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The Variation in Thickness of Toughened Glass from Car Windows

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The thickness of toughened safety glass in a large number of cars has been measured. In many cases this parameter has been shown to be a more effective means of discriminating between samples of safety glass than either refractive index or density measurements. Histograms describing the various distribution of thickness from windscreens, quarter-light and side-window populations are presented.

Introduction

Fragmentation of safety glass often occurs in crimes involving malicious damage to automobiles and in hit-and-run accidents. Crockett and Taylor (1969) measured the refractive index (RI) and specific gravity (SG) of 100 toughened safety glass (TSG) samples and found the values for these physical parameters to be within the range of major peaks of previous flat glass surveys (Cobb, 1968; Dabbs, 1968). Furthermore, the same authors reported the thickness distribution for the same 100 samples. On several occasions in our laboratory we have found the measurement of thickness to be much more useful than RI and SG measurements for discriminating between TSG samples. The study described in this paper was carried out in order to determine whether or not any significant changes had occurred, in the last 5–10 years, in the distribution of thickness of TSG used in automobile windows.

Experimental

Thickness Measurement Procedure

All car windows, with the sole exception of the rear window, were measured *in situ* using the techniques described below. Prior to measurement the glass surfaces were cleaned with a cloth soaked in absolute alcohol and dried. Unless otherwise stated a single measurement was taken.

Two types of micrometer screw gauge (Moore and Wright Ltd., Sheffield) were used for the measurements. One had a 2·5 cm "throat" and was calibrated in millimetres. The other was a 2″–6″ adjustable micrometer calibrated in inches. The latter micrometer was used to measure the thickness of windscreens and some quarter-lights since its "throat" was large enough to pass a door frame. To one end of the micrometer was attached a 4″ extension bar to which a $\frac{1}{4}$″ ball-ended extension had been fixed. The ball-end was placed in contact with the concave side of the window (where applicable) and a 2″ stainless steel slip placed against the other surface so as to make contact with the other jaw of the micrometer. Finally, the combined measurement of $\frac{1}{4}$″ ball, 2″ slip and window was made from which the thickness of the glass was determined.

The error involved in reading the small micrometer screw gauge was determined by measuring the thickness of the same piece of glass fifty times. A mean thickness of 4·973mm with a standard deviation of $\pm 0{\cdot}003$ resulted. The expermental error when using the large micrometer was determined by making fifty separate determinations of thickness on the same area of a single windscreen *in situ*. This exercise gave a mean thickness of 4·866mm with a standard deviation of $\pm 0{\cdot}003$.

Sampling

An attempt was made to select a sample of cars from the total population which was representative as regards both make and age. The chosen sample consisted of 110 cars and the breakdown into manufacturers is depicted in Table 1. Also included in the table are the results of a recent census of vehicles

TABLE 1

CAR POPULATION SAMPLE DISTRIBUTION

Manufacturer	*Number in this survey*	*Recent census %*
British Leyland	36	45
Ford	25	25
Foreign (Total)	25	10
(French)	(8)	
(German)	(8)	
(Dutch)	(2)	
(Swedish)	(3)	
(Italian)	(2)	
(E. German)	(1)	
(Japan)	(1)	
General Motors	10	7
Chrysler	14	12

on the road (C. F. Tippett, private communication). Although our survey contains an unexpectedly high proportion of foreign cars the final conclusions drawn should not be significantly affected.

The age distribution of the cars in the survey is shown in Figure 1.

