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Wax–Resin Lining and Colour Change: An Evaluation

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As many as ten 'detrimental and irreversible effects' have been described [1,2] in connection with the wax lining and impregnation of canvas paintings, processes that were, until recent years, applied almost uncritically. It is now generally accepted that the impregnation of a canvas painting with any adhesive is fundamentally irreversible, but in many cases where the structure of a painting is breaking down there may be no practical alternative to consolidation by means which disobey the basic ethic of reversibility. Neither is the problem confined to paintings alone: conservators of wood and stone are frequently faced with the choice of stabilizing an object irreversibly or allowing it to decay.

It may, therefore, be unrealistic to insist on absolute reversibility in consolidation treatments: but it then becomes even more important that materials used should neither deteriorate in themselves nor have immediate or long-term detrimental effects on the treated object.

Impregnation and lining of canvas paintings have been carried out using glue and drying oils, either separately or mixed in an emulsion, since the seventeenth century [3]; the use of beeswax as the basis for a lining adhesive probably began in the eighteenth century, but little is documented before the lining of Rembrandt's 'Night-Watch' in 1851 [4]. At first beeswax alone was used: as late as 1929 one of the leading European restorers still recommended pure molten beeswax [5], but long before this it had been discovered that addition of resins such as dammar and mastic, or balsams such as Venice turpentine improved adhesive and mechanical properties.

In the early 1930s the first scientific tests were carried out on lining adhesives in general [6] and wax-based adhesives in particular [7]. For the first time, the defects of various formulations were openly discussed. The disadvantages of glue and glue-paste mixtures were already well-known: in particular, their tendency to cause shrinkage, their brittleness, insolubility and putrefaction and their great vulnerability to changes in humidity.

Wax – resin adhesives appeared to have none of these drawbacks. Both beeswax and paraffin wax, with or without added resins, were inert, stable, remained soluble and were unaffected by moisture. Moreover, they seemed ideal for the particular requirements of the lining process in terms of melting point, viscosity and so on.

It was instinctively realized at that time that impregnation with lining adhesives could result in tonal changes in a painting, although the mechanism was at first misunderstood. It was thought that the inherent colour of the adhesive itself was the only thing that mattered, not its interaction with the materials present in the painting: 'Discoloration or stain is a defect which can be dismissed from extensive consideration because it is almost entirely apparent at the time when the adhesive is made up [. . .] wax – resin combinations are much less dark [than oils] and probably less apt to change color, but the technique of lining might be improved by bringing this type of adhesive to a lighter and clearer tone [8].'

But it could hardly go unnoticed that the discoloration caused by lining adhesives in some pictures was more than simply a function of their own colour: 'if the wax mixture penetrates exposed portions of the ground, they are almost certain to go lower in tone and so alter their relation to the superimposed or adjoining touches of pigment. This question of altered values, due to a change in the refractive index of the mediums or to impregnations with mediums of a character differing from those originally used, is a frequent source of distortion in the colour values of restored pictures [9].' Impregnation with 'some medium analagous to that originally used in producing the picture' was recommended.

But even this traditional view — that oil paintings could be impregnated with wax adhesives whereas glue and tempera paintings could not — was not wholly consistent with the observed facts. Some oil paintings were considerably darkened by impregnation, while some tempera paintings were apparently unaffected. It was difficult to predict what the effect would be. The only certainty was that any painting in which the canvas itself played a visible role should not be treated in this way. For the rest, it was the responsibility of the restorer to distinguish those paintings that would be affected.

Other possible disadvantages of wax – resin impregnation have been investigated since. The difficulty of subsequent consolidation with other materials [10], cracking of paint films and loss of resistance to solvents and abrasion [11,12], and alteration in the tensile properties of canvas [13,14] have all been reported.

Current research into lining materials and methods has moved away from impregnation techniques [15 – 18]. The different objectives of the lining process — fixing of flaking paint, reinforcement of support and elimination of deformations — can be achieved in separate operations which do not necessarily require overall impregnation. In some cases lining can be avoided altogether [19].

Yet in most restoration studios throughout the world, lining and relining of pictures by traditional methods is still a necessary and routine activity. A competent restorer will be aware of the dangers and limitations of a particular method and the possibility of darkening and colour change will be a major concern.

Until recently the degree of darkening, if any, was merely a matter of subjective opinion. Of course, it is easy enough to point to pictures undoubtedly affected, such as the Mantegna 'Triumphs of Caesar' at Hampton Court, saturated with wax in the 1930s [20], but the effects on easel paintings are usually somewhat more subtle than that.

Although very many paintings may be wax-lined without any appreciable change in their surface appearance it has been mentioned above that the paintings most likely to be susceptible to colour change or darkening after wax – resin lining are those in which there may be areas of exposed canvas or ground.

As a preliminary study, the effects of impregnation with traditional wax – resin mixtures on linen canvases and a number of prepared grounds were investigated. Recipes for grounds on canvas are numerous and may be found in standard handbooks on painting technique [21,22]. Grounds found in European paintings from the sixteenth to the twentieth centuries have been described [23] and are frequently reported in studies on individual painters in this *Bulletin* and elsewhere. The deterioration of grounds has also been discussed, together with the significance of lining and impregnation as both cause and remedy [3].

