National Gallery Technical Bulletin

Volume 9, 1985

Published by Order of the Trustees,
Publications Department,
National Gallery, London

National Gallery
Technical Bulletin

Garry Thomson, Scientific Adviser

Martin Wyld, Chief Restorer

Ashok Roy: Editor

ISBN 0 901791 97 0
ISSN 0140 – 7430

Designed by James Shurmer

Printed by Westerham Press,
Westerham, Kent

Lining and Colour Change: Further Results

Sarah Staniforth and David Bomford

We report here further results in our investigation into the colour changes of paintings which result from the use of various lining adhesives.

Our earlier article [1] considered the general problem of darkening and colour change in lined canvas paintings and the use of reflectance spectrophotometry in monitoring any changes that occur. The darkening effects of two beeswax–resin formulations upon canvases of different weights and upon single and double layers of various grounds were reported.

It was acknowledged then — and remains true — that measuring these effects on bare canvases and recently prepared grounds is not wholly realistic and that the situation with real, aged paintings must be somewhat different. However, with real paintings there are other variables to consider when carrying out spectrophotometry, such as discoloured varnishes and dirt trapped on or within the various layers of the picture. The lining process inevitably disturbs these layers and in subsequent experiments carried out on aged paintings we have found it impossible to be sure that any changes observed are an absolute measure of the colour change caused by the lining adhesive alone.

We therefore conducted experiments similar to those carried out before, using newly prepared grounds on a medium-weight canvas. As will be seen below, this was not without its problems either, since another variable — that of surface texture changes in the samples — had an effect on some of the experimental results.

The lining adhesives chosen were the two currently most in use at the National Gallery: a traditional aqueous glue–paste mixture used in conjunction with hand-ironing, and Beva 371, a synthetic adhesive based on ethylene vinyl acetate copolymers and developed specifically for the lining process [2].

The glue–paste mixture in use here [3] is similar to many others used over the last two centuries or more, in studios throughout Europe. Hand-lining using this kind of adhesive is a difficult — and, in inexperienced hands, a dangerous — operation, but the ageing characteristics of such a lining are well-known through long use. One of the principal disadvantages is the vulnerability of glue-based adhesives to humidity change, mould and so on. To combat this, it is fairly common practice to iron beeswax or some other moisture barrier into the back of the lining canvas when the adhesive is dry. In the experiments described here, the effects of glue–paste with and without subsequent beeswax impregnation are studied.

Beva 371 was developed as one of the most versatile of the new generation of heat-seal adhesives. Unlike hot-melts such as traditional wax–resin mixtures which are applied molten, Beva 371 is applied in solution. Also unlike wax–resin, Beva 371 does not flow uncontrollably when heat-activated; it combines powerful surface tack with high viscosity and therefore will remain on the surface of a fabric if required. However, its versatility lies in the fact that it can be made to flow and impregnate under more extreme conditions. We were interested to find out whether, when constrained to act as a hot-melt adhesive, Beva 371 would cause a darkening in any way comparable to that already observed for wax–resin, and whether, when used correctly as a heat-seal adhesive it would cause any darkening at all.

Experimental

Medium-weight linen canvas was stretched over two 18-inch square stretchers and sized with dilute rabbit-skin glue. No significant differences in the degree of discoloration in canvases of different weights had been observed in the previous tests and so only one type of medium-weight canvas was used this time.

The two canvases were prepared identically with strips of the following grounds:

1. Flake white (Winsor & Newton), single and double layers.
2. Titanium white acrylic primer (Winsor & Newton), single and double layers.
3. Gesso (gypsum in rabbit-skin glue), single and double layers.
4. Chalk in rabbit-skin glue, single and double layers.
5. Red ochre in rabbit-skin glue, single layer only. This was deliberately prepared under-bound so that the lining adhesives were more likely to penetrate the layer.

A more limited range of grounds was selected than for the previous tests; the 'Doerner' emulsion and the three coloured-oil-grounds were omitted. It was felt that the grounds selected here would demonstrate any colour changes that could be detected.

Numbered circles were drawn on each of the grounds and on the exposed canvas (Fig.1) for positioning of the reflectance measurements before and after treatment. The left and right ends of each test strip were treated with the chosen adhesive and the centre was left untreated as a control.

