MUSEUMS & GALLERIES COMMISSION
THE CONSERVATION UNIT

Museum Collections in Industrial Buildings
A selection and adaptation guide

BILL BORDASS

MAY CASSAR (Editor)
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Bill Bordass
May Cassar (Editor)
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First published 1996
ISBN 0 948630 38 8
Designed and typeset by Techset
Composition Limited, Salisbury and printed
in the UK by Bigwood and Staple,
Bridgwater, Somerset

Registered Charity No. 295943

The advice and information in this
publication is given in good faith and is
deemed to be an appropriate analysis of the
subjects under discussion. It does not
however constitute precise instructions to
enable a detailed solution to be carried out.
The Museums & Galleries Commission
strongly recommends that advice is
obtained from the appropriate specialists.

Cover illustration: The Museum Building Committee
Thanks to Tim Padfield, Nationalmuseet,
Copenhagen, for the cover cartoon.
While best read from beginning to end, this Guide is based on a series of relatively self-contained sections, most of which occupy a two-page spread.

Foreword

The primary aim of this publication is to improve communication among all those involved in the design and adaptation of premises housing collections. It is intended to empower the end-user, inform the developer and help the building designer avoid serious problems which are often quite elementary technically but which are frequently overlooked or not properly discussed at the appropriate time during the development of a project.

The Conservation Unit of the Museums & Galleries Commission has produced this Guide in response to a trend among museums to seek accommodation for reserve collections away from their main site. Traditional stores are developing as resource or support centres, thus providing museums with the opportunity to improve accessibility and care for their collections. While this Guide has been written primarily to advise museums on the procurement of storage buildings, its recommendations, particularly its approach to environmental control, can be applied more widely to other building projects.

While environmental control was the spur for the development of this Guide, other important issues were soon recognised and included. Safe access by visitors and staff is a key consideration. An off-site facility will not meet a museum's expectations if staff feel uneasy about working - possibly alone - with collections on a remote site. Equally important, visitors must not be put off by bad or messy neighbours if a new facility is located on an industrial site. Other important management considerations are whether a new facility can be operated from the main museum site and whether collection-care concerns over the transport of objects between distant locations can be addressed satisfactorily.

This Guide aims to encourage museums to carry out cost/benefit studies of the re-housing options before them and thus enables them to prioritise the use of available resources, given the wide range of issues that a museum needs to consider when developing a new facility: access, collection care, management, security, health and safety issues.

This Guide deals mainly with spatial planning and environmental management issues. It focuses on the selection, design and adaptation of industrial buildings in order to achieve appropriate internal environmental conditions at an affordable price and it links space requirements to collection need. But the Guide is also intentionally short and succinct, and therefore it cannot hope to cover in detail those aspects where specialist advice may be required, namely building fabric conservation and repair, maintenance, security and fire protection.

Neither does the Guide suggest that procuring cost-effective storage space is sufficient to achieve low running costs. Clearly, the way in which the energy consumption is monitored and managed will affect this, so the operating practices of the staff, including training, need to be considered.

While this Guide is both strategic and practical in its content, it can never replace the value of going out and looking at examples of museum collections in industrial buildings, when a museum is contemplating such a move. This advice also applies to the building designer. When the whole project team is looking at the same thing, there is less of a chance of confusion and misunderstandings, leading to costly mistakes which may be difficult to rectify later.

May Cassar
February 1996

Acknowledgements

This Guide was originated by the Museums & Galleries Commission and William Bordass Associates was commissioned to carry it out. Bill Bordass and Joanna and Peter Eley undertook the study and drafted this Guide. SVM Partnership Ltd undertook some of the case study investigations and related computer modelling. Financial assistance was provided by the Department of Trade and Industry under the Energy Design Advice Scheme (EDAS).

We would also like to thank BRECSU and the Department of the Environments Best Practice programme for their helpful comments on energy efficiency.

The assistance of all those who have given us their views, discussed their plans, shown us round their stores, and commented on drafts is gratefully acknowledged.
Introduction

'We have much more material in store than we can ever display.'

'It is increasingly hard to justify the cost of proper storage facilities unless public access is provided.'

'The stores are far from adequate but it is hard enough to finance the necessary work to the museum itself: can we get better, but low-cost, space?'

'The lease is running out: we need a new store urgently.'

- What do we really want?
- What advice do we require?
- What questions should we ask?
- What buildings are available?
- What type is best for us?
- What are the most important features?
- Should we rent or buy?
- Can we proceed in stages?
- What are the pitfalls and problems?
- Do good prototypes exist?
- Can we control the environment effectively and economically?
- What are the options?
- Do we need air-conditioning?
- Can we afford it?

Purpose of This Guide

This Guide addresses many questions like those above, both in general and with case-study illustrations. It is particularly aimed at:

- Museum curators and conservators.
- Collection managers and administrators.
- Funding bodies.
- Architects, engineers and builders.
- Building owners, developers, surveyors and estate agents will also find sections of interest, especially A, B, C, F, G & H.

The Guide's prime emphasis is on the main storage area - and, in particular, its internal environment - and on assessing and modifying part or all of an industrial building (both old and new, large and small) and reviewing developers' package deals. Much of the material is also relevant to museum storage generally.

Many problems that occur in practice can be traced to differing perceptions by building and museum professionals. The Museums & Galleries Commission hopes that this Guide will assist all those involved to share their understanding of the issues and make better decisions.

Museum Storage in Industrial Buildings

Housing collections is of fundamental importance to the function and purpose of museums [1]. However, stores are too often second-rate, having expanded incrementally into whatever cheap accommodation happened to be available at the time [27]. Storage is now under pressure as requirements for access, security and study increase, and accessible storage space in central museum buildings is earmarked for conversion into new public facilities. The importance to preventive conservation of good, well-managed storage conditions is also better recognised [20,42].

Industrial buildings, particularly old warehouses and newer industrial units, are increasingly being considered and used for museum storage. They promise low-cost space of suitable proportions and load-bearing capacity, and are particularly appropriate for collections including industrial and social history, architectural fragments and bulk archaeological finds. But industrial buildings also harbour many potential pitfalls: in functionality, cost and performance. Many available buildings, both new and existing, are unsuitable, poorly located or may require more repair and alteration than is initially apparent. Sometimes, even after much money has been spent, the desired results may not be achieved.

In the past, storage has not had high priority for funds from local authorities, benefactors, or appeals, and seldom has there been enough money for a new building. But do not set your sights too low: good storage is vital, and the growing tendency for stores to become resource centres with public access could well make storage more attractive to funders.

This Is Not a Recipe Book

While this Guide attempts to raise issues and to identify frequently occurring problems and solutions, each museum and building is unique and will need to work out its own questions and answers. The team (which includes client, building designers and advisers) must enquire into everything and learn from the specialist knowledge of all its members. While there will always be constraints, if one finds designers blindly following the brief, or, on the other hand, saying flatly that something that appears desirable cannot be done, clients should insist that options are carefully explored.

An integrated approach with clear thinking, specialist advice and good communications between members of a well-constructed team is essential for there to be practical, economical and effective solutions. While thought and advice will cost time and money in the first place, the investment will be well-rewarded and good, sound low-energy storage conditions can be achieved.

The Importance of the internal Environment

Internal environmental requirements, and especially the control of moisture levels, can be particularly exacting, and there are dangers of both over- and under-specification. The implications are not always well-understood when a building is selected and can lead to poor strategic decisions - at worst, the wrong building.

Plan the Move Carefully

Moving is always disruptive and time-consuming. It also has 'knock on effects, eg: items may need to be re-catalogued and new uses accommodated in space released. If the whole process is not done carefully and funded adequately, much effort may be wasted and items may even be damaged.
Initial Decisions: Defining the Requirements

The Process

<table>
<thead>
<tr>
<th>STAGE</th>
<th>ACTIVITIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inception</td>
<td>Appoint core team.</td>
</tr>
<tr>
<td></td>
<td>Define function and needs for space location,</td>
</tr>
<tr>
<td></td>
<td>access, staff, tenure.</td>
</tr>
<tr>
<td></td>
<td>Finalise brief.</td>
</tr>
<tr>
<td>Building decisions</td>
<td>Decide environmental needs.</td>
</tr>
<tr>
<td></td>
<td>Find finance/asset/budgets.</td>
</tr>
<tr>
<td></td>
<td>Specify works. Seek approvals.</td>
</tr>
<tr>
<td></td>
<td>Detailed planning/design.</td>
</tr>
<tr>
<td></td>
<td>Obtain tenders. Select contractors.</td>
</tr>
<tr>
<td></td>
<td>Inspect progress and standard of works.</td>
</tr>
<tr>
<td>Production</td>
<td>Plan occupancy and move-in.</td>
</tr>
<tr>
<td></td>
<td>Building services commissioning.</td>
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<tr>
<td></td>
<td>Completion and handover.</td>
</tr>
<tr>
<td></td>
<td>Drying-out the building.</td>
</tr>
<tr>
<td></td>
<td>Snagging and ‘tweaking’.</td>
</tr>
<tr>
<td></td>
<td>Monitoring, review &amp; feedback.</td>
</tr>
<tr>
<td>Occupancy</td>
<td></td>
</tr>
<tr>
<td>Move in in use</td>
<td></td>
</tr>
</tbody>
</table>

The sequence of activities until production will vary for each project, as perceived needs are matched to available buildings.

Related areas and activities must also be identified. If several departments, sites, or organisations share a new facility its viability may improve, but if things will need grouping by ownership, space requirements and costs will increase. Will a poor building or one on a short-lease be a cost-effective stop-gap or a waste of time and money? Will an expensive one be a wise investment or might the outlay threaten other budgets and staffing?

The Search

Once a general strategy has been agreed, a more precise brief will be required to provide criteria for a search or new design. Any existing land and buildings must be evaluated against the basic requirements:

- Do they meet them?
- If not, could they be modified to do so?
- At what cost?
- If an attractive building is not entirely suitable, should the search be widened or do the constraints need to be revised?
- Are there legislative restrictions (planning, building regulations, listing)?

If there are several options, the work necessary for each to meet the brief will need to be costed, at least in broad terms.

An Outline Brief

A written brief defines the requirements. It is needed at an early stage, even to modify an existing building. It can start short, evolve as a record of the progress of ideas and agreed requirements, and also help to inform new members joining the team. The final clear statement of requirements can be refined to assist specification, be referred to in the building contract, and used to help ensure that the requirements are met. If the work is to be in stages, later phases need not be specified in detail, but must be sufficiently well explored to ensure that any subsequent disruption, inconvenience and abortive work is kept to a minimum.

Requirements can be expressed in terms of the performance needed (see the Table opposite). Fundamental issues are size, security and environmental standards. References [7,19,21,22,23,24,30 and 38] contain much useful information.

Size and arrangement

This depends on many things:

- What and how much is to be stored? Consider floor area, height, weight, access and environment (see below).
- How will different classes of items be stored, how tall and how densely?
- Will the volume of stored items grow? How fast by how much? Remember that when items are properly packed they are likely to take up extra room.
- How easily will items need to be accessed and by what means?
- How will items be moved - what is their size, weight and fragility?
- How frequently will they be moved: for research, display, exhibition or merely rearrangement?
- Will there be other uses such as exhibition or conservation workshops, research study areas or wider public access? For how many people? Will this affect how facilities are arranged?
- Will ancillary facilities be required - catering or reception areas, study and meeting rooms, waiting areas, toilets? Always plan to make maximum use of the available volume with mezzanines, etc. You may not think you will need them but stores tend to fill up all-too-quickly.

Security and fire protection

Will you be putting too many of your eggs in one basket? Will they be safe? If necessary refer to MOC’s security adviser.

A Good Storage Building

- Structurally sound and weatherproof.
- Appropriate, secure and fire-safe internal environment for the stored objects.
- Good local environment, avoiding dust, chemical pollution, salt and pests.
- Good access, circulation and headroom.
- A convenient and safe location.
- Affordable capital cost.
- Low-energy and maintenance costs.
- Space for support staff and visitors.

The Team

Improving a building is a team effort on which everyone is on a continuous learning curve. Team members will each bring to the project their own set of preconceptions, skills and information. Knowledge and understanding must be shared for the project to succeed.

- Conservator
- Manager
- Curator
- Architect
- Engineer
- Contractor

More familiar with peoples’ needs than objects’ needs. May not be knowledgeable about conservation or requirements of funding bodies. May sometimes over-react and/or miss important points.

Staff and financial resources must be allocated. It costs much less to get things right from the start than to put them right later. The Energy Design Advice Scheme of the Department of Trade and Industry operates from four regional centres and may be able to provide financial assistance with consultancy costs for energy efficiency studies.

Allocate sufficient time and budget for team members to GET TOGETHER to:

- explore real needs;
- visit buildings of interest;
- exchange briefing information;
- prepare a strategic list of key points to be achieved;
- examine specifications and drawings;
- have regular progress meetings;
- undertake a thorough handover; and
- identify any outstanding problems with the completed building (‘snagging’).