Colour measurement and conservation

The use of the Wright-Wassall reflectance spectrophotometer in the Scientific Department of the National Gallery to record surface colours of paintings in the Collection and to monitor colour changes that may be occurring while the paintings are on exhibition has been reported in a previous issue of this *Bulletin* [24]. The instrument may also be used to monitor changes that may occur as the result of conservation treatment.

Methods of colour measurement have not been widely used in the conservation of paintings but there are a few reported instances. The changes in colour that result from the removal of a discoloured varnish from a painting were recorded using a Lovibond tintometer (a visual colorimeter) by F.I.G. Rawlins, the first Scientific Adviser to the Trustees of the National Gallery [25]. Reflectance spectrophotometric measurements have also been used to assess the effect upon colour of varnish removal, and the information gained has the advantage over visual colorimetric measurements of being objective and more detailed [26,27].

Reflectance spectrophotometry is also an appropriate technique to use for the detection of any darkening or colour change that may occur as a result of the wax – resin impregnation and lining of paintings. The darkening of an unprimed canvas following its wax – resin impregnation is a phenomenon of which conservators are well aware but other changes in the ground and paint layers may be less noticeable. Since the whole of the painting is impregnated before a wax – resin lining a subtle overall change may go unnoticed and undetected. Reflectance spectrophotometry provides a sensitive and objective method for quantifying any change that may occur and for discovering whether the change is an overall darkening or lightening or an actual change in colour or both.

The experiment described below represents a preliminary investigation to determine the types of paintings that might be susceptible to change after wax – resin impregnation. Care was taken during the experiment that the colour was the only measurable variable being affected.

Experimental procedure

Three canvases of different weights (coarse, medium and fine) were stretched on 18-inch square stretchers. they were sized with dilute rabbit-skin glue and allowed to dry.

The majority of the grounds selected for the test had been identified on paintings in the National Gallery Collection. The binding media in these grounds were either aqueous or oil. In addition it was decided to include an emulsion ground that might have been used during the nineteenth century and a commercial acrylic ground widely used in contemporary paintings.

Gesso and chalk grounds were applied in strips of two thicknesses (single and double layers) to the coarse and fine canvases respectively. Gesso grounds have been identified in late fifteenth and sixteenth century canvas paintings of the Venetian School [28]. A reference to this practice occurs in the late seventeenth or early eighteenth century 'Volpato Manuscript' [29]. A coloured aqueous ground consisting of red and yellow ochre bound in a medium of rabbit-skin glue

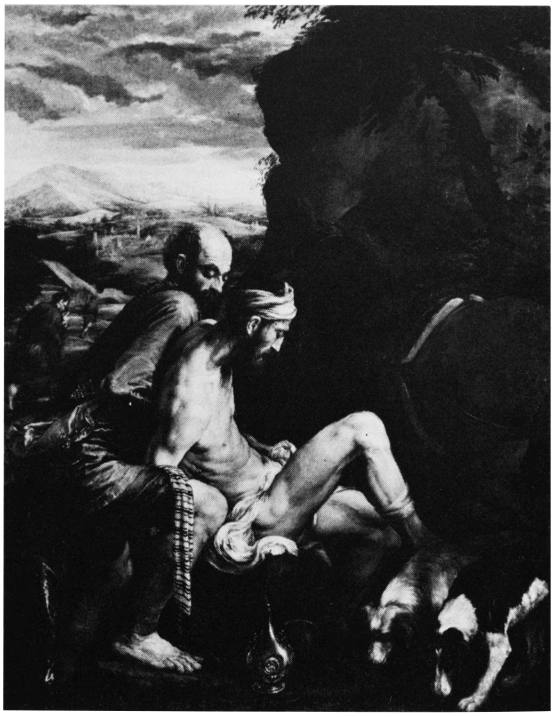


Figure 1 Bassano, *The Good Samaritan* (No.277). The ground consists of two pinkish layers containing red ochre, red lead, black and lead white bound in an oil medium.

was applied to the coarse canvas. This ground was very poorly bound to increase the likelihood of the wax – resin mixtures actually impregnating the layer.

Oil-bound grounds are most commonly found on canvas paintings since their flexibility renders them more suitable for a non-rigid support. A strip of two thicknesses of Winsor and Newton flake white oil paint was applied to the medium weight canvas. An oil ground identified in Dughet's *Landscape: Abraham and Isaac Approach the Place of Sacrifice* (No.31) [23] was simulated by adding a small amount of red lead to Winsor and Newton red ochre oil paint. A two-layer pinkish ground similar to that found in Bassano's *The Good Samaritan* (No.277) (see Fig.1) [23] was prepared by adding a small quantity of the dry pigments red ochre, red lead and black to flake white oil paint. The lower layer was slightly paler than the upper, and a strip of it was left exposed to allow measurements to be made. A Rembrandt-type double oil ground was also prepared. This has been identified in many paintings by Rembrandt and also in paintings by other Dutch artists of the seventeenth century [23]. The preparation of this ground is described in a contemporary manuscript on technique [30]. The lower layer was prepared by adding a small amount of red lead to red ochre oil paint and the upper grey layer by adding yellow ochre and black to flake white oil paint.

