The Rifle Magazine

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May-June 1970

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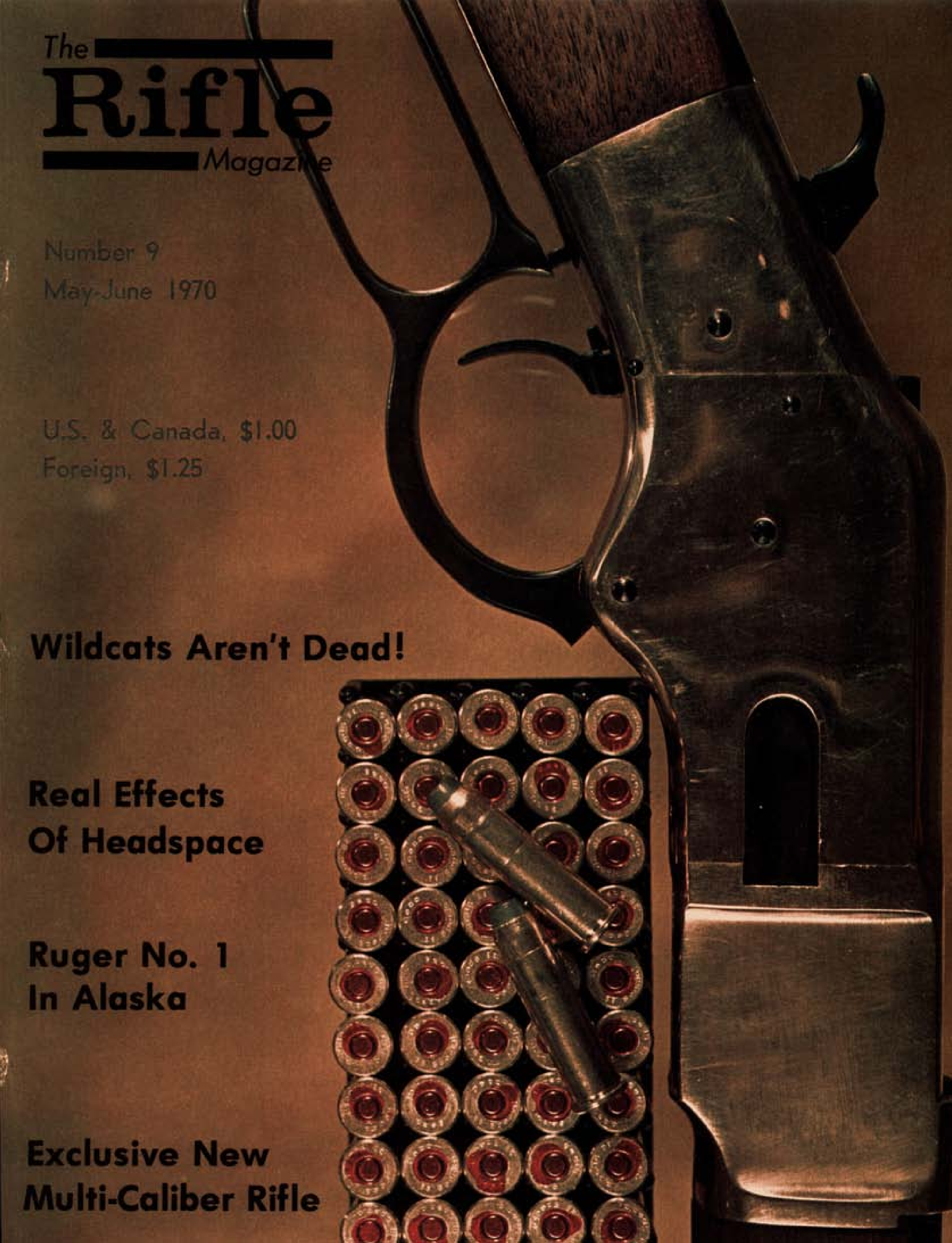

Wildcats Aren't Dead!

Real Effects Of Headspace

Ruger No. 1 In Alaska

Exclusive New Multi-Caliber Rifle

The Rifle Magazine

'Only Accurate Rifles Are Interesting
– Col. Townsend Whelen

Volume 2, Number 3
May-June 1970

In This Issue

Departments

Cover

The Navy Arms Yellow Boy .38 Special Carbine is a close copy of the rifle that started the Winchester saga, the Model 1866. With the brass frame that gave its name, it's handsome piece, but the century-old action wasn't designed for high pressure loads, as George Nonte reports in this issue.

Adopted in August 1969 as Official Publication For National Bench Rest Shooters Association

The Staff

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MUZZLE FLASHES

The ANTI-GUN FORCES in Washington have taken off the kid gloves. A few have even dropped the pretense that they're not interested in legislating against sporting arms. For instance, Rep. Leonard Farbstein (N.Y.) is trying to get the Treasury Department to outlaw the importation of soft point hunting bullets, on the grounds that "dum-dum" bullets are outlawed by the Hague Convention and that such bullets are inhumane. In addition, he's planning to introduce a bill outlawing the manufacture of such bullets in the U.S. From what I hear, he wants to make it unlawful to produce bullets giving more than a certain amount of hydrostatic shock. The trouble is, he hasn't been able to come up with a way of measuring hydrostatic shock—neither has anyone else.

He would be appalled at the amount of game that would be crippled and lost if there were no expanding bullets, but he would probably prefer to do away with hunting—and all guns—anyway.

Rep. Abner Mikvah of Chicago has also introduced a bill banning the manufacture of handguns, except for military or police use. His argument is that handguns are not sporting arms and that their sole purpose is to kill people. If handguns go, will rifles be far behind?

I don't expect anything to come of either of these efforts, but there could well be some action on a bill, as yet unintroduced, outlawing or regulating the "Saturday Night Special" pistols. The Administration, though generally friendly to gun owners, is in favor of getting rid of the $12.98 pot metal wonders that once were imported and are now being made in this country. No hunter, shooter or gun buff has any use for these pieces of junk, but the problem is: how do you get rid of them without also outlawing good guns?

Senator Dodd has a bill in the hopper which would apply the standards for hundgun imports to domestic-manufactured guns; those standards are based on the physical dimensions of the guns. As a result, fine guns such as the Colt Cobra or the S & W .22-32 Kit Gun would be outlawed. But many of us do use such guns for sport.