On the first canvas, glue–paste was applied to the back (except to the central control area which was masked off) and a conventional hand-lining on to fine linen carried out by ironing from the front through dry Eltoline tissue. The control area was ironed in exactly the same way to allow for any texture changes that might be detected during reflectance measurements. When the adhesive was properly dry, pure beeswax was ironed into the back of the lining at one end of the test strips only: the effects of glue–paste with and without subsequent wax impregnation were thus measured.

Table 1 Colour differences before and after wax–resin impregnation.

Ground	**Δ***E* **(Ketone N–beeswax)**	**Δ***E* **(Dammar–beeswax)**	**Δ***E* **(Control)**
Aqueous			
Gesso (thin)	−2.69	−1.34	−0.60
Gesso (thick)	−1.36	−1.22	−0.69
Chalk (thin)	−1.18	−0.35	+0.29
Chalk (thick)	+0.18	+0.16	+0.31
Ochre	−10.52	−9.96	+0.22
Oil			
Flake white (thin)	−2.63	−1.54	—
Flake white (thick)	−2.38	−1.28	−0.54
Acrylic			
W & N primer (thin)	−2.68	−2.43	—
W & N primer (thick)	−1.35	−1.48	+0.47
Canvas			
Medium	−21.57	−21.86	+0.35

The negative and positive signs before the ΔE values indicate how L^*, the luminance, has varied during the lining process. A negative sign is used when L^* has decreased (the sample has apparently darkened). A positive sign is used when L^* has increased.

Table 2 Colour differences before and after lining with paste.

Ground	**Δ***E* **(Paste)**	**Δ***E* **(Paste–wax impregnation)**	**Δ***E* **(Control)**
Aqueous			
Gesso (thin)	−0.12	+0.22	+0.45
Gesso (thick)	+0.50	+0.56	+0.53
Chalk (thin)	−0.27	−0.31	+0.60
Chalk (thick)	+0.25	+0.24	+0.46
Ochre	−6.08	−8.33	+0.61
Oil			
Flake white (thin)	−0.97	−1.50	+0.42
Flake white (thick)	−0.94	−1.28	−0.39
Acrylic			
W & N primer (thin)	−0.86	−1.22	+0.52
W & N primer (thick)	−0.56	−0.76	−0.30
Canvas			
Medium	−1.52	−7.44	+0.52

For the second set of tests, the *lining* canvas was treated with three coats of Beva 371, rolled on and allowed to dry between applications. This is a typical procedure for a 'nap-bond' heat-seal lining in which only minimum surface contact between the adhesive and the back of the picture canvas is required. In this experiment, however, we also required the Beva to act as a hot-melt impregnating adhesive. For this purpose, additional Beva was brushed on to the back of one half of the test canvas. The control area was isolated from the adhesive throughout by two thicknesses of silicone-coated Melinex.

The lining was carried out on a hot-table using silicone-coated Melinex as a membrane. The temperature was raised to the heat-seal activation level of 65°C, and the surface was lightly rolled with a soft roller to simulate a typical lining. The test canvas was then removed for colour measurement on the control area and on the half prepared only for heat-seal lining.

