9. MATERIALS SELECTION FOR DURABILITY

Museum curators, conservators and managers are rightly concerned with the preservation of museum objects. However, often not much attention is paid to the durability of the museum fabric. The degradation of the fabric may affect the operation of the museum in a number of ways including:

- necessitating costly repairs;
- breakdown in the function of the building, including leaking roofs; and
- degrading materials can give off organic or inorganic contaminants, which then affect the air quality of the museum.

For these reasons it is useful for museum staff to have a basic understanding of materials degradation and its relation to building design and climate.

9.1. Basic Mechanisms of Degradation

In Table 9.1. the most common degradation mechanisms affecting common building materials are given, as well as the susceptibility to various degradation agents. It is necessary to differentiate the mechanisms on the basis of location (inside or outside the building), as materials will be exposed to different degradation patterns depending on the extent of exposure.

Table 9.1. Degradation mechanisms and environmental factors.

Material	Position	Degradation mechanism	Environmental Factors							
			Temperature	Salt	Condensation	RH	Wetness	Biological agents	Pollution	UV
Metal	Exterior cladding	Corrosion	Moderate	Strong	moderate	Strong	Strong	None	Strong	Low
Coated metal	Exterior cladding	Corrosion	Strong	Strong	Moderate	Strong	Strong	None	Strong	Strong
Bricks	Exterior cladding	Weathering/salt attack	Weak	Strong	Moderate	Strong	Strong	Low	Moderate	Low
Concrete	Exterior cladding	Salt attack, freeze/thaw, AAR	Weak	Strong	Weak	Weak	Strong	None	Strong	Low
Tiles	Roof cladding	Salt attack/ fungal growth	Weak	Strong	Weak	Weak	Moderate	Moderate	Strong	Weak
Stone	Exterior cladding	Salt attack/ chemical dissolution	Weak	Strong	Weak	Weak	Moderate	Moderate	Strong	Weak
Adhesives	Exterior cladding	Water penetration, photo-oxidative degradation	Strong	Weak	Moderate	Strong	Strong	None	Moderate	UV
Glass	Exterior cladding		Strong	Weak	Weak	Weak	Weak	None	Moderate	Moderate
Timber	Exterior	Termites/ fungal attack corrosion of fasteners	Low	Low	Low	Moderate	Strong	Strong	Low	Moderate
Paint	Exterior	Chalking	Low	Low	Moderate	High	Moderate	Low	Low	High
Plastic	Exterior	Photo-oxidation	Strong	Weak	Weak	Weak	Moderate		Strong	Strong
Polyester-resins	Exterior	Yellowing	Strong	Low	Low	Low	Strong	None	None	Strong
Metal	Building envelope	Corrosion	Weak	Moderate	Strong	Moderate	Strong		Moderate	None
Timber composites	Building envelope	Hydrolysis of adhesive - internal bond failure	Strong	None	Low	Strong	Strong	Low	Low	Low
Timber	Building envelope	Termites/ fungal attack corrosion of fasteners	Low	Low	Moderate	Moderate	Strong	Strong	Low	Low

The degradation of some individual groups of materials is described below.

9.1.1. Plastics

Plastics must resist photo-oxidation, moisture effects and temperature ageing. Photo-oxidation is primarily promoted by UV irradiance. However, temperature and relative humidity (ie. higher degradation at higher temperature and RH) also influence the rate of degradation. The greatest hazard for polymer degradation occurs across all northern and tropical Australia with a particular hazard in the north west region of the country.

9.1.2. Metals and metal components

The life span of metals is limited by corrosion that is controlled primarily by pollutant level (including sea salt) and time of wetness for bare and metallic coated components. The same, plus UV irradiance applies for metals coated with a paint system. The highest hazard levels are found in the southern part of the continent where relatively high relative humidities (RH) occur combined with significant salt production by the southern ocean and distributed across southern Western Australia, parts of south Australia, Victoria and Tasmania by prevailing westerly winds. The hazard for painted metal is a combination of the UV hazard and corrosion hazard. It is also necessary to take into account a local hazard, in particular, industrial activity or sources of airborne salinity (e.g. surf beaches).

