DOND'S FULL DISTANCE CLINIC
COURSE OF FIRE
FOR RWVA®

Second Edition - Revised

PREFACE

This Full Distance Clinic is designed to incorporate KD concepts, including KDAQTs, and also to continue to greater distances. Portions of the Instructor Manual have been included so that this is now a stand-alone document. There is one exception to this. That is a discussion of the first part of the Sample COF included in the Instructor Manual which gives a review of the basic fundamentals of an Appleseed event.

My goal with this material is to foster an understanding of the concepts involved rather than to simply present material as fact with the assumption that it will be taken on faith and memorized. For example, instead of simply throwing equations out in a magical fashion with mysterious numbers in them, I attempt to derive them in a logical fashion using nothing more than simple mathematics. And if the resulting equations are desired to be transposed into a different set of units, such as different angular or distance units, explanations are supplied, along with examples, to accomplish that task. However, while doing this, especially in the section on range estimation, more mathematics is used than you may be accustomed to. If that is the case, I urge you to not let your mind shut down in immediate despair, but to try and follow it through. If you can do that, the results will be rewarding. On the other hand, if that can't be managed, please don't become discouraged because the results are summarized in a separate section and can be used directly from there. Furthermore, because of probable difficulties with the mathematics, the more tedious portions of it should not be presented at the event. However, the simpler aspects, and the results, should be covered.

There will probably not be sufficient time to explain everything in this manual during the event. The more important items, however, will be presented. Therefore, you are encouraged to study the entire manual beforehand and come prepared with any questions you may have. This will help ensure that you will be a much better informed Rifleman. It should also save much time and allow more shooting at the event.

Some may well contend that desired content has not been included in this manual. However, considerable thought has been devoted to its inclusions and omissions. But as with any COF, alterations can always be employed if deemed necessary.

The KD requirement can be satisfied in a couple of ways: (1) A regular KDAQT with a score of 200 or above. (2) Shooting a KDAQT at D targets with no scoring rings for 80% hits (40 hits out of 50 shots). Hits will mean in or touching the black 4 or 5 rings. No .30 caliber rule is permitted. For either of the above methods, doubling Stage 4 is acceptable.

Some equipment which should be brought to the event is listed below.

Notebook and pen: A three ring waterproof binder with 8 ½ x 11 sheets will probably work best.
Scientific Calculator: These can be obtained for about $10 to $15.
Metal tape measure.
Typical outdoor supplies, including water and snacks, and, I suspect, lunches.

FULL DISTANCE COF

HISTORY: History is to be given in the mornings and at lunch. The history presented may depend on the background of the shooters – whether they have been to a previous Appleseed event or not.

Beginning: Depending on the participants, go over the pertinent portions of the first 11 pages of the Sample COF in the Instructor Manual.

Three Challenges of a Rifleman:

There are 3 challenges which a Rifleman faces in his task: (1) Target Detection, (2) Range Estimation, and (3) Making the Shot. The latter (i.e., Making the shot) constitutes the bulk of the material presented at an AS, and it is the easiest of the 3 according to AS policy. Range Estimation will be discussed shortly, and the equations presented then could easily place it in contention as the easiest of the 3, provided an object of known size is available at the distance in question. In hunting situations the typical sizes of the animal being hunted can serve as an object of known size in order to determine the distance to the animal. However, in hunting situations it is absolutely critical that targets be identified with certainty. Otherwise devastating situations can occur.

Target Detection is considered to be the most difficult of the challenges of a Rifleman. Generally the topics involved are fairly obvious; therefore, little time will be devoted to them. Perhaps the easiest property of a target to detect is a possible movement. Similarly if its color or shape offers contrast with its surroundings, detection will be easier. If the target produces direct or secondary sound, that could lead to its detection. Lacking direct observations such as these, detection can be very difficult indeed. Systematic scanning with optical devices will then prove useful.

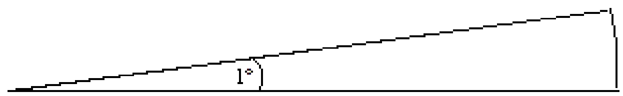
IMC:

Inches – Minutes – Clicks (IMC) is the method a Rifleman should use to take the information on a target and adjust the rifle sights to move the existing Point of Impact to the desired POI. It is also a method used to measure group sizes independent of range. But before this topic can be introduced and explained, most of the shooters must be able to shoot groups which are defined well enough that their centers can be determined. The center of a group will be the existing POI, and it will be the shooter's duty to place this point onto the desired POI, which will be the center of the target. Many shooters seem to approach this task by a lengthy series of sight settings based mostly on guesses. This is inefficient, time consuming, and expensive. A true Rifleman must be able to do this quickly, using a well-defined procedure with which he/she must be very proficient. And since there is an angular relationship between the line of sight to your target and the line of sight to your existing POI, this procedure must hinge upon angles. In addition, most rifle sights, and especially scopes, are based upon angular relationships. Therefore, this discussion must begin with a study of angles.

Minutes of Angle

Suppose you are looking at the vertical and horizontal crosshairs in a rifle scope. You are seeing four 90° angles. If you consider the top right 90° angle, it is easy to imagine ½ of it, a 45° angle, or a smaller angle, say 30°, or even a 1° angle (see Figure 15).

Figure 15. A 1 Degree Angle



The descriptions below will be enhanced tremendously with visual aids. An excellent method is with a white board, which may be transported with some ease. But if this is not possible, an alternative is to draw it on poster board which may be rolled up for transport.

Suppose that your rifle's sights are directed at the center of a target 100 yards away. Imagine a line drawn from your sights to the target center. Consider another line drawn from your sights to the point of impact on the target sheet which makes a 1° angle with the original line to the target center and which lies directly above the target center. You will find that the point of impact will lie 60 inches above the target center. We have constructed a triangle with the side opposite the 1° angle having a length of 60 inches. Therefore, it is clear that if we wish to make precise sight adjustments, an angle much smaller than 1° will be required. This could be achieved by dividing the 1° angle into 60 equal parts. Each of these smaller angles is defined as 1 minute of angle (MOA); or to state this another way, 1 MOA = $^{1}/_{60}$ of a degree.

Furthermore, if we examine our triangle again, we can see that if we divide the 1° by 60, resulting in 1 MOA, that the side opposite that angle, 60 inches, must also be divided by 60. Therefore, it will become 1 inch, which is an acceptably small unit of measurement for sight adjustment. Therefore, suppose we miss the center of our target by 1 MOA at 100 yards. The point of impact would lie only 1 inch above the target center, at least to a very good approximation.

To apply this unit of measurement, MOA, to different distances, construct an exaggerated triangle with 1 line drawn to the target center and another line making an angle of 1 MOA above the first line. The remaining side of the triangle will be 1 inch at the 100 yard target. Now extend both of these longer lines to greater distances. At 200 yards the distance between these lines will be 2 inches; at 300 yards the distance between these 2 lines will be 3 inches (see Figure 16); at 1,000 yards the distance between these 2 lines will be 10 inches. Therefore, if you miss your target by 1 inch at 100 yards, you will have missed your target by 1 MOA and will have to make a 1 MOA adjustment to your sights. If you miss your target by 5 inches at 500 yards you will have missed your target by 1 MOA and will have to make a 1 MOA adjustment to your sights. Therefore, it could be said that 1 MOA is represented by 1 inch per 100 yards.

Figure 16. Minute of Angle at Distances

It also follows that if you miss your target by 3 inches at 100 yards, you have missed by 3 MOA, and if you miss by 4 inches at 200 yards, you have missed by 2 MOA.

Let us consider the 1 MOA triangle again, but at distances less than 100 yards. At 50 yards, 1 MOA would be represented by ½ inch, and at 25 yards, 1 MOA would be represented by ¼ inch. Since most of our shooting will be done at 25 meters, and there is little difference between this distance and 25 yards, this latter figure will be of utmost importance to us. Thus, if you miss your target at 25 meters by ¾ inch, horizontally or vertically, you must make a 3 MOA adjustment to your sights. If you miss by 2½ inches, you must make a 10 MOA adjustment.

At this point on the white board, you can place a group of dots representing a group at 25 meters. Tell the shooters the diameter of the group and then ask them what the group size is in MOA. Then indicate the center of the group. This would be your POI. Also indicate the target center. Then draw a horizontal line and a vertical line through the center of the target. Indicate the perpendicular distance in inches from these lines to the POI, and ask the shooters how many MOA, horizontally and vertically, they would have to change their sights to place the POI onto the target center. Then how many clicks would they have to make if their rifles had 1 click per MOA, as many older military rifles do. Then ask how many clicks they would have to make with their scope if it was 4 clicks per MOA. You can tell them that most scopes, but not all, do have 4 clicks per MOA. Some scopes have 2 clicks per MOA and some have 8 clicks per MOA. It will enhance the shooters ability to understand this if you consistently use the expression clicks per MOA rather than MOA per click.