Initial Decisions

Requirements must be determined by the intended use. Items and groups to be stored must be assessed for size, weight, access, security, fire safety and environmental control.
Cost level
Trade-offs will be necessary between costs of building, upgrading, storage equipment, and environmental control. Make sure you can afford to meet the recurrent costs.

Environmental control
• Do all the items have similar needs?
• Are any exceptionally sensitive?

Some issues to be Considered in Briefing and in Selecting Buildings

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Purpose</th>
<th>Performance required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>museum staff researchers public image tenure and budget</td>
<td>Acceptable travel time, from relevant locations. Public transport desired for visitors and staff. Staff permanently on site. Will relocation disrupt them? Proximity to shops, food. Numbers and frequencies expected. Amenities they may require locally. Ease of identification, image, visitor numbers and frequency expected. Unprepossessing and undermaintained buildings may influence public, staff and funders’ perceptions of your operation and attract vandalism (so may some flamboyant buildings).</td>
</tr>
<tr>
<td>Access</td>
<td>vehicles object movement people</td>
<td>Number of car-parking spaces for staff and visitors. Right of access (exclusive where possible). Likely vehicle sizes and turning circles, especially during filling of the building. Will delivery vehicles park outside or enter a holding area for unloading and subsequent acclimatisation/decontamination? Fire and emergency access to all parts of the building. Maximum dimensions of objects and the carrying equipment needed for them: turning circles, width and height of doors* weight for loading capacity, through routes to final location. Type and dimensions of fork lifts, if to be used. Correct heights for handling, moving and seeing. Access for disabled people, convenient routes without unnecessary doors between frequently used locations. Suitable secure provision and segregated circulation routes for public access.</td>
</tr>
<tr>
<td>Size</td>
<td>floor area height future expansion</td>
<td>Amount to be stored by what method. Needs for separate rooms. Suitable allowances for access both within storage and for general circulation between different parts of the building. Will re-packing increase the volume of stored materials? Other activities to be included, with overall area, typical number of people, special requirements (access, view, proximity to other spaces, servicing, ventilation requirements, etc.). Minimum area acceptable on each floor. Height of racking - access and loading considerations - check height to structure at eaves if the roof is pitched. Is a multistorey building acceptable? How many storeys maximum? What lift capacity is needed? Can you use the available height efficiently? Are mezzanines useful? How much additional space may be required in the future? Must it be in one building? Could the building be extended or could there be a separate building on site, or elsewhere?</td>
</tr>
<tr>
<td>Security</td>
<td>access control theft/vandalism fire/flood/pollution systems and failures</td>
<td>Consider how different types of people will use the building. Security standards to be reached. Policy on 24-hour guarding. Types of lock and alarm systems to be used. Block off any unnecessary windows, doors and hidden spaces. Site perimeter security, quality of neighbours and extent of continuous surveillance. Check hazards from neighbouring and previous land uses. Plan to minimise risks. Review health and safety of staff and visitors. Alarm and extinguisher requirements. Are sprinklers necessary or acceptable? Pest control: inspections and treatment. Dust control: air intake filters. Hazards from piped services and rainwater systems: water bars to boiler/plant rooms. Complicated systems can fail more easily.</td>
</tr>
<tr>
<td>Floor loading</td>
<td>general special adding areas</td>
<td>Typical normal contents of shelves/racks, typical weights. Point loads may need spreaders - under-rack feet, for instance. Are floors sufficiently strong, flat, level and easily maintained? Review weights of extra large objects or fully loaded densely packed racking systems - for example, archives require three times normal office-loading capacity. Mezzanines or additional storeys. Information about existing structures may be hard to find. Check weights: strengthening and new foundations under columns may be needed. While the building is empty, consider adding foundation pads for future mezzanines.</td>
</tr>
<tr>
<td>Room types</td>
<td>objects other activities future changes</td>
<td>Is separation needed - by classification, type of environment, type of ownership, type of security, degree of public access or type of storage system. Staff: offices, workshops, laboratories, amenities (kitchen, rest area, toilets). Processes: plant, fumigation, drying, refrigeration, etc. Public: study areas, viewing, exhibitions, amenities. Appropriate circulation routes. Different items to store, new checking methods, more access by the public, altered requirements for environmental control, foreseeable within, say, next five and ten years.</td>
</tr>
<tr>
<td>Environment</td>
<td>variations ranges and tolerances control mechanisms utilities pests</td>
<td>Markedly different needs for relative humidity, temperature, light or air quality need grouping and quantifying. Different access requirements may require subdivision into further zones. Automatic adjustment may control humidity, temperature or combinations of the two. Locate monitoring equipment for environmental conditions, preferably providing past records. Will computer monitoring and remote control be needed? Who will make adjustments and how? Lighting controls need careful thought for effective and economical operation. Existing services: existence, condition, adequacy, capacity required. Potential for upgrading. Likelihood. Eradication and precautionary measures. Monitoring procedures.</td>
</tr>
</tbody>
</table>
Typical Characteristics of Industrial Buildings

Most industrial buildings will need upgrading to suit all but the most robust museum items. Nearly always work will be required to improve weather tightness, air leakage, insulation, security, internal environment and pest control. Many will also need new rooms or control zones inside (see Section 1).

Rent or buy?
Think long-term. For a short lease, is it worth the bother of the move? Can you afford the alterations you really need? And will you get value from the money that you do spend? For a long lease, some landlords may be prepared to make improvements for you and charge for them in the rent. It is always worth negotiating, but for specialised items you may be better off buying.

Type and Original Use

The plans, sections and notes on the right outline a few common building types, their characteristic features and the problems and opportunities they often present, both as buildings [45] and for museum storage. Desirable and undesirable characteristics are often present together, so careful assessment is necessary. WARNING: if numerous things are wrong, rebuilding might easily become more cost-effective than alteration and upgrading.

The same structural forms recur in buildings designed for a wide range of industrial uses. However, buildings originally for storage (especially the newer ones) are often better in the aspects that are most difficult to change, for example, shape, structure and relationship to roads and other buildings. On the other hand, public transport access to storage buildings is often poor and few buildings will have been constructed with a view to long-term storage of valuable items, sensitive to fluctuations or extremes in environmental conditions.

Structural Systems

Suitable industrial buildings tend to be of three distinct types:

- Loadbearing masonry
  Typically nineteenth century, usually three to six-storey. Massive construction, often with limited ceiling heights and internal steel, cast-iron or timber columns at close spacings.

- Steel or concrete frame
  Multistorey, typically early to mid-20th century, with brick cladding or infill, plus growing use of concrete or lightweight cladding from the 1930s on.

- Single-storey sheds
  Many shapes and sizes. Four common types are identified here. Roofs often metal or asbestos cement sheets, not always insulated, often with rooflights. Walls are similar, or of brick or block, at least at low level. Floors usually concrete, not always reinforced and seldom insulated. See Section 6.

Desirable and Undesirable Features

Desirable features

- Simple rectilinear floor plan.
- A large opening for loading.
- Where appropriate, high ceilings to allow tall storage units or mezzanines.
- Goods lifts when using several floors.
- Clear internal spans to ease movement.
- Smooth flat floors, no level changes.
- Designed for heavy loads.
- Site security (on some modern industrial estates and business parks).
- Low, anonymous profile (unless an image is required to attract the public).

See also references [40] and [41].

Undesirable: Need altering

- Poor and poorly insulated roofs; walls and floor may also need attention. Uninsulated and leaky doors.
- Poor airtightness. See Section H.
- Valley gutters, particularly if no relief overflows. Internal gutters and pipes.
- Cracked, uneven and dusty floors.
- Too many rooflights and windows.
- Unsuitable heating, ventilation and lighting.
- Damp.
- Inadequate mains connections.
- Poorly maintained, decayed and infested.

Undesirable: Hard to modify

- Close to dirty industrial processes.
- Constructed of unsuitable materials.
- Insufficient loadbearing capacity.
- Many closely-spaced columns.
- Low standards of construction.
- Isolated, unsafe vandal-prone locations.
- Saline/coastal/marshy locations.
- Land prone to flooding/dampness.
- Poor physical security. Lightweight construction prone to ram-raiding.
- Damp or flood-prone basements.
- Listed building status may be restricting.

Hidden hazards

- Concrete decay, especially where wet. Asbestos in insulation and cavities.
- Built-in timber rotten (eg joist ends).
- Built-in steel corroded.
- Industrial waste contamination of land and/or buildings. This and asbestos can be very expensive to deal with: if found late other work may need to be stopped.
- Water ingress, especially gutter leaks.
- Restricted energy choice and availability of mains supplies in some areas.

Common Types of Industrial Building

<table>
<thead>
<tr>
<th>Location and opportunities</th>
<th>Typical floor plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Built in nineteenth century</td>
<td><img src="image" alt="Universal shed" /></td>
</tr>
<tr>
<td>to before World War I</td>
<td>Usually built on deep inner city or old rural sites. Can appear dark and foreboding but its character can be exploited.</td>
</tr>
<tr>
<td>Usually built on deep inner city or old rural sites.</td>
<td><img src="image" alt="Concrete portal frame shed" /></td>
</tr>
<tr>
<td>Mix of sizes and shapes of buildings allow different uses. Good basic construction.</td>
<td><img src="image" alt="Sawtooth shed" /></td>
</tr>
<tr>
<td>Built in small suburban clusters, layout is highly variable. Great potential for reuse and refurbishment. Open layout usually allows easy access.</td>
<td><img src="image" alt="Modern portal shed 'box'" /></td>
</tr>
<tr>
<td>Built in industrial estates; may be used on a deep site. Large continuous spaces available.</td>
<td><img src="image" alt="Modern portal shed 'box'" /></td>
</tr>
</tbody>
</table>

Universal shed
Built in small suburban clusters, layout is highly variable. Great potential for reuse and refurbishment. Open layout usually allows easy access.

Concrete portal frame shed
Usually front onto slip roads on ribbon development sites. Cheap form of building; can be reclad and upgraded (or demolished).

Sawtooth shed
Built in industrial estates; may be used on a deep site. Large continuous spaces available.

Modern portal shed 'box'
Built in industrial areas. Usually has better quality landscaping.

Properties of Typical Industrial Buildings

Ideal for items needing long-term storage. However, buildings originally for storage (especially the newer ones) are often better in the aspects that are most difficult to change, for example, shape, structure and relationship to roads and other buildings. On the other hand, public transport access to storage buildings is often poor and few buildings will have been constructed with a view to long-term storage of valuable items, sensitive to fluctuations or extremes in environmental conditions.

Suitable industrial buildings tend to be of three distinct types:

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<table>
<thead>
<tr>
<th>Building type characteristics</th>
<th>Typical section</th>
<th>Typical features and some opportunities as museum stores</th>
<th>Disadvantages and constraints in converting to museum stores</th>
</tr>
</thead>
</table>
| Thick wall; heavy masonry (stone or brick, eg cotton mills). Columns, piers, trusses or beams; Multistorey. | ![Thick Wall Building](image) | • Strong form, interesting spaces.  
• Architectural features, trusses and windows, good stone and brickwork.  
• Definitive presence.  
• Often good floor loading.  
• Much space available.  
• Some floors can be 5 m or more in height, giving space for mezzanines.  
• Often possible to remove parts of floors and walls quite easily.  
• Some in good city locations. | • Often too many storeys.  
• Will need lift.  
• Too many large windows: security, heat loss and gain (may need to be blocked).  
• Minimal insulation: will often need more, especially to roof.  
• Can be too big and may need sharing with others.  
• There may be security and risk problems if access is shared.  
• ‘Listing’ may restrict alterations. |
| Multistorey building, flat roofed with concrete frame or steel frame. Infill cladding - bricks or panels - eg flatted factories. Purpose-built for large companies. | ![Multistorey Building](image) | • Some interesting architectural features, but not usually as strong as above.  
• Independent structural frames which can often be sound.  
• New cladding can be applied if needed.  
• Usually has facilities that can be upgraded (offices, lavatories). | • If structure was designed or used for specific industrial process, shapes or spaces may be inconvenient and the building or the land may be polluted.  
• Metal windows and roof lights will often need replacement (but openings may need blocking anyway).  
• Concrete may be decaying. |
| All built from nineteenth century to World War II. Single-storey with truss roof, usually pitched. Brick walls. Examples are garages and workshops. | ![Single-Storey Building](image) | • Easily identifiable building with character (but many of the best ones have often already found new uses).  
• Solid brick walls, easy to change.  
• Traditional construction, often straightforward to repair. | • Siting may be difficult.  
• Access may be awkward, particularly in residential areas.  
• Space available may be too small or compromised unless several units can be combined.  
• Asbestos cement commonly used.  
• Roof structure may be unsound. |
| Built between the wars and afterwards. Single- and double-height, possibly with ‘domestic’ office blocks attached. Example is the standard factory. | ![Built Between the Wars](image) | • Frame basically relatively simple to reclad.  
• Access usually straightforward.  
• Cheap building/site.  
• Offices often situated between visitors’ approach and storage space. | • Typical locations are often lacking in facilities and amenities.  
• Local environment can be poor and in an industrial area.  
• Failures at roof junctions and internal gutters are very common.  
• Asbestos cement cladding, if powdery, is a health hazard and may need total replacement.  
• Concrete might be decaying. |
| Built in 1950s. Single- (some double-) storey with asbestos and translucent roof. | ![Built in 1950s](image) | • Roof profiles very varied, including steel and concrete, shells, top hat sections with a central raised part, etc.  
• In urbanised areas of large cities and old Industrial estates’.  
• Usually large areas of space available with minimum column interference.  
• Usually reasonable access and space around building. | • Too much natural light for museum storage. Glazing is an environmental and security risk and may leak.  
• Valley gutters risky: take care.  
• Compartmentation, if needed, may prove to be awkward.  
• Roof structure may be corroded/weak.  
• Generally not recommended, but there are exceptions. |
| Built in 1960s onwards. ‘Modern’ steel and concrete storey. Single- and double-storey with profiled coated steel roof and cladding; from ordinary type to high-tech style. | ![Built in 1960s](image) | • Modern buildings, built relatively recently.  
• Should have some amenities.  
• Usually sound structural specification.  
• Relatively easy to reclad and/or upgrade and reroof.  
• Car parking, adequate access, loading, etc, will all usually be in place.  
• Typical Advanced Factory Unit (AFU). | • Sometimes the ceiling height near the eaves can be too low for a mezzanine. Minimum desirable 4.5 m clear below structure, 5 m or more preferable.  
• Untried or low-cost short-life cladding materials can fail, look unattractive, and may need replacing.  
• Poor quality insulation will deteriorate and off gassing may affect stored objects.  
• Airtightness is often poor, even in new and ostensibly well-insulated buildings.  
• Check condition of concrete. |
Evaluating Sites and Buildings