The test canvas was returned to the hot-table and the

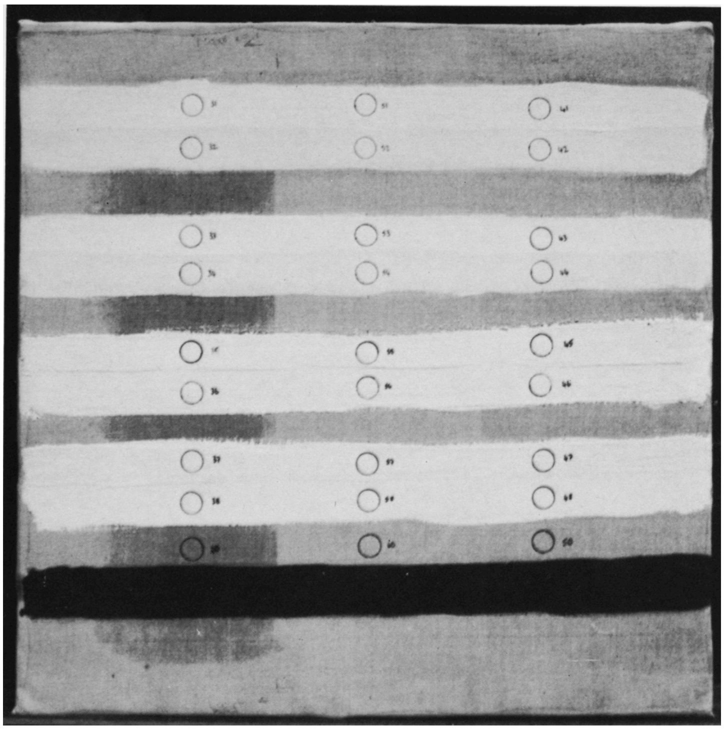

Figure 1 One of the test canvases. The left side is impregnated with Beva 371; on the right, Beva 371 has been correctly used as a heat-seal adhesive.

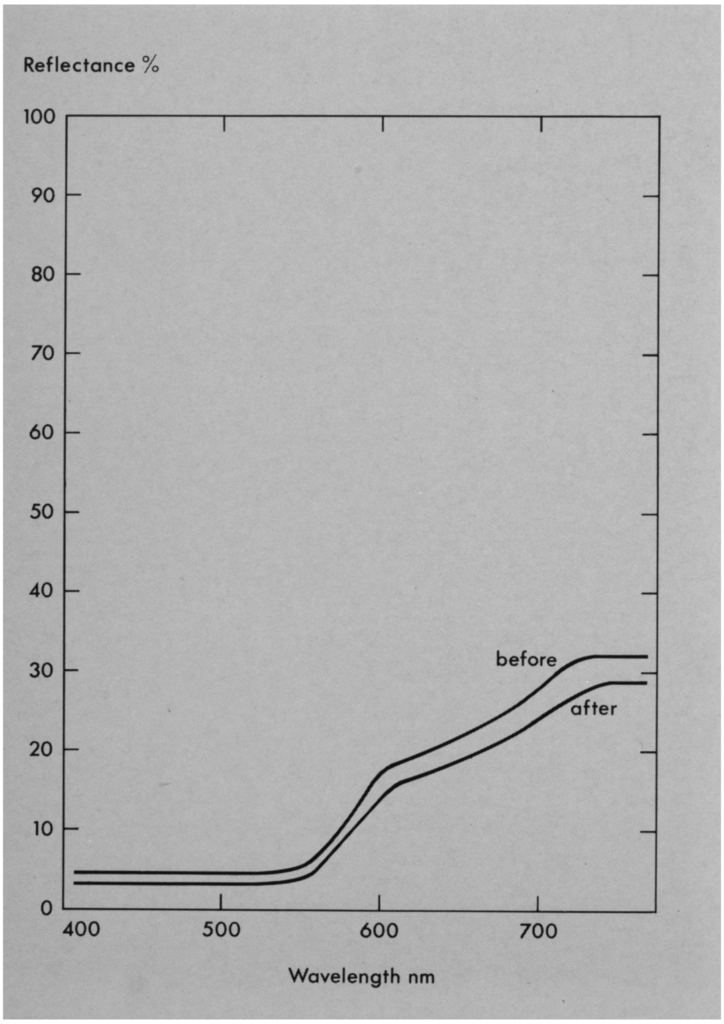

Figure 2 Reflectance curves for poorly-bound aqueous ochre ground before and after lining with paste ($\triangle E = 6.08$).

temperature raised to above 80°C. At this level, the additional Beva on the back of the other half of the test canvas was persuaded to flow and impregnate. After removal from the table, reflectance measurements were made for this area also.

Results

The reflectance curves were recorded every 10 nm from 400–760 nm and the results were used to calculate the CIE 1976 $L^\star a^\star b^\star$ chromaticity data [4]. For comparison, the results from the earlier article on this subject were converted into this colour space (they had been given in the CIE 1976 $L^\star u^\star v^\star$ system which is more correctly used for the chromaticity of light sources). Colour differences were calculated using the formula:

$$\triangle E = (\triangle L^{\star 2} + \triangle a^{\star 2} + \triangle b^{\star 2})^{\frac{1}{2}}$$

Wax–resin

The colour differences recorded in the previous experiment are given in Table 1. Darkening is apparent for all of the ground layers with the exception of chalk. The canvas and poorly-bound ochre ground have darkened because the refractive index of the medium surrounding the textile fibres, in the case of the former, and the pigment particles, in the case of the latter, has changed from air to that of the wax–resin adhesive. The other grounds have darkened because the darkening of the canvas shows to a greater or lesser extent through the overlying layers. These effects are discussed in detail in [1].