This process is simplified by the 1 inch square practice targets in current use at 25 meters. The 1 inch squares are placed on a grid of ¼ inch squares. It follows that each of these ¼ inch squares represent 1 MOA. Therefore, to determine how to adjust your sights, you simply count the resulting number of squares from the point of impact to the center of the 1 inch square target, both horizontally and vertically. Then adjust your sights by the appropriate number of MOA in both the horizontal and vertical directions.

We must determine which direction to move the POI onto the target. A rifle scope will indicate the appropriate direction to move the POI onto the target. With iron sights, the rear sight is moved in the direction you want the POI to move. The front sight is moved in the opposite direction you want the POI to move.

An alternative explanation which is frequently used is to compare the rear sight with a well-behaved and considerate child who does what you tell him/her, and compare the front sight with an unruly and contentious child who always does the opposite of what you tell him/her.

The only thing remaining now is to relate the rifle's sighting mechanism with the number of MOA needed for adjustments.

Clicks

Many sights operate with a detent mechanism such that the number of clicks will correspond with a number of MOA. For example, 1 click of the sights on a typical Garand or M1A will correspond with a 1 MOA adjustment. Therefore, we could say that the sights on these rifles have 1 click per MOA. Most, but not all rifle scopes, have the description of: ¼ inches at 100 yards. Thus, 4 clicks would be required to move the POI 1 inch at 100 yards. Therefore, such a scope would have 4 clicks per MOA. The process of sight adjustments, therefore, can be reduced to a simple 3 step procedure.

1. Determine the number of INCHES which the POI must be moved, horizontally and vertically, to bring it onto the target center.

2. From these numbers of inches, determine the number of MOA, horizontally and vertically, required to bring the POI onto the target center.

3. Then, knowing the number of clicks PER MOA for your sights, calculate the number of clicks required to accomplish the task, horizontally and vertically.

Rifleman's Quarter Mile:

A Rifleman should be able to shoot 4 MOA with a stock rifle and ammunition, using only a sling. At either 25 yards, or meters, this means being able to place all his rounds in a 1 inch square. Let's continue this concept out to larger distances. You should remember that 1 MOA at 100 yards is represented by 1 inch, and shooting 4 MOA means hitting a 4 inch square at that distance. At 200 yards, 1 MOA is represented by 2 inches, and shooting 4 MOA means hitting an 8 inch square. Likewise, at 300 yards, 1 MOA is represented by 3 inches, and shooting 4 MOA means hitting a 12 inch square. At 400 yards, 1 MOA is represented by 4 inches, and shooting 4 MOA means hitting a 16 inch square. At 500 yards, 1 MOA is represented by 5 inches, and shooting 4 MOA means consistently hitting a 20 inch square.

Since the width of a man size object is approximately 20 inches, this means that a Rifleman can control everything within 500 yards, and this is called the Rifleman's quarter mile.

Furthermore this tells you that if you can place all your rounds into a 1 inch square at 25 yards, then you could hit a man size object at 500 yards. This is the definition of a Rifleman.

KD example of IMC at 300 yards:

Suppose you are shooting a target at 300 yards. Your group size is 9 inches and its POI is 12 inches above the target center, and 6 inches to the right.

How large is your group in terms of MOA? ______

What corrections should you make to your sights, assuming your scope says ¼ inch at 100 yards?

Horiz: _____ MOA; ______ Clicks

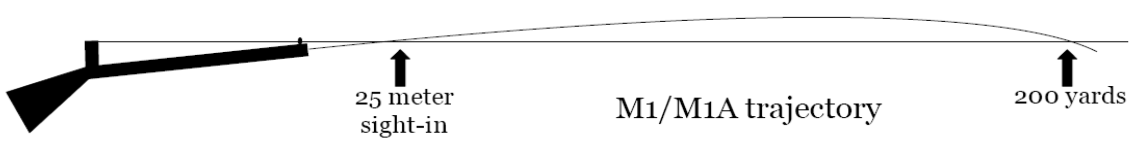
Vert: _____ MOA; ______ Clicks

Trajectories:

Consider 2 balls rolling along a flat table top which is located on a flat floor. One ball is rolling very slowly and falls off the table almost vertically, while the other is rolling very quickly and lands on the floor at a considerable distance from the table. Assume that they both leave the table at the same instant. As they leave the table, gravity will act on each of them in an identical manner. This means that they will both strike the floor at the same instant. A bullet fired from a perfectly horizontal rifle barrel will behave in very similar manner. A rock dropped from the same height as the barrel at exactly the same instant the bullet leaves the barrel will strike level ground at essentially the same instant that the bullet does. Therefore, if a bullet is to strike a target at the same horizontal level as the muzzle of the barrel, the barrel must be tilted upward. Indeed, the same phenomena can be observed easily by throwing a ball to a companion at such a velocity that the ball follows a path which rises and falls in a parabolic path. Since the ball will be traveling at a slow speed, it won't be affected by air resistance; however, by virtue of its high speed, the bullet will be affected by air resistance. Therefore, it will slow down in its path and will depart somewhat from true parabolic motion. It should be emphasized that even though the bullet is traveling upwards, it is still acted upon by gravity in the same manner as everything else. Therefore, it will begin falling the moment it leaves the barrel due to this effect. This means it will be falling away from its initial straight line path which it had in the barrel. Perhaps it should be mentioned that other forces will also be acting on the bullet. Some of these will be mentioned later, but they will, for the most part, not be pertinent for the relatively elementary discussion presented here.

Suppose you are firing at a target which is 25 meters distant. Let's assume you are firing a .30 caliber M14. The bullet will continue on a near parabolic path and strike a target 200 yards away at the same level as the target at 25 meters. This means that the rifle barrel had to be tilted upward slightly and the bullet was rising as it struck the 25 meter target, and falling as it struck the 200 yard target (see Figure 17). In other words, if the rifle is zeroed at 25 meters, it will also be zeroed at 200 yards. This is a very good approximation, but would have to be confirmed for each rifle and choice of ammunition. Similarly, if an AR .223 rifle with the rear sight on a carry handle is used, and is zeroed at 25 meters; it would also be zeroed at 300 yards, at least to a very good approximation.

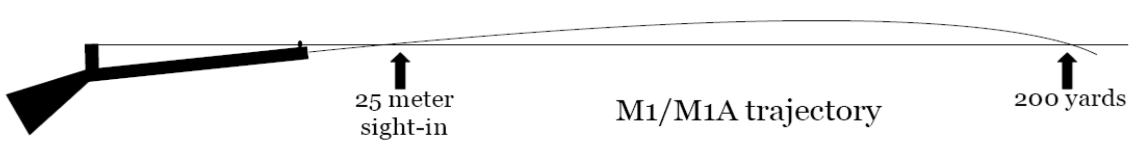
Figure 17. 30 Caliber Rifle Trajectories



This means that if you zero your M14 at 25 meters, you should be able to go to a 200 yard range and hit a target there without changing your sights or your Sight Picture. The same would hold true for an AR .223 at a 300 yard range. At least this procedure should get you on paper, and an application of Inches - Minutes – Clicks (IMC) can be used for more precision targeting.

It should be noted that while the rear sights on M1 rifles are indicated in yards, M14s and ARs are indicated in meters. When sighting in an AR at 25 meters, the rear sight should be set on 300 and vertical adjustments should be made on the front sight. For sighting in M1s and M14s, the rear sight should initially be set from 8 to 12 clicks from the very bottom. When the sighting in process is confirmed at 200 yards, or meters, count the number of clicks required to bottom out the sight. While at this bottom sight setting, loosen the screw in the drum on the left side of the rear sight. Then holding the drum with your fingers, retighten the screw, being sure that the rear sight does not move in the process. One thing you must avoid in this entire process is holding the drum with pliers. This could break the drum. Now being sure that the sight is at the bottom, raise the sight through the number of clicks which were counted earlier. Again hold the drum with your fingers and loosen the screw. Rotate the drum until the 2 mark is aligned with the indicator mark on the sight. While doing this, be sure that the sight does not move. It may help to hold your thumb tightly on the rear sight to help monitor this. Hold the drum with your fingers and tighten the screw again. Rotate the drum until the rear sight is raised to its highest position. Now tighten the screw thoroughly. Rotate the drum again to bottom out the sight and then raise it to the 2 mark again, while counting the clicks required to do this. It should be the same number counted previously. At this point the sight should be set so that the other distances will be properly indicated by rotating the drum until the number appearing on the drum coincides with the indicator mark. For example, from the 2 mark, three clicks, or three MOA, should be required to rotate the drum to the 3, for 300 yards, or meters. Remember that the sights actually refer to meters on the M1A.

The rear sights of AK’s are indicated in meters and should be set on 200 when sighting in at 25 meters. Then while the rifle is being sighted in at 200 yards, or meters, the front sight can be reset accordingly to accomplish this process.



Notice that the near zero is at 25 meters and the far zero is at 200 yards in the figure above. Also notice that the sight line is horizontal and that the rifle barrel is tilted upward. Now let’s take the same rifle and install taller sights on it. The sight line would still have to be horizontal, but in order to zero the rifle at 25 meters, the barrel would have to be tilted at a higher angle than before. And this means that the trajectory would change such that the far zero would now be greater than 200 yards. It is mainly for this reason that the far zero of an AR is at 300 yards rather than at 200 yards. Therefore, the heights of the sights, or scope, on a rifle will influence the zeroes associated with it at various distances.

