ONLINE ISSN 2069-7430
ISSN-L 1841-4737
PRO LIGNO
www.proligno.ro
Vol. 19 N° 4 2023
pp. 122-132

SURFACE COATING PYROGRAPHY: FURTHER STUDY WITH UV STABILISERS

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Abstract:

Pyrography is known among practitioners to undergo fading/colour change when exposed to ultra violet radiation and visible light. Previous tests have concluded that the level of fading is governed by the temperature of the tool with which the image was made. As most pyrographic images include different shades of brown, which will have been made at lower temperatures, this means that any coating system can only offer a compromise to longevity. In this paper the hypothesis is tested to examine if a stabilised coating system, containing an ultra violet absorber (UVA) with or without the addition of a hindered amine light stabiliser (HALS), can reduce the amount of fading usually observed with more traditional coatings. Two strips of English sycamore were 'scorched' at five different temperatures, with dedicated equipment, to make colour scales suitable for testing, leaving one segment blank on each sample to act as a control. One strip was left plain before 'scorching' and the other was previously coated with a HALS pre-treatment. Both colour scales were brush coated with an isolation layer in white spirit, and top coated with a thick water-borne varnish containing a red-shifted ultra violet absorber. Samples were then exposed to 110 days of natural light through window glass, while periodically testing with colorimetry. The results indicate that the discolouration can be retarded at low temperatures, after which it accelerates for the higher temperature settings. However, the sample originally dressed with a HALS pre-treatment prior to 'scorching' showed an increase in deterioration, suggesting that the HALS acted as a pro-oxidant, causing the decoration to fade more quickly. Consequently, this pre-treatment should not be used with pyrography. Due to the limited ability of different coatings and photostabilisers to provide long term protection, exposure of artwork to UV radiation and, particularly, violet/blue light, should be minimised.

Key words: *Pyrography, surface coatings, colour change, Tinuvin®, Lignostab®*

INTRODUCTION

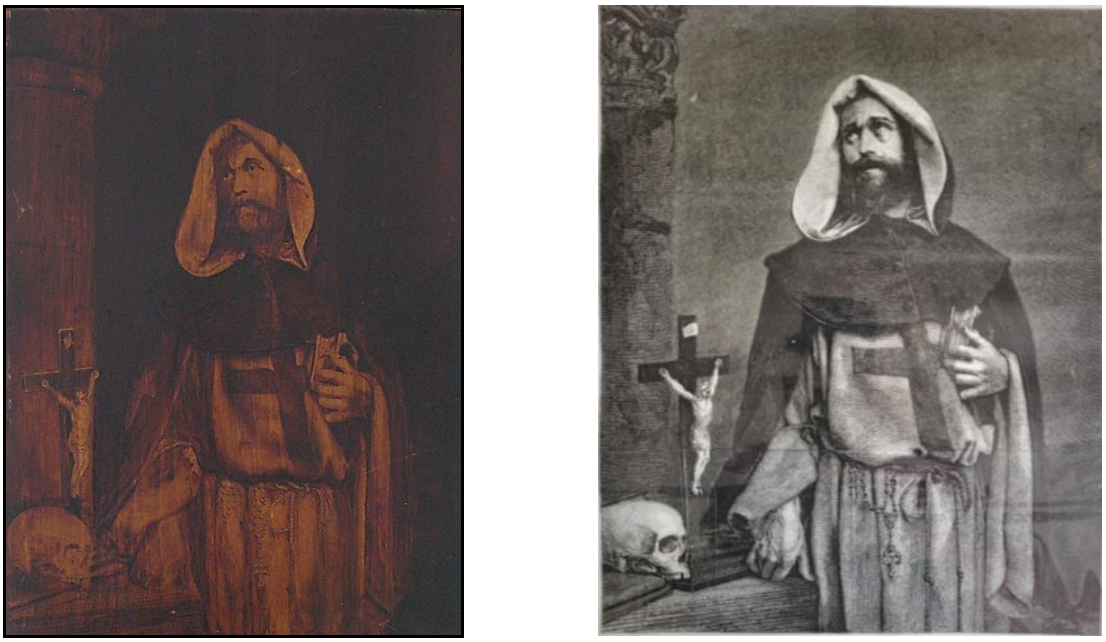
There are two main classes of object showing pyrographic techniques that are held in museum collections, and are currently turning up at auction houses; objects that are tribal in provenance, many of which have been purposefully blackened by heat, and those formed from an art and design perspective. The vast majority of the second group are utilitarian in nature. However, among these objects are a small number of pictures showing considerable skill and flair, especially when reflecting on the way they were made. Those known to still exist usually date from the last quarter of the eighteenth century. Thus, many of them were created by using simple metal tools heated in a charcoal burner. Because the method was so difficult, it would have been vital to have worked from a detailed illustration and, for that reason, it seems that many of the artists copied the engravings of well-known paintings. From a conservation perspective, it is important to understand these techniques, for the long term care of pyrographic objects in museums and private collections.

