

ANNOYING ENERGY, PART II - SOLAR HEATING OF DARK LEATHER*

by

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ABSTRACT

Automobiles represent a large and important investment, and luxury appointments of which leather is by far the best example bestow upon the car interior a degree of comfort and pride of ownership which translates to a strong selling point. Anything which detracts from the luxury experience creates customer dissatisfaction. Part I of this series outlined the problem of interior noise that originates from the friction of two leather surfaces rubbing against each other and demonstrated that the origin of the noise is energy dissipation manifesting itself as an annoying squeak. A way to test for noise was explained, and a comprehensive leather finish solution was described. This paper examines the issue of solar radiative heating of dark leather surfaces, reviews the applicable physical basis, and makes available a cost-effective solution, in this case a remarkably simple one, to the leather finisher.

RESUMEN

Los automóviles representan una gran e importante inversión, y el cuero es un detalle de lujo que cubre los interiores y concede en gran medida un grado de confort y orgullo a su propietario, lo que se traduce en un punto fuerte de ventas. Cualquier cosa que interfiera en la experiencia de lujo crea descontento en el cliente. La primer parte de esta serie abarcó el problema del ruido interior que se origina por fricción de dos superficies de cuero que se frotan uno contra otra y demostró que el origen del ruido es disipación de energía, manifestada como un chirrido molesto. Una manera de probar el ruido fue explicada, y una solución comprensiva sobre el acabado de cuero fue descripta. Este papel examina el tema del calentamiento por radiación solar en la superficie de cueros oscuros, repasa las bases físicas aplicables, y pone a disposición una solución costo-efectiva, en este caso simplemente una, para el terminador de cueros.

INTRODUCTION

It is been known since the fledgling days of spectroscopy that different elements and chemicals behave differently as to how they respond to electromagnetic radiation. Today's modern depiction of atomic and molecular structure and of electronic transitions that can occur in atoms and molecules under the influence of electromagnetic radiation gives us a sound basis for understanding why pigments and dyes are colored. In addition to their color, we also can understand why they and other molecules and chemicals absorb or not at wavelengths other than in the visible region. Customarily we display how a chemical responds to electromagnetic radiation using spectral curves: plots of absorbance or transmittance on the vertical axis as a function of wavelength or frequency of the electromagnetic radiation on the horizontal axis. For materials that are opaque or are not completely transparent such as pigments, we use plots which have % reflectance as the vertical axis plotted versus wavelength. Wavelength (or frequency) ranges are selected to cover whatever region in the electromagnetic spectrum upon which we want to focus our attention. Color - visible color - is concerned with the region of the electromagnetic spectrum that runs nominally from 400-700 nanometer wavelength. At just above 700 nm - above the red -- humans perceive not color but heat and we call that region the infrared; and at just below 400 nm, below the violet, begins the ultraviolet region of what is a continuous electromagnetic spectrum running from beyond gamma rays and x-rays as we go towards the high energy end and beyond radio and microwave radiation as we go in the lower energy, higher wavelength direction.

In the leather field practitioners in the tannery are normally only concerned with the visible region. We match colors, and when we use spectrophotometers to do that color matching instrumentally, we commonly resort to reflectance curves to compare how the match may differ from the original color within the 400-700 nm range in the visible region. Those differences constitute the important property of metamerism. The chemists, though, that we work side-by-side with may on the other hand be looking at plots of how various chemicals including pigments and dyes

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behave in the ultraviolet region or infrared region of the electromagnetic spectrum. Whether we look at plots of reflectance of incident radiation, which is what most color matchers would be doing, or absorbance or transmittance which is how most data is presented to chemists doing investigations of spectra in the ultraviolet or infrared regions, we are all doing exactly the same thing: measuring how a material of interest responds to radiation in some particular region or regions of the electromagnetic spectrum. Furthermore, you do not need to be a chemist or spectroscopist to know about, be concerned about, or deal with what happens in different regions of the electromagnetic spectrum. We measure differences in how finished leathers behave in Weather-Ometer or Fadeometer testing, and of course we tan ourselves in the sun, both of which deal with effects of ultraviolet radiation, and we when we bask in the warm sun, or go to our local hardware stores and buy infrared lamps or heaters, we benefit from the heat produced when infrared energy is absorbed. Sometimes we want that heat; other times it is less desirable, hence this paper.