In recent weeks there have been some behind-the-scenes meetings between legislators, government people and manufacturers looking for a solution to the problem. We'll keep you posted.

* * *

One evening last spring, Dave Wolfe, Dick Lee of Lee Loader fame, and I were talking guns and flying when Dick mentioned the number of people who are devotees of both sports. Since then I've been noticing just how many of my gun friends are also pilots or interested in flying. There are far too many for it to be merely a coincidence.

I don't know what the head-shrinkers would make of this, but the same school of psychiatrists which claims our fascination with guns stems from fears of sexual inadequacies makes the same claim for pilots. (In case anyone asks, I have four children; so does Dave.) Cartridges, especially the big magnums, are said to be "obvious phallic symbols," and the same pointy-head psychiatrists say long propeller spinners are "obvious phallic symbols" to pilots.

The only reason I bring this up is because we gun owners sometimes think we're the only ones getting slapped around by sensation-seeking politicians, a biased press and distorted statistics emanating from governmental agencies. Not so. Every time there's a tragic air crash, the nation's private pilots get the same kind of brutal going-over that we gun owners get after an assassination or a sniper incident.

For instance, after the collision of a light plane and an airliner near Indianapolis a few months ago, columnist Jack Anderson, former partner and successor to Drew Pearson, wrote an article in *Parade* newspaper supplement. Anderson's unreasoning tirade of misstatements, factual errors and distortions in that article is equalled only by his similar "articles" on guns and gun legislation. He uses the same half-truth technique for each subject, but if you're not a reasonably well-informed gun owner or a reasonably well-informed pilot, you don't know it.

Just as gun owners are in a fight to keep from losing their right to lawfully own and use guns, private pilots are in a fight to keep from being legislated out of the air—and both groups need outside support. So talk to your pilot friends, explain to them that we gun owners have been getting precisely the same treatment from politicians and the press that general aviation has been getting.

Give them some examples of the anti-gun crowd's tactics—for instance, the politicians who screamed for gun registration after Bobby Kennedy was murdered with a *registered* gun; and point out that those same politicians passed the '68 Gun Control Act as a result of that murder, though that law could not possibly have prevented Sirhan from having the murder gun.

Similarly, the "crowded skies" you've been reading about are a myth. Dave and I flew from Illinois to Idaho and back last fall, more than 3,000 miles, and saw precisely 14 airplanes, other than around airports. Several reports on the Indianapolis crash flatly stated that the private plane "crashed into" the airliner. Will someone tell me how a 130 m.p.h. plane can "crash into" a 500 m.p.h. jet, even if the airliner is obeying the 288 m.p.h. low altitude speed limit? Does the "reporting" technique seem familiar?

General aviation pilots aren't advocating "no regulations" for flying any more than gun owners want every man on the street packing a pistol, but, like gun owners, pilots want their regulations to deal with real, not imaginary, problems; and they want reasonable, effective solutions to those problems. They don't consider it reasonable to be forced out of the skies, whether by restricted airspace or requirements for expensive equipment—no more than we consider giving up our guns a reasonable solution.

Gun owners need support; general aviation pilots need support. Giving that support to each other would appear sensible and to our mutual benefit.

* * *

Sometimes those of us who constantly report on new products fail to mention good old products. This brilliant observation came to mind a few days ago while I was repairing a scratch on a stock finished several years ago with G–B Lin-Speed. Even after a lot of handling and normal abuse over the years the stock still looked good—and it only required some judicious cleaning and sanding and a few drops of Lin-Speed to take care of the scratch. Try patching a scratch on some of the newer, more exotic finishes!

Lin–Speed, which is a highly refined kettle-boiled linseed oil with all the non-drying parts (called foots) removed, is not so tough as the newer polyurethane finishes, but it's quite serviceable and one of the easiest finishes to apply. It's been a favorite for years, and is used by many of the top gunsmiths and even by some of the factories on custom grade guns. Manufacturer George Brothers, Great Barrington, Mass., 01230, put out an excellent booklet on oil finishing about three years ago. If you're wanting to try your hand at oil finishing, or if you are dissatisfied with the results you've gotten in the past, I suggest you route a buck to George Brothers, asking that he send one out.

* * *

"You can't judge a book by its cover" and neither can you judge one by its title, but that's what many buyers of gun books must do. Few book stores have good firearms reference works in stock, so most gun books have to be bought by mail.

Norm Flayderman, Squash Hollow, R.F.D. 2, New Milford, Conn., 06776, gives the bibliophile a tremendous amount of help in his book catalogue, the fourth edition of which is just off the press. It lists hundreds of books in the firearms and weapons fields, each of them given a brief review by Norm, with photos of many—and all are in stock. If Norm is a bit over-enthusiastic in some of his reviews it can be forgiven, for he is in the book-selling business, but he is also well-qualified to write the reviews for he is a man of great curiosity and tremendous knowledge in military history, weapons, and many other subjects.

His "offices," nestled in the beautiful Connecticut hills, contain an inventory of arms, armor, paintings and countless other items that would turn many museum curators green with envy. In fact, museums are among his best customers. If you're planning and want to know more about the books that are available, I strongly recommend that you obtain a copy of the 100-page Flayderman Book Catalogue No. 4, which is available for a paltry two bits. It's a rare bargain.

