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The Prevalence of Original Equipment Manufacturer (OEM) Factory Repairs in Automotive Paint Samples

ABSTRACT

This study was conducted to enhance the ability of trace evidence examiners to include interpretative statements in comparative examinations, using automotive paint as an illustrative example. Some comparisons of mass-produced manmade materials are straightforward. However, it is not uncommon to encounter samples that require further discussion to convey the degree to which two or more items are concluded to be "associated". As an example, it is appropriate to question the significance of an OEM factory repair paint chip comparison between a known source and an unknown paint chip.

To gain some knowledge of the frequency with which OEM repairs occur, approximately 1000 physical samples representing model years 2000-2013 were microscopically examined for OEM factory repairs. Samples containing factory repair topcoat layers (e.g., clear/basecoat layers over a typical 4 layer OEM layer system) were noted. The repair rate in this study was on par or lower than reported industry expectations or standards for OEM factory repairs of topcoat systems. However, the number of permissible OEM topcoat layers was observed to be greater than expected based on discussions with industry contacts. Based on these two factors, the presence of an OEM factory repair in comparative paint examinations is noteworthy with respect to the interpretative language that should be used to describe an association. It is hoped that this work will provide a talking point as to how a non-routine occurrence can be handled in the context of report writing and interpretation.

Keywords: OEM Factory Repairs, Paint Data Query, Interpretation, FTIR, Reference Collections

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INTRODUCTION

In recent years, the trace evidence community has begun to develop language to convey significance of association in comparative examinations of a wide variety of materials, to include paint [1]. The strength of association in reporting a fracture match or the discrimination of paint chips with obvious differences in physical or chemical characteristics can be conveyed using relatively straightforward text. Likewise, the rationale for associating a standard four-layer original equipment manufacturer (OEM) paint chip with a known vehicle(s) of corresponding layer construction and chemical compositions can be succinctly described with appropriate caveats to alert the reader to the existence of other vehicles also painted in the same manner.

Some aftermarket automotive refinishes are unusual, such as a basecoat color change or a formulation not commonly observed on automotive exteriors (e.g., latex, or nitrocellulose on late model year vehicles). These types of paint systems can provide high discrimination in comparison examinations and are often readily understood by a lay audience once a foundation has been established as to how vehicles are coated. What is less clear to interpret is the number of OEM repairs that are common to a given manufacturer, plant, or paint process (e.g., tri-coat). Further, it is not well understood in the forensic community how many applications of OEM repair layers are permissible before the coating efficiency begins to fail on a vehicle. Similarly, there is no baseline to conclude how many OEM repair layers need to be present in a paint comparison case in order for the presence of additional (repair) layers to be considered significant.

The 2008 edition of *Automotive Paints and Coatings* states that "[T]he best car makers achieve a 'no touch' rate of 75%, that is, 75% of the car bodies handed over to the assembly line without any polishing or repairs in the top coat, 20% need spot or panel repair, and 5% would require total repair." The authors, current or former employees of the OEM automotive groups at BASF and Herberts/DuPont (now Axalta) in Europe, contend that ~ 25% of the time surface polishing and buffing or OEM coating repairs are needed on one or more layers of an automotive paint system [2].

Based on this information, industry representatives in North American assembly plants and OEM paint suppliers were contacted. Each was asked to estimate the rate of OEM repairs, that is, the application of repair paint layers prior to factory release of the vehicle. North American-based manufacturers estimated that first pass-through quality assurance on the paint line averaged between 85 – 90%. Discussions with OEM automotive paint suppliers yielded consistent estimates for this question [3]. All six sources stated that these averages referred to additional basecoat/clearcoat applications with primer surface repairs rare and electrocoat primers never repaired. In the "extremely rare" event that an operator sanded through to bare metal, a corrosion resistant flash (air dry) primer would be applied. The decision to repair the finish in a spray booth versus panel replacement can be plant dependent as the supply of parts and physical space at the end of the paint line dictate the manufacturers' repair options. Repair areas on a body panel can involve the entire panel or a section on the order of a foot across (termed a "spot" repair). Spot repairs are most common/necessary on vertical surfaces. The general consensus among industry representatives is that no more than two complete topcoat repairs (3 topcoats over primer/e-coat equating to an 8-layer paint system) are permissible before a manufacturer's corrective action options become limited (e.g., panel exchange or scrapping the vehicle).

Given the European and North American estimates of OEM factory repair rates, in concert with the reality that they do occur to some extent, members of the Scientific Working Group for Materials (SWGMAT) paint group began discussions into developing a project to study observed OEM repair rates on factory released vehicles. A logical resource for a steady supply of vehicles representative of those on North American roads is the Paint Data Query (PDQ) database, which is maintained by the Royal Canadian Mounted Police (RCMP) in Edmonton, Alberta, Canada. PDQ is not an adequate resource as a population database because not all vehicles are represented for every model year or assembly plant. However, it is representative of the vehicles people have access to, and contributors obtain samples for PDQ from a wide range of resources: late model year aftermarket sunroof installations, collision centers, and occasionally, salvage yards. A quick review of PDQ's total inventory of OEM repairs for several of the laboratories represented in PDQ and SWGMAT was conducted in 2010 by the PDQ Maintenance Team. In Figures 1 through 3, each chart displays the manufacturer distribution of the samples as parenthetical percentages after the manufacturer name. The three-letter codes used to denote each manufacturer are the codes used in PDQ and may represent a make (e.g., AUD, POR, VLK rather than Volkswagen Group) or manufacturer (e.g., GEN rather than BUI, GMC, PON).