We have titled this paper "Annoying Energy. Part II", where we talk of consequences of undesirable energy effects. The first paper in this series referred to annoying energy in the form of sound, and dealt with elimination of squeaks when one finished leather surface rubs against another surface (which could also be leather) with which it is in contact.

Returning to the subject of this present paper, just as it follows that you expect variation in reflectance of incident radiation

over the visible region, you must surely not find it unexpected in your experience to find that what you experience in the visible will not necessarily carry over into the entire electromagnetic spectrum. We would never expect that a material that absorbs or reflects at one wavelength or in one particular region would necessarily do so in other regions.

But first to make an obvious point: what light energy in the visible region is reflected is not absorbed. What energy is not reflected is absorbed or transmitted and absorbed further down into the leather. What infrared energy is absorbed generates heat.

That brings us to the subject of polar bears. We of course expect that a polar bear should be black in order to absorb what solar energy there is in extreme northern regions at times of year there is solar energy at all. At the very least one might expect that the polar bear would be engineered to be warmed by solar energy. Mother Nature in her wisdom made polar bears white, probably so they would not stand out from their surroundings in great expanse of their snow and ice habitat. But actually Mother Nature had a plan because a polar bear's white fur actually does keep it warm in sunlight because, though in the visible region of the electromagnetic spectrum a polar bear's fur is white and *reflects visible light*, it actually *absorbs light in the near-infrared* and thus the bear is warmed by solar energy. We can do the opposite to what the polar bear's fur accomplishes: we can make a dark surface that does not absorb much in the near-infrared and thus make it less hot exposed to the sun than we might at first glance suspect. And

Infrared Reflecting Pigments

For color strength, you read tints at MAXIMUM ABSORBANCE WAVELENGTH and curves you print out are REFLECTANCE curves (what is reflected is what you see as color)

Whatever is reflected in the NIR is not available to be absorbed as heat
 Whatever is NOT reflected is EITHER
 -absorbed (as heat)
 -or transmitted through until MAYBE it is absorbed further down

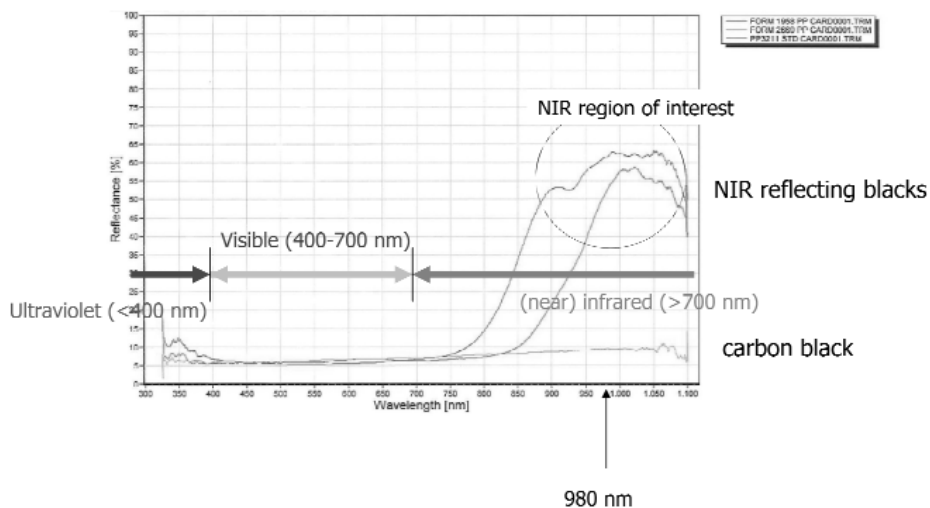


Figure 1: Reflectance curves illustrating behavior of three pigment pastes over a spectral range extending beyond the visible in both directions into the near-ultraviolet and into the near-infrared. The vertical axis is % of incident radiation that is reflected.

Instrumentation to measure NIR reflectance is very accessible



Avantes AvaSpec - 2048 Fiber Optic Spectrometer
Est'd. cost (USA) \$3,000 to 4,000 incl. software (you supply a PC)
www.avantes.com

Small: size of a pocket book: 7" x 7" x 3" (max) + separate sensor head

Figure 2: Apparatus used in this study to characterize colorants for % reflectance in visible and near-infrared portions of the electromagnetic spectrum.