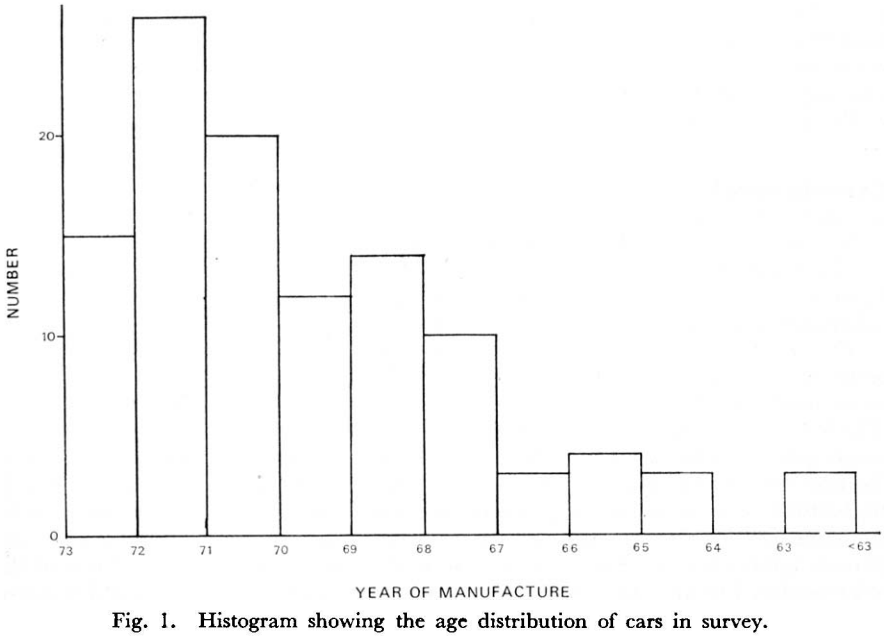

Fig. 1. Histogram showing the age distribution of cars in survey.

Results and Discussion

Type and Make of Glass Encountered

The majority of windows studied had a clearly visible manufacturers' identification mark and approximately 80% of windows were found to have been manufactured by Triplex. All Triplex glass is manufactured by Pilkington Bros. Ltd. and consequently is now, and has been for approximately the last

10 years, produced by the float process. Other windows encountered were manufactured by the following companies: Splintex (next most frequent); DAMW; Securit; Tremplex; Indestructo; Armourglas; Sunex; Sicursiv; Nissan and Sangaban.

Only one car with tinted glass windows was noted in the survey; this was a Japanese Datsun. Of the 110 windscreens measured *in situ*, 8 were found to be of the laminated type and consequently were not included in the thickness distribution curves. Cars are not necessarily fitted at the assembly stage with windows from only one manufacturer. For example, a 1971 Vauxhall Viva was known to have windows from three different manufacturers when new. Usually however, the presence of windows of more than one origin indicates that the vehicle concerned has had a replacement window fitted either because of accidental or malicious damage during its lifetime.

Overall Distribution of Thickness

Thickness measurements were made on a total of 742 windows. This number included 102 windscreens, 435 side windows and 205 quarter-lights. The histogram illustrating the distribution of thickness is shown in Figure 2 and is

