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Precision SHOOTING

a magazine for shooters by shooters

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DENVER RIFLE CLUB TEAM.

WINNER OF THE COORS CHAMPIONSHIP CUP.

HIGH POWER TARGET RIFLE SHOOTING

by

Creighton Audette

From the early 1900's until after WW II, high power, target rifle shooting in the U.S. was confined almost entirely to the use of the model 1903 Springfield, as issued, and to shooting on military targets. After WW II, when high power shooting was resumed, the National Rifle Association broadened the rules to permit the use of bolt action, target rifles, based largely on the specifications of the Winchester, Model 70, target rifle, in .30-06 caliber. The NRA rules adopted the then existing, military targets with a 12", 5 ring for 200 and 300 yards, and a 20", 5 ring at 600 yards. The old, "C" target, with its 36", 5 ring and 20", V ring was continued in use at 1000 yards.

For the high power shooting of this era, the stock, model 70 target rifle, or even a restocked, 1903 Springfield, or a 98 Mauser, rebarreled to .30-06 and equipped with metallic, target sights was quite adequate. Although custom barrels were used to some extent, few, even among the better shots, felt it necessary or economical to invest in a stainless, benchrest grade barrel and then proceed to burn it out with the rapid fire stages of the national match course. Custom stocks tended to follow the M70, Marksman, stock design, rifle weights were restricted to 10½ pounds maximum, and the 200 yard, standing stage was required to be fired in the extended arm position, i.e., hip rest was not permitted.

In the late 1960's, several factors resulted in the redesign of high power rifle targets. Among these was the adoption of the M16 rifle, the decision of the armed services to largely discontinue competitive, high power shooting, reduced military support for the civilian marksmanship program, and the fact that the 5 ring targets did not provide a good basis for competition between top level shooters with good equipment and good ammunition. Matches were often won by a shooter with a possible and a low X count, while other competitors might have 99's with many more X's. A target series with smaller center rings and more closely spaced rings appeared necessary.

In 1967, decimal targets were adopted, with the 200 and 300 yard target having a 7", 10 ring, with a 3", X ring and the 600 yard target having a 12", 10 ring, with a 6", X ring. The sizes of the aiming blacks were increased to provide a better sight picture. A couple years later, the "C" target for 1000 yard shooting was replaced by a decimal target with a 20", 10 ring and a 10", X ring.

Over a period of several years, rules governing the rifles used were changed to eliminate weight restrictions (although the same rifle must be used, over the course, in an aggregate match) and other restrictions were relaxed. The 7.62 NATO caliber was added, with the adoption of the M14, and the rules were later changed to permit the use of any, centerfire caliber. Use of the hip rest position was permitted in the 200 yard, offhand stage, and stocks with deep forends, adjustable butt plates, adjustable cheek pieces, and detachable cheek pieces appeared, along with a few thumbhole stocks. In the last few years, some shooters have built target rifles, with heavy barrels and target stocks, on commercial actions of the M14 type, equipping them with metallic, target sights, and other refinements. On some of these rifles, arrangements permitted turning off the semi-automatic, gas operation of the action, to shoot the 600 yard stage with manual operation of the bolt. In theory, this gives the best of both worlds — semi-automatic operation for the rapid fire stages and manual operation for greater accuracy at the longer, slow fire stage. It remains to be seen, if this is the wave of the future.

The higher accuracy levels demanded by the current, high power, rifle targets have caused the adoption of many of the practices of the benchrest shooters. Top quality, stainless steel barrels are now common on the firing line. Virtually all, high power shooters handload their own ammunition, with the exception of a comparative few shooters from the armed services or reserves. They, and civilians shooting in service rifle matches, where the M1 or M14 rifles must be used, and, where the rules require it, use match quality, military ammunition. Under present, NRA rules, covering the match rifle, a variety of equipment is used. Only one, U.S. manufacturer now offers a high power match rifle and probably 90% of the rifles seen on the line are custom or customized, to some degree. For anyone interested in taking up high power rifle shooting, the quickest way to obtain the most information is to visit a range where a high power match is in progress.

Space here does not permit a discussion of shooting positions, techniques, accessories, or handloading details in this book, covering a wide area of the rifle shooting game. For specialized information on high power rifle shooting, it is recommended that the reader order the manual, "Highpower Match Rifle Shooting", from The National Rifle Association, 1600 Rhode Island Ave., Washington, D.C. 20036. It is our intention, here, to cover only some of the more important and often overlooked aspects of the high power game.

Although the current targets demand a rifle and ammunition of high accuracy, it is, for a number of reasons, impractical and of little benefit for the high power rifle shooter to attempt to refine his rifle and ammunition to obtain the quarter minute, or less, grouping demanded by the benchrester. The national match course includes 200 yards standing, 200 yards rapid fire sitting, 300 yards rapid fire prone, and 600 yards slow fire prone, using metallic sights. Ammunition must be loaded in quantities, prior to the match. A weekend shoot will require from 100 to 200 rounds of ammunition, the nationals, three to four times this amount. The rapid fire stages necessitate full length sizing of cartridge cases for easy, rapid, bolt operation. There is generally some loss of cases in the rapid fire stages. It is much better for the shooter to devote time and ammunition to practicing, rather than to spend a lot of time in handloading and in equipment refinements, to obtain a very high level of accuracy.

For the majority of high power rifle shooters, a rifle-ammunition combination that will generally deliver ten shot groups of about a minute of angle is entirely adequate for high power rifle competition. Shooters in the top, 5% are beginning to look for results closer to the half minuet mark, because it takes a possible with a fairly good X count to win 600 yard matches in good weather and the more accurate rifle-ammunition combination leaves more margin for error in shooting and in judgement of wind and weather conditions. From all the indications, the demand for accuracy will continue to grow. This has been the history of the shooting sports.

PROBABILITY

Whether the shooter is a high master or a marksman, it is of importance that he has an understanding of the performance he may expect of his rifle and ammunition, and that he use that knowledge to center the group on the bull, early in the string and to maintain that group location, during the course of the string. While the following discussion is particularly applicable to long range, slow fire shooting, the basic principles are applicable to the offhand and rapid fire stages at the shorter ranges.

It is typical of most shooters that they think of rifle-ammunition performance in terms of the best groups they have fired. Few shooters fire enough groups, under controlled conditions, of any of the loads they test, to determine what variation in group size they may expect from group to group, in an extended test. In competitive shooting, they also tend to overlook the limitations of their ability to aim with metallic sights, to hold, and to consistently break the shot clean. In consequence, they tend to make full, or nearly full, corrections to bring the next shot or group to center. The net result is often a shot, or group, out in the opposite direction, enlarged groups and lowered scores.

Space here does not permit a lengthy discussion of the subject of probability, as it relates to the sizes of a series of shots or groups, fired under controlled conditions. At the same time, it is necessary to cover the subject in a manner to provide every shooter with some, basic understanding of the subject, sufficient to enable him to get the best possible score out of his rifle-ammunition combination, by knowing what he may expect of it, on the average, and making corresponding sight adjustments.

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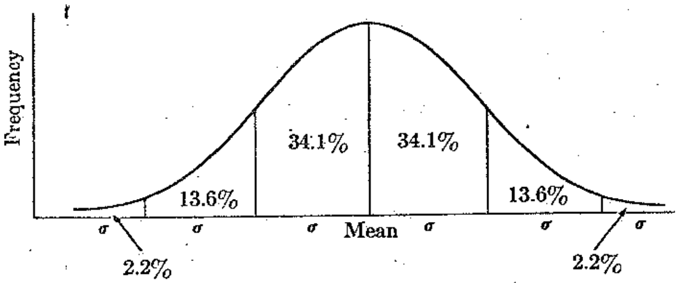

Figure 1. The normal frequency curve.

Figure 1 shows a normal, frequency distribution curve. This curve has been well known to physical scientists since about 1800, because it is obtained from almost all measurements of physical quantities. It is applicable to such diverse subjects as human measurements (i.e., height, weight, weight of brain, length of arms, head size, foot size, bra size, etc.), the weights of apples or other fruits of any one variety, length of ears of corn of any one variety, the dimensions of mass produced items, such as ball bearing races, etc. We are concerned here with its application to the frequency distribution of rifle bullet impacts, measured from the mean point of impact, or the frequency size distribution of a number of groups of the same number of shots. As shown by the curve, the measurements cluster about one central value, the mean, just as the shots of a good rifleman will cluster about the center of the ball.

The symbol at the bottom, which looks like the letter Q, with the tail displaced, is the Greek letter s, or sigma. In this chart, it represents standard deviation. Standard deviation is the most useful measure of dispersion, or distribution. It is the population distribution of a range of physical measurements from the mean. While its computation is not difficult, using the small, electronic calculators now commonly available, the written explanation is somewhat involved and will be skipped here. For our purposes in rifle shooting, it may be simply defined as a standard, taking into account the mathematical relationship of the points of impact of all the shots fired, to the mean point of impact of all those shots. The curve shown is reasonably representative of the performance of a good, .30 caliber, match rifle, fired for a very large number of shots under controlled conditions.

The vertical lines are one standard deviation apart and the area in each of the resulting sections under the curve represent, for the rifleman, the number of shots which will fall within that distance from the mean point of impact. Or, if a very large number of groups were fired and the frequency distribution of the sizes of these groups plotted, a similar curve would result. There would be a large number of groups of sizes close to the mean, a small number of very small groups, a small number of very large groups, etc. The "tail" to the left could represent small groups, that to the right large groups. Note that the "tails" do not come down to meet the bottom line. Theory says that the smallest possible group would be one hole, of bullet size, having a 0 center to center measurement and that the largest possible group is infinity. These remote probabilities encompass something like 0.1% of the total, but the chance does exist.

The dimensions of the curve for a benchrest rifle and for the average hunting rifle would be different, but the general shape of the curve would be the same. Standard deviation is a reliable measure of precision and the benchrest rifle would produce more groups near the mean and fewer small and large groups, than the hunting rifle. The curve for the benchrest rifle would thus be narrower and taller.

With this background to give some feel for normal dispersion, let us look at the probabilities of what one may expect from a .30 caliber, match rifle. If a large number of groups, fired under controlled conditions, resulted in a mean (average) group size of 1 minute of angle, only about 50% of all groups will be a minute of angle or smaller. Only about 10% will be smaller than .7 moa and about 10% will be 1.5 moa and larger. About two-thirds of all the groups will run between .5 and 1.4 moa. Except for the vary occasional, freak, small or large groups, about 98% of all groups will run between .5 and 1.9 moa. The term controlled conditions means that all sources of error except those of the rifle and ammunition are eliminated.

The same, basic, distribution or dispersion pattern will occur in individual groups, except that the groups tend to increase in size with the number of shots fired. If 10 shot groups average 1 moa, 3

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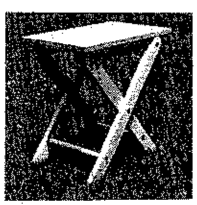

shot groups will probably average .65 moa, 5 shot groups .81 moa and 20 shot groups 1.17 moa. The shooter who tests his long range loads in 5 shot groups, then extrapolates directly and assumes proportional performance in the 20 shot group required by the match is simply fooling himself.

The point of impact of any bullet is random, within the probability factor. The spread of any one group is also random, within group size probability. Although groups, particularly of the larger numbers of shots tend to be round, they may be vertical, horizontal, or diagonal. The location of successive groups is random, within the spread which is probable for a large number of groups. It is important to remember this in establishing rapid fire zeros.

It takes only a bit of reflection on the above to conclude that the high power shooter, who has just fired a shot that struck the 10 line at 3:00, after firing several shots, grouped well inside the X ring, with no apparent change in conditions, should take time to consider the probabilities of the 3:00 shot simply being a normal, wide shot in the group. If he does decide to put on left wind, the probabilities are that a half correction is much better than a full correction. The same philosophy applies to the benchrest shooter, although to a lesser degree, because of the difference in shooting conditions.

The lower the standard of accuracy of the rifle-ammunition combination, the more important it is to center the group early, and to keep it centered. Our cousins from the British Commonwealth nations have developed an admirable system for doing this. Their high power rifle shooting is done with selected lots of military, ball ammunition. The accuracy standard is low and it is much more sensitive to wind than that normally used by our shooters. In general, the acceptance standard of the 7.62 NATO ammunition is something like 7.5″ mean radius, from machine rest, at 600 yards. The selected lots used for target shooting are likely to have a mean radius of about 3″ to 3.5″, corresponding to an **average** extreme spread of something like 10″ to 12″ at 600 yards. This is just a bit smaller than the center ring of the target, counting 5 points. Possible scores are not common. Occasional threes result from the wider shots within groups of normal probability. Centering the group early and keeping it centered is most important. The problems of the British Commonwealth shooter are compounded by their custom of shooting in pairs or threes, alternating shots and scoring for each other. The benchrester can "machinegun" his shots down range, more or less, to minimize variations in conditions. With good pit service, U.S. high power shooters tend to shoot shots in rapid succession, for the same reason. The B.C. shooter has to do a lot more doping of changes in conditions, but he does have the advantage of a greater amount of time for keeping a more complete scorebook.

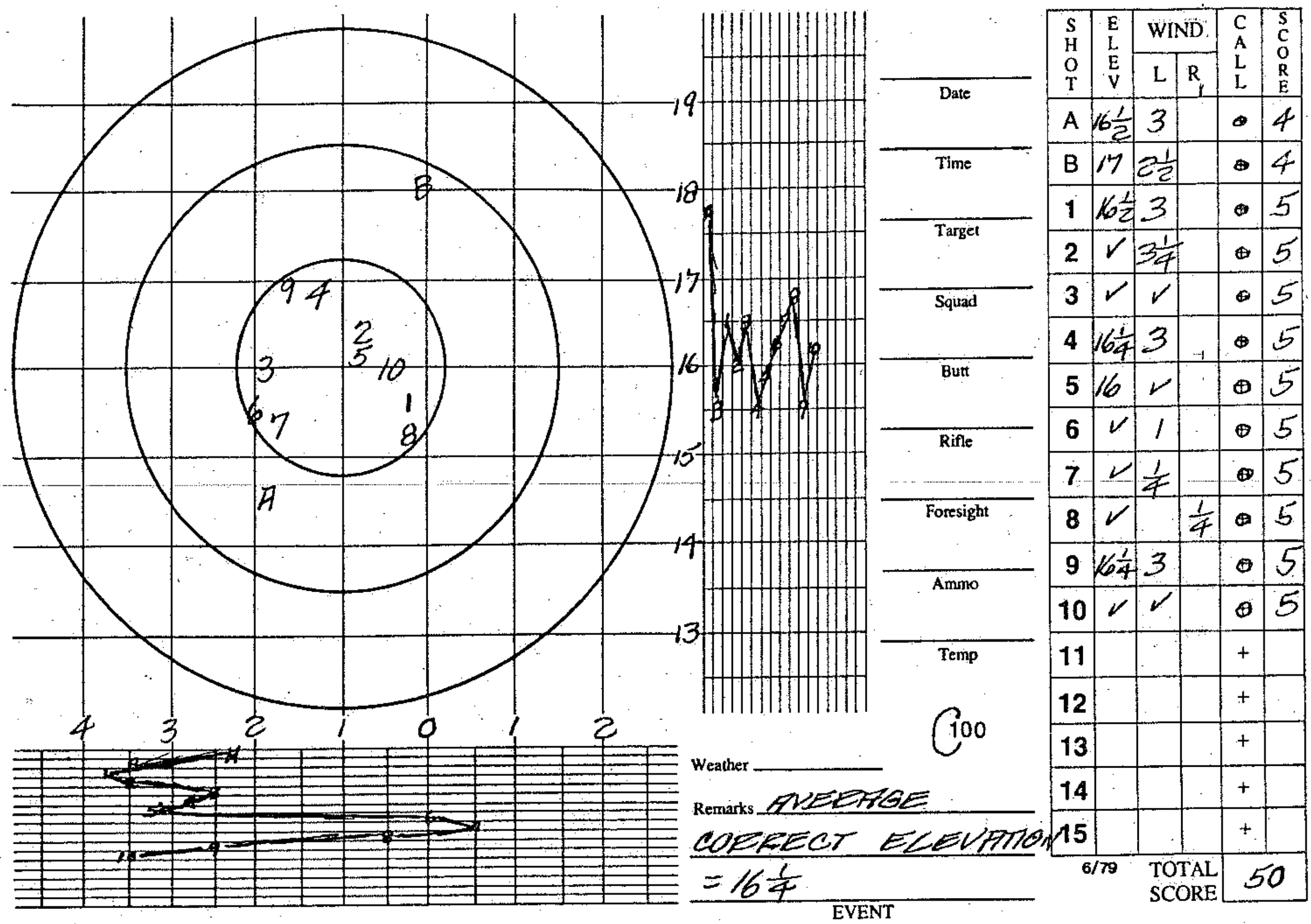

Figure 2.

Figure 2 is a completed, 600 yard, score sheet, typical of those kept by the better, B.C. shooter. A and B were the sighting shots, the numbered shots the ten fired for record. A complete explanation of this sheet, including the shooter's assessment of wind changes, his reasoning for the amount of sight changes he made, shot to shot, etc., would require about three pages. It is a good, mental exercise for the experienced shooter to analyze the sheet, shot by shot and change by change.

The important thing about this score sheet is the graphs, one for wind and one for elevation, and how they are used. The grid on the targets is in minutes. Before starting to shoot, the graphs are numbered in minutes, for recording sight settings. The elevation graph is numbered to provide several minutes above and below the normal elevation for the range being fired. The windage graph is numbered to provide a range judged sufficient for the range and wind conditions then prevailing. As each shot is fired and scored, the score sheet is filled out in the columns on the right with the usual record of sight settings for windage and elevation, call of shot and value of shot.

The windage and elevation graphs are filled in with letters or numbers, as the sequence of shots is fired and these are connected by lines. **The location of each shot on the graphs is the sight setting which would have resulted in a center shot.** This is assuming no shots were called out. While it is obvious that wind changes and decisions of the shooter to alter sight settings enter in, let us assume, for purposes of explanation, that conditions are

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HIGH POWER TARGET RIFLE SHOOTING

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constant and the shooter makes no sight changes. The shot locations and the lines on the graphs would then wander about the graph lines designating the **correct** sight settings in both windage and elevation and these correct sight settings would conform to the laws of probability, increasingly with the number of shots fired.

Wind velocities and directions, for a specific location, day and period of time, also tend to follow the general laws of probability. Shooters unconsciously recognize this in watching the wind prior to shooting and during the preparation period, when they try to determine the prevailing wind conditions. With a little consideration of wind and weather conditions during the string of shots, the graph system includes a factor for the prevailing wind and weather conditions, more or less automatically.

What the better, B.C. shooter is doing, with the graphs, is to make the best estimates he can, of necessary sight changes, based on the laws of probability. His rifle-ammunition combination, even with good holding, can only be **depended on** to stay in the 5 ring for about two-thirds of a large number of shots, although he may draw 10 rounds, or a larger number of rounds, which, fired in sequence, will easily stay in the 5 ring, simply by luck. He has to bear in mind that one or two shots out of 10 will probably be 4's and about one or two shots in 20 or 30 may be a 3. Winners of aggregate matches under these conditions are those that work with the probabilities and they are, almost invariably, the shooters who plot the graph sections on their score sheets. Used in conjunction with some judgement concerning the sight changes which have been made in response to changes in conditions, the graphs inform the shooter of the optimum sight settings to center that over-large group on the bull, obtain the maximum number of bullet impacts in the scoring ring of highest value, and the minimum number of bullet impacts in scoring rings of lesser value.

Comparatively few U.S. high power rifle shooters keep score books. To develop the same information from our scorebooks as provided by the graphs requires a comparison of bullet impacts on the target diagram with sight settings in the record columns, etc. Often, the shooter does not feel he can take the time to do this to go back over the last two or three shots, and it is obviously impossible to keep track of these comparisons for all the shots of a string, as the graphs do. Most U.S. shooters will claim that they cannot take time to make out the graphs. B.C. shooters, who are accustomed to the process will complete scorebook entries for a shot in about 15 seconds, which is often just about the time that the target remains in the pits, between shots.

In any event, the important thing is the principle involved. Whether the shooter is a high power shooter, firing alone, rapidly, or a benchrester, machinegunning them down range, the principle is the same. **Bet on the probabilities and make sight adjustments accordingly.**

WIND

Here are the basic rules for wind doping.

1. Even if you have a shot which is out of what you would consider your normal group, as the group builds up on the target, it is usually inadvisable to make a correction, and dead wrong to make a full correction, unless you can see evidence of a change in conditions. Turning the sight knobs is certain to move the center of impact of your normal group, if you are using a sight suitable for match use. You may find the succeeding shot far out on the other side of the bull. Many a long range match has been won by a shooter who simply got well centered, shot pretty much under prevailing wind conditions, and simply held them center and broke the shots clean. "Chasing the spotter" is sometimes a useful technique for the proficient rifleman, shooting rapidly, who adds or takes off a click or two as the group builds up and conditions changed slightly. For the neophyte, chasing the spotter is usually productive of enlarged groups and low scores.
2. The wind charts found in scorebooks are quite reliable (assuming reasonably similar ammunition characteristics) for open ranges, such as those at Camp Perry, Ohio, Connaught Ranges, Ottawa, Canada, and a few others. Many of the high power ranges are more or less pro-

tected by trees, earth contours, etc., and wind effects are altered accordingly. Familiarity with the range and its wind characteristics gives the experienced shooter an advantage. A notebook, with notes on wind effects and peculiarities of each of the ranges you shoot on is highly useful, particularly if you do not keep a scorebook, complete with such notes. There is a thousand yard range in the east where the firing line is on a hill, with the ground sloping off in front and the targets perhaps 75 to 100 feet below the level of the firing line. The terrain and soil conditions are such that mirage readings in the spotting scope tend to pick up mirage conditions near the target, in the last third of the range. There are small trees and brush along the sides of the range, near the firing line and these are much more reliable indicators of wind conditions, usually, than the mirage. Not only do they give wind conditions near the line, which is important for reasons mentioned below, but they are more nearly in line with the path of the bullet, which is high over the ground, over much of the range.

3. It has been said and printed many times, but it bears repeating:

For winds coming from the 3:00 or 9:00 quarters, watch for changes in the strength of the wind.

For winds coming from the 6:00 and 12:00 quarters, watch for changes in the angle of the wind.