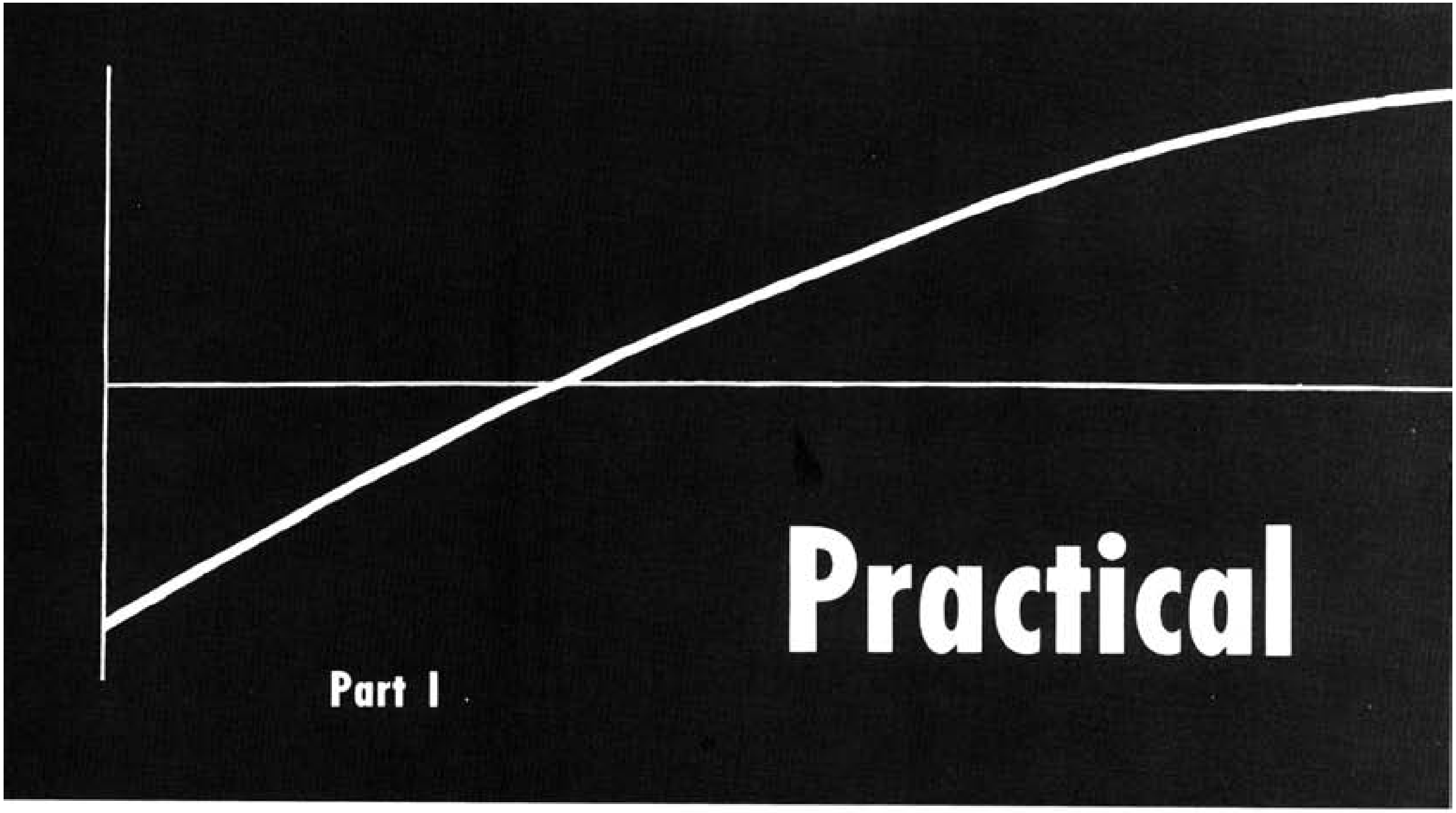
* * *

I've been using them all my life, but I hate standard slotted-head stock screws. With a few exceptions, they've got to be kept absolutely tight, but even with a perfect-fitting screwdriver it's easy to burr them if the rifle isn't in a cradle. In the field, or at the range, I seldom have either a cradle or a perfect-fitting screwdriver for that particular gun. Result: burred screws.

So I was pleased to see the set of hex socket rifle guard screws which stockmaker Jim Baiar, Box 352, Columbia Falls, Montana, 59912, sent me a few days ago. These are well-cut (or ground), closely matching the original threads. The sample set, for a Mauser, uses a 5/32 socket and wears a high-polished blue. They're quite handsome, and I'll take them over a slotted-head screw any day.

The principle users of hex-head screws are bench shooters, who prefer them because they can more accurately adjust tension (some use a torque wrench). Baiar's screws will allow the same thing on your sporter, though they're a bit on the expensive side—$3.95 for two-screw sets and $4.95 for the three-screw types, such as the Model 70. The price includes a wrench and postage. In addition to the Model 70 and Mauser, he has the screws for Enfield, Springfield, Remington 40X and Model 700, and Sako actions. The Sako screws have a 1/8-inch socket. In addition, Baiar will make up special sets, if he has the original screws, normally for the same price.

Neal Knox



Practical

Part I

EXTERIOR BALLISTICS calculations by the accepted methods present no great problem. One need only to be possessed of a few degrees in higher mathematics, an understanding of the problems, a set of references, a list of the basic formulae, and the will to spend hours on end at the job. Slide rules are helpful, but an electronic computer is better. There *had* to be an easier way.

After "Practical Trajectory Calculations" was published in *Rifle* No. 1, Editor Neal Knox suggested the development of a simplified method of applying the ballistic coefficients supplied by bullet manufacturers to trajectory calculations. Further, he wondered if there were a relatively simple method of computing ballistic coefficients for bullets for which a ballistic coefficient is not available. I agreed to give it a try, not fully realizing the extent of the problem at the time.

As I've indicated above, the calculation of external ballistics normally requires higher mathematics and, even then, can be quite time-consuming. The "project" was to study the problems and, if possible, develop a system whereby the non-mathematician shooter can accomplish the job through arithmetic—exacting arithmetic perhaps, but arithmetic *only*, nevertheless.

Hundreds of hours have gone into the project and many computer runs were made to verify the accuracy of the results. At long last, we arrived at relatively simple methods by which most readers can calculate ballistic coefficient and velocity, time of flight, wind drift and drop. We've also established similar methods of trajectory calculation and estimation of muzzle velocity from range data. Space doesn't permit including them here, but they will appear in a subsequent article.

