A Dutch seventeenth-century European lacquer cabinet. Material-technical analysis to gain insight into the deteriorated surface

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Abstract

A cabinet of unknown provenance in the collection of the Cultural Heritage Agency of the Netherlands has drawn the attention of conservators and art historians due to its peculiar appearance: a 'typical' seventeenth-century Dutch cabinet-on-stand decorated with imitation lacquer depicting Asian-inspired motifs mixed with European features. The lacquer suffers from craquelure, alligatoring, discolouration, bloom and lacunas which impair the brightness of the colours and the lacquer's smoothness, transparency and gloss, reducing the readability of the decoration. The scarce knowledge about the cabinet and its current aesthetical appearance required a diagnostic research. The cabinet and in particular the lacquer decoration have been the subject of macroscopic and microscopic examination: cross-sections were taken to determine the lacquer's stratigraphy and samples of the lacquer layers have been analysed to investigate the material composition. The results indicate that the cabinet and the lacquer decoration could be contemporary with a late seventeenth- or early eighteenth-century Dutch cabinet-on-stand. However, both the cabinet's construction and the lacquer decoration have undergone several restorations which can partly be related to the lacquer's degradation phenomena.

Keywords: European lacquer, imitation lacquer, japanning, Dutch cabinet-on-stand, material-technical analysis, alligatoring

Introduction

This paper presents a case study of a late seventeenth- to early eighteenth-century Dutch cabinet (figure 1) decorated with black European lacquer

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Figure 1 Anonymous, cabinet-on-stand decorated with European lacquer, the Netherlands, late seventeenth to early eighteenth century, 202 x 158 x 57 cm. Rijksmuseum, inv. nr. BK-2017-37. Front and right side.

Figure 2 Detail from the left side panel of the deteriorated lacquer surface.

(i.e. imitation lacquer), depicting a mix of Far Eastern-inspired and European motifs. The lacquer surface shows various degradation phenomena that affect the lacquer's original transparency and gloss and the original colours of the underlying decoration (figure 2), significantly reducing the readability of the lacquer decoration.
The cabinet was inscribed in the collection of the Cultural Heritage Agency of the Netherlands (RCE) in 2005, in conjunction with an inventory of the furniture at the Dutch Ministry of General Affairs in The Hague.[1] Unfortunately, this is all that is known about the cabinet's provenance. The scarce knowledge about the cabinet and the reason for its current appearance required a diagnostic research that was aimed at determining the cabinet's date and origin of production and gaining insight into the causes of the deteriorated lacquer surface.

European lacquer

Far Eastern lacquerware made its way into Europe during the sixteenth century.[2] With the foundation of the United East India Company in 1602 Amsterdam became Europe's leading trade hub for the Far East, and prosperous economic times followed soon after. The exotic appearance of lacquerware with its highly glossy surface and decorations of sprinkled gold and painted motifs appealed to the European upper classes. Consequently, a constant flow of imported lacquerware was needed to fulfil the ever-increasing demand. Due to the growing popularity of Far Eastern lacquerware, European artisans developed methods that would imitate the expensive Far Eastern lacquer coatings and decoration techniques.[3]

Although European lacquer workers of the seventeenth century had contact with imported lacquerware, they had no access to the natural resinous raw material from the lacquer trees of the *Anacardiaceae* family which the artisans in the Far East used to produce lacquerware. Therefore, they turned to materials and techniques from varnishing and mimetic practices.[4] Intercontinental trade made a wide variety of inorganic and organic substances available, including plant exudates such as resins (fresh and fossilised), gums, and vegetal oils. The resins and gums that were the ingredients for a lacquer recipe were measured and ground before being dissolved in solvents (spirit varnishes and essential oil varnishes) or dissolved with the addition of heat in drying oils (oil varnishes). By applying these lacquers in several layers onto a coloured or decorated ground with constant polishing in between layers, the artisans were able to produce a lustrous coating that closely imitated its Far Eastern equivalent.

The historical variety of recipes and techniques used for producing lacquer-imitating coatings has been confirmed by previous research on imitation lacquer.[5] The complex nature of imitation lacquer makes the ageing and degradation processes rather unpredictable. Moreover, fluctuating ambient conditions and UV exposure as well as historical treatments can change the original physical and chemical integrity of the lacquer, resulting in an alteration of the original appearance. Examples of these changes include severe yellowing and cracking, which cause surface and internal scattering of incoming light and affect the lacquer's transparency, gloss and colours.
Because of this diversity of materials and variation in degradation phenomena, it is difficult to predict the lacquer's composition and comprehend the observed degradation phenomena without macroscopic and microscopic examination complemented by chemical analysis. A deeper understanding of the object is essential to establish a proper proposal for treatment.

The Netherlands' role as an importer of Far Eastern lacquerware is well known. However, knowledge about the native production of imitation lacquerware is scarce. To date only a handful of Dutch imitation lacquerware objects are known, such as the small casket attributed to Willem Kick in the collection of the Rijksmuseum.[6] Strikingly few objects are identified and preserved in collections in general.

Figure 3 The back of the cabinet. On the right, the different wood species of the framework are coloured in Photoshop CS5: green = softwood (presumably from the *Pinaceae sp.*), purple = beech (*Fagus sp.*), blue = oak (*Quercus sp.*) (note: the side panels are of softwood), orange = a light coloured hardwood, possibly poplar (*Populus L.*).