Figures 1 through 3 provide a quick overview of vehicles owned and operated in North America. Not surprisingly, the majority represent domestic manufacturers while the number of domestic plants is not as easily discerned. That number is estimated to be over 75% of the samples in these charts based on assembly plant data available from Automotive News [4]. It is necessary to note that these samples include all substrates, not just metal. The manufacturer abbreviations in the table are the three-letter designations used in the PDQ database.

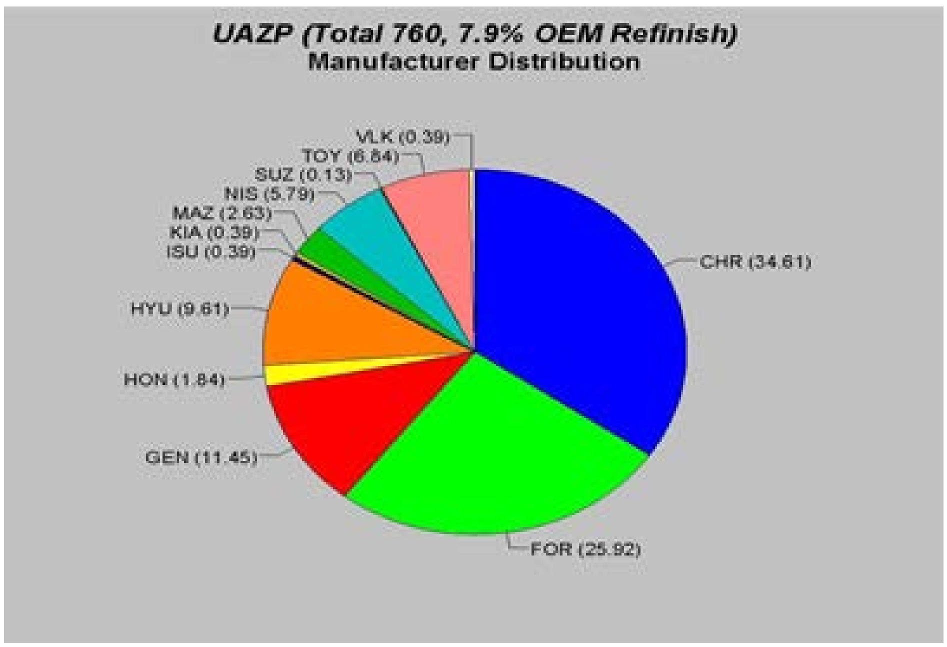

Figure 1: The percentage of OEM repairs in PDQ samples from Arizona averages about 7.9%. This percentage is based on 60 OEM factory repair systems observed in the 760 samples assessed. These samples are collected from 27 dealerships that contract with a single body shop for installation of aftermarket roof panels; the excised portion of the vehicle roof is used to gather samples for PDQ. Clockwise from top right (alphabetically): Chrysler, Ford, General Motors, Honda, Hyundai, Isuzu, Kia, Mazda, Nissan, Suzuki, Toyota, and Volkswagen.

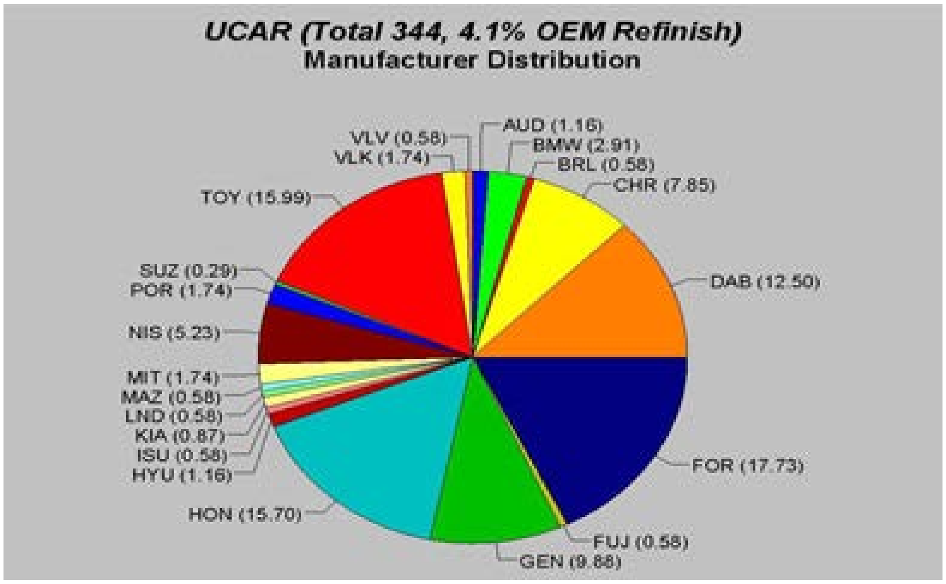

Figure 2: The percentage of OEM repairs in PDQ samples from California averages about 4.1%. This percentage is based on 14 OEM factory repair systems observed in the 344 samples assessed. These samples are collected from collision centers throughout the geographic areas where the California DOJ has laboratories. Clockwise from top (alphabetically): Audi, BMW, British Leyland (Jaguar/Land Rover/Mini), Chrysler, Daimler Benz, Ford, Fuji Motors (Subaru), General Motors, Honda, Hyundai, Isuzu, Kia, Land Rover, Mazda, Mitsubishi, Nissan, Porsche, Suzuki, Toyota, Volkswagen, and Volvo.

