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# Backward Fragmentation from Breaking Glass

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*When a glass window is broken by a blow, small fragments fly off in a direction opposite to that of the force which breaks the pane of glass.*

*Such backward fragmentation from breaking glass sheets was photographed by movie and still cameras, and a high speed movie film suitable for police instruction was made.*

*The extent of the spread of chips from both twenty-four ounce window glass and quarter-inch plate is reported. Whenever a window is broken, it may be expected that numerous fragments will strike a person standing within a few feet.*

## Introduction

In breaking and entering crimes, fragments of broken glass frequently occur as physical evidence. A defence counsel, in a court proceedings in Auckland, questioned whether it would be reasonably possible for glass chips to be present on the clothing of his client. Although authors such as Kirk (1953) explain how backward fragmentation is the source of most of the fragments of broken glass found on the clothing of suspects, we were unable to find published experimental observations on this phenomenon. Thus it was desirable to obtain experimental data in order to assist the courts if this became necessary.

The usual explanation of backward fragmentation is as follows. Except where there are gross inhomogeneities in the interior of a glass object, a fracture always starts from the surface and always in an area under tension (Phillips, 1965). Hence when glass breaks, it is usually due to tensile stresses pulling the surface of the glass apart. If an external force is applied to one side of a sheet of glass, e.g., a window, the glass is bent away from the force so that tensile stresses are set up in the opposite surface of the sheet and compressive stresses in the surface to which the force is applied. When the applied force is great enough to exceed the elastic limit of the glass, the surface under tensile stress ruptures as a star-shaped series of cracks which spread outwards as radial fractures. At the same time the cracks travel from the surface under tension to the surface under compression so that the whole compressive force is exerted along the broken edges in contact. This force causes flaking at the broken edges of the glass sheet at the compressed surface and these flakes fly off with considerable velocity. As this flaking from the radial fractures comes from the side of the glass to which the force is applied it is the major source of the glass fragments which are commonly found in the garments of persons breaking glass windows, e.g., shopbreakers and burglars.

W. J. Cadman, of the Orange County Sheriff's Laboratory (California), and his associates prepared a film of experiments in which five window-panes of various sizes were broken by means of a brick on the end of a long wire pendulum using different velocities. Collection of the glass fragments resulting from these impacts demonstrated that in each case fragments had flown in sufficient quantity and a sufficient distance to have reached the clothing of the "burglar" or perpetrator standing at a normal distance. Glass fragments were obtained at distances up to 10 feet. As these data of Cadman's (personal communication) had not been published, they could not be used in court proceedings here.

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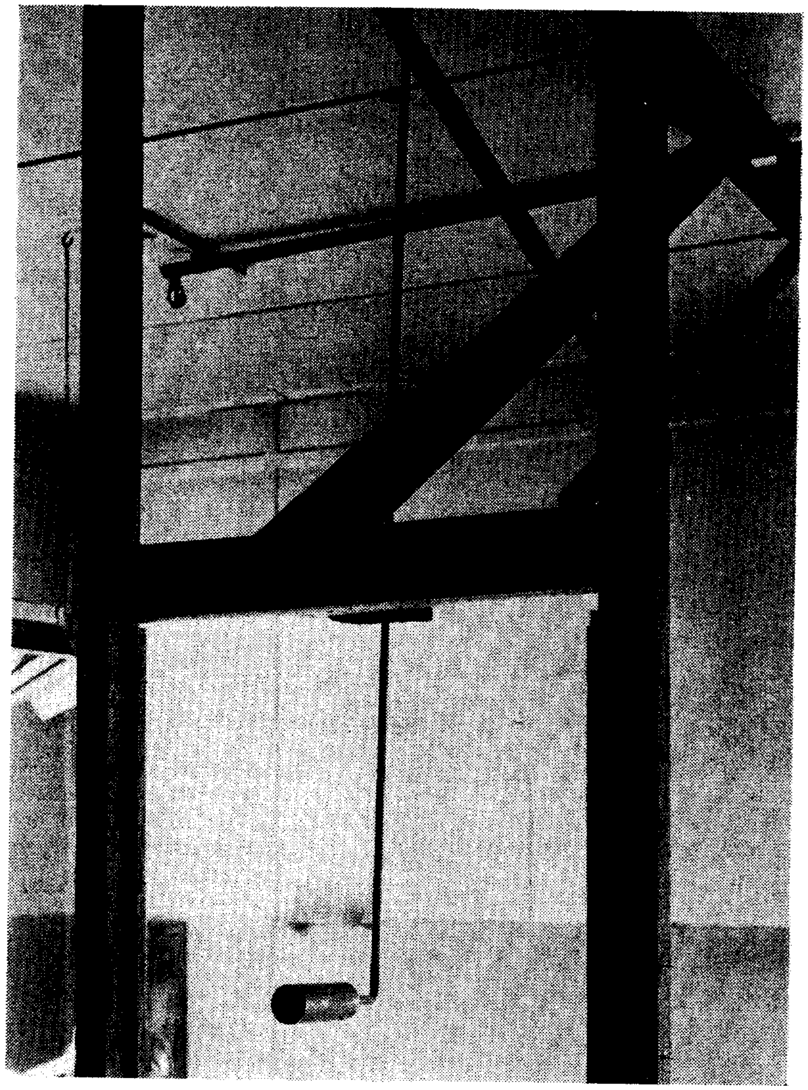