9.1.3. Masonry

The most common form of deterioration of masonry units (bricks) and mortar beds is salt attack, although they may be susceptible to freeze/thaw attack in cold climates (highland areas in southern Australia) and to erosion. Under severe conditions, prolonged wetness and wet/dry cycles may also promote deterioration by assisting salt attack. Masonry units are also subject to moisture-induced expansion and efflorescence. The former may promote cracking and the latter decrease the aesthetics of the structure.

9.1.4. Concrete

Concrete may suffer from alkali-aggregate reactions and freeze/thaw effects. Iron reinforcement in concrete may corrode with the rate of corrosion being controlled by state of carbonation, oxygen availability, wetness and presence of salts and pollutants.

9.1.5. Timber

Any timber component in a house structural, architectural, cabinets and furniture, may be subject to insect attack (termites, lyctids and furniture beetles section 3.5) and fungal attack (section 3.2). Timber in exposed situations may also be subjected to weathering, chemical degradation or deterioration around corroding metal.

Timber types are assigned a ‘Natural Durability’ rating which refers to the durability of the heartwood of the timber with respect to resistance to decay and termite attack in an in-ground location. Class 1 timbers are highly durable and include grey ironbark, forest red gum and Cypress pine, while Class 2 or durable timbers include jarrah, spotted gum and blackbutt. Class 3 timbers are moderately durable and include messmate and rose gum whilst Class 4 timbers are non-durable and include Radiata pine, Douglas fir and slash pine.

9.2. Environment classification for durability

Durability scientists refer to macro, local and microclimates. The macro is on the scale of a climate zone (e.g. tropical or sub-tropical), local being the immediate few streets around a building, and micro being actually adjacent to the components.

Some local effects such as the severe marine, marine, severe industrial and industrial environments are defined in Australian Standards. Other local effects are less well defined. Local effects predominantly influence climate and wind patterns. Wind in turn may carry rain (wind driven rain), human made pollutants (sulphur oxides, nitrogen oxides) and natural aerosols (sea salt/dust etc) and pollutants. Local effects can cause significant variations in degradation between buildings located in relatively close proximity. For example, it is well established that the corrosion rate adjacent to surf beaches is very high due to the corrosive effect of marine aerosol. Breaking waves give rise to a fine salt rich aerosol, which is then carried by winds across the land. On clear flat land it is found that airborne salinity decreases in an exponential manner with distance from the coast.

However, it has been observed that in urban areas or in forests the airborne salinity below the roof top of houses or canopy of trees is much lower than in the case of open terrain. Furthermore, rather than the salinity decreasing in an exponential manner, its decease is abrupt at the first few layers of houses or trees. What in fact happens is that the aerosol is deposited on the obstacles and then depleted to the height of the obstacles. Aerosol from above this height gradually settles down but this is a slow process. This effect thus leads to very high corrosion rates on houses facing surf beaches and surprisingly low corrosion rates for houses (in built up areas) behind the first two or three rows of houses. This effect also occurs for dust particles. If a cultural building is positioned in a zone where there is likely to be significant airborne matter the impact on the building can be reduced by planting trees or building other barriers to trap such matter.

The environment can be altered on the micro-level even more than on the local. Some of the ways the micro-environment can alter the magnitude of the degradation parameters are defined below:

- *Shading* In the context of material durability, shading of external walls is important to reduce heating of walls. The additional heating effect of direct sun on a dark vertical surface may be 20°C or more, in comparison to the ambient air temperature. It is also important in order to reduce the effect of wind driven rain. Shading to reduce the effect of UV follows the same principles as that to reduce the heating of sunlight.

- *Airflow* External flow patterns are important in that they can channel wind driven rain, pollutants and particles onto the building facade. Use of barriers as discussed above can reduce these effects. The deposition of air transported species on a facade is rarely uniform, rather deposition commonly occurs where the building form promotes an abrupt change in air speed or direction. Airflow within the building envelope is also vital. The building functions as a whole and often air from the sub-floor may flow up the wall cavities into the roof space. This can be beneficial in terms of reducing temperature and humidity variations, although in some circumstances, it may promote condensation.

