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Variability of Refractive Index and Thickness of Tempered Glass throughout an Automotive Window

ABSTRACT

In forensic glass casework, a representative known sample is not always received. The goal of this study was to determine if one sample collected from a known window can be representative of the entire window. Ten vehicle side windows were examined for thickness and refractive index. No significant difference in thickness was found throughout a window and the location from which a glass sample is collected does not significantly alter the refractive index findings considering the expected variation within automotive tempered glass side windows.

Keywords: Glass, Refractive index, Thickness, Tempered, Automotive window, Variation

INTRODUCTION

In 2003 a study was conducted on tempered glass from ten vehicle windows to determine the variability of thickness and refractive index (RI) throughout a given window. It has been recommended by SWGMAT that a known “sample should be collected from various locations throughout the broken portion of the object in order to be as representative as possible” (1). While this might be the ideal collection process, it is not what is typically submitted to the laboratory. The goal of this study was to determine if one sample collected from a known window can be representative of the entire window.

The objectives addressed in this study were (i) the consistency of the refractive index from top to bottom of a tempered side automotive window; (ii) the consistency of the refractive index between the inside and outside of a tempered automotive glass window; and (iii) the consistency of thickness from top to bottom of a tempered automotive window.

METHODS

The vehicles selected for this study were chosen to represent different production years, manufacturers, and models to account for possible variation (Table 1). Glass samples were taken from the side windows of these damaged vehicles in the Cincinnati Police Impound Lot.

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Each window was divided into three sections: top, middle, and bottom. Each car window was gently broken with a hammer to keep as many pieces of glass in the window as possible for collection. One sample of glass was carefully loosened and removed from each section of the window and individually wrapped in butcher paper. Each piece of glass was marked with a red and blue permanent marker in order to distinguish between the inside or outside surfaces of the window, respectively. The packaging was then marked in order to document the make and model of the car, and the location from which it was obtained.

The thirty glass fragments representing the top, middle, and bottom of the ten car windows were examined in the laboratory for thickness and refractive index. Starrett Calipers (checked with certified gauge blocks and accurate to .001 inches) were used to obtain ten thickness measurements of each fragment from which a mean was calculated.

Prior to refractive index analysis by Automated Glass Refractive Index Measurement System (GRIM2) the glass samples were gently crushed, and chunks with red and blue surfaces, representing glass near the inside and outside of the windows, were separated and washed with acetone to remove the colored markings. Then each chunk was crushed for GRIM2 examination. As stated in Munger et al., "Float glass is known to have a range of RI values across the thickness of the glass with very different values near each surface when compared with the remaining bulk of the glass" (2). Care was not taken in this study to ensure surface glass was not analyzed. For this reason the variation in some samples could be greater than expected; however none of the RI values were of the magnitude expected had float surface fragments been measured (3). Original surfaces should be avoided in casework. Six samples were examined from each vehicle: top, middle, and bottom of the inside of the window; and top, middle, and bottom of the outside of the window. Ten edge count measurements were made of each vehicle sample and the mean was calculated.

RESULTS

The numbers one through ten were arbitrarily assigned to each of the ten cars listed in Table 1. Of the ten car windows tested, cars 1, 2, 3, 4, 5, 7, 8, 9, and 10 had a measured variation of 0.001 inches (0.025 millimeters) or less. Car 6 had the greatest discrepancy within a window of 0.002 inches (0.051 millimeters). A comprehensive list of thickness measurements and refractive indices can be seen in Table 1.