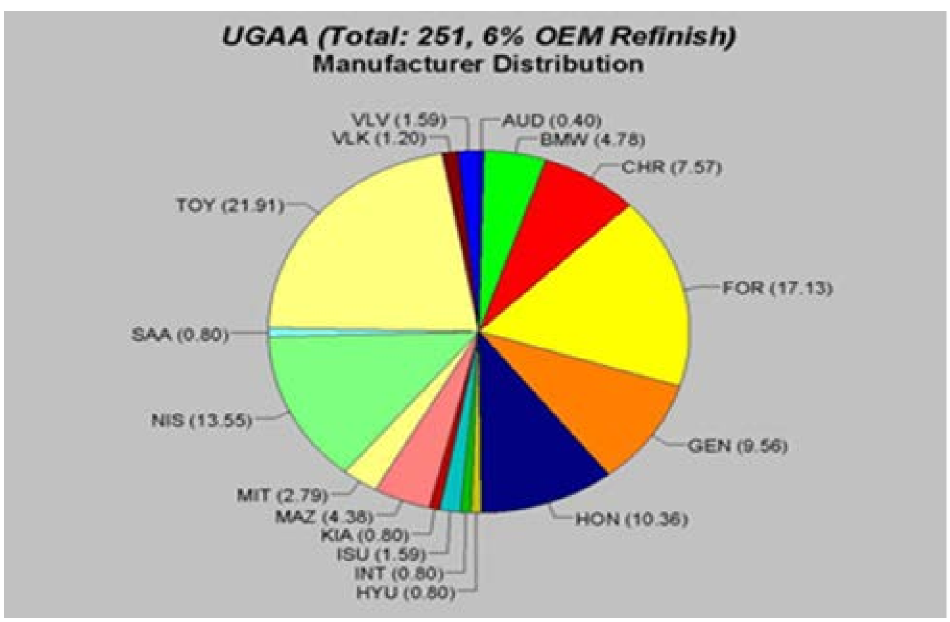

Figure 3: The percentage of OEM repairs in PDQ samples from Georgia averages about 6.0 %. This percentage is based on 15 OEM factory repair systems observed in the 251 samples assessed. These samples are collected from body shops in the Atlanta/Decatur area where the Georgia Bureau of Investigation is located. Clockwise from top (alphabetically): Audi, BMW, Chrysler, Ford,

General Motors, Honda, Hyundai, Integra, Isuzu, Kia, Mazda, Mitsubishi, Nissan, Saab, Toyota, Volkswagen, and Volvo.

Over half of the vehicles in each pie chart are represented by Chrysler (now Fiat-Chrysler, or FCA), Ford, or General Motors with the remainder of each chart comprised of between nine to eighteen additional manufacturers. Of the total number of samples shown in each chart, the OEM repair rate averages between 4-8%, an estimate at or below the reported rates obtained from the industry representatives contacted by the authors. It should be mentioned that PDQ no longer analyzes OEM factory repair layers for the database, but the presence of these layers is annotated in the database entry for each sample that is analyzed.

Other than the estimate of a “no touch” rate (encompassing both repair paint layer applications and polishing of surface defects) by Streitberger and Dössel, there is scarce discussion of OEM repair rates in the scientific or trade literature. However, OEM factory repair frequency is a great topic for significance of association discussions because it is a known entity in terms of the paint chemistries used. It is also a variant that manufacturers would strive to keep at a relatively low rate of occurrence. Therefore, greater investigation into the frequency of OEM repairs is warranted in order to allow for discussion as to how significant this type of layer system might be in comparative casework.

To that end, the FBI Laboratory selected a finite number of late model year range samples to assess the rate at which OEM factory repairs occur. Based on the information provided by PDQ, that database was concluded to be the best resource for obtaining a sampling of makes and models of late model year vehicles with adequate sample size, known collection and assembly information, and gathered from a broad range of geographical locations. A sample set of approximately 1000 samples was determined to be a manageable number to assess while providing enough data to report an OEM factory repair rate with some context.

Part of that context must also come from the realization that 1000 samples over a multi-year production schedule is a small fraction of the number of vehicles produced every month in North America. Table 1 is a summary obtained from the trade periodical *Automotive News*, in which the production for December, 2013 as well as the annual production for all of 2013 were published for cars and trucks assembled in North America: Canada, Mexico, and the United States [4].

