Out at the target— where it really counts—exactly what is...

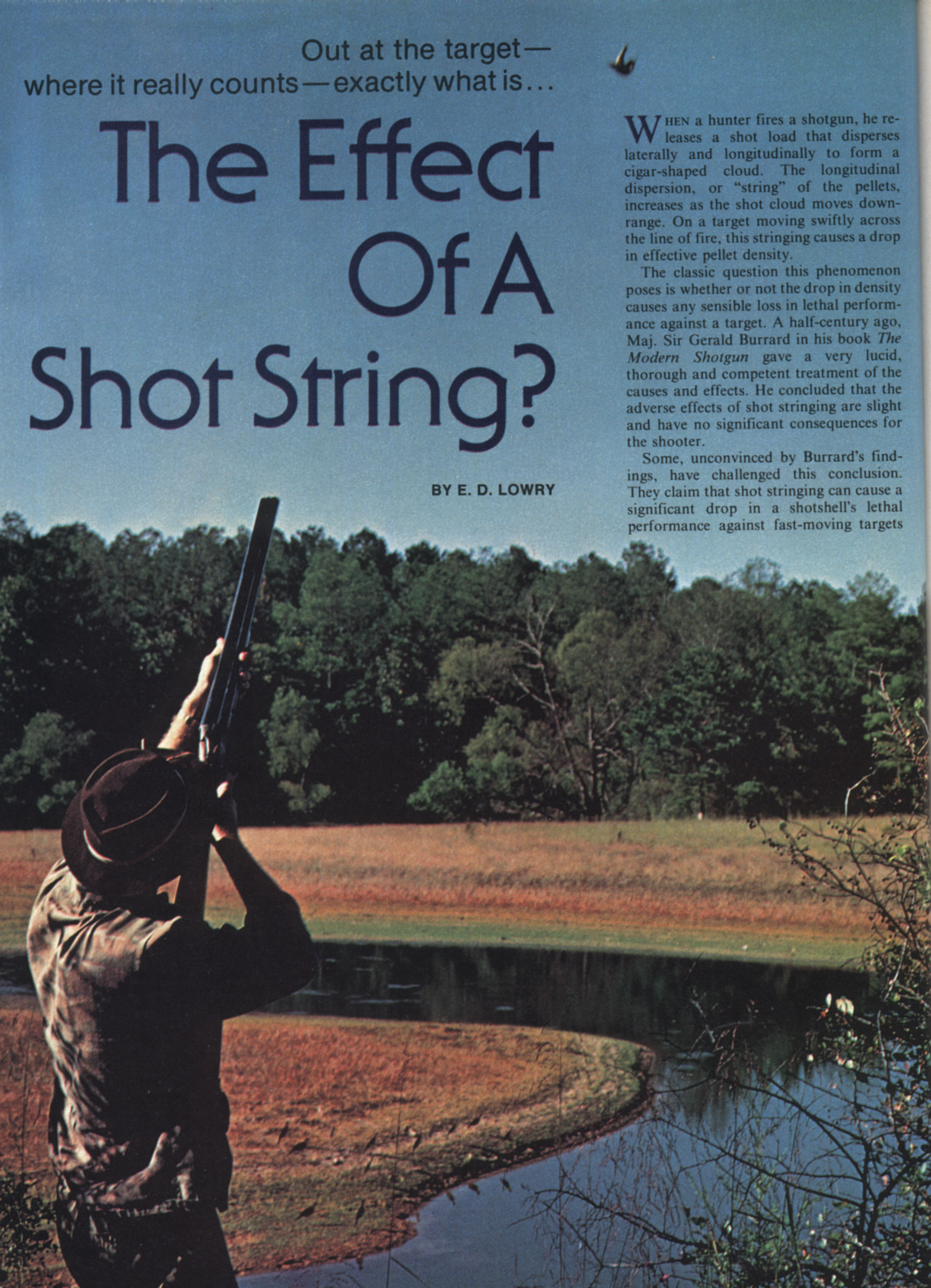
The Effect Of A Shot String?