That pyrographic techniques are steeped in history is beyond doubt, but perhaps the most distinguished pyrographic artist of the mid-nineteenth century was Robert Ball Hughes (1804-1868). Born in London on 19 January, 1804 (Pyke 1973, Gunnis 1951), at an early age, he showed a rare talent for modelling. This was not ignored by his family and he soon found himself apprenticed to the studio of the eminent sculptor, Edward Hodges Baily, RA, (1788–1867) (Stevens 2001), perhaps best remembered for his monument to Admiral Horatio Lord Nelson at Trafalgar Square in London. It would appear that at about the same time, Ball Hughes received a scholarship to attend the Royal Academy School of Art, where he enrolled on 3 September, 1818 (King 2004). Under the guidance of John Flaxman, RA, (1755-1826), who was Professor of Sculpture from 1810 until his death (RA Collections 2006) the young Ball Hughes was a very successful student, earning many prestigious prizes throughout his 9-year studentship. With such training and talent, his career prospects in sculpture seemed certain to succeed. Yet, sometime during a professional visit, Ball Hughes was introduced to some American gentlemen, who later seduced him with the foolish promise of a contract to execute a monument to General Washington (Brown 2009). Thus, on 12 November 1828, and newly married, he took his bride and left the shores of England, never to return.

When the ship docked on 20 January 1829 (District of New York, Port of New York 1829), Robert Ball Hughes was …'perhaps, the most talented and technically proficient sculptor in the United States'… (Smithsonian Institution, National Museum of American Art Library 2006). In 1831, he was elected an

Honorary Member of the National Academy of Design (Gardner 1965), and by 1833, he was also a director of the American Academy of Fine Art (Williams 1833).

It would appear to have been in later life when he took an interest in pyrography. Times were hard, due to a lack of patronage, and he had come to rely on the income received from lecturing and the revenue from his wax cameos, medallions, and busts, for which he was well known (Gardner 1965). Ball Hughes may have remembered the visit he made with his sweetheart to an English country fair years before, where they had watched the process demonstrated by some showmen (Fosdick 1891). On this particular day, when his wife left the house, he stayed in the kitchen to sit by the fire and noticed some clean shingles on the table. When his wife returned she found him still in the kitchen but shrouded in smoke, with an outline drawing of one of Fuseli's witches burned on a shingle in one hand and in the other the kitchen poker. This was the start of an affluent period in the Ball Hughes household. People came from afar in order to purchase his 'pokerisms' as he called them, and to order commissions, and they paid handsomely for them (Brown 2009). Fig. 1a, shows a basswood panel of 'The Monk,' after the original photograph by William Lake Price (1810-1896), which was engraved by Henry Linton (1815-1899). The reversed image shows that the artist copied the engraving, rather than the photograph, and the engraving was published in the Illustrated London News, on 22 March, 1856 (Fig.1b). As prints of other works, executed by Ball Hughes, have been found in editions of the same paper, this was obviously one of his main sources for inspiration (Millis 2012).



a. ***b.***

Fig. 1.
a -The Monk, Robert Ball Hughes, 1866; b - The Monk, Henry Linton, 1856.

In a previous paper (Millis 2013), the potential surface chemistry of pyrography was discussed, and it was shown that an unprotected surface supporting the decoration suffered extreme fading when exposed to natural light aging for 110 days. Moreover, a later paper (Millis 2017), indicated that two traditional surface coatings, in this case linseed oil and shellac, could moderately retard this deterioration, over a 110 day period, particularly when 'scorched' at temperatures of 375^{o}C and above. The study then moved forward with a third paper (Millis 2019), based on a pilot test, which was designed to investigate an idea for a stabilised coating solution to be developed for pyrography. Thus, building further on these research studies, the paper presented here reports the results of a test in natural light, which utilised a red-shifted UV absorber in a thick commercial water-based coating, as the study progresses.

OBJECTIVE

The purpose of this study was to examine the effects that a coating solution containing a bathochromic UV absorber, with and without a HALS pre-treatment, had on the stability of pyrographic decoration, when exposed to 110 days of natural light aging. As such, it offers a contribution to the available knowledge of pyrographic surfaces, and a platform for further research.

MATERIALS, METHOD, AND EQUIPMENT

It is beyond the scope of this article to disclose and discuss the science and background of UV inhibitors. For a comprehensive review of these, the author directs the reader to the excellent work by Evans *et al.* (2015) (Millis 2019).

The Products

The products mentioned here have been used in the study. A sample of Lignostab®1198 was provided for the project by Ciba® Speciality Chemicals (now under the auspices of BASF Corporation); a sample of Tinuvin® 477 DW was provided by BASF Corporation; a sample of Quick Drying Clear Varnish was provided by Mylands, London; a quantity of Regalrez® 1126 was purchased commercially.

Lignostab®1198

This hindered amine light stabiliser sold as orange flakes, which readily dissolve in water, should be applied to bare wood in a 1-3% aqueous or aqueous/alcohol solution, as a pre-treatment before coating. The company literature also states that Lignostab® can be successfully used to stabilise dye-tinted or micronised pigment-stained wood (Ciba® 2009, Millis 2019). It is in the latter context that it was used in this research.