BSZ:

In combat situations, the military has found it convenient to set their rifle sights at 300 yards and call this setting the BSZ. This is advantageous because it allows them to aim precisely at a target anywhere from 0 to 300 yards away and not miss their target by much more than 6 inches vertically, a fact which we will demonstrate with the Come-Ups for the M14. These come-ups, along with others, are tabulated below.

With our sights set at BSZ, 300 yards, assume we wish to fire at a target 200 yards away. Notice from the Come-Ups table (Table 3) that as you go from 300 to 200 yards, 3 MOA are involved. Since 1 MOA at 200 yards is represented by 2 inches, 3 MOA is represented by 6 inches (see Figure 16). Therefore, the target would be struck 6 inches high. Now if you wish to fire at a target 100 yards away, notice from the Come-Ups table (see Table 3) that in going from 300 to 100 yards, 6 MOA are involved, and since 1 MOA at 100 yards is represented by 1 inch, 6 MOA would be represented by 6 inches. Therefore the target in this case would be struck 6 inches high also. Now if we proceed out to a target at 400 yards, we see that 4 MOA again are involved. Since 1 MOA at 400 yards is represented by 4 inches, 4 MOA would be represented by 16 inches, and since the bullet would be falling past 300 yards, the target would be struck 16 inches low. Of course, this procedure could be carried out to greater distances.

It should be noted that the official BSZ for an M14 is 250 meters or 275 yards, however, 300 yards seems to be an excellent choice, as well as being a particularly easy BSZ to work with.

SUGGESTION: The customary setting for your sights should be at the BSZ, which most likely will be 300 yards. After firing your rifle to determine the come-ups associated with it, record the sight setting for your BSZ. Alter your settings from there according to circumstances, and finally, return it to BSZ.

COME-UPS: Standard Appleseed Come-Ups

	STD (M14)	M1	AR15	AK47 (Calculated)
100yds->200 yds	3	2	2	3
200yds->300 yds	3	3	2	5
300yds->400 yds	4*	4	3	6
400yds->500 yds	4	4	4	8
500yds->600 yds	5	4	5	9
600yds->700 yds	5	5	6	XXXX
700yds-> 800 yds	6	6	7	
800yds->900 yds	8	6	XXXX	
900yds->1000 yds	8	7	XXXX	

*Appleseed standard policy uses a 3 here, but 4 seems more appropriate.

These come-ups are only approximate! They should be good enough to get you on paper. Then you can use IMC at various distances to obtain the proper come-ups for your rifle. Then these proper come-ups should be entered on a card and taped to the stock of your rifle, along with the type of ammunition used and information about your scope.

However, based on the come-ups above, and the assumptions stated, some questions are in order.

1. Suppose you are zeroed at 25 meters with an M1A. Where would you expect to hit on a target 100 yards away?
2. If you are zeroed on a target 100 yards away, where would you expect to hit on a target 200 yards away?
3. If you are zeroed on a target at 25 meters with an AR, where would you expect to hit on a target at 100 yards and a target at 200 yards?

WIND:

A fairly simple estimation of the effect of wind on a bullet is given by the following statement. For every 10 miles per hour (mph) of wind, perpendicular to the bullet's path, the bullet will be deflected by 1 MOA per 100 yards in the direction of the wind. Thus at 200 yards, a 10 mph wind would cause a bullet to be deflected by 2 MOA, or 4 inches. At 400 yards, a 20 mph wind would cause a bullet to be deflected by 2 × 4 MOA, or 2 × 16 inches, or 32 inches. Again, this assumes the wind is striking the bullet path at a 90° angle.

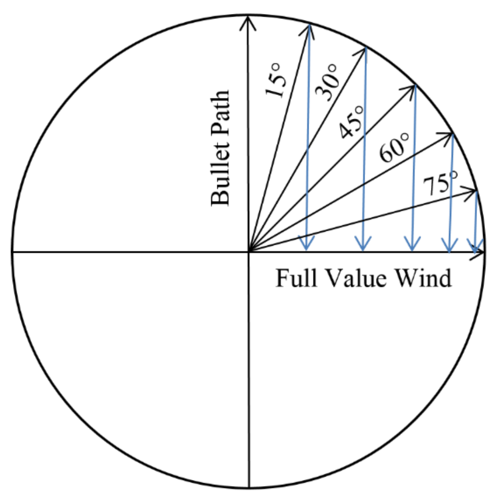
Wind Direction

A wind striking at 90° is called a "Full Value" wind. A wind striking the bullet path at an arbitrary angle will affect the bullet by a smaller amount, and this amount is usually stated in terms of the effect of a Full Value wind. Figure 19 illustrates these concepts.

The bullet path in the diagram is upward, or we can say "north" or perhaps 12 o'clock if we consider a clock face. A Full Value wind is 90° to this, toward the east in the diagram, or toward 3 o'clock on a clock face.

Now consider a wind directed 30° east of north, or toward 1 o'clock on a watch face. A perpendicular line has been dropped to the horizontal line depicting Full Value, and it is seen that it intersects this line at its half-way point. This means that a wind at 30° to the bullet path would only affect the path by ½ the amount of a Full Value wind; or we could say that a 30° wind (a 1 o'clock wind) is only a 0.5 (or Half) Value wind.

Figure 19. Wind Effect on Bullet Trajectory



The other illustrated wind direction is directed at 45° east of north. The perpendicular line dropped to the horizontal intersects the Full Value line at 0.7 of its length. Therefore, a wind at 45° to the bullet path will affect the path by 0.7 times that of a Full Value wind. If you are of a mathematical bent, you may recognize that 0.5 is the sine of 30° and 0.7 is the sine of 45°. Therefore, if you can estimate the angle of the wind with respect to the bullet path, and have a calculator with you, you can simply find the sine of that angle to give you the wind Value.

It should be noted that winds blowing in the exact opposite directions of those shown would have the same effects on the bullet that as shown, except that the deflection would be to the west instead of the east (i.e., opposite direction). Furthermore, winds in the same, or opposite directions to the bullet path, would not deflect the path at all.

There is a range of angles around each of these particular angles where the wind effect would be so similar to those stated, that little difference would be observed. The deflection will depend somewhat on the caliber and weight of the bullet, but not as much as might be expected. For example, a .308 would not be deflected quite as much as indicated above and a .223 would be deflected a little more. Tables exist for deflections of different calibers and different weight bullets, but they will demonstrate that there is not as much difference as might be expected. Furthermore the deflections will depend somewhat on distance. For example, at distances greater than 500 yards, the deflections will be greater than indicated above.

Based on the material above, a couple of questions are in order.

1. Suppose you have a Full Value wind of 10 miles per hour and you are shooting at a target 400 yards away. By how much will you miss the target?
2. In the problem above, suppose the wind would have been at 30 degrees instead of Full Value. By how much would you miss the target?

The above material assumes that the wind is constant over the entire path of the bullet. This is rarely the case. Varying terrain features on the range may influence Wind Speed, and often the wind will be different at different heights above ground level. Wind at higher elevations is generally stronger than wind at ground level. The wind may even be blowing in different directions at different distances on the range. For these reasons, the effects of wind can be very difficult to determine.

Perhaps it is appropriate at this stage to mention Fred's Simplified Wind Rule: If you think the wind will make a difference, correct 3 MOA at 300 yards and 5 MOA at 500 yards. From the discussion above it is easily seen that the assumptions made here are that a Full Value wind of 10 mph is blowing and that the corrections for smaller distances are negligible.

Wind Speed

There are a number of ways to estimate wind speed. Perhaps the easiest way is with an electronic wind meter. While some of these are rather expensive, some may be purchased at reasonable prices. It is suggested that you use a wind meter to determine how winds of different speeds feel on your face. It shouldn't take long for you to make fairly good estimates of wind speeds simply by their feel on your face.

However, these values will only give the wind speed at the location of the shooter, and not along the entire bullet path. A knowledgeable person can judge the wind speed at different distances by observing the wind's effect on grass or trees at these distances.

Another, more natural method, has to do with the effect of wind on different items. If you can feel the wind slightly on your face, it is about 3-5 miles per hour (mph). If it causes leaves to agitate continuously, it is about 5-8 mph. If it blows loose paper around, it is about 8-12 mph, and if small trees are swaying, it is about 12-15 mph.

There are still other methods which may prove useful. For example, you could drop a light object, such as a handful of grass and observe the angle, in degrees, it makes with the perpendicular as it falls to the ground. Dividing this angle by 4 will give the approximate speed of the wind in mph. Similarly, flags may be located on the range at different locations. Dividing their angles with respect to perpendicular by 4 will also approximate the wind speed in mph. In such cases it is not unusual to notice that the wind may be blowing in different directions at different distances from the shooter. The best choice in these cases is to select the wind at the distance midway between the shooter and the target.