Figure 1 Frame and hammer used for breaking glass sheets

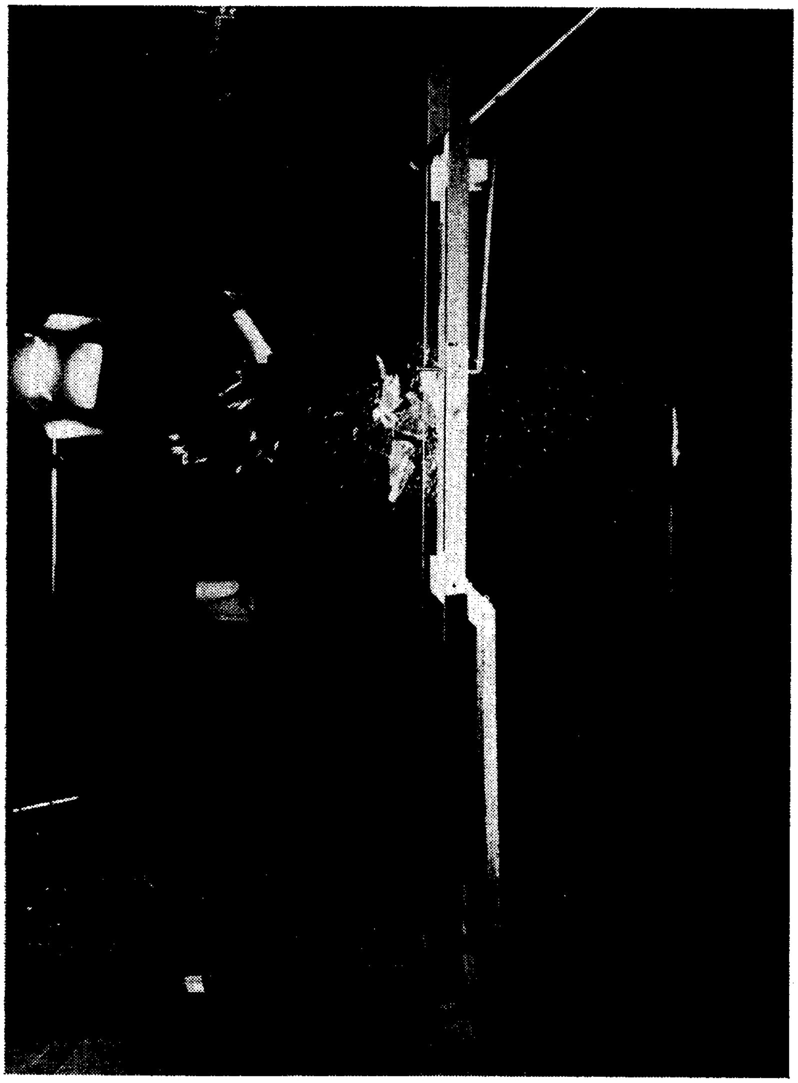

Figure 2 Quarter-inch plate glass being broken by a blow of medium force. Still camera 1/400 second

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It was decided to carry out experiments to obtain data and moving pictures of backward fragmentation which would be available to demonstrate the likelihood of glass fragments being present on the clothing of a person who breaks a window.

## Methods

The experiments were carried out partly at the Physics and Engineering Laboratory, Gracefield, and partly at the National Film Unit Studios, Wellington.