- *Ventilation* The role of ventilation is complex with regard to microclimate and durability. Ventilation into spaces with a moisture source can be extremely beneficial as it exchanges the relatively dry external air for the moist building space air. This is particularly the case for sub-floors where moist soil provides a continuous moisture source, and ventilation is mandated to control sub-floor conditions. On the other hand, ventilation can sometimes raise the RH if the building space is at a lower RH, or it can promote condensation if significant temperature gradients exist.

- *Condensation* It can occur when there are significant temperature or humidity gradients across the building fabric.

- *Soil moisture/drainage* As described above, a classic example of a moisture source in poorly ventilated building spaces, is a sub-floor above moist soil. A number of actions can be taken, including ensuring good ventilation, ensuring that there is good drainage away from the sub-floor or providing a vapour barrier on the soil to prevent moisture entering the sub-floor.

- *Building practice* Unfortunately, the microclimate in a building is often the result of bad practice, absence or failure of damp courses or water-proof membranes, etc.

- *Solar effects* Radiative heating and cooling may have pronounced effects on the microclimate. The classic example is the metal roof which reaches high temperatures during the day as it absorbs radiative energy, but then radiates heat during cloudless nights to cool well below ambient. As well as exaggerated mechanical movements in the material and its fixage, the conditions underneath the roof sheeting show a very wide variation in both RH and temperature, with condensation on the underside of the sheeting being common.

- *Food sources* It is well established that termites are more prevalent in buildings where there are external food sources for the termites. Such food sources may include dead trees, unprotected cut timber etc.

Having analysed the environment that a component is subjected to, the challenge is to select a material that is suitable for that environment.

There are a number of standards and guidance documents that give materials a resistance rating which is then matched to the hazard level of the environment, or alternatively give a list of suitable materials for a given environment hazard.

10. ENVIRONMENTAL CONTROL OF DISPLAY CASES AND STORAGE AREAS

If it is possible to control the museum environment at the building or room level, then conditioning of display areas and cases, and of storage areas is not critical. However, as will be more common in most museums, it may not be possible to achieve adequate control of T, RH and air pollution in particular, and therefore it is necessary to use display cases and storage rooms and containers as a secondary level of environmental control (see also section 7.1.3.). Objects which are on open display in the museum, will obviously be subject to effects of the environment, however, it is possible to provide better control for objects which can be enclosed.

10.1. Control of display cases

Similar to the proposals for providing a stable environment for a museum building using passive means, it is necessary to control the T, RH, illumination and UV levels, air pollutants and pests inside a display case. However, the first step is to determine the type of display case, in particular the materials of construction and how air tight it is. Due to problems of availability of materials and quality control in constructing display cases for museums, it must be assumed that display cases will be somewhat ‘leaky’, and therefore the following advice concentrates on leaky display cases rather than perfectly sealed ones.

10.1.1. T and RH

The location of display cases within the museum is important. If these are free standing then air in the room will tend to provide a first level of environmental control, which will be made even more stable by the fact that the case is closed. However, if cases are against walls, then care is required as the cases may be heated or cooled depending on the solar gain of the wall. Changes in temperature of the wall will be conducted to the case causing corresponding changes in RH. If on a wall away from the sun, it could be cool enough to increase the RH behind or inside the rear wall of the case causing condensation, and increasing the potential for mould growth. For such cases an air gap or insulation is necessary to avoid these problems.

If there are large air gaps in the display case then the internal T and RH will be similar to the levels in the room. If these are acceptable then no further control of the case environment is required. If control is required, then the first step is to make the case as air tight as possible, using inert silicone sealant materials to seal the gaps. Do not use rubber seals (section 3.4. and 9.1.1.).

The RH changes in the ‘sealed’ case will be determined to a large extent by the local temperature changes. This means that direct sunlight must never be allowed to fall on a case, and any artificial illumination must be external and far enough away not to heat up the contents of the case. A stable temperature will ensure a stable RH, and even if this is too high, or too low, it can be controlled locally.

This is possible with the use of buffering materials which act in a similar fashion to organic materials. As discussed in section 7.1.2.5. (on RH control), organic materials take in moisture as the RH increases and release moisture as the RH decreases, levelling out the RH fluctuations. Instead of using the objects inside the case to provide this buffering effect - as if too severe it may damage the object in the process of buffering the RH, materials such as silica gel and activated charcoal are now commonly used in museums. Both work by adsorption, and adsorb and desorb moisture in opposition to changes in RH. Whereas silica gel can only adsorb water, activated charcoal has the added benefit of being able to remove air pollutants such as the oxidising gases of sulphur and nitrogen oxides, and ozone (section 7.2.1.).