Table 1: North American production in December 2013 and totals for 2013

Vehicle Type	December, 2013	2013 Totals
Total Canada car	63,877	963,847
Total Mexico car	89,346	1,771,107
Total US car	288,727	4,566,010
Total North America car	**441,950**	**7,300,964**
Total Canada truck	97,491	1,414,472
Total Mexico truck	81,279	1,269,104
Total US truck	455,470	6,606,424
Total North America truck	**634,240**	**9,290,000**
Total Canada	161,368	2,378,319
Total Mexico	170,625	3,040,211
Total US	744,197	11,172,434
Total North America production+	**1,076,190**	**16,590,964**
Total North America light vehicles	*1,051,261*	*16,190,372*

+ includes medium and heavy duty truck production

METHODS AND MATERIALS

Sample Set:

The sample set was comprised of paint submissions from labs in Phoenix, Arizona (AZP), California, Riverside Laboratory (CAR), Georgia Bureau of Investigation, Atlanta (GAA), and Columbia, South Carolina (SCC). These laboratories were chosen because they were SWGMAT/PDQ contributors of long standing, each with a proven history of providing samples that would meet the criteria of the optimal sample set (e.g., sample size, condition, >100 large samples/year from late model year vehicles, wide range of makes/models/plants).

As an example, Arizona PDQ samples are obtained from an auto body repair shop that contracts with 27 local dealerships in the Phoenix area to install aftermarket sunroofs. These 27 dealerships breakout as follows: 5 Chevrolet; 1 GMC; 3 Chrysler; 5 Ford; 2 Lincoln; 3 Hyundai; 2 Mazda; 3 Nissan; 1 Suzuki; and, 2 Toyota. The excised roof panels are held at the dealership until a lab representative can retrieve them for submission to PDQ. The remaining lab systems cull through the available vehicles at local salvage yards specifically targeting late model year samples. Using these four lab systems, a sample set of 1057 samples was obtained.

Given the typical lag time between manufacture and submission to PDQ, vehicles no older than model year (MY) 2000 were chosen for this study. This benchmark provided a span of fourteen years of manufacture, MY 2000-2013. Table 2 provides the breakdown for the number of each laboratory's submissions that was used to create the dataset for this study.

Table 2: Distribution of samples used in the assessment of OEM factory repairs.

PDQ Partner Laboratory	Number of Samples Analyzed
AZP	551
SCC	340
CAR	118
GAA	48
Total	**1057**

Visual and Microscopical Examinations:

Thin cross-sections were prepared using a scalpel with the sample held on edge, such that the visual characteristics of the layer system were visible: number of layers, sequence, relative layer thicknesses, and thickness uniformity across the layer. Any chip that contained additional sequential layers of a basecoat/clearcoat was further examined for consistency with the underlying topcoat. If the subsequent basecoat layer(s) was comparable in appearance to the lowermost basecoat with respect to color and sequence and no additional layers of primer or body filler were observed between the topcoat layer applications, that sample was set aside for further assessment.

FTIR Analysis:

The topmost and bottommost clear coat layers were analyzed by Fourier transform infrared spectroscopy (FTIR), using methodology that has been described previously, to confirm the consistency of an OEM binder formulation between these systems [5]. If the clearcoats were not consistent in chemical composition, the factory repair topcoat layer was not concluded to be an OEM factory repair. If a topcoat factory repair was sandwiched between the lowermost and uppermost dissimilar topcoats layers, the middle clearcoat(s) was also analyzed by FTIR to determine if it was consistent with the lowermost clearcoat. Visual and chemical consistency between basecoat/clearcoat layer systems within a paint sample was considered indicative of an OEM topcoat repair.

Figure 4 is a graphic of the body panel location where each sample was collected from a vehicle. The large percentage of roof samples is a natural consequence of the number of samples included from Arizona, which are traditionally available as the excised portion of the roof from vehicles where aftermarket sunroof installations are ordered. These samples are ideal for PDQ and for this study of OEM factory repairs because they represent the steel frame of the vehicle, not a possible replacement part (e.g., door, hood, decklid, liftgate). The miscellaneous category refers to samples from other vehicle parts such as gas caps, bumpers, or mirrors.