In choosing a particular site or building, or in assessing a building which happens to be available, one can learn from good precedents and bad experiences. These may not only be technical: for example, staff may be unhappy to go alone to a large empty building on an isolated site.

Professional surveys may seem expensive, but for shortlisted buildings they are essential. Technical data necessary to assess performance (e.g., design floor loadings, likelihood of hidden defects, budgets for repair) can be difficult to get. Accurate drawings are essential to ensure efficient planning and selection of storage equipment. Those not familiar with interpreting drawings should also review possibilities on site.

The five boxes on this sheet outline aspects of sites and buildings which need to be compatible with your requirements:

1. Site Location.
2. Site Coverage.
3. Building Form and Type.
4. Layout: spatial configurations.

<table>
<thead>
<tr>
<th>1. SITE LOCATION</th>
<th>Site surrounded by development</th>
<th>Isolated industrial site/estate</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Local social amenities (catering).</td>
<td>• Room to expand, room for vehicles.</td>
<td></td>
</tr>
<tr>
<td>• Usually better public transport. <strong>but</strong></td>
<td>• Less conflict with neighbours. <strong>but</strong></td>
<td></td>
</tr>
<tr>
<td>• Higher land values.</td>
<td>• Security more of a problem.</td>
<td></td>
</tr>
<tr>
<td>• Limited expansion.</td>
<td>• Little infrastructure for public access.</td>
<td></td>
</tr>
<tr>
<td>• Vehicle access sometimes difficult.</td>
<td>• Staff may feel isolated or unsafe.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2. SITE COVERAGE</th>
<th>90% city block</th>
<th>60% rambling complex</th>
<th>40% single building</th>
<th>40% several buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Storage all together. <strong>but</strong></td>
<td>• Courtyard can be attractive,</td>
<td>• Recognisable image to outside world,</td>
<td>• Best for incremental expansion,</td>
<td></td>
</tr>
<tr>
<td>• Overdense, reliant on lifts.</td>
<td>• Potentially good security,</td>
<td>• Potentially good security. <strong>but</strong></td>
<td>• Parking and loading flexible. <strong>but</strong></td>
<td></td>
</tr>
<tr>
<td>• Higher maintenance.</td>
<td>• Limited vehicle access and loading.</td>
<td>• Strung out and may be wasteful.</td>
<td>• More elaborate maintenance,</td>
<td></td>
</tr>
<tr>
<td>• Access, loading and parking difficult.</td>
<td>• Entrance may be difficult to define.</td>
<td></td>
<td>• Security and control more difficult.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3. FORM AND TYPE OF BUILDINGS WIDELY AVAILABLE ON THE MARKET</th>
<th>Opportunities/advantages</th>
<th>Constraints/disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 'As found' spaces: eg caves, fortifications, cellars, viaduct arches.</td>
<td>Special character but usually impractical for the long-term. Large volumes available that no-one else wants, cheap. Often thermally stable but too damp. Possible use as outer envelope into which secondary containers are placed.</td>
<td>Access usually inconvenient. Particularly difficult to waterproof, insulate, draughtproof and/or ventilate. Local pollution, low quality. Sometimes too much of the area and environment is difficult to control. Prone to vermin.</td>
</tr>
<tr>
<td>• Higher specification: Heritage and polite architecture eg chapels, institutions, schools, post and telecom buildings.</td>
<td>Character can be exploited. Enhances a place where people will be working. Can be in a pleasant part of town, neighbouring amenities, (catering, public transport).</td>
<td>Access often awkward. Total building often covers plot. Limitations of architectural features, structural systems and room shapes and sizes. Heritage status, and especially 'listing' may restrict scope for alterations.</td>
</tr>
<tr>
<td>• Built for manufacturing:</td>
<td>Can have individual character. Usually equipped with office space and facilities. Can be used for control, and study areas.</td>
<td>The building enclosed specific processes, creating odd shapes and volumes. Old plant/machinery or noxious residues sometimes difficult to remove. Land and/or building may also be polluted. General environment can be harsh.</td>
</tr>
<tr>
<td>• Purpose-built for storage:</td>
<td>Usually planned to deal with vehicles, loading. Usually on one major level, can use forklifts, pickers. Relatively easy to build structures inside.</td>
<td>Insulation often poor or absent. Poor performance building components, may lack robustness and durability. General environment often uninspired and underpopulated. Security problems in location/isolation.</td>
</tr>
</tbody>
</table>
5. CONSTRUCTION CHECKLIST

**Flat roofs**
Check weatherproofing, adequate drainage outlets and falls' security and insulation.

**Flimsy or fragile roofs**
Ideally rebuild or severely limit access, strengthen key points for maintenance. Consider security and pest implications.

**Parapet and valley gutters**

**Rooflights**
Check weatherproofing. Remove and roof over in storage areas. Fit blinds in areas people use regularly. Replace and fit safety/security glass in office/amenity areas.

**Asbestos**
Inspect thoroughly. If at all friable, encapsulate or ideally remove.

**"Too many windows**
Block securely, incorporating adequate insulation. If windows are retained externally, ventilate the space behind them to outside air to reduce risks of decay.

**Basements**
Check for damp, flood risk and insulation. If for storage, waterproofing, access/fire escape and ventilation may need upgrading.

**Attics**
Check floor loadings, fire safety/escape, security, weathertightness and insulation.

**Roof structure protruding down**
If potentially restrictive, seek structural engineer's advice on possible removal.

**Very high ceilings and roofs**
Test possibility of mezzanines. Can existing staircases be extended to fit? Consider insulated suspended ceilings.

**Too many columns and supports**
Examine plans to locate 'pinch' points. Take structural engineers advice about adding beams to allow key columns to be removed or relocated.

**Floors**
Take structural engineers advice if weak or crumbling. Sometimes possible to consolidate, but full or part replacement may be needed, or new foundation pads for mezzanines and racks. If uneven or dusty, consider levelling and sealing. Avoid changes in level - ramps take up a lot of space.

**Walls**
Check for stability and damp. Check that sheet cladding is sound.

**Heating, etc., in place**
Take building-services engineer's advice on suitability, useful life, optimum operation and potential for reuse and upgrading. Existing systems will often be unsuitable (see Section K).
Storage Planning and Systems

Storage Classifications

Many characteristics must be borne in mind when planning. And building professionals will not necessarily think of all of them. Needs and priorities will vary with the museum and its stored items.

Time scale
The length of time objects will be stored and frequency of viewing will affect packing and access, for example:
- **Short Term:** recently accessioned or awaiting dispatch or conservation.
- **Medium Term:** often material held pending decisions. Can you save space by allocating time to decide now?
- **Long Term:** Study collections of high-quality material on which items are drawn for inspection and exhibition.
- **Loan Collections** with frequent in and out flow.

Size of objects
This affects handling methods and access space. Mechanical handling, usually by forklift, is increasing with health and safety requirements, even for quite small items.
- **Small:** can be lifted safely by one person.
- **Medium:** lifted by a team and moved on trolleys or pallets and forklifts.
- **Large:** size and/or weight requires powered transport: forklifts or cranes.
- **Extra large:** Over 15 m long or 10 tonnes.

Different materials
Audit what you plan to store [20, chapter 3] and consider its needs as accurately as possible, see references [2 and 4]. Items which need very different conditions may have to be in separate areas or specially packed. Compromises will often be required, both for convenience and economy, and for objects made of several materials (eg a cart ideally requires metals dry bodywork medium and wheels damp!).

Environmental Needs
These vary from object to object, and any values chosen will be a compromise. Protection from excessive light and an appropriate range of relative humidity is usually most important, preferably at cool temperatures, see Sections E & F and graph below, adapted from reference [46].

<table>
<thead>
<tr>
<th>RELATIVE HUMIDITY STABILITY ZONES</th>
<th>GENERAL COLLECTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOLOGICAL ATACK</td>
<td></td>
</tr>
<tr>
<td>MECHANICS</td>
<td></td>
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<tr>
<td>SALTS</td>
<td></td>
</tr>
<tr>
<td>BUILDING</td>
<td></td>
</tr>
<tr>
<td>METALS</td>
<td></td>
</tr>
<tr>
<td>CELLULOSE</td>
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<tr>
<td>PROTEIN</td>
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<tr>
<td>MINERALS</td>
<td></td>
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<tr>
<td>UNSTABLE GRASS</td>
<td></td>
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<tr>
<td>HYDROPERS</td>
<td></td>
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<tr>
<td>SPECIAL CASES</td>
<td></td>
</tr>
<tr>
<td>ACTIVE</td>
<td></td>
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<tr>
<td>COLLECTIONS USE</td>
<td></td>
</tr>
<tr>
<td>KEY</td>
<td></td>
</tr>
<tr>
<td>CAUTION</td>
<td></td>
</tr>
<tr>
<td>MODEL</td>
<td></td>
</tr>
</tbody>
</table>

Points to Watch
- Poor planning wastes space and can make access difficult. Room sizes and areas, column spacings, width of security corridors, and entrance/exit points will all affect layout and rack sizes.
- Plan the mix of objects to equalise loads if possible. Floors may need reinforcing for heavy and point loads.
- Full flexibility to place any object anywhere will only be achieved at the expense of reduction in volume stored.
- Plan for future mezzanines and storage on top of internal rooms. Ensure that access to them is easy and safe. See diagrams opposite.
- Match the range of container and rack depths, widths, and heights to the objects. Space wasted at ends, front and top of each shelf quickly adds up.
- Identify any special storage furniture and equipment which may be needed.
- Allow for space taken by pallets and containers when calculating storage needs. Nesting designs can reduce space taken by empty pallets and containers.
- Long runs of shelves are harder to plan and access efficiently. Mobile racks seldom go beyond 12-14 m long.
- Floors must be smooth and extremely flat for safe and effective use of trolleys and fork lifts. Tiny steps and hollows impede movement and shake objects about. Ramps also waste space.
- For mobile racks, insist on tracks flush with the floor, positioned before the floor is finished. CONTRACTORS OFTEN PREFER TO PUT TRACK ON A RAISED PLINTH AFTERWARDS - AVOID THIS IF YOU CAN, PARTICULARLY IF TROLLEYS AND FORKLIFTS ARE TO BE USED
- Keep lights and heaters away from shelves. Ensure switches and power points are easily accessible.
- Do not block all circulation: raise lowest shelves and keep racks away from external walls, especially if they are not well insulated. Plan for easy cleaning and checking for pests.
- Remember that requirements for public access to stores is likely to grow How will you deal with it?

Storage Planning
Approaches vary with type of object:
- Large or awkward items: free standing
- Medium to heavy items: pallet racking
- Light boxes, papers: mobile racking
- Light but fragile items: fixed racking
- Flat textiles: suspended
- Shallow fairly light objects: drawers
- Sensitive/unique items: own microclimate
- High value small items: strongroom
- Maintenance stores: lower security.
- Once moved, and if not labelled and assigned a location, an object can be lost forever. Use the move as an opportunity to improve records. Seek and allocate resources for this.