Regalrez® 1126

This is a hydrocarbon, low molecular weight resin, with a glass transition temperature (Tg) of 65°C. It is soluble in both aliphatic and aromatic solvents. It is used in this research as an isolation coat. For further information about using this resin in conservation, the author directs the reader to the work by Piena (2001).

Tinuvin® 477 DW

This is an aqueous red-shifted, 2-hydroxyphenol-s-triazine, UV absorber, with high heat stability and photopermanence, for long-wavelength UVA protection (BASF Corporation 2019).

Mylands Quick Drying Clear Varnish

This is a clear, water based, alkyd varnish, suitable for interior or exterior use. In this research, it provided a thick, easy to apply, self-levelling, vehicle for Tinuvin® 477 DW.

Wood samples

The term ‘samples’ in this case, refers to strips of wood material supporting surface colour change as a direct result of heating with a hot tool. Samples made from English sycamore (*Acer pseudoplatanus*) were examined in this project.

The sycamore wood was sawn into a sheet approximately 300mmx200mmx1mm (longitudinal by tangential by radial). It was abraded with P320 carbide paper, followed by 00 ‘flour’ glass paper, to a smooth surface. Assessment was made by touch. Moisture content of 8.4% was determined using the oven dry method as defined by BS EN 13183-1:2002, and density calculated at 631kg/m^3, based on the oven dried material. The sheet was then divided into two equal-sized pieces.

One piece was left untreated, and was ‘scorched’ at a range of temperatures from 325°C to 450°C with incremental changes of 25°C (NL1). The ‘scorching’ method was the process used in previous work that utilised a temperature controlled stylus, which was driven from side to side in a smooth and linear fashion at a uniform speed, leaving an impression on the surface. Each temperature segment was 40 mm wide and, a minimum of 20mm deep. This method produced consistent and comparable gradient scales for the various temperatures and one untreated section to act as a control. As very little colour change occurred at 325°C, this segment will not be mentioned further.

The second piece was treated with 5 brushed coats of 2% Lignostab®1198 in distilled water, and allowed to air-dry thoroughly. The sample was then ‘scorched’ as before (NL2). Fig. 2, shows sample NL2 at the end of this phase.

Fig. 2.
Sample NL2, showing the effect of heating on wood colour.

Manufacture and application of coatings

Isolation coats

As pyrography shows sensitivity to water, 5 brushed coats of a 20% solution of Regalrez® 1126 in white spirit/turpentine oil (GPR) were applied to both samples as an isolation coat. This was to protect the pyrography from interaction with the water-based top coat.

Top coats

Both samples were then treated with 5 brushed coats of a 20% solution of Tinuvin® 477 DW in Mylands quick drying interior and exterior varnish. 20% Tinuvin® 477 DW is twice the recommended maximum but this coating remained clear with it. Previous, personal experiments had shown it to be very effective after 50 hours exposure to 'solar simulation' (unpublished data). Tinuvin® 477 DW is usually limited to the lower percentage of 10% due to clarity and when using 20% in a thinner vehicle the result was hazy. The stabiliser could be seen clearly under magnification. No recommended HALS additive was added to either coating. Fig. 3, pictures a close-up of a coated sample at X20 magnification, at the end of testing.

Fig. 3.
X20 magnification of the coating, showing the clarity at the end of testing.

Natural light aging

As the purpose of this test was to replicate the effects of light exposure on pyrographic decoration in a usual interior situation, the term 'natural light aging' refers to exposing the samples day and night, through window glass, on a south-westerly facing window sill for a term of 110 days/nights. At location 51.680, -0.802, and an altitude of 204.0 m above mean sea level. Exposure took place between April and July (Millis 2017, Millis 2019).

Why use natural light?

Whereas it might be thought that using an accelerated aging process would produce faster and more reproducible data, it is largely dependent upon the light source available. Searle (1994) states quite clearly that…'the type of light source used in durability testing significantly influences the stability ranking of materials as well as the mechanisms and type of degradation'… Many tests were conducted, during the overall research project, under a metal-halide UVA lamp, 'solar simulation' (https://www.hoenlegroup.com). However, these results were not comparable to those produced in natural light (Millis 2017, Millis 2019).

Exposure

In this case, the wood sample colour scales were mounted on foam core board by covering the left side section with a foil sleeve lined with MT20 ultra violet protective film (http://www.sun-x.co.uk/products/mt20-dark-neutral-uv-window-film), which was secured in place over the sample with two brass tacks (Fig. 4). Then the right halves of the samples were exposed to natural light aging for 110 days/nights. The left side of the samples acted as a control only.

Light exposure for the 110 day period was quantified in lux as 10,500,000, by monitoring an in situ British Standards blue wool fading card dosimeter. No attempt was made to measure UV radiation, and the control of temperature and relative humidity were beyond the scope of the study (Millis 2013, Millis 2017, Millis 2019).