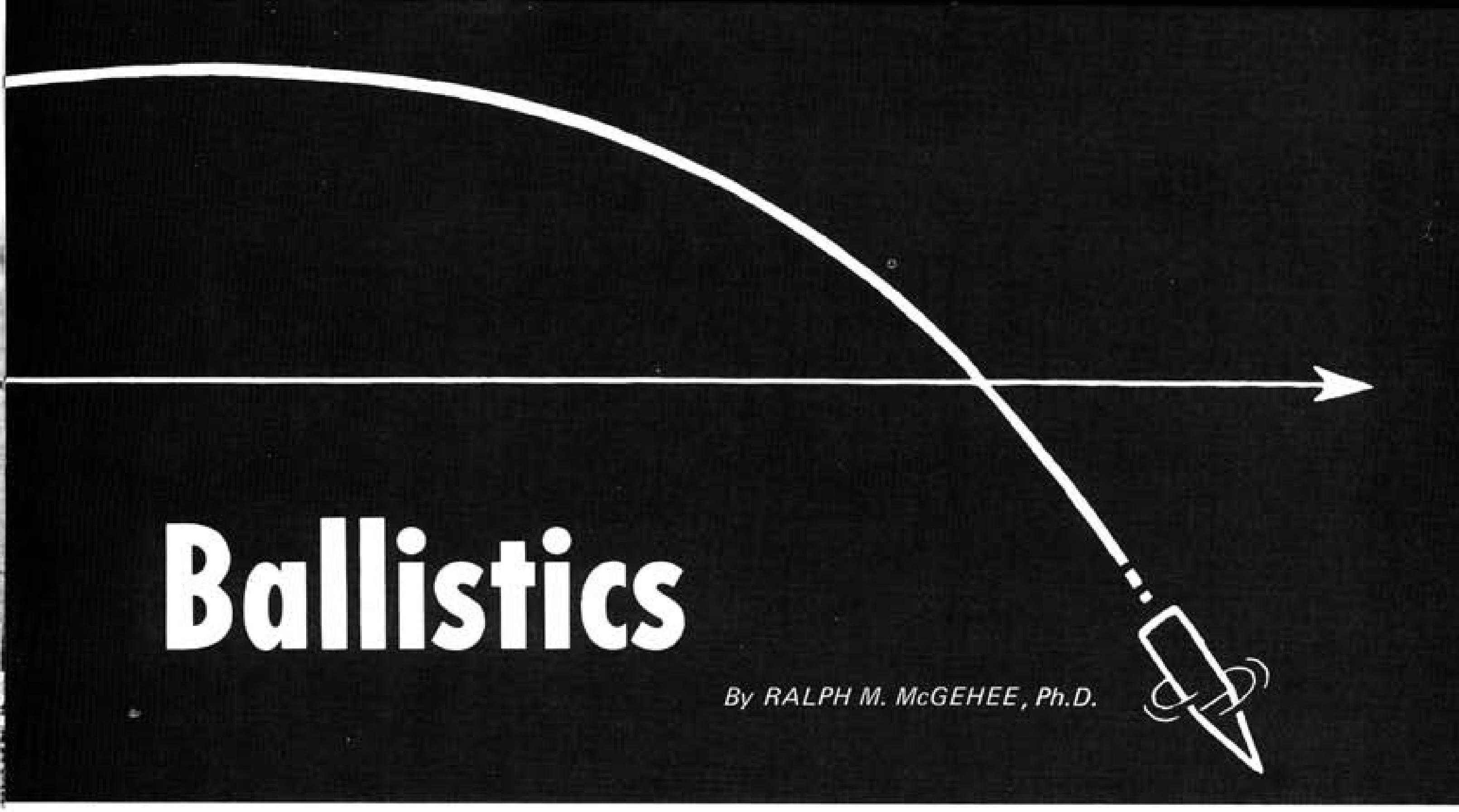
Most of the following material is easily understood if followed in logical sequence. If you get lost, back up a few paragraphs and begin again. Once you understand the example given for each problem, the hard part is over. Whatever you do, don't be intimidated by the mere appearance of a list of frightening formulas. You *can* understand and use them if you follow line-for-line, step-for-step, for as already stated, only arithmetic is required. The most involved computation required is the derivation of square root. I strongly recommend a slide rule or log tables.

Several pages could be devoted here to the manner in which Ingall's Tables and Mayevski formulas (upon which U.S. exterior ballistic calculations are usually based) have been used to develop these methods and formulas. That isn't really needed to follow through and might even be a source of confusion. Should you wish to explore those subjects more deeply see "Hatcher's Notebook," Stackpole, 1962. It is sufficient to say here that Ingall's Table's list various standard projectiles and values for them and that my formulas use the same ballistic coefficient scale.

Mayevski's functions establish a retardation curve which actually appears in cusped segments, that is, it is not a smooth curve. During this project a single smooth curve was found which interlaces the Mayevski curve in the supersonic region.

This curve, I contend, is a more accurate curve than the Mayevski curve for velocities above 1,350 fps. For the derived to be better than the reference is something of a paradox, but consider Figure 1, which compares the two curves, with the difference scaled up by a factor of ten for clarity. The single smooth curve is definitely more representative, though the maximum difference between the curves is less than one percent, therefore hardly significant.

Using the single smooth retardation curve, differential equations were set up and solved for scaled time and distance



Ballistics

By RALPH M. McGEHEE, Ph.D.

(range) as functions of velocity. The range-velocity curve was inverted to find velocity as a function of range; then time of flight, drop and wind drift formulas were derived and simplified for practical application. Finally, the drop formulas were used to estimate muzzle velocity.

In developing the formulas and methods shown here the inevitable errors of approximation have been held to a practical minimum, though approximations are found in calculations of ballistic data for several reasons. Air resistance at supersonic velocities is so complex that accurate analytical development of precise, practical formulas has not been possible. All formulas, to the best of my knowledge, are empirical fits to experimental data obtained with "standard" projectile shapes. Since small arms projectiles do not precisely copy standard shapes, extrapolation is necessary to select *approximately* correct values. Proportionalities have been assumed which may not be strictly valid but which have produced adequately accurate results.

Other approximations are also involved in development of my formulas, but their error is small compared to other variables normally present. The formulas are valid in the supersonic range of 1,350 fps to 5,000 fps, and produce adequately accurate results down to one-half the muzzle velocity, within those limits. There are few centerfire rifle applications that do not fall within this range.

These formulas produce entirely adequate accuracy. Comparison of calculated data (using my formulas) with published manufacturers' data on 16 different factory loads shows discrepancies usually less than two percent. That is less than the lot-to-lot and gun-to-gun variation normally encountered.

The Working Formulas

In deriving the ballistic formulas, we rescaled time and range variables to incorporate the ballistic coefficient and obtain a basic set of "universal" formulas. This set is simplified by appropriate approximation and rescaled back to real time and range to produce the working formulas.

In simplification of the working formulas, there is a compromise between simplicity and working range; the range to half muzzle velocity was chosen as a reasonable working range for most applications. The formulas may be used somewhat beyond the working range, but error will increase.