Make good use of the volume of the building: Do not pay for height you don't need. Racks and mezzanines, where suitable, can maximise floorspace. Pallets simplify handling of heavy and bulky items. Low-cost volume may be useful as a buffer space (See Section K).

Use layout drawings to decide the best use of available space and plan lighting layouts, access routes, etc. You must make careful measurements and you may need expert help. 'Free' advice from storage manufacturers can be useful, but avoid getting locked in to one supplier's range.

Case Study — Storage strategy
Bar End — Winchester

- **A fixed shed for a growing collection.**
- **Initial budgets allowed for only 30% of the racking to be mobile.**
- **Supplier chosen had a good service record and had fixed and mobile systems which used the same racks.**
- **Tracks for mobile racks were fitted at the start, level and flush with the floor.**
- **As pressure for space has increased, additional racks and mobile bases have been put chased.**
- **The occupier would now recommend using powered trolleys and forklifts for horizontal movement.**
- **A fixed shed for a growing collection.**
- **Initial budgets allowed for only 30% of the racking to be mobile.**
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- **As pressure for space has increased, additional racks and mobile bases have been put chased.**
- **The occupier would now recommend using powered trolleys and forklifts for horizontal movement.**

If You Use Fork Lifts
- Allow sufficient space for movement and turning.
- Plan racks accordingly.
- Use small simple equipment where possible: it requires less manoeuvring space and may not need trained operators.
- Bulky fork lifts take a lot of space: If you really need them, consider mobile pallet racking or side-loading equipment to reduce aisle widths and improve space use.
- For access to mezzanines, consider hinged sections of guard rail with pad-bolts.
Try to Use Relationship Diagrams

Relationship diagrams like this are useful both to plan and to assist discussions with building professionals. Major spaces are shown as boxes (minor spaces can be added too), with functions and activities written inside and linkages shown as lines. Here the main storage area (at the top) is linked to three interrelated groups below: process, staff and public areas. Often these four parts will need to be segregated, particularly where visitors need to be controlled. Other requirements can be included, here surveillance of vehicles and visitor access and rooms requiring some daylight.

- **Process Areas**: These areas are an integral part of any store.
- **Staff Areas**: These areas are usually needed but the amount varies from store to store.
- **Public Areas**: These areas are not required if there is no public access. However, the need for them is increasing.

**Planning entrances and aisles**

Decide if vehicles are to enter the loading bay, and if so, up to what size - a Luton van, a pantechnicon? Usually one should have secure, and preferably airtight and insulated doors between store and loading bay. Storing large awkward items near the loading doors, and smaller ones further in will save aisle and manoeuvring space. If practicable, a goods entrance on the 'long' side (as here) may avoid wasted circulation space.

**Do not waste vertical space**

Do not waste volume, but do not pile things too high. If a large fork lift is needed for some items, zone vertically, using mezzanines, or horizontally using some wide and some narrower aisles. Provide fork lift access gates in mezzanine railings where appropriate. Avoid low-roofed buildings in which you hit your head on the beams: this is extremely inconvenient and you will need hard hats.

**Eventually you will always want to put things on top of enclosed spaces such as offices and secure stores. Make them strong and flat, avoiding obstructions by cables, pipes ducts, etc. Allow space for access. Plan to link them to mezzanines, etc., at a single level. Even small level changes are difficult to negotiate.**

If you have mezzanines in separate parts of the store, as in the plan above, try to link them up. This will improve access, reduce the number of escape stairs required and maximise usable area.
Environmental Control: Requirements and Principle

Storage Conditions for Objects

If the building can potentially meet the basic requirements of watertight, secure, accessible, clean and pest-free shelter, then the main priority becomes the internal environment: temperature, RH (relative humidity) light and air quality.

Considering Standards

At present there is much debate about acceptable standards. While published guidelines (eg [4]) must be consulted, each collection is unique and appropriate solutions must be chosen to suit its particular needs and circumstances [46], including the environment to which it has become acclimatised [20, chapter 2]. Most contain varying proportions of:

1. **Robust** items needing little more than avoidance of extremes.
2. **Intermediate** items needing conditions within a defined range.
3. **Sensitive** items requiring stability and sometimes close control.

Stores for large or **robust** objects often have a multipurpose main storage area, plus a few small rooms or containers for the more **sensitive** or valuable items. In practice it has proved difficult to get the right standard for the main area: too often one finds **intermediate** items in thermally poor spaces with few services, and sometimes quite elaborately serviced places for largely **robust** collections. Building professionals, often used to designing primarily for human comfort, may need to review their assumptions in relation to priorities for effective and economic collection care, for instance:

- Unlike people, most objects are more affected by moisture levels than by temperature.
- Most objects prefer low temperatures, which help to slow down chemical and biological decay, although increased moisture levels may occur at low temperatures and counteract this.
- **Robust** stability may be preferable to energy-dependent constancy.

**Are variations acceptable?**

Published museum standards often assume temperatures at comfort levels, with RHs controlled within narrow limits. Necessarily they are for typical circumstances and not for specific items or collections which may have survived well in different environments [11]. In storage there may be more flexibility: comfort is often less of an issue, a degree of daily and seasonal fluctuations in conditions may be permissible, and sensitive items can be segregated.

Many **intermediate** items may tolerate RHs which vary by ± 10% about a suitable mean value, plus occasional slow excursions beyond, within overall limits of typically 30-70%, see [12] and [46]. While metals prefer RHs at the low end, higher RHs may be acceptable if they are clean and machinery can often be protected with grease. Using the strategies outlined opposite, improving the building's performance (Section H), and using zoning principles (Section I), one may be able to bring suitable buildings (or parts of them) to appropriate intermediate standards while avoiding unnecessary capital or running-cost expenditure on building services.

**Indoor Air Quality**

Heat, moisture and pollutants are released internally by the occupants, their activities and equipment. Some stored objects also release pollutants, which can affect both people and other objects. Some building materials also emit volatile chemicals, dust and moisture (rising and penetrating damp). These problems must be minimised and suitable ventilation provided [34].

The influence of the Building

For long-term survival of a collection in permanent storage, environmental control should ideally be primarily a 'passive' function of the building (with appropriate storage and management policies), and power-assisted only to the degree absolutely necessary. Buildings modify the internal climate using the following main mechanisms:

- Sheltering from the weather.
- Restricting the passage of air.
- Impeding the flow of heat and moisture, both in and out.
- Storing heat and moisture in their fabric and contents.
- Trapping solar radiation.

The effects are often, but not always, beneficial. Local climate is of course influential, eg dampness problems in buildings in waterside locations or in areas with heavy rain-fall.

**An Appropriate Use of Building Services**

In recent decades, dependency upon evermore complex heating, ventilation and air-conditioning (HVAC) systems has tended to rise while the role of buildings and contents in helping to stabilise conditions has often been ignored. Today, the wisdom of this reliance upon engineering systems is in question. Expensive to buy, systems can be expensive (sometimes too expensive) to run. Lower-powered systems, designed to trim the environment to avoid adverse conditions can potentially be less expensive, less energy-hungry, safer and more reliable than higher-powered systems upon which the collection is completely dependent.

**Control Strategies**

Strategies which set out to modify conditions by no more than is necessary to look after the objects, are particularly appropriate for storage buildings where:

- Budgets are often tight.
- Preservation can often be allowed to take precedence over human comfort (but staff will also need somewhere to go which has local heating).
- Inputs of heat from lights and heat and moisture from people are often small.

A range of alternative strategies should be considered, including those outlined in the Table on the facing page. While close-control air-conditioning may sometimes be the only way to provide the necessary environment, it should be seen as the last resort and applied only in circumstances and in areas where it is really needed.
The seven strategies outlined in the Table below range from completely free-running through to close control within a narrow band. In practice many stores will use variations, combinations and hybrids to suit their own needs. Practical examples can be found below, and in the case study in Section M.

Appropriate solutions will also depend upon the balance between comfort and storage. For example, where visits are made for security and checking only criteria for economical storage can dominate and conservation heating may be suitable. If the building is a resource for the public, comfort will be more important, at least in some areas. Additional systems may also be needed to improve comfort and to meet workplace legislation. For instance, staff may require a warm room, or local electric radiant heaters (see Section K) which can be activated for short periods as required. However, if the content is worked on and exhibited frequently, then full control may become necessary.

<table>
<thead>
<tr>
<th>Approach</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Comments</th>
<th>Capital Cost</th>
<th>Energy Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approach 1. No Heating</td>
<td>Shelter only. Follows external conditions if well-ventilated. Frost protection is desirable. Uncomfortable in winter. Useful protection for objects normally kept outdoors or in simple shelters. Low running cost. If internal, may be insulated by neighbours.</td>
<td>Will usually be too damp. Light, poorly insulated and ventilated buildings can overheat on sunny days, particularly if windows or rooflights are large.</td>
<td>Uninsulated metal roofs can drip condensation on clear still nights. Widespread condensation may occur after cold weather. Building may deteriorate.</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Approach 2. Comfort Heating</td>
<td>Conventional heating system with room temperature control. For economy the building needs to be relatively well-insulated and airtight. Choose the lowest temperature practicable.</td>
<td>Well understood. Suitable for people. Air will often be too dry in cold weather, particularly if ventilation rates are high. Energy costs will be high if the building is draughty or poorly insulated.</td>
<td>Where possible avoid heating the whole store to comfort levels. Greatest danger to organic materials and composites if overheating occurs when it is below freezing outside. Designers may forget object needs.</td>
<td>££££</td>
<td>££££</td>
</tr>
<tr>
<td>Approach 3. Heating with Humidification</td>
<td>Conventional heating system augmented by local or central humidifiers. The store needs to be insulated to good practice levels, with good air- and vapour-tightness. Permits people to be comfortable while avoiding low wintertime relative humidity (RH) for objects.</td>
<td>Relatively high running cost. Good control, reliability and air distribution is vital. Fit extra humidity controls to sound alarm and shut down humidifier if the RH goes above limits.</td>
<td>Useful for composites where comfort is also needed. Humidification can cause overt or hidden condensation dampness in walls, roofs, and adjacent unheated spaces - review risks carefully.</td>
<td>£££££</td>
<td>£££££</td>
</tr>
<tr>
<td>Approach 4. Conservation Heating</td>
<td>The heating is operated to keep winter RHs within an acceptable range for the objects. Extensively used by The National Trust. Best for largely unheated stores. May be uncomfortable in winter. Low-powered with modest operating costs. May be able to re-use some existing heating systems under humidistat control.</td>
<td>Cool in winter, typically 5°C above external. RH rises in summer because the temperature required to limit it is too high. In well-sealed stores 'hgyrothermal run-away' might occur unless there is a high temperature cut-off.</td>
<td>Effective even in stores which are not very airtight. Higher summer RHs may often be acceptable. If they are not, supplementary dehumidification may be added (see Strategy 5 below).</td>
<td>£££</td>
<td>£££</td>
</tr>
<tr>
<td>Approach 5. Dehumidification Only</td>
<td>Often no direct heating. Store must be relatively airtight. Particularly useful for metals needing a dry environment year-round. Uncomfortable in winter unless heating is added. Better limitation of RH than possible naturally or with conservation heating. An energy-efficient option where heating is not needed for objects or people.</td>
<td>Refrigerant-based dehumidifiers may not work well under about 10°C and may heat the air too much. Desiccants in chemical units may contaminate stores - use inert material (eg silicagel).</td>
<td>Maintenance costs can be high. Most chemical desiccant units need ducts to outside air. Refrigerant units usually need condensate drains - buckets can be used instead but are not recommended.</td>
<td>££</td>
<td>££</td>
</tr>
<tr>
<td>Approach 6. High Inertia</td>
<td>Relies largely upon a heavily built, airtight, well-insulated store for stability of temperature &amp; RH. May use low-powered heating, ventilation and humidity control. See reference [39]. Stable RHs possible with relatively low energy input. Particularly useful for densely stored organic materials and archives.</td>
<td>May not be appropriate if occupancy rates are high. Appropriate low-powered services can prove difficult to obtain, design and control. Possible ‘hygrothermal run-away’.</td>
<td>Internal heat gains in particular from lights and fans must be kept to a minimum (this is always desirable in any event). Used for archives (see reference [8] for examples); of increasing interest for museum stores.</td>
<td>£££££</td>
<td>£££££</td>
</tr>
<tr>
<td>Approach 7 Full Control</td>
<td>A wide range of options for heating, cooling, ventilation and humidity control is available. The store needs to be insulated to good practice levels, with good air- and vapour-tightness. Can potentially be tailored to any required specification. Attractive if future needs are unknown or uncertain (but so is waiting until you are sure what you really want).</td>
<td>Capital, energy and maintenance costs tend to be high. Control and reliability is critical and needs careful consideration. ‘Flexibility’ is no panacea and its benefits may prove illusory.</td>
<td>Often seen as the ideal but is sometimes regrettet afterwards. Try to limit to areas with high occupancies and/or exacting requirements. Needs good design, monitoring and maintenance.</td>
<td>£££££££</td>
<td>£££££££</td>
</tr>
</tbody>
</table>
Lighting

Light is destructive to many materials (including packaging), and can be one of the greatest threats to long-term care.