HOLD-OVERS AND HOLD-OFFS:

We have studied and used the concept of come-ups and wind corrections in terms of changing our sight settings in units of MOA. However, it may not be necessary to actually change the sight settings. In particular, if we know the distance to the target and, therefore, the come-up required, we could simply use the MOA associated with our scope reticle or front sight. We could simply hold the cross hairs, or sight, over or under the object by the required number of MOA to achieve a good hit. Similarly, to make a correction for the wind, we could simply use the scope or sight to hold off to the side by the required number MOAs. Furthermore, if we have our sights set on BSZ, no change in sights at all would be necessary to achieve a decent hit on an object from contact distance to the BSZ distance, except for a wind correction.

We will soon learn how to determine the MOA associated with our front sights or the reticles of our scopes.

If the target distance is unknown, we will soon learn how to estimate that distance using scopes or front sights in order to determine the appropriate come up.

NOTEBOOKS AND DATA SHEETS: A notebook should be carried to the range to record your observations and conclusions. A suitable one would be a water proof three ring binder containing 8½ x 11 sheets of paper, which gives plenty of room for your notes. But you might prefer something smaller. Items included in the notebook would consist first of the rifle and ammunition, date, and temperature. **Additionally some information about your scope or front sight should be entered. This will be discussed later and it is extremely important. Blanks for these items are included in the Data Sheets at the end of this COF.** The approximate or expected come-ups should be entered in your notebook to give a basic idea of how to begin obtaining your true come-ups.

SHOOTING: Proceed to the range.

The shooters should be reminded to first adjust the focus on their scopes to ensure that their reticles are sharply defined.

Ball and Dummy at 25 meters:

Use this exercise as a sight-in procedure. Before beginning this exercise it would be advisable to reread the sighting in process in the Trajectories section. After obtaining the zero at this distance, the sight setting should be recorded in the Notebook.

CAUTION DURING BALL AND DUMMY: While shooting at 100 yards in the standing position a severe problem could exist if recommended procedures are not followed. For example, shooters should be cautioned to hold the trigger back after firing. If this is not done, the trigger finger could easily cause a negligent discharge during recoil and the bullet could go over the berm. This is especially important with larger calibers. Therefore, it is recommended that this be emphasized during the ball and dummy exercise. Furthermore, instructors should be vigilant to observe that shooters follow this properly.

AT GREATER DISTANCES: It would be informative for the shooters with M1As to fire at a target at 200 yards with no change in sight picture, and for AR shooters to similarly fire at a target at 300 yards to investigate their near and far zeros. However, time is generally not available for this. Instead it is recommended that shooters begin at 100 yards to zero their rifles at that distance.

Sighting in rifles at 100 yards can be begun by using the same sight settings they had at 25 meters. The resulting POI shouldn't be very many inches from the desired impact on the target.

Questions: About how many inches high would they expect to be for M1As? For ARs?

In order to obtain a better zero at this distance, and greater distances too, it is permissible to use a rest, such as a bag of some kind. Five rounds are advisable for sighting in. The group size in MOA and the location of the POI should be recorded in the notebook. IMC should be used to place the POI on target and the associated MOA for correction should be recorded. Once the POI is on target, the sight setting should be recorded.

When the sighting-in process has been concluded, Stage 1 of the KDAQT may be engaged.

Caution: Again the shooters should be reminded to hold their triggers back and instructors should be vigilant in observing this.

As this is being done, I have been recommending that while firing from the standing position, the shooters loosen the sling enough that the upper arm can be rested firmly on the ribs for additional support, with the support hand placed under the trigger guard, or perhaps under the magazine. The upper body should be relaxed, or slumped, to minimize muscle tension. Furthermore, I can even recommend that the sling not be used in this position at all. However, a problem can develop from faulty ammunition, such as some reloads. The casing could be weakened enough from excessive reuse that it could rupture during firing, which could result in the magazine being blown out, possibly injuring the support hand if it is under the magazine.

Sighting in rifles at 200 yards can be begun with the setting used at 100 yards.

Questions: How many inches, high or low, would they expect to be for M1As? For ARs?

The IMC process for determining the sight setting for 200 yards should be recording and the resulting sight setting itself should be recording. The come-up from the 100 yard sight setting should be recorded.

The sight setting for M1As should be compared with their sight settings for 25 meters. Furthermore, if the sights used on the M1As are the original sights, this setting may be used now to calibrate these sights to read 200 using the process described in the trajectories section above. Alternatively this may be deferred to a later time.

Stage 2 of the KDAQT may be engaged now.

Sighting in rifles at 300 yards can be begun with the setting used at 200 yards.

Questions: How many inches, high or low, would they expect to be for M1As? For ARs?

The process of sight setting and come-up from 200 yards should be recorded, as was done previously.

The sight setting for ARs should be compared with their 25 meter setting.

Stage 3 of the KDAQT may be engaged now.

Sighting in rifles at 400 yards:

Questions: If this process is begun with the same sight setting obtained at 300 yards, how many inches low would they expect to be for M1As? For ARs?

With the answers to the above question in mind, and the size of their target backings, they may wish to add a few MOAs to their sights initially. If so, these should be recorded.

The same process and recordings used previously should be employed at the distance.

Stage 4 of the KDAQT may be engaged now.

Sighting in rifles at greater distances: The same processes used previously may be employed.

Following this, the information obtained above can be summarized by entering it on a data sheet such as those at the end of this COF. It is also important that the come-ups obtained, the ammunition used, and the scope or front sight information, to be treated later, should be copied on a sheet of paper, laminated, and taped to the stock of your rifle so it will be immediately available when needed.

CLASS TIME:

RANGE ESTIMATION:

Range Estimation with Battle Sight Zero

The front sights on M14s and ARs are also designed around the 300 yard BSZ. The width of these sights is chosen to totally cover the width of a human sized object at 300 yards. A human sized object is assumed to be 20 inches wide, and since 1 MOA at 300 yards is represented by 3 inches, this object subtends approximately 7 MOA at 300 yards. Therefore, the front sight on these rifles typically subtends approximately 7 MOA. Therefore, if 1 of these sights covers only ½ of a human sized target, the target must be 150 yards away, and if 1 of these sights appears twice as wide as a human sized target, the target must be 600 yards away.

For completeness it should be said that the actual width of the front sight, in terms of MOA, depends on the actual width of the front sight and its distance from the rifleman's eye, which means that it may depend upon the length of the barrel and the location of the shooter's Cheek weld. As a result, its width may be in the range of 7.5 to 8 MOA, or even larger.

Range Estimation in General

The concept of range finding can be made clear by thinking back to an Inches - Minutes – Clicks presentation. Draw an exaggerated 1 MOA extending back to 100, 200, 300, yards, etc. (see Figure 16). Then draw the 1 inch, 2 inch, 3 inch lines, etc. between the angular lines at the successive distances. Then consider a 2 MOA diagram with the similar distances involved. We could even construct larger angle diagrams with the same purpose in mind. There are 3 quantities of interest for each of the angles: (1) the angle, (2) the distance, and (3) the distance between the angular lines.

The distances between the angular lines are representative of the target, or any other object at the respective distances for that matter. What we see in the IMC discussion is that if we know the distance and the distance between the angular lines, we can determine the angle (i.e., the number of MOA involved). This means that if we know any 2 of the 3 quantities, we can determine the third. Therefore, if we know the size of the object involved and the angle which subtends this object, we can determine the distance to the object.

Figure 16. Minute of Angle at Distances

Suppose we consider this 1 MOA diagram. A moment's consideration will tell us that an object whose size in inches, O(inches), at a distance in hundreds of yards, R_{100}, can be described in terms of its size in MOA, as

$$O(MOA) = \frac{O(inches)}{R_{100}} \qquad \text{Equation 1}$$

For example, consider a 1 inch object at 100 yards.

$O(MOA) = \frac{1}{1} = 1$ which means that this 1 inch object at 100 yards subtends 1 MOA.

Next consider a 2 inch object at 200 yards.

$O(MOA) = \frac{2}{2} = 1$ which means that the 2 inch object at 200 yards subtends 1 MOA.

And finally consider a 4 inch object at 100 yards.

$O(MOA) = \frac{4}{1} = 4$ which means that the 4 inch object at 100 yards subtends 4 MOA.

If we know any two of the quantities in the original equation, Equation 1, we can find the third. Therefore, if we know O(MOA) and O(inches), we can find R_{100}.

To accomplish this we will first write Equation 1 in an equivalent form and use a simple algebraic short cut. This procedure will also prove valuable in future work. Following this we will proceed through a more mathematically complete method to accomplish the same purpose, and it will also prove valuable in future work.

First, rewriting Equation 1;

$$\frac{O(MOA)}{1} = \frac{O(inches)}{R_{100}} \qquad \text{Equation 1}$$

To explain the algebraic short cut, first consider the diagonal quantities in the equation. These would be the couple O(MOA) and R_{100}, and the couple 1 and O(inches). Any diagonal quantity can be moved in a diagonal fashion. Therefore, we will simply interchange the quantities O(MOA) and R_{100}, with the result,

$$R_{100} = \frac{O(inches)}{O(MOA)} \qquad \text{Equation 2}$$

We can now to accomplish the same task more rigorously. This method is not of much importance at the moment but the process will be important for us later. We can realize that if we multiply and/or divide both sides of an equation by the same quantity, the resulting equation will also be true.