Can you get NIR reflectance with your existing colorants? Stahl experience (Waalwijk)

NIR reflectance data Colorant 00 series (measured @ 980 nm)
 (measured 200µ pure draw down on Leneta card, #103, ave=20 s=6)

Sorted by Colorant xxx Designation			Sorted by NIR Reflectance (descending order)		
Colorant	Color	Reflectance (%) 380 nm	Colorant	Color	Reflectance (%) 380 nm
Color 10	Creamy White	97	Color 22	Golden Yellow	39
Color 11	Carbon Black	7	Color 17	Creamy White	37
Color 12	Mustard	7.2	Color 37	Blush White	36
Color 14	Burgundy	7.3	Color 38	Creamy White	35
Color 15	Black	5	Color 29	Reddish Yellow	33
Color 21	Light Red	9	Color 27	Light Red	31
Color 24	Dk Brown	7	Color 87	Scarlet	30
Color 28	Golden Yellow	93	Color 83	Rubine	30
Color 29	Reddish Yellow	93	Color 84	Bright Red	35
Color 30	Violet	63	Color 74	Burgundy	7.9
Color 37	Bluish White	36	Color 72	Maroon	7.2
Color 38	Creamy White	96	Color 31	Marlet	36
Color 39	Tan	44	Color 67	Blue	53
Color 41	Blue	53	Color 63	Havana	45
Color 49	Havana	45	Color 59	Tan	47
Color 71	Green	27	Color 85	Ecru	42
Color 80	Scarlet	30	Color 85	Ecru	30
Color 83	Rubine	30	Color 77	Green	27
Color 84	Bright Red	35	Color 77	Carbon Black	7
Color 87	Scarlet	30	Color 24	Dk Brown	7
Color 88	Ecru	42	Color 15	Black	5

Select the most NIR reflectant ones to color -match in the visible

Figure 3: Pigment pastes used in a commercially available colorant line: The table at the right is sorted in order of decreasing % reflectance in the near-infrared.

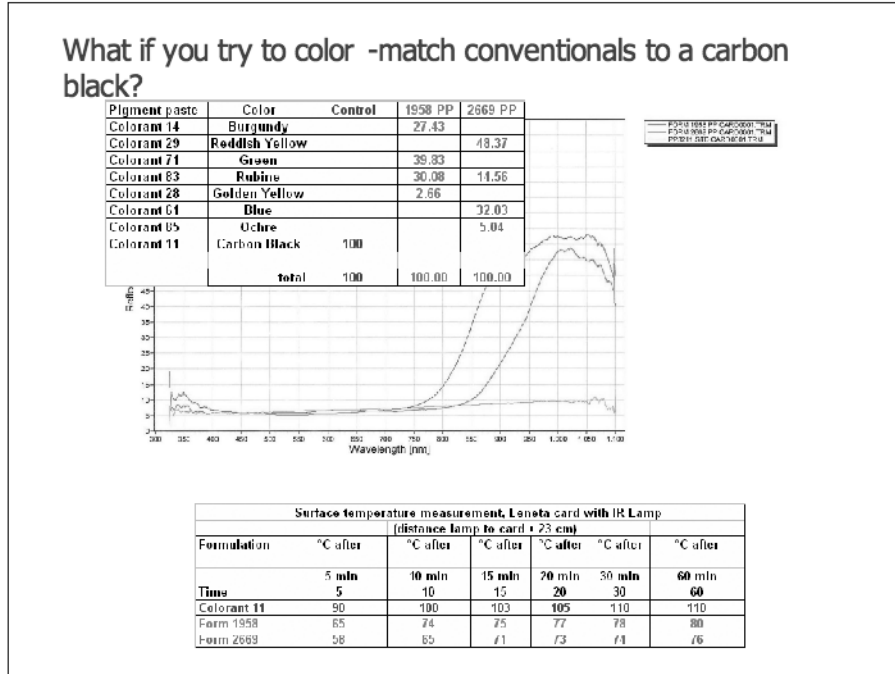


Figure 4: The spectral curves of Fig. 1 with additional information. The bottom curve is carbon black (paste). The two near-infrared-reflecting upper curves represent attempts to color match to black. The color match is shown in the upper table, and temperature rise upon irradiation with a simple, hardware-store-purchased infrared lamp is shown in the lower table.

