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Evaluation of Automobile Paint Flakes as Evidence

Paint, normally in the form of dried flakes, is one of the most common types of evidence encountered by the forensic chemist. It may be from sources such as buildings, tools (frequently while being used to enter buildings), and most importantly, motor vehicles. It may be desired to identify the make and color of a suspect vehicle from paint left at the scene or on the clothing of a hit-run victim. Alternatively, it is frequently necessary to compare such paint flakes with reference flakes from a suspect vehicle.

Preliminary and microscopic examinations will reveal any difference in the number and order of the layers, their color, thickness, and reaction with solvents. Chemical examination may then be used to classify the paint according to type and to reveal minor differences in resin, as well as differences in pigment or trace elements.

The value of such paint flake comparisons as evidence of identification in court varies considerably, being affected by such factors as the make, age, and color of the vehicle and whether the paint work is in its original condition or has been refinished, perhaps a number of times.

Without precise information concerning these factors, such as would be obtained from a survey of the motor vehicle population, the significance of the results cannot be properly assessed. Though surveys have been conducted on paint flakes from buildings [*1*] and in men's outer clothing [2], there is a lack of detailed information on motor vehicle paint flakes. This paper presents the results of such a survey from motor vehicles in New South Wales, Australia. Local variations in motor vehicle populations do occur due to factors such as vehicle make, age, and color differences and paint composition, undercoating, and refinishing methods. These have been considered in the presentation of the results to enable them to be of substantially general application.

Survey Sampling

Five hundred vehicles, taken at random from a motor vehicle insurance company's yard of "write-off" vehicles, were sampled. It was considered that these would be reasonably representative of cars on the road and should not contain a preponderance of older vehicles. They could possibly be vehicles more prone to accidents than the total population. If so, they would actually relate more truly to those encountered in casework.

The samples were obtained during the period July-October 1974 by proceeding along the rows of vehicles prepared for auction and taking paint flakes from the front

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mudguard areas. Where possible, the samples were collected as discrete flakes with all the layers intact. The only vehicles not sampled were those where flakes could not be removed without markedly disfiguring them or where the paint could not be obtained as discrete flakes of satisfactory size. In some cases the paint flaked off the car into fragments which did not contain all the layers; this was considered acceptable as being the way the vehicle would be expected to behave in an accident. Large trucks and other heavy vehicles were not sampled.

Examination Procedure

The following are the techniques normally used in casework for multilayer samples. These were applied to the samples to determine to what extent the 500 could be differentiated.

Preliminary and Microscopic Examination

The color of the topcoat layer is compared, both macroscopically and with a stereo-zoom microscope (magnification, × 7 to × 30) under varied lighting conditions. Similarly, texture and other features such as metallic iridescent finishes are noted. On a fresh cross section of the flake, color, thickness, and reaction to acetone of each layer are examined. Also, one drop of concentrated sulfuric acid is applied to the topcoat layer. Any color reaction or dispersion on agitation is noted.

Infrared Spectrophotometry

Infrared (IR) spectra are run from 4000 to 400 cm^{-1} as KBr disks, where possible using the topcoat layer only.

Emission Spectrography

Samples are prepared by digestion with concentrated sulfuric acid in a preformed graphite electrode coated with polystyrene. A Hilger Large Quartz Spectrograph is used, covering the range of 230 to 630 nm in two exposures. Examination of the plates is essentially qualitative, recording elements as major, minor, or trace.

Pyrolysis/Gas Chromatography

A Pye curie point pyrolyzer is used, pyrolyzing for 7.5 s at 770°C. The chromatograph is programmed at 130 to 200°C using a Porapak Q column [*3*].

Initially the samples were divided into nine color groups: blue, green, brown, gray/silver/black, orange, purple, red/pink, white, and yellow, according to the color of the topcoat layer. Further color differentiation was made later in the program.

Each of the samples was examined individually in cross section. The layer sequence was noted, describing the colors by the above groups. Where filling materials such as spray putty were encountered they were recorded as paint layers unless they were present as the innermost layer, when they were disregarded. The reaction of each layer to acetone was also noted.

The samples in each topcoat layer group were then divided into a further nine groups according to the color of their second layer, using the same color groupings. Each of these groups was further similarly subdivided according to the color of the third layer. The process was repeated for succeeding layers, until as many individual members as possible had been differentiated. Those differentiated were not considered further.

Each small group of samples having an identical layer sequence was then further

differentiated according to the reactions of the individual layers with acetone. The members of the remaining small groups were then examined comparatively. They were differentiated where possible by (1) noticeable differences in the color or appearance of the topcoat layer, (2) obvious differences in the colors and appearances of the remaining layers, (3) marked differences in layer thicknesses, and (4) reaction of the topcoat layer with sulfuric acid. Analysis of the remaining groups was then carried out by IR spectrophotometry, emission spectrography, and pyrolysis/gas chromatography.

Results and Discussion

Generally, car manufacturers coat their vehicles in distinctive ways in regard to topcoat systems and type and number of undercoats. Hence the cars examined were classified according to make (Table 1).

The percentages obtained were compared to those of the total population of cars (including station wagons, panel trucks, vans, and pickup trucks) registered in New South Wales, showing a correlation coefficient of 0.95. The 500 vehicles examined were therefore taken as being representative of those on the road. Table 2 shows the breakdown of the samples into the nine groups according to the colors of the topcoat layers. As expected, white is by far the largest group. Only two black vehicles were encountered.