Winds from 6:00 and 12:00 have almost no effect on the point of impact of the bullet, with modern rifles and bullets. A 10 mile an hour wind has a velocity of about 15 feet per second. This is insignificant compared with high power rifle bullet velocities and the normal velocity spread in a 10 or 20 shot string. On some ranges, head or tail winds may result in up or down drafts as the wind passes over raised points between the shooter and the target or other features of the surrounding terrain.

4. Assuming an open range and reasonably uniform wind condition over the range, the wind near the firing line has the most effect on the flight of the bullet. This is because the bullet acts as a gyroscope, turns to point into the direction of least resistance, and assumes a flight path at an angle to the line of the rifle bore, under the influence of a side wind. If there was a side wind for some distance ahead of the firing line, say 25% of the range, and a dead calm existed from there to the target, the bullet would continue to move in the downwind direction from the point in space at which it entered the calm air and it would impact on the target substantially farther in the downwind direction. With a uniform wind, over the full range, some authorities claim that ½ to ⅔ of the total wind drift is caused by the wind in the first 25% of the range.

5. Mirage is most useful as an indicator for light and rapidly shifting winds. As the wind velocity moves above approximately 12 miles per hour, changes in wind velocity do not change the appearance of the mirage. What mirage is and how it is used by the shooter will be covered later.

6. What the shooter sees as mirage is dependent to a considerable degree on vegetation, soil and moisture conditions. Ranges with a patchwork of sandy soil and vegetation, or those with swampy areas of puddles of water will produce mirage readings quite different from a range covered with vegetation, under the same conditions of wind and sun.

7. Make a habit of reading the mirage at the same distance from the firing line. For 600 yards, focus on something at the 300 yard firing line. You will then be reading the mirage at the near end of the range. Changing the focus of the spotting scope increases or decreases the apparent strength of the mirage and unless you read it consistently at the same distance, you are likely to misjudge its strength.

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8. Where it is possible, experienced shooters take advantage of all available wind indicators and combine the knowledge obtained from flags, trees, brush, grass, the feel of the wind on face and hands, with the appearance of mirage. The need is for a leading indicator, which will inform the shooter of wind shifts before those shifts actually reach the path of the bullet. It takes a minimum of 3 to 4 seconds from the time the shooter last views the wind conditions until the shot is fired and it may take 10 or 12 seconds. In a shifting wind, it is easy to lose points from a wind change in that interval. Look for an upwind indicator, keeping in mind the path of the bullet and its height above the ground. It is common for shooters to watch the warning flags at the ends of the target butts, the flag over the clubhouse, or something readily apparent and being moved by the wind. Quite often, those things are of little use as wind indicators. The shooter wants a leading indicator in that area of the range where the wind is likely to affect the flight of the bullet the most.

MIRAGE

From the scientific viewpoint, there are many misconceptions among shooters as to what causes mirage and just how it affects the shooter's aiming process. Most of the descriptions and explanations in books on shooting are either incorrect or incomplete. It is commonly written and believed that mirage displaces the target image, upward in the case of the rising mirage that shooters refer to as a "boil", and downwind, when there is a side wind.

Most of us know, from our high school physics courses, that the speed of light in air is about 186,000 miles per **second**. At that speed, it is quite evident that any air movement caused by wind simply cannot result in bending the path of light between the shooter and the target, or moving the path of light sideways.

Light waves are bent by refraction, when they move from a medium of one density into a medium of a different density. All of us are familiar with the "bent" appearance of a stick, when part of it is immersed in water, so, for our purposes here, we will simply accept that it does happen, rather than going into an explanation of why and how it happens. The amount of the refraction is the result of the change in density (air is 186,000 mps and water 140,000 mps) and the angle of the density change interface, relative to the path of the light waves.

Light waves also bend in passing from a body of air of one density into a body of air of another density. It is commonly said that this is caused by heat and it is true that changes in air density caused by the sun's heat are those of most importance to the rifleman. We should be aware, however, that anything which causes a change in the air density will produce the same result. Changes in humidity cause changes in air density and light waves bend in passing the boundaries between different layers or areas of humidity in the air. Cold can cause a change in air density. Most of us have seen spark photographs of bullets in flight, which show the sound wave streaming out from the point of the bullet and the vortex, caused by the partial vacuum at the base. These are visible in the photograph simply as a result of the refraction of light waves due to the change in air density resulting from compression or expansion of these sections of the air mass, relative to surrounding sections.

Air itself, is warmed very little by the passage of the sun's rays. The earth is warmed by the sun's rays and, in turn, gives off this heat, or some of it, to the air which is in contact with the earth. Reduced in density, this heated air rises, displacing cool air above it, which sinks. The rising air cools off as it rises, again changing in density. The rate at which the earth takes on and gives off heat from the sun varies with the type of soil, amount of vegetation, moisture, color, etc. The range between the rifleman and the target is a patchwork of areas of an infinite variety of sizes and three-dimensional shapes, taking on and giving off heat at different rates. Every time a light wave from the target to the rifleman passes a change in density, it is refracted. The amount and direction of refraction depend on the change in density and the angle of the density interface, relative to the light path. The density varies in all directions, vertically as well as horizontally, caused by differences in temperature and humidity. The result is what is commonly called "heat shimmer". Astronomers and surveyors refer to it as "scintillation". It causes the twinkling of the stars and makes observations and photographs difficult for astronomers. The normal, gradual, temperature gradient and change of air density from the earth into space results in gradual bending of light rays, and we "see" the sun for some minutes after it has actually disappeared below the horizon.

In reality, the scintillation effect simply causes the target image to shimmer about its true location. All of the myriad, different volumes and shapes, of air of different densities, drifting along, with the wind, result, through light refraction, in the wave motion, seen through the spotting scope. The velocity of the wind immediately at the earth's surface is very low, but increases rapidly with increasing distance from the earth. It is likely that this plays a part in forming the wave pattern, typical of mirage. When the spotting scope is focussed directly on the target face, only the mirage produced in air near the target face is visible. Focussing at some point between the shooter and the target permits a much greater depth of mirage to be seen and it shows the wind drift nearer to the firing line. The wave motion, seen through the scope, is an indicator of wind speed, the waves appearing to flatten out with increasing speed, up to about 12 miles per hour, as stated previously.

There are a number of accounts in shooting literature of experimenters who have set up telescopes in stable mountings in the cool of the first light of morning, set the cross hairs on some stationary object, and they claim that the object moves, relative to the cross hairs, with the heat of the day and the development of mirage. Others performing the same test report that the object may appear distorted and that it shimmers, but deny that the movement is related to wind drift or that there is any drift in the apparent position of the object, related to mirage movement. The object simply shimmers about an average of its position. This is a difficult test to set up and to control, with exactitude. Probably those best qualified are professional surveyors. They state, unequivocally, that the object simply quivers about its true location and they make no allowance for the effects of mirage. For higher accuracy, surveyors work at times when there is a minimum mirage effect, they repeat measurements so as to obtain an average which will be more accurate and they use a technique known as doubling the angle, which involves rotating the surveying instrument 180 degrees, sighting on objects 180 degrees apart, making a series of measurements and averaging.

When there is little or no wind, the appearance of the mirage is an upward, wavy movement, a bit like boiling water. The rising and descending volumes of heated air cause refraction mostly in the vertical plane. Direct, head and tail winds produce the same effect. One way to tell true wind direction when the mirage is running is to turn the spotting scope, adjusted for mirage, into the wind until the mirage looks as though it is boiling. The scope is then pointed directly into the wind. It is likely that the high shots which sometimes result from firing in a "boil" are the results of updrafts, over irregular range terrain. They may also be the high shots which will occur now and then as a normal probability. The fact that they chance to occur coincident with a boil leads the shooter to conclude that they are caused by the boil.

CARTRIDGE CASES

Benchrest shooters and others interested in precision shooting have known for many years that the concentricity of the neck of the cartridge case had an effect on accuracy, as does the concentricity of the bullet with the loaded round. Both of these affect the entrance of the bullet into the throat, its alignment, and the amount of distortion the bullet receives in passing through the throat and into the rifling. Any distortion tends to upset the balance of the bullet and the relationship of the center of gravity to the center of form, with a consequent loss in accuracy.

Benchrest shooters have also known for a long time that there were variations in cartridge cases which affect accuracy. Cases were weighed, flash holes measured and deburred, and, in the final measure, shooters selected the better cases by the slow, cumbersome, and expensive method of testing by shooting and weeding out the cases that produced shots which the shooter felt were out of the normal group. (A little study of probability indicates that doing case selection by this method is far from an easy task! It also indicates that the effects of case errors must be substantial, if it is possible to se-

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lect the good cases by this method, because it depends on orientation in the chamber, as will be described.)

Except for long range loads, the high power shooter, in general, has done little in the way of case selection. Ammunition for the offhand and rapid stages is generally loaded with empty, military, match cases, picked up at ranges or bought, once fired, at low cost. Long range loads are likely to be loaded into new, commercial cases, then these kept segregated and used only for long range shooting. The quantity of cases needed for a summer of shooting precludes doing a great deal of work on case selection, considering the grouping potential really necessary, as described earlier.

Careful tests of cartridge case errors and an analysis of the dynamics of the rifle barrel, bolt and receiver have resulted in tools and methods of selecting the best cartridge cases by measurement, prior to firing, or cases in use can be graded.

It has been discovered that the radial uniformity of the thickness of the case body wall and the squareness of the case head both have a definite and substantial effect on accuracy. For a long time, the better gunsmiths have known that it was necessary to pay attention to certain details of the barrel, receiver, and bolt, in barreling a rifle, in order to obtain good accuracy. The receiver threads have to be in line with the bolt axis, receiver and barrel shoulders square to threads, bolt lugs lapped in for maximum and equal contact of both lugs with receiver shoulders, and the bolt face square to the axis of bolt and barrel. It is somewhat surprising that, in doing this, little or no attention has been paid to the cartridge case, which is supported by these same parts, so carefully fitted and aligned!

It is quite well understood by shooters who have done a considerable amount of reading in firearms literature that rifle barrels whip and vibrate, while the bullet is moving down the bore and that these barrel movements have an appreciable effect on the point of impact of the bullet. In fact, exacting tests have clearly shown that these barrel movements actually start with the fall of the firing pin. If the impulse of the firing pin, weighing a few ounces, propelled by a spring load of something in the range of 20 to 30 pounds can set up movements in a heavy, rifle barrel, it is quite evident that some 40,000 to 50,000 pounds of gas pressure, created in about .0002 of a second, and thrusting the cartridge case back against the bolt face must do so to a much greater degree.

All of the materials familiar to us on earth are elastic, in varying degrees, most of them a great deal more than our senses enable us to realize, and this includes the steel of the barrel, bolt, and receiver. Moreover, the bolt and receiver have to be designed to permit opening and closing, with a rotation of 90 degrees or less; openings are cut into the receiver for magazine feeding, for loading, and for ejection, and the remaining metal of the receiver is not distributed symmetrically about the bolt axis; and the conventional, 98 Mauser type action in common use has only two, rather narrow, locking lugs, which are in the vertical plane when the bolt is locked and ready to fire. Since all of the parts which support the back thrust of the cartridge case during firing are of elastic materials, and since the support of these parts is not symmetrical about the axis of the bolt and receiver, it follows that the backthrust must produce a lateral whip of the barrel, during firing, while the bullet is still in the bore. The direction of this lateral whip and the amount and angular location of barrel movement, as the bullet exits from the muzzle will affect the path taken by the bullet in flight. It also follows that any variation in the location of the backthrust force of the case head on the bolt face must change the lateral whip, in amount, and direction, or both. Remember your high school physics, where you learned that force diagrams were solved by finding the point at which the force was applied?

If the wall of the case body is not of uniform, radial thickness, it is evident that the thin side of the case will stretch more than the thick side, as gas pressure rises above the elastic limit of the brass, and that this will result in a greater movement of the case head, in line with the thin side of the case wall. If the case head were square, prior to firing, it would go out of square, resulting in impact of the case head at some point on the bolt face other than the axis of the bolt. The resultant, elastic movement of the bolt and receiver will be different than that which results from a similar impact on the centerline of the bolt, the lateral whip of the barrel will be different, and the direction in which the barrel, at the muzzle, is actually pointing during bullet exit will be different. The net result is a difference in the location of the bullet impact on the target. From testing cases with different wall errors, with these wall errors oriented, radially, to different quarters in the chamber, it is possible to predict the direction in which the bullet impact will occur and the amount by which these errors will cause the bullet to land outside the normal group, fired with cases having walls of uniform, radial thickness.

If the off-axis impact of the case head on the bolt face is in the vertical plane, more or less in line with one of the locking lugs, the effect on lateral whip is minimal, because of the direct support of the lugs. If the impact is at 3:00 or 9:00, it is in an area which is not directly supported by the locking lugs and the result is a horizontal whip of the barrel and resulting, horizontal enlargement of the group. The amount of side whip and the resulting group enlargement is directly proportional to the case wall error and is influenced by other factors, including the power gas pressure, diameter of the case body, fit of case, length of case body, stiffness of the barrel, etc. With reduced loads, or loads for lead bullets, the gas pressures developed may not be sufficient to make the case head impact on the bolt face; because, as the gas pressure expands the thinner, forward end of the case, this section expands to grip the chamber walls, and the case itself is strong enough to hold the gas pressure exerted against the inside of the head. Users of reduced loads are familiar with the fact that fired primers often stand several thousandths above the case head and that this distance will sometimes increase, with repeated loading and firing of the case. It is clear that under these conditions, the case head does not impact the bolt face. Only the primer does, as it backs out of the case under gas pressure and the impact of the primer is on the bolt axis.

Case heads tend to square up against the bolt face with repeated firing, in a properly made rifle. It has been argued that neck sizing and repeated firing eliminates or reduces the effects of case wall errors. It may reduce them to some degree, but both theory and tests show that neck sizing does not eliminate them. All of the metal parts of the action are elastic materials. The brass of the cartridge case is also elastic. Therefore, the off-axis impact on the bolt face will still occur, if the case wall is not uniform. Cases wear out in repeated loadings, either as a result of splitting of the neck due to working of the brass or partial or complete separation of

Continued on next page

the case body, a short distance ahead of the solid section of the head. With full loads, there is a tendency for the case to separate at this point, because the thin front section grips the chamber walls under initial gas pressure, while peak gas pressure forces the head of the case back against the bolt face. The process starts with the first firing, which thins the case body wall slightly, producing an annulus, a narrow ring, at this point. Since this is now a weak area, thinning continues at each shot, with the thinning being greater on the thin side of the case wall. Cases with non-uniform, radial, wall thickness will tend to produce poorer groups, with continued loading and firing.

Cases with body walls of uniform, radial, body wall thickness, but without square heads will produce the same effects as those with non-uniform body walls, for obvious reasons. The best method of obtaining cartridge cases to get the best accuracy out of a rifle is to select cases for uniform wall thickness, fire them in practice with a full load and then reload them for match use. If it is necessary to use new cases in an important, long range match, select them for wall thickness uniformity, then check head squareness, mark the high point of the head, and load the round into the rifle chamber with this high point aligned consistently with one of the locking lugs. Careful and extended tests have shown that it is possible to find the effects of case wall errors, in a good, .308 Winchester caliber, match rifle, when the radial, wall thickness variation is as little as .002″. It is not uncommon to find cases with walls that vary .005″ to .006″ and they may vary as much as .012″ to .014″. The resulting error can add as much as two minutes to the group size, depending on the radial orientation of the case in the chamber, prior to firing. It is possible to find the effects of case head squareness errors when they get above .001″.

A gage has been developed which will measure case body wall variation, neck thickness variation, and head squareness. It can also be adapted to measure the concentricity of the bullet with the case in the loaded round, and the uniformity of the distance from the point on the bullet ogive where it touches the rifling to the case head, round to round. The high power rifleman can now select cases for better accuracy, easily and quickly. The gage is available from the author of this chapter. The photos show the gage set up for simultaneous measurement of the neck and body and for measurement of head squareness. Loaded round concentricity and ogive to head measurements are done in that part of the gage used to check head squareness, by the use of simple adapters and adjustment of the indicator.

Earlier, in this chapter, it was stated that the minute of angle rifle (to use a general term and forget probability, for the moment) was entirely adequate for the majority of high power, competitive shooters. It was also stated that the top shooters, the 5% who really stand a chance of winning a big regional or the nationals, were now looking for rifle-ammunition combinations capable of close to the half minute mark. Selection of cartridge cases can make that difference.

Creighton Audette

All of the groups shown, in fact all of the groups fired in making tests of cartridge case errors, were fired at 300 yards, prone, double sandbag rest, using a 20X telescope. Bullets, powder, and primers were from the same lots. Cartridge cases were all 7.62, Lake City match, '64. The same load, seating depth, etc. was used in all tests shown. The only differences were in the selection of cases and the orientation of the cases in the chamber. These are representative groups. Over 400 shots were fired in testing cartridge case errors, to provide statistical reliability.

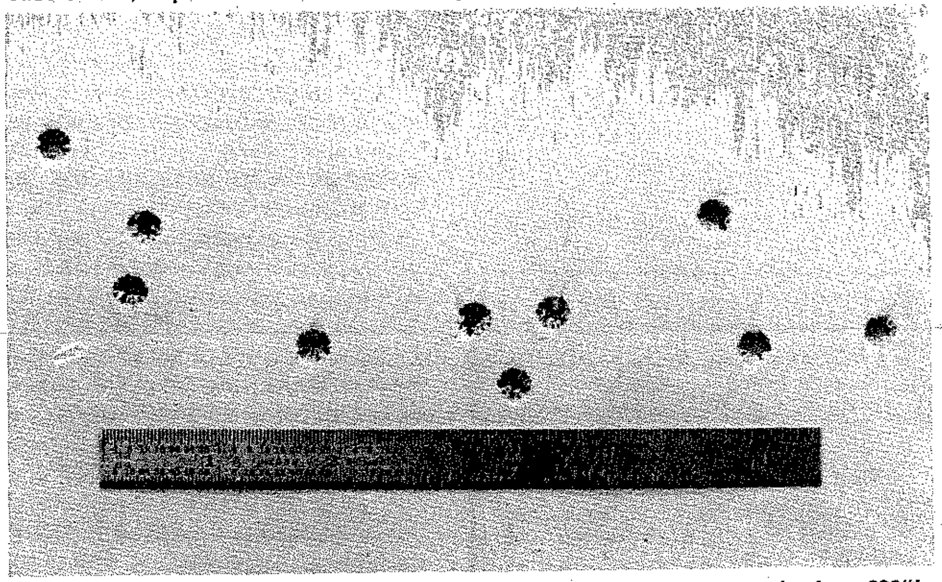

PHOTO #1. Cases were selected with the error in the radial wall thickness varying from .002" in the best cases to .012" in the worst. Cartridges were oriented in the chamber with the thin side of the cases alternately at 3:00 and 9:00. The bullet impacts vary horizontally in direct proportion to the error in the case body wall.

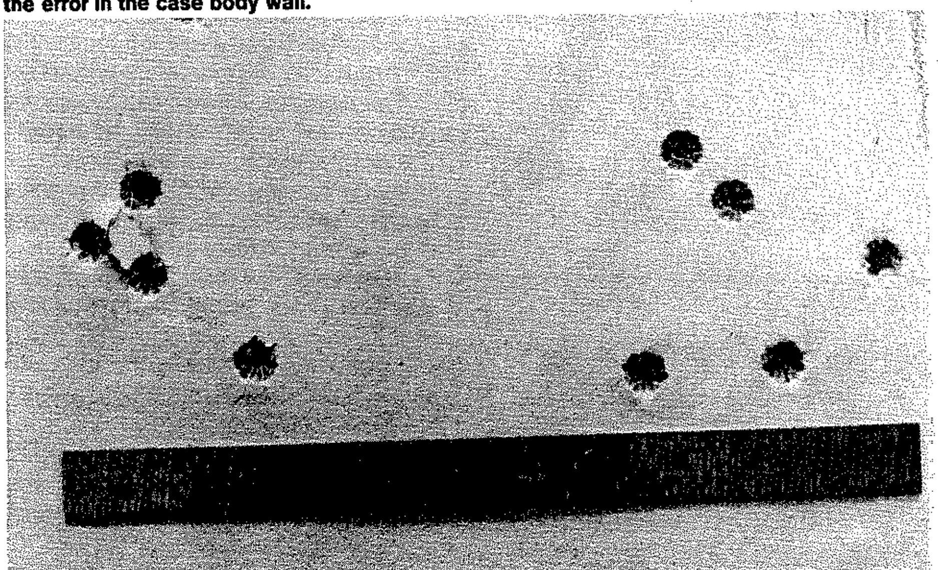

PHOTO #2. Fired with cases selected to have the same amount of wall thickness error, and oriented in the chamber with the thin side of the cases alternately at 3:00 and 9:00.

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HIGH POWER TARGET RIFLE SHOOTING

Continued

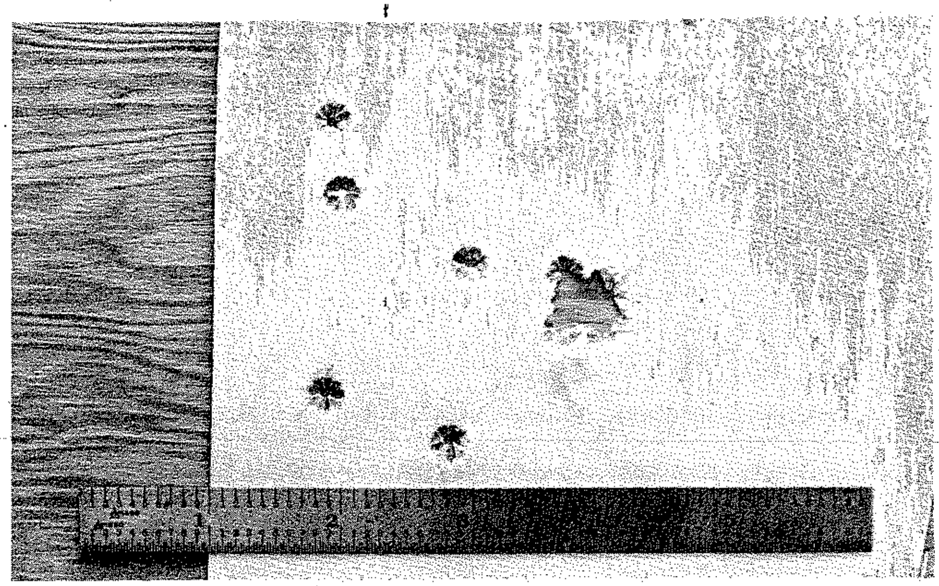

PHOTO #3. Fired with cases having varying amounts of wall thickness error, similar to photo #1, but with the thin side of the case walls all aligned at 12:00 in the chamber, in line with the upper, bolt, locking lug.