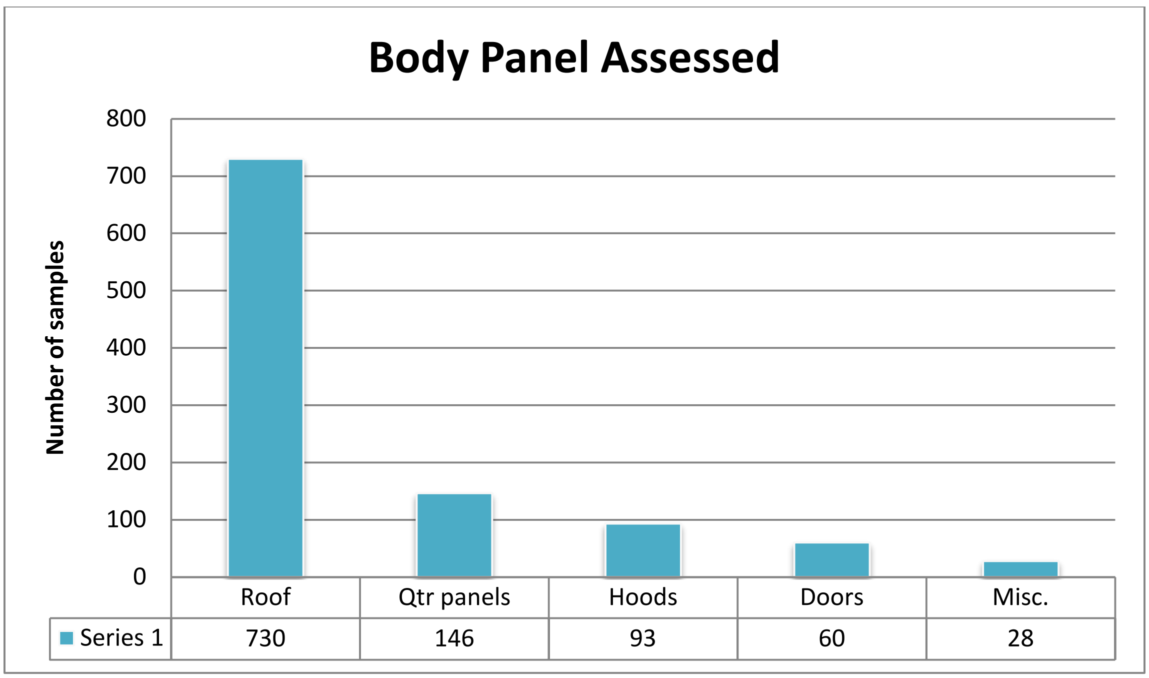

Figure 4: The types of body panels examined for OEM factory repairs.

RESULTS AND DISCUSSION

Analysis of the 1057 samples yielded an OEM factory repair rate of 7.8% for Model Years 2000-2013. This number corresponds quite well with industry estimates obtained from personal communications with industry contacts. The rate also appears to be noticeably lower than reported by Streitberger and Dössel, whose experience was based on European plants. It is unknown if the rate of OEM factory repair is actually that much greater in European assembly plants.

Figures 5 and 6 represent an example of an observed factory repair topcoat layer system that was confirmed to be OEM via FTIR analysis. The figure caption designates each layer according to the nomenclature developed by the RCMP for use in PDQ to label each layer above and below the transition between the basecoat and the uppermost primer. If that transition is imagined to be a line labeled as “0”, then the adjacent OEM layers would be 1 in either direction and thus labeled as a topcoat or undercoat, respectively. Thus, in this system, all original topcoats are assigned an “OT” designation, whereas aftermarket refinish topcoats are described as “RT”. Original undercoats are designated as “OU” where an original primer surfacer would be labeled “OU1” and the next underlying layer (e.g., e-coat) would be “OU2”. Using this naming system, the first basecoat above the primer is considered to be OT1 followed by a clearcoat layer (OT2). A subsequent OEM basecoat would be OT3 with its accompanying clearcoat layer designated OT4. If this extra topcoat system was concluded to be an aftermarket repair, the basecoat would be identified as RT1 and the clearcoat as RT2. [6]

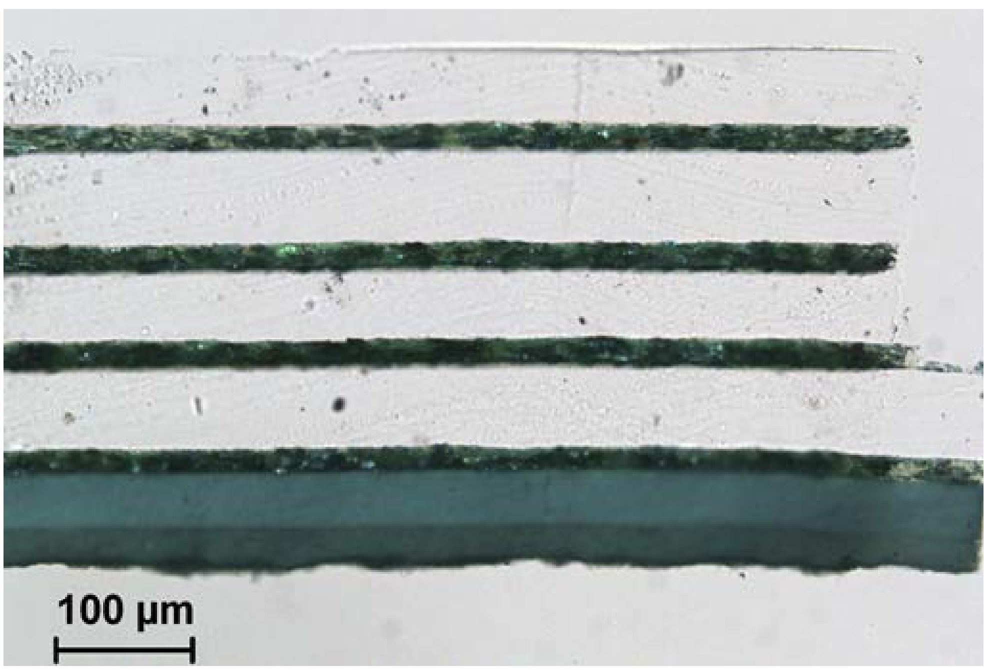

Figure 5 Manual cross section of a 10-layer OEM paint chip (using both transmitted and reflected lighting). From the bottom of the chip, light gray e-coat (OU2), medium gray primer surfacer (OU1), light green metallic basecoat (OT1), clearcoat (OT2), light green metallic basecoat (OT3), clearcoat (OT4), light green metallic basecoat (OT5), clearcoat (OT6), light green metallic basecoat (OT7), and clearcoat (OT8). In addition to the color consistency of the repetitive basecoat layers, the consistency of the relative thicknesses of the alternating base and clearcoat layers is indicative of OEM factory repairs. Image by Thom Hopen.