A recipe for a nineteenth century emulsion ground described by Doerner was followed [22]. One part of rabbit-skin glue was added to one part of zinc white and one part of chalk. The mixture was stirred on a hot plate and one-half part of linseed oil was dripped in.

Finally, thin and thick layers of Winsor and Newton acrylic primer were applied to the medium weight canvas.

On each of the three canvases strips of the unprimed canvas were left exposed.

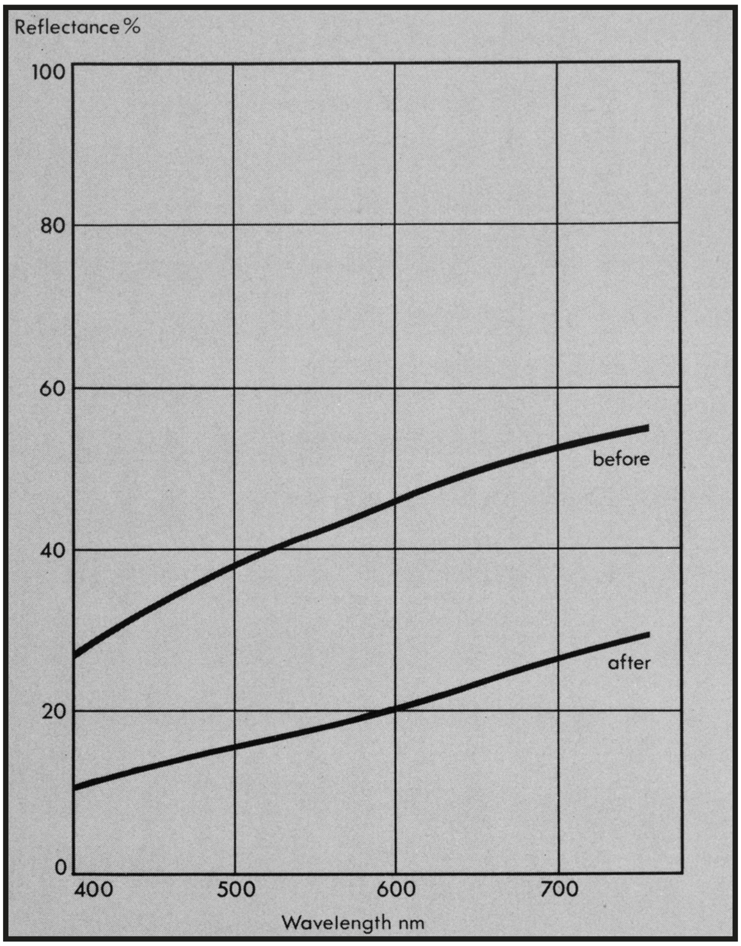
A summary of the types of ground and the weight of canvas to which they were applied is listed in Table 1 below.

Three numbered circles were drawn on each of the strips of applied grounds and on the exposed canvas. A black-and-white negative of each of these areas was taken prior to the reflectance measurement to ensure accurate relocation of the light spot after impregnation. For each area reflectance measurements were recorded at 10 nm intervals from 400 – 760 nm. The reflectance data were used to calculate the tristimulus values X, Y and Z and chromaticity coordinates x and y for the 1931 C.I.E. standard observer in a D6500 (standard daylight) illuminant. The 1976 C.I.E. $L^*u^*v^*$ values were also calculated since this colour space has a closer approximation to the eye's visual discrimination. For a description of these computations see the previous article on reflectance spectrophotometry in this *Bulletin* [24].

The canvases were divided into three areas vertically, one was impregnated with refined beeswax and dammar (in the proportion 2:1), the second was impregnated with refined beeswax and Ketone N (in the proportion 2:1) and the third was left untreated as a control. The wax – resin adhesives were melted and

Table 1 Compositions of grounds tested

Description of ground	Colour	Inerts	Pigments	Medium	Canvas weight
Aqueous					
Gesso	White	Calcium sulphate	—	Animal glue	Coarse
Chalk	White	Calcium carbonate	—	Animal glue	Fine
Ochre	Red	—	Red ochre, yellow ochre	Animal glue	Coarse
Emulsion					
'Doerner'	Cream	Calcium carbonate	Zinc white	Animal glue and linseed oil	Medium
Oil					
W & N flake white	White	?	Lead white	Linseed oil	Medium
'Dughet	Red	—	Red ochre, red lead	Linseed oil	Fine
'Bassano'	Pink	—	1. Red ochre, red lead, black, lead white 2. Red ochre, yellow ochre, red lead, black, lead white	Linseed oil	Medium
'Rembrandt'	Grey	—	1. Red ochre, red lead 2. Black, yellow ochre, lead white	Linseed oil	Fine
Acrylic					
W & N primer	White	?	Titanium white	Acrylic	Medium