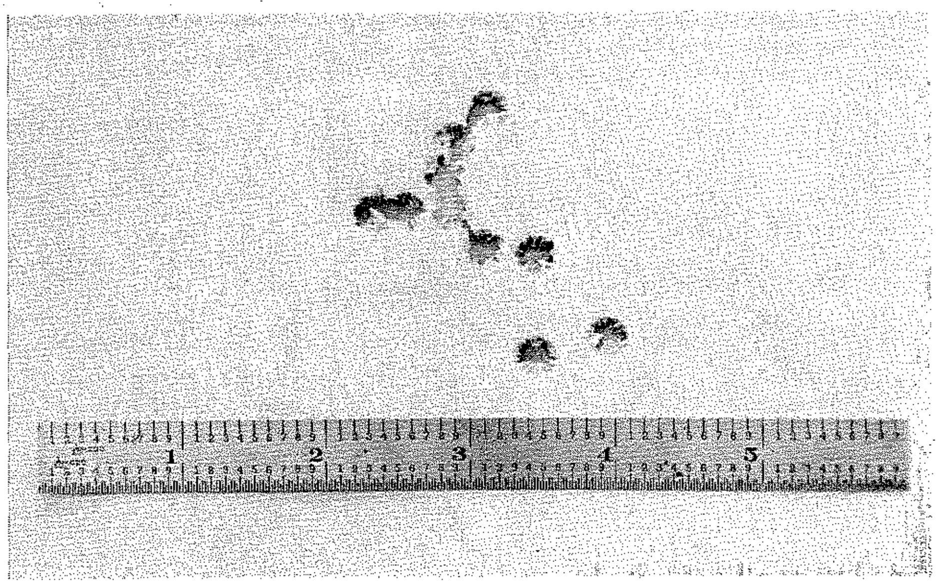

PHOTO #4. Fired with cases selected for wall thickness. Case walls were uniform within .002″ and the cartridges were loaded in the chamber at random.

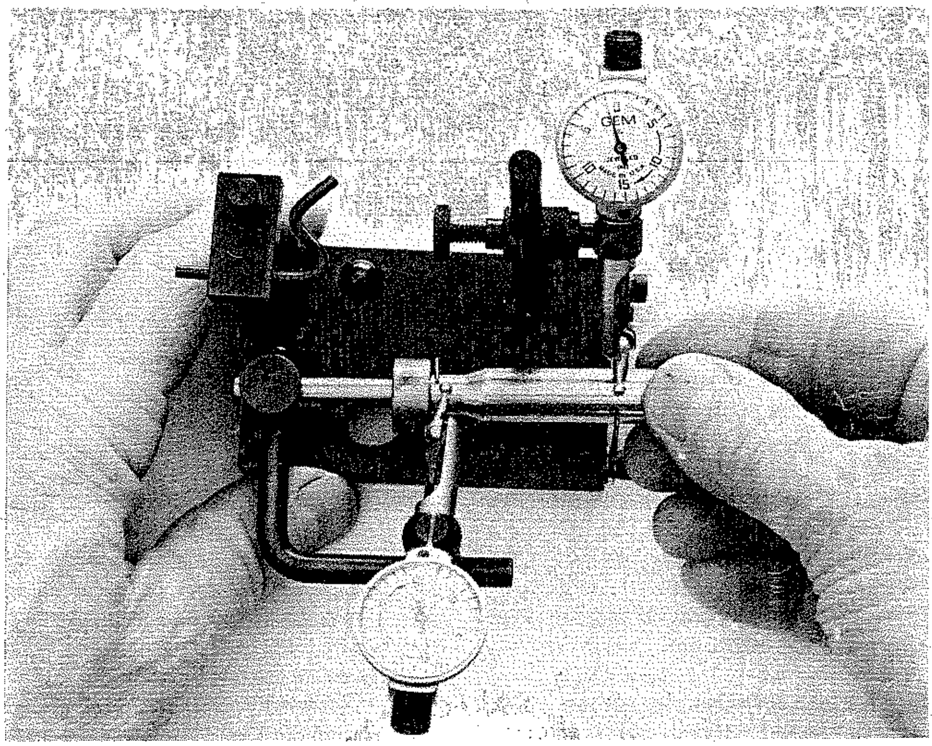

PHOTO #5. **Measuring both the neck wall thickness variation and the body wall thickness variation on 7.62 cases, at one handling of the case. With the .30 caliber parts, the gage will measure cases from something smaller than the .30-30 up through the .30 magnums, by simple adjustments. The gage is changed over to other calibers by changing the horizontal support assembly and the ball support, then readjusting for the size case being measured.**

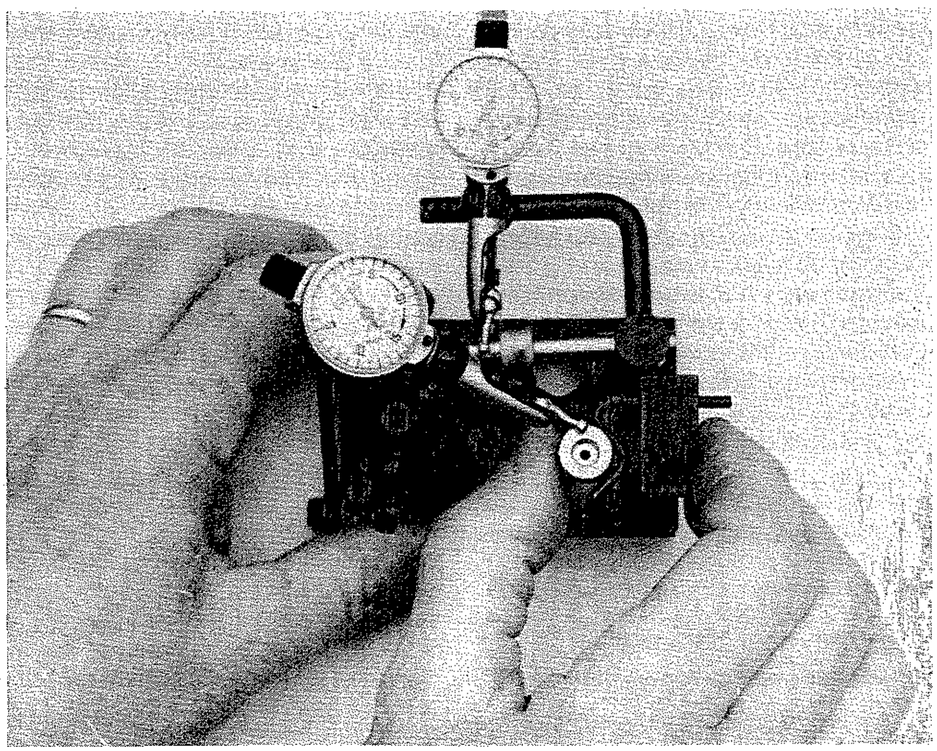

PHOTO #6. **Shows the head squareness measurement, with the case neck supported on a hardened steel ball.**

RECENTLY OVERHEARD

The NBRSA Nationals ended on Saturday afternoon, August 2nd. This phone discussion, with Red Cornelison calling me at my office, took place on Tuesday afternoon, August 5th.

"Red, how are you? What's up?"

"Well, if you answered the phone, I guess that you're still alive. Get home all right?"

"It's an eleven hour drive for me, Red. I got in around noon on Sunday, and slept like a log for ten hours Sunday night. Man, I was tired! How about you?"

"Oklahoma is a bit further away. I finally got in at 3:00 am Monday morning, after what seemed like forever on the road. When I collapsed into bed, about 4:00 am, I was so tired that frankly I never wanted to see another benchrest rifle, another benchrest shooter, or another benchrest range for as long as I lived. Even now, 36 hours later, I feel like I've been run over by a truck, and I'm still exhausted".

"I know how you feel, buddy; I'm still wiped out myself. Okay, what are you calling me for?"

"Hey, give me the name of a good motel for the IBS Nationals, will you please".

— End —

CREIGHTON AUDETTE

(Editor's introduction. Recently one of our readers wrote to me. Essentially the gentleman related that he was doing a lot of match shooting with the .308 cartridge. He was frequently at gun shows where U.S. military "match brass" was for sale, and he wanted to know which were "the good years" that he should be on the look out for. Not having the foggiest idea how to respond, I bundled the letter off to Creighton Audette, and asked him to do the honors. A copy of Creighton's response letter is herewith).

Dear Mr. Cleveland:

Your letter to Dave Brennan was forwarded ot me, since I am probably more familiar with .308 match cases than most benchrest shooters.

You use the term, ".308 US match cases". I assume that you refer to the 7.62 NATO cases made at Lake City on which the headstamp includes the letters LC. There is a great deal of misunderstanding of what these cases really are. I have a copy of the drawing for the case and it is the same drawing to which the cases used for the regular, military, ball ammunition are manufactured. The "MATCH" in the headstamp does not refer to cases manufactured to special, match dimensions. It is there to identify the loaded round. Further, unless the cases were segregated at the time of firing, there is no way of telling what lot they came from, since they bear only two numerals signifying the year the case was manufactured.

These cases are not of match quality, although many shooters believe they are. I have inspected many hundreds of them, to select the better cases which I use only at 200 yards, offhand, and rapid fire, in highpower shooting. In some lots, I reject probably 2/3 of these cases for excessive variation in wall thickness.

There are, or have been, many other types of 7.62 target ammunition, made for the military. In 1958, Western loaded thousands of rounds of special, match ammunition, with a 200 grain, boattail bullet. The cases are probably the best, 7.62 cases that have ever been made. They are extremely uniform in body wall and neck wall thickness, and of excellent weight uniformity. They are made to special dimensions, internally, to give greater powder capacity and they are of excellent quality brass. They weigh about 150 grains, where most commercial cases weigh 165-170, and the LC cases weigh as much as 185 grains.

The larger capacity is desirable in cases used for 600 to 1000 yard, highpower shooting. The WCC 58 cases are much sought after, by serious highpower shooters, but they are extremely difficult to find.

I have seen 7.62 cases which were headstamped WCC 60. They are heavier than the WCC 58. I do not know if they are match cases. It is possible that you will find 7.62 cases headstamped WCC that came from 7.62 military, ball ammunition. These will not be of match quality.

It is my experience that there are differences in the quality of different lots of commercial cases, and, on the average, I reject about 1/3 of those I buy, for long range shooting. The Federal match cases are as good a buy as any, when one is looking for quality.

Sincerely yours,
Creighton Audette

CREIGHTON AUDETTE

William Davis
Box 913
Wellsboro, PA 16901

Dear Bill:

Thank you for you letter of November 2 and the consideration it shows. I have read the photocopies, which you sent of the pages from a physics book, with much interest. I admit to error in regard to the length of the mean free path of air molecules.

With your indulgence, and that of the Editor of *Precision Shooting*, I would like to pursue the discussion of the effects of cartridge case shape further. Arguments over the effects of case shape on "cartridge performance", to use a broad, all-encompassing term, have been going on in magazine pages and among shooters and reloaders, at least since the 1930's. It is difficult for me to believe that the subject is all that abstruse. The problem is that the writing and argument is being carried out by individuals who have little or no knowledge of the physics involved, most of whom are simply repeating what they have read, and many of whom have, to a degree, a vested interest in believing, or in convincing others, that a change in case shape does improve "cartridge performance". That vested interest includes ego by the case designer: note how often his name becomes a part of the cartridge designation. Vested interest includes those who have something to gain from the belief, i.e., those who have a product to sell. It seems to me that the question can be answered by some one with an adequate knowledge of physics, as applied to firearms and cannon. It also seems to me that, if case shape, or chamber shape, in the case of cannon, did make any substantial difference, there would be mention of it in books on ordnance and ballistics, which were among the earliest subjects for scientific investigation. While my access to books on these subjects is limited, I have yet to find any mention of it.

Acknowledging, again, a rather elementary knowledge of physics, I would like to set forth a hypothesis as to what happens inside the cartridge case. Perhaps you, or another reader can clarify the matter, if the hypothesis is in error.

To start, I quote again from books on physics or science.

"Pressures exerted by gases on the walls of vessels which contain them are due to the continuous bombardment of the walls by gas molecules. The greater the number of molecules, the greater the gas pressure. Thus by pumping more molecules of air into a container, we increase the pressure in the container. An increase in the temperature of gases causes an accompanying increase in molecular velocity. Hence the hotter the steam in a boiler, the greater the velocity of the steam molecules and the greater the pressure."

Conversely, it must be that fewer molecules result in a drop in pressure, as does a drop in temperature.

"Gases expand indefinitely when released, not because of repulsion between the molecules, as formerly supposed, but because the molecules are in constant motion and do not stop until they collide with something. Air is not "forced" out through a tire puncture; only those air molecules pass out which, in their aimless wanderings, happen to encounter the opening. Molecules also pass in from the outside; but since there are several times as many per unit of volume inside as outside, many more pass out than in. This continues until a statistical equilibrium being reached, the air inside is no more dense than the air outside, and the tire is "flat". The rapidity with which this takes place emphasizes the speed of the molecular motion and the relative insignificance of the "internal friction" opposing it."

"What appears to be a steady pressure is due to the incessant impacts of gas molecules on any surface exposed to them."

It would seem to be self-evident that gas flow can only occur where there is a pressure drop, but I will quote from that section covering the Lagrange Approximation in "Theory of the Interior Ballistics of Guns", by Corner.

"The first and most important of the hydodynamic problems of the gun is of respectable age, having first been studied by Lagrange in 1793. This problem is to find the distribution of pressure, density, and gas velocity between the breech and the base of the shot at all times during the firing. That there will be usually a higher pressure at the breech is obvious from the fact that the propellant gases have themselves to be accelerated by this difference in pressure. (Emphasis added.)

Figure 1 is a drawing of the internal shape of the .222 Remington case, with a bullet in the neck. The arrows represent the pressure of the powder gases, on the inside wall of the case, before the bullet starts to move. It is the constant motion of the gas molecules striking and rebounding from one another and from the case wall, which creates the pressure. The sum total of the random motion and rebounding creates pressure which, for purposes of analysis or engineering, is taken as "normal" to the surface at any point on the surface. That means the pressure is perpendicular to a flat surface or perpendicular to a tangent on a curve, at any particular point. Were the situation such that the bullet was kept from moving forward and the amount of powder such that the pressure developed by the burning powder was within the pressure limitations of case and rifle, the gas pressure would remain the same, indefinitely, if means were provided to keep the temperature the same. Without means to keep the temperature the same, the gas pressure would drop to a level determined by the temperature of the case and chamber.

In normal firing, the gas pressure rises until the sum total of the pressure exerted by those molecules coming in contact with the base of the bullet is enough to start it forward, out of the case and into the throat. The forward movement of the bullet creates a pressure drop, in the area of the bullet base, because more space has been provided for the molecules in that area. Consequently the number of molecules in the area is less and the distance between them is greater. Molecules from other areas of the case, "which, in their aimless wanderings happen to encounter the opening", i.e. the additional space in the case neck provided by the bullet movement, rush in, tending to create "a statistical equilibrium". The direction of movement of any molecule is random and subject to collisions between molecules and between molecules and the case wall. The direction of many is away from the bullet base, but, since there are fewer molecules in the area of the pressure drop, more pass into that area than out of it. It would not seem that there should be a gas flow down the slope of the shoulder which would dominate the gas movement into the case neck and bore. Gas movement into the case neck would seem to be the result of the total number of molecules, "which, in their aimless wanderings", pass from the area to the rear of the neck, into the neck.

The total process is, unquestionably, much more involved than this description would indicate. The burning rate of the powder is constantly changing, higher pressure increasing the burning rate and lower pressure decreasing it. The initial movement of the bullet from the case neck does not require much pressure. Engraving of the bullet in the throat requires a great deal of pressure. Tests mentioned in "The Thermodynamics of Firearms" state that the starting pressure of the bullet in the standard, German army rifle is about 4600 psi, while the pressure to keep the bullet moving is only about one quarter that amount. The smooth rise of the pressure curve depicted in books on ballistics obviously cannot be exactly correct. The pressure builds up until the bullet takes a jump forward into the rifling. This produces a drop in pressure and a corresponding sudden drop in burning rate. The process tends to repeat and tests have shown that bullets actually move down the bore in a series of jumps. Perhaps this has something to do with the pressure waves bouncing back and forth between the bullet base and the head of the case, which were referred to in my last letter. The literature states that an increase in loading density reduces the wave effects.

It appears to me that there is a general misunderstanding among shooters and reloaders as to how smokeless powder burns in a rifle barrel. I am reasonably sure that, in most rifles, with normal loadings, i.e., a power type and charge weight suitable for the case volume, caliber, weight of bullet, etc., that virtually all of the powder that is going to burn, has burned, somewhere near the peak pressure, which occurs when the bullet is only an inch or two down the barrel. Under this situation, unburnt granules occur in most calibers. In the higher pressure, higher velocity rifles, they are blown out of the barrel. I have done a considerable amount of firing over snow, sometimes fresh, clean snow, and have observed these granules on the surface of the snow, after firing. One year, firing a 1000 yard match at Camp Perry, using a 28" barreled, .308 Norma Magnum, with a full load of DuPont #4350, behind a 190 grain bullet, in a rather stiff wind, directly from the direction of the target. I was puzzled to feel some small particles impacting on my face very shortly after firing a shot. It did not happen every shot. The firing line was entirely grass covered and it did not appear to be dirt particles blown up by the muzzle blast. The particles were unburnt powder granules, blown out the muzzle. Anyone who has done much shooting of lead bullets, or low power loads using jacketed bullets, has observed partially burnt, powder granules inside the cartridge cases and deposited in the rifle bore, after firing. It will be noticed that the majority of granules in the bore are deposited in the first few inches ahead of the chamber, under conditions of relatively low pressure and velocity. Higher pressure and velocity tends to blow the granules out the muzzle. Books on internal ballistics of cannon state that the powder granules "lag" behind the gas flow, during firing.

As the bullet moves down the bore and powder gases expand behind it, there must be a continuation of the pressure drop and molecular action resulting in gas flow. Since the powder granules burn in layers, both inside and outside, in the case of extruded, perforated granules, burning takes time, the powder granules are carried forward in the gas flow and there is always some burning of powder in the barrel bore, perhaps a sub-

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CREIGHTON AUDETTE

Continued

stantial part of the total. I shall come back to this question, further on.

Figure 2 shows a .222 Remington cartridge, which has been "improved". The shoulder angle has been increased to 45 degrees and the shoulder diameter increased a few thousandths. The arrows indicate the direction of gas pressure on the case wall and bullet base, as in Figure 1.

Figure 3 is a wildcat on the .222 Remington case, designed by a wildcatter who has read, "ad infinatum", that steep shoulder angles create "a churning effect, inside the case body, turning the powder gases back on themselves, improving combustion and giving higher velocities, as the result of a more efficient case design." He has gone the steep shoulder boys one better and put in a radius which, he is sure, "will really turn those powder gases back on themselves!" He had a bit of difficulty in finding some one to make the chamber reamer and it cost him a bundle, but "It will be worth it, to get the improvement in performance."

Figure 4 is an enlarged view of the shoulder, with the arrows drawn in to represent gas pressure on the inside of the shoulder radius.

If, as seems reasonable to me, there can be gas flow only where there is a pressure drop, there cannot be a whole lot of difference in the gas flow from the case into the bore between any of the three case designs. The greatest amount of pressure drop must be at the base of the bullet. There must be a pressure drop between the shoulder and the neck. There must be a pressure drop between the inside of the case neck and the shoulder. I cannot see how there can possibly be any pressure drop which will cause "a churning action of the powder gases" inside

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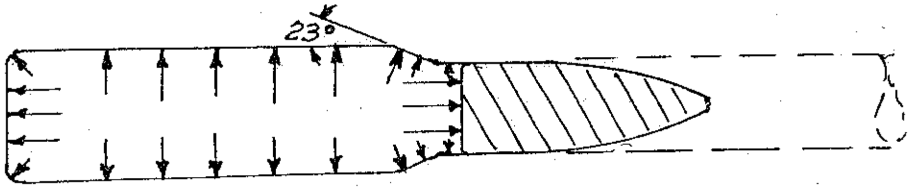

FIGURE 1

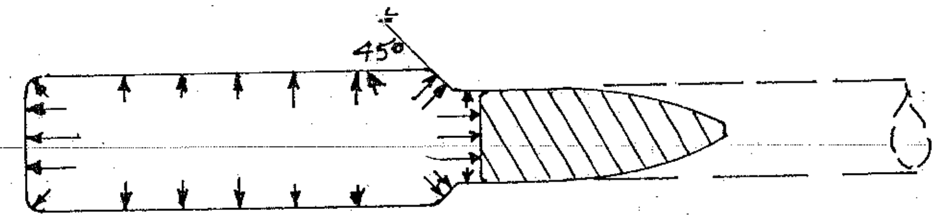

FIGURE 2

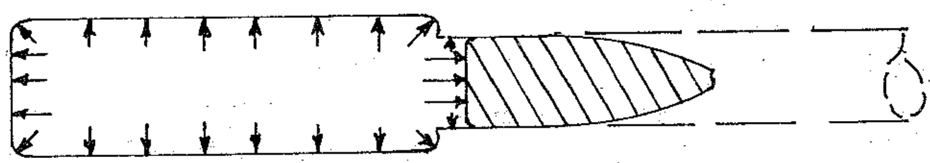

FIGURE 3

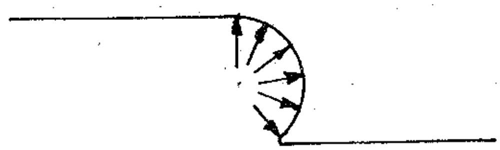

FIGURE 4

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CREIGHTON AUDETTE

Continued

the case body. There undoubtedly is violent motion of the gases inside the bodies of all three cases, from wave action, perhaps from powder granules slammed forward by the force of the primer and rebounding, etc., but I fail to see anything to cause any, significant difference in gas flow between the three case designs.

Further, were the dimensions of the three cases such that the cubic capacity, behind the bullet base is the same and all other conditions of firing the same, I would expect identical performance in all three cases, within the normal variations of any, one case, in an extended test.