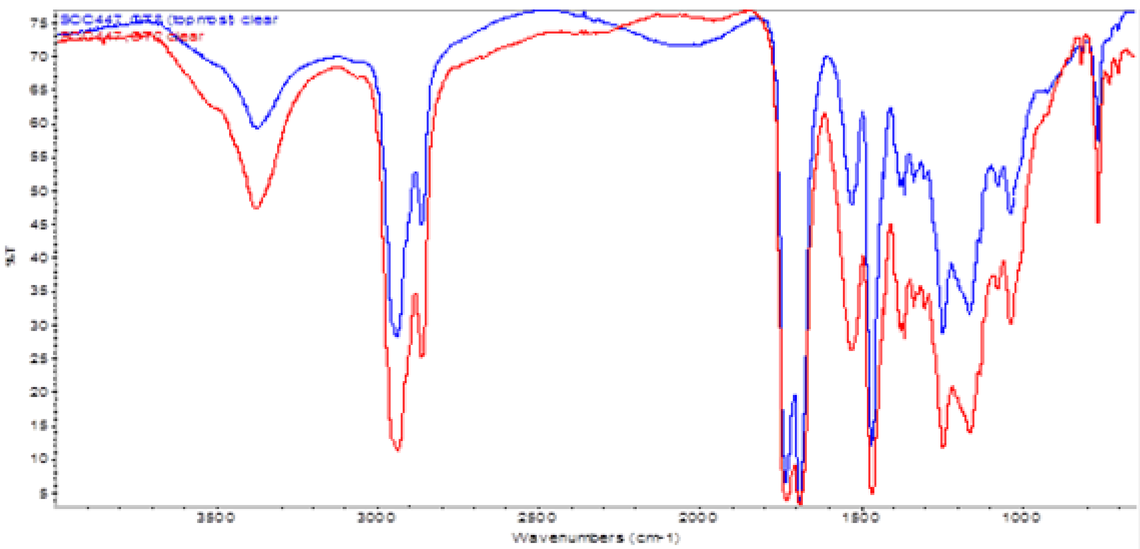

Figure 6: FTIR spectral overlay of two of the four OEM clearcoats (OT2, red; and OT8, the topmost clearcoat, displayed in blue) described in Figure 5. The consistency of the spectra confirm the visual indicators described for Figure 5 that demonstrate no physical or chemical differentiation between the lowermost and topmost clearcoat layers.

Figures 7 and 8 provide an analogous example of an observed multilayer system that was documented with a light micrograph image and then analyzed by FTIR to determine if the topmost layer was OEM or aftermarket. Figure 8 confirmed the aftermarket coating system alluded to in Figure 7.

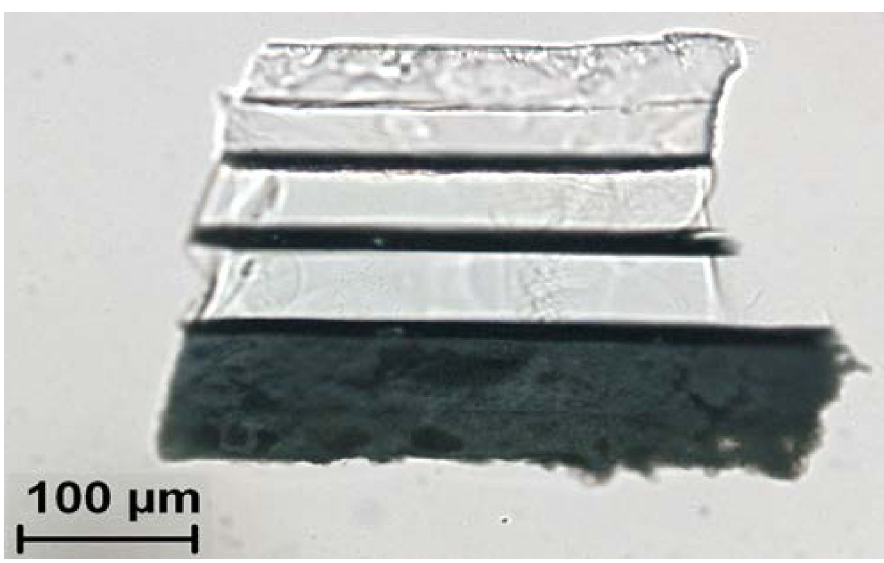

Figure 7: Manual cross section of a 9-layer paint chip (using both transmitted and reflected lighting) where two OEM factory repair topcoats are further covered by an aftermarket clearcoat refinish. From the bottom of the chip, medium gray e-coat (OU2), dark gray primer surfacer

(OU1), black basecoat (OT1), clearcoat (OT2), black basecoat (OT3), clearcoat (OT4), black basecoat (OT5), clearcoat (OT6), and aftermarket clearcoat (RT1). Note the boundary line between the top two clearcoat layers, the presence of which can be indicative of an aftermarket repair. Image by Thom Hopen.