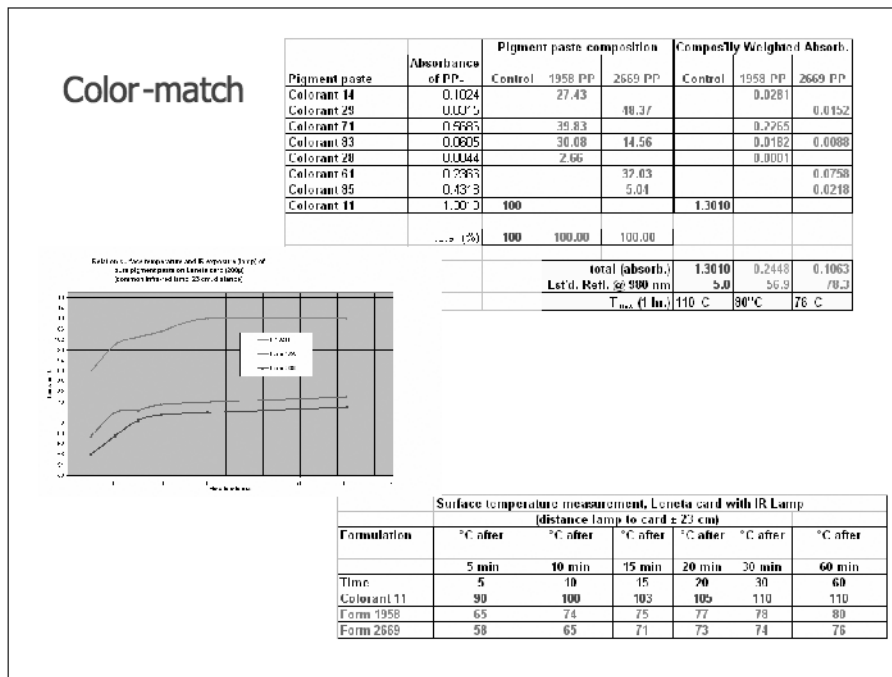


Figure 5: Figure 4, but with the reflectance spectrum replaced by the infrared heating profile (temperature rise vs. time of exposure to an infrared lamp). The upper table includes a pair of columns for a parameter akin to a spectroscopic absorbance (refer text), and from that an attempt was made to back-estimate what the reflectance in the near-infrared would be in the color match.

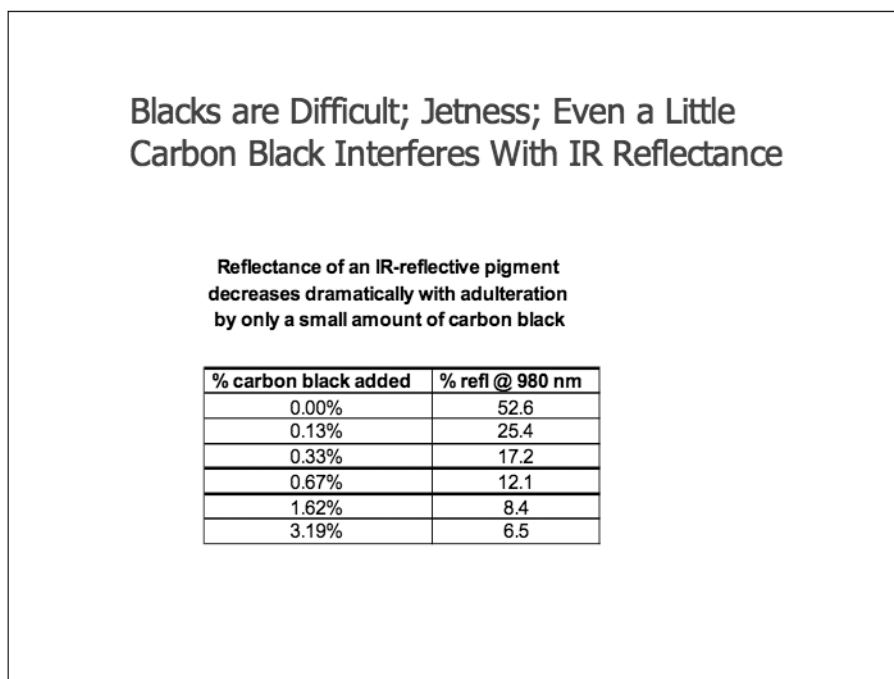


Figure 6: % reflectance of a special, commercially available high near-infrared reflecting pigment with different levels of adulteration with carbon black. As little as 0.4% carbon black cuts reflectance down by two-thirds.

today we will show how to do that to a useful degree using ordinary pigments, including ones that have been around, it seems, forever. We will accomplish our desired end using no more than well-established existing technology, but, we will resort to a little out-of-the-box thinking in doing so.

