Development of show cases for archaeological metals in aggressive environments

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Abstract

The display of archaeological metal artefacts presents one of the most challenging environmental problems, with rapid deterioration being commonly observed for both iron and copper alloy artefacts. One method used to prevent corrosion occurring is to store and display such artefacts in low RH environments. Thus removing one of the factors required for deterioration. In order to achieve this modifications have been made to off-the-shelf display case designs. Monitoring of the modified display cases over a year have shown low RH environments can be created and used successfully to display archaeological iron.

Keywords: showcases, iron, dry environment, preventive conservation

Introduction

The recent English Heritage policy to present more associated collections at all sites, has increased the number of objects displayed in historic buildings. Many of these buildings are poorly sealed; some have water percolating through historic masonry and most are unheated. This combination of factors often leads to high relative humidities internally, which create a particularly aggressive environment to display the site's finds, especially metals. Additionally, a large proportion of English Heritage's estate lies within one kilometre of the sea, causing enhanced corrosion rates because of sea salt aerosol deposition. The main part of the material being returned to site is archaeological. Common materials include iron and copper alloy contaminated with chlorides.

It is well known that both archaeological iron and copper alloys deteriorate when exposed to ambient RHs, with iron being susceptible at lower RHs (Turgoose 1982; Scott 1990; Watkinson 2004). Akaganeite formation has been reported at 19% (Watkinson and Lewis 2004). Recent experiments found akaganeite formation at 18.2% when humic acid was present and 16.1% when copper ions were present. A second threshold at 30% when deterioration increased dramatically was also observed (Thickett and Odlyha 2005). This work suggests to safely display archaeological iron an environment of 15% RH or lower would be required, with RHs below 30% retarding the corrosion rate to a low level.

The sites displaying archaeological collections are spread across England, with the number increasing annually. Visits for maintenance are often an annual or biannual event and power is limited at most sites. Even where power is available and electrical dehumidification could be used, a power failure could mean corrosion occurs and the fault may not be noticed for relatively long periods. Therefore it is desirable to use methods that do not need regular maintenance and are likely to perform over long periods. For this reason a passive method of dehumidification, silica gel, was chosen. However present display case designs are not able to maintain the low RH for sufficiently long periods of time to ensure the stability of archaeological iron. In order to meet this demand, a specification for a low RH display case was drawn up.

Investigation of current off-the-shelf designs

Approximately thirty desktop type showcases had been installed in a range of English Heritage properties over the previous five years. The performance of these cases was monitored (Temperate and RH, air exchange rate, AER, dust and pollutant ingress) and the cases were examined. A number of issues were identified which limit their ability to maintain low RH environments.

Gaps

The air exchange rate of each case was measured using the carbon dioxide tracer gas method (Calver et al. 2005). Gaps in cases and their seals are often not visible, but the resulting leaks can dramatically increase the AER. These can result from problems during manufacture or as a result of inadequate sealing of joints when the cases are installed on site. A chloro fluoro carbon (CFC) leak detector was used to locate any hidden gaps. Top hinged cases often showed large leakage through this hinge and had high air exchange rates.

Medium density fibreboard (MDF)

All of the display cases included the wood product, MDF, as baseboards and mounts. To prevent organic acid emissions these were sealed with Dacrylate, however this has been shown to be ineffective against acetic and formic acids (Thickett 1998). At Helmsley Castle cases with MDF inserts were monitored