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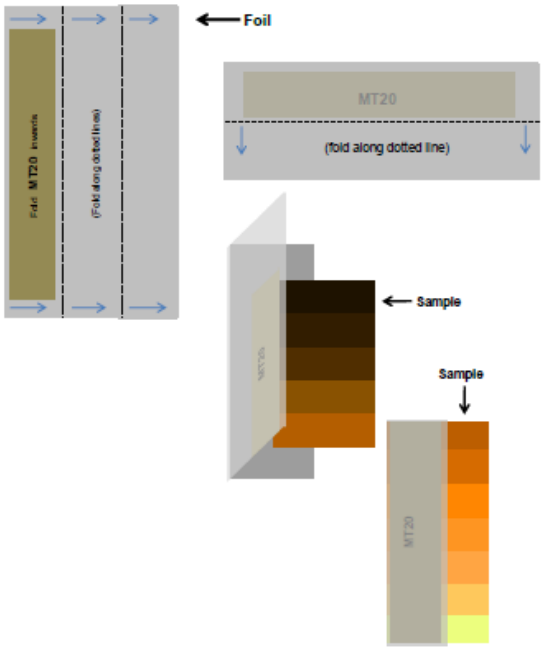

Fig. 4.
Natural light aging, sample preparation plan (Millis 2013, Millis 2017, Millis 2019).

Colour measurement

As the colour of pyrography is heterogeneous, for accurate colour comparison to be made, it was essential to make sure that the colorimeter was sited at the same place each time a reading was taken. This was because of the influence wood grain has on the surface colour. To aid in this, a template was made from Perspex. It consisted of a shallow tray with built-up sides and was 45mm wide in the centre, just large enough to insert the sample. Another piece of Perspex fitted closely inside, into which three 22mm holes were bored; one to the left, another to the right and a third in a central position. These allowed enough room for the tip of the colorimeter to be sited flush with the sample. Paper rulers were adhered to each rim of the template, which permitted pin-point accuracy to be observed. Only readings made in the same position of the same sample were compared (Millis 2013, Millis 2017, Millis 2019).

A Konica Minolta Chroma Meter CR-300 was used to monitor changes in the surface colour of the 'scorched' samples. The measuring head of the instrument incorporated an 8mm measuring area, was index set to use D65 illumination and calibrated to a 2° observer angle. Calibration was performed at the start of each measuring session. Measurements were taken from the left side, right side, and the centre section, making a total of 18 readings for each sample scale, covering the full five segments of colour change and the control segment. The colorimeter, fitted with a 22mm light protection tube (CR-A33a) was index set to take three tristimulus measurements and then calculate a mathematical average for the segment. The *CIE L*a* b** (1976) colour space was selected for interpretation. For this system *L** represents lightness and is on a scale of 100, where *L** = 100 is white and *L** = 0 is black. The *a** measurement characterises the green (- *a**) red (+ *a**) axis and *b** the blue (- *b**) yellow (+ *b**) axis. All measurements taken were absolute. Total colour change was calculated from these measurements by using Equation *(1)* (for full method see BS EN ISO 105-J03:1997).

(1)

$$\Delta E^*_{ab} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

$$Where \quad \Delta L^* = L^*_T - L^*_R$$

$$\Delta a^* = a^*_T - a^*_R$$

$$\Delta b^* = b^*_T - b^*_R$$

R = Reference sample (before exposure)
T = Test sample (after exposure)

Before exposure began the colour parameters were determined for each segment, with relevant examples presented in Table 1(a). Subsequent measurements were mathematically compared to these data sets in order to gain an accurate insight to the photochemical stability of the pyrographic image after surface coating with a bathochromic UV stabilised finish. Colour differences after exposure are shown in Table 1(b).

Table 1

Colour parameters of selected segments, for samples NL1 and NL2, before exposure to natural light aging, with colour difference values recorded after exposure (grey)

Sycamore	Temperature	(a) Colour measurements before exposure			(b) Colour differences after exposure			
					50 days		110 days	
		L^*	a^*	b^*	ΔE^*_{ab}	ΔL^*	ΔE^*_{ab}	ΔL^*
NL1	Control	68.80	7.53	27.32	6.81	2.24	8.62	5.81
	350°C	70.18	8.34	29.44	7.57	3.16	9.40	6.55
	375°C	67.01	9.85	31.35	7.54	4.11	10.28	8.17
	400°C	56.90	12.84	31.81	8.27	6.58	14.27	13.37
	425°C	47.16	15.04	27.47	8.43	7.69	16.39	15.26
	450°C	41.44	14.40	21.32	6.74	5.78	16.20	13.95
NL2	Control	68.31	8.24	28.19	6.23	2.87	8.36	5.79
	350°C	61.84	10.84	30.35	8.70	6.96	13.41	11.64
	375°C	59.02	12.14	31.04	8.56	7.29	13.57	12.19
	400°C	52.34	13.97	30.28	8.55	7.91	15.31	14.59
	425°C	41.73	15.22	23.21	9.60	8.13	18.75	16.41
	450°C	34.03	12.92	13.79	10.01	7.41	19.28	14.53

RESULTS AND DISCUSSION

The colour changes that took place in the samples were the direct result of exposure to natural light aging, through window glass, for 110 days and nights. In these charts, 0 represents no change in colour at all. A difference of just *CIE*ΔE^*_{ab} 3 has been determined to be the minimum value of colour change that can be recognised by the human eye (Hon and Minemura 1991, Sundqvist 2004, Millis 2013, Millis 2017, Millis 2019).