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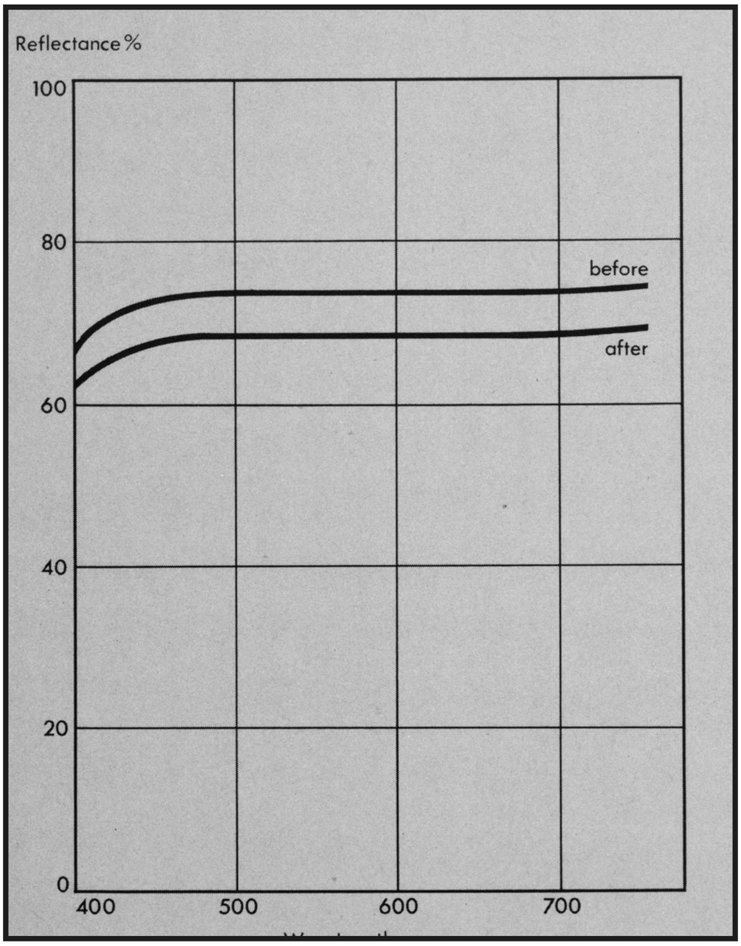

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applied to the reverse of the canvases with a brush as the canvases lay face down on a sheet of Melinex. The quantity of adhesive applied was the amount that would generally be applied when lining a painting. The wax – resin was then ironed into the reverse of the canvas using a hand-lining iron. The reverse of the unimpregnated area was also ironed to allow for any change in surface texture that might have occurred. Any change of this sort would be kept to a minimum by only lightly ironing the reverse of the canvases as they lay face down on a cushioned surface. After the canvases had cooled to room temperature they were reattached to their stretchers and any excess wax that had penetrated to the front was removed by wiping with white spirit.

The reflectance of each area was remeasured and the colour difference, ΔE, was calculated for the impregnated and control areas. There is a description and example of the colour difference calculation in the Appendix on p.64. There is also an example of the results for one sample area. There are examples of reflectance curves in Figs.2 – 5. A summary of the results is given in Table 2 (p.63). A photograph of the medium weight canvas with strips of prepared grounds after impregnation with the wax – resin adhesives is shown in Plate 9 (p.43).

Results and discussion

If the spectral reflectance is lower after wax – resin impregnation than before then visually this is observed as a darkening of the sample. As far as the C.I.E. $L^*u^*v^*$ values are concerned this results in a reduction of the L^* value. Within the limits of experimental accuracy a value of the colour difference $\Delta E>1$ can be considered a significant result representing a measurable change in colour. In many areas of the C.I.E. $L^*u^*v^*$ colour space, a colour difference of $\Delta E = 0.5$ may be perceived. The larger the value of ΔE the more noticeable the difference.

It can be seen from Table 2 that all of the values of ΔE for the control area (the area that was ironed but not impregnated) show $\Delta E<1$ with the exception of the coarse canvas. It is likely that ironing the coarse canvas resulted in a change in surface texture that was detected by the spectrophotometer.

Although there are differences between the changes resulting from impregnation with the Ketone N – beeswax mixture and the dammar – beeswax mixture these differences are not consistent and do not suggest that one mixture has a greater effect on colour or darkening over the other.

The maximum colour differences observed were in the unprimed canvases. No significance can be attached to the relative ΔE values between the coarse, medium and fine canvases. These differences probably

Figure 2 *(Left, above)* Reflectance curves for medium weight canvas before and after impregnation with Ketone N – refined beeswax. ($\Delta E = 21.65$)

Figure 3 *(Left, below)* Reflectance curves for Winsor and Newton flake white oil paint (thin layer on medium weight canvas) before and after impregnation with Ketone N – refined beeswax. ($\Delta E = 2.65$)

result from the different original colours of the canvases.

This darkening of the canvases is caused by the replacement of the air that originally surrounded the textile fibres with a medium of higher refractive index, that is, the wax – resin lining adhesive. The refractive index of air is 1 whereas that of the mixture is approximately 1.5. When the textile fibres are surrounded by a lower refractive index medium there is a larger component of scattered visible light which results in the canvas appearing lighter than when impregnated with a higher refractive index medium when the absorption of visible light is increased.

