



BSI Standards Publication

Conservation of cultural heritage — Guidelines for design of showcases for exhibition and preservation of objects

Part 2: Technical aspects

National foreword

This British Standard is the UK implementation of EN 15999-2:2025.

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

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Erhaltung des kulturellen Erbes - Leitfaden für die Konstruktion von Schauvittrinen zur Ausstellung und Erhaltung von Objekten - Teil 2: Technische Aspekte

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European foreword

This document (EN 15999-2:2025) 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of an identical text or by endorsement, at the latest by December 2025, and conflicting national standards shall be withdrawn at the latest by December 2025.

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

EN 15999 consists of the following parts, under the general title “*Conservation of cultural heritage — Guidelines for design of showcases for exhibition and preservation of objects*”:

— *Part 1: General requirements*

— *Part 2: Technical aspects*

Any feedback and questions on this document should be directed to the users’ national standards body. A complete listing of these bodies can be found on the CEN website.

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Introduction

A key objective of a showcase is to display objects of cultural heritage while acceptably reducing their conservation risks. Conservation risks include total loss, physical damage, chemical and biological deterioration (e.g. by accidents, theft, vandalism, natural disasters, humidity, temperature, dust, pollutants, light, pests).

This document addresses stakeholders who are engaged in projects that involve showcases and who are expected to understand the properties of a showcase, such as end-users, designers, manufacturers, and contracting authorities who are in charge of the cultural institutions.

The proposed categories and classifying of technical aspects of the showcases for conservation, safety and security, use and management of the showcase should facilitate the dialogue between the stakeholder and can be used in the procurement phase or in the operating phase; e.g. to define showcase properties for objects on loan.

While recognizing that aesthetics of showcases are very important, the present document emphasizes functional design of the showcase, the practical needs of the user and the requirements of the objects for better preservation.

1 Scope

This document classifies properties of passive showcases of cultural heritage objects for better preservation. It applies to most uses of the showcase: showcases for so called permanent or temporary exhibitions, historical or modular showcases, showcases in uncontrolled ambient environment, etc. It specifies how the performance of the showcase for the safe and secure display - as derived from needs identified during the risk assessment approach described in EN 15999-1:2025 - can be technically assessed by using classified properties.

Aspects of active showcases (those using electricity to directly condition their microclimates) and anoxic showcases (those containing inert atmospheres instead of air) are mentioned in this document, but their properties are not defined, nor classified.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 410, *Glass in building — Determination of luminous and solar characteristics of glazing*

EN 1023-3, *Office furniture — Screens — Part 3: Test methods*

EN 1630:2021, *Pedestrian doorsets, windows, curtain walling, grilles and shutters — Burglar resistance — Test method for the determination of resistance to manual burglary attempts*

EN 15898:2019, *Conservation of cultural heritage — Main general terms and definitions*

EN 50131 (all parts), *Alarm systems — Intrusion and hold-up systems*

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

EN ISO/IEC 17025:2017, *General requirements for the competence of testing and calibration laboratories (ISO/IEC 17025:2017)*

EN IEC 60332-1-2, *Tests on electric and optical fibre cables under fire conditions — Part 1-2: Test for vertical flame propagation for a single insulated wire or cable — Procedure for 1 kW pre-mixed flame (IEC 60332-1-2)*

EN IEC 60332-3-24, *Tests on electric and optical fibre cables under fire conditions — Part 3-24: Test for vertical flame spread of vertically-mounted bunched wires or cables — Category C (IEC 60332-3-24)*

ISO 20653:2023, *Road vehicles — Degrees of protection (IP code) — Protection of electrical equipment against foreign objects, water and access*

ISO 21348:2007, *Space environment (natural and artificial) — Process for determining solar irradiances*

EN 15999-1:2025, *Conservation of cultural heritage — Guidelines for design of showcases for exhibition and preservation of objects — Part 1: General requirements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 15898:2019 and in EN 15999-1:2025 and the following apply.

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

- ISO Online browsing platform: available at <https://www.iso.org/obp/>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1 airtightness

capacity of an envelope to limit the entrance or escape of air or other gas

3.2 end-user

person with assigned responsibility for cultural heritage on display in showcases or for the showcases themselves

3.3 environment

physical, chemical and biological conditions surrounding the showcase

3.4 humidity buffering

smoothing of the peaks and troughs in relative humidity, whilst not changing the average relative humidity

3.5 humidity control

maintaining a relative humidity value different from the average relative humidity value of the *environment* (3.3)

3.6 independent expert

competent person who has the necessary training, knowledge, experience, expertise and skills, sufficient to complete their allotted task

3.7 pollution sorbent

material that captures some specific gaseous pollutants to reduce their concentration

3.8 relative humidity

ratio of the actual vapour pressure to the saturation vapour pressure

[SOURCE: EN 15757:2010, 3.9]

3.9**volatile organic compound****VOC**

organic molecule with a high vapour pressure at room temperature, including VVOC (very volatile organic compound) and SVOC (semi volatile organic compound)

Note 1 to entry: VOCs can be found in construction materials and might be responsible for odour or considered as air pollutants.