Though a little higher for NL2, the charts in Fig. 5, and Fig. 6, showed that absolute colour change followed a similar pattern for both samples up to 37 days. At 50 days it became clear that NL2 was displaying a slightly increased shift for the segments 'scorched' at 425°C and 450°C particularly, when compared with NL1. Colour change increased further at 84 and 110 days for the higher temperature segments specifically. However, an unprecedented rise was visible for NL2 (Fig. 6) from 350°C-450°C inclusively, over and above that recorded for NL1. This can also be seen in the data shown in Table 1(b).

Comparisons

Further analysis of the data indicated that significant colour change took place in both samples during exposure. However, it is not until these data sets are compared with other samples that it becomes possible to fully comprehend the results. The chart, pictured in Fig. 7, represents the absolute colour differences caused by exposure, at the end of the testing phase (ΔE^*_{ab}). In this chart samples NL1 and NL2 are presented alongside samples shown in previous work, which had been exposed under the same conditions (Millis 2017, Millis 2019); uncoated, shellac coated, linseed oil coated sycamore, and a stabilised coating, also on sycamore, based on 2-hydroxyphenol benzotriazole technology, combined with a HALS pre-treatment (P.1). Colour coordinates for the latter samples are shown in Table 2(a), with the differences thereof in Table 2(b).

ONLINE ISSN 2069-7430
ISSN-L 1841-4737
PRO LIGNO
www.proligno.ro
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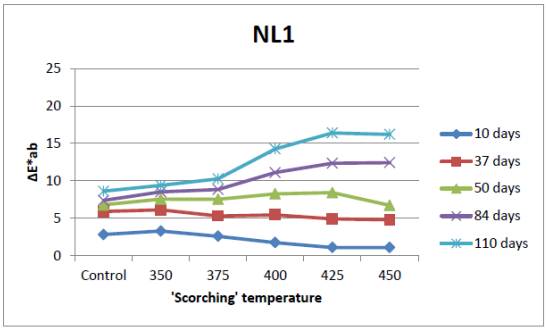


Fig. 5.
Colour differences after testing for Sample NL1.

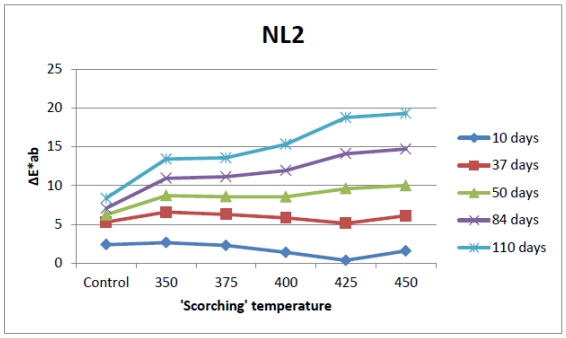


Fig. 6.
Colour differences after testing for Sample NL2.

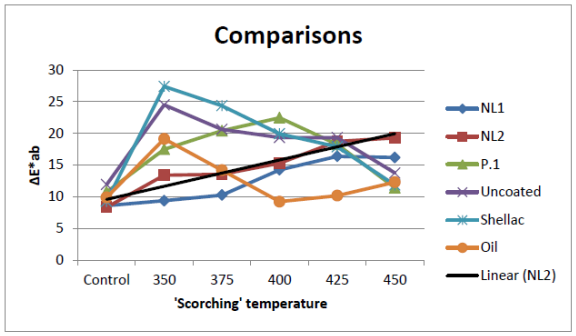
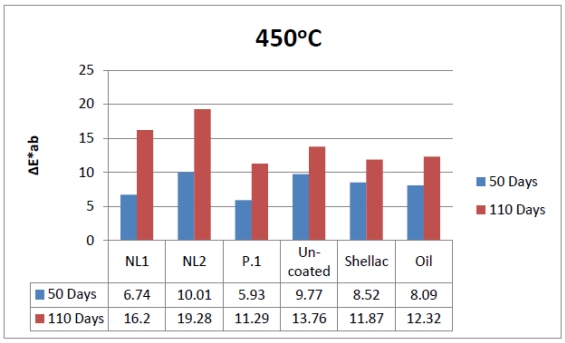


Fig. 7.
Colour differences for six samples after testing



	NL1	NL2	P.1	Un-coated	Shellac	Oil
50 Days	6.74	10.01	5.93	9.77	8.52	8.09
110 Days	16.2	19.28	11.29	13.76	11.87	12.32

Fig. 8.
Comparisons of six samples 'scorched' at 450°C, after 50 days and 110 days

