;
- colour and black and white ink-jet prints;
- optical discs (CDs and DVDs).

Cool storage can also be used for the following materials, if placed inside a microclimate package conditioned to the RH specified:

- magnetic tape (data, audio, video) on polyester base, conditioned at 25 %RH;
- gramophone discs (acetate, shellac, vinyl), conditioned at 30 %RH.

To achieve an RH microclimate, the packaging should be sealed and include a buffer (such as silica-gel) pre-conditioned to the relevant RH. A humidity indicator should also be incorporated and inspected annually to ensure that the recommended RH is being maintained. Cellulose acetate based material stored in this manner should have a permeable wrapping around each document and a molecular sieve or other type of pollutant scavenger incorporated inside the outer packaging to absorb internally generated acetic acid vapour (see also 4.9.3). This scavenger should also be monitored and might need to be replaced periodically.

With the exception of optical discs (e.g. CDs and DVDs), all of the above can also be placed in cold storage as defined in 4.3.3 if they are placed inside suitable packaging (see 4.3.3).

4.3.3 Cold storage

Cold storage is defined in this Published Document as $-15\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$.

A cold storage environment can preserve most forms of photographic, audio visual and electronic media in the long term, with the exception of optical discs (compact discs and digital video discs) which should not be frozen because of the risk of layer separation. All documents removed from cold storage for use should be acclimatized by being placed inside a sealed enclosure for 24 hours until they have reached the same temperature as the reading room, in order to avoid condensation.

Since mechanical cooling is unavoidable to achieve the low, cold storage temperatures, it will be more reliable if the temperature is held constant, regardless of external conditions. Cold storage should not fall below $-30\text{ }^{\circ}\text{C}$ to avoid the risk of ice crystal formation in archival materials equilibrated to a moderate RH at room temperature.

The RH in a freezing environment is determined by the level of RH present at the time the document was sealed up inside its freezer packaging. The maximum RH at which the document formats listed in 4.3.3 should be packaged is 50 %RH.

All materials selected for cold storage should be prepared and packaged depending on their type and format. Packages should be sealable and airtight polypropylene or polyethylene bags or boxes. Humidity indicators should be incorporated inside freezer packaging, along with a humidity buffer that absorbs moisture when archival material is removed from the cold storage environment. Specialist advice should be sought from a conservator before placing material in cold storage, so that the archival material is correctly identified, that the right level of internal RH will be achieved and that the correct packaging is used.

Cold storage is recommended for:

- colour and black and white acetate photographic negatives and transparencies;
- colour and black and white acetate moving image film;
- cellulose nitrate photographic sheet film and moving image film;
- colour photographic prints, all formats;
- colour ink-jet prints;
- acetate magnetic tape (audio and data).

4.4 Protecting from mould, infestation and pollution

4.4.1 General

Documents accepted for storage should not be brought into the repository until they have been checked for insect or fungal infection and treated, where necessary, in accordance with BS 4971. A separate area should be provided for this purpose and precautions should be taken to confine contamination to it.

4.4.2 Mould

Damp documents should never be placed into a repository as localized damp conditions promote the growth of mould. Individual damp items should be placed in a drying room or cabinet maintained at a RH level below 60 %RH until each document has reached equilibrium with its surrounding air. Books and blocks of paper in other forms of gathering need to be monitored and where possible will need to be fanned out to allow for air penetration. A conservator should be consulted for the storage of damp material. Archives should always be stored away from cold or damp walls or unregulated air vents. Storage equipment should be placed to allow for a gap between archival materials and the surface of walls (see 6.12.6). A cold zone in a repository might 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 materials, promoting the growth of mould. Repositories with uneven conditions should be monitored in all affected areas (see 4.5). The causes of these differences should be established and, where practicable, remedied to avoid the risk of undetected mould growth. Where the physical or mechanical deficiencies causing these differences cannot be remedied sufficiently so that the temperature and RH levels conform to 4.2 (for example where there is low thermal inertia in an external wall of a protected historic structure), archives should be moved away from the area affected. Alternatively, air from the acceptable areas of the space can be directed into these zones, balancing conditions across the repository. This can be achieved with fans until the source of damp or colder temperature can be remedied. If mould is germinating, specialist advice should be sought about the health risks and the spread of mould spores.

NOTE Since 65 %RH is the point at which mould can, in general, germinate, it can be assumed that there is a risk of mould in a space usually maintained at X %RH if a drop in temperature reaches $(70-X)/3$ °C. For example, there is a risk of mould in a room maintained at 55 %RH in any part of the room that is 5 °C colder than the average temperature in the main volume of the space. See also PAS 198.