- Light levels required for the safe use of the store can be quite low. A safe rule of thumb is 200 lux at 1 metre above the floor in designated areas where perception of detail is required.
- Do not put sensitive items on top shelves: near lamps and rooflights the illumination may be much higher.
- Fit ultraviolet (UV) filters to all lamps which might shine onto stored objects, unless 100% sure that they will only be on for very short periods.
- Minimise usage: arrange switches to stop lamps being on unnecessarily.
- Switch off lights as much as you can, to avoid unnecessary exposure, save energy and avoid unwanted heat gain.

Exposure to light

A cumulative lux-hour approach (illuminance multiplied by hours of exposure) may permit higher light levels (say 500-600 lux) from time to time for detailed examination and study. Mobile task lights can be helpful, but they must be mechanically stable for safety and cool-running (normally fluorescent) to minimise fire risk.

However, for items 'resting' in storage, lower exposures are highly desirable, with items in the dark or at least in very subdued light, for as long as possible.

Light sources and fittings

Tubular fluorescent lights in reflector fittings are normally most appropriate; other sources tend to cast too many shadows. Lamps should be enclosed for UV protection and in case they shatter. Fittings should be above the aisles in shelving and racking: this needs either careful planning or easy relocation. To light the shelves effectively reflectors should be chosen in relation to mounting height and aisle width. To simplify maintenance, lamp types and sizes should be standardised as far as possible and there should be easy access for re-lamping and cleaning.

Select the most efficient and low-energy lamps and fittings you can afford, particularly for lights which may be on for long periods, eg for security, main circulation, and externally. Further information is available in references [13, 14, 28 and 29].

If 'hands-free' operation is desired, eg where forklifts are regularly used and all the lights would otherwise be left on permanently, 'occupancy sensors' may be considered: these switch on if they detect movement and/or off some time after an area is vacated. They are not necessarily expensive and may also be convenient in corridors, WCs, storage containers and for security. Care must be taken to avoid nuisance and danger if the lights were to go off inadvertently.

Daylight and sunlight

Daylight should be eliminated owing to its destructive effects, and security hazards with windows and rooflights. Sunlight's high intensity makes it very much more damaging, particularly to anything it hits directly; and it may also heat the building significantly.

Daylight however improves the appearance of interiors and objects, and saves energy. It may be appropriate for:
- zones in which all objects are durable;
- parts of resource centres which are occupied for much of the time; and
- offices, workshops, study areas and rest rooms.

Where stored items may be affected, UV protection is required (eg by a film - some plastic rooflight materials already absorb UV) and security hazards must be addressed. Rooflights and windows should be preferably north-facing to restrict entry of direct sun, and shutters and blinds are desirable to control light levels and to avoid unnecessary daylighting during unoccupied periods.

Lighting for mobile racking

With mobile racking, lights with a broad-spread distribution are normally run perpendicular to the shelves. Try to avoid too many lights shining uselessly and wastefully on the tops of the racks by lighting the main circulation only and controlling aisle lights in small groups, for example with pull-cord switches in the main aisle, just above head height, or by suitable detectors and/or remote controllers.
The Building's Performance As a Protective Enclosure

General Requirements

To help control temperature and relative humidity stores need, in order of approximately decreasing priority:

1. A shell which is structurally sound and watertight.
2. Low air infiltration to reduce unwanted ventilation.
3. Good thermal insulation, to reduce heat losses and gains through the walls, ceiling, floor and windows.
4. Limiting heat gains from the sun and internal sources such as lights.
5. High thermal capacity, to reduce temperature fluctuations. Moisture storage capacity is also often helpful.

Some issues are outlined here, with 'passive' solutions in Sections H and J.

A building shell with good thermal performance, plus careful planning of space, will greatly assist preventive conservation by having good, stable, low-energy 'passive' characteristics. With the right control strategy (Section E), this will minimise requirements for energy-consuming equipment. Try to:

- Seek buildings which allow stable conditions to be obtained straightforwardly, and if possible, cheaply.
- Keep solutions simple, avoiding complex technical 'fixes' unless there are no alternatives.
- Try not to condition larger volumes than absolutely necessary.

If you have the chance, monitor internal and external temperatures and RHs in possible buildings, preferably over a full year, see [2, 20]. This will help you to understand how they actually perform.

1. A Sound Shell
   
   Existing buildings need to be carefully checked for risks of flood, rising damp, leaks from roofs or rainwater systems, failure of flat roofs and structural decay. These must be eliminated if possible: sometimes by repair, sometimes upgrading. Alternatively (see Section J) a robust but imperfect building may sometimes provide shelter and an environmental buffer zone to containers within: inside these the environment can become more stable or better controlled.

2. Low Air Infiltration
   
   To improve control over temperature, RH or air quality, draughtproofing will frequently be a priority. Industrial buildings (even new ones, as in the photograph below) are notoriously leaky - not only at doors and windows but at joints between panels, at the eaves, where lightweight roofing or cladding meets the ground or perimeter brick walls, and where brick or block walls abut steel or concrete columns.

   As much heat may be lost by unwanted air infiltration as by conduction through the solid elements of the building shell, particularly in a well-insulated building. The air will also carry dirt, spores, insects and pollutants. Whatever the building, unwanted ventilation will make it difficult to maintain stable RHs and will massively increase the running costs of humidifiers and dehumidifiers. Means of reducing air leakage are discussed in sections H and J.

3. Good Insulation

   Many old buildings are uninsulated, and in newer ones insulation is often poor, in specification or in execution (as in the photograph on this page). Ideally all outer surfaces should be insulated: walls, roofs, and windows and, if possible, the floor, particularly its perimeter.

4. Limiting Heat Gains

   Windows and rooflights can admit large amounts of solar radiation, particularly if sunshine enters directly. This reduces thermal stability and may even cause overheating. Internal heat gains from people, lights and equipment must also be taken into account: a strategy (eg conservation heating) which may work well in a lightly occupied store may become inappropriate if the store is lit and occupied for long hours.

5. High Thermal Capacity

   Thermal capacity helps to reduce the building's rate of response to change: to the weather; occupancy-related gains; or system failure. It usually resides primarily in masonry walls (both internal and external), concrete floors, and the contents themselves. (Note: if these are insulated internally, the temperature-stabilising effect of their mass will be much reduced; external or cavity insulation is preferable). Many buildings material also have moisture-storage 'sponge' capacity which also helps to stabilise moisture levels, as do the stored objects themselves.

An all-too-typical cross-section of the wall of a modern portal-framed shed, showing faults which significantly degrade its insulation and airtightness. The insulation stops short of the bottom. The metal Z-spacer and the cill are cold bridges. Air will also enter directly under and over the cill section, where there are no seals. Air will also infiltrate indirectly via joints in the cladding and the inner liner sheets via the airspace and the permeable insulation. This will also reduce the insulation's performance.
Improving the Thermal Performance of The Building Shell

What is a U-Value?
The rate of heat transfer through a building element is termed its U-value, measured in Watts per square metre per degree Celsius temperature difference between inside and outside (and expressed as W/m²K). The smaller the U-value, the better the insulation.

in many stores, extra insulation will be desirable. In some - depending on the objects stored and the control strategy adopted - it may not be necessary.

For new industrial buildings which require heating at a rate of over 50 W/m² of floor area, the 1995 Building Regulations AD Part L require the following maximum U-values: (W/m²K)
- Outside walls, floors and roofs 0.45
- Walls to unheated spaces 0.6
- Windows, doors and rooflights 3.3
- Vehicle access doors 0.7

To meet these normally requires about 75-100 mm of mineral fibre insulation (or 40-75 mm of foamed plastic, depending on type) in lightweight walls and roofs, and less in more heavyweight or multi-layered constructions. Windows and rooflights must be double-glazed and vehicle access doors insulated and draughtproofed.

However, many existing buildings are very much less well-insulated than this, for instance:
- U-value (W/m²K)
  - 225 mm (9 inch) brick wall 2.3
  - 275 mm (11 inch) brick cavity wall 15
  - Ditto with 25 mm cavity insulation 0.7
  - Uninsulated sheet metal cladding 5.7
    - with foil-backed plasterboard inside 19
    - plus 25 mm cavity insulation 0.8
  - Sheet metal cladding with 150 mm lightweight concrete block inside 10
  - Uninsulated sheet metal roof 6.7
    - foil-backed plasterboard lining 2.0
    - plus 25 mm insulation L1
  - Single-glazed windows:
    - Wooden frame typical 4.7
    - Metal frame typical 5.6
    - Rooflights 6.6

These values vary with exposure, from typically 10% more on windswept sites to 10% less in sheltered urban areas. Without good design and workmanship, U-values in completed buildings may not match textbook values. Performance of doubtful insulation can be checked by infra-red survey.

For more information, see references [5 and 9] and manufacturers’ literature.

Upgrading Insulation and Airtightness

Insulation reduces heat transfer between inside and outside and is usually worth upgrading where practicable, particularly if there is none already, or where an element needs repair or replacement. However, there can be pitfalls (see box below), professional advice is necessary, and workmanship needs constant checking where insulation is built-in.

Floors in existing buildings are seldom insulated. Adding insulation is seldom practical unless replacement is needed for structural reasons or to avoid dampness. Since most heat loss occurs at the perimeter, floor insulation is not statutorily necessary in new buildings more than 15 metres wide (or more than 10 m wide if over 27 m long). However, in museum stores perimeter insulation is always desirable, otherwise it will tend to be colder and damper here. See also reference [10].

Lightweight walls and roofs in industrial buildings often had little or no insulation until the 1970s. This made them cold in winter, hot in summer, and prone to condensation. Uninsulated cladding and particularly roofing will usually need upgrading, either replacement by an insulated system, or insulating internally. Systems usually have thin inner linings like plasterboard, but a new inner block wall will give better security and thermal stability.

Masonry walls have thermal capacity and some insulation (see box). Unless clad, or with cavities suitable for filling, they can be difficult to insulate cost-effectively. External insulation with cladding or rendering (in a light colour to reduce solar gains and radiation losses) will improve the appearance of a poor building but be unacceptable for a good one. Internal insulation will cover the exposed thermal mass; and may reduce thermal stability particularly where heat gains (eg from occupancy and rooflights) or losses (eg by air infiltration) are large and vary rapidly.

If insulation is difficult, approaches which minimise temperature differences between inside and outside, eg dehumidifying, conservation heating, and/or using buffer zones may be useful. See Sections E, J and M.

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Roofs generally. Maximum solar gain and heat loss often occurs through roofs. Good insulation, a light-coloured finish and no roof lights is usually best. If an otherwise sound roof needs more insulation, an insulated lining or suspended ceiling may be suitable if there is sufficient loadbearing

Better insulation can create problems and reveal defects which are less significant in uninsulated structures. For trouble-free performance, careful attention is needed to design and supervision, particularly in a humidified building. Try to avoid:

- Using combustible insulants.
- Obscuring any structure which requires inspection or maintenance by added insulation.
- Fire spread in wall and roof cavities.
- Damage from water spillage.
- Air leakage paths where air, heat and moisture by-pass insulation. These reduce stability, waste energy and may lead to condensation. Air seals and vapour checks may be required.
- Cold bridges where gutters, beams, columns, purlins, fixings, mezzanine supports, etc, by-pass insulation. Again, condensation can occur here.
- Overheating of inadvertently insulated electrical cables. See also reference [15].

For more information, see reference [5 and 9] and manufacturers’ literature.

<table>
<thead>
<tr>
<th>INSULATION AND AIR LEAKAGE: POINTS TO WATCH</th>
</tr>
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<tbody>
<tr>
<td><strong>Glass wool</strong></td>
</tr>
<tr>
<td><strong>Insulation boards</strong></td>
</tr>
<tr>
<td><strong>Insulation blankets</strong></td>
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<td><strong>Insulation batts</strong></td>
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<tr>
<td><strong>Insulation panels</strong></td>
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<td><strong>Insulation slabs</strong></td>
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**Table**: Insulation and Air Leakage: Points to Watch

- Using combustible insulants.
- Obscuring any structure which requires inspection or maintenance by added insulation.
- Fire spread in wall and roof cavities.
- Damage from water spillage.
- Air leakage paths where air, heat and moisture by-pass insulation. These reduce stability, waste energy and may lead to condensation. Air seals and vapour checks may be required.
- Cold bridges where gutters, beams, columns, purlins, fixings, mezzanine supports, etc, by-pass insulation. Again, condensation can occur here.
- Overheating of inadvertently insulated electrical cables. See also reference [15].
capacity. Take care to avoid condensation [15], particularly in humidified buildings. Dark finishes will get colder on clear, still nights (making them more prone to condensation), and hotter in the sun.