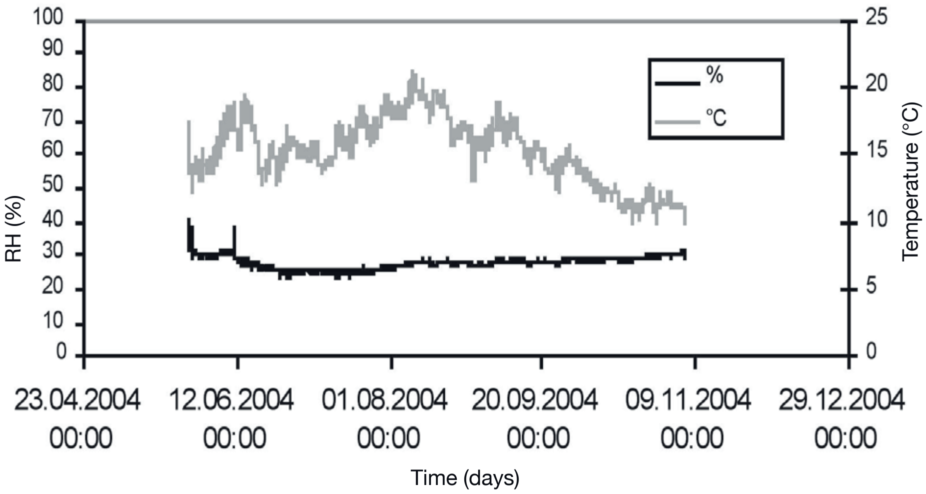

Figure 1: Conditions inside case with MDF inserts

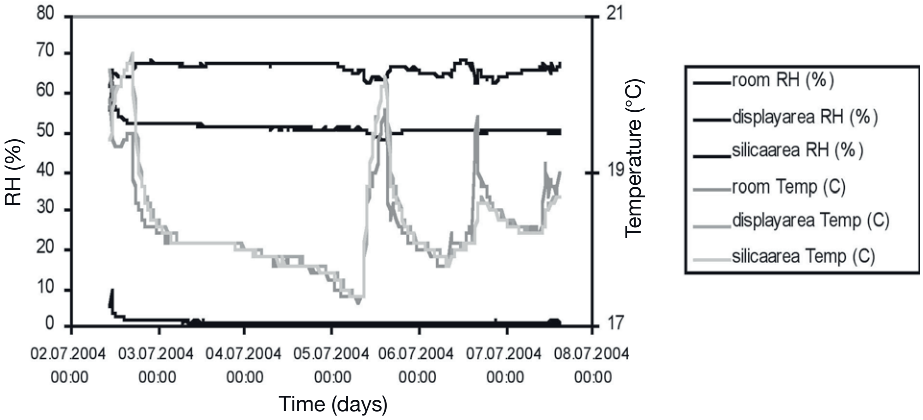

Figure 2: Conditions in various compartments of commercial case

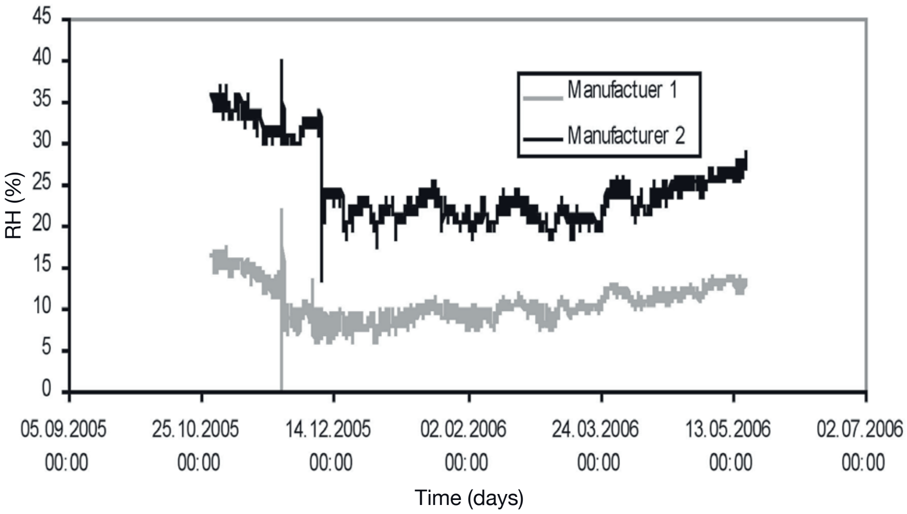

Figure 3: Relative humidities inside trial cases

(see figure 1). The buffering effect introduced by the MDF, caused a slow drying of the internal RH. A minimum of above 25% was reached and the RH then rose back above 30% within 45 days. To maintain the desired low humidity the silica gel would need to be replaced this often.