Wildcatters have made preposterous claims about the "efficiency" of small, wildcat cases. The .219 Donaldson Wasp is a case in point. It was stated that the Wasp reached the velocity of the .220 Swift, using 10 grains less powder. Proof of this was the statement that the load had been tested on the Winchester chronograph. See Landis's book, ".22 Caliber Varmint Rifles", published in 1947. I knew some of the people who worked in research at Winchester at that time and asked one of them about it. He laughed and said the test had been run on a weekend, by an unauthorized employee, who did not understand the operation of the chronograph and the conversion tables used with it. He also said it was rather ridiculous to believe that an amateur, without any of the lab equipment available to the research people in the arms and ammunition industry, could come up with great advances in cartridge design and performance and that the wildcatters had no idea of the pressures of some of the loads they were using. Speer's "Reloading Manual for Wildcat Cartridges" includes this statement on the Wasp: "A cartridge company technician, who refuses to be quoted, has said that the classic Wasp load of 27½ grains of #3031 with a 50 grain bullet gives pressures of about 60,000 pounds. Speer gives a velocity of 3436 fps for a load of 27 grains of #3031, behind a 50 grain bullet.

It is often stated that short, fat cases provide better and more uniform ignition of the powder charge. Different primers undoubtedly produce differences in peak pressures and velocities and would therefore appear to produce some change in the burning rate of the powder. Relatively little data on these factors and their relationship is available to the handloader. You authored an article in the May, 1984 "American Rifleman" on .308 target loads which does, perhaps, give some idea of the differences that might be expected. The constants in the test, other than the test equipment, were the case make, bullet, and powder charge, respectively: Lake City, 168 grain Sierra, and 40.5 grains of IMR-4895. The "hottest" primer, if that is a proper term, was the Winchester 120, which gave a velocity of 2626 fps and a pressure of 52,200 psi. The mildest primer was the CCI 250, which gave a velocity of 2579 fps and a pressure of 46,100 psi. There was a percentage increase in pressure of 13% while the velocity increase was less than 2%. An explanation of the reasons for this is given in Naramore's "Principles and Practice of Loading Ammunition." You might, some time, in one of your magazine articles, explain to your readers why this happens.

The energy of primers is more than sufficient for powder ignition, under normal conditions, provided the primer is properly seated in the case and struck by a proper firing pin and firing pin blow. The difference in velocity, above, is 47 fps, an amount which is less than the differences in different rifles, using the same load; an amount which is about the equivalent of a temperature change of 30 degrees F, in the temperature of ammunition and rifle, between two tests of the same ammunition, in the same rifle; and it is less than the maximum variation in muzzle velocity, shot to shot, in a 10 shot series in a great deal of centerfire ammunition, both handloaded and factory loaded. It seems highly improbable that case shape can have any, substantial effect on ignition, which would result in significant improvements in "cartridge performance".

I believe that there are some advantages to cartridge cases with little body taper and relatively steep shoulder angles. Under the same conditions, the case with less body taper produces less back thrust on the bolt face. With rimless cases, the steep shoulder gives better support to the firing pin blow and the forward thrust of the primer explosion, prior to any, substantial rise in powder gas pressure. With proper chamber clearances, the case with little body taper and steeper shoulder is likely to give longer case life in reloading.

In the early days of the .220 Swift, statements were printed in gun magazines to the effect that "The .220 Swift case not only lengthens, in firing, but the neck wall thickens as a result of brass flow. Consequently, the cases must not only be trimmed to length, between loadings, but the necks must be reamed, periodically, to keep the neck wall of the proper thickness and to provide proper neck clearance. If this is not done, the result may be very high pressures." It was further stated that the "forward brass flow was a result of gas pressure, in this, very high pressure case."

There is no doubt but what the Swift

case, like other, rimless cases, lengthens in firing and should be trimmed to length, as necessary. The lengthening in the Swift case, as in most other calibers, also tends to result in thicker necks. I very much doubt that this has anything to do with gas flow. Neck thickening is the result of the following chain of events:

1. The force of the firing pin blow, plus the force of the primer explosion drives the case forward in the chamber and sets the case shoulder back, creating space between the case head and the face of the bolt. I have measured the amount, a number of times and, while it will vary, depending on the circumstances, it is quite usual to find .004″ to .006″ setback, per shot. That is with proper fit of case headspace to chamber headspace.

2. With the rise of powder gas pressure, the relatively thin walls in the forward 1/4 to 1/3 of the case grip the chamber firmly. If the force created by the gas pressure is not high enough to exceed the yield point of the brass in the case wall, the primer will stand above the head of the fired case, showing that the case head did not touch the face of the bolt, during firing. This is a frequent occurrence in .30-30 rifles, having some excess headspace from wear and use, such as the older Winchester, model 94's, with factory loads.

3. If the yield point is exceeded, the case wall will be permanently deformed, stretching, predominantly a short distance forward of the solid head section, until the head comes in contact with the bolt face. The result is a forward movement of the case wall, ahead of the point of major stretching. The effective headspace at the time of firing must be added to the .004″ to .006″ setback given above. The total can result in case lengthening of .010″ to .015″ per shot and it may be necessary to trim cases to length every couple firings.

4. Cartridge case walls taper in thickness because the wall must be thicker back near the case head to resist high pressures and to spring back from the chamber wall, after firing; and because the thin neck is required for proper bullet pull, crimping, and gas sealing during pressure rise. When the whole case body moves forward, ahead of the major stretch area, during high pressure, it is obvious that the result of continued firing and trimming will be a thickening of the neck wall.

The shape of the .220 Swift case, its thick walls to resist high pressures, and the loads typically used in this caliber all tend to result in just what is described above. "Brass flow as a result of powder gas flow" has nothing to do with it!

Firing and sizing also change the overall length of cases and can change neck wall thickness. Firing a standard case in an improved chamber shortens the case as the increase in diameter results in shorter length, overall, and thinner walls. As most handloaders know, reducing the larger diameters produced by firing, in full length sizing, also increases overall length and, consequently, neck wall thickness.

I am of the opinion that, in addition to all the major improvements in bullets, barrels, primers, scopes, stocks, knowledge of bedding, and improvement in stock materials during the modern, benchrest era, there has also been an improvement in the uniformity of cartridge cases. Take a look back at the lengths to which shooters used to go, and still do, to a lesser extent, to find enough "good" cases for benchrest shooting. Uniformity of the wall thickness and neck thickness, radially, is of great importance. Uniformity of case capacity and temper are important. The highly successful PPC cases show remarkable uniformity in wall thickness and capacity. I have fired hundreds of rounds in .308 match rifles in testing the effects of case wall uniformity and am entirely convinced of its importance. Some months ago, through the courtesy of Lou Palmisano, I received two each 7.5 Swiss and 7.62 Russian, loaded cartridges, obtained at the last 300 meter, World Championships in Sweden. I pulled them down, to measure bullets and cases. In all four cases, the wall thickness variation, a little forward of the solid head section, was less than .001″, and the neck wall variation was less than .0005″. I have measured neck and body wall variation on thousands of rounds of .308, .30-06, and magnum cases. From experience and from a little knowledge of statistical probability, I believe the odds are thousands to one against finding four such cases, randomly, with wall thickness within such a narrow range of error, unless the wall thickness variation in all of the cases made was very closely controlled in manufacture. And, the Russians and the Swiss are just the people who would understand the importance of uniform, cartridge case walls, and who would establish manufacturing methods to produce such cases, in order to provide their 300 meter shooters with the best ammunition possible.

Your comments and input would be appreciated.

ON BULLET VELOCITY

Dear Mr. Audette,

Your last few letters have been interesting, as always. In the interest of accuracy, however, I think the "Lagrange approximation" needs further discussion. This approximation is a derivation of the ideal gas laws and should actually state that the velocity of the gas at any point in the barrel is in ratio to the projectile velocity the same as the volume of gas behind the point in question is in ratio to the volume of gas in the total system. Since the whole thing is based upon the expansion of the gasses, the relative velocity of the gas is dependent upon how much gas is being expanded behind the point in question as opposed to how much gas there is altogether.

If the internal case diameter was the same as the groove diameter, then the approximation as you stated it would be correct. This would be true with many muzzle loaders and artillery pieces. With a modern bottlenecked cartridge, however, we have to calculate the actual volumes involved rather than just basing the calculation on the distance ahead of the case base. If you would just visualize a .30 cal. case of one inch length and one foot diameter, it becomes apparent that the volume of gas ahead of the shoulder would be less than one percent of the volume behind the shoulder and that the gas velocity at that point would then be nearly the same as the velocity of the projectile. In the end, it turns out that the gas velocity at the shoulder would be in inverse proportion to the expansion ratio of the cartridge at the time the bullet is at the muzzle. This assumes that the bullet's base is seated at the forward point of the shoulder.

Speaking in round numbers, a .220 Swift with an expansion ratio of about six would provide us with a shoulder gas velocity of about one sixth the muzzle velocity of the bullet when the bullet is ready to exit. A .222 Rem. with an expansion ratio of 9 would give us an equivalent velocity of about one ninth the muzzle velocity. In either case, the gas velocity jumps dramatically when the bullet exits the muzzle because the restraining force that keeps the gas from expanding drops at that time. Gas velocities at other times during the bullet's travel could be approximated by calculating the expansion ratio for a barrel only as long as that which coincides with those various bullet positions. Projectile velocity would have to be measured or calculated for the short barrels.

Using the Phil Sharpe chronograph data from the 30-06 barrel shortening experiment that was documented in the Feb. and March 1950 American Rifleman, we can calculate the following shoulder gas velocities based on the Twin Cities APM2 ammo when the bullet is about to exit. The numbers are rounded off.

30 in. barrel - 2744 FPS MV - Exp. Ratio 9 - Gas Vel 300 FPS.

20 in. barrel - 2618 FPS MV - Exp. Ratio 7 - Gas Vel 375 FPS.

9 in. barrel - 2025 FPS MV - Exp. Ratio 3 - Gas Vel 700 FPS.

This data shows that maximum shoulder gas velocity does not occur when the bullet is at the muzzle. In fact it occurs relatively early in the bullet's travel and at a time when pressures and gas temperatures are high. This fact can be confirmed by using standard industry velocity figures for .22 RF Sto. Vel. ammo in both rifle and pistol barrels. Your version of the formula would be nearly correct in this case because of the internal case diameter being nearly bore diameter. Using a one half inch length for powder space, the numbers would be as follows, again rounded off.

26 in. barrel - 1145 FPS MV - Exp. Ratio 50 - Gas Vel 20 FPS.

6 in. barrel - 950 FPS MV - Exp. Ratio 12 - Gas Vel 80 FPS.

As you stated, the velocities are much lower than most of us had originally pictured them to be. It should be pointed out, however, that the gasses reach much higher velocities during their early life than the values you quoted. Also the gas velocity increases dramatically when the bullet exits the bore. This would be at a time when the gas temperature is probably at a minimum, but the bore surface temperature would probably be at near maximum due to the time of exposure.

A good test to validate the gas "blasting" theory would be to set up a .30 cal. machine gun with an 8 or 10 inch barrel. The gas velocity in the throat would become extremely high when the bullet exited the barrel because of the high pressures involved at that time. A couple thousand rounds of comparative firing with the short and normal length barrels would be enough to show any major influence. It would be necessary to monitor outside barrel temperature in the throat region and perhaps make a change in the cyclic rate of fire to ensure that temperatures were the same as they would be in a full length barrel.

These calculations are not really exact, because as is stated in the book "The Thermodynamics of Firearms" by C.S. Robinson on page 17, gasses at the high pressures and temperatures involved in firearms do not exactly follow the behavior of ideal gasses. Correction factors have to be applied to the ideal gas equations to give accurate results. Progressive burning powder further complicates things because we are dealing with a changing amount of gas during the early part of the process.

Strictly theoretical. — Regarding case shape, if we use exaggerated examples and rough numbers to work with, we could have a .17 cal. rifle shooting 25 grain bullets and using 40 grains of powder. This isn't unrealistic. If we were to use a .25-25 style case of about six inches length, we would end up igniting the rear two inches of the powder column at the instant of ignition and would be driving a 25 grain slug of powder up the barrel in addition to the 25 grain bullet. Since this is occurring at the time when acceleration is normally at near maximum, it would seem that we would loose some velocity because of the extra 25 grains of projectile weight. Granted, the powder weighs the same in its gaseous state as it does in the solid state, and we would gain back some of the disadvantage when it finally burned, but the whole projectile-propellant acceleration curve would be different than what would be in effect if we used a .348 Win. case necked down and shortened to give the same capacity because we wouldn't be pushing as much unburned powder. The .348 case would provide an environment where most of the powder would burn in the case, whereas the "pencil" case would cause most of the powder to burn up in the barrel. This could also affect barrel temperature to the extent that it might influence erosion rate. It would almost certainly be a factor in automatic weapons barrels. I think this is the point that Bill Davis alluded to in his letter to you.

May you never run out of controversies to stir up.

Brad Richardson
P.O. Box 225K
Cedar Springs, Mich. 49319

CREIGHTON AUDETTE

Dear Merrill:

Thank you for your letter of December 7. I trust you will not object if I comment on several of the views you expressed.

Bullet slippage, producing land marks on fired bullets which are wider than the lands in the barrel from which the bullet was fired are common. It is not a question of whether the rear 50% of the bullet upsets, or how much of the bullet upsets, it is a question of the strength of the bullet alloy in shear versus the forces to which the bullet is subjected in its passage out of the case, through the throat and down the bore. There is very little data available on the shear strength of lead and lead alloys, since these metals are not generally used in service where they are subjected to shear, except in bullets. Lead, relative to its melting point of 621 degrees F, and to absolute zero, -460 degrees F, the point at which all molecular action ceases, is actually "hot" at room temperature. Its characteristics, relatively speaking, can be compared with steel at forging temperatures, where it has much lower strength than steel at room temperature and reacts to bending, compression, tension or shear much like taffee candy. The shear strength of pure lead is only about 1800 psi, but I have found no data on the shear strength of lead alloys. In describing lead alloy bearing materials, "Machinery's Handbook" states: "When considering the effect of temperature, it may be considered that a temperature rise of 100 degrees F will halve the strength of the metal." This would be a rise from normal room temperature.

Since the lands are only .0025″ to .004″ in height, the area of of the bore which is in shear contact with the bullet is very small. In stress calculations, impact loads are given twice the value of static loads and bullet engraving, which happens in a few microseconds, is certainly an impact load. Measuring the illustration of bullet 160-308 RCBS in your November article and calculating its proportions, the total bullet land length in contact with the .004″ high, rifling lands is approximately .25″, when there is not enough upset of the bullet nose to give appreciable contact on the sides of the lands. This gives a contact area of .001 square inches per land, or .006 square inches with the 6 land barrel. If 1 square inch of pure lead will resist a force of 1800 pounds in shear, before yielding, .006 square inches will resist only 10.8 pounds before yielding, in a static situation. Divide by 2 for impact loads and the figure is 5.4 pounds. Overstressed in shear, lead bullets start to yield at comparatively low stress, producing land marks wider than the actual lands and channels for gas escape which vaporizes lead and deposits it down the barrel ahead of the bullet, producing leading and poor grouping, though the land marks on the bullet may appear quite smooth, as a result of surface melting by the hot gases. This does not refer to conditions which produce obvious gas cutting. Recovered bullets will look quite normal, unless the land marks are measured under a microscope with a measuring reticle and compared with the marks on a lead slug, carefully upset in the same barrel. I have measured land marks on .45 caliber bullets which were .018″ to .020″ wider than the lands in the barrel. And these are marks where both sides of the channel are very nearly parallel, not the somewhat triangular shape seen on fired pistol bullets. Any bullet slippage is detrimental to accuracy and the degradation is roughly proportional to the amount of slippage. Slippage also tends to cause leading, due to gas blow by vaporizing the lead, which is then deposited in the bore, ahead of the bullet and ironed on to the bore surface by bullet passage.

Describing the P wad as "a controlled fluid" would seem to be at odds with the laws of physics. It is a solid and reacts to stress like most solids, except that it is more elastic than most solids. Stressed within the elastic limit it will resume its original shape, when the stress is removed. Stresses beyond the elastic limit produce permanent deformation, as in the case of the wad I fired, which hit the raised lettering on the body of the skyscreen, producing a mirror image of that lettering.

Reference to a textbook on "strength of materials" or to Marks' "Mechanical Engineering Handbook" will give information on what happens when a body, such as the P wad, is placed under compressive stress. Figure 1, copied from this book, shows a cube under compressive stresses P and P.

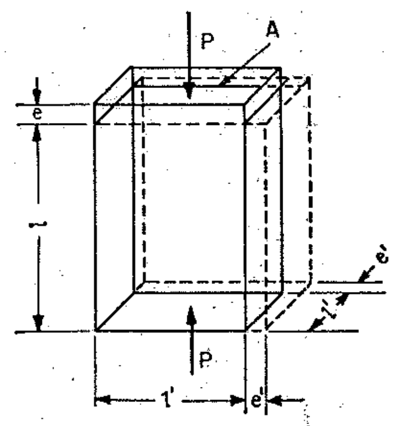


Fig. 1

These compressive forces cause deformations, also called "strains", so the cube is shortened in the axis of the forces and widened at 90 degrees to those forces. To quote the handbook:

> Accompanying a longitudinal deformation e, is a lateral deformation, e', (Fig. 1). The ratio of s'/s is Poisson's ratio, m. Values of m are : glass, 0.244; brass, 0.333; steel, 0.303; lead, 0.430, concrete, 0.10 to 0.20 at working stresses and 0.25 at higher stresses.
>
> (1 is length, A is area, e is gross longitudinal deformation, s is unit longitudinal deformation, s' is unit lateral deformation, and m is Poisson's ratio.)
>
> Stress is an internal distributed force; it is the internal, mechanical reaction of the material accompanying deformation. Stress always occur in pairs. (In the situation of the P wad, longitudinal stress is accompanied by lateral stress.)

If the wad were made of brass, each unit of compressive stress would produce a unit lateral stress of .333, within the elastic limit. With increasing force Poisson's ratio gradually increases until there is sufficient force to cause plastic flow, when it reaches a maximum of .5, in the case of ductile metals. I am not sure that the figure of .5 maximum is correct for other materials, but "Machinery's Handbook" lists Poisson's ratio for rubber as .5 and it seems reasonable that this ratio would be not far wrong for polyethylene.

On this assumption the unit pressure of the surface of the wad on the diameter, where it is constrained from expanding by the barrel bore would be half of the unit pressure of the powder gases and that is why a thin, flat P wad is actually a poor seal against gas pressure.

Whether the chamber gas pressure is less than the compressive strength of the wad is immaterial. As soon as the gas pressure increases above the static pressure inside the loaded, cartridge case, the longitudinal compressive force on the wad produces a corresponding increase in the unit pressure of the wad diameter on the bore which will be .5 times the unit gas pressure.

The problems associated with lead fouling, or copper alloy bullet jacket fouling, in rifled bores are difficult to understand, unless one has a bore scope and can examine the effects of various cleaning procedures. With a borescope it is possible to see the copper fouling, where looking through the bore simply will not reveal it. Even in the best of hand lapped barrels, there will often be a thin layer of copper, literally welded to the bore surface and it often takes dozens of applications of bore solvent to dissolve it. The only leading which comes out with conventional cleaning methods with brushes, solvent and patches is loose particles and those particles not firmly attached to the bore. There are times when the bore may be "tinned" with a smooth, thin layer of lead fouling, which is very difficult to see, even with a borescope and virtually impossible to remove, except with proper use of abrasives.

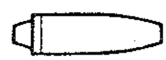
Claude Roderick, of Monette, MO, was one of the original founders of the National Muzzle Loading Rifle Association, a master machinist, single shot rifle enthusiast and a most thorough experimenter. Years ago, his articles appeared in "Muzzle Blasts" and in "Precision Shooting" and he wrote of just this phenomenon in experiments with scheutzen rifles. The thing that convinced me that it does happen was the experience of using lead-tin solder to attach ramp front sights to rifle barrels. With the ramp held by a jig, both surfaces tinned, then heated together, I would wipe off the excess solder with a cotton cloth while the solder was still fluid. Using very fine abrasive cloth, I would then remove the solder on the barrel outside the joint. I found that the only way I could tell when I had removed all the solder was to use a cold blue which would blue the steel, but had little effect on the solder. Without that, I could not tell where the surface was solder and where it was steel. I have since observed the same phenomenon with lead fouling in rifle bores which Roderick described. It was very difficult to see the fouling in the borescope and abrasives had to be used to remove it.

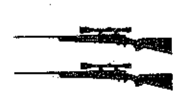
Virtually every barrel which has been fired with jacketed bullets will have some jacket fouling in the barrel, after normal cleaning methods. The usual method of wetting the bore with solvent, waiting for some period of time, then repeating the process until evidence of copper residue is not found on a patch does not necessarily guarantee that the bore is free of copper fouling. I often find it, with the borescope, after just such an attempt at bore cleaning.

I doubt if the usual, thin films of copper fouling, scattered here and there in the bore, have much effect on lead bullet grouping, since the copper fouling is much harder than the lead and the requirements for a plain bearing are fulfilled. It is unlikely that the coefficient of friction between lead and steel and lead and copper, in the presence of lubricant, is significantly different. If shooting has developed a thin layer of lead fouling, literally soldered to the bore, that fouling must be removed before satisfactory grouping with lead bullets can be achieved. Claude Roderick made that clear in his experiments and writings and my own experience leads me to believe he was correct.

I think it likely that it was not copper fouling from the gas checks which you removed in your cleaning that made the difference in subsequent shooting, but lead fouling.

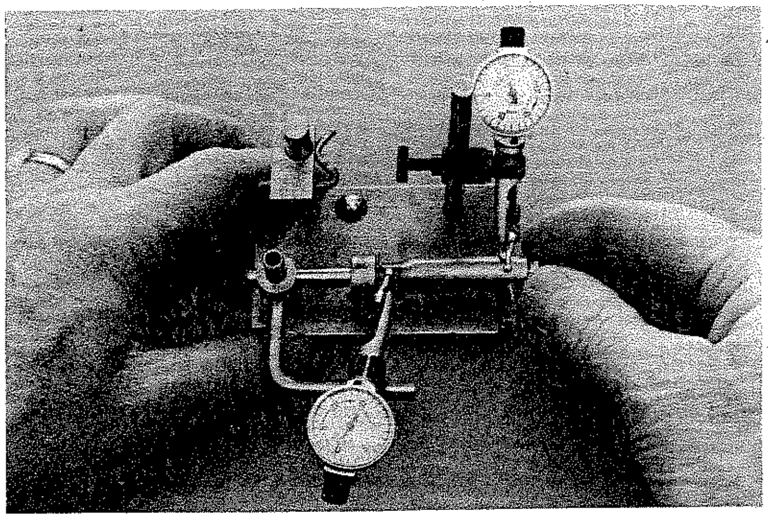
Sincerely yours,
Creighton





Seely Masker

by Seely Masker
261 Washington Ave.
Pleasantville, N.Y. 10570



The Creighton Audette case checking device.