Table 1: Consistency of Automobile Tempered Window Glass*

Car #	Car	Sample Location	Mean RI	Std. DEV.	RI Range	Thickness	Δ Thickness
1	89 Chevy Corsica	Top outside	1.5196	2.5E-05	0.0002	0.155in	<0.001
		Top inside	1.5194	4.5E-05		0.155in	
		Middle outside	1.5196	1.0E-05		0.155in	
		Middle inside	1.5196	7.5E-06		0.155in	
		Bottom outside	1.5195	4.5E-05		0.155in	
		Bottom inside	1.5194	4.5E-05		0.155in	
2	89 GMC Vandura	Top outside	1.5184	3.0E-05	0.0002	0.191in	<0.001
		Top inside	1.5183	4.0E-05		0.191in	
		Middle outside	1.5184	2.0E-05		0.191in	
		Middle inside	1.5183	4.0E-05		0.191in	
		Bottom outside	1.5182	2.5E-05		0.191in	
		Bottom inside	1.5184	3.0E-05		0.191in	
3	90 Buick LeSabre	Top outside	1.5183	2.0E-05	0.0001	0.161in	0.001
		Top inside	1.5183	1.0E-05		0.161in	
		Middle outside	1.5184	2.0E-05		0.161in	
		Middle inside	1.5184	2.5E-05		0.162in	
		Bottom outside	1.5183	3.5E-05		0.162in	
		Bottom inside	1.5184	2.5E-05		0.162in	
4	91 Ford Taurus	Top outside	1.5191	2.0E-05	0.0003	0.153in	<0.001
		Top inside	1.5190	7.0E-05		0.153in	
		Middle outside	1.5190	5.0E-05		0.153in	
		Middle inside	1.5189	2.0E-05		0.153in	
		Bottom outside	1.5192	3.0E-05		0.153in	
		Bottom inside	1.5190	5.5E-05		0.153in	
5	88 Dodge Shadow	Top outside	1.5183	4.0E-05	0.0003	0.130in	<0.001
		Top inside	1.5181	7.0E-05		0.130in	
		Middle outside	1.5181	4.0E-05		0.130in	
		Middle inside	1.5183	3.5E-05		0.130in	
		Bottom outside	1.5182	3.0E-05		0.130in	
		Bottom inside	1.5180	7.5E-05		0.130in	
6	75 Ford LTD	Top outside	1.5188	3.5E-05	0.0003	0.225in	0.002
		Top inside	1.5190	4.5E-05		0.224in	
		Middle outside	1.5189	1.0E-05		0.224in	
		Middle inside	1.5190	3.0E-05		0.223in	
		Bottom outside	1.5190	5.0E-05		0.223in	
		Bottom inside	1.5191	7.5E-05		0.223in	

Car #	Car	Sample Location	Mean RI	Std. DEV.	RI Range	Thickness	Δ Thickness
7	2000 Lincoln	Top outside	1.5200	6.0E-05	0.0001	0.153in	<0.001
		Top inside	1.5199	5.0E-05			
		Middle outside	1.5199	2.0E-05		0.153in	
		Middle inside	1.5200	1.0E-04			
		Bottom outside	1.5199	1.0E-06		0.153in	
		Bottom inside	1.5199	1.0E-05			
8	85 Ford Thunderbird	Top outside	1.5193	3.0E-05	0.0002	0.192in	<0.001
		Top inside	tinted	glass			
		Middle outside	1.5192	5.0E-05		0.192in	
		Middle inside	1.5192	4.0E-05			
		Bottom outside	1.5194	6.0E-05		0.192in	
		Bottom inside	1.5193	4.0E-05			
9	2001 Porsche	Top outside	1.5231	3.0E-05	0.0002	0.155in	<0.001
		Top inside	1.5230	4.5E-05			
		Middle outside	1.5231	4.5E-05		0.155in	
		Middle inside	1.5229	1.0E-05			
		Bottom outside	1.5229	3.0E-05		0.155in	
		Bottom inside	1.5229	1.5E-05			
10	65 Buick Riviera	Top outside	1.5237	1.5E-05	0.0004	0.232in	0.001
		Top inside	1.5233	4.0E-05			
		Middle outside	1.5237	6.0E-05		0.233in	
		Middle inside	1.5235	2.5E-05			
		Bottom outside	1.5236	3.5E-05		0.232in	
		Bottom inside	1.5233	2.0E-05			

*Note: The original GRIM2 RI data is no longer available, but GRIM2 was capable of reporting to five decimal places. However, in this Table the mean RIs were rounded to four decimal places which does not impact the results of this study.