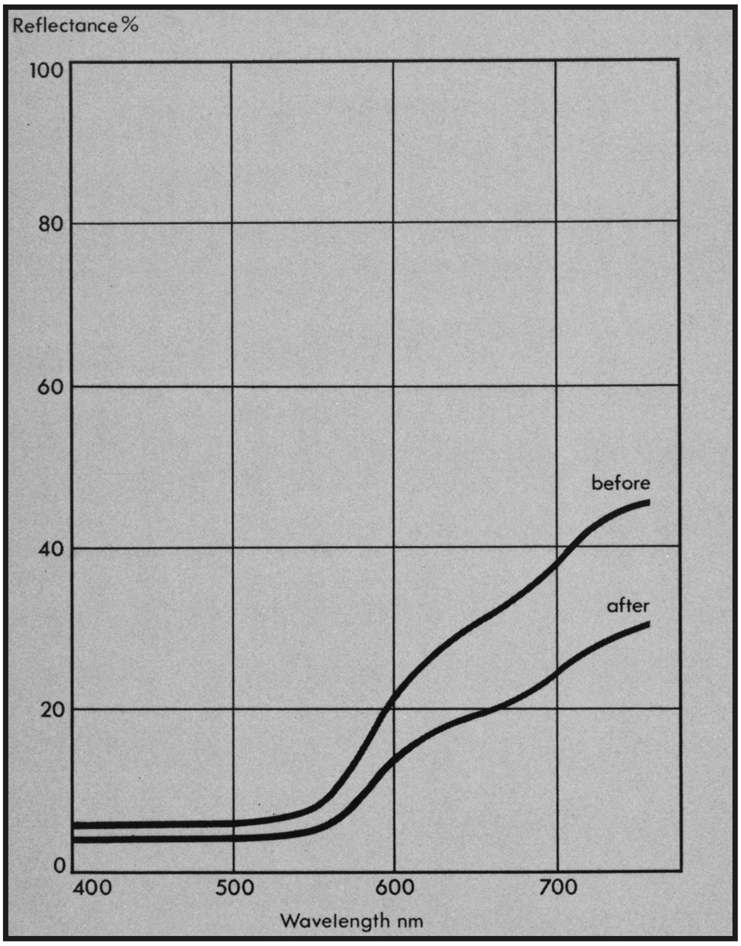
There is no evidence from the results to suggest that the weight of canvas to which the primings were applied affected the degree of darkening although this could only be properly tested by applying each of the grounds to each of the canvases in layers of equal thickness. Intuitively it would seem more probable that a coarse canvas with a pronounced weave structure might have more effect on darkening since some of the impregnated canvas threads might protrude through a thinly applied ground layer.

It would appear that any darkening of the painting caused by wax – resin adhesive is a two-stage process. The first is the darkening of the canvas support observed in the results for the unprimed canvases and which may also be seen on the reverse of the impregnated supports. This darkening may be concealed to a greater or lesser extent according to the thickness and transparency of the superimposed ground layer.

The transparency of a ground layer depends upon the relative refractive indices of the pigments, inert materials and binding media. When the refractive index of the binding medium approaches that of the inert materials and pigments, the ground will increase in transparency. For example, a ground prepared from chalk bound in oil is far more transparent than that resulting from chalk bound with glue.

The second stage of darkening occurs when the wax – resin penetrates into the ground layer itself. In a poorly (leanly) bound ground, where there is a small proportion of medium compared with pigment and inerts it is possible for a second medium, in this case the wax – resin, to penetrate into the ground layer and to surround some, if not all, of the pigment and inert material particles. In effect, it changes the refractive index from that of air to that of the wax – resin mixture. As with the impregnation of the raw canvases the visible result is a darkening of the sample. In a well bound ground the pigment and inert material particles are completely surrounded by the medium and the wax – resin is unable to penetrate into the layer.

The ochre aqueous ground, which was very poorly bound, shows a large colour difference after impreg-



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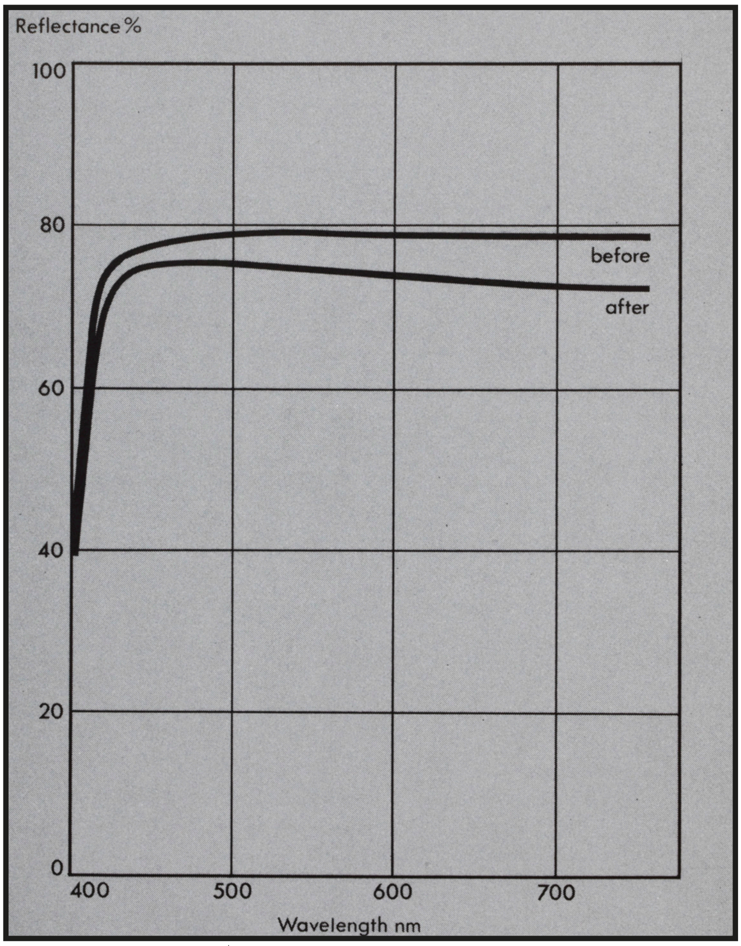