Dear Dave,

I am not one hundred per cent certain that I believe you when you tell me that your tape player "ate" my last four tapes, which are now described as being hopelessly ruined. I have mildly suggested that you get the darn machine fixed, but you have told me that it works just fine, and you like it the way that it is. While all this seems quite strange and unjust to me, I have none the less reached the decision to write you letters instead from this point on. (Editor: We all have our dreams . . . . and I used to dream about taking one of his tapes, cutting it into several hundred pieces, each about an inch or two long, pounding the plastic tape housing into so much plastic mush with a hammer, and sending it back to him with a short note to the effect that he was apparently buying cheap, inferior tapes that did not play well at all in my tape recorder).

You have told me to stay on one subject. I can't stay on one subject. There are three subjects here. (Editor: well, at least I've got him down to three . . . .).

Some time ago I remarked to you about the subject of breaking in a new barrel. You, as usual, were not listening to me; I seem to recall that you had your head in my refrigerator, looking for another beer at the time. Much of the great wisdom of life has passed you by while you had your head in my refrigerator, David. The "shoot it and clean, shoot it and clean" method is what I am talking about. The system has been around a while, and I certainly am making no claim at originating it. (Editor: well if you're not claiming to have invented it, that's one less thing I can be billed for. Over the past year Dick Maretzo and I have been billed for the invention of the wheel, the discovery of fire, the discovery of America, and a few dozen other assorted things. Last time I talked to Dick we discovered that we had each been billed for the discovery of the theory of relativity).

The first time that I tried this method, I was amazed. (Editor: were you amazed at the results . . . . or how hard it was?). Fire a single shot. First, a patch wet with Shooters Choice. Then a bore brush wet with Shooters Choice, 5 or 6 passes, and a couple of dry patches. Next a loose patch, wet with Sweets, and let the barrel soak from 20 to 60 minutes. Repeat this for 8 or 9 cycles . . . . one shot . . . . followed by the cleaning cycle. (Editor: it helps a lot if you are retired, or at least not holding a job). If you have a barrel anything like the one that I was working with, the sight of that first blue patch will sort of stand you on your ear. Each resulting "cycle" showed less blue on the patch, with cycle number nine showing hardly any. I carried the theory forward, and then progressed to three shot groups, then stop and go through the cleaning cycle again. I have very, very few fouling problems with my barrels, and I credit it to two things: my method of barrel breaking-in, described here, and the fact that I really fire only a few sighters on each target . . . . thus I am hardly loading up that barrel with the copper fowling of fifteen shots. In a typical "yardage" of a warmup and five record targets, my rounds fired will be in the 45-50 vicinity for a total.

Topic number two: our esteemed editor allowed me to borrow his Creighton Audette case selection gage. This was after said editor, who everyone agrees is a mechanical dimwit (even he admits it), was showing me how some Aardvark cases from the factory checked out. It was an interesting mental dilemma . . . . with a complete lack of modesty, I can tell you that I am generally regarded as the greatest living benchrest gunsmith in Pleasantville. The editor is a mechanical dimwit . . . . and he was showing me things with this Audette gage that were enough to blow one's mind. I tried not to look awed . . . . instead I told him that I didn't think it was working correctly . . . . but I would try to fix it for him. Following which I threw him out the shop door, locked it behind him, and returned to the Audette device . . . . like one who had just discovered the basic secret of alchemy.

After a half hour with it . . . . I was convinced of one thing . . . . it ranks right up there with pretty girls, Lite Beer commercials, and buttered popcorn.

While gloating over my new toy, I was aware . . . . of a tapping, tapping . . . . at my chamber door. (Editor: wait a minute, Seely; thats from *"The Raven"*, by Poe). It was a new shooter, Leo Gustafson, dropping by. I dragged out three 6 PPC cases, sat Mr. Gustafson down, and said . . . . "watch this". The Audette tool turned up runouts of .0015-.0020 . . . . not too shabby. Then I dragged out three cases for the 6 SM, which of course is basically a Donaldson Wasp, necked up to 6 MM, and based on the .225 Winchester case. The case has been an enigma to me . . . . it should shoot better than it does. Well, those three cases had run-outs of .005, .008, and .009. That's good enough for me; now I know why it doesn't shoot to my satisfaction. It's a 25 inch barrel, and it's about to become a 24 inch 6 PPC.

I used the Audette case checker on some of my 30x44 cases (made from Remington BR brass) and I know that brass is not that highly regarded by the benchrest clan, but Dave, they were not all that bad. I measured 55 cases, and out of that number I came up with 26 that ran out .003 or less . . . . certainly match grade cases. Most of the remainder held at .004, except that five had .005 runouts, which was the absolute maximum found for these cases.

I've just ordered an Audette device for myself. Every time the editor calls, asking for his case checker back, I tell him that it is all goofed up, and I am still trying to straighten it out. As soon as mine arrives, I'll tell him that I fixed his device, and he can have it back.

As I said earlier, it ranks right up there with, beer and buttered popcorn. If you want one, contact Creighton Audette, R.F.D. #1, Springfield, Vermont 05156. Phone number is (802) 885-2331. Tell him that Seely sent you.

Topic number three . . . . let's talk about scopes and scope rings and mounts.

Scopes, as they come from the factory, are set with their windage and elevation adjustments set at the center of their limits (or at least they should be). If they are not centered, for some obscure reason, this should be done before installation on the rifle.

Then if we find that the rifle prints a foot off the paper, one can logically assume that either: A - The scope mounts are not true and in line with the bore, or B - the action has been drilled and tapped off center. If the latter is the case, then a windage adjustable mount is the only solution. Usually the mounts which have windage adjustments will be a problem if your scope and rifle combo weights real near the weight limit.

I am less that estatic about at least one set of rings in common usuage. These particular rings will attach to Weaver bases, and the maker advises that they are reversible for windage. In my experience however I have repeatedly found that when I had a rifle that was impacting a foot to the left of the target . . . . and I reversed the rings . . . . I was now impacting a foot to the right of the target . . . . an amusing solution to the "left impact" problem. These rings fit the bases so loosely that they are pulled out of shape when tightened. Some even bottom out at the clamp limit, leaving them loose on the bases.

Very, very few sets of rings can be removed, and then replaced with an absolute return to zero. This is especially true with the windage adjustable bases.

To me there are three prime requisites for the benchrest scope mounts: 1.) positive alignment, 2.) ease of removal, 3.) exact return to zero when replaced.

For the past year I have been using the rings manufactured by George Kelby, and I can say without reservation that these rings meet all three of the above requirements.

Continued on page 28

Coping With Conditions

By Gary L. Anderson

As an international three position and highpower rifle shooter, I am indebted to benchrest shooting for accuracy contributions that have helped my shooting, but until August 1978, I had never fired in a benchrest event. That year, the International Benchrest Shooters Varmint and Sporter Championships were at the Council Cup Range near Wapwallopen, Pennsylvania and Doc Garcelon, long-time IBS president had invited me to stop by for a visit.

I arrived on the 200 yard sporter rifle day and quickly agreed to "shoot if we find a rifle and equipment for you". Jack Deming provided a 6 x 47 mm Hart-barreled M660 Remington, complete with a Lyman-Siebert 25X scope, dies and brass. Jack advised a load of 748 powder (29.5 grains) and 68 grain Remington bullets. I was amazed when he set the powder measure by visually checking powder volume in the case, instead of by weighing. I was soon making ammo for the warm-up match, asking as many questions as I could, and looking forward to enjoying a new shooting experience.

Conditions that day were, as I recall, tricky, but definitely readable. The 5-10 mph wind was coming in mostly from one to two o'clock with a maximum direction change of about 90 degrees. I spent the warm-up match learning to shoot the rifle, but my first group was less than .50 MOA and even that was impressive compared to the .75-1.00 MOA groups I had learned to expect in most target guns. It gave me some hope that I wouldn't make a fool of myself.

The warm-up group also showed that even though my bench position was strange, I could get the rifle to perform by using the same shooting techniques I used in position shooting. With no hold movement, I was able to turn my attention to the wind as I began the first record groups. When the second and third shots in the first group printed lower, I also began to suspect that I would have to be making some vertical changes in my hold points too. The first two groups measured just above and just below .20 MOA. Trips to the waiting wall showed me there were a few better groups, but not many. I was pleased because the rifle was shooting well and my hold over decisions for wind changes were working.

After I finished the third match with another group under .20 MOA, I picked up my rifle and gear and started back to the loading bench. As I walked behind the line I overheard someone say, "if he keeps this up, he'll break the record". I thought, "this is great, not only am I having fun, but I might be here when someone sets a record."

Our loading table conversation after my fourth group made it obvious I was the one working on the record. The fifth group opened up a bit, but the congratulations I received before I left the line made it obvious I had broken the record. The five group aggregate was range measured at .2049 MOA and officially measured at .2104 MOA. I was doubly pleased that this not only broke the existing IBS Sporter Rifle Record of .2720 MOA but that it was also better than the varmint and heavy varmint records at the time.

Was this a classic story in beginner's luck or, as many experienced benchresters have suggested, the application of condition reading skills I had learned in other target sports? One of the remarkable things about that day was the feeling I had been there before. The experience of anticipating rifle changes, reading wind conditions and making aiming changes was no different than what I had done in lots of other matches. I didn't fire a single group where I used the same aiming point for all five shots, just as I have fired lots of rifle position matches while changing sight settings before almost every shot.

In that match, and with the fine rifle and load I was using, conditions, especially wind, were clearly the biggest variable. Whether it be in benchrest or bullseye target shooting, skill in coping with conditions is frequently the decisive factor in winning and it is from this starting point that I would like to discuss the techniques and tactics of shooting in conditions. I must also add the caveat that one benchrest success doesn't make me an expert. There have been many days when someone else in my target games had better conditions skills; but hopefully I can share some collective experiences that may repay a small part of our debt to benchrest shooting.

Our first task is to define some terms. Conditions is a term shooters use to describe the varying effects that wind, temperature, light and mirage have on the strike of the bullet on the target. Techniques and tactics are the actions or strategies which the shooter applies to accommodate or compensate for the effects of conditions. My approach to coping with conditions is divided into three phases: 1) Shooting skills and equipment; 2) Evaluating conditions and 3) Techniques and tactics.

It all begins with fundamental shooting skills and accurate equipment, that is the foundation. You can't learn to shoot a good score or tight group in difficult conditions until you have the ability to shoot a good group or score in ideal conditions.

An accurate rifle and ammunition eliminates some windage error by itself. Veteran long range highpower rifle shooters say, "a good rifle is worth a half minute of wind". The rifle I used in setting the benchrest record was the finest shooting rifle I had ever fired. That rifle may actually have been one of several rifles which were capable of breaking the record but the important point is that you can't shoot a record in wind unless you have a rifle that can do it in ideal conditions.

Similarly, a shooter must have good shooting skills. In my bench rest experience, I repeated the things I learned in bullseye target shooting. When I applied uniform shoulder, cheek and hand pressure; concentrated on getting a clean, smooth, consistent trigger release and allowed the rifle to recoil uniformly after every shot, I could get the rifle to perform to its potential. Many shooters have difficulty with conditions because they blame them for wide shots when those shots are really due to shooting errors. To become skilled at coping with conditions, a shooter must first acquire good equipment, learn how to make good ammunition and do enough shooting in ideal conditions to fully master the fundamental skills of firing accurate shots. Only then is the shooter ready to take on the challenge of mastering conditions.

The second phase in coping with conditions is evaluating conditions. You need to be able to recognize conditions and know how much those condition changes will affect the strike of the bullet before you can devise and apply strategies for coping with those changes.

Two condition variables, temperature and light can be dealt with quickly when conditions are considered from a practical point of view. Temperature changes do change the strike of the bullet but range temperatures are never likely to change so dramatically as to shift the strike of the bullet during the time it takes to fire a single group. The only major effect of temperature to be dealt with in shooting is the effect of leaving a cartridge in the chamber for an extended period of time while waiting for the wind to return to a preselected condition.

Light can change during the firing of a single group, but it is very simple to evaluate. Either the sun is out or it is diminished by cloud cover. With iron sights light changes sometimes cause zero changes, but that ordinarily does not happen with scope sights. A few sighters can verify whether light changes need to be considered.

The evaluation of mirage is more complicated and significant. The only effective way to see mirage is with a telescope and since the telescope used on the rifle must be focused on the target to avoid parallax errors, the use of a separate spotting telescope focused at a closer distance is required. In outdoor position rifle shooting, particularly on ranges where good wind flags are not provided, the spotting scope is located as close to the non-aiming eye as possible so that mirage can be checked just before and just after firing a shot.

There are pitfalls in reading mirage. The telescope can only be focused at one distance so mirage at other points on the range cannot effectively be evaluated. The shooter has to decide where the visible mirage tells the most accurate story about how the wind is moving the bullet. A good starting point is to focus half-way to the target as the wind closer to the shooter is usually more important. The ideal focal point will vary with different ranges.

Mirage is often difficult to see, especially at shorter ranges, and you may have to use mirage wherever it can be seen, such as in front of a number board below the targets. Mirage driven by winds above 12 - 14 mph is the same irregardless of wind velocity and is not going to provide useful information. Mirage changes don't always coincide exactly with wind. The mirage at the National Matches at Camp Perry, Ohio is notorious for not changing until after the wind has changed.

Learning to read or evaluate mirage requires practice. Some of my most important practice sessions have been days when I fired shots without wind adjustments, trying to correlate the strike of the bullet with mirage and wind changes.

An important argument regarding mirage is whether it is simply a useful tool for reading wind or whether mirage itself has an effect on the strike of the bullet independent of the effect of wind. Most shooters and shooting books state that mirage displaces the target image in the direction it is moving. While emphasizing that I am a shooter, not a scientist, I have concluded that this seldom happens in practice.

Particularly at longer ranges, mirage may cause the bull to dance around to the point

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COPING WITH CONDITIONS

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where achieving a consistent aiming point is nearly impossible, but it does not ordinarily, produce a consistent or measurable displacement of the aiming point. In spite of all its shimmering and dancing, the average position of the aiming point almost always remains in place.* For practical purposes, then, the shooter is not concerned with mirage except as a very excellent wind indicator in many types of wind conditions on some ranges.

Wind itself is by far the most important condition to evaluate. One of our most successful smallbore rifle prone shooters used to say, "the wind talks to me". During my firing of the bench rest world record, I was able to make numerous successful changes in my aiming point as a result of wind changes I read in the flags on the range, without going back to the sighter to check those changes. A successful shooter must be able to identify specific wind conditions when they recur and to translate changes in wind direction or velocity into specific sight adjustments or aiming point changes on the target.

The best place to start in learning to read wind is to acquire a specific knowledge of wind effects. You need to know how far winds of different velocities and directions will move the strike of your bullet. At Wapwallopen, I had to use sighters to do this, but a better way to begin is to prepare wind deflection charts for your specific load, using information which can be found in the *Sierra Reloading Manual* or other publications. The idea is not to have this chart available to consult before every shot, but to use it as an aid in developing a more precise mental picture of the impact shifts you are likely to encounter with different wind changes.

Remember that wind direction changes do not change bullet deflection in direct proportion to the amount of direction change. Changes closest to 12 and six o'clock have a proportionately greater effect. A practical guide is given in the table below.

VALUE OF WIND DIRECTION CHANGES **

Wind Angle	Value
12 & 6 o'clock	None
12:30, 5:30, 6:30, 11:30	1/4 value
1:00, 5:00, 7:00, 11:00	1/2 value
1:30, 4:30, 7:30, 10:30	7/10 value
2:00, 4:00, 8:00, 10:00	7/8 value
2:30, 3:30, 8:30, 9:30	Full value
3:00, 9:00	Full value

A parallel step in this process is to learn to estimate wind velocity. A good shooter should be able to accurately determine wind velocities to within 1 or 2 miles an hour up to velocities of about 15 miles an hour. By being able to do this, and by having a knowledge of wind deflections for your load, it is much easier to decide how much to change a sight or holding point to compensate for a wind change.

The estimation of wind velocity is a matter of reading or interpreting wind indicators available on the range. In the order of priority, they are 1) flags, 2) the feel of the wind on the shooter's body, 3) mirage and 4) any other indicators available such as dust, leaves or grass.

Flags are the best and most reliable way to read wind if the range has enough flags in the right places. The Council Cup Range was an excellent example of a range adequately equipped with flags. There were multiple rows of flags located so that every shooter could easily keep 4 or 5 flags in view at all times. Ranges where just one or two flags can be watched are generally not adequate.

The correct way to use flags is to watch as many flags as possible. Try to develop a feel for the overall wind pattern on the range. A beginning shooter may not be able to effectively use more than a couple of flags, but through practice you should attempt to broaden your awareness to see as many flags as possible as a total picture. Watch only the flags on the upwind side of the range with your greatest concentration on the flags closest to you. Reading range flags should work like the exposure meter on a modern camera that gives the greatest weight to the light in the center of the image. In this case, the flags closest to the shooter on the upwind side of the wind are given the greatest weight.

The feeling of the wind on the shooter's body is important because wind on the first 25 percent of the range ordinarily has the greatest effect on the bullet. Many times when the wind begins to change in velocity it can be felt by the shooter before it will show up in either the flags or the mirage. The wind propellers now popular with smallbore prone shooters have become an important aid to reading wind on the line.

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* For a discussion of this see Creighton Audette's Comments on mirage pages 46-48, in the 1980 edition of *Highpower Match Rifle Shooting*, published by the National Rifle Association.

** From *Competitive Rifle Shooting*, by James Sweet

COPING WITH CONDITIONS

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The use of mirage as a wind indicator depends on the range. The Council Cup Range had a good set of flags so I preferred to use them. On ranges without flags or with improperly placed flags, mirage is often the best wind indicator available. Learning to read mirage is a matter of practice, but after awhile a shooter can learn to differentiate between the different mirage movements and the wind velocities they indicate. Mirage can also provide, within limits, information of direction changes, but since they are so critical it is best to have some additional means of checking direction when mirage is being used as the primary doping tool.

The use of other wind indicators such as dust, trees and grass is chancy and usually depends on a special feature being present on a particular range. Nevertheless, they can't be overlooked because I've been in too many matches where the winner says all he did was watch a blade of grass in front of his target or some other unique range feature. I have seen ranges where dust behind the target (when the wind is coming towards the shooter) or a tall blade of grass will provide a very reliable indicator. Sometimes the sounds which trees around the range make when the wind is changing provide an early warning of a change. The trees at the Wapwallopen range gave me excellent information about wind changes that were brewing. One of the best of these occasional wind gauges is rain. Its angle of fall is an especially accurate indicator when it is available.

In summation, the basic rules for evaluating wind are:

1. Give preference to flags if adequate flags are available.
2. Read the wind on the side where the wind is coming from.
3. Give preference to the wind indicators closest to the shooter.
4. Develop as wide an awareness of wind indicators as possible, so as to get a total picture of the wind.
5. Pay careful attention to direction changes, especially those closest to 12 and six o'clock.

Being able to evaluate wind and other conditions is still not sufficient to produce good shooting results in those conditions. This is where the third phase of coping with conditions, techniques and tactics, come into play. The shooter must be able to accommodate or compensate for the condition changes as they are identified and evaluated.

The first step in condition shooting tactics is to have a game plan or strategy. This derives from the fact that there are three different techniques for dealing with wind changes and I will list them in priority order: 1) Pick a specific condition and shoot only when that condition prevails; 2) estimate wind changes and change the sight or aiming point to compensate for the estimated changes and 3) follow the last shot, using it to determine holdover on the next shot.

The strategy or selection of the correct wind doping technique depends on the wind change pattern which prevails on that particular day. During my benchrest record aggregate, I noticed before the match and during my warmup group how the wind was gradually changing. There did not seem to be a prevailing condition. This dictated a shooting strategy of changing my aiming point to compensate for the changes as they occurred.

My favorite strategy in most international competitions was to pick a specific condition and then to shoot only when that condition occured. This is normally the best strategy if there is a common or "median" condition prevailing most of the time. Or if you have sufficient time to wait out changes.

The strategy of following the last shot is generally a strategy of last resort. It works well if the changes are gradual and if the shooter can machine gun the shots downrange. I can't shoot that fast and sustain my performance and besides, wind changes on most days are frequently very abrupt. If your technique does not allow you to maintain an awareness of the wind, it's likely that you will be caught by such a change.

One of the most important things to do in getting ready to shoot is to spend some time before the match observing what the wind is doing in order to work out a game plan. You should know before you start which wind doping technique or strategy you are going to use. If you spend the first two or three shots trying different techniques a good poor group is the likely result.

An important technique for shooting in the wind is to develop your ability to use the non-aiming eye to maintain an awareness of wind conditions while the shot is being fired. I spent a couple of years training myself to maintain a subconscious awareness of wind conditions with my non-aiming eye so that if a wind change began to occur a signal would immediately register for me to stop squeezing the trigger. If you are using the correct wind indicators, this technique makes it almost impossible to get caught by a change. This proved to be one of my most valuable condition techniques at Wapwallopen.

Another condition technique relates to the proper use of sighters. Most shooters tend to use sighters as a substitute for wind estimation ability — anytime they aren't sure of a change they go back to the sighter. The problem with this is that the wind is just as likely to change while going from the sighter to a record bull as it is between two record shots. Nevertheless, when you aren't sure of a condition, sighters should be used.

The most effective use of sighters is to determine exactly how much the wind is changing. If sighters are used to confirm or adjust a game plan or wind deflection estimates which have previously been developed, they can be extremely valuable.

Successful wind doping on bullseye targets requires paying special attention to keeping the zero or point of impact in the center of the target. That's not as easy or simple as it sounds. It is often difficult to tell where the center of a one, two or three shot group is, but it's important because a well-zeroed rifle can still catch a ten at three on a shot that would be a nine at four if the zero were really a quarter minute low.