Paste and paste impregnated with wax

The values of $\triangle E$ for these treatments are given in Table 2. As in the CIE 1976 $L^\star u^\star v^\star$ space a colour difference, $\triangle E > 1$ in the CIE 1976 $L^\star a^\star b^\star$ colour space can be considered a significant result representing a measurable change in colour. We should note, however, that in many areas of this colour space a colour difference of $\triangle E > 0.5$ may be perceived.

The colour differences for the control areas which were ironed during the lining process but were not impregnated with adhesive are all less than 1. The most significant result for colour change after lining with paste is for the poorly-bound ochre ground. This shows a darkening of $\triangle E = 6.08$. The reflectance curves for this area are illustrated in Fig.2. As with the darkening during wax–resin impregnation this is the effect of the change of refractive index from that of air to that of the paste mixture. The bare canvas also shows a significant darkening of $\triangle E = 1.52$, which is the result of a similar effect.

Impregnation of the reverse of the lining canvas with wax after lining shows an increased darkening of the ochre ground and a considerably increased darkening of the bare canvas. In addition this darkening of the canvas is apparent through the thin layer of oil and acrylic grounds, demonstrated by the colour differences of 1.50 and 1.22 respectively, and of 1.28 through the thick oil ground.

It would seem from these results that ironing wax into the reverse of the lining canvas after a paste lining could be expected to have similar results, although to a lesser extent, to a full wax–resin lining and similar precautions should be observed, namely, paintings with exposed canvas or transparent ground and paint layers should be tested before proceeding with this treatment.

Beva (heat-seal and impregnation)

The colour differences recorded before and after these treatments are given in Table 3. Without doubt the most perplexing question is why (with the exception of the exposed canvas impregnated with Beva) these should all have appeared to have lightened. This is a consequence of the optical configuration within the measuring head of the spectrophotometer, in which the light is at a normal angle of incidence on the sample and is collected at 45° to the normal. This effectively eliminates any measurement of gloss on the sample [5]. If there is a change in surface texture then this will affect the reflectance readings. Polishing of the surface is visible, particularly on the oil/flake white strips, which implies an increase in gloss normally resulting in a decrease in reflectance when measured by an instrument with 0/45° optics. Why the reverse has happened is not clear.

We hesitate to draw any conclusions from these results since the experiments were performed on fresh samples of the grounds which may not have dried completely and therefore had more vulnerable surface structures than a painting which had reached the age when it required lining. The darkening of the bare canvas when impregnated with Beva at 80°C ($\triangle E = 12.95$) does indicate potential problems with paintings in which the canvas is exposed or covered with transparent ground and paint layers. It is possible that the darkening of the canvas is discernible through some of the ground layers but this effect is disguised in the reflectance readings by the change in surface texture.

There is little difference between the control areas and those in which Beva has been used as a heat-seal adhesive which suggests that any differences recorded (some of which approach or are greater than 1) are the result of surface changes during the hot-table treatment rather that the direct effect of the adhesive.

Conclusions

The most obvious measure of the effect of the adhesive is that of the darkening of the bare canvas. Comparing the colour differences measured for the six lining processes we see that the greatest darkening has occurred for the areas impregnated with the beeswax–resin mixtures. By its nature as a hot-melt adhesive beeswax–resin will flow and coat the fibres of the canvas thus altering the refractive index of the surrounding medium. Heat-seal adhesives, such as Beva, were formulated in such a way that they will provide adhesion without flowing into the materials which they are joining. Nevertheless at elevated temperatures and with a sufficient amount of adhesive present Beva can be made to flow and behave as a hot-melt adhesive.

Used as an impregnating, hot-melt adhesive Beva shows an appreciable darkening of the bare canvas, although only about half of that which occurs with beeswax–resin. But used as intended, as a heat-seal adhesive, no darkening of the canvas was detected.