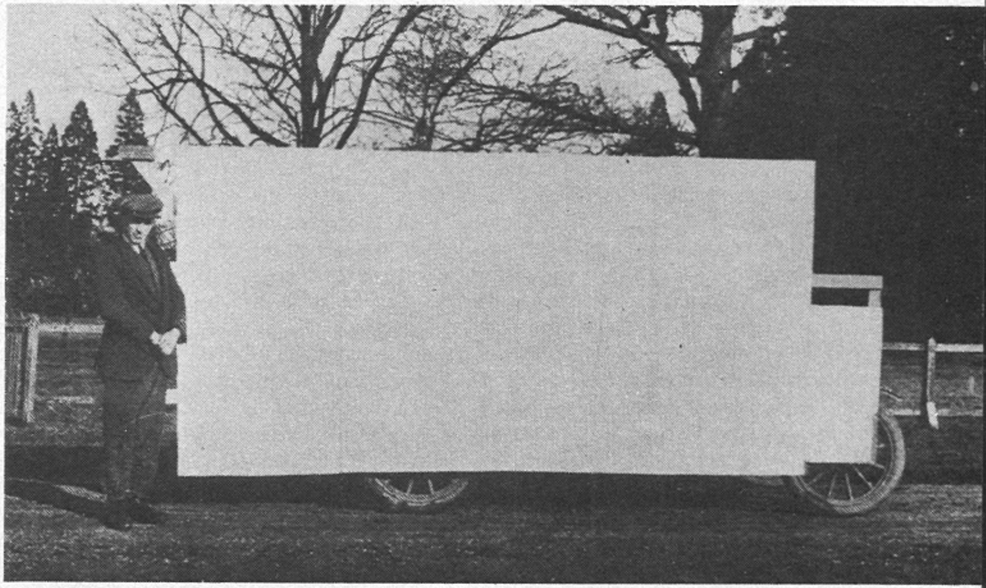
BY E. D. LOWRY

WHEN a hunter fires a shotgun, he releases a shot load that disperses laterally and longitudinally to form a cigar-shaped cloud. The longitudinal dispersion, or "string" of the pellets, increases as the shot cloud moves downrange. On a target moving swiftly across the line of fire, this stringing causes a drop in effective pellet density.

The classic question this phenomenon poses is whether or not the drop in density causes any sensible loss in lethal performance against a target. A half-century ago, Maj. Sir Gerald Burrard in his book *The Modern Shotgun* gave a very lucid, thorough and competent treatment of the causes and effects. He concluded that the adverse effects of shot stringing are slight and have no significant consequences for the shooter.

Some, unconvinced by Burrard's findings, have challenged this conclusion. They claim that shot stringing can cause a significant drop in a shotshell's lethal performance against fast-moving targets





Burrard tested the effects of shot stringing in the 1920s by firing against this 6 ft. x 12 ft. sheet iron target attached to the side of a truck. Its maximum speed of 40 m.p.h. is comparable to that of a mallard in flight. Fig. 2 below shows results at 55 m.p.h.

such as ducks and geese. They also contend that shot-string length affects performance in another way. The rear pellets in the string, they argue, move at lower velocities than the forward ones and so deliver lower energies to a target.

Because of this disagreement, it seems appropriate to reassess Burrard's views. A further reason is that we now have much better ballistic data on the behavior of shot clouds. We can now establish the actual amounts of change in performance caused by shot stringing.

One way of gaining insight into the nature of shot stringing is to observe the comparable pattern distributions of pellet impacts across fixed and moving signature sheets. A shot charge fired against a stationary sheet will produce a pattern like the one centered in a 30″ circle shown in Fig. 1. In this typical distribution, vertical dispersion is equal to horizontal dispersion. The location of each pellet impact on the pattern, moreover, is for the most part unrelated to its longitudinal location in the shotstring.

Suppose now, that we attach a signature sheet to the side of a boxcar. As the train pulls it by us at high speed, we fire an identical shot cloud at the same range against it. Fig. 2 shows the result. Although the vertical dispersion remains unchanged, the horizontal dispersion has increased. In this case, the longitudinal location of a pellet in the shotstring has a definite influence on its horizontal impact location on the pattern. The general effect is as if the pattern had been placed on a rubber sheet which had then been stretched horizontally to produce an elliptical pattern.