Silica gel is not only a desiccant, but can be conditioned to a set RH by holding it at this RH for as long as possible, at least two weeks. It has been found from theory and practice, that about 20kg of conditioned silica gel will be required to control the RH inside a display case of one cubic metre capacity, but this does require the case to be sealed. A leaky case will require much more silica gel, and therefore if too leaky the use of silica gel may be a waste of time. There are more efficient forms of moisture control based on silica gel such as ‘Artsorb’ and ‘Arten Gel’.

If silica gel is used to control the RH inside a display case then continuous or at least regular monitoring of the case environment is required to determine if the RH is being controlled effectively. No sorbing material is 100 per cent efficient as it takes in and releases moisture, and after time (depending on the rate and magnitude of the RH fluctuations), the silica gel will need to be reconditioned. Display cases will have to be specially designed to accommodate the silica gel, normally as a tray or drawer built into the bottom of the case which is easy to remove for reconditioning. The trays or access ports will also require good seals. The silica gel which comes in the form of granules, should be laid out as thinly as possible and not more than 2-3cm deep. ‘Artsorb’ is also available in the form of cartridges and felt, which can be placed within the case.

The RH can also be buffered by the use of organic materials, in particular cotton. Such materials must be stable, eg using undyed cotton which has not been treated with chemicals such as fire retardants which, can release harmful vapours within the case.

A traditional means of controlling mould growth in cupboards in tropical countries is to use a low intensity heat source, such as a low wattage incandescent light bulb. This is located at the bottom of the case (or cupboard) and the increase in temperature from the bulb lowers the RH sufficiently so that mould growth does not occur. This heat source also produces air movement by convection which is useful in preventing mould growth. If this system is used in a display case then it must be vented to allow air flow through the case. Care must also be taken that the increase in air temperature does not cause other problems. Although a common practice in storage cupboards for clothes it is not widely used in museums.

10.1.2. Light

As discussed in section 3.3. it is necessary to control both the illumination (lux) and UV radiation (µwatt/m^2) levels in the museum gallery and also that falling on the displays in cases. The recommended levels of illumination and UV (section 4.2.) will apply, as will their methods of control. Remember in general, incandescent lights produce heat but low levels of UV, whereas fluorescent lights are cool but unless covered by perspex diffusers, give out high levels of UV.

It is preferable to have any light source outside the display case, as if inside it can cause a rise in temperature, and corresponding fall in RH when the light is switched on and off. This of course depends on the type of light source with incandescent producing more heat than fluorescent. Other problems using internal light sources are that it becomes more difficult to filter out UV radiation, and also to use the inverse square law to reduce illumination levels doubling the distance will quarter the illumination level. Note also, some insects are attracted to light, and many display cases can be seen containing the remains of dead insects. This is unsightly and requires cleaning, but more important the insects may have damaged the objects in the case. However, there are occasions where internal illumination of objects is required, and careful selection and design of the lighting system is necessary to produce the best effect but reduce risk of damage to the objects on display. For example, any lights should be at the top of the case with upright cases and at the side and top for table cases. The cases must also be vented to enable any heat build up to escape but screens must be in place to prevent entrance of pests.

With the use of clear UV absorbing filters it is possible to reduce the levels of UV at the display case level. If these are incorporated into the design of the case by using laminated glass containing a UV filter, or applying the UV filter to the glass, then UV levels can be controlled to the accepted levels. It is very difficult to achieve the same effect with illumination levels and heat from light sources, as the required filters will either alter the colour temperature within the case or darken the case. These factors should be controlled outside the case.

10.1.3. Air pollutants

Within a display case it is necessary to remove the air pollutants which come into the building and any pollutants produced by the materials of construction of the display case. With a well sealed case, the exterior pollutants should not be a problem, and materials of construction should be chosen or well sealed so as not to release harmful organic vapours. For leaky cases the air pollution problem can arise from both inside and outside the case.