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Figure 4 *(Right, above)* Reflectance curves for aqueous ochre ground (on coarse canvas) before and after impregnation with Ketone N – refined beeswax. ($\Delta E = 15.44$)

Figure 5 *(Right, below)* Reflectance curves for Winsor and Newton acrylic primer (thin layer on medium weight canvas) before and after impregnation with Ketone N – refined beeswax. ($\Delta E = 2.80$)

Table 2 Colour differences before and after wax – resin impregnation

Ground	ΔE (Ketone N – beeswax)	ΔE (Dammar – beeswax)	ΔE (Control)
Aqueous			
Gesso (thin)	2.75	1.48	0.85
Gesso (thick)	1.40	1.29	0.82
Chalk (thin)	1.31	0.46	0.38
Chalk (thick)	0.25	0.16	0.51
Ochre	15.44	13.97	0.21
Emulsion			
'Doerner'	1.88	2.47	0.91
Oil			
Flake white (thin)	2.65	1.62	—
Flake white (thick)	2.38	1.29	0.71
'Dughet'	0.54	0.45	0.44
'Bassano' (layer 1.)	1.80	1.48	—
'Bassano' (layer 2.)	1.59	1.32	0.34
'Rembrandt'	0.33	0.21	0.57
Acrylic			
W & N primer (thin)	2.80	2.87	—
W & N primer (thick)	1.43	1.49	0.67
Canvas			
Coarse	22.01	17.29	1.19
Medium	21.65	21.86	0.54
Fine	19.08	13.80	0.65

All colour differences in the ΔE (Ketone N – beeswax) and ΔE (Dammar – beeswax) that are <1 result from a reduction in L^*, that is to say, the samples are darker (lower reflectance) after impregnation than before.

nation because the wax – resin has effectively replaced air as the medium surrounding the pigment particles. A poorly bound ground might result from poor preparation (as in this case) or from deterioration of the medium. In this experiment natural ageing played no part since the grounds were freshly prepared, but in real pictures deterioration of the binding medium becomes an important factor. It is hoped that future experiments will study this effect.

The differences that are observed between all the grounds in this experiment (other than the aqueous ochre ground) are a consequence of their different transparency and thickness of application. Where two thicknesses of ground have been applied, in all cases, the thin layer has darkened more than the thick. For example, the thin layer of acrylic primer shows colour differences of 2.80 and 2.87 with the two adhesives, whereas the thick layers only change by 1.43 and 1.49. Since the binding medium and pigments and inert materials for the thin and thick samples is constant the greater colour change in the thin layer can only be due to its reduced covering power with respect to the thicker allowing the darkening of the canvas to show through to a greater extent. This is equally true for the other samples applied in two layers.

It is not possible from the results of this experiment to draw any conclusions about the relative transparencies of the various prepared grounds since there was no control over their thickness of application. That is to say, the magnitude of change in the thin layer of acrylic primer is not directly comparable to that in the thin layer of flake white oil primer, nor to any other of the single layers of grounds.

Three of the areas of the chalk sample, and the 'Dughet' and 'Rembrandt' type grounds do not show significant colour changes. This is because they all have sufficient covering power to conceal the underlying effect of the darkening of the canvas.

Conclusion

Whilst this experiment is by no means exhaustive of the possible types of ground that may be found on canvas paintings and does have limitations in its comparability to the real situation of a painting that has undergone a natural deterioration of the canvas, ground and paint layers, it does draw attention to possible dangers that may be encountered in the wax – resin lining of paintings with certain grounds.

In the future it is hoped that a study will be made of the effects of impregnation and lining on paintings that have aged naturally. Further work will be carried out on the effects on colour of lining with other types of adhesives.

This article serves as an introduction to the applications of reflectance spectrophotometry in monitoring colour changes during conservation treatments. In addition to further experimental work a future article will include a statistical interpretation of such results and will explain more fully the significance of measured colour differences and their relationship to visual perception.