Description of the cabinet

Construction

The cabinet is composed of a rectangular two-door upper case and a stand (202 x 158 x 57 cm). The stand has four spiral legs on bun feet joined by a spiral X stretcher at the bottom and rails with double-doweled mortise-and-tenon joints at the top, except at the front, which holds a large drawer. The centre of the X stretcher has a diamond-shaped appliqué. All parts of the stand appear to be original, except for the sides, the back and the bottom of the large drawer and the drawer runners.

The sides and the doors are a simple construction of vertical planks which seem to be butt-joined or joined with dowels. On the inside of the doors, horizontal imprints in the lacquer are visible in both the upper and lower part of the doors, which may suggest that cleats originally have been a part of the construction. The doors are mounted with secondary pivot hinges; the original hinges have been replaced. The inside of the right door has a variant of a half mortise spring lock. The lock seems to be the original lock; however, it has been re-worked and re-screwed onto the door. The key entrance has been replaced.

The back of the cabinet is constructed of a wooden framework holding six panels. It is assembled of four different common European types of wood: softwood (presumably from the *Pinaceae sp.*), beech (*Fagus sp.*), oak (*Quercus sp.*) and a light hardwood, possibly poplar (*Populus L.*) (figure 3). All other parts of the cabinet are coated with lacquer decoration. However, softwood can be observed through lacunas in the lacquer at several different locations, which leads to the assumption that the cabinet is constructed of softwood.

The top of the upper case has a cornice with a simple moulding. Two wooden planks joined by tongue and groove and nailed with forged nails cover the top. Two shelves divide the interior space, each with two drawers beneath it. The construction of the drawers is nailed. The backs and bottoms of all four drawers have been restored.

Figure 4 Detail of the depicted humans, birds, flowers, buildings and stylised leaf border, left door.

Figure 5 Details of the various deterioration phenomena of the lacquer.

Lacquer decoration

The lacquer depicts buildings, flowers, human figures, birds, and stylised leaf ornaments in green, red, orange and white, and sprinkled and painted metal speckles and powders in various tints of 'gold' applied onto a black ground (figure 4).[7] The depictions on the doors and on the sides respectively are mirror images. The buildings, some of the birds and flowers, the clothes, and the facial hair of the male humans are of a Chinese nature. However, the eyes of the human figures and the stylised leaf ornaments are of a European nature. The inside of the cabinet also has a black coating.[8] The front of the drawers and the doors are decorated with stylised leaf and floral motifs. The stand, including the spiral legs and stretcher, is also decorated with stylised leaf and floral motifs.

Degradation phenomena

The degradation phenomena on the cabinet include cracks, craquelure and crazing, alligatoring and wrinkling, yellowing and darkening, bloom and lacunas (figure 5). There are also areas where the lacquer structure has been lost completely, notably on protruding parts and edges. Large cracks on the doors and side panels run through the whole lacquer structure and in some cases through the wooden substrate. These types of cracks parallel to the wood grain are commonly related to changes in the ambient climate, which lead to a divergent expansion and shrinkage between the wooden substrate and the lacquer. All lacquered parts exhibit various extensive craquelure with both narrow and wide cracks; secondary craquelure (checking) is also visible under UV. The patterns differ in different areas on the cabinet. Most of them are randomly ordered and have no predominant direction; the cracks run parallel, perpendicular, and diagonal to the wood grain direction of the substrate. The cracks are in general smooth, with no jagged edges, and are either straight or slightly curved.[9] Both ageing and drying cracks can be distinguished.[10] The craquelure of the stand is of a different character: it has an extensive network of fine cracks (crazing).

A number of lacunas in the lacquer surface are clearly visible under UV. The lacquer's surface is heavily yellowed and darkened, which strongly affects the true colours of the decorations. Many parts of the lacquer show a cloudy surface haze or bloom. In one particular area on the right door, the surface is almost white, reducing the transparency of the top layers significantly.

The most disturbing degradation phenomenon is the surface alligatoring and wrinkling. In the areas along the edges of the side panels the lacquer's surface has formed into islands with round edges and an increased thickness compared to the surrounding areas. As a consequence of this, the reflective light is scattered, resulting in a significantly less saturated black surface and reduced visibility of the decoration. This affects the contrast between the black lacquer and the brightly coloured decorative elements, which constitutes the essence of the lacquer decoration.

Method

Considering the complexity of the lacquer decoration, a multidisciplinary strategy was used to address the two leading questions of the diagnostic research: determining the cabinet's date and origin of production, and gaining insight into the causes of the deteriorated lacquer surface.[11]

Macroscopic examination

Macroscopic examination in both visual (VIS) and UV light is standard procedure for diagnostic research of any art object. This examination provided fundamental information about the cabinet's construction and finish, including a categorisation of the various degradation phenomena and stylistic features. The macroscopic examination also discovered previous interventions, both in the construction and the lacquer surface. These could be observed through the use of different materials, changes in the construction, tool marks, and retouches of the lacquer. This provided important information when choosing suitable sample locations.