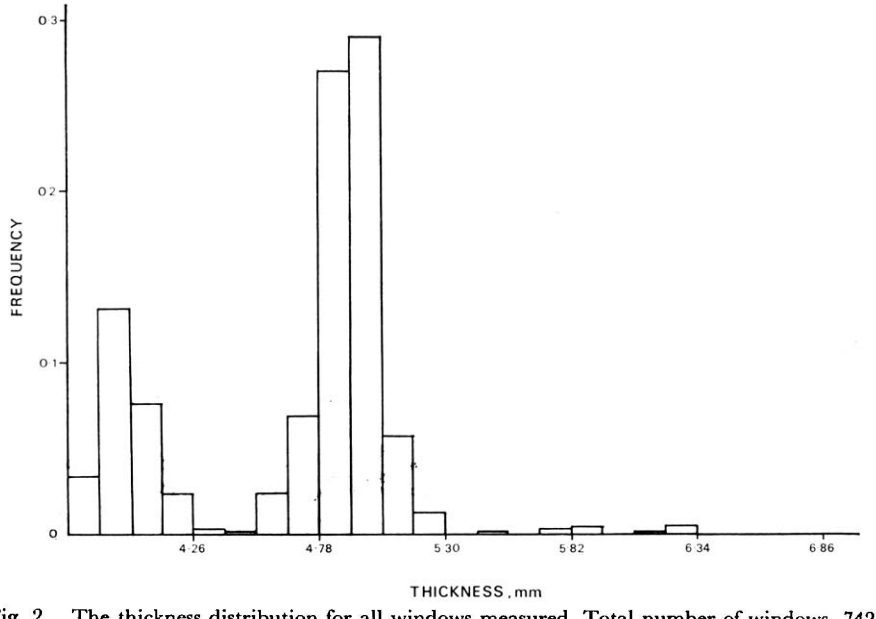

Fig. 2. The thickness distribution for all windows measured. Total number of windows, 742. Class interval, 0·13mm.

composed, primarily, of two groups each with an approximately normal distribution. The first group lies between the limits 3·80 to 4·34 mm with a mean of 3·98mm and a standard deviation (SD) of $\pm$0·10, and the second lies between the limits 4·46 to 5·24mm with a mean of 4·91mm and an SD of $\pm$0·12. The means of 3·98 and 4·91mm correspond to the nominal thickness for TSG for automobiles (British Standard Specification) of 4 and 5mm, respectively. It is of interest to compare this overall distribution curve with the distribution obtained by Crockett and Taylor (1969). Their data are shown plotted (in modified form) in Figure 3; the two peaks of their distribution have means of 5·00mm and 6·35mm, respectively. A comparison of the Crockett and Taylor histogram (Fig. 3) with the results of this study (Fig. 2) reveals two interesting differences. Firstly, the predominant normal distribution with a mean of 6·35mm in Figure 3 has practically vanished from Figure 2 and secondly, the normal distribution in Figure 2 with a mean of 3·98mm does not appear in Figure 3.

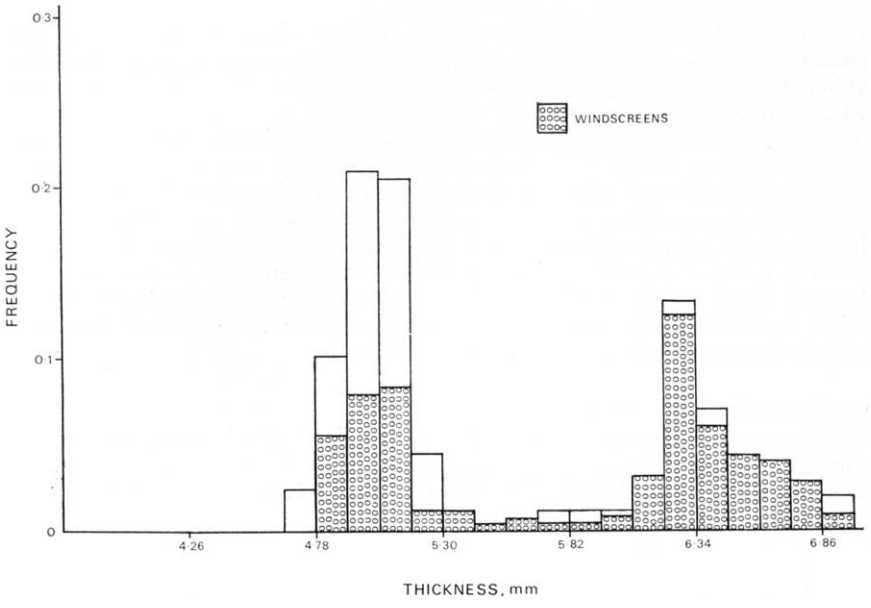

Fig. 3. Histogram constructed from the date of Crockett and Taylor (1969). Total of 253 measurements. Class interval, 0·13mm.

These results clearly demonstrate that during the last 5–10 years automobile manufacturers have, in the main, refrained from using nominal 6mm glass, but, on the other hand, have introduced a large proportion of nominal 4mm glass into automobiles.

Typical variations in glass thickness from window to window within a given car are shown in Table 2 for a random selection of 10 cars from the survey. It appears from the data in this table that the *combination* of window thicknesses for a particular vehicle is unique and offers a novel method for the identification of cars.