Notation

x - Range in hundreds of yards
($x = 2.5 \sim 250$ Yards)
t - Time in seconds to range x
v - Velocity (more properly speed) at range x in thousands of feet per second ($v = 3.2 \sim 3200$ feet per second)
v_m - Muzzle velocity (at $x = 0$)
y - Vertical drop from effective line of bore (negative value), or height above line of sight in inches at range x
z - Wind drift in inches at range x
C - Ballistic Coefficient (Ingalls Tables scale)
w - Cross component of wind in miles per hour
• - Multiplication symbol (omitted when multiplication is clearly implied by juxtaposition.)

The use of velocity units in thousands of feet per second and range units in hundreds of feet keeps these numbers small and reduces the chance of decimal point error.

Formulas (1)

$$K = 1/(Cv_m^{3/4})$$

(This combination occurs repeatedly)

Velocity (2)

$$v = v_m/\left[(A_2x + A_1)x + 1.003\right]$$

$$A_1 = 0.0823 \cdot K(1 - 0.45/v_m)$$

$$A_2 = 0.198 \cdot K(1 - 1.65/v_m) \cdot A_1$$

The error in (2) is less than one half

percent for $0.6v_m \leqslant v$ and less than one percent for $0.5v_m \leqslant v \leqslant 0.6v_m$.

Time (3)

$$t = \left[(G_3 x + G_2)x + G_1\right]x$$
$$G_1 = 0.301/v_m$$
$$G_2 = 0.0410\cdot K(1 - 0.45/v_m)\cdot G_1$$
$$G_3 = 0.132\cdot K(1 - 1.65/v_m)\cdot G_2$$

The error in (3) is less than one fourth percent in general, and is only slightly larger at velocities near $v_m/2$.

Drop from Line of Bore

Two formulas are given for the drop from effective line of bore. (The effective line of bore may be slightly different from the geometric line of bore because of barrel vibrations.) The first formula is more accurate, especially at long range and with small ballistic coefficient (say less than about 0.25). The second formula is simpler, and is adequately accurate for most purposes. The formulas are designated y_q and y_c for the quartic (fourth degree) and cubic (third degree) expressions, respectively.

(4)

$$y_q = -\left[(B_4 x + B_3)x + B_2\right]x^2$$
$$B_2 = 17.6/v_m^2$$
$$B_3 = 0.0500\cdot K(1 - 0.6/v_m)\cdot B_2$$
$$B_4 = 0.1815\cdot K(1 - 1.2/v_m)\cdot B_3$$

The error in (4) is less than about 0.02 minute of angle over the working range.

(5)

$$y_c = -(B_3'\cdot x + B_2')x^2$$
$$B_2' = 15.8/v_m^2$$
$$B_3' = 0.120\cdot K(1 - 0.72/v_m)\cdot B_2'$$

The error in (5) is less than 0.1 minute for $0.6v_m \leqslant v \leqslant v_m$, increasing to about 1/3 minute as v drops to $v_m/2$.

The drop formulas are applied later to trajectory calculation and estimation of muzzle velocity.

Wind Drift (6)

$$z = D\cdot w$$
$$D = (D_3 x + D_2)x^2$$
$$D_2 = 0.212\cdot K(1 - 0.45/v_m)/v_m$$
$$D_3 = 0.217\cdot K(1 - 1.47/v_m)\cdot D_2$$

The error in (6) is less than 1 percent over most of the practical range, and less than 1.5 percent at extremes of the working range. The fractional error is larger at short range, but the drift value is also small so that the error is not significant.

Ballistic Coefficient (7)

$$C = \frac{\dfrac{x}{13.41}}{\dfrac{v_m - 2.34}{(v_m - 0.585)^{1/4}} - \dfrac{v - 2.34}{(v - 0.585)^{1/4}}}$$

The formula for C is derived directly from the reference retardation curve without approximation.

The above set of formulas may appear formidable to some. However, the coefficient values (A's, B's, etc.) are calculated only once for a given load, and then only for the ballistics desired. The formulas are set up to minimize arithmetic. Calculations must start within inner parentheses and work outward, as illustrated later.

Calculation of Square Roots

The use of a slide rule, log tables, or a calculator with square root capability is most efficient for evaluation of square roots. The square root of the number N is simply the number which when multiplied by itself gives an answer of N. Symbolically, let $s = N^{1/2}$ where s is the desired square root of N. To find the value of s that fits a given N, first make a guess of what number multiplied by itself will give N. Use the guessed square root, s_o, in the formula (8).

$$s = \left(\frac{N}{s_o} + s_o\right)/2$$

This calculation will give a closer approximation to the value of s than the original guessed s_o. Repeat the calculation to find a better estimate of s by using the last s calculated in the above equation in place of s_o. The calculation should be repeated until s doesn't change between calculations.

To illustrate, let N = 3.2 and take s_o = 2 (a very rough guess). Formula (8) becomes

$$s_1 = \left(\frac{3.2}{2} + 2\right)/2 = 1.8$$

$$s_2 = \left(\frac{3.2}{1.8} + 1.8\right)/2 = 1.789$$

$$s_3 = \left(\frac{3.2}{1.789} + 1.789\right)/2 = 1.789$$

Three significant figures, or perhaps four when the lead digit is 1, is adequate accuracy for ballistic calculations. The data are seldom this accurate, though frequently stated more precisely.

Now (9)

$$N^{1/4} = (N^{1/2})^{1/2}$$

$$3.2^{1/4} = (1.789)^{1/2} = 1.338$$

Also (10)