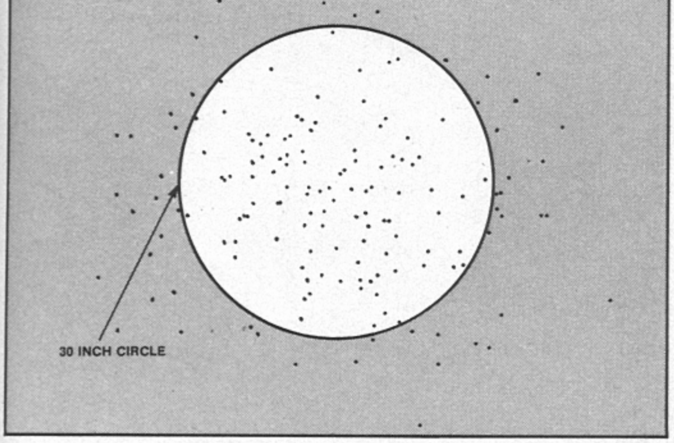
The exact effect is the result of the interaction of pellet velocities, signature sheet velocity, and shotstring length which moves the point of impact of each pellet right or left according to its position in the string. If we want to measure the difference between the patterns illustrated in Figs. 1 and 2, we simply draw a new 30″ circle inside the ellipse, as shown in Fig. 3, and then determine the percentage of pellets in the inner circle.

The difference between this percentage and the one obtained from the stationary target of Fig. 1 shows the influence of target motion. For example, if 75% of the pellets land in the original circle and only 70% in the second circle, the effect of target motion is a reduction of 5%. While the reduction illustrated in Fig. 3 is obviously small, it is actually greater than that of typical 40-yd. patterns. The exaggeration over normal density loss is for illustration purposes only.

Although it is not usually feasible to shoot at box cars, there are other ways to move signature sheets. Burrard did so back in the mid-1920s by attaching a large 6 ft. x 12 ft. sheet-steel target to the side of a small truck. With this rig he did much of his shotstring experimentation, firing alternately against a stationary target and the moving one. One difficulty that plagued his experiments was a maximum achievable speed of 40 m.p.h. More recent repeats of this kind of testing have had the benefits of faster moving motor cars and modern shotshell loads. This technique of firing against moving signature sheets is very interesting, but it has not provided enough information to resolve the shotstring question in a quantitative manner.

FIGURE 1

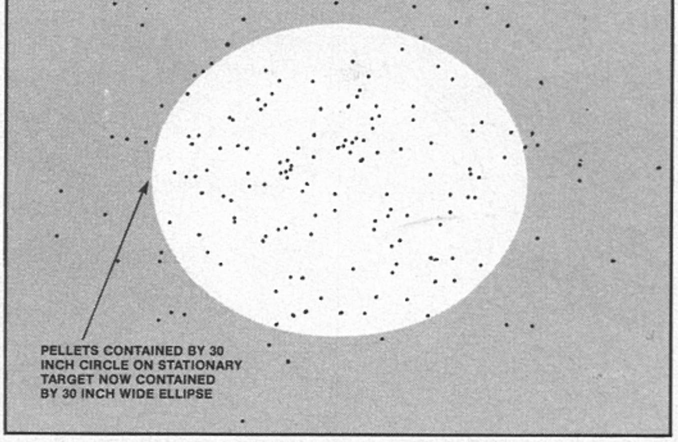
PATTERN ON STATIONARY SIGNATURE SHEET



Stationary target shows typical round pattern with horizontal and vertical dispersion about equal. The traditional 30″ circle is circumscribed around the pattern's most dense part.

FIGURE 2

PATTERN ON MOVING SIGNATURE SHEET



Moving target shows elongated pattern containing the same number of pellets. The circumscribed ellipse is 30″ high x about 36¾″ wide. The elongation is typical for a target speed of 55 m.p.h.

What we need are answers to the following type of specific question. "Given the downrange pellet velocity, the 90° crossing speed of a target and the length of the shotstring, how much loss is there from the stationary pattern?" That question will be answered here.

First, we will consider several combinations of pellet velocity and shotstring length. This information will then be applied to three specific 12-ga. shotshell loads fired at ranges from 40 to 65 yds. against a target with a crossing speed of 80 feet per second (55 m.p.h.). This is a high speed for a game bird and applies only when it is flying at exactly 90° to the line of fire.