Control of air pollutants in display cases may be achieved by one or all of:

(a) minimising access of air pollutants to display case interior by constructing a tightly-sealed unit;

(b) constructing the display case with low- or non-pollutant emitting materials (section 10.3.); and

(c) air cleaning of the interior of display case.

Experiments with a display case that was not tightly sealed showed that removal of pollutants with sorbents present was typically one order of magnitude faster than without sorbent. However, in general it is expected that the level of reduction by passive sorbents will depend on the relative levels of ventilation and surface area of sorbent presented to the display case interior.

Activated carbon (or charcoal) powder is the favoured absorber for pollutants. It is placed in a shallow tray or purchased in the form of cartridges or as fabric which can be used to line the interior of the case.

If wood or wood products (e.g. fibreboard) have to be used for constructing display cases, then from recent research there are procedures which can be carried out to lessen the emission of harmful gases which are normally formaldehyde, acetaldehyde, acetic and formic acids. It is necessary to seal the wood and prevent the organic gases from escaping into the atmosphere, and the best materials are barrier foils such as plastic or aluminium, which have to be applied to the wood surface and well sealed. However, as activated charcoal filters and barrier foils may be difficult to obtain in some places, then coating systems are a second alternative (section 7.2.1.2.). Here research has shown that the best coating systems are polyurethane lacquers, with varnishes and water-based systems not being very effective. It should also be noted that ventilation of the case can make some difference to the concentration of organic gases inside, but by itself is not sufficient to provide a pollution-free environment.

10.1.4. <u>Pests</u>

Pest control is much easier at the display case level compared with controlling a room or building. If cases are well sealed then few insects will enter, however, even with just a few minor cracks insects may get in, remembering that the case will be illuminated, even if from outside, which will attract some insects. Integrated Pest Management is required to control pests (section 7.2.3.1.), and if there is concern about insects then precautions are necessary, using baits and traps around the base of the case or inside the case, and placing insect screens over any gaps, noting that it is impossible to seal cases with sliding doors.

The problems of mould growth will be controlled if the RH is controlled (section 7.2.2.), and it is unlikely that large pests such as rats and mice will get into display cases as these should be excluded at the building or room level.

10.2. Control of storage areas

Storage rooms are probably the most important area of the museum, as the majority of museum objects spend most of their life in storage. In addition, objects may lie in storage for years without being inspected, which means that if they are in an adverse environment or attacked by insects, there can be serious damage occurring to the objects which is not observed until too late. It is, therefore, essential that storage areas provide a stable environment at appropriate levels of T and RH, free from air pollutants and pests.

If store rooms are only used for storage purposes (they should not be used as work areas), then staff enter infrequently and for a short time, so there should be little load on the environment from the presence of people and the use of lights. A few buildings in temperate climates have been especially constructed to provide passive environmental control for the contents, usually a library or archive, but as yet there have been few specifications for repositories for tropical climates.

As different materials, particularly organic and inorganic, prefer different levels of T and RH for long term preservation (section 4.1.), if possible objects should be sorted and stored according to material type. Then separate storage environments could be created. This may be possible, but it depends on the use of the collections, and especially the involvement of the collection manager and curator. A curator is more likely to want a collection from say an archaeological site or historic house kept together, rather than being split into material type. It also depends on the availability of funds and adequate storage space to provide different storage environments. If such environments are available, then care must be taken in transferring an object from one environment to another, as stresses may be caused to the object due to rapid changes in T and RH. In particular condensation must be avoided. For these reasons it is unlikely that small museums will be able to afford the luxury of different storage areas for different materials, and therefore the approach will be to provide a storage area which will reflect the general environmental requirements of the museum, but hopefully provide a more stable and safe environment.

Storage units, like display cases, must not be located against walls, especially if these are outside walls to the museum building. Adequate space is required between units to allow air movement if necessary.

The materials of construction of storage units and containers follow the same principles as for display cases (section 10.3.). They must not release harmful chemicals and if possible should be absorbent to help buffer the RH, and be of neutral pH (or alkali buffered if acidic materials are being stored). Wood must be sealed (section 7.2.1.2.) to prevent the release of organic vapours therefore wood cannot be used for its moisture buffering capacity. Metal is more dangerous than wood in the event of a fire, due to the 'oven effect', whereby the heat of the fire is rapidly conducted through the metal cabinets extending the effects of the fire. However, metal is normally preferred to wood as a material of construction, but is usually more expensive.

