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THE BEHAVIOR OF BULLETS FIRED THROUGH GLASS*

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Law enforcement officers are frequently required to exchange fire with armed criminals under conditions which depart radically from those of ordinary target shooting. Occasionally, for example, it becomes necessary to fire through glass windows, either in buildings or in automobiles. A cursory review of the literature fails to disclose any investigation as to the accuracy of fire under such conditions. As a consequence, tests have been conducted to determine the behavior of bullets passing through glass. The object of this paper is to report on the results of these tests.

While the mechanism of puncture of glass by a bullet does not lend itself to rigorous mathematical treatment, one may at least anticipate the consequence of such a puncture. Some of the consequences are:

(a) *Deformation of the Bullet.* This factor is of great importance where soft nose bullets are involved. Excessive deformation will not only disturb the stability of the bullet in flight, but will affect all subsequent penetrations or punctures.

(b) *Loss of Energy and Momentum.* The work expended by the bullet in effecting the puncture represents a loss of energy which increases with the thickness of the glass. This loss of energy,

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combined with any bullet deformation, reduces the over-all effectiveness of the bullet.

(c) *Deflection of the Bullet.* This factor is of practical interest to the police officer. The deflection of the bullet by the glass decreases the accuracy of fire. (Note: The words *deflection* or *deviation,* are used here to include both *direction* and *range* errors.)

No attempt has been made in the present work to study bullet deformation. However, a few bullets were caught in saw-dust bags to determine if minute glass particles had been caught in the bullet. In the nose and cannelures of the soft nosed bullets finely powdered glass was found. In some instances powdered glass was also found on the jacketed types of bullets.

The evaluation of the energy loss was also considered unimportant for the present purpose.

To study the deflections, a portable rectangular wooden frame was constructed, which served as a means of holding the glass panes. The glass was cut into panels 9″ x 12″. The frame was arranged so that the glass could be easily and quickly replaced. This frame was supported in such a way that it could be located at any point in the line of fire.

Three types of glass were employed: window glass $\frac{3}{32}$″ thick, plate glass ¼″ thick, and standard automobile safety glass. All firing was done with a Police Special target revolver having a six inch barrel chambered for the .38 special cartridge, with the exception of one series of tests made with a .357 Magnum revolver. The ammunition employed was of three types: .38 Special (lead bullet), .38-44 (metal cased "Super Speed" bullet), and .357 Magnum (metal piercing tip). The gun was fired in the normal manner without a rest, and all the firing was done by one officer.

The deflection in all cases was found to be of a random nature, thus introducing an accidental error of indeterminate form. To evaluate the average magnitudes of such deflections it was necessary to fire a series of rounds under controlled conditions without glass and then note the increase in dispersion of a similar series resulting from the passage of the bullets through glass. The officer conducting the tests first fired a series of rounds at the target in the usual manner without the glass in the line of fire. This permitted sighting the gun and bringing the center of impact of the group to coincide with the center of the target. After this adjustment of fire, twenty rounds were fired and the mean deviation determined by averaging the absolute deviations of all points of impact from the center

of the target. The mean deviation without glass for the officer firing the tests was roughly 1.5 inches with the .38 Special ammunition on the 25 yard range and 4.5 inches for the .357 ammunition on the 50 yard range. The deflection was first studied with ordinary window glass. The glass, in the previously described frame was oriented so as to be normal to the line of fire. The glass was placed 4 feet in front of the firing position and the officer fired through the glass at the 25 yard target in the same manner as when firing without the glass. Previous tests had been made which showed that errors in aiming, due to refractive irregularities in the glass, were unimportant.[1] To economize on glass it was decided to determine the mean deviation of twenty rounds under each of the test conditions.

Using plate and automobile safety glass, the firing was repeated. The supporting frame was then moved out from the firing position in the direction of the target, thereby decreasing the distance between glass and target. In this manner it was hoped that actual firing conditions would be at least partially simulated. With the glass near the firing position the conditions are roughly similar to those in which an officer fires from within a car through the safety glass windows at a target 25 yards away, whereas with the glass near the target the condition is similar to that of firing at a target within a car or behind a window at this distance.

The results of the tests are shown graphically in Figure 1. A representative list of deviations of 20 rounds is given in Figure 2. The curves in Figure 1 have been arbitrarily extended with dots to meet the ordinate at 50 yards. The mean deviations indicated for this range probably are actually greater than shown. This is because the mean deviation without glass will increase with range. No reliable data could be obtained at the 50 yard range using .38 ammunition due to the fact that a large percentage of shots missed the entire target, thereby making deviation measurements difficult. The maximum observed deviations were greater than the mean by a factor ranging from two to three times.

Although the present tests have been made with a revolver chambered for the .38 Special cartridge, cursory tests have demonstrated similar inaccuracies with guns of other calibres.

Curve A in Figure 1 gives the mean deviation or deflection

[1] The line of fire was held within $\pm 5°$ of normal to plane of glass at all times. Within this angle the refractive error is small compared with the human error of aiming and firing.

for the .38 Special lead bullet fired through ordinary window glass. The mean deviation with the glass 25 yards from the target (i. e., with the glass at the firing line) was 9 inches. This exceeds the mean deviation without glass (1.5 inch) by a factor of six times. Other points on the curve were obtained by placing the glass 17 yards (and 7 yards) from the target.