To answer the question, it is first necessary to identify a quantity that we will call the shotstring factor. It is equal to the shotstring length times the target velocity divided by the shot cloud velocity at the target. Fig. 4 illustrates the physical meaning of this quantity. It shows a bird flying in a direction perpendicular to that of an approaching shot cloud.

It is apparent that those pellets which hit the bird all lie in a "cylinder" that cuts through the shot cloud at an angle that is determined by the relative velocities of the shot and the bird. If both bird and shot velocities change, but in such a way that the ratio of velocities does not, then the tilt of the cylinder will not change. It is also apparent that if the shotstring length is increased, then the shot velocity must increase correspondingly in order for the same pellets to remain in the cylinder. Thus, the effect of shotstring can be seen to depend on the way that shot and bird velocities combine with shotstring length to obtain this one quantity — the shotstring factor.

Before we can compute the shotstring factor, it is first necessary to settle on some consistent and efficient measure of shotstring length. One of my first assignments as a ballistician at Winchester was to find such a measure. At that time, a technique had just been perfected for photographing a shotstring with a high speed movie camera that records the holes made by each pellet as it penetrates a sheet of lead foil. Some 60 shotstrings had been filmed with various loads at 40 and 60 yds. Part of my assignment was to reconstruct each of these shotstrings. To do so, I had to enlarge the individual frames from the motion picture film and then place each pellet into its proper location in the string. Although this process was much more accurate than any previous method for the measurement of shotstring, it required several hours for the complete reconstruction of one shotstring. Our objective was to find a single measure that would take less time and yet be meaningfully descriptive.

Table A lists eight candidate measures. We settled on the smallest length that included 80% of the shotstring. It measures the length of optimum density and excludes, roughly, the front 4% and the rear 16% of the cloud. An analysis of the 60 reconstructed shotstrings showed that all had the same characteristic shape with dimensions in the same proportion to each other as those in Table A. This meant that the total properties of a shotstring could then be estimated from the measured value of its 80% length.

With this measure of shotstring length, we can calculate a shotstring factor and see what it means. For an example, suppose we have a load that has an 80% length of 80" at 40 yds., and patterns 75% in a 30" circle. Suppose, also, that the pellet cloud has a 700 f.p.s. velocity at 40 yds., and that it is fired against a crossing target at that range having a speed of 70 f.p.s. For this example,

$$\text{Shotstring Factor} = (80\%)\ \text{Length times}\ \frac{\text{Target Velocity}}{\text{Pellet Velocity}} = 80\ \text{times}\ \frac{70}{700} = 8.$$

The significance of this number appears in Table B. For our example the shotstring factor has the value 8 and the initial pattern value is 75%. The left-hand column lists the input values of the shotstring factor. In the row that corresponds to a shotstring factor value of 8 and

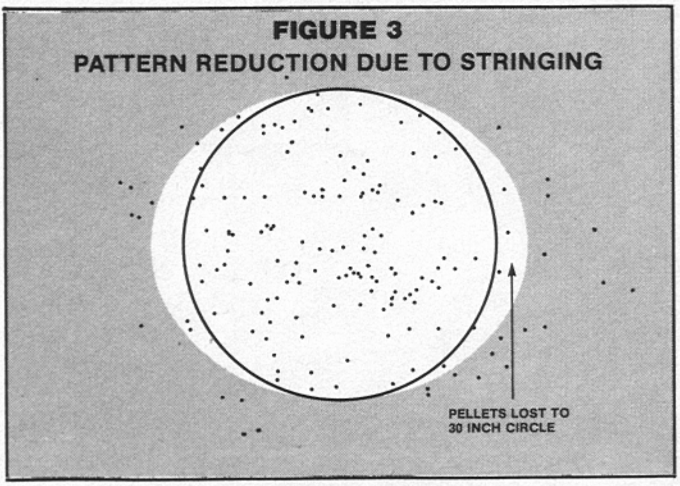
TABLE A

Typical 40 Yard Shotstring Properties Of A 12 Gauge, 2¾" 3¾ Dram Equivalent Load With 1¼ Ounces Of #4 Shot

DISTANCE, IN INCHES, FROM FRONT PELLET THAT INCLUDES			
50% OF PELLETS	**80% OF PELLETS**	**90% OF PELLETS**	**95% OF PELLETS**
58	88	105	120
SMALLEST DISTANCE, IN INCHES, THAT INCLUDES			
50% OF PELLETS	**80% OF PELLETS**	**90% OF PELLETS**	**95% OF PELLETS**
43	80	100	117

