BC Chrono©
System 89

User's Manual

The bullet speaks the truth;
the System 89 listens well.

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Preface

Muzzle velocity and time-of-flight measured over long distance characterize a bullet's flight. A ballistic coefficient properly calibrated with these two measurements from your ammo and gun yields accurate predictions.

Development and testing of the ***BC Chrono***© *has extended over years. Two men deserve special thanks. Richard Larson has written most of Oehler's software for forty years. Richard not only provided computer code for the '89, but gave valued guidance during the entire project. We have worked with Buford Boone on ballistic testing for decades. Roughly ten years ago we recognized the need for better long range predictions. Buford's suggestions, support and thorough testing through all the stages of development have been invaluable.*

If you just can't wait, **Quick Start** *instructions are on the next page. Helpful videos are on the USB setup stick.*

Contains FCC ID: MCQ-XB900HP

The enclosed device complies with Part 15 of the FCC Rules.
Operation is subject to the following two conditions.
(i) this device may not cause harmful interference and
(ii) This device must accept any interference received,
including interference that may cause undesired operation.

WARNING

Oehler Research, Inc. does not authorize the export of this system outside of the United States of America. The equipment described within is controlled for export by the U.S. Department of State, under the International Traffic In Arms (ITAR) regulations (22 CFR, Parts 120-130), and/or the Department of Commerce under the Bureau of Industry and Security Export Administration Regulations (15 CFR, Parts 730-774). To export these products outside the United States of America, you must comply with the regulatory agency's license and documentation requirements.

Quick Start Instructions

Before going to the range:

- Install software on your Windows PC using the **SetupSys89** program from thumb drive.
- Open the **Sys89 Demo** program and **Replay** a few tests. Fire tests using the **Test** screen and the **Shot Sim** button. Try it; it won't bite.
- If all operations are not apparent, you may peek at the balance of this book.
- Connect one controller unit to the PC USB. If your PC has internet access, it should install proper USB driver.
- Start **Sys89** program and register both controller units using **Unit Registration** under **Tools**. Close **Sys89** program.

At the firing line:

- Place skyscreens on rail in front of muzzle.
- Place a controller with laser reflector even with start skyscreen.
- Connect skyscreens and PC to controller. Start, middle, and stop skyscreens connect in order to **EVENT A**, **EVENT B** and **EVENT C**.
- Open the **Sys89** program. Turn controller units **ON.** Light will blink twice and go dark.
- Select **Radio Check** under **Tools** to verify communications and battery voltage.
- Leave units **ON** with **Radio Check** running as you set up target.

At the target:

- The controller LED should continually blink indicating communication with gun.
- Install the flyover target mics in a line below the line of fire. Starting at the left, connect mics to event inputs A, B, C, D.
- Place controller even with mics and measure the exact distance from target to start skyscreen.

Back to the firing line:

- The Sys89 program should still be open. Click **End Radio Check**.
- Click **Setup** and **New**.
- Provide a unique test file name and enter test conditions.
- Choose G1, G7 or other drag function.
- Leave signal level at 80 for gun unit. Enter the distance between start to stop screens.
- Select **Fly-over Target** type. Leave signal level at 80. Enter distance between widest mics as target size.
- Measure and enter the exact range from first screen to target.
- When you are ready to fire, click **Test.** You will see **--- Working ---** .
- Fire your first shot after you see **--- Ready ---**
- The system will momentarily display **Working** and will show the measured data within 20 seconds.
- You may fire another shot each time **Ready** is displayed. The **Summary** updates automatically.
- At test completion click **End Testing**.
- Update your home screen in anticipation of next test. Increment the **Test Name** by clicking **Next Test.**
- Check ambient temperature and click **Test** when you are ready to fire the next group.

The System 89 measures time-of-flight. Time-of-flight has been seldom used because few people could measure it. We've made the measurement practical; it is easy only if you follow instructions. You would honor us by reading the balance of this book.

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Table of Contents

These instructions are a work in progress. The working copy has been on Dr. Ken's computer for years and is continually amended. Writing and editing continue. This table of contents is a rough map of the book.

After-thoughts

A collection of topics we thought helpful.

How does the System 89 work?

Shooters have long relied on predictions made using an assumed drag function along with book values for both muzzle velocity and ballistic coefficient. For accurate predictions, you must use the muzzle velocity and ballistic coefficient generated with your gun. Both muzzle velocity and ballistic coefficient vary from gun to gun. You must measure the behavior of your ammo fired from your gun. You can't accurately predict what you haven't accurately measured.

The legacy drag functions (G1 and G7) can give accurate predictions if the ballistic coefficients are calibrated to your ammo and gun at sufficient distance. To calibrate the ballistic coefficient, you must measure three things.

1. Initial velocity.
2. Distance to target.
3. Time-of-flight to target.

The time-of-flight predicted must match the observed time-of-flight. If they don't match, you must change the ballistic coefficient until they do.

If you want the absolute accuracy of your ballistic coefficients to be better than 1 percent, then your measurements must typically be accurate to 0.1 percent. With a screen spacing of at least eight feet, Oehler skyscreens can provide velocity accuracy to 0.1 percent and a reliable start signal for the TOF measurement. The third skyscreen provides a redundant measurement to verify the initial velocity.