Microscopy of cross-sections and the lacquer topography

A microscopic study of several cross-sections was carried out in order to understand the general stratigraphy of the lacquer and to categorise the various layers according to their respective function: preparatory layer, ground layer, decorative layer and lacquer layer(s). Cross-sections were taken from both the upper case and the stand for a comparative study of the stratigraphy and the different types of degradation. The samples were embedded in a one-component non-fluorescent methacrylate that cures under UV and dry-polished with 12000 grit Micro-Mesh cushioned abrasive.[12] The layer structure was studied and documented by means of optical microscopy under VIS-BF (bright field) and UV. To gain a deeper understanding of the lacquer's various degradation phenomena the topography was further studied with a 3D-digital Hirox RH-2000 microscope. The 3D-digital microscopy was carried out on the right door, which was chosen as a representative area for different degradation phenomena and decorations.

Chemico-analytical techniques

The chemico-analytical techniques described below were performed with the aim to identify both organic and inorganic materials of the lacquer and their spatial distribution within the lacquer structure.

Organic analysis

Histochemical staining of the cross-sections was performed to identify the organic binding media groups of the different layers in the lacquer's build-

Figure 6 Detail one of the human figure faces, on the right door. Where the discoloured lacquer is absent the colour of the face is clearly white. Hirox 3D-digital microscope, 20x, VIS.

Figure 7 Detail of the metal particles (powder) and speckles of the 'gold' decoration on the right front door. A crack in the transparent lacquer layers runs horizontal through the picture, exposing the larger and irregular metal speckles to the left and the finer metal powder to the right. Hirox 3D-digital microscope, 80x, VIS.

up. Although histochemical staining is a widely recognised low-tech method for the identification of organic compounds, the methodological approach has only recently been optimised for the characterisation of Asian lacquer.[13] By adapting the original methodology it can also be used to detect binding media groups such as protein, starch, protein/oil and oil/lipids in European imitation lacquer.

The staining methodology was based upon the procedure presented at the Recent Advances in Characterizing Asian Lacquer (RAdiCAL) workshop by Nanke Schellmann.[14] The original exposure times used for soaking, staining and rinsing cross-sections of Asian lacquers were reduced by applying the solutions in intervals, since some components of European lacquers can be more sensitive to the solutions used.[15]

The following stains were used on the embedded cross-sections (in order of staining): (1) Amido black 10B for proteins, (2) Lugol's solution for starch, (3) Nile Blue sulphate for oil/proteins, and (4) Sudan Black B for oil/lipids. Before staining, all cross-sections were studied and photographed under VIS-BF and UV using an optical microscope (50x to 500x). These reference images are paramount for the interpretation of the results after staining.

Thermally assisted hydrolysis and methylation-pyrolysis-gas chromatography-mass spectrometry (THM-Py-GC-MS) is a commonly used technique to identify organic components of lacquers.[16] To identify compositional differences between the individual layers of the lacquer structure, the lacquer, ground and preparatory layers were sampled layer-by-layer, allowing layer-unique analysis. Two layer-by-layer sampling methods were executed to collect thirteen individual layer samples directly from the lacquer surface with a small scalpel, and from a larger cross-section using a micro-chisel.[17] Sampling was performed under optical microscopy with alternating VIS and UV to minimise cross-contamination of adjacent layers. Each sample was analysed by THM-Py-GC-MS separately.[18]

Inorganic analysis

X-ray fluorescence spectrometry (XRF) was performed as it provides a non-destructive tool to detect inorganic components of the lacquer, such as metal powders and pigments. The right door was chosen as a representative area for the XRF analysis as all the different colours (black, green, red, orange and white paint) and the metallic gold-coloured decoration are present. Additionally, several lacunas in the door's lacquer layer allowed direct measurements on the preparatory layer. A total of nineteen locations were selected and analysed with XRF.[19]
For each location the present layers were measured (e.g. white preparatory layer/black ground/red paint/lacquer) and the absence or amount of lacquer was noted (e.g. 'measure point without lacquer', 'measure point between or on lacquer accumulation') to be able to compare the spectrum of detected materials. At least two points of each colour and 'gold' tint were measured for comparison of the results.
Scanning electron microscope with energy dispersive X-ray spectroscopy (SEM-EDX) was performed on the cross-sections to identify any inorganic components of the lacquer and their spatial distribution within the lacquer structure.[20]

Results

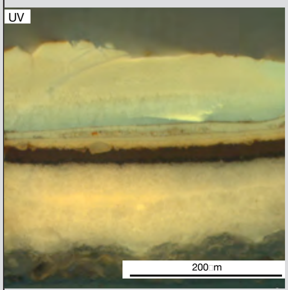
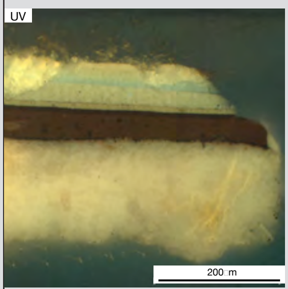
Stratigraphy and material composition of the lacquer

Three lacquer structures were identified on the cabinet, located on: I. the decorated areas on the upper case; II. the spiral stretcher of the stand; III. the pronounced alligatored areas along the side panels. [21]