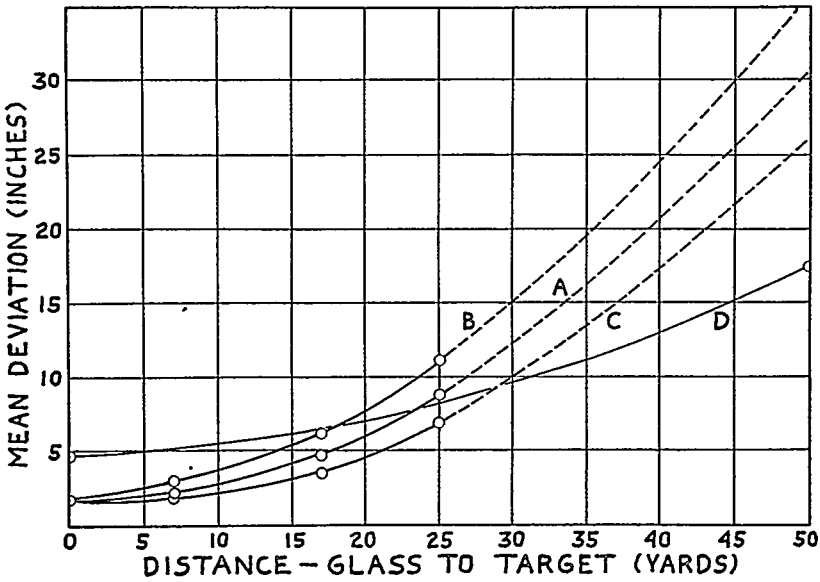

FIGURE 1

(A) Ordinary window glass pierced by .38 special lead bullet.
(B) Automobile safety glass pierced by .38 special lead bullet.
(C) Automobile safety glass pierced by .38 Super Speed bullet.
(D) Automobile safety glass pierced by .357 Magnum metal piercing bullet.

Curve B in Figure 1 is for the same ammunition fired through automobile safety glass. Plate glass gave substantially the same deflections with this ammunition and therefore its deviation is also represented by curve B.

The .38 "Super Speed" metal capped ammunition, by virtue of its greater velocity and energy, gave correspondingly less deflections when fired through safety-glass. This is shown by curve C.

The mean deflections noted when firing the .357 Magnum through safety glass, is given by curve D. This firing was done at 50 yards, instead of 25 yards. As indicated by the intersection of this curve with the ordinate axis (the mean deviation when no

glass is used) the mean deviation is greater than with the .38 Special. This may be attributed in part to the increased range and in part to the inexperience of the officer in firing the Magnum. The greater effectiveness of the Magnum is evident in comparing the extended deviations (dotted extensions) of the .38 Special with the deviation of the Magnum at 50 yards.

FIGURE 2

Absolute Deviations of 20 Rounds, .38 Lead Point, Fired Through Window Glass 17 Yards From Target, and With Shooter Nine Yards From the Glass

Round	*Deviation—Inches*	*Round*	*Deviation—Inches*
#1	5.5	#11	4.0
#2	5.0	#12	4.5
#3	2.0	#13	5.5
#4	3.5	#14	7.5
#5	0.5	#15	5.5
#6	3.0	#16	5.2
#7	3.5	#17	5.7
#8	4.0	#18	6.2
#9	8.0	#19	5.2
#10	4.7	#20	3.2

Mean Deviation: 4.6 inches + or — 0.3 inch.

One must bear in mind that the numerical values of the deviations as shown by the curves are averages based on a series of only twenty shots. Since the statistical fluctuations are relatively large, a few off-hand shots fired under any of the conditions as outlined may give deflections differing materially from those recorded. Due to these fluctuations, and the fact that only twenty rounds were used in each instance, the mean deviations are not wholly reliable but are offered to demonstrate the relative ineffectivenss of gun fire through glass.

While small departures from perpendicularity between glass and line of fire have but little added effect on the existant dispersion, for angles of oblique impact approaching 30° to 40° the dispersion is markedly increased. No attempt was made to obtain experimental data when firing at an angle through the glass. The deflections become so great that all shots fall off the target and make deviation measurements impossible. One must bear in mind that as the angle of obliquity is increased, an angle is finally reached at which the component of force of the bullet normal to the glass surface will be insufficient to produce a puncture and the bullet will then ricochet.

It was further noted that a large percentage of shots made "key hole" punctures on the target, indicating that in passing

through the glass the bullets had lost their gyroscopic stability and were "tumbling" along their trajectories.

Conclusions

The one obvious conclusion to be drawn from the results of these tests is that firing through glass is inaccurate and relatively ineffective. However, there are conditions under which an officer would be justified in shooting through glass ,and consequently our conclusions can be outlined as follows:

(1) When firing at long range (25 to 75 yards) through glass located at or near the firing point, the accuracy is greatly reduced. Further, where the glass concerned is thick (plate or safety) and lead bullets are used, the deformation and energy loss is so great that subsequent puncture of such material as auto body steel would be unlikely. Thus, under these conditions, one concludes that fire is ineffective.

(2) At short ranges, where it is not necessary to puncture additional material before reaching the target, one could shoot effectively through glass since the deflection and energy loss would be inappreciable.

(3) Where the glass is located near the target the fire will also be effective over the longer ranges; assuming again that after puncturing the glass subsequent punctures of glass or other material will not be required to reach the target.