For example,

$$10 = 10$$

$$\frac{(2)\,10}{(4)} = \frac{(2)\,10}{(4)}$$

$$5 = 5$$

Therefore, if we multiply both sides of Equation 1,

$$O(MOA) = \frac{O(inches)}{R_{100}}$$

by

$$\frac{R_{100}}{O(MOA)}$$

we obtain

$$\frac{R_{100}\,\cancel{O(MOA)}}{\cancel{O(MOA)}} = \frac{\cancel{R_{100}}\,O(inches)}{\cancel{R_{100}}\,O(MOA)}$$

with the result, again being

$$R_{100} = \frac{O(inches)}{O(MOA)} \qquad \text{Equation 2}$$

Let us apply this result to a 21 inch object which subtends an angle of 7 MOA.

$$R_{100} = \frac{21}{7}$$

$$R_{100} = 3, \text{ which means that its distance is 300 yards.}$$

And this is the result treated above in the study of **Range Estimation with Battle Sight Zero.**

The equation, and its application above, are very good approximations, but are not exact. The reason is that our basic assumption that 1 inch represents 1 MOA at 100 yards is an approximation. In actuality, a much better value is that 1.047 inches represents 1 MOA at 100 yards. Therefore, this introduces an error of about 5 parts per 100 yards in the result, which is not bad, but the error increases as distance increases, of course. Notice that it was stated that a certain number of inches **represents** 1 MOA above, and **not** that a certain number of inches **equals** 1 MOA. That is because length and angles are different kinds of quantities. Therefore, they cannot be equal to one another.

An important question, though, is should the 5 yards per hundred yards be added to or subtracted from the calculated value. Notice that an MOA defined more correctly as 1.047 inches, will be a larger angle than if it is defined in terms of 1 inch. And notice that in Equation 2 for R_{100} above, that O(MOA) appears in the denominator. Therefore, the actual value for R_{100} will be smaller than it would be otherwise. This means that if you define a MOA using 1.047 inches, that the actual distance to the object, $R_{100,}$ will be five yards per 100 yards smaller than the one calculated using 1 inch. Therefore, in the example above, the actual distance would be

$$R = 300 \text{ yards} - 15 \text{ yards} = 285 \text{ yards} \qquad \text{Equation 3}$$

Of course, if R_{100} is not given in multiples of 100 yards, it gets a bit more complicated. But reasonable approximations can still be made.

An equation giving the exact distance, R_{100}, will be derived later, but it is not appropriate at this point. And it will not be that much different from the results obtained above, as will be shown.

Incidentally, some scopes have reticles which are marked in MOA. And these are marked with the more accurate MOAs described above. Indeed, some are marked even more accurately than the ones just discussed.

Scopes and Front Sights:

Now we need to address the problem of actually finding the value of O(MOA) so it may be used in the equation for R_{100}. This is easier to do with a scope than with a front sight, so that will be done first. The scope involved may either be a First Focal Point or a Second Focal Point scope. The concept of these scopes and focal points will be treated at the conclusion of this COF.

Each of these scopes has advantages and disadvantages. For a First Focal Point scope the reticle will be magnified along with the image. Therefore, information obtained from the reticle will not depend on the magnification of the scope. On the other hand, the reticle may be difficult to see at low magnifications and the lines of the reticle may be somewhat thicker at higher magnifications. For a Second Focal Point scope the reticle will not change size as the image changes sizes with different magnifications. Therefore, information obtained from the reticle will generally only be valid for one particular magnification of the scope. This is frequently the largest magnification of the scope, but that is certainly not the case for all such scopes. Second Focal Point scopes are much less expensive than First Focal Point scopes and are, therefore, much more common.

Many scopes have duplex reticles, while others have mil dot reticles or MOA reticles. We shall concentrate on Duplex and mil dot scopes, although the MOA reticles are treated in the same fashion as the mil dots.

Duplex reticles are common and perhaps the easiest and they can be easily applied to the discussion for determining R_{100} above. Therefore, the procedure for using them will be addressed first. This will be followed by the procedure for mil dot scopes, and then the procedure for using the front sight itself. However, before proceeding to the range to apply these, they will all be discussed individually, and then we shall go to the range to apply the procedure for the shooters' individual rifles.

Duplex Scopes – For Second Focal Point scopes:

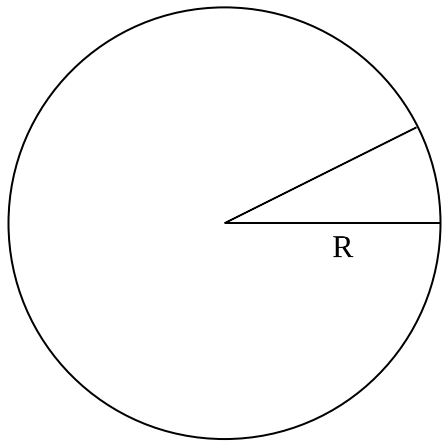
While we are at the range we shall take a 12 inch ruler and mark it with tape at 3, 6, and 9 inch lengths and place it at 100 yards. Another set of lengths could be used if desired, such as marking the ruler at 2 inch intervals. At the maximum or appropriate magnification, we shall determine how many MOAs are included in full or half duplex markings. An alternative is to select a magnification which gives you a nice number of MOAs which are easy to work with. Therefore, we can use this to determine the angular dimension of an object in MOA, O(MOA), as discussed previously, to determine the distance to the object. For simplicity, we are assuming here that 1 inch will represent 1 MOA and use Equation 2 or Equation 3 to calculate distances later. **Enter that magnification and number of MOAs in your Notebook, Data Sheet, and the sheet taped to your rifle stock.** If you don't have a Duplex scope, use what you have and try to obtain the same goal.

Since some scopes have Bullet Drop Compensation (BDC) marks, it may be advantageous to place the rulers vertically instead of horizontally in order to determine the MOAs associated with these marks.

Mil Dot Scopes:

Mil Dots are not a difficult topic, but to understand the concept a discussion about them is required. This is preferable to memorizing material which has no other meaning to you.

A mil is defined in terms of an angular measurement called a radian. And since mils and radians are angular measurements, there must be a relationship between them and degrees and MOAs. We shall develop these relationships soon. But first let's begin the definition of a radian. Consider the diagram below.



It consists of a circle of radius R and an angle, Θ, which subtends a portion, S, of the circle's circumference, C. The angle, Θ, in radians, is defined in terms of S and R as

$$\Theta = \frac{S}{R} \qquad \text{Equation 4}$$

Thus, if S=R,

$$\Theta = \frac{R}{R} = 1 \text{ radian}$$

And 1 radian is approximately equal to 57 degrees.

Equation 4 has some important implications for us. For example, S could be the width or length of an object at a distance, R, from us. And just as with Equation 1 previously, if we know any two of the quantities in the equation, we can find the third. Therefore, if we know the size of S and if we could determine the angle, Θ, in radians, which subtends S, then we could immediately determine the distance, R, to the object. This will be simplified if we alter Equation 4 and solve it for R. This will be done shortly, but first we shall further examine the relationship between mils, radians, degrees, and MOA. To accomplish this we shall first solve Equation 4 for S. To do this, remember that we can move any of the diagonal quantities within that diagonal. Therefore, we can simply move R up alongside Θ with the result

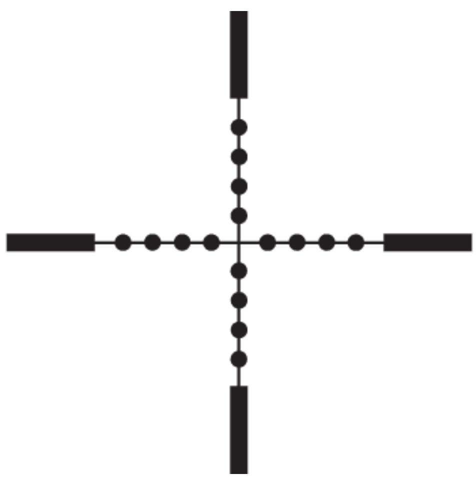
$$S = \Theta R \qquad \text{Equation 5}$$

However, it must be kept in mind that Θ must be in radians and that S and R must be in terms of identical units, such as inches, feet, yards, or meters.

But we haven't yet defined a mil. A mil is one thousandth of a radian, or what we frequently refer to as a milliradian.

$$1 \text{ mil} = 1/1000 \text{ rad}$$

And this leads us to the mil dot reticle of a scope.



The dots on a mil dot reticle are 1 mil between the dot centers and the dots are 0.2 mils in diameter. Therefore, we can use this to measure the angular dimension of an object in the same manner we did with a Duplex Scope in an effort to determine distance to that object.