Regarding the refractive indices of glass, there was generally little variation within a particular car window. Cars 1, 2, 8, and 9 each had a range in RI of 0.0002. Cars 3 and 7 had a range of 0.0001. Although these ranges seem rather small compared to the published ranges observed in tempered window glass, it is probably due to the fact that the largest RI variations in tempered glass are typically observed throughout the thickness of the window (4, personal communication in 2016 with Timothy Bellovary at PPG Industries). Cars 4, 5, and 6 had a range of 0.0003, while car 10 had a variance of 0.0004. Only one of the ten cars had a refractive index range slightly greater than the expected variation within a tempered (toughened) glass window previously reported by Locke to be 0.00032 (5,6). However those in the glass industry report, as did Locke, that “it is not surprising that particles from toughened glass show larger variations in RI than

generally observed in non-toughened windows” (4, personal communication in 2016 with Timothy Bellovary at PPG Industries). (Figure 1)

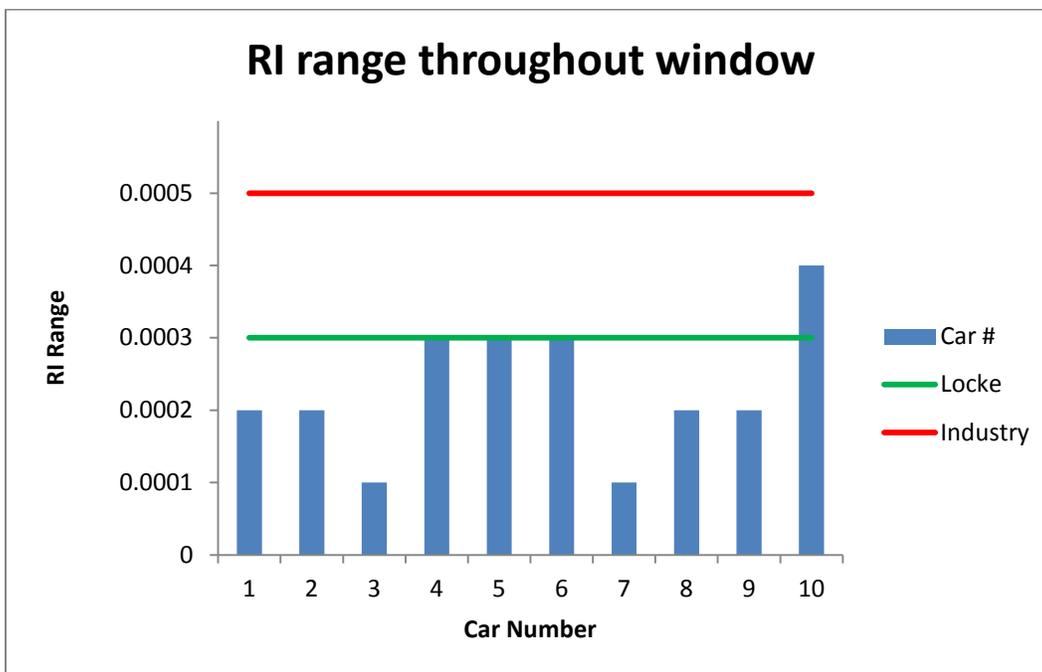


Figure 1: Refractive index range throughout one whole window per car tested. The green line shows the Locke reported expected range of RI variation in a tempered window of (+/- 0.00016) 0.00032 (5,6). The red line shows the industry’s reported expected range of RI variation in a tempered window of 0.0005 (personal communication in 2016 with Timothy Bellovary at PPG Industries).

CONCLUSIONS

In summary, this study has demonstrated that the location from which a glass sample is collected does not significantly alter the refractive index findings considering the expected variation within automotive tempered glass side windows. There also appears to be no significant difference in thickness throughout a window. These findings are consistent with exclusion criteria of greater than 0.006 inches (0.15mm) for float glass (7,8). The aforementioned findings imply that a forensic investigator may retrieve a sample of known glass from any location on an automotive side window, though an effort should always be made to try to retrieve a sample as close as possible to the point of impact if known. Laboratory analysts should be aware that the refractive index could vary by a slightly wider margin than the reported average range of variation for tempered glass of 0.00032 (5,6). Further research may be helpful to include variation of elemental composition as well as thickness and refractive index within a source of vehicle glass including tempered windows, windshields, and headlamps. Note that an article was recently published on the variation of refractive index in laminated vehicle

windshield glass that does indicate the location of sampling may be of concern in that material (2).

ACKNOWLEDGEMENTS

The authors would like to thank Katie Gabbard, Dana Greely, and Emily Weber of the Hamilton County Coroner's Crime Laboratory for helping to resurrect this work. These three forensic scientists made substantial contributions to the interpretation of data, drafting the article, revising it critically for important intellectual content, and final approval of the version to be published.

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