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Examination of U.S. Automotive Paints: I. Make and Model Determination of Hit-and-Run Vehicles by Reflectance Microspectrophotometry

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ABSTRACT: The feasibility of using the Nanometrics DocuSpec I microspectrophotometer for paint analysis was investigated. The reflectance spectra of 15 paint panels of visually similar color from the Reference Collection of Automotive Paints were stored in the DocuSpec computer's memory. Paint samples taken from salvage yard vehicles were compared against this reference library, and in eight out of eleven instances the DocuSpec correctly identified the right panel as a possible source of the paint fragment. The DocuSpec I can be used as a rapid and discriminating screening tool in the determination of the make and model of a hit-and-run vehicle from a paint chip found at the scene.

KEYWORDS: criminalistics, paints, spectroscopic analysis, microspectrophotometer

In the examination of automotive paint evidence from hit-and-run cases, the investigator may ask various questions depending on the circumstances of the case. Often, a direct comparison of paint fragments collected at the scene and paint from a suspect vehicle is requested. In such cases the examiner will determine whether the paints are of the same composition and, if so, draw a conclusion as to the likelihood that the paints originated from the same source.

A second situation occurs when the offending vehicle is unknown. In this instance, the examiner is asked to provide an investigative lead by determining, from the paint found at the scene or adhering to the victim's clothing, the make and model of the vehicle from which the paint originated. If a suspect vehicle is subsequently found, a comparison of the paint chips can then be performed to confirm or deny that vehicle as a possible source.

When performing a paint comparison, there is no one analytical step that will prove the chemical similarity of the two paints. Several steps are necessary before it can be determined that two paints are of the same formulation—usually a combination of elemental analysis, infrared spectroscopy, or pyrolysis gas chromatography. However, any analytical scheme for the comparison of paint fragments should include as its initial step a microscopic examination of the chips for color, texture, layer sequence, and thickness. Direct color comparisons are easily performed with a $\times 10$ stereomicroscope. Color discrimination can be enhanced by placing the chips on a background of a complementary color.

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Determination of Make and Model of Hit-and-Run Vehicles

When no suspect vehicle paint standards are available in a hit-and-run accident, the examiner is faced with the problem of providing the investigator with information about the offending vehicle as soon as possible. It is important to locate the vehicle before the driver has had an opportunity to repair any damage, repaint the vehicle, or otherwise dispose of any incriminating evidence. The examiner must have available to him the materials and methodology to identify the source of an unknown paint chip.

Some laboratories, such as the FBI Laboratory, maintain a reference file of automotive paints that contain panels supplied by the various auto manufacturers. An alternative to soliciting paint panels from the auto makers is to subscribe to the Reference Collection of Automotive Paints (RCAP), distributed through Collaborative Testing Services, McLean, VA.

When an unknown paint chip is received into the laboratory, the initial step in the identification procedure is usually to compare visually the color of the chip with each panel in the reference file, which, depending on the popularity of the color, can be a time-consuming process. The need for a system of rapidly screening a collection of paint samples for color matches has been demonstrated [*1,2*]. In addition to speed, another requirement of a system is that it be nondestructive. Often the amount of paint found at the scene is small, and enough sample must be maintained so that the chemical and instrumental tests necessary to confirm the paint match can be performed.

The feasibility of using reflectance spectroscopy as a method of comparing the colors of small paint samples was demonstrated by Paul [*3*]. The introduction of the Nanometrics 10S Microspectrophotometer permitted the objective evaluation of color using the Commission Internationale de l'Eclairage (CIE) system of chromaticity coordinates [*4*], and the use of reflectance spectra to identify the pigments in the paint [*5*].

Materials

The DocuSpec I (Nanometrics, Inc., Sunnyvale, CA) is a computerized microspectrophotometer with built-in programs that will perform visible wavelength (380- to 764-nm) spectral pattern comparisons. It consists of a modified Olympus BHT microscope with brightfield and darkfield reflectance optics and quartz-halogen lamps, a holographic grating monochromator, a gallium arsenide photomultiplier detector, and a CS-2 computer with 32K RAM capable of storing up to 172 reference spectra, which can be arranged in up to 32 program libraries. Comparisons between a sample and a stored spectrum are made by summing the quantitative spectral differences over a specified wavelength area. The degree of similarity in color of the unknown and the library references is reported as a match number that ranges from 0.00 (total similarity) to 100.00 (total dissimilarity). A threshold value can be selected between 0.00 and 1.00; if the match value falls below this user-defined threshold, the computer will identify the sample as a match with that reference.