3.10**security personnel**

those people in the organisation that have been assigned security related duties

Note 1 to entry: These people may or may not be employees of the organization.

[SOURCE: ISO 28001:2007, 3.22, modified, “in the supply chain” deleted]

4 Symbols and abbreviated terms

AER	air exchange rate
RH	relative humidity
T	temperature
VOC	volatile organic compound
UV	ultraviolet
IR	infrared
-1	divided by

5 Specification of properties of a showcase**5.1 Environmental factors****5.1.1 General**

Showcases can enhance the physical protection of objects from environmental risks arising from incorrect humidity and temperature, pollutants, pests, from UV to IR radiation.

5.1.2 Airtightness and air exchange rate

The protective capacity of the showcase against the environmental factors listed below is mainly determined by its airtightness. This allows it to:

- limit entry of gaseous pollutants present in the showcase's environment, e.g. external use of corrosive cleaning products, outdoor gaseous pollutants;
- reduce water vapour exchanges and improve microclimate control. Moisture exchange due to low airtightness limits the effectiveness and useful lifetimes of added moisture sorbent. It also decreases hygrometric control of buffering showcases, which rely on high loading of moisture sorbent in conjunction with higher airtightness;

- limit entry of particulate matter present in the room coming from indoor and outdoor sources (e.g. smoke, dust, spores, pest eggs) that deposit on objects or infest them, and to decrease cleaning frequency of showcase interior.

When pollution comes from a source inside the showcase (e.g. an object releasing VOCs), and objects made of vulnerable materials are present, higher airtightness is unfavourable for object preservation. Intentional leaks (vents) should be created using natural or forced ventilation, or a material able to absorb and retain the pollution should be added.

Airtightness of showcases generally decreases with time due to ageing and wear of sealing materials (e.g. joints, adhesives, door-gaskets) and misalignment of the showcase with its closures (e.g. for display space, technical compartments) and its joints due to deformation of glass and metal sheets.

Showcase airtightness is quantifiable by the air exchange rate (AER). Categories of AER and showcase performance affected by the air exchange rate are indicated in Table 1. Different classes of AER are characterized by different levels of airtightness from low airtightness ($\text{AER} \geq 5 \text{ day}^{-1}$) to high airtightness ($\text{AER} < 0,4 \text{ day}^{-1}$).

Table 1 — Class labels according to AER with indicative capacity to maintain a suitable environment

Class Label	AER [day^{-1}]	Capacity to buffer against external (RH) fluctuation	Capacity to maintain internal hygrometric conditions (RH)		Capacity to provide protection against the ingress of pollutants ^b	Pollutant accumulation from off-gassing showcase materials and/or objects
			Passive control	Active control		
AE 0	$\geq 5,0$	Can significantly reduce daily, but not weekly, fluctuations with very large amounts of moisture sorbent ^a	no	Yes with high capacity systems	Slight. Some protection offered against external pollution, but not recommended	Least build-up
AE 1	$< 5,0$ to $3,0$	Can significantly reduce weekly, but not monthly, fluctuations with large amounts of moisture sorbent ^a	will struggle to control RH depending on room environment	Yes	Some. Between most stringent recommended levels (in rooms with low pollution background values) up to ~25 % protection compared to the environment	Very low risk of build-up
AE 2	$< 3,0$ to $1,0$	Can significantly reduce monthly, but not seasonal variations with medium amounts of moisture sorbent ^a	can struggle for part of the year, depending on environment	Yes	Good. Between most stringent recommended levels up to ~50 % protection compared to the environment	Low risk of build-up