Starting with the control segment (not treated with heat), it can be seen that major lightening of the wood surface took place under the stabilised coating of sample P.1, which amounted to a lightness difference of 9.44 (ΔL^*), and an absolute colour change value of 10.77 (ΔE^*_{ab}) after 110 days. However, this was not equalled by samples NL1 and NL2. Here, the results reached the lower figures of 5.81 (ΔL^*) and 8.62 (ΔE^*_{ab}) for NL1, and 5.79 (ΔL^*) and 8.36 (ΔE^*_{ab}) for NL2. These results show that during the current project the coated wood surface did not bleach as much as it did for sample P.1, even though the percentage of additives, in the coatings, were greater. Whereas there were large overall colour differences recorded for the uncoated, shellac coated and oil coated control segments, they were caused by significant increases in yellowing (+b axis, not shown), and changes in lightness were minimal. Then at 350°C and 375°C, NL1 returned 9.40 (ΔE^*_{ab}) and 10.28 (ΔE^*_{ab}) respectively. Significantly increased rates occurred in NL2, over NL1, which can be seen in Table 1(b). They remained higher for the rest of the temperature scale. Comparison with previous samples shows that the colour change figures for NL1 and NL2 were much lower than for earlier samples. These can be seen in Table 2(b). However, the coatings both appeared to have increased colour change at the higher temperature levels; 450°C, NL1 16.20 (ΔE^*_{ab}) NL2 19.28 (ΔE^*_{ab}), which indicated an altered overall pattern of fading. Also shown in Fig. 7, is that at low temperature settings the coating of NL1 dramatically retarded the amount of colour change recorded, when compared with the other samples. Colour change for NL2 was also retarded, but to a lesser extent.

Fig. 8, presents a column chart of the six segments 'scorched' at 450°C. Included with the chart are the absolute colour difference values at 50 days and at 110 days. It is clear that the distance between the two data points was much greater for samples NL1, NL2, and also P.1, though to a lesser extent. The first pair of columns represent sample NL1, for which the colour change value was 6.74 (ΔE^*_{ab}) at 50 days, and developed to 16.20 (ΔE^*_{ab}) at 110 days. This amounted to a percentage increase between the two values of 140%. For NL2 the percentage increase was less, at 92%. This was because the initial amount of change over the first 50 days was higher, than for NL1, at 10.01 (ΔE^*_{ab}), which was clear from the chart. Percentage

increase for the other samples were; 90%, 41%, 39%, and 52% respectively. Fig. 9, pictures a chart showing the 450ºC segments of the six samples at three stages of time; 10 days, 50 days, and 110 days. It is clear in this chart that samples NL1 and NL2 are changing direction and moving away from the other four samples, which are arching to the right. These results support the hypothesis that the coatings containing UV stabilisers changed the rate of colour change in this research, but not favourably.

Table 2

Colour parameters of selected segments, for samples P. 1, uncoated, shellac coated, and oil coated, before exposure to natural light aging, with colour difference values recorded after exposure (grey)

Sycamore	Temperature	(a) Colour measurements before exposure			(b) Colour differences after exposure			
					50 days		110 days	
		L^*	a^*	b^*	ΔE^*_{ab}	ΔL^*	ΔE^*_{ab}	ΔL^*
P.1	Control	66.46	9.77	24.94	7.07	6.18	10.77	9.44
	350°C	53.87	11.68	24.26	12.52	12.21	17.50	16.84
	375°C	42.76	14.10	22.77	13.44	12.25	20.41	19.25
	400°C	32.14	12.85	13.92	14.37	10.44	22.46	17.99
	425°C	25.06	7.29	4.37	10.91	6.62	18.26	12.48
	450°C	23.21	1.96	0.48	5.93	3.38	11.29	7.25
Uncoated	Control	78.43	6.70	16.78	8.52	-1.43	11.94	-1.91
	350°C	39.71	10.80	13.63	20.03	14.81	24.49	17.68
	375°C	35.73	7.72	8.56	16.23	9.94	20.64	13.07
	400°C	35.72	5.97	6.11	14.80	8.97	19.33	11.94
	425°C	36.26	5.81	6.25	14.35	8.98	19.33	12.22
	450°C	34.32	3.69	3.84	9.77	5.74	13.76	8.25
Shellac	Control	73.78	7.59	22.48	6.0	0.57	9.28	1.25
	350°C	36.81	12.22	16.28	22.86	17.01	27.39	20.42
	375°C	30.83	9.27	9.23	19.60	11.73	24.35	15.02
	400°C	28.81	6.68	5.62	15.19	8.51	19.94	11.78
	425°C	28.38	5.53	5.22	14.02	8.07	17.88	10.44
	450°C	26.73	1.89	1.42	8.52	3.74	11.87	6.30
Oil	Control	75.81	8.90	26.57	6.35	-3.10	9.90	-3.18
	350°C	31.78	9.22	8.40	14.88	8.84	19.14	11.39
	375°C	28.24	4.42	2.93	11.01	5.50	14.20	7.31
	400°C	27.94	1.88	0.73	5.57	1.82	9.25	3.76
	425°C	27.85	2.53	1.08	6.31	2.34	10.20	3.94
	450°C	29.22	3.34	1.56	8.09	2.97	12.32	5.11