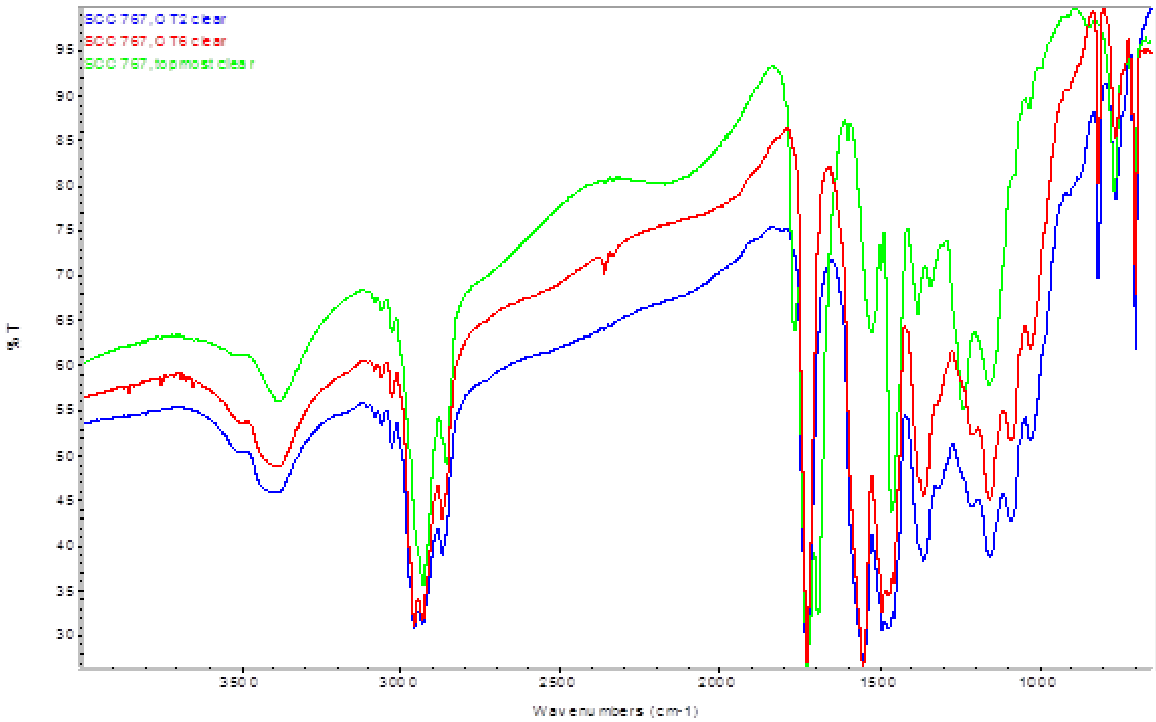

Figure 8: FTIR spectral overlay of the two OEM factory repair clearcoats (OT2, blue and OT6, red, each depicting strong melamine peaks at ~ 1550 cm-1 and ~ 815 cm-1) for the sample described in Figure 7. The green spectrum indicates that the topmost layer is a polyurethane-based aftermarket refinish (RT1).

Table 3 depicts the number of samples assessed in each model year, the number of OEM factory repairs observed per model year, and the number of OEM factory repair layers observed per automotive layer system. The greatest number of samples per model year was distributed in the midrange (2006-2007) of the timeline examined. Fewer late model vehicles were available and early model years were not as desirable for this sample set. In the midrange, there were a greater number of relatively new samples available (e.g., containing the latest technologies, models, and assembly plants still in use).

Table 3: Number of samples analyzed and OEM factory repairs observed per model year.

Model Year	# Samples	Total # OEM Factory Repairs	# of Topcoat Factory Repair Systems Observed
2000	4	1	OT3/OT4 (1)
2001	4	0	N/A
2002	0	0	N/A
2003	6	0	N/A
2004	19	3	OT3/OT4 (1); OT5/OT6 (1); OT7/OT8 (1)
2005	69	5	OT3/OT4 (4); OT5/OT6 (1)
2006	199	21	OT3/OT4 (20); OT5/OT6 (1)
2007	187	19	OT3/OT4 (13); OT5/OT6 (6)
2008	117	6	OT3/OT4 (4); OT7/OT8 (2)
2009	126	7	OT3/OT4 (5) ; OT5/OT6 (2)
2010	106	4	OT3/OT4 (4)
2011	84	6	OT3/OT4 (6)
2012	116	8	OT3/OT4 (6) ; OT5/OT6 (2)
2013	20	2	OT3/OT4 (2)
Totals	**1057**	**82**	**OT3/OT4 (67); OT5/OT6 (12); OT7/OT8 (3)**

As Table 3 also demonstrates, more than 2 factory repair topcoat systems were observed on three samples despite unanimous industry discouragement of the practice. Of the 82 OEM factory repairs studied, 67 (or 82%) consisted of a single topcoat repair (basecoat/clearcoat) over the existing topcoat. These repairs translate to 6 coating layers covering the metal substrate. Twelve additional topcoat repair systems were noted, accounting for an additional two layers of paint on those samples, or an 8-layer paint system. The three samples containing a third topcoat OEM repair are equivalent to 10 layer paint systems on the metal substrates.