Fig. 1 shows spectral curves of three colorant pastes and illustrates reflectance behavior ranging over parts of three named regions of the electromagnetic spectrum. This spectral example extends from the near-ultraviolet (<400 nm), through the entire visible region (400-700 nm), and into the near-infrared (>700 nm). The region shown in the infrared extends only as far as to 1100 nm, though infrared extends still further. The value 980 nm has been arbitrarily selected as a wavelength at which we can crudely characterize with a single number behavior in the near-infrared.

The bottom curve is for carbon black, which absorbs strongly in the visible and strongly in the near-infrared. The other two are for pigments, actually pigment mixtures, that absorb in the visible but reflect strongly in the near-infrared. Those last two curves are actually color matches made to resemble the black - and they admittedly are not as jet. The color matches favored conventional colorants that are not strongly absorbing in the near-infrared. In other words, we chose pigments that reflect significantly in the near-infrared. We will come back to how those matches were done, and what their temperatures rise to after prolonged exposure to infrared.

Instrumentation to measure reflectance over the visible and near-infrared is relatively easy to find and can be quite inexpensively obtained (Fig. 2).

Fig. 3 contains two tables of colorant-paste near-infrared reflectance data. The two tables differ in that they are sorted differently. The left table is sorted according to a color tag used in the product designation, and the right by near-infrared reflectivity at a wavelength of 980 nanometers in order of descending reflectivity. What was measured was reflectivity at 980 nm of the concentrated pigment pastes used to make the actual product that is sold. Concentrated pastes were measured in order to assure good visual hiding and to make certain that what we were measuring was a characteristic of the pigment(s). It turns out that good visual hiding may not be necessary to the determination of useful near-infrared reflectance parameters.

No so-called "special near-infrared reflecting pigments" - pigments promoted and sold on the basis of particular spectral attributes in the near-infrared - are included. Nevertheless, the spectral properties of these "ordinary" pigments does encompass their near-infrared properties and it is very clear that many already are near-infrared reflecting to an appreciable degree. Note that carbon black - color 11 - is poorly reflective in the near-infrared.

Fig. 4 shows the result of attempting color matches of a black with non-black colorants, selecting only pigments with fair to good reflectivity in the near-infrared, and rejecting those with poor near-infrared reflectivity. The spectral curves are the same

USA Experience: A different colorant series
Masstones (as supplied, not as tints or concentrated pastes)

sorted by colorant designation	coverage (at 100% _{max})			NIR reflectance (λ=950 nm)		sorted by NIR reflectance over white (best to worst)	coverage (at 100% _{max})			NIR reflectance (λ=950 nm)	
	λ _{max} nm	Contrast Ratio	R _{max} = % of C _{max}	20° white over black	20° white over black		λ _{max} nm	Contrast Ratio	R _{max} = % of C _{max}	20° white over black	20° white over black
C-colorant 02	570	21.08	91.60	83.83	2.73	Colorant 05	680	20.48	80.13	92.84	52.12
C-colorant 06	680	30.48	80.13	92.84	52.12	Colorant 06	400	30.48	75.58	92.37	43.57
C-colorant 08	670	29.61	99.29	79.16	1.62	Colorant 11	640	27.11	82.35	89.38	1.11
C-colorant 10	590	32.78	91.13	78.99	2.72	Colorant 25	490	20.48	80.37	89.14	2.57
C-colorant 11	680	29.74	101.83	5.20	5.55	Dul-colorant 28	420	59.92	65.75	88.98	3.17
C-colorant 12	600	30.92	97.03	5.78	5.41	Colorant 17	500	50.00	86.23	87.68	7.20
C-colorant 13	590	31.98	91.30	78.85	3.14	Colorant 04	490	26.30	87.86	86.79	2.39
C-colorant 17	660	58.85	86.23	87.68	7.20	Dul-colorant 01	640	30.72	82.70	86.64	3.23
C-colorant 23	640	25.21	99.58	64.50	3.12	Colorant 40	530	39.78	90.44	86.30	3.37
C-colorant 26	420	32.48	75.58	92.37	43.57	Colorant 02	570	21.08	91.60	83.83	2.78
C-colorant 27	640	19.04	105.32	73.18	1.25	Colorant 11	640	27.11	82.35	89.38	1.11
C-colorant 29	470	50.92	65.75	88.98	3.12	Colorant 06	400	30.48	75.58	92.37	43.57
C-colorant 29	470	50.92	65.75	88.98	3.12	Dul-colorant 08	610	75.64	99.29	79.16	3.32
C-colorant 35	490	70.48	80.37	89.14	2.57	Colorant 11	640	27.11	82.35	89.38	1.11
C-colorant 40	640	19.04	90.44	86.30	3.37	Colorant 11	640	27.11	82.35	89.38	1.11
C-colorant 41	590	33.75	88.58	83.77	3.43	Colorant 15	590	31.98	91.30	78.85	3.14
C-colorant 44	540	34.11	82.35	89.38	1.11	Dul-colorant 27	630	38.08	105.32	73.18	1.25
C-colorant 45	670	27.64	98.70	61.56	1.21	Colorant 21	640	27.11	99.58	64.50	3.12
C-colorant 51	530	37.47	87.70	86.64	3.23	Colorant 06	400	30.48	75.58	92.37	43.57
C-colorant 54	460	26.30	87.86	86.79	2.39	Dul-colorant 16	610	77.61	98.70	61.56	3.29
C-colorant 71	600	26.24	97.96	55.69	1.00	Colorant 21	600	26.24	97.96	55.69	1.00
C-colorant 84	470	31.45	93.94	46.46	23.33	Colorant 04	490	26.30	87.86	86.79	2.39
C-colorant 86	640	19.04	101.31	31.56	24.73	Dul-colorant 06	640	19.04	101.31	31.56	24.73
C-colorant 90	570	20.85	99.30	62.31	5.33	Colorant 12	600	28.58	97.03	5.78	5.41
C-colorant 96	660	28.44	91.74	80.09	2.31	Colorant 11	660	28.74	101.83	5.20	5.55