Class Label	AER [day ⁻¹]	Capacity to buffer against external (RH) fluctuation	Capacity to maintain internal hygrometric conditions (RH)		Capacity to provide protection against the ingress of pollutants ^b	Pollutant accumulation from off-gassing showcase materials and/or objects
			Passive control	Active control		
AE 3	< 1,0 to 0,4	Can significantly reduce monthly, and most seasonal variations with medium amounts of moisture sorbent ^a	can work for most environments	Suitable with most control systems for most situations	Very good. Large showcases, and/or with hard and smooth materials (e.g. glass and aluminium), cannot satisfy most stringent recommended levels	Moderate risk of build-up
AE 4	< 0,4 to 0,1	can significantly reduce monthly, and seasonal variations with medium amount of moisture sorbent ^a	Yes	Yes	Very good. Nearly always satisfy most stringent recommended levels. Large showcases in naturally ventilated buildings or in conditioned buildings with insufficient chemical filtering in urban environments, cannot satisfy most stringent levels	High risk of build-up
AE 5	< 0,1	unlikely to be required for RH buffering or control, except in most extreme situations with low amount of moisture sorbent ^a	Yes	Yes	Excellent. Very few showcases need this low AER	Highest risk of build-up
^a Very high loading of moisture sorbent: e.g. 10 kg/m ³ ; high loading of moisture sorbent: e.g. 6 kg/ m ³ ; medium loading of moisture sorbent: e.g. 3 kg/ m ³ ; low loading of moisture sorbent: e.g. 1 to 2 kg/ m ³ . ^b Protection levels are based on showcases placed in indoor environment.						

Active climate conditioning systems can offer an alternative. However, the risk of technical failure should be considered. The performance of many active systems is very temperature dependent. Experience has shown that the showcase air exchange rate influences active conditioning (see Table 1). Many manufacturers give indicative showcase volumes and air exchange rates that a certain active climate conditioning unit will work with and requirements for space around the unit, which should be adhered to. Humidifiers and dehumidifiers have large capacities and can successfully condition large showcases with high air exchange rates. If both humidifiers and dehumidifiers are used together, correct settings on the control sensor are essential. Mixing chambers can be used for smoothening RH fluctuations induced by humidifiers and dehumidifiers units that run alternately. It comprises a space between the display volume and humidifier or dehumidifier units. For greater effect, a mixing chamber is possibly equipped with moisture sorbent. Several units based on Peltier coolers and water reservoirs are available. Many have limited dehumidification capacity and can struggle at high room RH or high temperatures.

5.1.3 Air exchange rate measurements

Two methods adapted from building measurement standards are suitable for measuring showcase air exchange rates. They measure:

- tracer gas concentrations;
- air pressure differences.

Measuring showcase airtightness to estimate protection against the environmental factors outlined in the previous section (see 5.1.2) is typically achievable with the tracer gas decay method. This is because it measures air exchanges resulting from the complex interplay between the construction of the showcase, and a variety of environmental contributions that often vary over time (see Annex C). As a consequence, air exchange rates measured by tracer gas decay vary according to the changing ambient environmental conditions. For this reason, tests running over periods longer than one day are recommended to obtain an average air exchange rate; arriving at results representative of the exhibition conditions. See Annex E for an example of air exchange rate measurement procedure by tracer gas decay.

Measuring the extent of showcase air exchange via gaps is typically achievable with air pressure difference methods, e.g. air pressure difference decay, constant air pressure difference. With these methods air exchange is measured under a consistently controlled test environment which dominates over ambient environmental conditions. As a result, air exchange rates measured by air pressure methods are less subject to changing ambient environmental conditions; according to the unchanging construction/geometries of the showcase and its gaps. This high test repeatability stems from its mechanically-induced air exchange, which also enable tests to be completed in minutes. See Annex F.

Before taking air exchange rate measurements, the objective/s shall be clearly defined. This can help to choose the suitable measurement method/s; especially in terms of the test duration, equipment and environmental conditions. Unless preliminary tests are being undertaken, showcases shall be tested as part of their final assessment, with all features installed, e.g. security/lighting devices and wiring. Sealing surfaces and seals on all openings should be cleaned, and openings properly shut with all locks engaged.

The objectives can be to determine the:

- construction quality of showcases versus targets from specifications in procurement contracts with showcase suppliers, or from ad hoc exhibition needs;
- lifetime/amount of sorbent needed for buffering RH (see also Annex G, G.2);
- lifetime/amount of sorbent needed for controlling RH to a limit/threshold (see also G.3);
- protection of objects from externally generated pollutants (see also G.2);
- accumulation of internally generated pollutants (see also G.4);
- venting of internally generated pollutants (see also G.4);
- remedial alterations to airtightness made during maintenance or retrofitting of door-gaskets, hinges, joints, gas struts, vertical lift systems and joints resealing around lighting/cableruns, etc. on existing showcases;
- alterations to airtightness made after relocating existing showcases;
- influences of ageing and wear on alterations to airtightness of existing showcases.

Active microclimate conditioning systems will interfere with accuracy of airtightness measurements, so should be turned off and have any plumbing connections closed when performing the measurements.