Flat roofs. Flat roofs should usually be avoided in the main store; there are many pitfalls and the consequences of failure may be severe. However, there are a few good ones and expert advice should be taken. Sometimes, subject to structural capacity, a new pitched roof constructed above can create a useful double roof with insulation, ventilation and access for maintenance in between (Section).

Traditional roofs. Slate and tile roofs with ceilings beneath can perform well after any necessary repair. Insulation can be added above the ceiling, with air/vapour seals and roofspace ventilation as necessary. However, where the underside of the covering is immediately visible from inside the building, considerable alteration may be necessary to improve insulation, airtightness and resistance to ingress of rain and snow in high winds.

Windows and rooflights. Rooflights in storage areas may often need to be replaced with insulated roofing materials, and windows removed and their openings filled in to match or contrast with the surrounding walls. In historic and rented buildings, one may have to retain unwanted windows and close them up internally: windows may then deteriorate through condensation and neglect. To reduce this risk, the internal closure should be well-insulated, fit tightly, and be removable for maintenance, while the space between it and the window should have some ventilation to the outside air. Essential windows should have good seals, at least double glazing, and UV protection where necessary. Shutters are helpful both thermally and for security. In public areas, staff offices and conservation workshops or laboratories, a balance must be struck between daylight, view and the related environmental and security problems.

Internal openings. There should be no more openings in walls and between floors than strictly necessary, and no larger than required for daylight, goods, people, and fire escape. If large objects will only be taken on certain routes, use smaller doors elsewhere. Consider closing redundant doorways, enclosing vertical shafts and stairs between floors, and adding mass and insulation to portions of walls originally thinner than the rest.

Air leakage at junctions. Junctions between components are often very leaky, both to the outside and sometimes between rooms. Careful detailing and construction is necessary to avoid unwanted air infiltration, particularly where tight control is required, see references [5] and [44]. Typical weak spots include:

- At joints between sheets of profiled metal roofing and cladding, particularly at the eaves and the ridge, even with modern insulated systems.
- Notoriously at the junction between lightweight cladding and foundations or lower masonry walls.
- At junctions between brick and block infill and structural steelwork.
- Missing mortar in joints in brick and block walls. If necessary, internal plastering can avoid this.
- Around the outer perimeter of doors and windows - suitable seals must be specified and checked on site.
- Vehicle doors can be particularly leaky. See Section.

Air infiltration rates in warehouse buildings are typically around 1 air change per hour (ac/h) with the doors closed, and can often be halved by simple remedial measures (see diagram). Some leakage paths will be visible with the lights off, others may be traced using a hand-held smoke puffer. New designs and careful refurbishments should aim for 0.2 ac/h or less. Carefully controlled ventilation may need to be introduced in areas where materials (objects or otherwise) are suspected of off-gassing. Pressure tests can be carried out by specialist organizations to determine air-leakage characteristics.

![Smoke puffer in use, revealing air exfiltration where a structural steel column penetrates the inner leaf of an outside wall.](image)

**Relationships Between Temperature, Relative Humidity and Moisture**

Air contains water vapour, up to a maximum (saturation) content which rises rapidly with temperature. The ‘psychrometric chart’ (a) below shows the saturation curve (top), and curves of constant RH (expressed as % of saturation) beneath. For air of a given moisture content (constant vertical distance), RH falls as temperature rises: hence one usually needs stable temperatures if RH is to be controlled.

The alternative of Conservation Heating (see Section E) manipulates air temperature to control RH. The horizontal line in (a) shows the RH falling from 80% to 60% as the air is heated from 15°C to 20°C.

Moisture is constantly exchanged between building, contents and the air. If object and air are at the same temperature, the object's moisture content depends primarily on the air's RH (see (b) below). As the temperature rises, the RH also needs to increase slightly if a constant moisture content is to be maintained, see [3] and [6]. Hence the elevated RHs which can occur in UK buildings in summer may be acceptable.

![Relationships Between Temperature, Relative Humidity and Moisture](image)
Buffer Zones, Airlocks, Doors and Containers

Problems with Poor External Walls

Ideally, storage areas for sensitive, intermediate or even some robust items should not have external walls, particularly if these are deficient in performance. Lightweight cladding, for example, offers little physical security.

Poorly insulated walls reduce thermal stability and increase the energy and equipment needed to control the internal environment. They also increase the risk of dampness and mould in winter (and hence possible damage by fungi, rust, moulds and insects):

- at edges and corners (where heat losses are higher);
- where material is placed close to them (owing to its insulating effect); and
- where air circulation is poor (reducing the transport of heat to them).

In such buildings, at the very least avoid placing shelving and objects close to outside walls. Better access to the walls also means that faults are more likely to be detected and more easily dealt with.

Planning Buffer Zones

Even in unpromising buildings, it will sometimes be possible to devise internal layouts which greatly improve passive environmental conditions for storage, reducing the need for size of, and energy consumption by building services equipment. The following principles are applied:

- Try to limit the store area's outside wall by putting circulation routes, offices, etc. around its edge.
- Provide loading areas in which doors can be opened and goods moved (and if necessary held for inspection, etc.) without affecting the store proper.
- Put sensitive objects in separate rooms or containers, (with their own environmental control systems if absolutely necessary) and surrounded by areas for more robust items, circulation, or people.
- Finally, consider creating micro environments for individual items, for example, by using sealed boxes [43, 20 chapter 8]. These can also keep the light out and include physical protection, wrappings, and silica gel as a buffer to maintain appropriate humidity levels.

Caution: Boxes and furniture made out of some hardwoods (particularly oak), a few softwoods (eg Douglas fir) and man-made composite boards (eg plywood) may themselves create corrosive acidic atmospheres.

The Advantages of Internal Rooms

- Better security by extra physical protection and by permitting devices around their perimeter (for instance, movement detectors in corridors and vibration sensors on doors and walls).
- Isolation from changing weather, possible condensation, water ingress, and unscheduled fabric maintenance.

The climate in internal rooms may sometimes be stable enough to need no supplementary environmental control systems. Where they do, equipment can be lower-powered, more easily controlled, and will use less energy. Some types of equipment are outlined in chapters 7 and 8 of reference [20].

Roof Buffer Zones

The roof is often a weak spot. Upstairs rooms and roof voids above can be used to buffer sensitive areas. For really secure storage, a double roof can provide an environmental and security barrier and a second line of defence against water ingress or roof failure. Such roofs can also be inspected and maintained without intruding upon the storage area.

Doors for Goods, Vehicles and People

New external doors should be insulated (as required for new buildings in 1995 Building Regulations [16]) and have multi-point locking. Except to areas used for shelter only, all doors, including internal doors to stores of any sensitivity, need good seals. Resource centres regularly visited by the public may need draught lobbies to main doors.

Appropriate Containers

Containers used in stores include polythene tents, steel tool stores, relocatable building modules, and more conventional structures in plasterboard and blockwork. All have their uses: see the facing page and Section M. Second-hand transport containers can also be used, but be sure that insulation is not damp, decayed or infested.

Caution: Heat from occupancy, lights, refrigerant-based dehumidifiers and even fans may cause insulated and sealed internal rooms and containers to overheat, particularly if well-insulated or if adjacent rooms are warm. Try to minimise unwanted heat sources and, if necessary, consider using low-powered ventilation systems to remove heat and internally generated pollutants.

Insulated and well-sealed loading doors are now available.
1. **Buffer Zone Planning At Eagle Wharf Road**

The Museum of London converted a 1960s steel stockholding warehouse into a store and resource centre. A steel structure was built in the southern part of the main storage area to support an intermediate concrete floor. The two floors were each divided into four main areas by concrete block walls, with an access corridor for people and light objects to the south. A double-height access zone to the north admits large objects (vehicles and machinery) into the ground floor stores, while fork lift trucks can raise pallets to the first floor.

Each area has independently controlled conservation heating (see Section E) using the original hot water boilers (soon to be replaced by smaller, more efficient ones). One upstairs and three downstairs bays were fitted with new high-level pipe coils. The remaining bays retained the original suspended radiant panels.

On completion, conditions were monitored and soon found good enough for the more robust items. However, and as expected, finer control was needed for intermediate and sensitive items (see Section E for definitions of items in italics). A site survey revealed that:

- The control and commissioning of the conservation heating needed attention.
- The well-insulated roof needed draughtproofing, particularly at the eaves, hips and ridge. The uninsulated valley gutters also needed attention.
- Junctions between block walls and steel structure also needed sealing.
- All the large doors, both for vehicles and the fire shutters to the stores, were uninsulated and too leaky.

Computer modelling showed that the circulation areas worked well as buffer zones, and that with conservation heating there was no need to upgrade external wall insulation. If the airtightness of the doors was improved, and the conservation heating was controlled to achieve its theoretical performance, then most of the space could also suit intermediate items, with only small compartments required for sensitive items needing closer control of RH. Residual air infiltration (averaging about 0.2 ac/h) was expected to be adequate for ventilation needs. The predicted annual energy cost was £2/m² for the conservation heating, plus a similar amount for the fine tuning in the compartments, against £24/m² for full air-conditioning.

2. **Conservation Heating and Plastic Tents Successfully Used By English Heritage**

English Heritage rented a former warehouse to hold the contents of a mansion while it was restored. The controls for the existing ducted warm air system were modified to provide Conservation Heating. The system was fine-tuned to give the necessary control for robust and intermediate objects and has worked well. A relatively high RH of 60-65% was chosen to match conditions in the house and to limit the upward drift in humid summer weather.

The first trace shows wide fluctuations in temperature achieving a much more stable RH in the main store, but with occasional dips when the wind changes and the moisture content of the outside air falls faster than the store can cool. The lower trace shows the stabilising effect of the plastic tent, both on temperature and particularly RH: the heat and moisture content of the stored materials were enough to avoid the need for supplementary humidity control equipment.

3. **An Unheated Store with an Air-Conditioned Plasterboard Container**

Bewdley Museum’s store is in the middle of a recently completed block of industrial units. Its main, unheated, area contains industrial, household, agricultural and building items. More sensitive items are housed in the low-cost insulated timber studwork container, on the right, which is clad in plasterboard and security-protected. Light items are also stored on top of it. A small packaged air-conditioner keeps the container at 16°C and dehumidifies it if necessary.

In early 1995, there was a paint spray explosion in the unit next door (to the left). The solidly constructed party wall substantially contained the serious fire that followed. However eventual partial collapse knocked blocks from the party wall on to a few objects and showered the collection with dust. While the stud work container completely protected the sensitive objects, they might not have been so lucky had the explosion been on the other side. This experience draws attention to some of the hazards of neighbours on industrial sites which need to be considered very seriously when selecting appropriate buildings.
Heating Equipment

The table and diagrams opposite outline key features of heating equipment often found in industrial buildings, classified as:

A. High temperature radiant units.
B. Warm air heater units.
C. Ducted warm air systems.
D. Hot water systems (with boilers).
E. Other electric systems.

Note that existing systems will often be unsuitable for museum stores, and frequently in poor condition. Remember to look at the boiler room if there is one.

Warm air systems usually recirculate most of the air, sometimes introducing a small or variable proportion of outside air, filtered as necessary. This can help:

- Introduce a known quantity of fresh air.
- Pressurise the building, so air leakage is out rather than in, which increases cleanliness but can cause interstitial condensation where the inside air is humidified.
- Use outside air for cooling as required, particularly at night in summer.

General principles for storage
Where required, heating for stored objects should be gentle, continuous (at least during the heating season), uniform, and energy-efficient. Aim to minimise risk from fire and flood (see box), and:

- Moisture and pollution in combustion gases from fuel-heaters (also known as direct-fired heaters) including oxides of nitrogen and sulphur.
- Unsuitable or variable conditions.
- Heating objects too much in hot air streams from air grills, radiators and convectors, or by radiation - particularly with high temperature overhead sources.
- Stratification of warm air at high level, prevalent with warm-air heaters, high-output natural convectors and some radiant systems. This wastes energy and makes upper shelves too warm.

If stratification is a problem, `punkah ceiling fans can help to mix the air.

Conflicting comfort requirements
Cool winter temperatures, suitable for objects, may cause complaints from visitors and staff. Try not to provide comfort conditions throughout: this is not only expensive, but may incur extra costs of humidification to counter the consequent drying effect, and increase the risk of instability if any of the systems go wrong. Instead consider appropriate clothing for staff, separate warm rooms to which staff and visitors can retire, and local radiant heaters to improve warmth in specific places (or possibly underfloor heating panels in well-used areas).