I. Decorated areas of the upper case (table 1.I)

The decorated areas on the upper case – the doors and the centre parts of the side panels – seem to have three chalk-based preparatory layers bound with starch and protein. A black ground follows the preparatory layer. A preheated linseed oil was identified as binding medium, possibly mixed with pine resin. The black colouring substance is lamp black (soot). In the painted decorations three pigments could be identified: lead white, verdigris and vermilion. In one sample, however, barium and sulphur were encountered. This may suggest the use of barium white. These elements were only found in the greyish shading of one of the geese depicted on the left side panel (seen in figure 2), which is applied onto a lacquer layer that covers the white paint underneath.
XRF analysis confirmed that the yellow-seeming flowers and the faces of the human figures are in fact pure white (lead white paint), which is also clearly visible under the 3D-digital microscope (figure 6). One sample of paint was taken to analyse the binding medium. This contained linseed oil mixed with about 5-10% rapeseed oil. The 3D-digital microscope revealed fine cracks (ageing cracks) in the painted decorations.
The 3D-digital microscopy in combination with XRF analysis allowed a close-up study of the metallic decoration (figure 7). The metal is an alloy of zinc and copper, i.e. brass. The various tints seem to be obtained by using speckles and powders in varying shapes and sizes, some of which are densely distributed and others more scattered. It was also found that the metal alloy in the more red-tinted areas has a lower content of zinc: ca. 0.7% in comparison to ca. 10-20%.[22] Another possibility for the varying tints is the use of a coloured lacquer. Colouring the lacquer with a yellow or red dye is a historically-documented technique used for material imitation also mentioned in recipes for European lacquer.[23] The presence of a coloured lacquer on top of the metallic decoration could not be distinguished microscopically due to the heavily aged and discoloured top layer. Therefore, the use of a

Table 1 Stratigraphies and material composition

Location	Layers	Material composition	Cross-sections/Stratigraphies
I. Decorated areas on the upper case.	Topcoat[1]	Paraffin and beeswax	
	Varnish layer[1]	Linseed oil, a non-drying oil (raw castor oil and/or rapeseed oil), pine resin, indication of copal, metal driers (Pb, trace of Fe, Mn)	
	Varnish layer[1]	Dammar, pine resin, linseed oil**, non-drying oil**	Stratigraphy window on the right door.
	Original lacquer layer[1]	Results inconclusive	
	Decorations		
	Binding media[1]	Linseed oil, rapeseed oil, pine resin	
	Pigments[2,3]		
	White	Lead white (Pb)	
	Grey	Barium sulfate (Ba, S)	
	Orange	Mercury sulphide (Hg, S), lead (Pb)	
	Red	Mercury sulphide (Hg, S)	
	Green	Verdigris (Cu)	
	‘Gold’[2]	Brass (Zn, Cu)	
	Black ground layer[1]	Preheated linseed oil, pine resin, soot (lamp black)	
	Preparatory layer[3, 4]	Chalk (Ca), indication of starch, protein	Cross-section decorated area centre of left side panel.
II. Spiral stretcher of the stand.	Topcoat[1]	Paraffin and beeswax	
	Original lacquer layer/ Varnish layers and black ground layer[1],*	Linseed oil, trace of a non-drying oil (raw castor oil and/or rapeseed oil), pine resin, trace of triterpenoid resin (likely dammar), indication of copal, soot (lamp black)	
	Preparatory layer[3, 4]	Chalk (Ca), markers for protein and starch/ gum	
III. Alligatored and non-decorated area along the edge of the left side panel.	Topcoat[1]	Paraffin and beeswax	
	Varnish layer[1]	Linseed oil, a non-drying oil (raw castor oil and/or rapeseed oil), pine resin, indication of copal	
	Pigment layer[1]	Soot (lamp black)	
	Varnish layer[1]	Linseed oil, a non-drying oil (raw castor oil and/or rapeseed oil), pine resin, indication of copal	
	Black ground layer[1]	Linseed oil, pine resin, indication of copal, indication of bitumen and/or Kassel earth and coal tar	
	Preparatory layer1, [3, 4]	Chalk (Ca), markers for protein and starch, Linseed oil**, pine resin**	
	Substrate	Wood (*Pinaceae sp.*)	

1 Analysed with THM-PY-GC-MS, 2 analysed with XRF, 3 analysed with SEM-EDX, 4 analysed with histochemical staining.
* The layers could not be separated for individual analysis. ** Presence likely due to cross-contamination with adjacent layer.

dye in one of the subsequent lacquer layers cannot be completely excluded without chemical analysis. The painted and metallic decorations are covered with one original lacquer layer, two varnish layers and a wax topcoat.[24] The components of the original lacquer layer could not be identified.[25] The first varnish layer has a clear bluish fluorescence, and contains dammar and pine resin. The presence of linseed oil and the indication of a non-drying oil are likely contaminations from the subsequent varnish layer. This third layer is relatively thick (ca. 60-100 µm). The linseed oil seems to be preheated, likely with the addition of metal driers. XRF analysis shows the presence of lead at all measurement points. Further analysis with SEM-EDX showed lead particles present in the surface of the top varnish layer. No lead was found in the foundation layer. Iron, manganese and zinc were also found in almost all XRF measurements. Like lead they have a higher peak on points of lacquer accumulation. Since no other logical origin of these elements could be found, this might suggest they have been added as driers. SEM-EDX analysis gave no indication of the spatial distribution of these elements.

2. *Lacquer on the stretcher of the stand (table 1.II)*
The lacquer on the stand has two chalk-based preparatory layers bound with protein and starch. The following black ground layer and subsequent lacquer and varnish layers were not successfully separated for individual analysis. Again, soot was detected. Four transparent layers can be distinguished on top of the black ground. The third layer, with a clear bluish fluorescence corresponds in appearance to the first varnish layer on the upper case in which dammar was identified. The components of the second varnish layer on the upper case are also present in the sample from the stand. However, on the stand this varnish has been applied much thinner.