Air movement between the silica gel compartment and display volume

Environmental monitoring of a commercial showcase design (see figure 2) demonstrated a large, long term significant RH difference between the silica gel compartment and the display volume. This completely compromised the cases performance. It was possibly caused by a combination of stratification in the 30 cm chimney between the silica gel tray and the display volume and insufficient air pathways (approximately 8mm gap around the edges of the MDF baseboard) between the two.

Table 1: Air exchange rates and pollution ingress into trial cases

	Air exchange rate (?day)	Dust deposition (percentage coverage)	Chloride deposition (μg/cm2)	Nitrogen Dioxide Concentration Range (ppm)	Sulfur Dioxide Concentration Range (ppm)	Hydrogen Chloride Concentration Range (ppm)
Room		0.73	8.03	6.89-9.63	0.13-0.24	0.24-2.10
Manufacturer 1 case 1	0.65	0.24	2.14			
Manufacturer 1 case 2	0.45	0.15	2.38			
Manufacturer 2 case 1	0.3	0.05	0.83	0.10-0.14	0.08-0.20	0.56-1.12
Manufacturer 2 case 2	0.13	0.08	0.34			

Access

Three cases at St Augustine's Abbey were found to be performing very well keeping the RH below 13%. However the silica gel is within the display volume and requires the case to be opened in order to replace the silica gel. The glass lids are heavy and difficult to remove requiring a minimum of four people to be present. The amount of silica gel required is also substantial, 35 kg per case.

Case specification

The aim of the display case was to maintain below 30% RH for 6 months and hopefully lower. An RH of 15% was thought unachievable given current case performance and limitations on the resources available to change silica gel. The specification was developed from the conclusions of the assessment of current cases. A desktop case was chosen as a single level seal, can produce a low air exchange rate. The major mechanism of air ingress in many cases is the stack effect with the mass of a column of air, pushing air through vertically separated horizontal gaps. Table cases rather than plinth bases were chosen to allow greater disabled access. A number of further features were required for to maintain low RH.

Low air exchange rate

A low air exchange rate (AER) is essential. This will increase the length of time the silica gel is effective for and reduce the number of visits for maintenance. To achieve six months between silica gel changes a half life of 226 days is needed, requiring an AER below 0.4 changes per day (day^{-1}), preferably lower. A desktop case with a well sealed five sided glass lid, hinged along the lower back edge, was selected as most likely to meet the criteria. The weight of the lid and an overlapping metal flange also help the compression seal to function efficiently. Recent work by Thickett et al. (2006) has confirmed that decreasing the AER will also reduce the ingress of pollutants and dust.

No wood products

Wood products are known to emit organic acids and in sealed environments these will concentrate. Acetic acid has been shown to accelerate the deterioration reactions of archaeological iron at the concentrations likely in wood containing showcases. A further problem in trying to create low humidity environments in display cases is the moisture released by organic materials in the case, most often MDF baseboards. Buffering by wood products affects the creation and maintenance of low RH environments suitable for the display of archaeological iron objects. As metal baseboards and acrylic mounts are inert and available for a similar cost to wooden materials these should be used instead.

High silica gel volume

In order to have a sustainable maintenance programme a minimum hygrometric half life of 226 days was required. If the AER of 0.4 day^{-1} was met for a 1m^3 case then Thomson (1977) predicts 5.65 kg of silica gel would be required.

Silica gel tray close to the display area

The air exchange between the silica gel tray and the display area has been found to be a critical factor in the effectiveness of maintaining a dry environment. Also easy access required to a silica gel compartment can compromise its sealing. The closer this opening is to the horizontal seal of the display volume, the less the potential stack effect will be and hence the lower the AER with the same gaps.

Baseboards

It can be difficult to ensure sufficient gaps around solid baseboards to give adequate air exchange between the silica gel compartment and display volume. A minimum of 15mm has been recommended by the Canadian Conservation Institute (Tetreault 1999). The specification included a perforated baseboard, with holes of at least 15mm diameter covering 50% of the area. Sealing a wood product baseboard with such holes is unlikely to be effective, resulting in emitted organic acids and buffering. Hence metals baseboards were specified.