$$N^{3/4} = N^{1/2}\cdot N^{1/4}$$

$$3.2^{3/4} = 1.789\cdot 1.338 = 2.39$$

Application of formulas has been reduced to elementary arithmetic

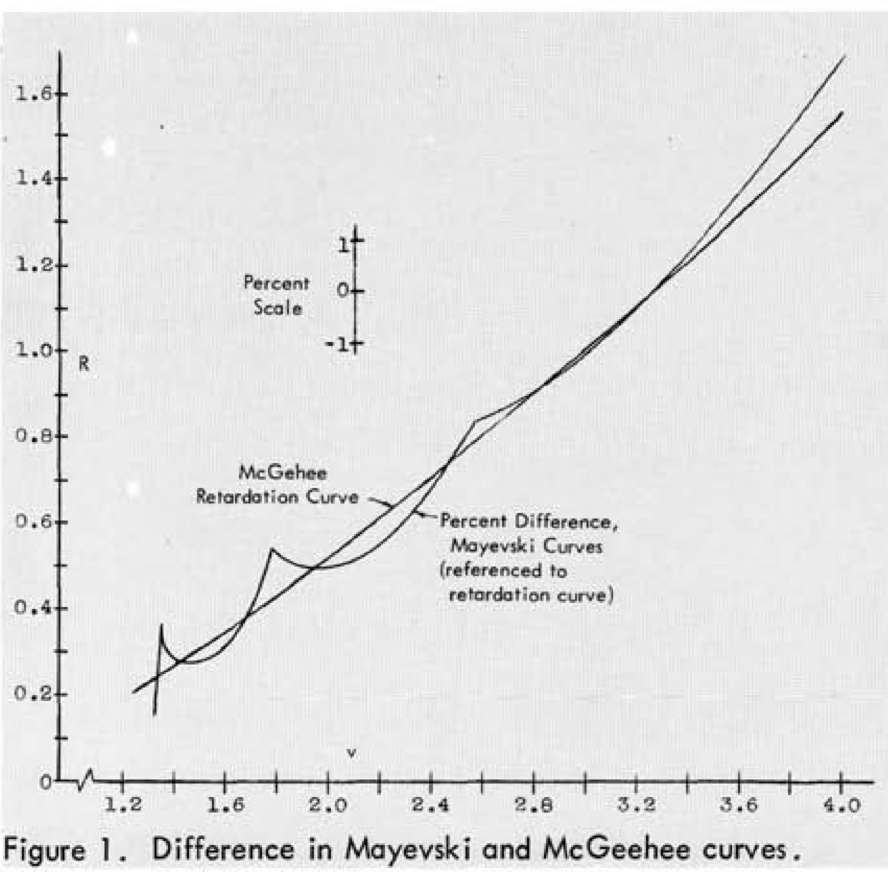


Figure 1. Difference in Mayevski and McGeehee curves.

operations. To check square root calculations, square the root; the square should be accurate to about as many places as the root is accurate.

Example Problems

The .222 Remington cartridge is used to illustrate formula applications. A primary reason for this choice is to permit comparison of results with Hatcher's examples. Also, this cartridge is in a "worst case" category, having a relatively small ballistic coefficient.

Ballistic table data for this cartridge are:

x (range)	v (speed)	Midrange Height
0	3.20 (= v_m)	0.0
1	2.66	0.5
2	2.17	2.5
3	1.75	7.0

Examples 1 - 8 are keyed to the same examples in Hatcher.

(1) Ballistic Coefficient

All of the formulas involve the ballistic coefficient C, a factor of K. C is determined using (7). Data at the longest range available are preferred. Take v = 1.75 at x = 3.

$$C = \frac{\frac{3}{13.41}}{\frac{3.2 - 2.34}{(3.2 - .585)^{1/4}} - \frac{1.75 - 2.34}{(1.75 - .585)^{1/4}}}$$

$$= \frac{0.224}{\frac{0.86}{1.270} + \frac{0.59}{1.038}} = 0.1798$$

It is misleading to state C to four significant figures, because the data are not that accurate and consistent. Three figures at most are actually significant. Thus take

$$C = 0.180$$

Air density correction to C can be made as described in Hatcher, p. 574.

For a consistency check, values of C were calculated also for x = 1 and 2, giving C = 0.182 and 0.180, respectively. The spread in values is about 1 percent and is negligible for practical purposes.

Formulas (2) thru (6) will be used in the examples. It is convenient to find the coefficients for all before proceeding to examples. (Usually, only the coefficients for one or two formulas would be desired.)

$$K = \frac{1}{0.180(3.2)^{3/4}} = \frac{1}{0.180 \cdot 2.39} = 2.32$$

$$A_1 = 0.0823 \cdot 2.32\,(1 - \frac{0.45}{3.2}) = 0.164$$

$$A_2 = 0.198 \cdot 2.32\,(1 - \frac{1.65}{3.2}) \cdot 0.164 = 0.0366$$

$$G_1 = 0.301/3.2 = 0.0940$$

$$G_2 = 0.0410 \cdot 2.32\,(1 - 0.45/3.2)\,0.0940 = 0.00768$$

$$G_3 = 0.132 \cdot 2.32\,(1 - 1.65/3.2)\,0.00768 = 0.00114$$

$$B_2' = 15.8/3.2^2 = 1.54$$

$$B_3' = 0.120 \cdot 2.32\,(1 - .72/3.2)\,1.54 = 0.333$$

$$B_2 = 17.6/3.2^2 = 1.72$$

$$B_3 = 0.0500 \cdot 2.32\,(1 - .6/3.2)\,1.72 = 0.162$$

$$B_4 = 0.1815 \cdot 2.32\,(1 - 1.2/3.2)\,0.162 = 0.0427$$

$$D_2 = 0.212 \cdot 2.32\,(1 - .45/3.2)/3.2 = 0.132$$

$$D_3 = 0.217 \cdot 2.32\,(1 - 1.47/3.2)\,0.132 = 0.0360$$

Then

(a)
$$v = 3.2/\left[(.0366x + .164)x + 1.003\right]$$
(b)
$$t = \left[(.00114x + .00768)x + .0940\right]x$$
(c)
$$y_c = -(.333x + 1.54)x^2$$
(d)
$$y_q = -\left[(.0427x + .162)x + 1.72\right]x^2$$
(e)
$$z = \left[(.0360x + .132)x^2\right]w$$

(2) Form Factor calculation--see Hatcher, p. 585.

(3) Find remaining speed at range x, given C and v_m: Use formula (a). For x = 2 (200 yd.),

$$v = 3.2/\left[(.0366 \cdot 2 + .164)2 + 1.003\right] = 3.2/1.477 = 2.17$$

Ballistic table value is v = 2.17.

Hatcher gives v = 2.18.

The fraction denominator calculation is conveniently done in a tabular sequence as illustrated.

```
   .0366
    · 2
   .0732
+  .164
   .2372
    · 2
   .4744
+ 1.003
  1.477
```

For x = 3, v = 1.75

(4) Given v_m, and v at x = 1, find v at x = 2 and x = 3.