The assembly for breaking glass sheets is illustrated in Figure 1. The glass used was 24 oz. window glass and quarter-inch plate glass in sheets 2 feet by 3 feet. These sheets were held by wooden bead strips in a vertical frame, the bottom of which was 3 ft. 6 in. above floor level. The "hammer" for breaking the glass was a pendulum of half-inch steel rod, six feet long bearing a weighted striker on a horizontal arm about one foot long. The pendulum was supported and pivoted at the ceiling at a point above and slightly in front of the middle of the window so that when the pendulum was at its position of rest, it hung in front of the window, and the horizontal arm was in contact with the window. The striker was a steel cylinder 6 inches long, 2 inches in diameter, weighing 5 pounds. In preliminary experiments, the striker was fixed to the horizontal arm of the pendulum but in later experiments, it fitted loosely over the pendulum arm. When the pendulum was arrested (so that it would not go through the window and complicate the fracture) the striker left the pendulum arm and moved on through the window.

To break the window, the pendulum was raised through an angle of 60° from its position of rest and, when the high-speed camera was operating, released. Swinging with gravity was adequate to break the 24 oz. window glass. With the plate glass, however, it was necessary to give the pendulum a push at the time of release in order to be sure of breaking the glass.

On the side of the equipment opposite the observers, there was a deadblack background and the floor on the pendulum side was covered with matt-black paper so that small glass chips could be observed, photographed or recovered as desired. In order to aid both visual observation and filming and to obtain maximum visibility of flying glass fragments there was strong general illumination from the camera and observer side at an acute angle and strong back lighting from both floor and ceiling opposite the cameras but just outside the angle of view of the camera.

The breaking of the glass was photographed with an Eastman 16 mm High-speed Camera, Type III, 2,000 frames per second, and a 35 mm movie camera at the normal speed of 32 frames per second.

## Results

In this study, nineteen sheets of glass were broken and backward fragmentation was observed on each occasion. One of the observers described the backward fragmentation as "a cloud of glistening dust".

Two quarter-inch plate glass sheets were broken with the fixed striker on the pendulum, one being struck near a corner and the other in the middle. The blow striking near the corner fractured more of the pane but produced less backward fragmentation than the blow striking in the middle. Although a few chips travelled as far as 10 feet, most of the chips fell within 4 or 5 feet, being spread over the whole sector of 180°. With the free striker, the results were substantially the same. It was found that increasing the speed of the striker led to a reduction in the size of the hole in the window, the quantity of backward fragmentation, its spread and the distance travelled. The fastest blow caused an 8 inch hole compared with an 18 inch hole from the slowest blow, while the flakes fell within a sector of 45° on each side of the mid-line for the fastest blow compared with 90° on each side of the mid-line for the slowest blow. The maximum distance of backward travel observed for the fastest blow was 6 feet compared with 9 feet for the slowest blow. Figure 2 illustrates fragmentation from a blow of medium speed. Figure 3 is selected frames from a 35 mm film photographed at normal speed.

Four sheets of 24 oz. window glass were broken with the fixed striker. Although the glass fragments travelling backwards were variable in quantity, they were most concentrated in a zone of almost 180° arc out to 3 or 4 feet from the window, with the limit of travel about 6 feet. Experiments with the free striker gave similar results except that a few fragments travelled more than 6 feet and, in one experiment, the fragments travelled 9 feet. As with the plate glass, it was found that with faster blows, the angular spread of the fragment shower was reduced.

When the 24 oz. window glass was broken, the fragments travelling back were flakes and chips varying in size down to dust whereas when the quarter-inch plate glass was broken, in addition to flakes and chips of all sizes, there was a noticeable proportion of needle-like fragments. With both types of glass, the fragments thrown for greater distances tended to be chunky, probably because very thin flakes would lose their velocity more rapidly than chunky pieces.

When 24 oz. sheets were broken by hand with a hammer, fragmentation was variable. In one experiment most of the fragments fell within 4 feet. In the experiment shown in figure 4 it was obvious that the striker was showered with a large number of chips. Some fragments travelled as far as 11 feet.

When the films of these experiments were studied it was interesting to observe the chips progressively leaving the glass as the radial cracks travelled outwards from the point of impact towards the edges of the sheet.

## Discussion and Conclusions

These experiments may be summarised as follows:—

1. Backward fragmentation was observed in each experiment when the main shower of small fragments travelled back a distance of at least three feet from the window.
2. A slower blow produced a larger hole in the glass than a faster blow and produced considerably more backward fragmentation which travelled further than that from a faster impact.
3. A blow striking near a corner of a pane, although fracturing a greater part of the pane tended to produce less backward fragmentation than a blow striking near the centre.
4. Although most of the backward fragmentation from 24 oz. window glass was flakes and chips, the fragmentation from quarter-inch plate glass also included an appreciable number of needle-like slivers.