Figure 7: A different commercial color series with colorants in the series characterized for near-infrared reflectance as their masstones, instead of as their before-letdown pigment pastes.

as in Fig. 1. Note that we have achieved a decent reflectivity in the color matches, admittedly at the expense of jetness which so characteristically is assured in the carbon black control. The bottom table in Fig. 4 illustrates how well the color matches do versus the carbon black control in terms of reduced heating up on exposure to an infrared lamp. After one hour the two color matches did not exceed 80°C, compared to 110°C for the carbon black control. Fig. 5 is derived from Fig. 4 but substitutes the plot of temperature rise versus time in place of the spectral reflectance plot, and we have added a column labeled “Absorbance of PP-“ to the upper table.

In spectral transformations of transmittance to absorbance, a logarithmic relationship is often used to relate a quantity called absorbance, also called extinction or optical density, to transmission. We have invented a similar parameter defined mathematically in a similar way

$$\text{Absorbance of colorant} = -\text{LOG}_{10}([\% \text{ reflectance}]/100)$$

with which we can then do a weighted average for all colorant constituents in our color match, and from that weighted average we can re-estimate a % reflectance for the match as

$$\% \text{ reflectance} = 100 \times 10^{-\text{(absorbance weighted average)}}$$

This is an empirical technique, and is useful indeed. As near-infrared energy is distributed over a region, the estimation of the near-infrared reflectivity of a color match could probably benefit from measuring the area under the

reflectance curve in the near-infrared region, and using those areas instead of the single-wavelength peak reflectance values.

Figure 6 illustrates that even a low percentage of a component that is highly infrared absorbing can destroy high reflectance in a colormatch. But this caution is noteworthy not only in regards to the finish: while your attention may fall to impurities in the pigmentation as factors that can have a strongly deleterious effect, not only what is in the finish can defeat the goal of low reflectance, but also what is in the leather crust. Some dyes and dye impurities can absorb infrared energy and heat up. A holistic view of the entire leather composition including the range of process chemicals used in the wet end needs to be considered if your goal is to make near-infrared-reflecting leather.

CONCLUSIONS

With the advent of renewed interest in near-infrared reflecting pigmentation to reduce energy absorption and resultant heating of dark surfaces, we have shown how ordinary colorants can be put to effective use in matching dark colors to produce matches with decent reflectance in the near-infrared, and adequately low infrared heating. In this brief presentation we have shown how that can be done by color matching from the colorants you now use but selected on the basis of their near-infrared reflectances. We have additionally introduced a crude but useful mathematical approach for estimating how well those matches will perform in terms of near-infrared reflectance, and suggested a way that mathematical tool could be improved.