A $\times 20$ objective with a fixed aperture viewing area of 18×126 μm was used. The 100% reflectance calibration standard used was a white paper standard supplied with the DocuSpec. The DocuSpec is capable of averaging up to nine spectra of a sample to generate an averaged spectrum for storage and comparison. In this study, nine spectra from different areas of the paint chips were averaged for each sample. Care was taken to position the aperture over an area free of metallic flakes to insure that only the spectrum of a pigmented area was collected.

Reference Collection of Automobile Paints (RCAP)

The RCAP consists of 25- by 40-mm panels of each paint used as an original finish on General Motors, Ford, American Motors, and Chrysler vehicles. Each panel is individually coded by manufacturer, type of paint, year of introduction, and a color number. Because different

manufacturers may supply the same color of paint to an auto maker, the RCAP will, in many cases, contain several panels with the same color number. The RCAP is supplied as a book containing one panel of each color number, and a Chemical Supplement file containing any additional panels for each color. A reference manual included with the RCAP contains the information on the years and models on which each color was used. As of the 1984 supplement, the RCAP contained 1101 paint colors.

Paint Samples

For the first half of the experiment 15 silver metallic paint panels were chosen from the RCAP, as visually similar in color as possible. The panels selected are listed in Table 1. Silver metallic panels were chosen as a worst-case scenario because we felt that if the DocuSpec I could differentiate gray colors whose reflectance spectra are basically featureless (Fig. 1), it would be at least as effective with other colors. Because silver metallic is a popular color for automobiles, it was important to show that the DocuSpec I would work well with that color.

For the second half of the experiment, paint samples were removed from salvage yard vehicles. They were chosen to be the same color as one of the 15 panels selected from the RCAP and were visually inspected to insure that they were the original finish. The samples were collected from whichever surface of the vehicle was most readily accessible. The eleven samples used are listed in Table 2.

Method and Results

The first step in this investigation was to determine how well the DocuSpec I would discriminate among like-colored paints, and what minimum threshold value could be used to define a

TABLE 1—*Paint panels selected from the reference collection of automotive paints (RCAP).*

RCAP Code[a]	Years Used	Models Used on
74 0052	1973-1976	GM cars
FN 74 0092	1973-1983	Ford, Lincoln, Mercury
PN 75 0149	1975-1977	Dodge, Chrysler
FX 75 0153	1975-1977	Thunderbird, Lincoln
KN 75 0172	1975	AMC cars
	1977	GM cars
DA 77 0334	1978-1981	Corvette
PN 78 0385	1978-1981	AMC cars
PN 78 0388	1978-1979	Dodge, Chrysler
CN 78 0404	1978	Chrysler
DA 78 0426	1978-1980	GM cars
FN 78 0472	1978	Ford trucks
FN 80 0632	1980	Thunderbird
FN 80 0651	1980-1983	Ford trucks, Lincoln
DB 81 0796	1981-1983	GM cars
PC 83 0932	1983	AMC Alliance

[a]Key:

First letter: manufacturer

- C = Jones-Dabney
- D = DuPont
- F = Ford
- K = Glasurit America (Cook)
- P = PPG

First two digits: year of introduction

Second letter: paint type

- A = acrylic solution lacquer
- B = acrylic dispersion lacquer
- C = acrylic enamel
- N = nonaqueous dispersion enamel
- X = not specified