Trials of prototypes

Two companies produced cases to the modified design, which were installed in spring 2005. Some differences were evident immediately. A panel placed over the front of the silica gel tray for one design, minimised the possibility of wheelchair access by reducing the height of the table. The same manufacturer had also produced a metal baseboard with smaller holes than

Figure 4: The best performing case design

specified, although the number of holes was greater. When initially testing the cases for leaks, more gaps were found with this manufacturer's design and the AER, measured during the installation, also showed this case did not meet the specification. During the installation it was also noted that the locks were difficult to close and some have since needed to be replaced. Monitoring has taken place since installation and the results are described below.

Temperature and RH

The four prototype cases were installed at Portchester Castle where the room environment varies between 60 and 90% RH. The silica gel was changed around 6 months after installation, the RH is shown in figure 3. For Manufacturer 1's case the RH had crept up above 30% during the first 6 months, however the silica gel used was not completely dry when inserted (12% compared with 5% RH). After the silica gel change the RH was reduced below 25%. During the second 6 month period the RH gradually increased but is still under 30%.

Manufacturer 2's case showed a smaller increase in RH during the first 6 months, with the RH around 15% when the silica gel was changed. The RH decreased to 10% and has since slowly risen. It is currently just under 15% RH. Plotting a regression line of the second period of data shows the RH would reach 20% after a further 9 months. This demonstrates the case could be passively controlled below 20% RH with an annual change of dry silica gel. As a result it will be possible to control the case below 30% RH with an annual change of silica gel.

Two cases from Manufacturer 2 were installed at Pevensey Castle during spring 2005. Monitoring of the environmental conditions in the display room show the humidity varies between 65 and 95% RH annually. After 11 months monitoring both the cases are still below 30% RH, however the silica gel has not been changed during this period. Air exchange rates have not been measured but the cases came from the same batch as those at Portchester Castle. This demonstrates that the chosen, modified case design is performing not only as desired but better than expected. In fact the two cases from manufacturer 2 held an RH below 20% for over twelve months.

The RH in the showcases from manufacturer 1 was observed to rise above 30% in some of the six month periods over the past three years since installation. Fresh corrosion, identified as akaganeite by FTIR, was observed on archaeological iron objects in those cases. No corrosion was observed in the cases from manufacturer 2, were the RH stayed below 22%, despite having similar objects that had shown similar potential for corrosion when displayed previously (Thickett and Odlyha 2004).

Pollution

Pollution monitoring with diffusion tubes has been undertaken at Portchester Castle in the case from manufacturer 2 with the highest measured air exchange rate. Tubes were exposed for four week periods with three measurements being taken, equally spread over a year. Hydrogen chloride concentrations were also measured as Porchester is in a marine environment with medium concentrations of industrial pollutants, which are reported to react with sea salt aerosol to generate hydrogen chloride. Dust deposition was monitored in the room and all four cases by exposing glass slides and then undertaking image analysis (Howell et al. 2002). The dust was then extracted with water and the chloride concentration determined with ion chromatography, to calculate a chloride deposition rate from sea salt aerosol. Results are shown in table 1.

The cases from manufacturer 2 met the 0.4 AER criteria, those from manufacturer 1 did not. The case is shown in figure 4 and the design is lodged as reference EH1 with manufacturer 2, Click Netherfield. The degree of pollution protection demonstrated and utility of the case is also markedly superior.

Conclusion

This work has shown that controlling the RH using passive methods such as silica gel can be used to maintain low RH environments suitable for the display of archaeological iron. The research has demonstrated the benefit of working with display case manufacturers in order to improve the case performance. The chosen design continues to out-perform the other prototype and has actually out-performed the required specification. Initially it was hoped the silica gel would be effective in maintaining the humidity below 30% for 6 months. It was also hoped that an environment of 20% RH or less could be maintained for 6 months. However the monitoring has demonstrated this condition has been met for almost a year. This is significant in terms of the reduction in staff time to visit sites, change silica gel and regenerate the wet gel. More than fifteen cases of this design have now been installed into seven different site displays. Monitoring has shown all are performing to provide environments below 20% RH and requiring only annual changes of silica gel. This work has been extended to develop other display case designs, allowing greater freedom for exhibition design.

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