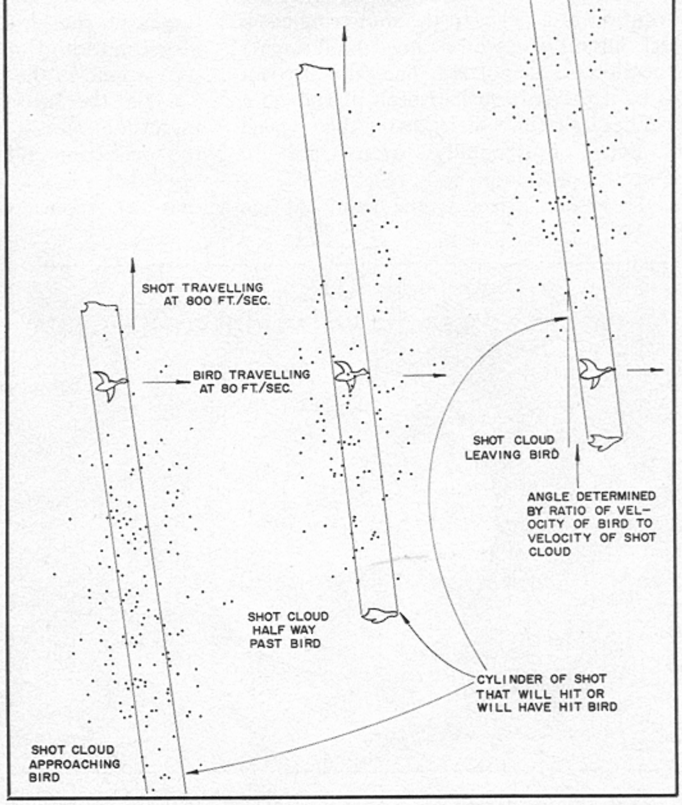
FIGURE 3

PATTERN REDUCTION DUE TO STRINGING



Combining the 30" circle of Fig. 1 and the ellipse of Fig. 2 shows that only a few pellets between the circle and the ellipse are lost due to shot stringing. The effect, for better or worse, is very small.

FIGURE 4



Velocity of the shot load is ten times that of the bird. The pellets which hit the bird lie within a cylinder angled to the line of fire. It depends on the ratio of the shot speed to the target speed.

in the column for a 75% pattern level, we find the value 4.8. This means that the stationary target 75% pattern level is reduced by 4.8. In other words, the effect of the moving target and shotstring length is to produce an effective percentage (as shown in Fig. 3) of 75 – 4.8 = 70.2%. This value of 4.8, as well as all the others in Table B, was produced by a computer (which also produced Figs. 1, 2 and 3). It computed the percentage lost for each combination of shotstring factor and original pattern level. This is equivalent to the difference between the percentages in the circles shown in Figs. 1 and 3. The use of shotstring factors with Table B provides a direct, quantitative method for determination of the true effect of shotstring.

Before making any such assessments, we first need background on typical shotstring lengths and the causes of stringing. For unbuffered, unplated 1¼ oz., 12-ga. loads, the typical 40-yd. shotstring lengths are as given in Table A. They have not changed materially since the first known measurements made by Burrard in the last century. Burrard attributed stringing of shot to variations in pellet size and shape. However, it now appears that this is only a minor cause.

If shotstringing is caused by variations in pellet size and shape, then the way to get very short shotstrings would be to shoot steel ball bearings. At Winchester during the course of an extended series of shotstring measurements conducted in 1969, we measured the shotstring lengths of 12-ga. shells loaded with ⅛″ diameter ball bearings. The 80% lengths at 40 yds. averaged 50″ from both cylinder and full-choked barrels.

In the course of these tests, we learned that variations in pellet size and shape are only partial causes of stringing. The main cause, it seems, is the way the pellets individually leave the protection of the undispersed shot column during the first few yards of travel. This is somewhat analogous to the way a group of swimmers would be strung out in the water after having jumped off a fast-moving boat.

Will the length of the shot column improve or detract from these hunters' chances of bagging geese? Every objective study concludes it will make little difference in either direction. Of the loads listed in Table C below, steel shot at 55 yds. was the worst.