Inserting x = 1, v_m = 3.2 and v = 2.66 in (7), C = 0.182; K = 2.99, A_1 = 0.162, A_2 = 0.0357, $v = 3.2/\left[(.0357x + .162)x + 1.003\right]$.

x = 2: v = 2.17; x = 3: v = 1.77.

Overall accuracy was better with C = 0.180.

(5) Find t, given v_m, C and x: Use formula (b).

For x = 3,
$$t = \left[(.00114 \cdot 3 + .00768)3 + .0940\right]3 = 0.382.$$

(6) Find maximum height of trajectory for range x, given v_m, C and x.

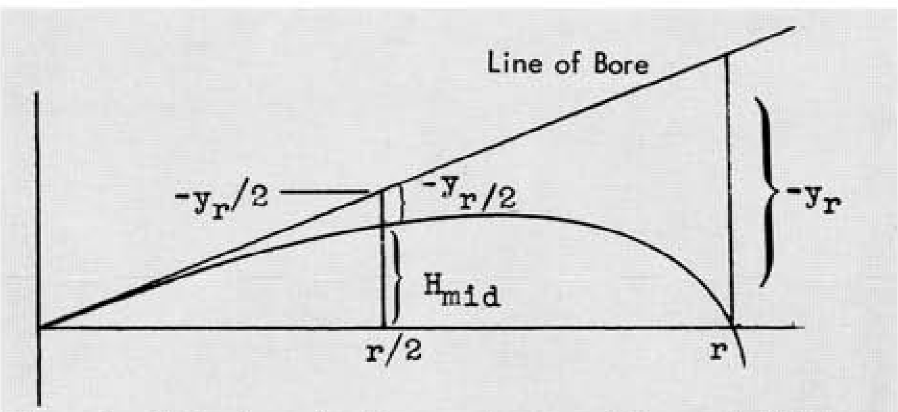


Figure 2. Side view of trajectory showing midrange height

The formula for maximum height given in Hatcher, $H = 48t^2$, is not strictly valid; the nonlinear coupling between horizontal and vertical acceleration is neglected. However, the formula appears to give fairly accurate results. Using this formula and the results of problems 5 (x = 3):

$$H_{max} = 48(.382)^2 = 7.00 \text{ (inches)}.$$

The midrange height of trajectory can be stated simply in terms of drops, y. From Figure 2,

(11)

$$H_{mid} = y(x/2) - y(x)/2.$$

Using formula (5), whose pattern reduces to (4) if $B_4 = 0$,

(12)

$$H_{mid} = \left[\left(\frac{7}{16}B_4 x + \frac{3}{8}B_3\right)x + \frac{1}{4}B_2\right]x^2$$

For the .222 Rem., using (c) and (d),

(f)

$$H_c = (.125x + .385)x^2$$
$$x = 3: \; H_c = 6.84$$

(g)

$$H_q = \left[(.0187x + .0607)x + .430\right]x^2$$
$$x = 3: \; H_q = 7.02$$

At x = 3, $v/v_m = 0.55$. It was previously noted that some dropoff in accuracy of y_c is expected for $v < 0.6v_m$. A discrepancy of 0.2 inch in a 300-yard midrange will seldom be significant.

The actual maximum height of trajectory will be somewhat greater than the value of H_q; maximum height occurs beyond midrange. The maximum height of trajectory and initial slope problems are treated in detail in a second article on trajectory calculation.

(7) Given midrange trajectory, find time of flight--see Hatcher, p. 587.

(8) Given v and bullet weight, find energy--see Hatcher, p. 588.

(9) Compare y_c and y_q values at x = 1, 2, 3, 4.

x	y_c	y_q
1	- 1.9	- 1.9
2	- 8.8	- 8.8
3	-22.8	-23.0
4	-46.0	-48.8

The difference 2.8 inches at 400 yards is about 0.7 minute of angle. However, the .222 Rem. isn't a 400-yd. cartridge.

(10) Find the wind drift at 200 and 300 yd. in a 10-mph crosswind: Use formula (e).

$x = 2$: $z = \left[(.036 \cdot 2 + .132)4\right]w = 0.82w$; $w = 10$: $z = 8.2$ inches.
$x = 3$: $z = 2.2w$; $w = 10$; $z = 22$ inches.

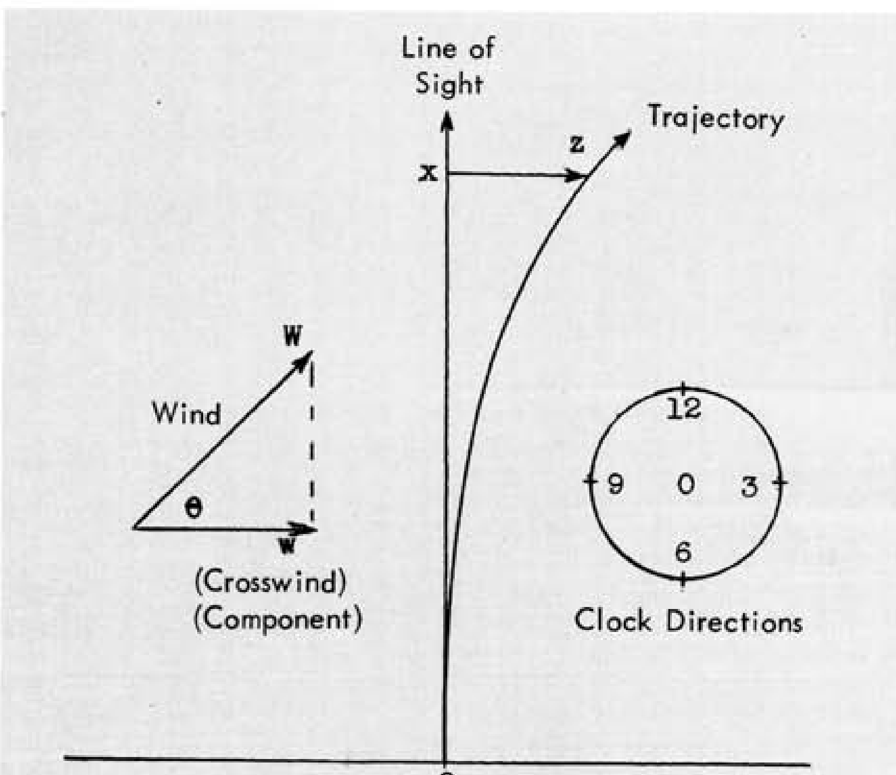


Figure 3. Plan view of trajectory showing wind drift.