Visual interpretation

Fig. 10, illustrates samples NL1 and NL2, with the blue wool fading card, after exposure to 110 days/nights of natural light aging. It is clear from the image that sample NL2 (centre) was darker in colour than NL1. This was considered to be the result of applying Lignostab®1198, which has a slight orange tint, to the wood surface before the 'scorching' process began. The colour coordinates in Table 1(a) confirmed that the difference was visible in the *L** axis, even though for the control segment the actual wood colour was very similar, and the temperatures used were kept at a stable rate. In this research Lignostab® 1198 was used to test the company information that it would add longevity to wood dye stuffs, thus making them more light fast. Therefore, it seemed reasonable to think that it could do the same for pyrography. However, pyrography is not a dye, though it does have similar qualities. Perhaps, it could be likened better to the historic pigment bistre, which was made from burning beech wood and collecting the soot (Winter 1983). This pigment, used for watercolour washes, was known to be fugitive (not light fast) in the 18th Century, because it contained products of incomplete carbonisation, otherwise known as brown carbon (Andreae and Gelencsér 2006). Lignostab®1198 is a hindered amine light stabiliser (HALS) and these are generally employed to prevent a surface coating from deteriorating by intercepting free radicals. Could this result in a change or a loss of colour? Winter (1983), while discussing pigments based on carbon, mentioned that carbons retard the drying mechanism seen in oil films, which is caused by a free radical chain reaction. It is feasible that a pyrographic surface would contain a large number of carbonaceous free radicals owing to its manufacture. Therefore, it could be that the introduction of a HALS to a pyrographic surface might cause a similar reaction. However, HALS also have another power, they can become pro-oxidants (Rabek 1990) and thus enhance the extent of fading occurring on the surface. This would account for the increased amount of colour change seen in NL2.

Padfield and Landi (1966) stated clearly that…'the fading of most dyes becomes slower as fading proceeds'… In general, this has been the same for pyrography. However, a change has been observed in this research, which can be seen in Fig. 9. There has been much research completed on the synergistic effects of combining UVAs with HALS in the same coating (Mills and White 1994). In the current study, the combination of the two additives within NL2 was not effective in this way. Sample NL1, which contained a single UV absorber proved to be more successful with pyrography.

Table 3, presents the absolute colour differences for the left, covered, sides of samples NL1 and NL2, which acted as overall controls throughout the experiment. It was clear that differences shown here were insignificant. This confirms that the changes that occurred in the right, exposed, sides, were the result of light exposure.

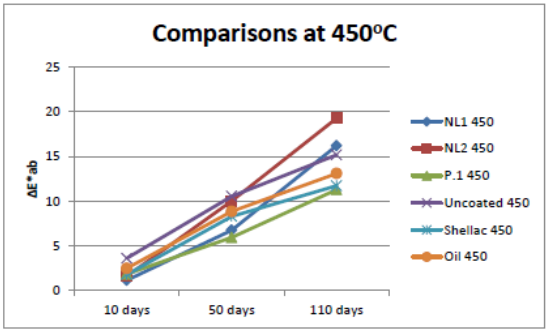


Fig. 9.
Comparisons of six samples 'scorched' at 450°C at three periods of time.

Fig.10.
NL1 and NL2, after 110 days, with the blue wool fading card.

Table 3

The absolute colour difference values found for the left (covered) sides of samples NL1 and NL2, after testing

Left	NL1	NL2
Control	0.76	1.44
350	0.51	1.53
375	1.09	0.87
400	2.59	1.29
425	1.07	0.17
450	0.52	0.96

CONCLUSION

The photo-discolouration of pyrography applied to samples made of English Sycamore, and coated with innovative UV stabilised finishes, has been investigated, after exposing them to natural light aging through window glass for 110 days/nights. Overall, it was found that large colour differences occurred in the samples.

Nevertheless, the final results indicate that the discolouration can be retarded initially, after which it slowly accelerates for the higher temperature segments over the remaining term. Furthermore, the sample originally dressed with a HALS additive prior to 'scorching' showed an increase in deterioration, suggesting that in the case of pyrography it may well have acted as a pro-oxidant. Thus, Lignostab® 1198 must not be used in a coating for pyrography. Both samples showed a change in the rate of deterioration, when compared with more conventional coatings.

Strict preventive conservation methods should be observed with pyrography. Objects should not be placed on permanent display. Low light levels (50 Lux with no UV) to be monitored at all times. There is a need for much further research to be achieved in this area.

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ACKNOWLEDGEMENTS

The author extends her sincere thanks to Gervais Sawyer FIMMM for his ongoing help and support. Thanks also go to Professor Phil Evans for his help. Susan M Millis would like to acknowledge the past support of staff at Buckinghamshire New University, under whom some of this research was originally achieved. Special thanks to Ciba® Speciality Chemicals, BASF Corporation, and Mylands, London, for providing samples for testing purposes.

This paper was presented within the International Conference "Wood Science and Engineering in the Third Millennium" – ICWSE 2023, Brasov, Romania, 02-04 November 2023.