Appendix 1

Example of set of results: Winsor and Newton acrylic primer (thin layer on medium weight canvas) impregnated with Ketone N – beeswax

Wavelength (nm)	*Reflectance before impregnation (%)*	*Reflectance after impregnation (%)*
400	40.7	39.2
410	64.9	62.2
420	75.0	72.8
430	76.7	74.7
440	77.3	75.2
450	77.8	74.9
460	78.1	75.0
470	78.6	75.5
480	78.5	75.2
490	78.6	75.4
500	78.5	75.2
510	79.2	74.5
520	79.4	74.2
530	78.8	74.7
540	79.0	74.5
550	79.0	74.6
560	78.7	74.4
570	78.9	74.0
580	78.6	74.3
590	78.6	74.0
600	78.4	74.2
610	78.6	73.9
620	78.3	73.7
630	78.0	73.6
640	78.2	73.3
650	77.8	73.5
660	77.9	73.1
670	78.3	72.6
680	78.2	72.7
690	77.9	72.3
700	78.0	72.2
710	78.0	72.0
720	77.9	71.8
730	78.2	72.2
740	78.3	72.3
750	78.4	72.2
760	78.2	71.9

C.I.E. 1931 tristimulus values X,Y,Z and chromaticity coordinates x and y

Before impregnation	*After impregnation*
$X = 74.34$	$X = 70.37$
$Y = 78.75$	$Y = 74.35$
$Z = 84.14$	$Z = 81.10$
$x = 0.3134$	$x = 0.3116$
$y = 0.3319$	$y = 0.3292$

C.I.E. 1976 coordinates $L^*u^*v^*$

Before impregnation	*After impregnation*
$L^* = 91.12$	$L^* = 89.09$
$u^* = -0.71$	$u^* = -0.93$
$v^* = 1.88$	$v^* = -0.13$

ΔE, Colour difference between before and after impregnation calculated using the following formula:

$$\Delta E = (\Delta L^{*2} + \Delta u^{*2} + \Delta v^{*2})^{\frac{1}{2}}$$
$$= ((L_b^* - L_a^*)^2 + (u_b^* - u_a^*)^2 + (v_b^* - v_a^*)^2)^{\frac{1}{2}}$$

Where the subscripts b and a indicate C.I.E. $L^*u^*v^*$ coordinates before and after impregnation, respectively.

For this example the colour difference is:

$$\Delta E = ((91.12 - 89.09)^2 + (-0.71 + 0.93)^2 + (1.88 + 0.13)^2)^{\frac{1}{2}}$$
$$= 2.87$$

Fig.6 shows a detail of the C.I.E. $L^*u^*v^*$ diagram near the neutral point illustrating this colour change.

References

1. BERGER, G. and ZELIGER, H., 'Wax Impregnation of Cellulose: An Irreversible Process', *Conference on Comparative Lining Techniques* (Greenwich 1974).

2. BERGER, G. and ZELIGER, H., 'Detrimental and Irreversible Effects of Wax Impregnation on Easel Paintings', *ICOM Committee for Conservation, 4th Triennial Meeting* (Venice 1975) (75/11/2).

3. PERCIVAL-PRESCOTT, W., 'The Lining Cycle', *Conference on Comparative Lining Techniques* (Greenwich 1974).

4. SCHENDEL, A. VAN and MERTENS, H., 'De Restauraties van Rembrandt's Nachtwacht' *Oud Holland*, **62** (1947), pp.1 – 52.

5. WILD, A.M. de, *The Scientific Examination of Pictures*, Bell (London 1929).

6. STOUT, G.L. and GETTENS, R.J., 'The Problem of Lining Adhesives for Paintings', *Technical Studies in the Field of Fine Arts*, **II** (1933), pp.81 – 104.

7. PLENDERLEITH, H.J. and CURSITER, S., 'The Problem of Lining Adhesives for Paintings: Wax Adhesives', *Technical Studies in the Field of Fine Arts*, **III** (1934) pp.90 – 113.