Fuel choice
Mains gas, where available, will often be the most convenient and economic heating fuel, and suits a wide range of heating equipment. Liquefied petroleum gas (LPG), is much more expensive. Solid fuels will seldom be appropriate.

Oil, in recent years often cheaper than gas, does not burn as cleanly and has extra storage, handling and maintenance requirements, so is usually used only where there is no mains gas. Electricity although expensive for heating, is particularly appropriate for:

- Fast-response on-demand local systems for personal comfort.
- Fine control in inner rooms or containers for sensitive objects.
- Off-peak for background and conservation heating, particularly for small buildings on remote sites and which need relatively little heating.

Ventilation Systems
In most industrial buildings, even well-sealed ones, natural air infiltration will often provide sufficient fresh air for museum storage purposes and remove normal levels of pollutants. Extra ventilation may however be needed for:

- Internal rooms and in particular those in which people congregate, pollutants are generated, or in which good conditions for sensitive objects are sought.
- Drying-out the building before and after handover, particularly if it is new, if new floors and walls have been built in concrete and masonry, or if wet objects or materials such as pallets have been brought in.

- Removing volatile chemicals introduced during construction, decoration, and in fittings and furnishings, and from stored materials which release pollutants badly.
- Removing unwanted heat, particularly in hot and sunny weather, or in well-insulated stores during periods of intense occupation, for example when loading-up.

Useful ventilation systems include:

- Fine capacity humidifiers and dehumidifiers for minimum fresh air requirements. It is easier to seal a room or building up tightly and to adjust ventilators as required, than to build less carefully and to hope things come out right.
- Automatically controlled fans or natural ventilators for more substantial or variable needs.
- Ducted heating and air conditioning systems. These can also pressurise the building to reduce air infiltration. Windows and doors may also be used, but control can be difficult if the site is not regularly occupied, security may be compromised, and birds and insects may be admitted unless screens are fitted.

Air must circulate freely. Natural circulation will often suffice but forced circulation can improve the uniformity of temperature and RH distribution, and will often be needed in large or obstructed spaces, particularly where heat sources are localised or where humidifiers and dehumidifiers are used. Avoid ‘dead spots’, for example solid-backed shelves tight from floor to ceiling, with no air spaces above or below. Do not put shelves and objects tight against outside walls, especially if these are poorly insulated, owing to the risk of dampness and related decay problems. (see Section J), and keep objects and bottom shelves off the floor, particularly near outside walls.

(Notes to table opposite)

Note 1. Unsuitable, except possibly in well-ventilated loading bays.
Note 2. Unsuitable, except possibly for loading bays, carefully defined personnel areas in the main store. and stores for robust objects like industrial machinery.
Note 3. Like a light fitting with infra-red lamps. Red glow. Low maintenance. Useful for on-demand comfort heating points in stores and loading bays.
Note 4. For safety and economy, consider fitting timbers to allow say 30 minutes’ operation only.
Note 5. Air leaving these heaters can be very hot, which will dry any items in the air stream. Take care.
Note 6. Stratification (warm air at high level) is very likely, affecting items on upper shelves and mezzanines. Punkah fans may help to avoid this.
Note 7. Ducts normally at high level! The better systems tend to be more expensive as they need more ductwork, etc, to ensure good air circuit circulation.
Note 8. Existing systems may have used process steam or medium- or high-temperature hot water. This may no longer be available on site.
Note 9. Automatically destratified, may include induction nozzles, particularly useful in tall buildings. Fuelless, direct gas-fired systems unsuitable.
Note 10. Take care to avoid overheating items above and near radiators. Stratification can easily occur if emitters are too hot or concentrated at too few points.
Note 11. Economical to run but, expensive to install. Only for background heating unless store is very well insulated. Danger from floor damage and drilled holes.
### HEATING SYSTEMS COMMONLY FOUND IN INDUSTRIAL BUILDINGS (PLUS OTHERS OF INTEREST)

**SEE ALSO REFERENCE [5]**

<table>
<thead>
<tr>
<th>Type of Equipment Description</th>
<th>Details</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A1. Gas-fired radiant plaque.</strong></td>
<td>Wall mounted or suspended.</td>
<td></td>
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<td></td>
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<tr>
<td><strong>A2. Gas-fired radiant tube.</strong></td>
<td>Ditto but flue gases are released</td>
<td></td>
<td>Very fast response, compact.</td>
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<td><strong>A3. Electric quartz lamp heater.</strong></td>
<td>Wall mounted or suspended.</td>
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<td>Fast responding, black heat.</td>
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<tr>
<td><strong>A4. Electric bar heater.</strong></td>
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</tr>
<tr>
<td><strong>A5. Electric radiant strip.</strong></td>
<td>Wall mounted or suspended.</td>
<td></td>
<td>Fast responding, black heat.</td>
<td></td>
</tr>
</tbody>
</table>

**B. Warm Air Unit Heaters**

| **B1. Gas or oil-fired unit heater.** | Wall mounted or suspended. | Out of the way. | Fewer needed than Type B1. | Difficult to maintain. Flue needed. |
| **B2. Gas or oil-fired unit heater.** | Floor standing with flue. | All types. | | |
| **B3. Unit heater with hot water heater coil.** | Wall mounted or suspended. | | | |

**C. Ducted Warm Air Systems**

| **C1. Low velocity.** | Heat exchanger in AHU. | Potentially good. | Boiler required. | See Note 7. |
| **C2. Low velocity.** | Oil or gas fired units. | Various heat sources. | No boiler needed. | See Note 8. |
| **C3. High velocity.** | | | Saves ductwork. | Type C1 usually preferable. |

**D. Hot Water Systems**

| **D1. Radiant strips and panels.** | Normally ceiling mounted. | Out of the way. | Can overheat items at high level. | |
| **D2. Radiators and convectors.** | Normally at perimeter. | Widely understood system. | Can get in the way. | |
| **D3. Underfloor heating.** | Pipes embedded in concrete. | Uniform, gentle heat. | Items need to be kept off floor. | |

**E. Other Electric Systems**

| **E1. Off-peak electric underfloor.** | Cables embedded in concrete. | Uniform, gentle heat. | Items need to be kept off floor. | Best for background heating. |

---

**Figure 1: GAS FIRED RADIANT PLACQUE**

**Figure 2: GAS OR OIL UNIT: WALL MOUNTED OR SUSPENDED**

**Figure 3: DUCTED WARM AIR: LOW VELOCITY**

**Figure 4: DUCTED WARM AIR: HIGH VELOCITY**

**Figure 5: ELECTRIC QUARTZ LAMP HEATER**

**Figure 6: ELECTRIC BAR HEATER**

**Figure 7: ELECTRIC RADIANT STRIP**

**Figure 8: RADIATOR STRIPS AND PANELS**

**Figure 9: OFF PEAK STORAGE: WARM AIR**
Control Devices

Controls are a complex subject, often taken too much for granted until the building is occupied, when it is usually much more difficult to put them right.

Controls need to do four main things:

- Operate systems safely to minimise risks of accident, breakdown, fire, etc.
- Provide the necessary control, alarm and monitoring to suit the stored items.
- Allow systems to operate economically.
- Let users know what is happening and intervene to the extent desirable.

Unfortunately:

- Designers may make false assumptions about how the building and its services will be operated, making controls difficult to understand or to use.
- Occupiers often think that the controls they need will automatically come with the equipment. Often one will need remote items such as humidistats, plus overlaid controls to unify all parts of a system within an overall strategy.
- The need to commission, maintain, check and re-calibrate controls is often overlooked.

Appropriate solutions will only emerge from careful discussions between the occupier, the designer and the supplier. Sensor positions need to be carefully considered. Take nothing for granted.

Air Conditioning

Strictly speaking, an air conditioning system should be able to:

- introduce outside air;
- circulate internal air;
- provide filtration to the level required;
- control air temperature within a specified band, by heating and cooling;
- provide humidity control within a specified band, by both humidification and dehumidification.

Colloquially, however, the term is used for systems which do only some of these things, resulting in misunderstandings and under-or over specification. For example, building occupants often call any central ducted ventilation system air-conditioning, while many packaged room ‘air-conditioners’ provide air circulation, cooling, and rudimentary filtration only, and may dehumidify when cooling whether you want it or not.

Make sure that your advisers know what you want and that you understand what you are being offered. When you visit other buildings of interest try to find out exactly what equipment they have got, and how it is actually controlled.

A general outline of air-conditioning can be found in reference [36], while [3] gives more information on principles and applications for museums, including filtration for both particulates and chemicals. In most stores in industrial buildings, air-conditioning will be restricted to packaged units in inner rooms for sensitive items only.

Close control units (as often used in computer rooms) provide the full range of temperature and humidity control functions in one package. However, since these are relatively expensive, often only the components necessary to avoid the worst problems are chosen. For example, items which need to be kept cool and dry might have a cooling-only room air-conditioner set to a maximum temperature of say 16°C and a dehumidifier set to 40% RH maximum.

If the main store requires some form of air conditioning, a central ducted system will normally be chosen, incorporating the features required. Its fans will normally operate continuously and can use a lot of electricity in the course of the year. It is therefore important for them and the associated plant to be efficient and to handle no more air at a pressure no higher than strictly necessary.

Boiler plant (where fitted)

Museum stores often require heat for long hours but in relatively small quantities, which makes it important that the boiler plant is efficient at a small proportion of the design load. ‘Condensing’ gas and oil boilers (see references [17] and [35]) although relatively expensive, should be seriously considered because they are not only highly efficient but they retain this efficiency over most of their load range. In multi-boiler installations, boilers should be sequenced, so that ones not required are not only switched-off but valved-off and can cool down. At the very least the lead boiler (which runs for the most time) should be condensing.

Humidification

Excess moisture can be removed from the air in two main ways:

1. Condensing it on a cooled coil in an air-handling unit (AHU) or a refrigerant-based package dehumidifier. These units do not work well in unheated stores - their efficiency drops in cold air and the coils can freeze.

   The cool dehumidified air will then need reheating - self-contained units have a second coil which re-injects the heat extracted plus heat from the compressor, into the leaving air stream. The extra heat can be useful, but in well-insulated stores, enclosed rooms, and in summer, the store may get too hot. Remember to provide drains for the condensate; it is not convenient or safe to be forever emptying buckets.

2. Absorbing it into silica gel or a similar insoluble material, supported on a drum honeycomb which rotates slowly, carrying it between the store air and a regenerating warm air stream. Avoid absorbents such as lithium chloride: these have sometimes been released into the air when the equipment went wrong and coated items in the store with hygroscopic salts.

Humidification

If humidifiers are required, and although there are many types to choose from, electrode boiler units may often be appropriate, as they produce sterile steam without chemical or biological contaminants. For fine control, variable output units are preferable. Humidifier breakdown can be very damaging: add safety humidistats which can shut down the system and sound the alarm.

These are particularly useful for unheated museum stores because they work better at low temperatures and have less heating effect (though this depends on model). Electric regeneration heating is convenient in small rooms, but gas is much cheaper and is preferable for larger units. Remember to provide ducts to the outside for the regenerating air.
The Choice

Exeter City Museum sought advice under the Department of Industry's Energy Design Advice Scheme (EDAS) on the choice between two portal-framed 'sheds'.

Building A. A recently completed free-standing steel-framed industrial unit with lightweight insulated cladding, 14 m wide, 27 m long and 5 m to the eaves.

Building B. A 1960s heavyweight concrete industrial unit in the middle of a terrace of similar units which shared thick blockwork party walls. This was 45 m long, 18 m wide and 7 m to eaves.

Building A is a typical modern Advance Factory Unit (AFU). Developers and government agencies build AFUs speculatively to suit a wide range of light industrial, service and warehousing activities. However, if the tenant is known before construction (a so-called 'pre-let'), the developer may be prepared to change the specification to meet their requirements, although the external dimensions, structural system and cladding materials will tend to be fixed.

The Stems to be Stored

Many museums seeking storage in industrial buildings have a relatively high proportion of heavy, bulky and robust items (see Section E). At Exeter, however, much of the material is light and relatively sensitive, including biological, mineral, textile and ethnographic collections as well as bulk archaeological. For reasons of management, environmental stability, security and fire safety, the different collections and material types would need to be kept in separate containers within the main store.

Site inspections of Buildings A and B

Although new, Building As thermal characteristics were disappointing. Walls and roof had theoretical U-values of 0.45 (see Section H), but being lightweight they lacked thermal stability; they also had 'cold bridges' (see Section G). The doors were uninsulated and they and the walls were also far from airtight. Its large rooflight area (12%) admitted excessive amounts of daylight, sunlight and solar heat and significantly reduced its thermal stability. It was also not big enough to accommodate everything under one roof, even with a mezzanine over much of its area. The portal frames would also slightly restrict headroom in the mezzanine near the eaves.