3. *Alligatored area on the side panels (table 1.III)*
The cross-section from the pronounced alligatored area deviates from the lacquer stratigraphies described above. The preparatory layer seems to be thinner than on other parts of the upper case, with only two layers instead of three. However, the composition seems to be similar. In the following black ground the analytical results indicate the presence of some black-brown colouring substances, bitumen and/or Cassel brown and coal tar. A thick varnish layer is applied onto the uneven black ground. This layer is composed of raw linseed oil mixed with a relatively high percentage of a non-drying oil, likely castor oil and/or rape seed oil, and small amounts of pine resin and copal. It also contains a thin pigment layer of lamp black. The composition is comparable to the second varnish layer on the decorated areas of the upper case and the stand. A topcoat of paraffin-beeswax is applied on all lacquered parts of the cabinet.

Discussion

The interpretation and contextualisation of the analytical results were carried out with the help of literature studies, historical recipes, and discussions with art historians, colleague conservators, and conservation scientists.

To answer the question whether the cabinet could be contemporary with a late seventeenth- or early eighteenth-century Dutch cabinet we have to characterise its constructional and stylistic features and distinguish original materials from non-original materials. The cabinet's style and construction correspond strongly to a Dutch cabinet-on-stand called a *kruisvoetkabinet*: a cabinet on an open stand where the legs are joined by an X stretcher; the legs and stretcher are often spiral-shaped. This type of cabinet seems to have developed from chests placed on open stands and baby linen cabinets in the early seventeenth century and became a standard type of cabinet in the Dutch Republic during the late seventeenth century to the early eighteenth century, when cabinets with closed stands and with drawers became the new fashion.[26]

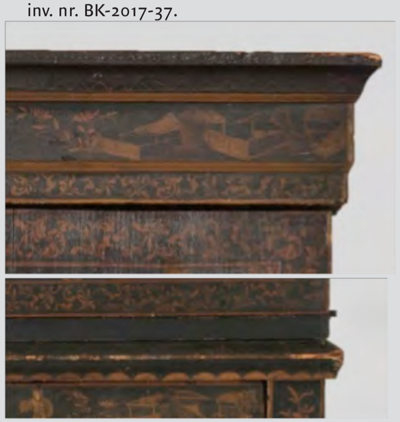
About a handful of somewhat similar cabinets have been found for comparative studies (table 2). They are considered of Dutch origin regarding their construction and the type of wood used. Cabinet A and B have a similar construction as the cabinet in this study. Regarding the lacquer decoration, some are reminiscent of each other, but no direct match of the figurative depictions of the cabinet in this study has been found. Nonetheless, there are three ornamental patterns that can be seen on all four cabinets (table 2). These ornamental elements have not yet been encountered on lacquered cabinets from other European countries like England and Germany. However, more examples are necessary to draw further conclusions.

A few things are noteworthy about the cabinet's construction. What first comes to one's attention is the framework of the back, which is made of several different species of wood. More commonly the back is of a simpler construction of vertical planks. The painted Dutch cabinets-on-stands are predominantly made of softwood.[27] Furthermore,

Figure 8 A few cabinets with similar construction and partly similar decorative elements of the lacquer decoration.

The cabinet

Anonymous, cabinet-on-stand decorated with European lacquer, the Netherlands, late seventeenth to early eighteenth century, 202 x 158 x 57 cm, collection Rijksmuseum, inv. nr. BK-2017-37.



A

Anonymous, cabinet-on-stand decorated with European lacquer, the Netherlands, 1680-1720, 189 x 143 x 52 cm. Antiquair W. Angevaren, Den Haag. Photo: Hofstede, Annigje. Nederlandse meubelen: van barok tot biedermeier 1700-1830, 2004. p. 36, fig. 36.

B

Anonymous, cabinet-on-stand decorated with European lacquer, the Netherlands, 1680-1720, 208 x 156 x 58.5 cm. Kölnisches Stadtmuseum (inv. nr. 1928/380).

C

Anonymous, cabinet-on-stand decorated with European lacquer, the Netherlands, 1720-1740, 122 x 156.5 x 57 cm. From; Christie's Amsterdam auction catalogue 28 September 2000, 'The Japan Sale In Celebration of the 400 Year Relationship between Holland and Japan', 2000, p. 60.

there is a visible difference in age between the parts of softwood and those of oak, beech, and poplar, where the softwood appears much older than the others. The panels of softwood have longitudinal open woodworm holes, which may suggest that they have been re-planed to be re-used. Tool marks from a circular saw on the parts in beech also support that the framework is of a later date than the cabinet.
Moreover, instead of the more typical construction where the side panels of the cabinet stand in a shallow groove between the profile along the top of the stand and what constitutes the bottom of the upper case, the side panels are glued to cleats on the cabinet's interior which are attached to the top of the bottom (figure 9).[28] Because of this, the doors are in a higher position and therefore a rail is placed under to fill the gap between the profile of the stand and the doors. The rail is joined to the cleats with triangular shaped corner blocks. On the outside the rail is rather eye-catching because of its lack of painted decoration which covers all other lacquered parts. It seems likely that this construction, as well as the framework of the back, is the result of a reconstruction of the cabinet.