The glue–paste adhesive is analogous to the beeswax–resin mixtures in that it impregnates the whole

Table 3 Colour differences before and after lining with Beva.

Ground	ΔE (Beva—heat-seal 65°C)	ΔE (Beva–impregnation 80°C)	ΔE (Control)
Aqueous			
Gesso (thin)	+1.07	+1.26	+0.98
Gesso (thick)	+0.71	+1.13	+0.90
Chalk (thin)	+0.70	+1.55	+0.99
Chalk (thick)	+0.95	+1.29	+0.53
Ochre	+0.31	+1.82	+0.40
Oil			
Flake white (thin)	+0.68	+0.70	+1.49
Flake white (thick)	+0.97	+2.03	+1.39
Acrylic			
W & N primer (thin)	+0.83	+0.66	+0.17
W & N primer (thick)	+0.95	+0.46	+0.51
Canvas			
Medium	+1.18	−12.95	+1.45

The colour differences given for the control areas are those recorded before and after treatment on the hot-table at 65°C; they are therefore more comparable with the results in the first column than in the second.

structure of the painting. However the darkening effect of the paste used on its own is very much less than that of either Beva used as a hot-melt adhesive or beeswax–resin.

It is unlikely that the paste forms a continuous layer within the canvas and this is confirmed by the fact that when wax is ironed into the reverse of the lining canvas it penetrates unevenly. The colour difference measured for this situation indicates that the wax penetration is not as complete as for beeswax–resin lining. In practical terms, however, the same caution should be exercised as with a normal wax–resin lining.

The second type of darkening demonstrated in these tests is exemplified by the colour differences recorded for the poorly-bound ochre ground after impregnation with beeswax–resin and paste. Here again the refractive index of the medium surrounding the pigment particles has increased from that of air to that of the adhesives. In the case of the well-bound grounds the continuous nature of the binding medium prevents penetration of the lining adhesive so that any darkening recorded must be the result of the transparency of the ground layers showing the darkened canvas.

Our experiments show that the technique of lining can have a significant effect on surface textures which the reflectance spectrophotometer can detect and record as a relative lightening. However to the human eye this is perceived as a polishing of the surface. It has long been known that the use of films such as Melinex over an unfaced picture could adversely affect the surface. The polishing effects recorded for linings performed using the hot-table are likely to be more severe for the tests than in the case of real pictures because of the relative newness of the samples.

Acknowledgement

Our thanks to Ann Stephenson-Wright who carried out most of the practical work on the lining of the test canvases.

Notes and references

1. Bomford, D. and Staniforth, S., 'Wax–Resin Lining and Colour Change: An Evaluation', *National Gallery Technical Bulletin,* **5** (1981), pp. 58–65.

2. See for example, Berger, G., 'Testing Adhesives for the Consolidation of Paintings', *Studies in Conservation,* **17,** 4 (1972), pp. 173–94.

3. The traditional recipe used at the National Gallery for many years is: $2\frac{1}{4}$lb plain flour, $3\frac{1}{2}$lb Croid Aero glue (animal glue) and 8 pints of water. The melted glue is added to the stirred flour and water mixture and heated in a double boiler for about one hour, with continuous stirring.

4. Commission Internationale de l'Éclairage, 'Recommendations on uniform color spaces, color-difference equations, psychrometric color terms', supplement No.2 to *CIE Publication No.15 (E-1.3.1), 1971/(TC-1.3)*(1978).

The CIE $L^\star a^\star b^\star$ coordinates are calculated from the CIE 1931 X,Y,Z tristimulus values using the following formula:

$$L^\star = 116\,(Y/Y_n)^{\frac{1}{3}} - 16$$

$$a^\star = 500\,[(X/X_n)^{\frac{1}{3}} - (Y/Y_n)^{\frac{1}{3}}]$$

$$b^\star = 200\,[(Y/Y_n)^{\frac{1}{3}} - (Z/Z_n)^{\frac{1}{3}}]$$

The tristimulus values X_n, Y_n, Z_n define the colour of the light source, D65.

5. Changes in gloss may be recorded using certain types of reflectance spectrophotometers. An integrating sphere with a gloss trap may be used to record reflectance readings with and without the gloss component. Unfortunately we do not have access to such an instrument and therefore can only speculate about the changes in surface texture.