Last four digits: RCAP color code

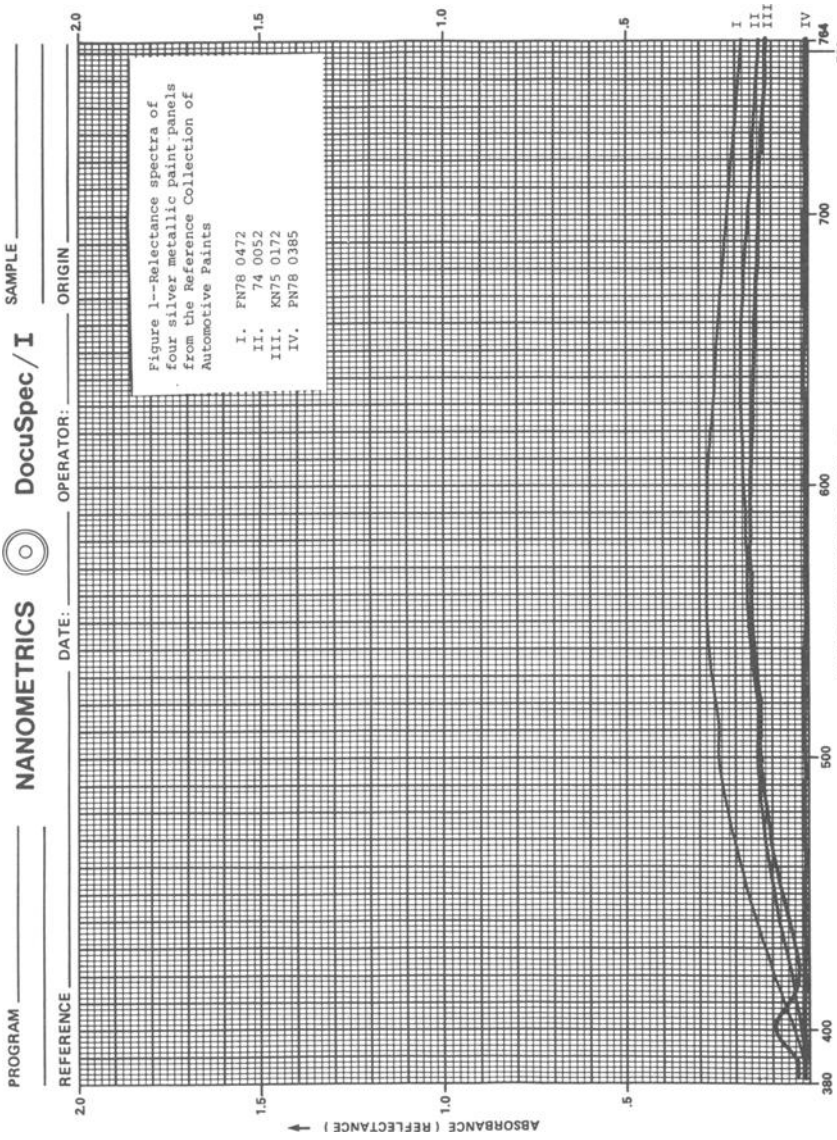

FIG. 1—*Reflectance spectra of four silver metallic paint panels from the Reference Collection of Automotive Paints:* (I) *FN78 0472;* (II) *74 0052;* (III) *KN75 0172; and* (IV) *PN78 0385.*

TABLE 2—*Salvage yard vehicle samples.*

Model	Year	Color Code[a]
Chevrolet Malibu	1975	0052
Oldsmobile 98	1975	0052
Ford Monarch	1975	0092
Ford Mustang	1976	0092
Ford Pinto	1978	0092
Ford Escort	1981	0092
Ford Thunderbird	1976	0153
Plymouth Horizon	1978	0388
Oldsmobile Cutlass	1978	0426
Chevrolet Chevette	1980	0426
Pontiac Phoenix	1980	0426

[a]This is the color code of the paint that the vehicle would be expected to have according to the RCAP Reference Manual. The actual type and manufacturer of the paint was not determined.

match. The spectra of each of the 15 panels from the RCAP were stored in the DocuSpec's memory as a library. After the reference library was assembled, each of the panels was again run, and then compared with the library. The results of this self-matching are presented in Table 3.

In every case, comparing a sample back to itself within the reference library resulted in a 0.00 match number, a perfect match. In eight out of fifteen samples, this was the sole 0.00 match listed. In the other seven cases, at least one other paint also gave a 0.00 match value.

Note that a sample recording a 0.00 match with a second paint is not necessarily a mutual situation. For example: three pairs, 404 and 388, 404 and 472, and 92 and 426, did yield 0.00 match values in both directions. However, although matching 796 to the library gave a 0.00 match with 334, matching 334 to the library gave a 0.05 match value with 796. There were four other situations in which a nonmutual 0.00 match resulted.

The explanation for the seemingly anomalous results could be that, because these paints are heterogeneous samples (as a result of the presence of metallic flakes), it was necessary to take the average of nine spectra (the maximum allowed by the DocuSpec I) for a particular sample.