4.4.3 Pest management

The level of insect activity inside and around a repository should be regularly and seasonally assessed and, where necessary, a programme of pest management initiated. Areas should be kept as clean as practicable and unused space should be accessible for cleaning. Materials that could provide a food source for insects, for example food and drink, pot plants and wool carpets, should never be introduced into a repository (see also 6.6).

4.4.4 Control of pollutants

Externally and internally generated airborne pollutants should be identified and measured, their impact assessed and measures taken to mitigate their effects in accordance with PAS 198 (see also 4.6.2).

Silver-based photographic material is vulnerable to chemically induced deterioration of image layers as a result of interaction with atmospheric pollutants, particularly hydrogen sulphide. It is also at risk of deterioration in contact with packaging having an alkaline buffer (see 4.9).

4.5 Environmental monitoring

4.5.1 General

An understanding of how well an archive is being protected and preserved can only be achieved by continuous monitoring of the environment in which material is stored, handled and exhibited. The information derived from monitoring should be reviewed regularly and the implications of trends in RH, temperature and atmospheric pollutants should be interpreted by a conservator or other specialist with knowledge of 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 outside recommended ranges and rectify the situation.

4.5.2 Equipment

Monitoring devices for temperature, RH and atmospheric pollutants should be provided and used within the repository, whatever the method of environmental control. Recording thermohygrographs, data-loggers, environmental reactivity monitors and sensors linked directly to a computerized building management system can all be used. If a building management system is in use it is also advisable to have some independent monitoring devices. Monitors and their sensors should be situated to provide readings that represent the typical conditions in the storage areas, 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, RH and pollutant levels should also be monitored.

Data from continuous monitoring systems (such as those integral to air conditioning or installed telemetric monitors) should be maintained and inspected at least once a week. Recorded data from stand-alone loggers should be downloaded 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 once every three months. Data should be retained indefinitely. Where readings show that conditions are outside those recommended in 4.2 or 4.3, the reason for any discrepancy should be investigated and plans made to remedy any identified problems.

NOTE See also PAS 198 regarding environmental monitoring.

4.5.3 Maintenance

Monitoring devices should 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 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.

4.6 Environmental control

4.6.1 General

Environmental control within the repository should be achieved by provision of a building or an enclosed space within a building that gives high thermal inertia, low air infiltration rates and that has an extensive hygroscopic buffer (see Clause 6). It should also be capable of providing ventilation, where necessary, as a means of changing air that has become polluted or following an increase in atmospheric moisture leading to levels of RH higher than those given in 4.2 and where no other means of dehumidification has been incorporated. The environment can be more easily controlled if the repository is sub-divided. Where this alone is insufficient to maintain an environment within the parameters recommended in 4.2 or 4.3, the strategy may be complemented, as necessary, by providing environmental control equipment.

Plug-in mobile dehumidification units, humidifiers, heaters or other electrical equipment can increase the risk of fire or flood in a repository and should only be used where no other means can be found of bringing an existing space within the RH or temperature ranges given in 4.2 or 4.3 and in conjunction with suitable safety cut-out equipment in the event of a malfunction. Sources of damp or weaknesses in insulation leading to colder areas should be identified and addressed first before implementing a mechanical means of control. A new repository should not be designed to incorporate mobile electrical units to be placed within it as a means of controlling the environment.

4.6.2 Air quality, distribution and ventilation

Even in a repository which meets the recommendation in 6.3.2 of no more than two air exchanges per day, air exchange and air distribution might be insufficient to maintain internally generated pollutants below the recommended limits defined in PAS 198 or to balance temperature and RH where weaknesses in historic structures cannot be remedied (see 4.4). An internal fan system can be used to distribute and balance air across the repository where conditions in localized zones are not within the ranges given in 4.2 or 4.3.

New repositories should be provided with a controllable mechanism for ventilation with clean fresh air where it is desired as a means of managing temperature and RH and controlling internally generated pollutants. It should be used at times of the year or of the day that allow the fresh air to bring the internal air into the recommended conditions (see 4.2 and 4.3). It should incorporate filtration to reduce external pollutant concentration levels that are above the acceptable levels defined in PAS 198. It should provide even distribution so that all areas of the repository are reached. Where internally generated acetic acid vapours are reaching $>100 \mu\text{g}/\text{m}^3$, the air inside a repository should be ventilated with fresh air to reduce levels.

The fresh air used to ventilate should not contain atmospheric pollutants at levels above those defined in PAS 198. Fresh air intakes should not be located close to sources of pollution, excessive moisture or heat. Dust should be collected through a coarse filter in accordance with BS EN 779:2002, Clause 6, G3, and a fine filter in accordance with BS EN 779:2002, Clause 6, F7. Materials used for filters should not be damaging to archival material. Filter performance should be regularly monitored and filters should be maintained according to manufacturers' instructions. Any equipment that produces ozone should not be used as this can be harmful to archival materials.