TABLE 2

VARIATION IN THICKNESS FROM WINDOW TO WINDOW WITHIN A GIVEN CAR

Model	*Year of Manufacture*	*Thickness (mm)*								
		Windscreen	*Nearside front quarter*	*Nearside rear quarter*	*Offside front quarter*	*Offside rear quarter*	*Nearside front window*	*Nearside rear window*	*Offside front window*	*Offside rear window*
Austin 1300	1972	4·85	4·95	4·88	4·58	4·93	5·04	4·89	5·05	4·91
Hillman Avenger	1972	4·88					3·93	3·91	3·97	3·90
Peugeot 404	1966	4·98					4·94	4·95	4·89	4·99
Austin A40	1968	6·30	4·94		4·84		5·17	5·05	5·10	4·96
Vauxhall Viva Estate	1969	4·88	5·08		4·83		4·01	4·88	3·87	4·86
Morris Marina	1972	4·86	4·93	5·01	5·16	5·01	3·92	3·95	3·91	4·05
Ford Corsair	1966	4·88	4·98	4·27	4·83	4·01	3·80	3·97	3·80	3·94
Hillman Hunter Estate	1972	4·91	4·96	4·91	4·96	4·86	3·97	4·14	3·98	3·92
DAF 66	1973	4·88					4·77	4·83	4·94	4·81
Jaguar XJ6	1970	4·93	5·07	4·98	4·91	4·95	4·97	4·87	4·85	4·98

Windscreens

The histogram shown in Figure 4 depicts the thickness distribution for 102 TSG windscreens and illustrates that the main group lies between the limits

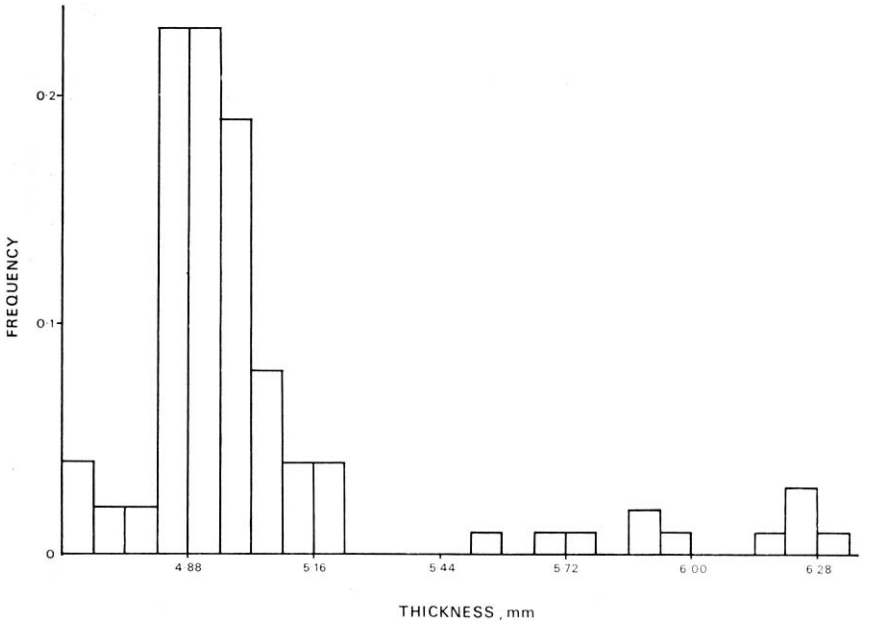

Fig. 4. Histogram showing the thickness distribution of windscreens. Total number of windscreens, 102. Class interval, 0·07mm.

4·63 to 5·23mm with a mean of 4·94mm and an SD of $\pm 0 \cdot 12$. Comparison with the windscreen data (see Fig. 3) of Crockett and Taylor (1969) shows that 6mm nominal thickness TSG windscreens, which represented practically half of the windscreen population about 7 years ago, are now relatively rare. In fact we did not come across any British manufactured TSG windscreens with a nominal thickness of 6mm on cars produced after 1968.