But first let us arrive at an exact relationship between radians and degrees. Consider Equation 5 again.

$$S = \Theta R \qquad \text{Equation 5}$$

If we extend S all around the circle, then S will become the circumference of the circle, C. And perhaps you remember from school that

$$C = (2\pi)R$$

where π is approximately equal to 3.14, and we can see that Θ has become (2π) radians in this case.

Therefore, it is seen that in a complete circle, there are 2π radians. Also remember that in a complete circle there are 360^0. Therefore, we see that

$$2\pi \text{ rad} = 360^0$$

We have been taught that 1 MOA subtends 1 inch at 100 yards, although we have just seen that this is not quite correct. Now let's see how many inches 1 mil subtends at 100 yards.

Using Equation 5 again,

$$S = \Theta R$$

and remembering that Θ must be entered in radians, we see that, since 1 mil = 1/1000 rad,

$$S = [(1/1000) \text{ rad}]\ (100 \text{ yards}) = 0.1 \text{ yard}$$

And converting this to inches,

$$S = 3.6 \text{ inches}$$

which means that 1 mil at 100 yards is represented by 3.6 inches.

However, with an eye to making more confusing conversions in the future, let's perform this conversion in a more specific, although more complicated, fashion.

It should be recognized that we can multiply any quantity by 1 and not change its value. Therefore, consider that

$$1 \text{ yard} = 36 \text{ inches}$$

And we have seen that we can divide both sides of an equation by the same quantity and still maintain an equality. Therefore, dividing each side of this equation by 1 yard,

$$\frac{\cancel{1 \text{ yard}}}{\cancel{1 \text{ yard}}} = \frac{36 \text{ inches}}{1 \text{ yard}} = 1$$

And we can use

$$\frac{36 \text{ inches}}{1 \text{ yard}}$$

as a conversion factor.

Therefore,

$$S = 0.1 \text{ yard} \times \frac{36 \text{ inches}}{1 \text{ yard}} = 3.6 \text{ inches}$$

Notice how the units of yards cancel out. Now does this mean that 1 mil is equal to 3.6 MOA? No, because we have seen that 1 MOA does not subtend 1 inch at 100 yards, but instead subtends 1.047 inches at 100 yards. To relate mils to MOAs, let's convert mils to MOAs.

To do this, observe that above we have shown that

$$\frac{36 \text{ inches}}{1 \text{ yard}} = 1$$

In a similar manner we can see that we have the additional conversion factors:

$$\frac{1 \text{ rad}}{1000 \text{ mils}} = 1; \quad \frac{360^0}{2\pi \text{ rad}} = 1; \quad \frac{1 \text{ MOA}}{(1/60)^0} = 1; \quad \frac{60 \text{ MOA}}{1^0} = 1$$

Therefore, we can find how many MOA are contained in 1 mil by multiplying 1 mil by these conversion factors to obtain the units of MOA.

$$(1 \cancel{\text{mil}}) \times \frac{1 \cancel{\text{rad}}}{1000\cancel{\text{mil}}} \times \frac{360^{\cancel{0}}}{2\pi \cancel{\text{rad}}} \times \frac{60 \text{ MOA}}{1^{\cancel{0}}} = 3.44 \text{ MOA}$$

Therefore,

$$1 \text{ mil} = 3.44 \text{ MOA} \qquad \text{Equation 6}$$

And notice again how all the units except MOA cancel.

We have shown above that 1 mil subtends 3.6 inches at 100 yards. Similarly, 1 mil will subtend 2 x 3.6 inches, or 7.2 inches at 200 yards, etc. Therefore, to be more complete, we could say that 1 mil subtends 3.6 inches per 100 yards.

Now with all the preliminaries out of the way, let us finally see how to determine the distance to an object using a mil dot scope.

Returning again to the formula, Equation 5,

$$S = \Theta R$$

To aid in using our diagonal algebraic short cut again we can rewrite this as

$$\frac{S}{1} = \frac{\Theta R}{1}$$

and move the Θ underneath the S, resulting in

$$R = \frac{S}{\Theta} \qquad \text{Equation 7}$$

Alternatively we see that we can solve for the distance R in a fashion we have used before, dividing both sides of the equation by Θ.

$$\frac{S}{\Theta} = \frac{\Theta R}{\Theta}$$

Or

$$R = \frac{S}{\Theta} \qquad \text{Equation 7}$$

And remember that S is some object of known size and Θ is the angle that object subtends in the scope in terms of radians. However, the scope is read in terms of mils, which can be easily converted to radians. Care must be taken that R and S be entered in the same units whether it is feet, yards, or meters. However, S could be entered in other units as long as those units are converted into the same units as those of R by using conversion factors.

Example:

A 6 ft man subtends 5 mils in the scope. How far away is he?

Keeping in mind that we would like the answer, R, to be expressed in yards, and that Θ must be expressed in radians, we can write the equation most directly as

$$R = \frac{S}{\Theta} = \frac{(6/3)\text{ yards}}{(5/1000)\text{ rads}} \qquad \text{Equation 8}$$

If the manipulation of the numbers in this equation is confusing, notice that they can be rewritten as

$$R = \frac{(6 \times 1000)\text{ yards}}{(3 \times 5)\text{ rads}} = 400\text{ yards}$$

Furthermore, angular units do not actually have dimensions; therefore, radians do not appear in the final answer of 400 yards.

In the preceding example, S was given in units of feet, which was converted to yards. A situation could be encountered in which the object, S, could be given in units of inches. And in this case, inches must be converted into yards.

Example: An 18 inch object occupies 2 mils in the scope. How far away is it?

$$R = \frac{S}{\Theta} = \frac{(18/36) \text{ yards}}{(2/1000) \text{ rads}} \qquad \text{Equation 9}$$

And this can be rewritten as

$$R = \frac{(18 \times 1000) \text{ yards}}{(36 \times 2) \text{ rads}} = 250 \text{ yards}$$

And for future reference with respect to Equation 11 below, notice that

$$\frac{1000}{36} = 27.8$$

We have just seen how easy it is to find the distance to an object, S, if its size is expressed in either yards or inches, by directly using a single simple equation,

$$R = \frac{S}{\Theta} \qquad \text{Equation 7}$$

However, most shooters are not aware of this and, therefore, use a number of equations which must be memorized individually. We will show how to arrive at these equations.

First we will consider an object size expressed in yards. If we examine the examples resulting in either Equation 8 or Equation 9, careful consideration will show that the distance to an object whose size is known in yards, S(yards), and whose size is given in mils, O(mils), as determined from a scope, can be given succinctly by the equation,

$$R(\text{yards}) = \frac{S(\text{yards}) \times 1000}{O(\text{mils})} \qquad \text{Equation 10}$$

Furthermore, if S is known in inches, we could express S in inches, S(inches), but we would then have to convert this into yards. This could be done by the multiplication of a conversion factor, as we have done previously.

$$R(\text{yards}) = \frac{S(\cancel{\text{inches}}) \times 1000}{O(\text{mils})} \times \frac{1 \text{ yard}}{36 \ \cancel{\text{inches}}}$$

Notice that the inches cancel. By making the indicated division, this equation can be stated succinctly, in terms of yards, as

$$R(\text{yards}) = \frac{S(\text{inches}) \times 27.8}{O(\text{mils})} \qquad \text{Equation 11}$$

and it is frequently given in this form.

Equations 10 and 11 are frequently written for quick calculations in the field. However, it should be pointed out that they are two equations which must be memorized to do so. And it is far easier to just memorize the one simple equation, Equation 7,

$$R = \frac{S}{\Theta}$$

and treat it in the same manner as we did in the examples which resulted in Equations 8 and 9.

The preceding work has dealt with distance, or range determination, using mils. But the same thing could be done using MOA if you have a duplex scope calibrated in MOA, as we've discussed, or if you have a scope reticle in MOA. We shall address that process now. Remember that the angle in Equation 7, above, must be entered in radians. Therefore, if we enter this angle in MOA, we must use a conversion factor to convert it into mils, and we must further use a conversion factor to convert mils into radians. We have shown previously that

$$1 \text{ mil} = 3.44 \text{ MOA} \qquad \text{Equation 6}$$

And we have also shown previously that

$$1 \text{ mil} = (1/1000) \text{ rad}$$

Or equivalently that

$$1000 \text{ mils} = 1 \text{ rad}$$

Applying these as conversion factors to Equation 7,

$$R(\text{yards}) = \frac{S(\text{yards})}{O(\text{MOA})} \times \frac{3.44 \text{ MOA}}{1 \cancel{\text{mil}}} \times \frac{1000 \cancel{\text{mils}}}{1 \text{ rad}}$$

which yields,

$$R(\text{yards}) = \frac{S(\text{yards})}{O(\text{MOA})} \times (3440) \qquad \text{Equation 12}$$

If we wish to express S in inches, we must use yet another conversion factor to convert inches into yards, which we have also done previously.

$$R(\text{yards}) = \frac{S(\text{inches})}{O(\text{MOA})} \times (3440) \times \frac{1 \text{ yard}}{36 \text{ inches}}$$

which yields,

$$R(\text{yards}) = \frac{S(\text{inches})}{O(\text{MOA})} \times (95.6) \qquad \text{Equation 13}$$

This equation could now be applied to the problem of a 21 inch object which occupies 7 MOA. This was treated earlier by two less accurate methods. One was the result of applying Equation 2, which gave 300 yards, and the other resulted in Equation 3, which resulted in 285 yards. We see now that

$$R(\text{yards}) = \frac{21}{7} \times 95.6 = 287 \text{ yards}$$

Front Sight:

The problem now is to determine the angular width of the front sight and to use that result to determine the distance to an object of known size. One simple way to determine the angular width of the front sight in MOA is to compare it with the width of a one inch square at 25 yards, remembering that 1 inch at 25 yards roughly represents 4 MOA. An easier alternative might be to place tape on a 12 inch ruler at 2 inch intervals. If 25 meters is used instead of 25 yards, keep in mind that a slight error will be present because of the difference between 25 meters and 25 yards. The ruler could also be placed at 100 yards.