Close wrapping of objects in archival or acid free paper is common practice to provide a barrier against air pollutants, high light levels, insects and abrasion, and to also add to the RH buffering capacity of the storage system. Although useful for collections in most climates, it is not recommended for hot humid climates, as the wrapping materials will hold moisture creating a microclimate which may be higher than outside the container. Also insects are attracted to the starchy components of paper. On the other hand, the storage of organic materials (e.g. ethnographic collections) in plastic bags has been found to provide a very stable level of RH due to the buffering capacity of the material.

10.2.1. T and RH

In order to provide a stable level of T and RH in a store room, it is first necessary to have as stable an environment as possible in the museum building, and to avoid extremes of temperature on and in the room.

The location of the storage room is important, as if on an outside wall, then as with display cases, the solar gain on the wall will be conducted into the room, causing a corresponding change in RH. If a wall is comparatively cold, then there may be problems of condensation. It is therefore advisable to locate store rooms in a central position in the museum, to enable the surrounding rooms to provide an environmental buffer. If this is not possible then a room should be chosen which is protected against solar heating, but which will not have condensation problems. The use of basement areas for storage is quite common, and this is more likely in a hot dry climate where the thermal sink of the ground will provide a more stable temperature. This is more difficult in a hot humid climate where buildings are often raised off the ground to enable air to flow under the building. If ever underground storage is used, care must be taken that the room cannot be flooded by heavy rain or rising water, and that rising damp is not a problem.

Especially in hot humid climates where air movement is used to prevent mould growth (section 8.1.2.), it is usual to store objects on open shelves. Storage units should be located away from the walls, and there should be adequate space between storage units and also between shelves for air movement from. The units should be arranged parallel to this air flow so that the flow is not hindered by the shelves and their contents.

The use of conservation heating, whereby the air is heated or cooled to adjust the RH, has been tried in museum storage areas, with varying degrees of success. This system avoids the need for humidification and dehumidification, relying on heating the air to reduce the RH in a hot humid climate, and cooling the air to increase the RH in a hot dry climate. Obviously care must be taken that that any heating or cooling is gradual so as not to cause any sudden changes in RH.

Moisture absorbent objects will control the RH of the immediate environment if they are reasonably well sealed in boxes, which if of cardboard should be of archival quality material or be alkali buffered to neutralise any acidity present in the organic materials.

Library and archive materials are usually stored this way and often produce an acceptable environment in the store room. If plastic containers are used care must be taken that there are no sudden drops in temperature which might cause condensation. The plastics must also be inert (section 10.3.). An extension of this is to store objects in metal cabinets (wood if unsealed may release harmful vapours), or on open shelves which are covered by plastic or cotton sheets (again not possible where air movement is used). Curators prefer plastic as they can visually locate an object, whereas a cotton sheet will necessitate good object location records for easy access to objects. So here it is necessary to have a small volume of air and a large volume of organic material to get adequate buffering of the RH by the object material. The amount of moisture movement in and out of the object required to provide this stable environment is so small that stress will not be placed on the object. As discussed in section 9, moisture buffering materials can also be used in the materials of construction of the store room, eg absorbent wall finishes.

10.2.2. Light

No natural daylight and in particular direct sunlight should be allowed to enter a store room. As the room will only be used on occasion, then the illumination and UV levels will not be significant compared to display areas (section 10.1.2.). Lights should be arranged so that only those sections to be visited in the store room are turned on, and notices placed to remind users to turn off the lights. The use of time switches is not recommended as a person could suddenly be left in the dark, although this can be avoided if safety lights are available.

It is important that illumination levels are high enough to enable objects to be examined, and again as only for a short period of time the levels detailed in Table 4.1, section 4.2, do not need to be adhered to. A level of about 500 600 lux is necessary to see the detail on the surface of an object, but as only for a few minutes, due to the reciprocity factor (lux times hours) this will not cause any damage to the object. UV levels should be as low as possible through the use of low UV lights or UV filters. It is normal to use low UV output fluorescent lights or perspex covered normal fluorescent lights in store rooms as they will not introduce heat into the room. Fluorescent lights should be arranged so that the light falls on the shelves of storage units and is not wasted covering tops of units.