The zero or point of impact of a rifle is dynamic rather than fixed — even in the best rifles, it may shift slightly as shooting progresses, in shooting my benchrest record, I was able to take advantage of the fact that the group consistently formed below the first shots so I changed my holding point not only horizontally for wind, but also vertically for zero changes.

Making elevation changes to keep the group centered or, in the case of benchrest shooting, to keep the point of impact centered in the group, leads to consideration of another factor that produces vertical changes. Wind deflection does not always occur in perfectly horizontal directions. The standard wind pattern for .22 rimfire bullets is ten o'clock to four o'clock. Centerfire bullets normally have a nine o'clock to three o'clock pattern, but wind effects on some ranges may add a vertical component to that pattern. The best solution is to keep careful records on each of the ranges where you shoot or, if you haven't been there before, to ask lots of questions. You won't ordinarily be lucky enough to discover these kinds of patterns in your sighters.

If there is a "safe" strategy in wind shooting, it is to keep the group or point of impact adjusted to coincide with the median wind condition. I have seen several winning 600 yard highpower scores fired in really difficult winds where the shooter said afterward, "I didn't change my sights a click for wind". Those shooters have successfully zeroed on the median condition and were lucky enough to avoid any big wind variations because they successfully played the percentages.

And just to prove that shooting in wind is often more of an art than a science, another frequently used strategy is to determine that a pick-up or let-off is more likely and then to keep the shots on the opposite side of the bull or group. This is another variation of playing the percentages where I have often accepted left or right tens without correcting my zero to the center to avoid a probable pick-up or let-off.

Good wind shooting technique requires that you always place the highest priority on firing a quality shot. Never sacrifice maintaining a consistent hold and smooth trigger release in order to rush a shot to beat a wind condition. It is more productive to be patient, wait until your condition is reestablished and take the time to correctly fire the shot. No amount of wind doping skill is ever going to make up for the poor execution of shooting skills.

A final consideration in coping with conditions has to do with attitude or psychology. Many shooters greet windy conditions with resignation. "Why did we have to be unlucky and get a lousy day like this." The truth is that wind doping is a skill which can be learned, trained and refined just as any other shooting skill can be developed. Warren Page in his book, *The Accurate Rifle*, called wind and mirage "at once the precision shooter's worst enemies and his greatest friends". Shooters who view the challenges of coping with conditions as skills to be learned will find that difficult conditions are their greatest friends.

Beginning In Standing, Making the Position Better

The beginning shooter who has just started to get the feel of the standing position and who has reached the point where he can keep all of his shots in the scoring rings has reached the stage where he can master specific techniques which will perfect and improve the position. The mastering of each of these techniques is important in the development of a successful standing position competitor.

Although this article is intended primarily for the beginning shooter who has received only the first stages of standing position instruction, it might also have some practical usefulness for experienced shooters who have not had the benefit of instruction which covers the latest standing position techniques.

Every shooter who wants to become a successful standing shooter should first master the basic checkpoints of the position and the basic techniques of shooting in the standing position, for it is upon these that the entire position is built. These were all covered in my Precision Shooting column last month.

Before going any further with the techniques considered here, each shooter should check to make sure that his feet are approximately shoulder-width apart and pointed ninety degrees away from the target, that his knees are straight, that his left arm is resting on his left side, that his left wrist is straight, and that he is holding the rifle correctly with his right hand and shoulder.

He should also make sure that every time he fires a shot, he accepts his wobble area, carefully centers his hold on the bull, attempts to concentrate as strongly as possible on making that hold smaller, that he is not releasing the shot too soon or too late, and that his trigger release is an easy semi-conscious action which usually surprises him when it is completed.

Once these beginning position checkpoints and techniques are mastered and the shooter has reached the point where he can keep all of his shots in the scoring rings, then he should begin to pay more careful attention to the details of the standing position, for these details are the summation of what we understand today are the fundamentals of the best standing positions.

Body Twist

One of the first details a new shooter becomes aware of is the twist which he must make in his body in order to keep his feet pointed ninety degrees away from the target while pointing his rifle at the target. It is really impossible not to twist the body in standing, but the important difference is in how the body is twisted. This twist must be made in the upper part of the shooter's body and not with his legs. The body twist is correct if the hips are parallel to the direction of fire and not turned as the rifle is brought down into position on the target.

Back Bend

Another extremely important detail is learning to bend the back to the rear and to the left, or away from the extended muzzle weight of the rifle. One of the most serious mistakes a shooter can make in standing is trying to stand up straight instead of bending back away from the rifle. The purpose of this back bend is to counterbalance the weight of the rifle as well as to tighten up the back and make it more stable. If this is not done the muscles of the back must hold the weight of the rifle up, but if the shooter bends back away from the rifle, then no muscle effort is necessary in order to hold the rifle up. As a general rule, a heavier rifle or a lighter shooter require greater back bend.

Left Hand Position

Once the back bend is mastered, the shooter can begin to pay more careful attention to the way he uses his left hand to support the rifle. Initially all that was necessary was to keep the wrist straight and the hand in a natural position. Now this hand position can be changed in order to get the rifle more accurately pointed at the center of the target. The purpose of using different hand positions is not to find the most comfortable hand position, but to find the hand position which gives the rifle the correct elevation on the target for that particular shooter's body build. Different hand positions raise and lower the rifle. Setting the rifle on the fist, for example, keeps the rifle relatively low, while setting the rifle up on the knuckles and thumb makes it much higher. Select a hand position which gives the rifle the correct elevation on the target after the body is bent back far enough to elminate any lifting strain on the muscles of the back.

Left Arm Relaxation

A fourth detail to be noted in building an ideal standing position is whether the left arm and shoulder are truly relaxed. This is the only part of the body which must be relaxed completely in the standing position. If any muscle effort at all is being used to hold up the rifle, then a mistake is being made, and the muscles in that arm should be relaxed completely. If, when it is relaxed, the rifle subsequently drops below the target, then a higher left hand position must be found so that the rifle can be pointed at the target with the arm relaxed.

Building a Single Rifle-Body Unit

The right arm also plays a role in building a good standing position. For the beginner, all that was necessary was to get a good firm grip on the pistol grip and then pull the rifle back into the shoulder. After becoming more accustomed to the standing position, it is possible to sense how the rifle can be made an integral part of the upper body by pulling it into the shoulder with the right arm. This right arm can be helped in welding the rifle to the body if the elbow is held out horizontally and not allowed to drop.

Movement Control

Learning to control the movements of the body in a standing position means learning to use the legs and feet in exercising this control. The beginner is taught only to keep his knees straight. After he has some experience with the position he learns that by keeping moderate muscle tension in his legs, that this tension will help him prevent his body from moving back and forth.

Balance

Another detail to be perfected in building the standing position is weight distribution and balance. Body weight should be distributed equally between both feet. The balance of the body as the shooter gets into position should be shifted slightly forward so that a little bit more weight is on the balls of the feet as opposed to being predominately on the heels of the feet.

Position Orientation

A final detail in working out a good standing position is the orientation of the position as it is determined by the location of the feet. Many tall, thin shooters will find that a position where both feet are pointed ninety degrees away from the target causes the rifle to point naturally to the left of the target. For them, the orientation of the rifle can be improved by pulling the right foot back slightly in order to move the rifle back onto the target. Heavier shooters, in contrast, often find that they must point their feet a little bit more towards the target. Many shooters also find they can improve their position by pointing the left foot slightly towards the target while the right foot remains pointed ninety degrees away from the target. Building a good standing position means, first of all, mastering the basic checkpoints of the position as well as the fundamental techniques of shooting standing. After those beginning lessons comes the step by step succession of going through each of the additional details for perfecting the position described here until each of them is mastered. At that point the mechanical position is about as good as it can get. All that lacks then is lots and lots of practice.

Technical Column

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SEPARATE SCOPE FOR MIRAGE

Has anyone tried a target scope on a spotting scope stand to check on mirage or other conditions? I thought that a target scope, identical to the one on my rifle, mounted on a solid stand, and with the crosswire centered on the aiming point, would provide a reference check on changing light conditions, etc. This could be used to vary the aiming point of the rifle.

Mr. T. Good
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Yes, a few shooters have used the system of setting up a scope with cross hair to judge mirage conditions. Many small bore shooters use a regular spotting scope focused on the prevailing mirage for doping. There are quite a few active in the bench rest game who have previously shot small bore.

It is surprising that this system is not used more. When the mirage is running heavy and changeable, it should be a valuable aid.

M. H. W.

MATCH CASES

Yesterday was the final shoot of the 1974 Sno-Ball league; and, keeping records per your admonition I know that my .222 40-x barrel has 3210 rounds through it. Question: Ought I NOW have the barrel cut off and a new chamber made — or shall I just keep on shooting until accuracy does deteriorate. As of now the gun is still shooting better than I'm able to shoot it. Although I am working hard at learning to read conditions.

Also, at the shoot yesterday I again noticed a few shooters with a small batch of cases that they reloaded for each relay. None of them could give a satisfactory or reasonable reason. Which brings up the question of what constitutes "match grade cases" we note referred to by writers like Mr. Warren Page in his book — and others.

It would seem to me that cases which are: Neck turned or reamed for uniformity, Checked for flash hole uniformity, Trimmed to uniform length and lastly matched for weight or capacity ought to suffice. I should be pleased to have your learned comments on this so that I might be assured I am doing what I can in this area or know what more might be done to assemble a batch of "match cases."

Again my real thanks for any help you can give.

Mr. R. O. Whitaker
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161-10 Jamaica Avenue
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Do not replace your .222 barrel until you are sure it is not producing results equal to your shooting ability. We have a few reports of .222 barrels going to 6000 to 7000 rounds.

The selection of cases has not been worked out scientifically. The selection of a few cases for match work generally has a psycological effect which can easily help the shooter.

My own, and many others experience indicates that selecting the .222 or the 6x47 by weight is useless.

Practically, neck wall variation is probably the best indicator of case quality. If you have a lot of cases with less than .002" neck wall variation, the chances are excellent that they will shoot well. Many shooters select their cases at the match by using the ones which produce the best results. This is probably also psycological.

The turning of case necks to provide a uniform wall and a uniform tension on the bullet is of value. Nevertheless, cases which have a large neck wall variation, say up to .004" or .005" before turning, will not be equal to those which have less variation to start with.

Flash hole uniformity and primer pocket depth uniformity are probably of some importance, but it has not been proven.

M. H. W.

The Rifleman's Corner

by Gary L. Anderson
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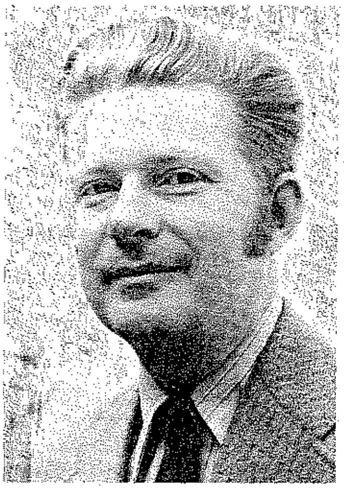

"TECHNICAL PREPARATION IS THE KEY"

Recently I was looking through one of my old shooting diaries written when I was still active in competition and rediscovered how much difference detailed technical preparations make in the scores any one shooter can fire.

I was reminded of this when I read my account of an early season match in which half of the points I lost were not lost because of a bad hold or poor trigger control, the two basic fundamentals we usually look to, but rather, because my lack of technical preparation resulted in numerous minor mistakes.

An analogy which might serve to make the point is the football player who obviously has the physical ability, speed and strength to be a star player, but who still spends hours each week studying films, learning the moves of his opponents, and making his own detailed technical preparations which are necessary for him to actually play like a star.

The same holds true for the competitive rifle shooter. The basic shooting abilities, holding the rifle steady and a good trigger control technique are undoubtedly the most important skills which a competitive shooter must master. But by themselves, they are not enough to produce a winning marksman. The ability to hold a rifle steady and pull the trigger correctly must be augmented by a whole series of minor technical skills which are needed to make that good hold and trigger control really produce high scores.

The need for technical preparation is most noticeably early in the shooting season or after a long training break. Quite often the hold will still be quite good and entirely adequate for producing good scores. Surprisingly, the trigger control is often also relatively smooth and well coordinated, but to the disappointment of many shooters, they find that in spite of their good hold and trigger control, they simply are not able to produce the scores which they feel they should. Aside from the experience of the unprepared early season marksman, the other dramatic need for paying careful attention to the details of technical preparation is when a shooter has developed an outstanding hold, but still cannot fire consistently good scores. Too often, these shooters think all they have to do is to be able to hold and pull the trigger, when in reality, they will never become winners until they master all the minor details, too.

The training program which any shooter goes through thus needs to be pointed to more then merely improving holding ability and trigger control techniques. It also must focus on working out each of the technical details that are part of firing the shot. Each of these taken alone may be worth only one or two points in a 120 shot competition, and yet a number of these details taken together can make the difference between an average score and a winning score. These technical details may not make much difference by themselves, but when they are added up, they are what truly makes the champion shooter.

Without attempting to make any kind of exhaustive survey of the various items of technical preparation, I would like to point out some of the specific areas of technical preparation on which competitive rifle shooters should concentrate in order to make themselves mindful of the roll which this kind of detailed preparation plays.

Many of the technical preparation details focus on the shooter's equipment. To begin, the rifle must be performing as well as possible. It takes a lot of shooting to determine whether the rifle is properly bedded, whether the right lot of ammunition has been selected, and whether the rifle and ammunition perform well in actual shooting conditions.

The adjustment of the many accessories on modern target rifles are also important aspects of technical preparation which cannot be worked out simply by picking up the rifle and going to the range once or twice. These are things which take a lot of time, a lot of thought and several minute adjustments before they are correctly worked out. They include determining the correct amount of cant for each position, the precise adjustment of each of the shooting accessories and the heighth of the sights and cheekpiece.

Many times it is necessary to use a rifle extensively before the shooter is assured it will function reliably. Triggers, for example, have a way of working well for a while, but then functional faults often appear which need to be corrected.

Another phase of technical preparation which all training programs must be designed to improve are the techniques of firing the shot in addition to simply holding the rifle still and releasing the trigger. Many of these techniques relate to the perfection of concentration. In order to have a good hold, it is necessary to be able to concentrate fully on that hold. In order to have good trigger control, it is necessary, once again, to focus concentration on certain aspects of the firing of a shot. The perfection of this concentration sequence is an extremely important detail in any shooter's technical preparation.

The technique of working on a shot in order to make it as good as possible must be developed through training. The slow shooter, for example, must develop the kind of patience necessary to wait for his hold or his release to come. This patience can only be developed as confidence in the hold quality is learned. The fast shooter, on the other hand, needs lengthy training time to really develop his timing.

There are other aspects of technical preparation which the shooter needs to pay attention to in order to actually reach his potential. Sometimes a shooter who is not technically prepared will find himself not reacting correctly to his sight picture. Sometimes he will find himself holding too long or not being ready when his good hold does come. Sometimes he will find he has not yet developed a feel for his hold or an ability to sense how and when hold movements will occur. Sometimes it is simply a matter of disciplining himself to perfectly center his hold each time and not to be satisfied with a release unless it is made on a centered hold.

A final phase of technical preparation concerns those things that occur in the firing of a competitive course of fire. These are often called shooting tactics. They include such things as paying careful attention to the centering of groups. Many times points are lost not because the hold is bad enough to put a shot out, but rather because the group itself was not perfectly centered.

Sometimes points are lost because a shooter has not settled himself down for the first or second shot in the prone or kneeling position or because he has not learned to perfectly center his point of aim before he starts for record.

Sometimes the shooter will find he cannot perform well because he has not learned the range or has not developed a feel for the wind or because he has simply not lived with his rifle and ammunition long enough to know exactly how they perform.

Each shooter, in getting himself prepared for the important competitions which he will have in his year's schedule, must make sure he has sufficient training time to look at these details of technical preparation. The items which I have suggested here are by no means all of the items of technical preparation to which a shooter must pay attention. Each shooter through his own personal experience should be making mental or preferably written notes about those details to which he must pay special attention in order to really be prepared to fire a match.

If he enters the competition not only with a well dveloped ability to hold the rifle steady and to pull the trigger correctly, but also with a thorough technical preparation, then he will be a potential winner.

The Rifleman's Corner

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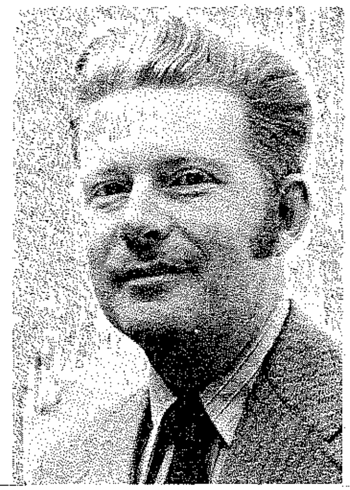


SPORT SHOOTING PSYCHOLOGY

Al Oerter, winner of four consecutive Olympic gold medals in the discus throw, told me he uses three forms of training: weight training, the actual throwing of the discus, and mental training. He said, "Of these, the most important proved to be mental training."

Bill Pullum, who is perhaps the greatest shooting coach in the world, claims that as much as 90 percent of a record shooting performance is mental and not physical.

Makhmoud Umarov of the USSR, an Olympic silver medalist and world champion in pistol shooting, wrote in his book on the psychology of shooting, "the greatest sport shooting meets . . . have become almost exclusively competitions of the emotional resources of the shooters, their moral qualities and their willpower!"

All of these great sportsmen echo what I have come to believe very firmly, that the psychological and mental factors are the most important yet least understood aspects in producing a sports champion. This month I would like to discuss some of my own observations regarding this very important part of winning. There are five basic psychological or mental factors which I would like to consider.

The first of these, motivation, is the key to all the rest. Motivation has to begin with a goal. I know that most young children are told it is wrong to daydream about unrealistic desires, but this is exactly what a future sports champion must do. There is nothing more unrealistic than dreaming about becoming the best in the world, yet most of the Olympic gold medals I know of began as the wild daydream of some schoolboy.

To become a sports champion, motivation and desire in almost fanatical proportions are necessary. It is possible to induce or teach ordinary motivation, but I'm not at all sure the super-motivation of a champion can be transferred. This kind of motivation usually has a history of some kind of previous experience of failure or defeat. It may have been in some other sport or activity in the same sport, but this seems to be a common element in many champions' lives. Motivation thus becomes a form of overcompensation, all of which says that the motivation of the champion is not a normal response at all. If the champion were normal, he would never have become a champion.

Thinking or the disciplining of the thought processes is the second psychological factor in sports victories. Olympic gold medalist Bernd Klingner says a good athlete has his ability in his body and a champion has his ability in his head. I believe I can safely say there is no such thing as a stupid champion shooter. Our sport has become so complicated and its performance standards so high, that is no longer possible to have a coach do the thinking for the shooter.

The shooter himself must discipline his thought processes during shooting so that he automatically goes through a process of analysis after each shot. Both the physical and mental activities of the marksman must be subjected to careful scrutiny. Many people do not realize that the muscles, their physiological reactions and the actions of the nervous system are constantly changing. The shooter will experience many different physiological and mental conditions through the duration of any competition and even greater changes from competition to competition. The consistent champion is the one who has disciplined his thought processes so that he can adjust to the changing conditions of competition.

The regular improvement and growth of the competitor is also dependent on his ability to correct the shortcomings of his positions and techniques. A coach can do some of this for a marksman, but only he himself really knows exactly what he is doing when he fires the shot.

A third psychological factor is concentration. There is a concentration sequence in any sport performance which traces the focus of the competitor's mind through the various physical actions of his event. In shooting, this concentration sequence traces the movements of the rifle from placement on the shoulder to taking and centering the hold to perfecting the hold to release of the trigger to the analysis of the shot just fired.

We know that it is best to have as little to concentrate on as possible — that is, as much of the shooting process should be relegated to the sub-conscious levels of awareness as can be done. Through the conditioning and learning processes that take place during training many formerly conscious shooting actions are slowly relegated to the sub or semi-conscious level. The number of things the shooter must consciously be aware of when he fires a shot are an indication of the state of his training.

Performance is generally best when active concentration is needed on only one phase of the shooting act. For most shooters, this means concentration on the hold and those factors which control the hold. If he begins thinking about other things, the result is usually a poorer performance.

The quality of physical performance is directly related to the quality of concentration. That means the more a shooter can concentrate on holding the rifle steady, the steadier the rifle will be. Intensity of mental effort does improve the ability of the body to perform a physical act such as holding the rifle still.

While most Europeans and Soviet shooters attempt to accentuate their concentration by shutting out the world for the duration of the competition, many of our shooters have developed a methodology of concentration where we interrupt our concentration between shots. Many dedicated shooting spectators have been shocked to see Lones Wigger or myself talking to a spectator between shots. Actually there is a method to our madness, for we believe that constant mental concentration is as exhausting as constant physical effort and that we need to give our mind regular rests from its concentration.

A fourth psychological factor in sports is the mental standards of the competitor. The four minute mile remained unbroken for so long

(Next page please)

because the leading trackmen of that day believed that that barrier marked the limits of human ability. There was a day when a shooter who found himself a few shots away from an 1150 suddenly felt an extra surge of nervousness pulse through his body. Now the magic barrier is 1160 and even 1170 is not too far away.

This is what Bill Pullum meant when he said psychology is so important in determining the result of a shooter. The task of a shooter's training is to establish rigid mental standards that are high enough to win. A shooter will never consistently fire a score that he has not already established as an attainable mental standard.

My own emphasis on mental standards is so great that when I go into an important competition I determine what score I will shoot before the match ever begins. I must fire a certain score for each ten-shot series, and if one score is too low, then I must go over my standard on the next one.

It is important to realize that the sportsman is practically a slave to his mental standard of performance. What the body does is determined by what the mind says it can or should do. The raising of these standards is not something that is done simply by saying, "I am going to shoot ten points higher tomorrow." Every training result and every known score of another competitor helps to constitute this standard. For this reason it is very important to make special efforts to learn the good scores of the good competitors both here and in Europe and to isolate oneself from the mediocre scores of not-so-good shooters.

What the mind does not think, the body cannot do! This is the key to the 1180's and 1190's that will be the rifle scores of the future.