When considering the lacquer's stratigraphy and the composition of each layer, the preparatory layer, the black ground (with exception of the edges of the side panels), the painted decorations and the first lacquer layer, all layers are made of materials that have been used by artists throughout several centuries. The materials also coincided with several results from previous studies of European lacquer and descriptions on lacquer imitation in historical recipes from the late seventeenth and first quarter of the eighteenth century.[29] Hence, the composition of the layers could well be contemporary with a late seventeenth- or early eighteenth-century cabinet.
The presence of barium white (barium sulphate) in the shading of one of the geese feathers could, however, not originate from such an early date, since barium white was first developed in the late eighteenth century.[30] The possibility that this shading is part of the original decoration cannot be completely excluded. Considering the presence of the lacquer layer underneath and the indication of a varnish added later on top, it seems more likely that this shading is a retouching which was added later.
The presence of rapeseed oil in the paint is notable. Rapeseed oil is seldom mentioned as a binding medium for paint; historically, it was used as lamp oil. Nonetheless, it has been found in some medieval paintings, as well as in twentieth-century paintings.[31] The rapeseed oil may have been added to prolong the drying time of the paint, or it has been used as an adulterant in the linseed oil.
Dammar is first mentioned as an artist material in the beginning of the nineteenth century. The dammar layer is therefore not thought to be original to the cabinet's date of production. The fact that there is a lacquer layer present underneath makes it plausible that the dammar layer is not original to the lacquer decoration, but was applied as a restoration measure to enhance the gloss of the surface.
The areas along the edges of the side panels with pronounced alligatoring clearly have a different stratigraphy and material composition from the decorated areas of the upper case and the lacquer on the stand (table 1). This strongly indicates that these areas were re-worked at some point in the cabinet's history, likely at the same time as the reconstruction of the cabinet's back, where oak styles were fitted to the softwood panels as a part of the new framework construction. The analytical results show the presence of bitumen and/or Cassel brown and coal tar in the black ground (table 1.III). The terms bitumen and coal tar are, together with asphalt/asphaltum, often used interchangeably for a dark brown-black, highly viscous liquid or a solid form of petroleum.[32] It seems like these terms have also historically been used interchangeably, due to their visual and physical similarities. The chemical composition of these materials is complex. The analytical result indicates the presence of coal tar, which can be distinguished from natural asphalt by its pyrene content, indicating that it is a by-product from the coke and coal gas manufacture. The derivation of coal tar from coal was first attempted in England in the late seventeenth century and in the late eighteenth century imputed by the development of coke as fuel.[33] Asphaltum is mentioned in some eighteenth-century recipe books for black imitation lacquer.[34] However, it is not sure if they refer to the natural asphalt or to coal tar. For example, Buonanni (1733) describes asphalt as 'another good bitumen' to make black lacquer ('*Vernis noir*'); this seems to concern natural asphalt.[35] The more commonly mentioned pigments for black lacquer are lamp black and ivory black.[36] Recipes for black lacquers made with pigments, asphaltum, or coal tar can also be found in nineteenth- and twentieth-century sources.[37]
The composition of the oil-resin varnish on top of the black ground is similar to the top varnish on the rest of the upper case, with the exception that a raw linseed oil has been used instead of a preheated linseed oil. Both top varnishes contain a non-drying oil, likely castor oil and/or rape seed oil. Castor

oil is a non-drying oil made from the seed of the plant *Ricinus communis*. The oil has been used since ancient times as lamp fuel and for various medical purposes.[38] Castor oil has unique physical and chemical properties due to three functional groups - a hydroxyl, a carboxylate and a carbon-carbon double bond - in its major component, ricinoleic acid.[39] The hydroxyl groups make castor oil soluble in alcohol and endow it with a high viscosity. Its properties make castor oil an important raw material for many industrial applications, among others as a plasticiser, which is also thought to be its intended function in the oil-resin varnish.[40] Castor oil does not seem to be commonly mentioned in cabinetmakers' or artists' recipe books. In this study, it has not been encountered as an ingredient in any recipe books concerning lacquers or varnishes for cabinetmakers or artists before the nineteenth century. In a few nineteenth- and twentieth-century recipe books for wood varnishes, castor oil was used as an ingredient in spirit varnishes and celluloid lacquers.[41]

What could have caused the deteriorated surface?

Having gained knowledge about the lacquer's stratigraphy and composition, we can relate the materials to the various degradation phenomena and thereby better understand what could have caused them. The wide range of coating failures that may be the cause of the visual and structural changes of the lacquer can be related to a number of factors: variables during manufacturing, such as ingredient preparation; processes during or shortly after application; processes during or shortly after setting or drying; previous interventions; environmental exposure; or simply natural degradation or use. The majority of the materials used in European lacquer systems are organic, and the fundamental cause of their degradation is oxidation.

Craquelure and lacunas

Regarding the five different types of craquelure identified in the lacquer surface, two types of cracks can be characterised: ageing cracks and drying cracks.[42] The ageing cracks can be related to embrittlement of the resins and drying oils as a result of natural ageing and degradation, whereby these materials become less able to withstand environmental fluctuations. The cracks in the dammar lacquer may also have occurred due to stress developed by the subsequent alligatored oil-resin varnish. The drying cracks are confined to the top oil-resin varnish and their occurrence are, as the name implies, related to the chemical and physical actions of the drying process that induce internal mechanical stress.[43]

Embrittlement and craquelure in the lacquer's surface are a starting point for the occurrence of lacunas. Adhesive failure between layers due to material incompatibility or degradation processes and temporarily applied external forces on the lacquer's surface are other likely causes for the creation of lacunas.