Table 4 depicts the number of OEM factory repairs observed per body panel assessed. The last column represents this number as a percentage. From this table, it appears that the horizontal surfaces represented by the roof and hood samples were more likely to be repaired than the vertical quarter panel and door surfaces. Since roof and quarter panels cannot be replaced, but hoods and doors can, the disparity in factory repair rates for the various body panel surfaces does not appear to track with either surface orientation or the ability to replace the part versus repair the paint system. Therefore, no conclusion can be drawn from this data regarding the likelihood of a repair layer system on a particular area of a vehicle. This assessment further serves as a caution for lab personnel to request known samples that originate from the same body panel as where the suspected damage occurred. Moreover, if a hood and quarter panel both exhibited damage, it might be true that the areas where these parts are adjacent would have comparable layer systems. However, that does not necessarily indicate that the lower areas of the quarter panel would also be analogous in layer systems. Therefore, it is always a best practice to request that each area of interest be sampled for both transfer and known exemplars that are then packaged separately for submission.

Table 4: Distribution of observed OEM factory repairs by body panel.

Sample Surface	# OEM Factory Repairs/Total Samples	% of Factory Repairs
Roof	67 / 730	9%
Quarter panel	5 / 146	3%
Hood	8 / 93	9%
Door	2 / 60	3%

Table 5 divides the 1057 samples into the number of samples assessed for each manufacturer represented in the sample set, as well as the number and type of factory repairs observed per manufacturer. Since many manufacturers can share a plant and even assembly lines, manufacturer names were omitted from the table to circumvent conclusions regarding quality control per manufacturer or plant. Nine of the represented manufacturers had no OEM factory repairs present in the 213 samples attributable to them. Therefore, the 82 OEM repairs that were observed in the study are represented by the remaining eight manufacturers.

Table 5: OEM factory repairs sorted by number observed per manufacturer observed in the study.

Manufacturer	# Samples Assessed	Total # OEM Factory Repairs	# Topcoat Factory Repairs by Type
A	9	0	
B	230	25	OT3/OT4 (17); OT5/OT6 (7); OT7/OT8
C	219	27	OT3/OT4 (27)
D	146	16	OT3/OT4 (10); OT5/OT6 (5); OT7/OT8
E	38	0	
F	77	10	OT3/OT4 (9); OT5/OT6 (1)
G	2	0	
H	40	1	OT3/OT4 (1)
I	38	0	
J	3	0	
K	5	0	
L	114	0	
M	3	0	
N	7	1	OT3/OT4 (1)
O	113	1	OT3/OT4 (1)
P	12	1	OT7/OT8 (1)
Q	1	0	
Totals	**1057**	**82**	**OT3/OT4 (67); OT5/OT6 (12); OT7/OT8 (3)**

From these results, it is apparent that the vast majority of samples examined were standard OEM layer systems (92.2% of the 1057 samples). Moreover, when an OEM factory repair was encountered, the most common number of topcoat repair systems was one additional clearcoat/basecoat application resulting in 4 topcoat layers (6.34%, or 67 of the 1057 samples). The 12 samples with 6 topcoat layers account for 1.14% of the 1057 samples, while the three samples with 8 topcoat layers equate to 0.284% of the samples analyzed.

In this regard, the rate of ~ 8% OEM factory repairs in this study aligns well with and/or is lower than the stated industry average, depending upon the source of the accounting. This rate indicates that observing an OEM factory repair in comparative casework warrants a statement as to the potential for increased significance in a reported association. It is not necessary to know how often a particular make, model, model year, or assembly plant requires an OEM factory repair process in order to provide some context to the significance of an association. A rate of ~8% indicates that most vehicles are produced without factory repair layers regardless of make, model, or assembly plant. The process of OEM factory repair may be considered common practice by industry standards; however, it may be unusual to an examiner that has never encountered an OEM factory repair in casework. Regardless of these impressions, it is not the normal coating process for over 90% of the vehicles produced.

This study assessed a very small fraction of the total car population produced each model year with no attempt to capture every make, model, or plant for the model year range chosen. No consideration was given to the popularity of a particular vehicle in terms of geographic region of North America or color preference. However, like PDQ, popularity was accounted for in terms of availability of samples submitted from the various regions of the country represented in the sample set. Unlike the searchable PDQ database, the samples studied were what was submitted to PDQ, not what has been entered into PDQ. In other words, samples were not preferentially selected for their white, black, or red topcoats, and neutrals were no more prevalent than what was available in the collection sites favored by the PDQ partners used for this study. In this regard, the sample set was about as comprehensive and arbitrary as what might be encountered in casework. It is further noted that aftermarket refinishes were observed in the sample population, but not counted in percentages because these systems represent a randomness that would be difficult to incorporate into a population study of any kind.

CONCLUSIONS

The observation of an OEM factory repair layering system may occasionally be encountered in routine casework and is not unique to a particular make, model, model year, plant, layer system technology, or basecoat color. The presence of more than one OEM topcoat factory repair layer system is less common. Successive OEM factory repair layers beyond that are discouraged by industry experts and therefore should be considered more unusual or rare. As a result, examinations that include this type of automotive paint system should include documentation to convey that OEM factory repair systems can increase the significance of the reported findings. At a minimum, the use of statements beyond the conventional laboratory language should be considered to draw attention to the presence of these additional factory-applied layers.

It is hoped that this study will provide examiners with context should an OEM factory repair be encountered in casework. Further, this study provides a talking point as to how a non-routine occurrence can be handled in the context of report writing and interpretation.

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