TABLE 3—*Comparison of RCAP panels to library of 15 RCAP panels.*

RCAP Color	Match Value to Itself	Other Colors Giving 0.00 Match Value
0052	0.00	
0092	0.00	0426
0149	0.00	
0153	0.00	0472
0172	0.00	
0334	0.00	
0385	0.00	
0388	0.00	0153, 0404
0404	0.00	0153, 0388, 0482
0426	0.00	0092
0472	0.00	0149, 0404
0632	0.00	
0651	0.00	
0796	0.00	0334
0932	0.00	

Apparently, some variations may occur as a result of this averaging process; however, they were not significant enough to prevent the DocuSpec from correctly matching a sample to an identical sample contained in its library.

Based on the results of these 15 samples, it was apparent that the DocuSpec I is useful as a screening tool for paint chips. After a library of reference paint samples was entered into its memory, the DocuSpec was able, in 2 min, to narrow the possible matches of a sample to between one and four sources. In all 15 cases, the correct answer was included in the list of possibilities.

After the DocuSpec I showed that it could correctly match laboratory samples, the next question was whether it could, with the same degree of accuracy, match samples removed from automobiles that had been exposed to the normal effects of weathering. Cousins has "shown that there are variations in the colour ... of manufacturers' original topcoat finishes from different points on a vehicle. However, they are relatively small and do not preclude the use of data banks of chromaticity coordinates for original finishes from known sources." These variations will be primarily due to the effects of weathering and aging as a result of sunlight and exposure to the elements [*6*].

The eleven samples removed from salvage yard vehicles used in this study ranged in age from four to ten years old. The results of the matching of these samples to the previously created reference library of 15 RCAP panels are given in Table 4.

In eight out of the eleven samples, the DocuSpec I was able to match the salvage yard sample to the proper RCAP panel with a 0.00 match value. In one instance, a 1976 Thunderbird, the correct standard was the only 0.00 match. Six times, one other panel was also listed with a 0.00 match value, and in one instance, two other panels were reported as 0.00 matches. As in the previous experiment the DocuSpec I had difficulty differentiating Color 92 (Ford) from Color 426 (General Motors).

The other three salvage yard samples did present a problem for the DocuSpec I. These three did not yield a 0.00 match at all; the proper standard was something less and never was the top-listed match. There is no ready explanation for why these three samples were not successfully identified. All three were from General Motors vehicles; however, two other salvage yard samples from GM vehicles were correctly matched. Whether the reason for this failure to identify 27% of the samples correctly is due to the effects of weathering or some other unknown cause related to the vehicle's history was not determined. More salvage yard samples from a greater variety of vehicles must be collected before any definite conclusions may be drawn.

TABLE 4—*Comparison of salvage yard samples to reference library of RCAP panels.*

Vehicle	Expected[a] Color Code	0.00 Matches Reported	Match Value with Expected Color Code	Rank[b]
1975 Malibu	0052	...	0.02	4
1975 Olds 98	0052	0052, 0334	0.00	1
1975 Monarch	0092	0092, 0632	0.00	1
1976 Mustang	0092	0092, 0426	0.00	2
1978 Pinto	0092	0092, 0426	0.00	2
1981 Escort	0092	0092, 0426	0.00	1
1976 Thunderbird	0153	0153	0.00	1
1978 Horizon	0338	0153, 0388, 0404	0.00	2
1978 Cutlass	0426	...	0.01	3
1980 Chevette	0426	...	0.07	6
1980 Phoenix	0426	0092, 0426	0.00	1

[a] See Table 2 for explanation.

[b] The DocuSpec lists the ten closest library matches in order. The rank is where the expected color code fell on this list.

Summary

The Nanometrics DocuSpec I is capable of differentiating paint chips that are similar in color based on their spectral reflectance patterns in the 380 to 764 nm region. It can be used to match the spectrum of a paint chip found at the scene of a hit-and-run accident to a reference library of stored spectra of known paint chips, such as the Reference Collection of Automotive Paints. As the DocuSpec I computer's 32K RAM is capable of storing only 172 spectra in its volatile memory, an optionally available disk drive should be added to the system so that the entire RCAP, with its over 1000 colors, may be permanently stored. When the entire reference library is stored in the memory, comparisons of unknown chips can be accomplished faster and with more discriminating ability than simple visual comparison to a collection of panels.

The DocuSpec I cannot be relied on to provide the correct answer every time, but it is an effective screening tool. The presence of 0.00 matches does not necessarily mean that the correct panel has been identified, and the absence of 0.00 matches does not necessarily mean that the correct panel is not in the reference collection. However, by looking at the listed 0.00 matches, the analyst has a starting point. Those panels can be pulled first and compared to the unknown chip by chemical and instrumental testing to confirm or disprove a match.

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