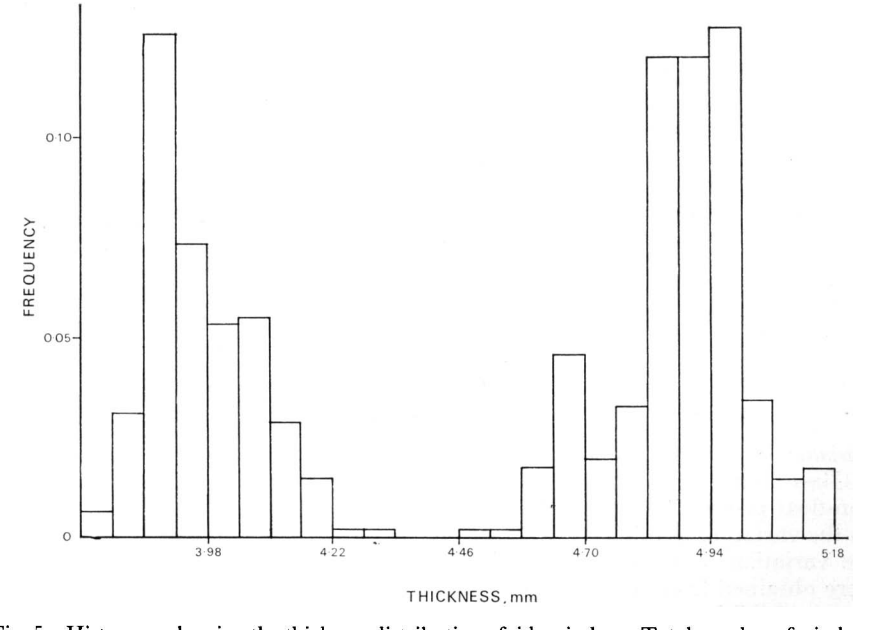

Fig. 5. Histogram showing the thickness distribution of side windows. Total number of windows, 435. Class interval, 0·06mm.

As mentioned above, the survey included one Japanese TSG windscreen which had tinted glass. Such windscreens are growing in popularity, particularly on foreign cars.

Windscreens with a nominal thickness of 4mm were not encountered.

Side Windows

Figure 5 depicts the histogram showing the distribution of thicknesses of 435 side windows. The histogram is composed of two normal distributions within the limits 3·80 to 4·35mm and 4·48 to 5·20mm and have respective means and SD's of 3·97±0·10mm and 4·89±0·12mm. Note, particularly, the absence of any side windows with a nominal thickness of 6mm. Again comparing this histogram with the results in Figure 3 of Crockett and Taylor (1969), which is devoid of any data in the 4mm region, it is apparent that nominal 4mm TSG has been increasingly used by the automobile manufacturers in the last 10 years (see Table 2). However, not all current models are fitted with nominal 4mm side windows, as shown by the data in Table 2.

Quarter Lights

The histogram shown in Figure 6 illustrates the variation in thickness for 205 quarter-light windows. The distribution is represented by one major distribution between the limits 4·58 to 5·22 with a mean of 4·92mm and SD of ±0·11, corresponding to nominal 5mm TSG. Relatively few quarter-light windows were measured with a nominal thickness of 4mm.