Initial subdivision of the samples into nine groups according to the color of the topcoat layer and then into small subgroups by the color groupings of the succeeding layers served to individualize 157 samples (31%). A further 129 (26%) were differentiated by their reactions to acetone. Of those remaining (204 or 41%), comparison of topcoat color, color of underlying layers, layer thickness, and reaction of the topcoat layer with sulfuric acid for each small subgroup differentiated all except 10 samples.

The layer sequence of paint flakes is the most significant point of comparison, particularly because of the variety of ways in which cars may be refinished. A large number of layers agreeing with regard to color, thickness, and layer sequence can be taken as proof of common origin without further examination. The numbers of layers possessed by the samples in the present survey were considered at several points during the study. The layer distribution of the samples is shown in Table 3. Only 5% had more

TABLE 1—*Samples grouped according to vehicle make.*

Make	Vehicles, no.	Vehicles, %
Australian Motor Industries [a]	38	7.6
Leyland	73	14.8
Chrysler	61	12.2
Fiat	11	2.2
Ford	71	14.2
General Motors [b]	131	26
Datsun-Nissan	32	6.4
Renault	7	1.4
Volkswagen	44	8.8
Colt	2	0.4
Honda	3	0.6
Jaguar	1	0.2
Mercedes	1	0.2
N.S.U.	1	0.2
Mazda	22	4.4
Subaru	1	0.2
Volvo	1	0.2

[a] Assembles Rambler, Toyota, and Triumph vehicles.
[b] Mainly Holden vehicles.

than six layers. Of the small groups not differentiated after examination of layer sequence and acetone behavior, only 2% (4 samples of 214) had more than four layers (Table 4). Of the five groups (10 samples) which remained for chemical examination, two had 2 layers and eight had 3 layers.

Particulars of these samples are given in Table 5. Each pair was examined chemically with the following results.

Pair A samples were judged by their appearance to be from vehicles with original paint and contained alkyd (baked) enamel. There were slight differences in IR absorption in the region 1000 to 900 cm^{-1}. Both were found to contain titanium, aluminum, and a trace of silicon. However, the relative proportions of titanium to aluminum were markedly different.

TABLE 2—*Samples grouped according to color of topcoat layer.*

Color Group	Samples, no.	Samples, %
Blue	72	14.5
Brown	52	10.5
Green	90	18
Gray/silver/black	31	6
Orange	10	2
Purple	5	1
Red/pink	34	7
White	171	34
Yellow	35	7

TABLE 3—*Layer distribution of samples.*

Layers, no.	Samples, no.	Samples, %
2	95	19
3	159	32
4	130	26
5	48	9.5
6	41	8
7	16	3
8	7	1.4
9	2	0.4
10	1	0.2
11	...	...
12	1	0.2

TABLE 4—*Layer distribution of samples not differentiated by layer sequence and acetone behavior.*

Layers, no.	Samples, no.	Percentage [a]
2	59	28
3	95	44
4	56	26
5	2	1
6	2	1
Total	214	

[a] Calculated as percentage of the 214 samples not differentiated by layer sequence and acetone behavior.

Pair B samples were from vehicles with original paint finished in acrylic lacquer. There were slight differences in IR absorption at approximately 100 cm^{-1}. They were differentiated by the second sample containing minor amounts of strontium and chromium and traces of calcium as well as increased quantities of iron, aluminum, and barium.

Pair C samples were from vehicles with original paint finished in acrylic enamel. There were slight differences in IR absorption in the region 1300 to 1250 cm^{-1} as well as in the relative proportions of titanium and aluminum in each. They were differentiated by marked differences in the proportions of pyrolysis products obtained.

Pair D samples were from vehicles of the same make in original condition finished in alkyd (baked) enamel. They could not be differentiated.

Pair E were from vehicles of the same make in original condition finished in acrylic enamel. They could not be differentiated.

Thus, of the 500 vehicles surveyed, all were differentiated except four. These were vehicles of similar make which had not been refinished and which had been painted in the same color. Pairs B and C also involved vehicles of similar make and color in original condition, but from notes made when sampling, different models appeared to be involved. Detectable differences in paint formulations had occurred in the intervals. Pair A involved vehicles of different makes and were also differentiated.

All samples from refinished vehicles were differentiated without recourse to chemical examination. It was noted during the examinations that of the 500 vehicles, approximately 25% possessed original paint in the areas sampled.

Conclusion

The examination techniques have been shown capable of differentiating all but 4 of the 500 samples. These were two pairs from vehicles of similar make, model, and color. All refinished vehicles were easily differentiated.

The New South Wales motor vehicle population is believed not to be significantly different from those of most other areas. Hence the results should be of substantially general application. Because of the many variables that can be encountered in actual

TABLE 5—*Particulars of samples remaining for chemical examination.*

Makes of Vehicles	Layer Sequence
Pair A	
Datsun	white
Honda Civic	light gray
Pair B	
Holden Torana (early model)	white
Holden Torana	red-brown
	black
Pair C	
Chrysler Valiant	white
Chrysler Valiant	gray
	red-brown
Pair D	
Morris Mini	yellow
Morris Mini	light gray
	red-brown
Pair E	
Chrysler Valiant	brown (metallic finish)
Chrysler Valiant	gray
	red-brown

motor vehicle accidents, it has not been attempted to draw statistical conclusions from the results. Rather these have been presented so as to facilitate their application to particular cases.

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