Alligatoring and wrinkling

The principle cause of alligatoring is the contraction of a rapidly drying top layer over a slower drying underlying layer. The more rapid-drying surface layer hampers oxygen absorption and possibly solvent evaporation of the underlying layer, leading to a difference in drying rate between the two, and causing the surface to contract the still-soft underlying materials into islands. Alligatoring is thus related to a difference in drying rate between layers or within a single layer that has been applied too thickly. The latter seems to be the case on the cabinet. The top oil-resin varnish is of a notable thickness; it may have been either applied as one very thick layer, or in several layers, but without sufficient drying time between the applications.

A difference in drying rate can also be induced by the inclusion of driers, phenol-containing tars and pigments, non-drying materials, or slow evaporating solvents. Coatings containing a drying oil, such as linseed oil, are particularly prone to alligatoring due to their drying process by oxidation, which is at its highest at the oil-air interface. Considering the material composition of the varnish in the areas along the edges of the side panels, i.e. the coal tar and bitumen/Cassel brown, the linseed oil, the non-drying oil, and the lampblack are all contributors to a decreasing drying rate.

Yellowing and darkening

The yellowing and darkening seem to primarily confined to the top oil-resin varnish. Yellowing and darkening are especially observed in oils with a high content of linolenic acid, such as linseed oil, which is the main component of the top oil-resin varnish.[44] It is also generally known that many resins also have the tendency to yellow and darken with age. The yellowing and darkening of ageing linseed oil has been attributed to autoxidation, thermo-oxidation, and co-oxidation of contaminants, but many questions about these processes remain unanswered.[45] Other materials that may be present in the varnish, such as pigments, dyes, and metal driers, are also likely to be involved in

Figure 9 The assembly of the stand and the upper case. The right door has been removed to show the bottom and the cleat of the cabinet's interior. A= bottom, B= cleat, C= corner block, D= front rail, E= side panel, F=profile along the top of the stand.

the chemical reaction of deterioration leading to discolouration. The darkening may also be caused by dirt attached to the surface.

Bloom

There are many different causes for the appearance of a white surface haze or bloom on the surface of an object.[46] Considering the materials found in the surface layer(s), the bloom on the cabinet could be due to migration of free fatty acids from the top oil-resin varnish, the formation of paraffinic or wax crystals, or the saponification or complex salt formation of the metal dries used in the top oil-resin varnish.

Conclusions

A multidisciplinary approach proved to be fundamental to understand the construction of the cabinet and the lacquer stratigraphy and material composition of the layers. The results of this method allowed us to form hypotheses concerning the cabinet's date and origin of production and possible causes to the deteriorated surface.

Summarising the results, parts of the cabinet and its lacquer decoration could definitely be contemporary with a late seventeenth- or early eighteenth-century Dutch cabinet. The cabinet and the lacquer seem to have undergone two or three restorations. Based on the identified materials, these treatments appear to have been executed at the earliest in the nineteenth century. The first restoration can be linked to the use of barium white for retouching and the application of the dammar varnish. The second restoration can be related to the reconstruction of the backside framework and the addition of the top oil-resin varnish, including the re-made areas along the edges of the side panels. The wax coating is possibly the result of a third restoration or maintenance.

The degradation phenomenon that affects the lacquer's appearance the most is the alligatoring. It confines to the non-original top varnish layers. The cause of the alligatoring can be related to the combination of materials and the layer thickness of the top oil-resin lacquer, where the more rapidly-drying surface layer hampered oxygen absorption and possibly solvent evaporation of the underlying layer, leading to a difference in drying rates between the two, and causing the surface to contract the still soft underlying materials into islands.

Further research

Although new insights were gathered, several questions remain. Further analytical and art historical research should focus on gathering in-depth information to refine the timeline of events related to the cabinet's history, particularly the remaining uncertainties regarding the material composition of the original lacquer layer on both the stand and the upper case. In addition, a more in-depth material-technical and art historical study of comparable lacquered objects should be performed to gain better understanding of their art historical context and to broaden the knowledge of Dutch lacquer. More information will support the arguments for the cabinet's date and place of production.

The cabinet's present appearance does not meet the aesthetic requirements for display. Therefore, treatment of the lacquer surface is desirable to improve its appearance. The results of this diagnostic research provide a starting point towards discussion and further research on possible treatment.