The fifth psychological factor in sports competition concerns the control of pressure. The champion sportsman may not appear to be feeling any pressure at all, but it is just as real to him as it is to the beginner at his first match. Pressure or nervousness is real; it is painful. The sportsman who faces an Olympic competition, for example, has his stomach tied up in knots and endures days of mental torture before the actual event, but he goes through the competition looking like he doesn't feel anything. Others go into competition and have their scores destroyed by the intense pressure.

Many shooting techniques are developed to produce good practice results when the muscles are calm and the pulse slow. Nervousness brings very definite physiological changes to the body such as a faster pulse and more active muscles. The best techniques are adapted for these and not practice conditions.

Many efforts have been made to combat the effects of pressure including alcohol and tranquilizers. I totally reject these approaches because both alcohol and tranquilizers may reduce the sensation of nervousness, but they also reduce the ability of the body to function as efficiently. Tranquilizers, for example, have a very detrimental effect on the will and mental standards.

Nervousness actually is a positive reaction and if the competitor does not fear it, he can use his nervousness to help him hold better, think or concentrate more acutely and control his reactions more precisely. The competitor who learns to use his nervousness will actually do better in competition than in training.

Ability to combat nervousness is improved by being in excellent physical condition. The sustained high pulse rate of matches places considerable physical strain on the body. A shooter in good physical condition will not be affected by the extra effort his body must make.

One of the most effective ways to combat pressure is through mental preparation. Discus thrower Al Oerter and I discovered that we both use the same technique to do this. We both prepare for a competition by mentally rehearsing every conceivable circumstance we could face in the competition itself. Makhmoud Umarov said, "Before the shooter can defeat his opponent, he should have conquered him in his imagination." If the match has been thoroughly rehearsed in the shooter's mind, then he will be so much better prepared to deal with unexpected circumstances that always seem to shake most competitors.

A final way to combat nervousness is through moral superiority. Basically this means having a rational attitude about winning or losing. The competitor whose whole world depends on winning puts a lot of unnecessary pressure on himself. The realities of sports competition dictate that a certain amount of luck is also involved in winning. The real champion is not the man who wins any one specific competition, but is the man whose name is consistently at or near the top match after match.

Benchrest Shooting Primer

Should one be inquisitive about the sport of Bench Shooting, but doesn't know how to start, he should read these instructions:

The act of Bench Shooting consists of sitting at a bench with a rifle resting on sand bags. The object of this position is to eliminate, as much a[illegible]ossible, the errors encountered [illegible]ne process of holding and firing [illegible]le. Bench Shooting is a sport, competitive or individual. The personal satisfaction gained in the ability to place one bullet on top of another, thus making a one hole group at 100 Yards and often at 200 Yards, has captivated an enthusiastic interest of many shooters for this kind of sport. It is particularly suited to both men and women who are not interested in indulging in the more vigorous or active sports. Therefore many Bench Shooters are of the older set. This does not mean, however, that it does not present a challenge to the younger shooter; it will engage and tax his capabilities as well.

The current popularity of this kind of shooting was generated in the years 1949 and 1950. At that time a competitive program was introduced and has since been expanded.

Once an individual has selected the most appealing Bench Class, **it is very important that he attends some of the Matches.** Here he will learn much by asking questions, observing the equipment and methods used for loading and shooting. Any Bench Shooter is more than anxious to help a newcomer.

The equipment needed to participate is available for the most part, from PRECISION SHOOTING advertisers. It includes rifles, telescopes, rests, sand bags, loading tools, bullets, cleaning materials, powder, primers, etc.

Lastly, if possible, get the advice of a person in the game before making purchases.

Should an individual or a club wish further information, write to Mr. Carl U. Lynn, R.D. 2, Box 20, Williamsport, Pa. 17701 or the Editor of Precision Shooting.

Reading the Wi

MOST OF THE problems of competitive rifle shooting can be solved by purely scientific means. Strangely, the one area where the advanced shooter loses most of his points is usually treated as a nebulous art. It is dealt-with by spontaneous reaction to whatever occurs from one minute to the next. No one seems to have defined "wind doping" so that we know what the shooter is really trying to do.

To me, wind doping is observing natural phenomena carefully and combining such observations with an objective appraisal of the results of the last shot. From this combination of observations, the shooter should be able to *predict* exactly where he must aim his next shot to line up all the *odds in his favor,* for the best probability of hitting the scoring ring he needs to hit to win the tournament.

Take note of the terms *predict* and *odds in his favor;* around these two concepts revolves the entire matter of reading the wind.

How important is wind doping in winning a tournament? We assume that the shooter has reached a relatively high level of mechanical performance, and that he has combined his skill with equipment (basically, rifle and ammunition) capable of winning a major tournament. Yet — although a Master-class shooter loses more points because of wind changes than from any other cause — I see wind doping as no more than forty-nine percent of the whole picture.

Why? Because if the shooter's skill and equipment don't enable him to put most of his shots within a quarter to half a minute of the point of aim when the wind is no problem, he hasn't the most important and critical basis he needs for wind doping: where his last shot hit, in relation to his point of aim.

The ability to predict the flight of bullets in varying wind conditions is of different values to rifle shooters. It is of utmost importance to the American smallbore shooter who is completely exposed to the wind and is using a bullet of poor ballistic coefficient with a relatively low rotational speed. It is of somewhat lesser value to the ISU English match shooter, because so often the range is highly baffled. The baffles introduce a host of small variables that probably can not be closely evaluated. It is of greater value to the high-power, long-range shooter. However, his problem is partially mitigated by the high ballistic coefficient of the bullet he uses and its high rate of rotation.

We will discuss the wind problem on the basis that we will dope wind *with our minds.* The sighting bull will be used to prove the accuracy or fallacy of our mental calculations, *not* to formulate the calculation. When you are in trouble, returning to the sighter should be not only permissible but mandatory. However, there is no indication that the wind is less likely to change after a sighting shot than after the previous record shot. As a matter of fact, it is a mathematical certainty that the longer the period of shooting is extended, the greater will be the number of wind changes during this period. This tilts the odds *against* us, the reverse of what we are endeavoring to accomplish.

How foolproof is this wind-doping formula? I believe it's as good as the ability *you* develop to use it quickly and accurately, with the same unconscious, instantaneous reaction you display in driving your car through heavy traffic. I tried many variations of it during my first twenty-five years of competitive shooting. I found all of them wanting. The only shortcoming in the one presented here has been my failure to observe or weigh the variables properly. Whereas I was able to prove its predecessors inadequate, I have not been able to prove that it is anything but accurate and reliable.

As with any computer, we need certain rules in deciding what data to feed into our minds, and in what manner and sequence. If these are faulty, it will be like the computer that mishandles your credit-card statement: "garbage in, garbage out." Later, we will try to offer suggestions on how to gather the data you will need for "processing."

There may be different rules and combinations of rules that could be used to produce good or perhaps better results. However, with the number of national championships and national records that have been fired using this method, you might consider using it until a better one is offered to you. This one operates through the application of six rules. If you are willing to put out the effort to reach your full potential, the use of all six is warranted. In the case of the "fun" shooter, the young or inexperienced shooter, where the desire is to keep shooting simple and uncomplicated, applying only the first two may suffice and be preferable.

Rule One: *sight-in with median conditions,* median both as to wind velocity and angle. The horizontal displacement of a bullet in flight by the wind is a multiple of two factors — angle and velocity. If the prevalent wind condition for the ten or fifteen minutes preceding a match has been a medium flow from seven o'clock, you should be "zeroed" with *that* condition to put the odds predictably in your favor. Any change in wind that you may not perceive — or perceive and still mishandle — will have less chance of costing you a point working from the median than if you had established your zero at some extreme condition such as a lull, a faster flow, a greater angle, or a combination of the last two.

Going a little further with this rule, if you predict and pinpoint them accurately, you may assume that there are *three* conditions under which you may risk continuing to fire: with your basic condition, with higher velocity and a shallower angle, or with lower velocity and a greater angle. You would give up a little elevation because of the variables. Unless you carry it to foolish extremes, you shouldn't penalize yourself.

Rule Two: *fire only when the wind angle is in the quadrant where you* 'nd

Champion marksman George Stidworthy discusses the subject from the standpoint of competition, but the principles apply to varmint and long-range game shooting as well.

established your zero. Divide the range into four equal quadrants. Under rule one, we assume that you may risk firing through changes that contain compensatory factors, where changes in velocity and angle may largely cancel each other out. However, *absolutely no such risk* can be assumed when the angle of the wind changes so much that it moves into another quadrant. Here, it is predictable that the variables *always* have a cumulative effect. For instance, the classic example is to be caught with left windage on your sight and have the wind swing around from a right-hand quadrant. Another is to be sighted with a wind from the rear and have the wind turn and come from the front. Here, you can anticipate an elevation change too great to risk, especially if high banks are involved.

If you applied no other technique than the two above, did it faithfully and intelligently, you would be pretty well served. If wind conditions in an iron-sight match become pretty bad, even some good shooters may find this the best and most predictable approach to playing the odds in their favor. If the wind becomes just plain terrible with iron sights or with a scope, the best of shooters may find that strict adherence to these two rules gives the least risk and the best salvation. Of course, the worse the conditions, the more critical becomes strict adherence to one recognizable condition, especially the angle. If the velocity increases or decreases fifty percent, it is easily sensed. If a shallow angle changes fifty percent, it is extremely difficult to detect, once you are committed to the sight picture.

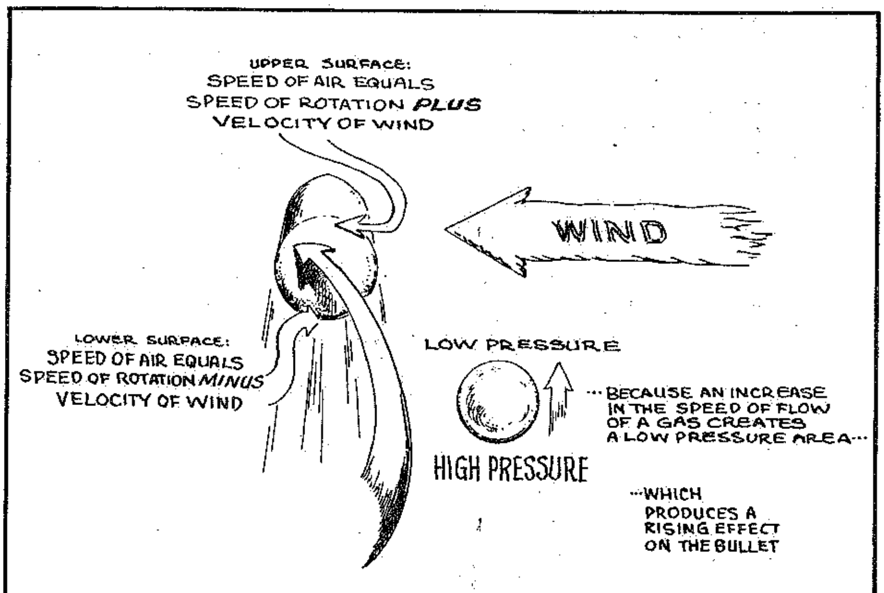
So much for the elementary school of wind doping. Let's move on to high school and finally your PhD.

Rule Three: *start doping the elevation in wind changes.* Anyone who has shot competitively very much, with some degree of skill, has surely observed that wind variations do not move the point of impact of his bullets straight toward three o'clock or nine o'clock. Instead, they move up and down as well. The basic pattern is a four o'clock, ten o'clock diagonal. In keeping with our objective to play the odds fully in our favor, it is immediately apparent that elevation errors add to the chances of losing points. For instance, a left-hand wind that moved a shot to the right would have made a nipper ten if it had hit directly at three o'clock. Instead, it is a nine, because it hit between four and five o'clock. Our philosophy dictates that we appraise and predict the variables that cause concomitant elevation changes.

Whereas the horizontal wind dispersion of our bullets is a multiple of only two variables, velocity and angle, the vertical dispersion is a combination of *four* variables. One, the Bernoulli effect (hereafter referred-to as BE), is basic or inherent. The other three — velocity, angle, and terrain — have the ability to amplify, neutralize, or override BE *or each other.* Some high-power shooters would probably add a fifth variable, an optical displacement of the bullseye caused by mirage. If they believe this, can prove it, and add it to their doping formula, I have no argument. I can say only that at the distances at which smallbore is fired, I can not prove that it exists. I *have* proved to my own satisfaction that it does not exist to any degree that can be predicted and included in *my* wind-doping formula.

Once again, let's first define the Bernoulli effect: wind generally tends to spread groups in a diagonal. If the shooter has observed wind effects closely, he has also noted that the diagonal is not a straight line. In a wind from three o'clock, the impact point tends to move disproportionately higher as velocity increases. Stated differently, our diagonal tends to curve upward toward ten or downward toward four o'clock. Unfortunately, I have no engineering background, only a lot of curiosity. As nearly as I can define it, what I see on my target relative to wind-caused elevation changes is a perfect reaction to the two parts of Bernoulli's law: an increase in the speed of flow of a gas or liquid creates a low-pressure area; and the aerodynamic effect varies as the square of the speed of flow. This is the law upon which the lift of the wing of a subsonic aircraft depends.

What does an airplane have to do with



bullets flying toward your target? Visualize a circle representing the base of a bullet from a right-hand-twist barrel, flying *away* from you, toward the target. With the wind from the right, the speed of the air over the *top* of the bullet is the speed of rotation plus the velocity of the wind. On the underside, the air speed is the speed of rotation *minus* wind velocity. We have, therefore, the equivalent of an airfoil, almost a doubly efficient one. There is a low-pressure area on top and a high-pressure area on the bottom. It is not difficult to see that unless we have been kidding ourselves about airplanes being able to fly, a right-hand wind not only moves a bullet to the left but also has a basic tendency to raise it. The higher the velocity (with no decrease in angle), the higher is the bullet's point of impact.

Perhaps the first thing that flashes through your mind is "how can a bullet spinning so fast be affected vertically by a ten-mile-per-hour wind?" Use your handy-dandy calculator to compute the velocity of the periphery of a .22 Long Rifle bullet. It emerges at about 1,080 feet per second from a barrel with a sixteen-inch twist. It has a diameter of 0.224 inch. It rotates at about thirty-two miles per hour. If we have a ten-mile-per-hour wind, directly from three o'clock, air is passing over the top of the bullet at about forty-two miles per hour and under the bottom of the bullet at twenty-two miles per hour — quite a difference! There is another *big* difference you might calculate while you're in the mood. Run the figures for a .308 bullet emerging from a ten-inch twist, at about three times the velocity of the .22, and with a circumference thirty-eight percent greater. You will see why high-power shooters do not get nearly the amount of vertical dispersion from the wind.

In addition to the basic vertical dispersion of your groups from BE, start to include these other variables in your vertical formula:

A tailwind tends to raise the point of impact.

A headwind tends to lower the point of impact.

Although both the above effects continue to some extent, they decrease quickly as the angle turns closer to three or nine o'clock.

Changes in velocity alter the effect of tailwinds or headwinds as well as BE.

BE tends to decrease as the angle recedes from three or nine o'clock toward either six or twelve o'clock. The speed of air passing over or under the bullet decreases as the angle decreases.

Elevation increases or decreases if the bullet travels through air being swept up or down by terrain features, such as a high bank close behind the target or banks along the length of the range. It has the same basic effect upon your bullet as it would upon an airplane flying near mountainous terrain.

It may take a lot of practice to force your mind to accept all this, to be able to put all the variables together and come up with the right answers under the stress of a match, and within your time limits. However, when you do it successfully, you have the mathematical certainty of "shooting at a larger target" than the shooters who don't dope elevation. You will find that you can spend more time shooting in controlled conditions than the shooter who wastes much prime time on his sighter. If you do it reasonably successfully, the increase in scores and personal satisfaction make it most worthwhile.

Rule Four: *always work from true zero.* Carry in your mind at all times (as nearly as you can "prove" it) exactly what your sight setting is in relation to true zero; how much your sights are changed, both horizontally and vertically, from what they would be for the range if there wasn't a breath of air moving. Let's look at what this puts in your favor.

You are working in difficult wind conditions, and you get a radical change (one from a different quadrant, remember?). You wait and wait, but your condition doesn't return. Finally, you realize that you are going to be forced to resight-in. It's a real joy (and relief) to say to yourself, "I'm six clicks right and two down. It looks as though it's now worth four clicks left and one up." You boldly go ten clicks left and come up three. Fire your shot (*on the sighter* if you're a smallbore shooter) and see it hit well into the X ring. It's a sense of satisfaction that can't be had by firing twenty random sighters while you're waiting and hoping for the return of your original wind condition.

This procedure has another big benefit. It makes predicting how much sight change to make so much easier, and it reduces considerably the chance for stupid errors. Let's take a basically simple wind change, one that stays within your quadrant and isn't severe. You are firing with three clicks left in a rather mild seven-o'clock wind. The wind velocity doubles (that really doesn't make it a tornado). Simultaneously, your angle swings around to about nine o'clock. Millions of points must have been lost because shooters didn't make any correction for such a "little" change or they added one or two clicks. However, if you have your sight setting firmly in mind, and are *working* on your wind-doping, your mind quickly calculates that a doubling of the angle means you need a total of six clicks. If the velocity has simultaneously doubled, you probably need ten or twelve clicks. If you're not crowded for time, it would be smart to wait. If time is short, crank on your prediction and shoot it on the sighter. If you're near the end of the time limit, crank on what you need and shoot it. You know what you need; you're no longer floundering in the wind. Now, you're a wind doper.

Next, let's discuss how you locate where you are in relation to true zero. The ideal would be to have a total calm when you start to sight-in. That's too good to be true, so don't count on it. However, after some months of working from true zero, you will become surprisingly proficient in looking at mirage, flags, and dust to decide the wind's value. Make your guess *before* the start of firing and proceed to prove it or disprove it on the sighter. As you work through changes on the sighter, you should be trying not only to get your shots going into the center of the bullseye, but you should be carefully appraising the effect of each change to prove your zero. Observed phenomena can usually be interpreted to closely define true zero. If either velocity or angle were to double or halve, you have an easily recognized situation upon which you should be willing to depend. However, each shot, whether on the sighter or for the record, should test *objectively* your original or current assumption of true zero.

Rule Five: *predict, predict, predict:* Good wind-doping is inherently prediction. You should carry the idea of predicting so far that you feel like a fortune-teller at a country fair. If you only "chase the spotter," you are always one or two steps behind the condition that will exist for your next shot. This is murder on windy ranges. However, your ability to learn instinctive, near-perfect prediction may be limited by the amount of wind changes on your home range, its lack of flags, its baffles or embankments that keep wind from flowing through it cleanly, or the absence of the terrain features that you encounter at other ranges. However, you may rest assured that the same laws of physics apply equally on all ranges. It is only the difference in the variables and their intensity that differentiates one range from another.

Here is a list of the factors that you should be predicting:

The probable median condition, based generally upon what you observe during the ten to fifteen minutes preceding *the start of the match*

The value of the wind, in relation to true zero, before *you fire your first sighter*

Where your first sighter will hit in relation to the median condition with which you want to get into step. I try to get my sighters going into the target where they should hit relative to observed deviations from the median I anticipate.

The optimum aiming point for every shot. The possibility of zero conditions over an entire range is almost nonexistent. No matter how benign the conditions appear to be, look everything over carefully. Dope what you see, no matter how harmless it looks. It's a good habit to form; it helps to prevent little surprises that suddenly appear and cost you points; it should improve both your groups and scores.

The value both vertically and horizontally of every observed change

When shooting with iron sights, where the bullet will hit by combining the "call" of your shot with any wind change you observe before *you spot the shot through your spotting scope. To keep your prediction "honest," you must force yourself to observe the factors by which you are doping and make your prediction* before *you spot the shot.*

When an observed change has become general over the entire area between you and the target. Predicting how to aim a shot when several conditions exist between you and the target is too difficult to risk.

Expected changes. You can hear or feel changes coming from behind you. Mirage behind or at the target — flags, dust, etc — can warn you of changes coming from the front.

It will also help your predicting if you look upon your sighter as *not* an opportunity to warm up your barrel and fire a few shots to settle your nerves but for you to *prove* the accuracy of your predictions. When you have proved the accuracy of your predictions for three consecutive shots on your sighter, you are ready to fire for record, whether you have fired three sighters or twenty — and not until then.

Rule Six: *have a battle plan.* Move this most important aspect of good shooting out of the category of tactical improvisation and move to the heights of strategic planning. Before starting a match, you should calculate what you "expect" your median conditions to be; the variations from it that you can expect to encounter; how you intend to handle those changes; and — especially — what you expect those changes to do to your bullets' impact. Your battle plan should be a mental preview of the match you are about to fire, all the anticipated problems and their solutions. Napoleon once said he never made plans for what he'd do if he won a battle, only what he'd do if he lost it. *Your* battle plan should revolve mainly around the problems ahead.

I have outlined a plan of attack. Next, let's examine the various means by which we can collect information on the variables you will be struggling with. I will list them in the order of their helpfulness to the shooter (as I see it):

Mirage

Basically, mirage is refracted light rays. To some shooters, it's an evil thing. It distorts their sight picture. It makes spotting shots difficult, sometimes impossible. It makes their "hold" worse than usual. On the other hand, the patriarch of American smallbore shooting once described it as "wind you can see." He's right. That's the reason I look upon mirage as a shooter's best friend.

Mirage is the only doping aid that reaches right out to the target and tells you what's happening *there*. If there is considerable space behind the target, and if you have basically a head wind, the mirage *between* the targets also tells you what is heading toward you and will soon affect your bullets. Since you are basically looking at the air itself, its reaction to change is immediate, with no lag, as there is with flags and dust. You're looking at what will *soon* affect flags and dust and what is *already* affecting your point of impact.

It's the only doping factor that has depth. Flags, wind dopers, dust all tell you only what the wind is doing where they are. However, in reading the mirage off the face of a one hundred-yard target, you are seeing what the wind is doing for at least twenty yards in front of the target. What is also important is that it is showing you what the wind is doing at the level above the ground where your bullets are traveling. It practically computes the relation of angle and velocity for you. Since you see this air moving past a fixed point (your target) from another fixed point (your spotting scope), you can see the true sidetravel, the same way you could tell whether a person riding a bicycle back and forth across the scope field was crossing from the left or right, going faster or slower.