Before or after taking air exchange rate measurements, searching for leaks may be appropriate (see Annex D).

Further information can be found in the Annexes:

- the physics of showcase air exchange (Annex C);
- the influence of showcase design on air exchange (see EN 15999-1:2025, Annex B);
- Example of air exchange rate measurement procedure by tracer gas decay (Annex E);
- Example of air exchange rate measurement procedure by constant air pressure difference (Annex F).

5.1.4 Protection against adverse climate

5.1.4.1 General

Showcases can be designed to provide appropriate climate conditions for the long term preservation of objects. Relative humidity and temperature are the principal climate parameters, but air pollution shall be considered for many objects as well. Relative humidity of air is linked to the air temperature. A temperature increase of 1°C can make the relative humidity decrease about 2 % to 3 %.

NOTE An enthalpy-entropy chart, a so-called Mollier-diagram, can be consulted to determine such changes. For example: the relative humidity in air with a temperature of 25 °C and a constant humidity mixing ratio of 9,9 g/kg, will drop from 50 % to 47 % when the temperature rises to 26 °C.

Four different qualities of showcases are described below to control its microclimate performances:

- Hygrometric half-time (5.1.4.2);
- Buffering against external relative humidity fluctuations (5.1.4.3);
- Capacity to maintain internal hygrometric conditions (RH) (5.1.4.4); and
- Thermal performance (5.1.4.5).

Whilst humidity buffering (5.1.4.3), is suitable if the room average relative humidity is acceptable, there are often occasions when it is desired to keep the showcase average relative humidity significantly different to the room (5.1.4.4).

The targeted relative humidity conditions for an object are obtained by selecting a showcase with a suitable hygrometric half-time (5.1.4.2) and corresponding replacement cycle of the moisture sorbent.

5.1.4.2 Hygrometric half-time

The capacity of a showcase to buffer against fluctuations in room relative humidity, or to maintain a specific microclimate relative humidity, is most easily expressed as the hygrometric half-time. The hygrometric half-time depends on two chief factors: (1) airtightness of the showcase envelope, and (2) the type, amount (loading for the moisture sorbent) of buffering material in the display space and technical compartment (see Annex I, Formula (I.1)).

NOTE Showcase construction, dressings, exhibit can also be hygroscopic.

A long hygrometric half-time signifies a large buffering capacity for RH fluctuations. The objectives for installing a certain amount and type of suitably conditioned moisture sorbent are to:

- adjust the microclimate RH to the target interval;
- increase the duration that the target microclimate RH can be maintained.

Examples for the calculated approximation of the hygrometric half-time are given in Annex I.

The hygrometric half-time of an existing showcase can be calculated from internal and external relative humidity data, see Annex J. When specifying existing showcases, the hygrometric half-time shall be quoted. When specifying new showcases, the anticipated showcase air exchange rate, and the volume of the technical compartment for moisture sorbent, shall both be quoted. These allow estimation of the hygrometric half-time. Hygrometric half-times are expressed in the following categories given in Table 2.

Table 2 — Categories of hygrometric half-time with some indicative uses

Class Label	Hygrometric half-time (days)	Example of use (the actual suitability is subject to environmental climate parameters)
HH 6	≥ 800	extreme climates: RH over 80 % for considerable amount of time (any kind of castle or underground building, as tunnels, mines, bunker, marine environment)
HH 5	< 800 to 400	Seasonal variations of 50 % RH in the environment
HH 4	< 400 to 200	Seasonal variations of 40 % RH in the environment
HH 3	< 200 to 100	Seasonal variations of 30 % RH in the environment
HH 2	< 100 to 50	Seasonal variations of 20 % RH in the environment
HH 1	< 50 to 10	two-week maintenance or repair period for air conditioning in many environments
HH 0	< 10	most favourable climates and air conditioned spaces

5.1.4.3 Buffering against external (RH) fluctuations

A high hygrometric half-time of a showcase indicates a high capacity to maintain a narrow relative humidity range over a long time.

If a technical compartment is used for moisture sorbents, sufficient air exchange with the display volume is essential and its installation adjacent to the display volume works best. Sufficient gaps for moisture exchange between the technical compartment and the display volume are essential to support the function of the moisture sorbent.

NOTE Experience has shown that 8 mm holes covering 25 % of the surface area of a fabric covered 2 mm thick metal board work well [1]. For slots, a 20 mm gap width has been proposed [2].

If air exchange between the display volume and sorbent compartment is too slow, electric fans can be used. However, their powering, maintenance and malfunction risks should be considered.