Whenever a window is broken it is to be expected that numerous fragments will strike any person within a few feet of the window. The number of fragments retained by the clothing of a person breaking a window will depend, of course, on the weave of the material, on features such as cuffs or open pockets, on movements of the wearer and on the time elapsing before the garments are secured for laboratory examination. As some of the flakes observed in these experiments were up to one-quarter inch across and even larger, there is a possibility of a "jig-saw" puzzle, and hence all the pieces of a broken window should be gathered.

In any investigation where window glass has been broken it is well worthwhile —in fact almost a matter of duty—for the investigator to secure samples of the

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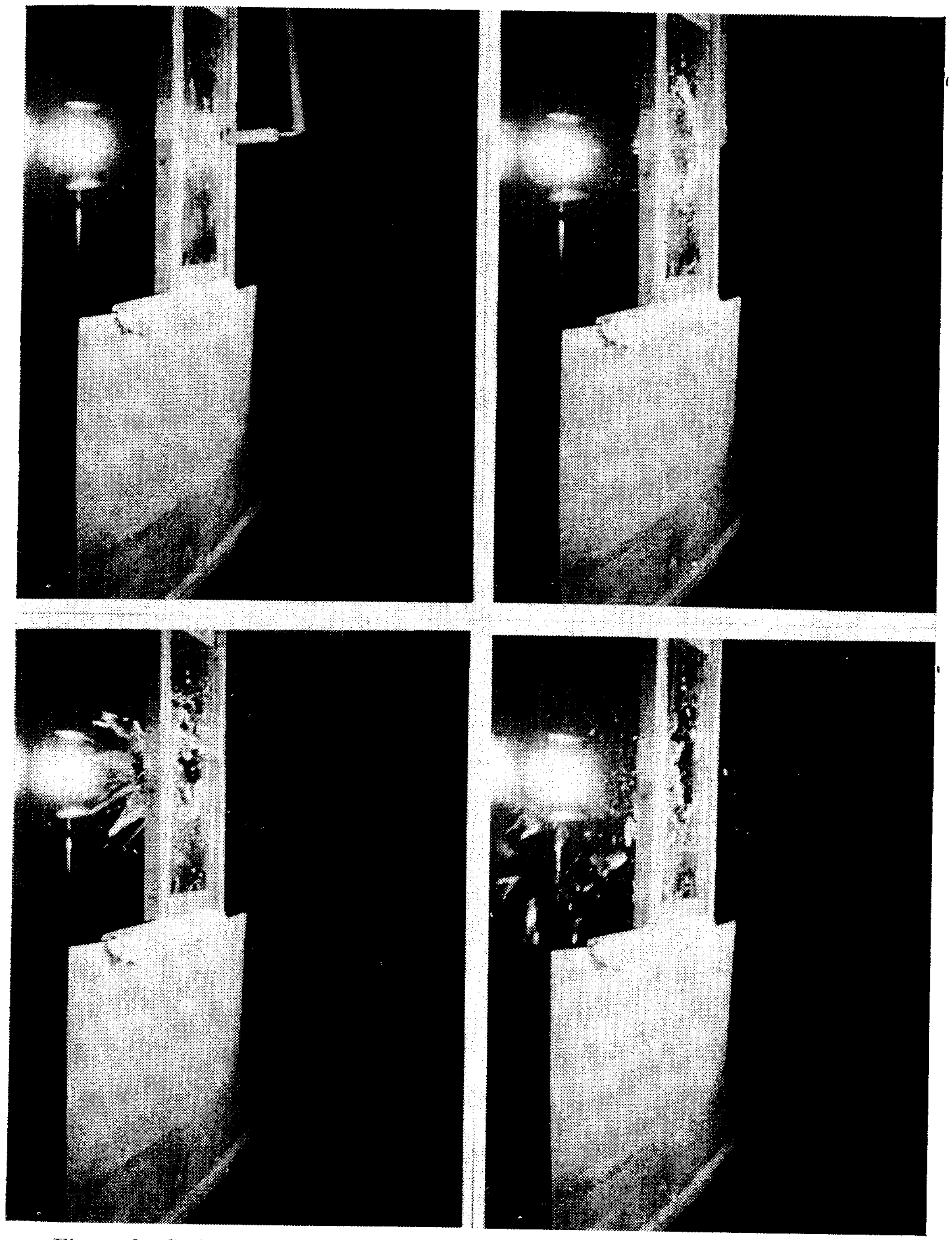