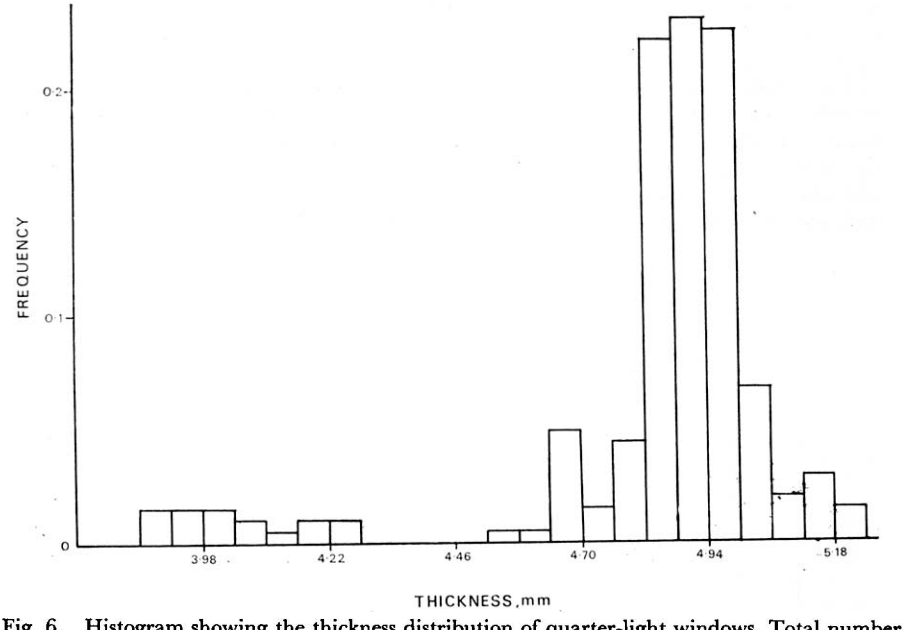

Fig. 6. Histogram showing the thickness distribution of quarter-light windows. Total number of windows, 205. Class interval, 0·06mm.

Variation in Thickness within a Single Window

Glass used in TSG windows is manufactured either by the float process or a non-float process. The significance of this difference in manufacturing process on the variation in thickness within single windows was estimated by measuring the variation in thickness over single sheets of TSG. Shattered windscreens were obtained from a local windscreen fitter and the thickness of 100 random pieces of TSG was measured for each of eight windscreens. The results are summarized in Table 3.

TABLE 3

VARIATION IN THICKNESS WITHIN A SINGLE WINDSCREEN

Model	*Windscreen Manufacturer*	*Float Glass?*	*Mean Thickness (mm)*	*SD*
BLMC Mini	Triplex	No	5·091	0·037
Morris Marina	Triplex	Yes	4·978	0·006
Morris Marina	Splintex	No	4·941	0·013
Ford Escort	Triplex	Yes	4·878	0·004
Ford Escort	Triplex	Yes	4·900	0·004
Ford Consul	Triplex	Yes	4·885	0·005
Ford Capri	Triplex	Yes	4·887	0·004

The variation in thickness of float glass windscreens is similar to the error of measurement with the small micrometer (see above), whereas the non-float glass windscreens exhibit a thickness variation up to an order of magnitude higher than that noted for float glass. A similar result was found for the variation in thickness over eleven side windows (four non-float) determined *in situ*. But since measurements could only be made along one edge of the window by this method the variation is not truly representative and, therefore, the results are not included. Because of the variations that can exist in non-float glass windows care must be taken when selecting samples of control glass.

It is perhaps noteworthy that our measurements included several on foreign manufactured windows in British manufactured cars, but we did not observe a single foreign car fitted with British manufactured windows.

Conclusions

Measurement of thickness has been shown to be a useful parameter for discriminating between samples of TSG from car windows, although to some extent the method is limited by the type of glass used in the manufacture of the window. For non-float glass with a thickness variation for a single window of up to $\pm 0{\cdot}05$mm the discrimination between samples of TSG has been calculated, for the normal distributions described in previous sections, to be no better than 1 in 5 for samples with thicknesses close to the mean of the distribution. This discrimination is of the same order as that obtained from the TSG windscreen RI distribution. On the other hand, for float glass, with a thickness variation over a single window corresponding to the measurement error, close to the mean of the thickness distribution the discrimination has been estimated to be of the order of 1 in 30. Thus the measurement of thickness of this type of glass provides, in many cases, a much better means of discrimination than the determination of RI and SG and requires the use of only simple apparatus and minimal time. When sufficient data have been collected it will be possible to construct probability tables.

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