To achieve the required hygrometric half-time, the:

- volume of the technical compartment shall be large enough to accommodate the calculated amount of moisture sorbent material (see 5.1.4.1);
- surface area of contact in the technical compartment shall be large enough to condition air being exchanged with the display volume.

Table 3 gives the expected RH microclimate inside showcases for selected hygrometric half-times related to annual RH intervals of the indoor environment.

Table 3 — Expected RH microclimate inside showcases for selected hygrometric half-times related to annual RH intervals of the indoor environment

Hygrometric half-time of the showcase (in days)	Environment seasonal interval (minimum to maximum annual RH (%))		
	between 30 to 70	between 20 to 80	between 10 to 90
	Expected showcase microclimate (minimum to maximum RH (%))		
800	50	50	50
400	50	50 to 51	50 to 52
200	50 to 52	49 to 52	49 to 53
100	49 to 53	48 to 54	48 to 55
50	47 to 55	46 to 57	45 to 59
10	35 to 63	29 to 68	23 to 72

The higher category is mainly useful for long-term relative humidity control when the room average is far from the desired average relative humidity, see 5.1.4.4.

5.1.4.4 Capacity to maintain microclimate hygrometric conditions (RH)

A high hygrometric half-time of a showcase indicates a high capacity to maintain a relative humidity microclimate over a long time. At the same time, the maintenance cycle for reconditioning the moisture sorbent material will be long. If large numbers of showcases are in use the resources (human, technical and financial) required for reconditioning the moisture sorbents shall be considered.

A relative humidity microclimate different from the room can be achieved by adding moisture sorbent (previously conditioned to the desired level). With time, the showcase average will move toward the room average relative humidity. This means the buffer material shall be replaced with new conditioned buffer. Calculations are available to predict moisture sorbent material lifetime (see [3]). Essentially, the lower the showcase air exchange rate is and the higher the amount of moisture sorbent material present, the longer the replacement interval will be.

The duration required to recondition the moisture sorbent of a showcase depends on the hygrometric half-time of the showcase, the room conditions and the target relative humidity.

Table 4 was generated with calculations extensively tested on 200 real monitored showcases in historic buildings in the United Kingdom. The time values have been found to have errors of less than 5 %. The hygrometric half-time is the indicator for the capacity of the showcase to maintain the RH microclimate. The moisture sorbent will need replacing after the time-periods indicated in Table 4. The seasonal relative humidity values can differ and influence the time-periods.

Table 4 — Illustration of how the hygrometric half-time influence the time period for replacing of a moisture sorbent

Hygrometric half-time (days)	Days to maintain the microclimate in a 40 % –60 % RH interval (with moisture sorbent material conditioned to 50 % RH)		Days to maintain the microclimate below 30 % RH (with moisture sorbent material conditioned to 5 % RH) ^a
	RH room interval between 20 % to 60 %	RH room interval between 60 % to 100 %	room at 80 % RH
800	~ 11 000 (30 years)	2 916	467
400	~ 6 600 (18 years)	1 500	233
200	~ 3 300 (9 years)	768	116
100	1 400	387	58
50	653	117	19
10	238	31	5

^a Source: [4]

5.1.4.5 Thermal performance

The performance of a showcase to control its microclimate can be very negatively impacted by heating; either from internal heat sources or external irradiation producing a greenhouse effect. Possible internal heat sources include waste heat from active climate control devices, light sources (including LEDs) and other electronic devices. If they are present, the temperature should be measured at the warmest point of the deck or backboard, with the heat source running for at least 30 min prior to the measurement, or in the centre of the display volume. Results should be expressed as the maximum temperature difference measured through a full day. The thermal performance of display space of a showcase should be placed in the following bands (see Table 5).

Thermal performance of display space of a showcase already installed on site can also be classified according to Table 5 by long-term temperature monitoring. The installation site of the showcase can affect the temperature inside the showcase due to a possible green-house effect. Green-house effects from natural light (even through blinds) will have a strong seasonal effect and results should be expressed as the maximum temperature measured throughout a full year.

Table 5 — Classification by maximum daily temperature difference $\Delta T_{\max}$ in the showcase compared to the environment

Class label	$\Delta T_{\max}$ (°C)	Expected adverse effect
TP 0	> 4,0	dramatic impact on performance, showcase protection is very likely to be compromised
TP 1	from > 2,0 to ≤ 4,0	impact on performance, AER will increase, medium amounts of buffer can struggle
TP 2	from > 1,0 to ≤ 2,0	some impact on performance, AER will increase, small amounts of buffer can struggle
TP 3	from > 0,5 to ≤ 1,0	little impact on performance
TP 4	≤ 0,5	negligible impact on performance