Learn to read mirage; forget its distortion. Pretty soon, you'll miss it when it isn't there to guide you. Since mirage is distortion, you can see it most readily in the most distorted area of a scope, the rim of the field. Hence, if the mirage is thin and difficult to see, adjust your spotting scope so that the bottom of your target frame is near the bottom of your scope field. However, if mirage becomes really heavy, making spotting difficult, set the bullseye you're shooting at in the middle of the scope field where you can spot bullet holes best. You won't have any trouble seeing enough mirage for doping.

Read your mirage as it passes along a horizontal line. The top or bottom line of the lower target number board, right next to the ground, is ideal. As you observe the mirage closely, you will note that it resembles the lines on an audio oscillograph. Like an oscillograph, it has two dimensions, frequency and amplitude. The slower the wind, the higher the amplitude and the slower the frequency. Conversely, as the wind speeds up, the amplitude decreases, and the frequency of the blips increases. If the blips bob wildly but seem to have no horizontal movement, the wind is flowing directly from either six or twelve o'clock. At about fourteen miles per hour, the amplitude is gone, and the lines are horizontal. Then, alas, you're in trouble. The mirage becomes useful again only if it reappears — warning, of course, that it is slowing down.

If possible, read mirage with the spotting scope focused sharply on the target. This will give you true wind speed downrange. If it is necessary to "back off" the focus (toward the firing line) to see an interpretable mirage, do so. The further you back it off, the faster the mirage appears to travel. You are then dealing in relative rather than actual horizontal speeds. To check this, sometime when you can read it well with the scope sharply on the target, start backing it off. You will be surprised how much and how quickly this appears to increase the apparent speed of flow.

Line Wind Dopers

Shooters have used everything from cigarette smoke to cotton balls on strings to indicate wind at the firing point. If you will learn to use it, one of the Raymer-Stephens dopers is extremely helpful for the smallbore prone shooter. You can make a fair appraisal of wind velocity from the sound and spin of the propeller. A change in the sound will often alert you when you are committed to your sights. It should be placed so you can see any major angle changes even while aiming. Its main value is giving you your best look at the angle of the wind. With the stabilization of its propeller, it's the most reliable indicator of angle changes.

Flags

Flags have a lot of strong points and a lot of shortcomings as aids to wind doping. Their weak points: They *must* be either too high or too low not to interfere with the targets. A flag shows a different angle from every firing point on the line, and every flag shows a different angle from the same firing point. It requires a certain "translation" on the part of the shooters. They tend to lag in reacting to wind changes. The majority of range flags are poorly designed and mounted. Most range flags give me the impression that their designer never shot, never shot well, or never bothered to watch his own handiwork. The ideal flagging material is twin strands of surveyor's tape about two and a half to three feet long. The angle shows well, and the flicking of the tips gives a pretty fair indication of velocity.

Their strong points: They're your best midrange dope if you can get tournament sponsors to mount them so they can be left at midrange. If they are mounted all over the range, including the corners, you can get a lot of warning by watching those flags *upwind* from you. You may even be lucky enough to draw a firing point where one of them is visible while you are aiming.

Dust

Dust can be a big help on some of the windy southwestern ranges. Like flags, it can be watched for a considerable distance *upwind* to give warning of changes. If there are high banks in the range area, the dust gives good indication of whether the wind is flowing along the banks or flowing up or down them. In the latter case, it indicates that you can expect sizable elevation changes.

Little People and Little Voices

There is nothing illegal or immoral about using other shooters' troubles to help your own doping. At the longer ranges, where your spotting-scope field can include your neighbor's target, divert it enough to see his as well as your own. Be sure to "use" the neighboring shooter whose abilities you trust most. The ultimate blessing is to be squadded next to an upcoming Junior, one with a good outfit, who holds like a rock, and holds dead center no matter what the wind does. Very few shooters, under the stress of a match, remain strong, silent, long-suffering Stoics. Consequently, little voices along the line can often be heard calling wind changes for you. Listen to them.

Grass

Some eastern and midwestern shooters seem to do a pretty fair job of doping grass on the range. I've never had much luck with it, but it's worth mentioning. When I finally resort to watching grass, I'm *really* desperate, and I have the feeling that I'm courting a fickle mistress.

In conclusion, a few miscellaneous notes: You must become merciless in appraising your own performance on the previous shot. Its point of impact is the unimpeachable proof that the combination of your mechanical performance and your prediction of the wind was good or bad. A fault in one must not be allowed to influence your judgment erroneously for the next shot. It helps my mental process if I picture the entire range area as a dry lakebed into which a wide river is flowing. However, instead of water, it's wind, but the action is exactly the same. This helps to dispel the notion that when a change occurs in one sector of the range, it will occur instantly all over, as some shooters seem to expect.

To play the odds in your favor, the place for the center of your group is in the *center* of the target. Such ideas as letting your group form toward the wind "because it might pick up" are completely fallacious. The wind is no more likely to increase than it is to decrease. Letting the group form anywhere except in the dead center is playing the odds against yourself. The only exception to this suggestion that might be in your favor would be to let the group form a little (not more than one click) *down*wind. The reason: a pickup gives you all kinds of warning. You can usually hear it, feel it, and see it. On the other hand, a decrease is insidious and lulls you into a false sense of security — therefore the possibility of gaining a small edge by slightly favoring a decrease in wind flow.

It is difficult not to be trapped by starting to dope entirely by individual shots. Never forget that the idea is to put *all* the shots in the group into the winning scoring ring. Therefore, you must make your predictions to center the *group*, not any one shot.

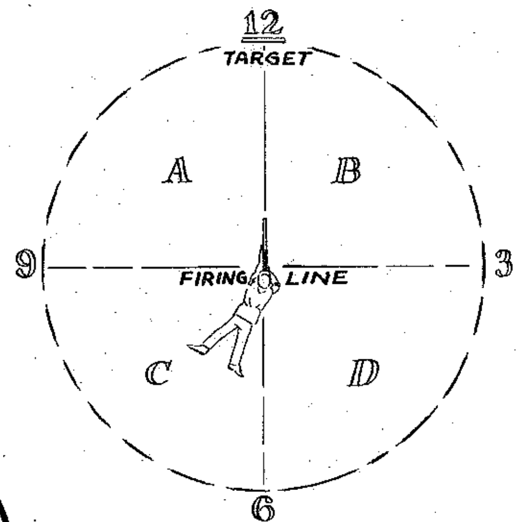
Your increment of doping should be a quarter of a minute or less. The rifle-ammo combination must be capable of putting ninety-five percent of its shots within the quarter minute you are trying to dope. Trying to learn wind doping by using cheap "practice" ammo that doesn't group too well is wasting both time and the cost of the cheap ammo.

Never fire a shot when there is a buffeting wind at the firing point, one that you can feel blowing with a "quivering" action. Strong winds can be predicted, but buffeting winds never. The rifle's ability to group seems to break up completely. I suspect, but can't prove, that the reason is this: after leaving the muzzle, a bullet yaws for a way before attaining gyrostatic stability. If it is flying through an erratic buffeting at this time, each bullet could be nudged into a different and unpredictable flight path.

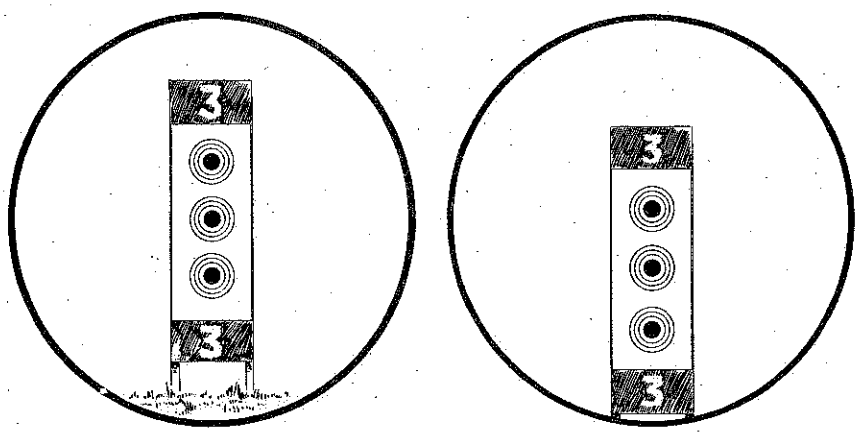
The foregoing is a summary of the observations and conclusions from thirty-nine years of open warfare with wind in all four corners of the United States. I believe the principles to be accurate. At least, I have not been able to fault them as I did previous systems. You won't learn to use them intuitively overnight. On the other hand, if you work with them every time you shoot, their use becomes progressively more automatic and reliable.

Reading the Wind... Addenda

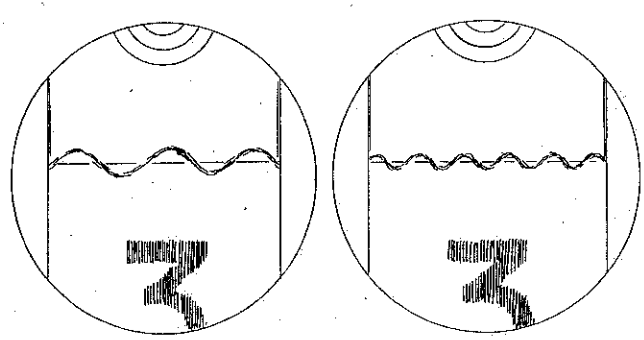
George Stidworthy's article in *Rifle* 74 elicited quite a bit of interest. While it described wind-doping techniques thoroughly, some comments and questions indicated that additional graphic explanations would be in order. We contacted Stidworthy and collaborated with him to produce the illustrations below.



The shooter should mentally picture himself at the center of an area divided into four quadrants. The "clock" reference points are generally used in referring to wind direction; the orientation of these reference points remains the same and does not change with variations of wind direction.



To be able to spot individual shots when mirage is fairly heavy, it may be not only permissible but necessary to center the bullseye in the center of the spotting scope's field of view — in its area of greatest optical resolution (left). However, if the mirage is light and difficult to see, it may be necessary to position the spotting scope so that the area where you can read the mirage (close to the ground) coincides with the most distorted section of your scope's field of view, its outer edge (right).



When read against a horizontal line such as the target frame, the appearance of mirage is almost identical to the display trace of an oscillograph. It has both amplitude and frequency. When it is slow, it looks pretty much like the left-hand illustration. As wind velocity increases, the amplitude decreases, and the frequency increases (right).

Fundamentals of Wind Doping

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There have been so many excellent articles on the subject of wind doping in smallbore rifle shooting, that I begin to write this with some misgivings. What I hope to accomplish here is to present an over-simplified doping strategy from which the beginning shooter may gain experience and ultimately develop his own doping methods. At the onset, it should be mentioned that the article is structured around outdoor prone smallbore, although some of the principles may apply to all phases of shooting.

First of all, what is wind doping? Fundamentally, wind doping is the ability to determine that the wind is blowing from a particular direction at a certain velocity. It is important to know the direction or angle with some degree of precision; it is not important to know the absolute velocity. How do you go about reading the wind? Use everything you can see, feel, hear, or smell. While your shooting can be somewhat mechanical and automatic, all your senses should be in tune with the wind. Flags on the range, a ball of cotton on a string, a simple weather vane, or the feel on your face can all be used to detect the angle of moderate to heavy winds. Mirage across the face of the target, the movement of grass or bushes, or the rustle of leaves in the trees are all indicators of the relative speed of the wind. For very light breezes, mirage across the face of the target is probably the best indicator of both speed and direction. Notice from these descriptions that it is quite often necessary to use two or more of your senses to determine both velocity and angle of the wind.

With practice, learning to read the wind becomes a relatively easy task. Knowing what to do with this information is the hard part, and that is the purpose of this article. Earlier it was stated that knowledge of the absolute velocity of the wind is unimportant. That sounds like a pretty radical statement, so I'd better address the subject now. Simple logic tells us that if the wind is uniform in both angle and velocity, the same scores may be fired as if there were no wind at all (assuming of course the shooter's position is not disturbed in the process). From this it may be deduced that the uniformity of the wind condition plays a more dominant role in the shooter's ability to produce good scores than the absolute velocity. This premise leads to the first rule:

RULE No. 1. Select a wind condition which is easy to quickly identify by any means at your disposal, and shoot as many shots as possible in this same condition.

This rule dictates that the shooting cadence must be constantly varied to fit the wind conditions, and development of the ability to shoot quickly will make maximum use of a favorable condition. Care must be exercised, however, not to sacrifice control for speed. The best example I can offer is my personal experience.

When I recognize my favorite wind condition, the feeling I get is a sense of controlled urgency. I spend the minimum time necessary to obtain a good sight picture and a controlled trigger squeeze (usually less than five seconds). Between shots, I will take the time required to locate the position of the last shot and get another reading on the stability of the wind. The whole process takes ten to fifteen seconds per shot, and although I can shoot faster, I don't believe I can maintain my awareness of the wind at the more rapid pace. Each shooter should develop his own speed by staying within his physical limitations and his ability to read conditions. Both will improve with experience. The most important thing to emphasize at this point, however, is not the rate of fire, but watching for a change in conditions.

To the new shooter, identification of the right wind condition may also pose a problem, and I can't overstress the value of non-competitive practice. Personal experience is the best teacher, but a few pointers may be given here. For example, if the wind has a slow variation in velocity, but is predominantly from one direction, the mirage is a good indication of changes. Quite often, it is better to pick the condition when the mirage is running rather than when the wind dies. Small variations in speed are easier to detect during a running mirage, and the chances for getting caught in a direction switch are minimized. As a general observation, I have noticed that a pickup in wind velocity is less subject to angle change and is usually more stable than a let off. Getting back to the point of watching for a change in conditions leads to the second rule:

RULE No. 2. When a change in the wind condition is detected, STOP! Don't gamble. Either wait it out, or go back to the sighter.

The choice of what to do at this point is determined by many factors. How much time remains? Is it merely a change in speed with no change in angle? Is it a totally new condition? If so, is it stable enough to make it worthwhile sighting in again? Can you recognize this new condition as easily and quickly as the one you started out with? If for any reason you feel uncomfortable with the new condition, the best advice is to wait. In other words go back to Rule 1 and wait for a condition you like. It might not be the same one, but if you can identify it quickly, it will do the job.

RULE No. 3. Whenever there is an element of doubt about the stability of a wind condition, check it on the sighter.

The usual thing that will trigger this doubt is a record shot which didn't go where it was expected — a scratch ten, or an unexplained elevation change. Don't assume the bad shot was a control problem unless it can be positively identified as such. There may have been a slight change in the wind which went undetected. If the sighter confirms a wind change, then apply Rules 1 or 2 as applicable. Don't return to the record target until you are satisfied that you are reading the new condition correctly.

RULE No. 4. Use the sighter as a measuring tool to determine the effect of any particular wind condition.

It is not necessary to memorize a lot of rules or mathematical formulae about the deflection of the bullet for a wind of "X" miles per hour at some specified angle. In the first place, few people can estimate the absolute velocity of the wind without the aid of instrumentation. In the second place, you would spend more time doing arithmetic than shooting on some ranges I know. The scoring rings on the sighter make a very convenient tool for measuring bullet deflection, particularly with telescopic sights. For example, the distance between rings on the 100 yard target is one inch. The drift of impact from the point of aim may be estimated very accurately using these rings. Care must be exercised, however, to watch for elevation changes with a corresponding horizontal drift. In general, the change in elevation is to 4 o'clock for a wind from the left, and to 10 o'clock for a wind from the right. A rule of thumb for any given horizontal correction; take one-half the correction in elevation, although this may vary from rifle to rifle and also between lot numbers of the same ammunition. The shooter should be thoroughly familiar with the characteristics of his rifle and ammunition before entering an important tournament.

Up to this point, much emphasis has been placed on the use of the sighting bull as a doping aid. It might be worthwhile to digress for a moment and talk about how to use the sighter efficiently. Nothing is more frustrating than to be down to the last two or three shots — short on time — a big switch in conditions — and the sighter looks like it had been used to pattern a shotgun! A few tips are offered here to help minimize that situation, particularly when shooting with irons. If the sighter is used heavily to check changes in condition, estimate the change and make a sight correction before firing. This will reduce the total number of shots in the nine ring, and make it easier to find a shot later in the stage. If the ten ring on the sighter is shot away, horizontal drift may be estimated by shading the sight picture to 12 or 6 o'clock. Similarly, elevation changes may be checked by shading 3 or 9 o'clock. The shooter should practice this shading technique to develop his confidence before attempting it in an important tournament. With telescopic sights, the advice is similar. Try to save a portion of the sighter in case it is necessary to go back late in the stage. Last but not least, don't use the sighter unnecessarily. Only use it to check conditions that you think you want to shoot in. If you don't like the looks of any particular condition, wait it out.

RULE No. 5. Play the percentages and always dope for a safe ten. Remember, they count the points first.

There is a sub-set of rules to go along with Rule 5, and these are derived from the logic or probabilities. If the wind is quartering; i.e., 8 to 10 o'clock, or 2 to 4 o'clock, and moderate to heavy, the most probable change in condition is a velocity change. Therefore by slightly over-doping the drift as noted on the sighter, a safe ten will be assured for either a small pick-up or let-off from the original condition. Conversely, if the wind is blowing from 11 to 1 o'clock or 5 to 7 o'clock, the most probable change is an angle switch. A slightly underdoped hold will minimize the chances of getting caught in the switch. If the wind is light to moderate, these rules do not apply because a small change represents a larger percentage of the original condition. In this situation, the hold should be as indicated by the drift on the sighter. Using the safe ten approach to doping may initially produce a lower X count. However, as experience is gained, confidence increases, and eventually your shooting should result not only in higher scores, but also more X's.

RULE No. 6. If you believe that the mere reading of this article will improve your scores, you are sadly mistaken.

Nothing in this article can, by itself, improve your shooting under adverse wind conditions. The only way to effect a consistent improvement in the wind is to utilize all the fundamentals and develop your own shooting strategy. All the doping tips or techniques that anyone can offer are worth every little compared to your own experience. In the final analysis, you are the best judge of the particular technique which suits your style of shooting.

The final advice is a lesson in psychology. How many times have I seen a shooter give up after firing a bad score in very tough wind conditions, and then watch his competitors fall by the wayside, one by one, in succeeding matches. How many times have I done it myself? The lesson is, when you think you've lost the aggregate — you've lost the aggregate! Many shooters psyche themselves into thinking they must shoot a 20X possible every time they lie down. When they get clobbered by rough conditions, they become demoralized. The wind is your adversary, but to conquer it, you must first conquer yourself. The virtues of a champion are dedication and patience, but most of all patience. Your goal should be, that after each 20 shots, you should be able to say to yourself, "I fired the best score I was capable of under those conditions; if someone beats me, I'll have to try a little harder next match." Good luck and good shooting.

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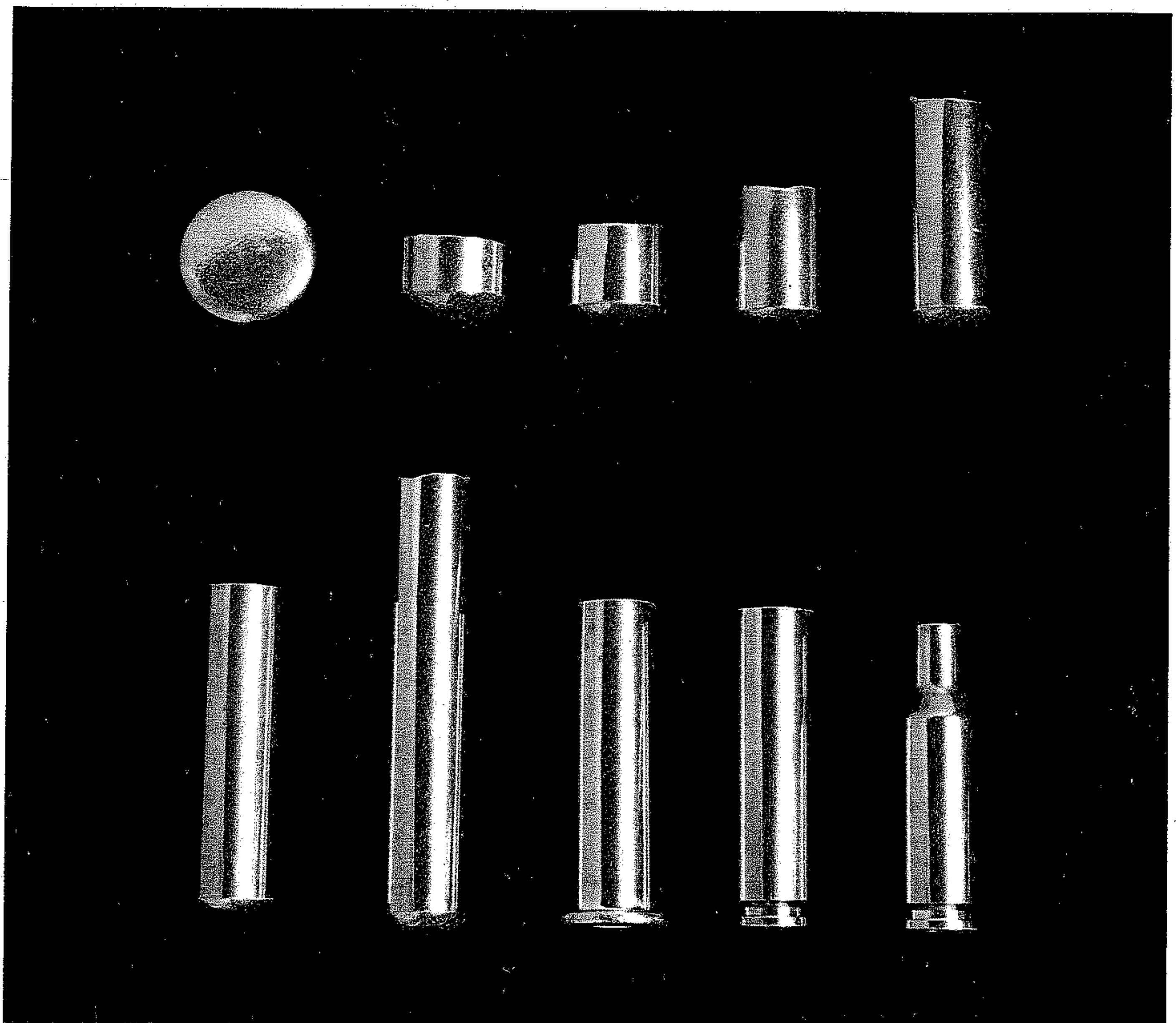

Cartridge Brass From Disk To Final Form

August 1995

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