To apply formulas (6) and (e), the cross-trajectory component of wind, w, must be estimated. Usually, wind speed, W, and direction are first estimated. To obtain the crosswind component, estimate the direction factor, F, using the table below and apply the formula (13) $w = F \cdot W$

Wind Angle to Line of Sight	Clock Direction	F
0°	6, 12	0.0
15°		0.26
30°	1, 5, 7, 11	0.50
45°		0.71
60°	2, 4, 8, 10	0.87
75°		0.97
90°	3, 9	1.00

To illustrate the application of (13), assume a 20 mph wind from 7 o'clock (or 1, 5 or 11). From the table, F = 0.50 and $w = 0.5 \cdot 20 = 10$.

Wind speed and direction often are variable and are difficult to estimate accurately. I recall having seen a wind drift formula years ago, probably in *The American Rifleman*, but haven't relocated it. I believe that it gave wind drift as crosswind component multiplied by time lag resulting from drag. Analysis shows that this formula is obtained if it is assumed that drift acceleration remains a constant fraction (w/v_m, properly scaled) of the retardation. This assumption is not valid because v decreases with range. Thus the time-lag formula gives drift values which are smaller than the true values. Formula (6) is simpler and more accurate.

(14)

$$t_d = t - 0.3x/v_m$$

(15)

$$z_{td} = w \cdot t_d \cdot \frac{44}{30} \cdot 12 = 17.6\,(t - 0.3x/v_m)w$$

If w = 10 mph

$x = 2$: $t_d = 0.0404$, $z_{td} = 7.1$ inches;
$x = 3$: $t_d = 0.101$, $z_{td} = 18$ inches.

The error in these values is significant, and likely could be demonstrated in a steady wind.

In developing formulas, it is reasonable to treat ballistic quantities as if precisely determined. Actually, there is variation in muzzle velocity, in the rifle and in the shooter; otherwise, all the bullets would go through the same hole. Effectively, the quantities calculated should be considered as averages. So long as errors are much smaller than group spread, they are negligible.

Ballistic coefficient increases with temperature and decreases with pressure. At or near sea level, changes are usually not large enough to justify correction. At high altitudes, the change will be significant. Correction factors are given in the Speer manual. My shooting is done at altitudes which range 5,000 feet and higher, so I usually multiply the nominal C by a factor 1.2; but for my elk rifle, normally used at about 10,000 feet, I use a factor of 1.35. The factor of air density variation makes the statement of ballistic coefficients to more than 3 significant figures ridiculous; the third likely isn't worth much.

Some inconsistencies are observed in ballistic table data and calculated data. Specifically, the calculated midrange heights for the .30-30 are definitely larger than the tabular values. I suspect that the tabular values are in error, but have no evidence to establish this. If the tabular data are accurate, the source of the discrepancy is in the assumption that the standard retardation curve matches the .30-30 ballistics.

Methods can be developed rather easily for ballistic calculations on individual loads without reference to standard curves. These methods would require more data than that needed for application of standard curves, such as a set of velocity measurements spaced over the desired working range of the load, or a set of transit time measurements. Such methods would be particularly useful for loads which pass through sonic speeds in their working ranges.

Although I doubt that the accuracy improvement obtained would be significant, I would be inclined to use somewhat more sophisticated formulas and methods for computer calculations. These haven't been worked out in detail because they would be of value to very few, though, judging from some published data I have seen, some bullet and ammunition manufacturers could put them to good use.

Trajectory calculation will be discussed in a forthcoming article in *The Rifle*.

Ralph M. McGehee

OUTSIDE READING:

'Small Arms Of World' Ninth Edition

Small Arms Of The World, W.H.B. Smith and J.E. Smith; The Stackpole Company, Harrisburg, Penn.; $17.95.

The original edition of this volume was compiled by the late Walter Harold Black Smith, eminent military small arms authority, and probably owes its initial success to the great demand that developed for it among military personnel during WWII. Since then, it has been repeatedly updated and the just-released 9th Revised Edition is the most comprehensive ever. For many years now, this volume has been recognized as *the* classic reference on military small arms of the entire world. During the past few years, the task of updating and revising it has been undertaken by Joseph E. Smith (no relation to the original) of the U. S. Army Material Command.

The basic format and content of this book are doubtless well known to most *Rifle* readers. In essence, it amounts to a historical summary of small arms development, followed by detailed information on all current and many obsolete military small arms from pistols up through heavy machine guns, exclusive of aircraft armament.

The 9th Revised Edition contains considerable new material. Significant among this is detailed information on the Belgian FN 5.56mm "CAL" rifle developed to compete with the U. S. M16. In this same category, we find information on the Swiss SIG SG530-1 .223 caliber rifle and the German HK33 designed for the same purpose. Equally interesting is the information on the Beretta M70/.223 Assault rifle. Several recent sub-machine gun developments are covered, including the Japanese Shin Chuo Kogyo and the Polish 9mm M63 machine pistol whose unusually short 13.1-inch length and 3.96 pound weight makes it virtually a one-hand weapon. Another new Polish item of interest is the 9mm (Makarov) M64 pistol which appears to be a reduced-size version of the Soviet PM.

Several interesting Soviet developments are shown, including the PK/PKS series of general purpose machine guns utilizing the old M1891 Rimmed 7.62mm cartridge; and SVD 7.62mm semi-automatic sniper rifle using the same cartridge. The latter item is of particular interest since it appears to be the first self-loading military rifle designed primarily for sniping.

Various other sections have been updated, revised, and corrected as necessary. This includes the addition of new information on Colt, Armalite, and Stoner .223 (5.56mm) rifles and machine guns. In addition, for the first time in its history, the book contains a separate chapter on sporting arms. Because of the limited space available, the type of detailed information given on military weapons is not present. However, most of the major makes and models encountered in the U.S.A. (whether of foreign or domestic manufacture) are covered in sufficient detail for one to make valid comparisons. All categories of sporting arms are included with the exception of single and double-barrel shotguns. Some people might feel that small handguns, particularly two-inch barrel revolvers, are not properly classified as sporting arms, but we disagree.

Generally speaking, this 9th edition of "Small Arms of the World" may be considered the most useful and all-inclusive of the entire series. It contains something for everyone and no student of gun design can consider his library complete without it.