An alternative analytical method, is to calculate it using the familiar Equation 4.

$$\Theta = \frac{S}{R} \qquad \text{Equation 4}$$

where S will be the diameter or width of the front sight, R will be the distance from your eye to the front sight, and Θ will, of course, be the angular width of the front sight, in radians, from your eye.

As an example, we shall calculate the result for an M1A front sight. The width of the front sight, S, measured with a caliper, is 0.074 inches, and we shall say the distance from the eye to the front sight in the prone position, R, is 31 inches. However, this might not be the case for you and your rifle. But this assumption would yield

$$\Theta = \frac{0.074 \text{ inches}}{31 \text{ inches}} = 0.00239 \text{ rad}$$

Now to convert this to MOA using conversion factors previously determined,

$$\Theta = (0.00239\ \text{rad}) \times \frac{1000\ \text{mils}}{1\ \text{rad}} \times \frac{3.44\ \text{MOA}}{1\ \text{mil}} = 8.2\ \text{MOA}$$

Or we could simply say, with decent accuracy, that

$$\Theta = 8\ \text{MOA}$$

In other words, with your cheek placed in its customary position on the stock, your front sight will subtend 8 MOA. Therefore, the front sight may be used as a rangefinder in exactly the same manner as a duplex scope reticle by observing an object of known size and determining its size in MOA using the front sight. **Enter your front sight information in your Notebook, Data Sheet, and the laminated sheet to be taped to your rifle stock.**

RANGE ESTIMATION SUMMARY:

In range estimation using MOA, an approximation may be obtained by the formula:

$$R_{100} = \frac{O(\text{inches})}{O(\text{MOA})} \qquad \text{Equation 2}$$

A refinement to this approximation can be obtained by subtracting 5 yards per 100 yards from the result obtained in the above equation. This was expressed in Equation 3.

An exact range using MOA may be obtained from:

$$R(\text{yards}) = \frac{S(\text{yards})}{O(\text{MOA})} \times (3440) \qquad \text{Equation 12}$$

or

$$R(\text{yards}) = \frac{S(\text{inches})}{O(\text{MOA})} \times (95.6) \qquad \text{Equation 13}$$

When using mil dots to determine range, the most direct procedure is to use the formula:

$$R = \frac{S}{\Theta} \qquad \text{Equation 7}$$

as demonstrated in the previous examples using feet or inches respectively:

$$R(\text{yards}) = \frac{S}{\Theta} = \frac{(6/3)\ \text{yards}}{(5/1000)\ \text{rads}} \qquad \text{Equation 8}$$

$$R(\text{yards}) = \frac{S}{\Theta} = \frac{(18/36)\ \text{yards}}{(2/1000)\ \text{rads}} \qquad \text{Equation 9}$$

Or if some memorization is preferred, the formula:

$$R(\text{yards}) = \frac{S(\text{yards}) \times 1000}{O(\text{mils})} \qquad \text{Equation 10}$$

or

$$R(\text{yards}) = \frac{S(\text{inches}) \times 27.8}{O(\text{mils})} \qquad \text{Equation 11}$$

may be used.

At the Range:

For shooters with second focal length duplex or MOA scopes we have previously discussed marking 12 inch rulers with tape at 2 and 3 inch intervals and placed at 100 yards. Those with duplex scopes can find a suitable magnification to use these intervals, or the full 12 inch length, to determine how many MOAs can be associated with their reticle spacing. For MOA scopes the magnification setting for proper MOA calibration can be confirmed.

A 12 inch ruler can also be taped at multiples of 3.6 inches for those with mil dot scopes. They can set their scopes at the preferred magnification which should cause the mil dots to coincide with the multiple 3.6 inch markings. If there is no preferred setting, a magnification can be selected so that the mil dots do coincide with the markings.

An alternative for the shooters with mil dot scopes would be to change the magnifications of their scopes until the mil dots coincide with either the 3 inch or 2 inch markings on the other rulers. Then the mil dot spacing would represent 3 MOA or 2 MOA, respectively, or whatever else they may choose. But remember that this will only be true for the magnification they have used. In this fashion, they may use their mil dot scopes to determine both MOAs and mils, which could be very useful.

Of course with first focal length scopes the mil or MOA reticles will hold for all magnifications.

Knowing all of this now it may be easier and quicker for shooters to use their reticles for Hold - Overs or Hold- Offs rather than to change their sight settings in some cases.

Those using their front sights as range finding tools can use the rulers with 2 or 3 inch markings to determine the angular width of their front sights in MOAs.

All of the shooters should enter the information obtained in this process in their Notebook, Data Sheet, and the laminated sheet taped to their rifle stocks.

SHOOTING:

Using scopes or front sights, as discussed above; determine distances to objects of known size. This would be more interesting if some of these objects are camouflaged, and/or partially concealed, so that Target Detection could also be exercised. If time is available and if the targets are appropriate, it is suggested that the targets should then be shot. A competition can even be used for this process.

Then continue KD AQTs as necessary.

Proceed to distances greater than 400 yards, 100 yards at a time, to determine the actual come-ups for these distances and record them on your data sheet.

MISCELLANEOUS:

Atmospheric Effects: Air density plays a role in the trajectory of a bullet. The quantities involved in air density are temperature, air pressure and humidity. Altitude enters into this because air pressure decreases with increasing altitude. Temperature matters because cold air is more dense than warm air and, therefore, offers more resistance to the bullet's motion. For the distances we are concerned with, there are some rather crude rules associated with the effects of altitude and temperature upon the trajectory. A change of 20^0 F results in a sight change of 1 MOA. A change of 5000 feet in altitude results in a sight change of 1 MOA. A change in atmospheric pressure, station pressure and not weather report pressure, results in a change of about 1 MOA. And humidity plays such a small role that it can be considered negligible for our purposes. A good ballistics computer program is required to treat these quantities adequately. Therefore, zeroing a rifle at different geographical locations and/or temperatures is recommended.

Shooting on a Slope: Shooting on a slope does not affect the trajectory significantly unless the slope angle is fairly large. And this is rarely the case. The important thing to keep in mind is that only the horizontal distance between the shooter and the target is of importance. If the distance along the slope to the target can be determined by methods discussed above, and if the angle of the slope can be determined, perhaps with a protractor of some kind, the horizontal distance can be calculated by multiplying the slope distance by the cosine of the angle. And this is true whether the slope is uphill or downhill. If this distance or angle cannot be determined, the shooter should aim lower on the target by an estimated amount.

Rifle Scopes and Optics: Light rays from a very distant object will enter a thin convex lens parallel to one another and be imaged at a point on the other side of the lens. You have surely observed this phenomenon previously at some time by focusing the sun's rays onto a point in your hand with a magnifying lens. This point is called the focal point of the lens, and the distance from the center of the lens to this point is called the focal length of the lens. Similarly if a point object is placed an equal distance from the lens center on the other side of the lens, rays from it will be refracted by the lens parallel to one another. Therefore, there are focal points on either side of the lens at equal distances from the center of the lens. The first one mentioned is created by an object which is at an infinite distance from the lens, while the second one has the image at an infinite distance from the lens.

If an object is placed at a distance greater than the focal length from the lens, or outside the focal length, a real image will be formed on the opposite side of the lens and it will be inverted. A real image is one which can be focused on, say, a sheet of paper. If an object is placed inside the focal length of the lens, a virtual image, one that cannot be focused on a sheet of paper, will be formed on the same side of the lens as the object and it will be magnified. It can be viewed by placing your eye on the opposite side of the lens from the object. This can be verified easily by taking a simple magnifying lens and placing an object close to it on the opposite side, as you must have done several times before. Now move the object farther from the lens and observe how it is magnified more. Eventually it will become very blurred. This is the focal point of the lens.

The use of individual single lenses in a rifle scope would present a number of difficulties. Therefore, lens systems, composed of two or more lenses are used instead of separate individual lenses.