10.2.3. Air pollutants

Controlling air pollutants in these areas will require similar strategies to those employed in other areas of cultural buildings, ie controlling indoor pollutant sources, minimising ingress of urban air pollutants, and air cleaning. There may be scope for operating these areas at low ventilation rates as they are unoccupied.

If store rooms are kept closed with reasonable door seals, then this will help to reduce the levels of air pollution in the room. This will be reduced even further by the use of containers or sealed storage units, however, if boxes are open or in the case of boxes for archive materials which contain a hole to pull out the box from the shelf, then this is sufficient to allow in air pollution. In hot dry climates where the major pollutant is likely to be particulate matter, cotton sheeting is the preferred material for covering shelving units as this can easily be washed. This is better than plastic or paper which can transfer the dust to the object.

10.2.4. Pests

Integrated Pest Management (section 7.2.3.1.) as applied to the museum building is essential for store rooms. What is important, however, is that the collections must be inspected on a regular basis. It is different for displays where museum staff are likely to see damage quickly, but objects in storage will not normally be seen except by chance. The use of insect traps (section 7.2.3.2) and rodent baits is essential, to monitor for the presence of pests and as the first line of pest control.

10.3. Materials of Construction for display cases and storage units

Materials used to construct display cases and storage units will include metals, woods, adhesives, sealants, coating systems and lining fabrics. They should be as stable and inert as possible so that they do not produce any air pollution such as volatile organic compounds (VOCs), or if in contact with objects do not cause any damage. It is just as important to select safe materials used for mounting or supporting objects on display or in storage such as wires, pins and tapes, as these will come into contact with the object, in addition they should not place stress or strain on the object. Ideally all materials should be tested before use, but if this is not possible, then the following guidelines will indicate which are potentially harmful and which are safe materials.

Before objects are placed in new display cases or storage units the materials of construction should be allowed to fully cure and dry, and this may take several weeks for coatings, adhesives and sealants.

The following materials are in general unsafe for use for constructing display cases or storage units:

- *adhesives* one-part epoxies, polysulphides, polyvinyl acetate (PVA), polyvinyl chloride (PVC), cellulose nitrate, urea formaldehyde, Blu-tack ®;

- *coatings* alkyd or oil-based paints, oil-modified coatings and varnishes, one-part epoxies, and chlorinated rubber;

- *metals* iron (mild steel) if uncoated;

- *nylon or polyester* fishing line for suspending objects (it can stretch or break);

- *paper* if acidic, such as newspaper and cardboard;

- *plastic products* polyvinyl acetate (PVA) and polyvinyl chloride (PVC) films and sheet;

- *sealants* acid-curing silicones, urea formaldehyde, natural and synthetic rubber;
- *textiles* if coloured or pre–treated with fire-retardant chemicals;
- *wood* most hardwoods, in particular oak, teak, chestnut, Douglas fir, red cedar;
- *wood composites* particle board, chipboard, interior grade plywood and fibreboard - depending on the adhesive used in their construction, with phenol formaldehyde which is used for exterior plywood being safer than urea formaldehyde; and
- *wool* including wool felts;

The following are considered safe, and may be used in combination, for example wood products can be coated to ensure any harmful volatile gases are sealed in:

- adhesives certain acrylics, two-part epoxies, starch paste, animal glues
- ceramics and glass;
- coatings acrylic lacquers, water-based vinyl acrylics, two component epoxies and urethanes, moisture-cured urethanes and air-drying enamels;
- metals aluminium, brass, bronze, stainless steel (including pins), coated mild steel;
- nylon or polyester-coated steel wires (for suspending objects);
- paper acid-free paper, tissue and board;
- plastic products polyethylene (PE), polypropylene (PP), polycarbonate, polyester cloth (*Stabiltex*), and film (*Mylar* or *Melinex*), acrylic textiles and sheet, *Dacron* wadding or fibre, *Foamcore*;
- plastic laminated panels such as *Formica* and *Micarta*;
- sealants neutral-curing silicones, polyethylene foams;
- textiles unbleached and undyed cotton and linen, polyester, nylon;
- wood certain species such as beech, birch, and perhaps hoop pine; and
- wood composites exterior grade plywood.

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