Building B was less well-insulated, with no wall insulation and a roof U-value of about 0.8 W/m²K. Its vehicle doors were even less airtight and it had a large glazed gable at the north end. On the other hand, Building B benefited in thermal stability from its massive wall construction and by being sheltered by its neighbours in the terrace, and this made it thermally more stable than Building A. If the redundant rear (south) vehicle door was bricked-up and a new wall built inside to create a loading bay, workshop and office area at the north end, then the building could potentially work well.

Conclusions

With the shortcomings in Building A, a pre-let (also available at the same 1995 rental level of about 4/ft² per year) was preferred. This could be larger, with better insulation, few rooflights, insulated doors, and attention to detail in design and on site to reduce air infiltration and cold bridges. The wall's inner leaf could also be of blockwork, improving thermal stability.

If Building B proved to be structurally sound, however, then it had advantages:
- immediately available
- a lower rental level (3/ft² or less), in spite of its greater height
- a better location
- a high floor loading.

Building B could serve effectively as an outer shell to protect a two-storey terrace of containers built inside and housing the sensitive items: this would assist environmental control, security and fire protection.

The diagram below shows how effective containers can be in stabilising the environment: suitable insulated blockwork containers would be ideal, provided that time could be allowed for them to dry out before occupation. If conservation heating were applied to the outer envelope, then for many of the containers it was likely that the amount of fine-tuning necessary would be small, and could normally be achieved simply by means of low-powered heaters and/or dehumidifiers.

The principles adopted were, however, applicable to a wide range of buildings. It was therefore recommended that other suitable buildings, better located for public access, should be considered before making a final decision.

The EDAS study has now been incorporated into the Museums Service Storage Plan.
These checklists, which are not comprehensive, pick up issues which had repeatedly caused difficulties in projects reviewed while the Guide was prepared.

### Organisational Checklist

**AT INCEPTION**
- Make sure you have an effective team, with designated individuals responsible for co-ordination on both the client side and the design side, and with the conservator fully involved throughout.
- Visit similar buildings as a team in order to aid decisions and to share ideas.

**BRIEFING STAGE**
- Consult the full range of users.
- Decide performance requirements.
- Identify containers/equipment needed.
- Think hard about future changes, including changing your mind.

**BUILDING SELECTION**
- Is the location convenient and secure?
- Will staff be happy to go there?
- Is there enough scope for adaptation and extension?
- Is the rent too high? Check local agents' knowledge and comparable buildings.
- Are there associated commitments?
- Will alterations change rent/rate levels?

**DESIGN AND CONSTRUCTION**

**Design stage**
- Don't leave it all to the design team: review designs regularly. Check plans, dimensions and technical proposals.
- Check flows of people and goods.
- Review security: reception, guarding circulation, views, surveillance.
- Visitor numbers may grow: is there sufficient provision?
- Prepare lists of critical items (eg sealing hidden joints) which need to be checked and signed off as built.

**During construction - check:**
- Junctions: are they properly sealed?
- Surfaces: are they smooth and clean?
- Openings: are they secure and airtight?
- Switches/controls: are they convenient?
- Prioritise carefully if budgets are cut.

**BEFORE HANDOVER ASK FOR:**
- Plans and specifications, including services, structure and drainage, with as-fitted (not design) drawings.
- Instructions for all equipment.
- Records of tests for all systems.
- Addresses of suppliers.
- Operating and maintenance instructions.
- Briefing in the maintenance and use of the building and its equipment

**Do not accept the building until you are sure you have got what you asked for and the contract required.**

<table>
<thead>
<tr>
<th>Technical Checklist</th>
<th>Storage Checklist</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FLOORS</strong></td>
<td>Don't pay to store air. If possible work out from the objects to be stored. Aisles too wide? Consider mobile racking or different access equipment. Do you have space for unused furniture and containers? Unless they fold or nest, empty containers and pallets take as much room as full ones.</td>
</tr>
<tr>
<td>Insufficient loadbearing capacity. Is reinforcement, consolidation or segregation of heavy items required? Uneven. Consider levelling and consolidation, particularly for mobile racking, trolleys and fork lift trucks. Dusty. Often a problem with concrete. Consider tough paints or consolidants, coloured to check coverage. Damp. Reconstruct.</td>
<td>MEZZANINES: TAKE CARE</td>
</tr>
<tr>
<td>Condensation and damp. Rising and from roofs, valley gutters, downpipes and unsuitable water and heating pipes. Cold bridges and exposed corners. Lightweight construction at low level vulnerable to cutters and ram raiding. Headroom restrictions. By structure, suspended lights and trunking. Think carefully when planning. Is the insulation effective? If necessary check by infra-red survey.</td>
<td>Beams too low. Ultimately you are nearly always going to want to put mezzanines in any area with enough height. Think carefully when selecting and planning buildings. Access poor. Provide easy stairs. Consider hinged sections of guard rail with paddocks, for fork lift access. Floors don't line up. Have a strategic plan. Where possible adopt a suitable common level. Not strong enough. People will ultimately want to use all available flat surfaces over offices, etc. Make them strong enough and avoid obstructions by electrical cables, etc. Not stable enough. Vibrations transmitted from walkers and trolleys.</td>
</tr>
<tr>
<td><strong>ROOFS AND WALLS</strong></td>
<td></td>
</tr>
<tr>
<td><strong>UNWANTED AIR LEAKAGE</strong></td>
<td></td>
</tr>
<tr>
<td><strong>ROOFLIGHTS AND WINDOWS</strong></td>
<td></td>
</tr>
<tr>
<td>Safe and secure? Damage by light or solar heat? Block-up or consider blinds or shutters. Avoid condensation if retained.</td>
<td></td>
</tr>
<tr>
<td><strong>LOADING BAYS</strong></td>
<td></td>
</tr>
<tr>
<td>Unlubricated or absent. Will air leakage, exhaust fumes and access of pests be tolerable? Security measures when open?</td>
<td></td>
</tr>
<tr>
<td><strong>BUILDING SERVICES</strong></td>
<td></td>
</tr>
<tr>
<td>Poor light switching. Consider how the store will be used and how to avoid lights on unnecessarily. Existing heating inappropriate. It often will be. Don't be too optimistic. Inadequate mains supplies. Check availability and capacity. Inadequate drainage.</td>
<td></td>
</tr>
<tr>
<td><strong>SECURITY</strong></td>
<td></td>
</tr>
<tr>
<td>see reference [18]. Poor area. Unsafe for staff and visitors? Poor physical security. Too far from police and fire stations? Difficult to supervise access. People, vehicles and all entrances need watching. Are there places to hide? Insufficient segregation of staff and visitors. Consider relationships early on. Expect visitor numbers to grow over the years.</td>
<td></td>
</tr>
</tbody>
</table>

### Points to Remember: Four Checklists

**Move-In and Occupancy Checklist**

Remember drying-out
- This may take months; even with careful management. Unwanted moisture is particularly troublesome if the building is completed in the autumn or winter.

Plan the move
- Have time and facilities been allowed for:
  - Sorting, cataloguing, decontaminating and re-packing material as it arrives.
  - Have you enough racks, pallets, containers and handling equipment, and space to put them?
  - Avoid multiple handling of items.
  - Document the whole process.

During occupancy
- Have a manual for managing the store.
- Have one person responsible for the building who can keep an overview.
- Make regular inspections.
- Monitor the internal environment [20, chapter 5]. Consider remote monitoring and alarms if unmanned.
- Keep statistics and records up to date.
- Set energy targets and review consumption regularly [31, 32].
- Undertake maintenance and where possible upgrade as you maintain.

Do you understand the building?
- Be briefed by the designers.
- Obtain record drawings and operation and maintenance manuals.
- Witness acceptance tests of the services.
- Arrange suitable training.
References

11. J. Ashley-Smith, N. Umney and D. Ford, Let’s be Honest - Realistic Environmental Parameters for Loaned Objects, IIC Ottawa Congress preprints, 28–38 (September, 1994).
25. F. Howie (ed), Safety in Museums and Galleries (Butterworth, 1987).
47. Best Practice Programme, Introduction to Energy Efficiency in Factories and Warehouses (EEO, 1994).
* References marked with an asterisk are available free of charge from BRECSU, BRE, Garston, Watford WD2 7JR, Telephone: 01923 664258.
Although some of these publications are specialised and/or expensive, somebody on your team could well have the one you want already. For example, many conservators will have [3], architects [15] [16] and [22] and building services engineers, the CIBSE publications.
Sources of Advice and Other Information

British Museum Materials Testing Service
Conservation Research Section
The British Museum
London WC1B 3DG
Tel: 0171-636-1555

BRE (Building Research Establishment)
Bucknalls Lane
Garston
Watford
WD2 7JR
Tel: 01923-894040

BSRIA (Building Services Research and Information Association)
Old Bracknell Lane West
Bracknell
Berkshire RG12 4AH
Tel: 01344-426511

CIBSE (Chartered Institution of Building Services Engineers)
Delta House
222 Balham High Road
London SW12 9BS
Tel: 0181-675-5211

CIRIA (Construction Industry Research and Information Association)
6 Storey's Gate
Westminster
London SW1P 3AU
Tel: 0171-222-8841

EDAS (Energy Design Advice Scheme)
The Bartlett Graduate School
Philips House
University College London
Gower Street
London WC1E 6BT
Tel: 0171-916-3891

University of Ulster
at Jordanstown
Newtownabbey BT37 0QB
Northern Ireland
Tel: 01232-365131

Royal Incorporation of Architects in Scotland
15 Rutland Square

Edinburgh EH1 2BE
Scotland
Tel: 0131-2297205

The University of Sheffield
PO Box 595
Floor 13, The Arts Tower
Sheffield S10 2UJ
Tel: 0114-2768555

EEO (Energy Efficiency Office)
2 Marsham Street
London SW1P 3EB
Tel: 0171-276-3000

Museums & Galleries Commission
16 Queen Anne's Gate
London SW1H 9AA

Area Museum Council for the South West
(Avon, Cornwall, Devon, Dorset, Glos, Somerset, Wilt, Isles of Scilly)
Hestercombe House
Cheddar Fitzpaine
Taunton TA2 8LQ
Tel: 01823-259696

Ferroners House
Bath Lane
Leeds LS12 5HA
Tel: 0113-2638909

Council of Museums in Wales
The Courtyard
Letty Street
Cardiff CF2 4EL
Tel: 01222-225432

West Midlands Area Museum Service
(Hereford & Wals, Shropshire, Staffs, Warwick)
Hanbury Road
Stoke Prior
Bromsgrove B60 4AD
Tel: 01527-872258

East Midlands Museums Service
(Derby, Leics, Lines, Northants, Notts)
Courtyard Buildings
Wollaton Park
Nottingham NG8 2AE
Tel: 01602-854534

Northern Ireland Museums Council
185 Stranmillis Road
Belfast BT9 5DU
Northern Ireland
Tel: 01232-661023

North West Museums Service
(Cumbria, Merseyside, Isle of Man)
Griffin Lodge
Cavendish Place
Blackburn BB2 2PN
Tel: 01254-670211

Yorkshire and Humberside Museums Council
(North & South Yorks, Humbers)
Farnley Hall
Hall Lane
Leeds LS12 5HA
Tel: 0113-2638909

North of England Museums Service
(Cleveland, Durham, Northumberland, Tyne & Wear)
House of Recovery
Bath Lane
Newcastle upon Tyne NE4 5SQ
Tel: 0191-2221661

Scottish Museums Council
County House
20-22 Torphichen Street
Edinburgh EH3 8JB
Scotland
Tel: 0131-2297465

RIBA (Royal Institute of British Architects)
66 Portland Place
London W1N 4AD
Tel: 0171-580-5533

The Royal Institution of Chartered Surveyors
12 Great George Street
London SW1P 3AD
Tel: 0171-222-7000
MUSEUM COLLECTIONS IN INDUSTRIAL BUILDINGS
A selection and adaptation guide

Many outstanding museums occupy prime sites in city centres. Museum managements wish to maximise the potential they have to attract visitors by offering better public facilities. However, space within museum buildings is often in great demand. A recent alternative is to seek accommodation off-site for reserve collections and other behind-the-scene activities. This provides the opportunity to re-house reserve collections in accessible, environmentally stable, safe and secure conditions.

The use of modern or old warehouses, often located on industrial sites, is attractive because of the perception that they are readily available and cheap to acquire. This may be so, but what does it take to make them accessible, environmentally stable, safe and secure?

The Museums & Galleries Commission's Museum Collections in Industrial Buildings: A selection and adaptation guide brings together strategic and practical advice to such projects. Using a series of two-page spreads to contain different types of information, the publication is designed as a planning tool both for museums seeking to develop off-site facilities and building consultants looking for advice on the housing needs of museum collections.

"The aims and objectives of this document are admirable. That there is a need for such information can be confirmed by our experiences in assessing potential buildings and developing a brief for the housing of the RIBAs Special Collections'.
(Dr Frank Duffy, PP RIBA.)

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