Light rays from an infinitely distant object will enter the objective lens system of a scope parallel to one another and be focused at a point within the scope tube. This is typically called the first focal point of the scope and it will lie within the first portion of the tube, before the horizontal and vertical adjusting knobs of the scope. This focused image will be a real one, but inverted. If the scope is a First Focal Point scope, this is also where the reticle would be located. However, since the image is inverted, it must be inverted again, or made erect, by an erector lens system. This will consist of two lens systems encased within a small tube which is controlled partially by the adjusting knobs which move it horizontally and vertically to adjust for “elevation” and “windage”. This erector system will also form a real and erect image farther down the scope tube. Some magnification may occur here but it will be insignificant. It is this image which is to be magnified by the eyepiece, or ocular system. This ocular system will have a focal length within the scope tube. And as we have seen before, if this real image is to be magnified, it must lie within the focal length of the ocular. And the closer to the focal point, the greater the magnification will be, until it begins to be blurred by getting too close. For a fixed magnification scope, this distance will be fixed. If the scope has a variable magnification, the magnification ring will move the erector system closer to or farther from the ocular system, but it will always keep the real image within the focal length of the ocular system. And the greater magnification will exist when the erector system is farther from the ocular system.

When Second Focal Length scopes are discussed, confusion, and even inaccuracies are encountered. Some say that the reticle is placed at the location of the real, erect image, formed by the erector system. If this were so, then the reticle would be magnified by the ocular system, along with the image itself. And the result would be the same as that of a First Focal Length scope. And in addition, this image is moved in the tube as the erector system is moved by the magnification ring. Instead, the reticle is placed at a fixed location within the focal length of the ocular system. If it were placed at the focal point of the ocular, it would be blurred and could not be focused. The reticle will be magnified by the ocular, but once it is focused properly, that magnification will be fixed. And, of course, the magnification of the real, erect image will depend on the location of the erector system. With some Second Focal Length scopes, you can shine a flashlight on the ocular and actually see the reticle.

Parallax: In the preceding section the focal lengths were defined in terms of an object or image located at an infinite distance from the objective lens. However, objects of interest to a rifleman are not that far away and as a result, the images of those objects would be located some distance away from the focal point. And, therefore, if the reticle is located at the lens focal point, this means that the image and reticle would not be at the same point. Therefore, if you place your eye along the optical axis of the scope, the image and the reticle will coincide with one another but will be located at different positions along that optical axis. Therefore, as you move your eye off that axis, the reticle and the image will move with respect to one another. This is parallax and is analogous to holding up your index fingers at different positions along your line of sight so they are aligned with one another, then moving your head so that the fingers seem to move with respect to one another. This parallax can be eliminated in the scope by an adjustment which either relocates the objective lens or by introducing another lens which accomplishes the same purpose. This adjustment can be located either near the objective lens or by a knob on the side of the scope. The result is that the image will then be located at the position of the reticle, which is located at the objective's focal point.

Scopes which do not have this adjustment feature are designed to be parallax free at a particular distance. For many centerfire calibers, this distance is 150 yards. For rimfire cartridges, it is typically 50 yards.

In spite of all this, however, parallax is not something a rifleman should worry about. With a good scope set to be free of parallax at 150 yards, according to Leupold, the maximum effect of parallax will only be 1.3 inches at 500 yards. And if a good cheek weld is achieved habitually, even this minor effect will be significantly decreased.

When using a scope, the first thing to do is to adjust the focus so that the reticle is very sharply defined. If possible, this is probably most easily done by pointing the scope toward a clear blue sky. Then for the distance at which the shooting is to occur, the parallax is adjusted so that the reticle and target images do not move with respect to one another as the eye is moved about the optic axis of the scope. This adjustment may or may not coincide with the indicated distance parallax indices on the scope, and it may or may not coincide with the sharpest image of the target. Furthermore, in a decent scope, the image of the reticle and the image of the target should lie in the same plane, or at least close enough, so that it is NOT necessary to focus only on the reticle. This is NOT analogous to using iron sights where it is necessary to focus on a sharply defined front sight placed on a blurry target.

Mirage: Mirage, as referred to here, is not related to the bending, or refraction, of light rays as they pass through different media.

An example of this is the refraction of light as it relates to temperature differences of different layers of air which seem to form a lake far ahead as you drive along a highway on a hot day. Instead it is related to heat waves rising from hot objects. Specifically it refers to heat waves rising from the ground on a hot day. These shimmering waves can only be observed through a powerful scope, such as a spotter scope. For the best effect, the scope should be focused about halfway to your target, with the focus adjusted so that the target becomes blurry. Try to focus on the shimmering waves, which are our "mirage". If the waves seem to be rising vertically, the wind is zero. If they are rising at about 30 degrees with respect to vertical, the wind is one to three mph. If it is about 45 degrees, the wind is 4 to 7 mph. If it is 90 degrees, or horizontal, it is 8 to 12 mph. And this is about the maximum wind speed that can be determined by this method. This is a method which accomplished shooters rely heavily on to determine speed.

DATA SHEET

Date: ___________ Rifle: _________ Scope: __________ Temperature: _______

Caliber: _______________ Ammunition: ___________________________

25 Meter Sight Setting: ____________ BSZ – 300 yard Sight Setting: ______________

Mil Dot Magnification: _____________ Front Sight Angular Width (MOA): ________

Half –Value Duplex (MOA): __________ At Magnification: ________________

Mil Dots used as MOA: Magnification: _____ where Mil Dot spacing = _____ MOA

Horizontal Sight Setting for no wind: __________________

Wind: You may wish to include this or additional information here or in the Notes below.

Distance (yards)	Come-Ups (MOA)	Notes – such as sight settings, group size, etc.
100 yd sight setting, group	----	
100 to 200		
200 to 300		
300 to 400		
400 to 500		
500 to 600		
600 to 700		
700 to 800		
800 to 900		
900 to 1000		

DATA SHEET

Date: ___________ Rifle: _________ Scope: __________ Temperature: _______

Caliber: _______________ Ammunition: ___________________________

25 Meter Sight Setting: ____________ BSZ – 300 yard Sight Setting: ______________

Mil Dot Magnification: _____________ Front Sight Angular Width (MOA): ________

Half –Value Duplex (MOA): __________ At Magnification: ________________

Mil Dots used as MOA: Magnification: _____ where Mil Dot spacing = _____ MOA

Horizontal Sight Setting for no wind: __________________

Wind: You may wish to include this or additional information here or in the Notes below.

Distance (yards)	Come-Ups (MOA)	Notes – such as sight settings, group size, etc.
100 yd sight setting, group	----	
100 to 200		
200 to 300		
300 to 400		
400 to 500		
500 to 600		
600 to 700		
700 to 800		
800 to 900		
900 to 1000		

DATA SHEET

Date: ___________ Rifle: _________ Scope: __________ Temperature: _______

Caliber: ________________ Ammunition: ____________________________

25 Meter Sight Setting: ____________ BSZ – 300 yard Sight Setting: ______________

Mil Dot Magnification: _____________ Front Sight Angular Width (MOA): ________

Half –Value Duplex (MOA): __________ At Magnification: _________________

Mil Dots used as MOA: Magnification: _____ where Mil Dot spacing = _____ MOA

Horizontal Sight Setting for no wind: ___________________

Wind: You may wish to include this or additional information here or in the Notes below.

Distance (yards)	Come-Ups (MOA)	Notes – such as sight settings, group size, etc.
100 yd sight setting, group	----	
100 to 200		
200 to 300		
300 to 400		
400 to 500		
500 to 600		
600 to 700		
700 to 800		
800 to 900		
900 to 1000		

DATA SHEET

Date: __________ Rifle: ________ Scope: _________ Temperature: ______

Caliber: ______________ Ammunition: _________________________

25 Meter Sight Setting: ___________ BSZ – 300 yard Sight Setting: _____________

Mil Dot Magnification: ____________ Front Sight Angular Width (MOA): _______

Half –Value Duplex (MOA): _________ At Magnification: _______________

Mil Dots used as MOA: Magnification: _____ where Mil Dot spacing = _____ MOA

Horizontal Sight Setting for no wind: _________________

Wind: You may wish to include this or additional information here or in the Notes below.

Distance (yards)	Come-Ups (MOA)	Notes – such as sight settings, group size, etc.
100 yd sight setting, group	----	
100 to 200		
200 to 300		
300 to 400		
400 to 500		
500 to 600		
600 to 700		
700 to 800		
800 to 900		
900 to 1000		

DATA SHEET

Date: ___________ Rifle: _________ Scope: __________ Temperature: _______

Caliber: ________________ Ammunition: ____________________________

25 Meter Sight Setting: ____________ BSZ – 300 yard Sight Setting: ______________

Mil Dot Magnification: _____________ Front Sight Angular Width (MOA): ________

Half –Value Duplex (MOA): __________ At Magnification: ________________

Mil Dots used as MOA: Magnification: _____ where Mil Dot spacing = _____ MOA

Horizontal Sight Setting for no wind: __________________

Wind: You may wish to include this or additional information here or in the Notes below.

Distance (yards)	Come-Ups (MOA)	Notes – such as sight settings, group size, etc.
100 yd sight setting, group	----	
100 to 200		
200 to 300		
300 to 400		
400 to 500		
500 to 600		
600 to 700		
700 to 800		
800 to 900		
900 to 1000		

NOTES