Figure 3 Series of 35 mm movie film of quarter-inch plate glass being broken

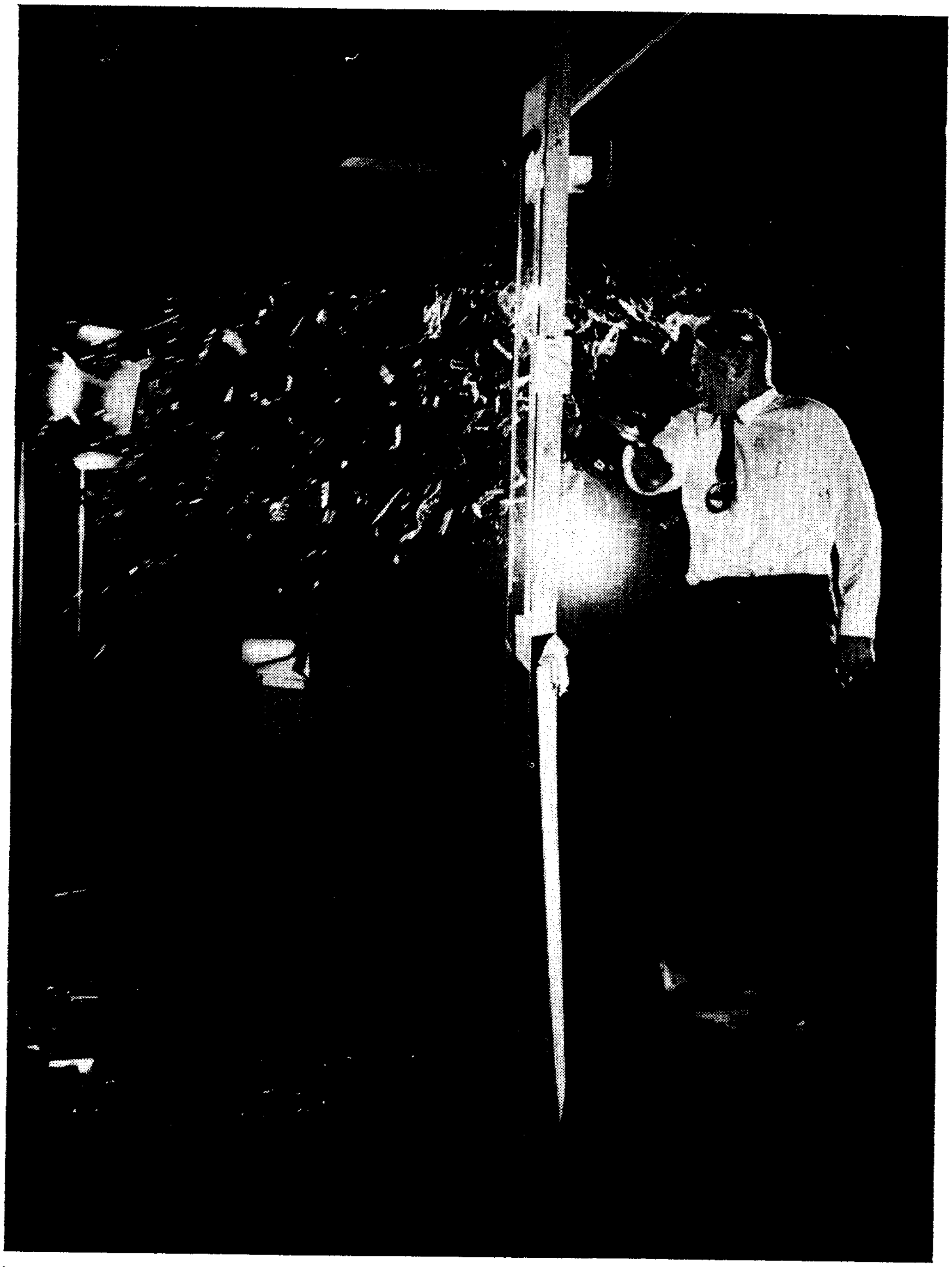

Figure 4 Window glass, 24 oz., being broken by a blow with a hammer. Still camera 1/400 second

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## Acknowled

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## References

CADMAN, W.
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broken glass and the clothing of the suspect and submit them for laboratory examination.

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