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Notes

[1] During the course of this study the cabinet was transferred to the Rijksmuseum Amsterdam collection, inv. nr. BK-2017-37.
[2] Huth 1971: 1-17.
[3] In Britain and North America the art of lacquer imitation is often referred to as 'japanning'.
[4] There are several historical recipe books and treatises discussing the art of lacquering and imitation lacquer, e.g. Salmon 1672 and 1710, Stalker and Parker 1688, *Traité de la peinture en mignature* 1708, Buonanni 1720, Watin 1755, Dossie 1758 and 1764.
[5] Most studies on European lacquers have been carried out within three large-scale research projects: the German-Japanese research project on the investigation and restoration of lacquers, Characterization of Asian and European Lacquers, and European Lacquer in Context; the latter two are still on-going. Publications of the German-Japanese research project on the investigation and restoration of lacquers can be found in Walch, Katharina, Johann Koller 1997, Kühlenthal 2000a and Kühlenthal 2000b, see also 'Characterization of Asian and European Lacquers', 'European Lacquer in Context'.
[6] Attributed to the Dutchman Willem Kick (Amsterdam, 1579-1647). One is dated 1618, collection Rijksmuseum Amsterdam (inv. nr. BK-2007-6).
[7] On the variety of used metals and alloys for decoration European lacquer in historical sources, see for example Stalker and Parker 1688: 5-8, Bernstein 1992, Webb 2000: 134-136 and Helwig 2001: 28.
[8] The black lacquer on the cabinets inside (except the drawer fronts and doors) seems to be covered by black high gloss paint, which is probably not original. In consultation with the Cultural Heritage Agency of the Netherlands materials analysis was focused on the exterior. Further research is necessary to determine the composition of the interior coatings.
[9] Bucklow 1997: 131.
[10] Hill Stoner and Rushfield 2012: 287-290.
[11] Due to the limitations on the paper's length, no technical details of the analytical instruments and chemical analysis are given. Please contact the corresponding author for questions regarding the former.
[12] Technovit 2000 LC.
[13] Schellmann 2012a: 31-77, Schellmann and Schilling 2016.
[14] Schellmann 2012b.
[15] There is a risk of swelling, leaching and dissolving certain layers, in particular the preparatory and isolation layers, which might contain water-sensitive binder types such as fish glue (isinglass), starch or gums. To detect any negative interaction between the samples and the solutions used, the sample's condition needs to be observed continuously with optical microscopy throughout the staining process.
[16] See for example European lacquers: Koller and Baumer 2000: 339-349, Decq et al. 2016: 1-8, Sawerwyns, Vermeulen and Van Binnebeke 2014: 64-75, lacquers: Van Keulen 2015: 134-141. For the analysis of Asian lacquers: Heginbotham, Khanjian, Rivenc and Schilling 2008: 608-616, Heginbotham and Schilling 2011: 92-106.
[17] J. Paul Getty Trust, 'Protocol for Sampling Individual Lacquer Layers', 2010, PDF.
[18] The THM-Py-GC-MS analysis was performed by Henk Van Keulen, senior specialist gas chromatography-mass spectrometry at the Cultural Heritage Agency of the Netherlands.
[19] The XRF analysis was performed together

with Jan Dorscheid, furniture conservator at the Rijksmuseum. The results were further discussed with Prof. Dr. Arie Wallert at the Rijksmuseum.
[20] The SEM-EDX was performed by Dr. Ineke Joosten, conservation scientist at the Cultural Heritage Agency of the Netherlands.
[21] The number corresponds to the layers in the cross-sections/stratigraphy shown in table 1.
[22] To estimate the ratio between the copper and the zinc, the XRF spectra were deconvolved with an open source software (PyMca 5.1.1) by Arie Pappot, PhD candidate in metals conservation at the Rijksmuseum/University of Amsterdam.
[23] See among others Webb 2000: 109, Salmon 1701: 862-863, Dossie 1764: 428-434.
[24] Note, an additional varnish layer is applied onto the greyish shade (cross-section I., table 1).
[25] Due to cross-contamination.
[26] Piena, in press.
[27] Piena, in press.
[28] Piena, in press.
[29] See for example articles in Kühlenthal 2000a and Kühlenthal 2000b, for historical art technological examples, see Stalker and Parker 1688, Salmon 1701 and Dossie 1764.
[30] Eastaugh 2008: 46.
[31] Van Keulen 2014.
[32] These terms are often confused with tar, wood tar, pitch, peck, and mummy.
[33] Carlyle 2001: 530 (footnote 7).
[34] See for example Neu-Entdeckte Lacquir-Kunst Oder Gründliche Anweisung [...] Nützlicher Kunst-Stücke 1709: 56-58, Buonanni 1720: 78-79, Dossie 1764: 129-130, Kanold 1718: 31, Cröker 1743: 31, 33-34, 227-228, Lacombe 1789: 13, Kok 1794: 17, 19-22.
[35] Buonanni 1733: 17.
[36] See for example Stalker and Parker 1688: 19-21, Salmon 1701: 877, 890-892, Dossie 1764: 419.
[37] See among others Watin 1823: 269-270, Byrn Lafayette 1866: 45, Livache 1899: 206. Hurst 1892: 403-404, 440-441, Recipes for the Colour [...] Trades 1902: 129-130.
[38] Nunn 1996: 140, 144.
[39] Nagaraj 2009: 109-122. Gilbert 1941: 386.
[40] Karak 2012.
[41] Livache 1899: 210, Recipes for the Colour [...] Trades 1902: 111-119, Andrés 1904: 4.
[42] The fine and narrow ageing cracks in the painted decorations, ageing cracks in the surface of the dammar varnish, drying cracks in the oil-resin varnish, a secondary craquelure (checking) in the oil-resin varnish and a fine-lined craquelure (crazing) on the stand.
[43] De Willigen 1999: 15-16.
[44] Mills and White 1994: 40.
[45] Mallégol, Gardette and Lemaire 2000: 257-263, and 2001: 121-131, Dietemann et al. 2009: 30-40, Feller 1976: 288.
[46] AIC wiki 'White surface hazes'.

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