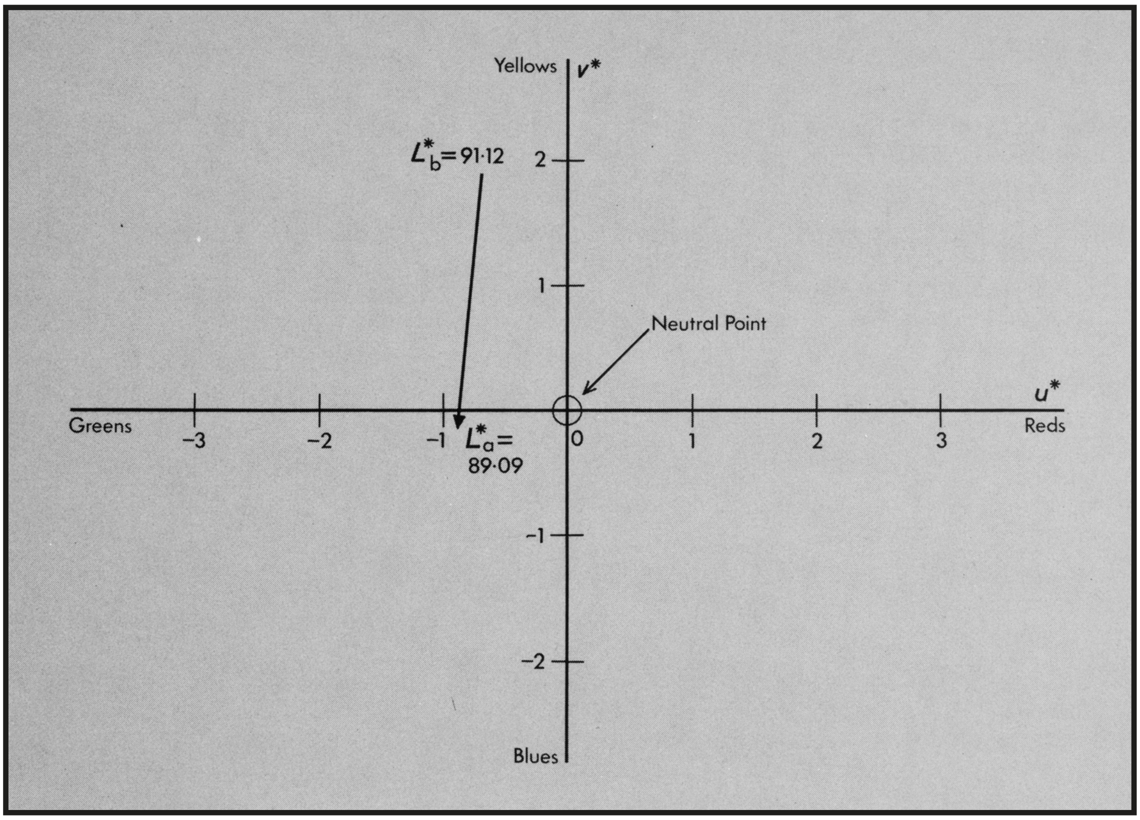

Figure 6
Detail of C.I.E. $L^*u^*v^*$ diagram near neutral point, illustrating change in colour of Winsor and Newton acrylic primer (thin layer on medium weight canvas) before and after impregnation with Ketone N – refined beeswax.

8. STOUT, G.L. and GETTENS, R.J., *op.cit.*, pp.94 – 5.

9. CURSITER, S. and WILD, A.M. de, 'Picture Relining', *Technical Studies in the Field of Fine Arts,* **V** (1937), pp.157 – 78.

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

11. BERGER, G., 'Some Effects of Impregnating Adhesives on Paint Films', *Conference on Comparative Lining Techniques* (Greenwich 1974).

12. MAKES, F. and HALLSTRÖM, B., 'Remarks on Relining' (Stockholm 1972).

13. HEDLEY, G.A., 'The Effect of Beeswax/Resin Impregnation on the Tensile Properties of Canvas', *ICOM Committee for Conservation, 4th Triennial Meeting* (Venice 1975) (75/11/7).

14. HACKNEY, S. and HEDLEY, G., 'Measurements of the Ageing of Linen Canvas', *Studies in Conservation,* **26,** 1 (1981), pp.1 – 14.

15. RABIN, B., 'A Poly (Vinyl Acetate) Heat Seal Adhesive for Lining' in N. Bromelle and P. Smith (eds.), *Conservation and Restoration of Pictorial Art,* IIC (London 1976).

16. BERGER, G., 'Heat-Seal Lining of a Torn Painting with Beva 371', *Studies in Conservation,* **20,** 3 (1975) pp.126 – 51.

17. MEHRA, V.R., 'Further Developments in Cold-Lining (Nap-Bond System)', *ICOM Committee for Conservation, 4th Triennial Meeting* (Venice 1975) (75/11/5).

18. FIEUX, R.E., 'Electrostatic Hold: A New Technique of Lining', *ICOM Committee for Conservation, 5th Triennial Meeting* (Zagreb 1978) (78/2/7).

19. BOMFORD, D., 'Moroni's "Canon Ludovico di Terzi": An Unlined Sixteenth Century Painting', *National Gallery Technical Bulletin,* **3** (1979), pp.34 – 42.

20. MARTINDALE, A., *The Triumphs of Caesar by Andrea Mantegna,* Harvey Miller (London 1979).

21. MAYER, R., *The Artist's Handbook,* Faber and Faber, 3rd ed. (London 1973).

22. DOERNER, M., *The Materials of the Artist,* Hart-Davis, Macgibbon (London 1973).

23. HENDY, P. and LUCAS, A., 'The Ground in Pictures' [with photomicrographs and commentary by Joyce Plesters], *Museum,* **XXI** (1968), pp.245 – 76.

24. BULLOCK, L.J., 'Reflectance Spectrophotometry for Measurement of Colour Change', *National Gallery Technical Bulletin,* **2** (1978), pp.49 – 55.

25. RAWLINS, F.I.G., 'Studies in the Colorimetry of Paintings, Part I' *Technical Studies in the Field of Fine Arts,* **IV** (1936) pp.179 – 86.

26. JOHNSON, R.M. and FELLER, R.L., 'The Use of Differential Spectral Curve Analysis in the Study of Museum Objects', *Dyestuffs,* **44,** 9 (1963), pp.1 – 10.

27. SANTINI, M., 'Determinazioni Colorimetriche Prima e Dopo il Restauro', *Bolletino dell' Istituto Centrale del Restauro,* 37 – 40 (1959) pp.204 – 208.

28. PLESTERS, J., in 'Titian's "Bacchus and Ariadne" ', section on 'The Materials and Technique', *National Gallery Technical Bulletin,* **2** (1978), p.38.

29. MERRIFIELD, M., *Original Treatises in the Arts of Painting,* Vol. II, Dover (New York 1967), p.730.

30. VAN DE GRAAF, J.A., 'Het de Mayerne Manuscript als Bron Voor de Schilder-technick van de Barok', Gedrukt door Drukkerij Verweij-Mijdrecht (1958) p.138.