Table C shows three 12-ga. 2¾″ loads. One is unbuffered lead, one is buffered lead and the third is a steel shot load. The first one is the very popular 1¼ oz. load of unplated, unbuffered shot. The second represents the optimum in performance for that shell size. The third, a steel shot load, is included because of some current beliefs that steel shot gives good pattern performance against crossing targets because of its short shotstring. As is evident from the results shown in Table C, there are no great differences in pattern loss. Although the differences were small, the worst one was with the steel load at 55 yds.

With any of these three loads, a crossing target moving at 80 f.p.s. requires a 10-ft. lead at 40 yds. This would seem to reduce even further the relative importance of shotstring on effective pattern delivery.

There are loads with longer shotstrings. Three 12-ga. examples are the 1½ oz. unbuffered load in a 2¾″ shell and the 1⅝ and 1⅞ oz. unbuffered loads in 3″ shells. However, their shotstrings are not so much longer that it will make a substantially larger difference in pattern loss.

The other concern about the effects of shotstring length has been the belief that the pellets in the tail of the shotstring deliver much less energy. Here again, the difference in velocity is too small to make a substantial difference.

The first purpose of this article was to offer a method for quantitative determination of the consequences of shotstring length. The method described here does so by simply calculating the shotstring factor, then referring to Table B for the resulting loss in effective pattern level. The other purpose was to reassess Burrard's conclusion that the practical effects of shotstring are very slight. The best evidence is that Burrard was right. ■

TABLE B

Loss In Pattern Percentage For Various Values Of Shotstring Factor And Pattern Level

Shot String Factor	Pattern Levels 50%	55%	60%	65%	70%	75%	80%	85%
2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4
3	0.3	0.4	0.5	0.6	0.7	0.7	0.8	0.8
4	0.6	0.8	0.9	1.0	1.1	1.3	1.4	1.4
5	1.0	1.2	1.4	1.6	1.8	2.0	2.1	2.2
6	1.4	1.7	1.9	2.2	2.5	2.8	3.0	3.2
7	1.9	2.2	2.6	3.0	3.4	3.7	4.1	4.3
8	2.4	2.9	3.3	3.8	4.3	4.8	5.2	5.6
9	3.0	3.6	4.1	4.7	5.4	6.0	6.5	7.0
10	3.6	4.3	5.0	5.7	6.5	7.2	7.9	8.4
11	4.3	5.1	5.9	6.8	7.6	8.5	9.3	10.0
12	5.0	5.9	6.9	7.8	8.8	9.8	10.8	11.6
13	5.7	6.8	7.8	9.0	10.1	11.2	12.3	13.3
14	6.5	7.6	8.8	10.1	11.4	12.7	13.9	15.0
15	7.2	8.5	9.9	11.2	12.7	14.1	15.5	16.7

TABLE C

Reduction In Effective Pellet Density Against A Target Moving At 80 Ft/Sec (55 MPH) Across The Line Of Fire

For Three 12 Gauge 2¾″ Loads: A Standard 1¼ Oz #4 Duck Load, A 1½ Oz #4 Buffered Load, A 1⅛ Oz #2 Steel Shot Load.

Range (yards)	Load	Average Pellet Velocity (ft/sec)	80% Shot String Length (inches)	Shot String Factor	Pattern Level (% in 30″ circle)	% Loss to Pattern
40	standard	738	79	8.56	72	5.1
	buffered	775	56	5.78	87	3.0
	steel	707	55	6.22	85	3.4
45	standard	696	94	10.80	58.2	5.4
	buffered	737	67	7.27	75.0	4.0
	steel	664	67	8.07	73.9	4.7
50	standard	658	109	13.24	46.2	5.1
	buffered	704	79	8.97	62.3	4.4
	steel	624	80	10.25	62.4	5.6
55	standard	624	124	15.90	36.4	4.5
	buffered	673	91	10.82	50.7	4.3
	steel	587	95	12.94	51.8	6.0
60	standard	592	139	18.78	28.8	3.9
	buffered	644	104	12.92	41.0	4.0
	steel	553	112	16.21	42.8	5.4
65	standard	561	155	22.11	23.0	3.4
	buffered	618	118	15.27	33.2	3.6
	steel	520	129	19.85	29.1	4.1