REFERENCES

Andreae MO, Gelencsér A (2006) Black carbon or brown carbon? The nature of light-absorbing carbonaceous aerosols. Atmospheric Chemistry and Physics Discussions. 6: Online at: www.atmos-chem-phys-discuss.net/6/3419/2006/

BASF Corporation (2019) Tinuvin® 477-DW (N). Technical Data Sheet. 4thRevision. BASF Corporation

BASF SE (2019) Coatings that stay looking good. BASF Brochure. Online at: https://www.btc-europe.com/fileadmin/user_upload/Downloads/Brochures Information/Coatings/Tinuvin_Chimassorb_Lignostab_EN.pdf

British Standards Institute (1997) BS EN ISO 105-J03:1997. Textiles – Tests for colour fastness. Part J03. Calculation of Colour Differences. BSI

British Standards Institute (2002) BS EN 13183-1: 2002. Moisture content of a piece of sawn timber. Determination by oven dry method. BSI

Brown Frederick R III, BROWN, David S (2009) Sketch of the life of Robert Ball Hughes. Hand-written account by Mrs Eliza Ball Hughes (undated and unpublished). further details on this manuscript can be found Online at: https://sites.google.com/robertballhughes.com/rbh1

Ciba® Inc (2009) Ciba® Lignostab® 1198 Wood Lignin Stabilizer. Paints and Coatings. Company literature

District of New York, Port of New York (1829) Notice of Immigration on 20.1.1829

Evans PD, Haase JG, Shakri A, Seman BM, Kiguchi M (2015) The search for durable exterior clear coatings for wood. Coatings. 2015 (5) 830-864. Online at: http://www.mdpi.com/2079-6412/5/4/830

Fosdick J William (1891) Burnt-wood decoration. The Art Interchange. An illustrated guide for amateurs and students with hints on artistic decoration. December 1891 issue. New York. The Art Interchange Company

Gardner Albert Ten Eyke (1965) American Sculpture: a catalogue of the collection of the Metropolitan Museum of Art. Greenwich, Connecticut. New York Graphic Society

Gunnis Rupert (1951) Dictionary of British Sculptors 1660-1851. London. The Abbey Library

Hon David NS, Minemura Nobuya (1991) Colour and Discoloration. Wood and Cellulosic Chemistry. New York. Marcel Dekker Inc. 395-454

King Elizabeth (2004) Telephone interview with the Archivist at the Royal Academy of Arts on 19.03.2004

Millis SM (2012) Understanding pyrography: the deterioration and conservation of decorative 'scorched' wood. MPhil thesis. Buckinghamshire New University. Brunel University

Millis SM (2013) Understanding pyrography, the photochemistry of decorative 'scorched' wood. Pro Ligno 9 (4). 684-692. Online at: http://www.proligno.ro/en/articles/2013/4/Millis_final.pdf

Millis SM (2017) In search of a suitable coating for pyrography. Pro Ligno 13(4):404-413. Online at: http://www.proligno.ro/ro/articles/2017/4/MILLIS.pdf

Millis SM (2019) Surface Coating Pyrography: A preliminary investigation with UV additives. Pro Ligno 15(4):107-117. Online at: http://www.proligno.ro/en/articles/2019/4/MILLIS.pdf

Mills JS, White R (1994) The Organic Chemistry of Museum Objects. Oxford. Butterworth-Heinemann

Padfield Tim, Landi Sheila (1966) The light fastness of the natural dyes. Studies in Conservation. 11. 1966.181-196

Piena Hans (2001) Regalrez in furniture conservation. Journal of the American Institute for Conservation. 40 (1) Spring 2001. The American Institute for Conservation of Historic & Artistic Works

Pyke EJ (1973) A Biographical Dictionary of Wax Modellers. Oxford. Clarendon Press

Rabek J F (1990) Photostabilization of Polymers: Principles and Application. London, New York. Elsevier Science Publishers Limited

Royal Academy Collections (2006) John Flaxman RA. http://www.racollection.org.uk/ixbin/indexplus?_IXACTION_=file&_IXFILE_=templates/full/person.html&_IXTRAIL_=Academicians&person=5659.

Searle ND (1994) Effect of light source emission on durability testing. Accelerated and outdoor durability testing of organic materials. ASTM STP 1202. Philadelphia. American Society for Testing and Materials. 52-67

Smithsonian Institution, National Museum of American Art Library (2006) Miscellaneous research papers from the files of Robert Ball Hughes and J William Fosdick. Collected by Col. Merl M Moore Jr. acquired on 18.7.2006

Stevens PF (2001) It happened here. Dorchester's first couple of the arts in the 19th Century. The Dorchester Reporter. Boston. Boston Neighbourhood News Inc.

Sundqvist B (2004) Colour Changes and Acid Formation in Wood During Heating. PhD Diss, Sweden. Divisions of Wood Material Science, Skellefteå Campus, Luleå University of Technology

Williams Edwin, Ed. (1833) New York as it is in 1833; and Citizens' Advertising Directory. New York. J Disturnell

Winter John (1983) The Characterization of Pigments based on Carbon. Studies in Conservation. 28. 2. May 1983. International Institute for Conservation of Historic and Artistic Works. 49-66