Distance accuracy of 0.1 percent means 1 meter at 1000 meters or 0.5 meter at 500 meters. Your rangefinder's accuracy should be verified before you trust it.

Measuring the time-of-flight (TOF) is difficult. We start a clock when the bullet passes over the first skyscreen and stop the clock when it gets to the target. The impact of the bullet on a target plane or the Mach cone hitting the microphones provides an accurate stop signal.

The System 89 uses two controller units linked by radio. The operator talks to the unit at the gun via USB cable from his Windows computer. The unit at the gun monitors the muzzle skyscreens and communicates with the target unit. The target unit monitors the downrange microphones. Each time a controller unit recognizes a signal from a skyscreen or microphone, the unit records the exact time the signal occurred. We call each trigger an event. The PC collects and analyzes these event times.

The PC requests data from the controllers approximately one hundred times per minute. There may be a delay of several seconds before the PC gets all the data from both units. The PC accumulates the event times from the controllers and sorts them into logical shot groups. Each shot group starts with the trigger of the first skyscreen at the gun. Because of communication delays and the long time-of-flight, it takes several seconds for the PC to respond to a shot. The computer can be confused if you fire before the PC indicates **Ready**.

Measurements made at a single target distance is usually adequate for supersonic loads. Ideally, the target should be located at the range at which the velocity has decayed to approximately Mach 1.2. Ballistic coefficient measurements made using G7 over this range typically provide hold-over predictions accurate to 0.1 mils through the supersonic range. Drop and wind deflection computed using the measured initial velocity and the time-of-flight over the long distance appear to be almost independent of the exact drag function chosen. If the measured ballistic coefficient changes as initial velocity is varied, or changes when you measure it over different ranges, it indicates that your chosen drag function does not exactly fit your bullet. Things work best if you can start with a drag function fitting you bullet. G7 is usually adequate. If you lack a custom drag function, you can use the test data from two or more ranges to construct your own "stepped ballistic coefficients".

If you lack the long range required for optimal test results, remember that most published BCs were measured at factory ranges of 200 yards or shorter. Even at these close ranges the System 89 can accurately calibrate the BC of your ammo better than did the factory. The factory did not test your ammo fired from your gun.

If you test with your target at the transonic range (where velocity has dropped to approximately 1350 feet per second), it is difficult to spot the impact of your shots. We anticipate this problem and provide an indication of where the bullet hit within the desired target array. Four microphones placed at the corners of a square target provide the best accuracy. This *fly-through* arrangement allows you to observe apparent hit location and adjust aim to keep following shots within the desired target area. The user must provide the square mounting frame usually made with PVC pipe. The maximum side length is 3 meters or 10 feet. A side length of 6 feet or less is more convenient.

The simple *flyover* or line array of microphones on the ground is easier to set up. Scoring accuracy is inferior to the square array, but you still get an accurate ballistic coefficient and reasonable indication of shot location at the target.

When the bullet has become subsonic at long range, there is no Mach cone to trigger microphones. You must sense the impact of the bullet striking a physical plane. A sheet of plywood or drywall material with one or more mics attached works well. Multiple sheets can be used to make a larger target. The microphones supplied with the system can sense the bullet impact on the sheet. The accurate measurement of BCs extending from supersonic down into the subsonic velocity range may require tests at both the transonic and subsonic ranges.

Subsonic 22 rimfire bullets always require use of an impact plane. Either a sheet of plywood or a sheet of steel works well. With the rimfire, you cannot tailor your load, but you can test and select ammo based on demonstrated uniformity. You should evaluate ammo based not only on short range accuracy and uniform muzzle velocity, but also on the uniformity of long-range time-of-flight. Uniformity of TOF translates directly to uniformity of drop.

System Setup

You should first learn about the *BC Chrono* system in the convenience of your home or back yard. A test range located miles from home is not the best place to learn a new system. The system works with airguns, 50 BMGs and all in between. Twenty windy yards is extreme long range for a airgun pellet.

Computer Considerations

The software has been tested to work with Windows 7 through Windows 10. We urge you to install the software on both your desktop computer and your laptop. Memory requirements and processor speed are almost insignificant. Windows 10 with internet access gives the easiest and most reliable installation of the required USB driver. Manual driver installation is required for earlier versions of Windows.

There are two important considerations for a field computer.

1. Battery life must be adequate for a day at the range. This often means the ability to recharge the computer from a vehicle or other power source.
2. The display must be usable in bright sunlight. A beautiful display in your office may be almost useless in the sun. A non-reflective screen and a large cursor are helpful. Choose a Windows display with high contrast. Adjusting vertical display to 600 pixels will maximize size of windows if you need larger type.

If all else fails, you can mimic the ancient photographers and drape a dark cloth (poncho, blanket, garbage bag, cardboard box, anything) over your head and the display. We keep a large square of black cloth, along with a few clothes pins, in our range toolbox.

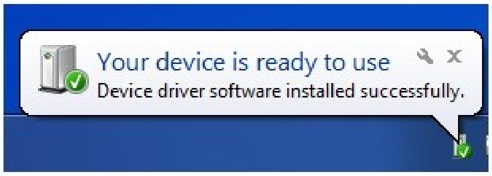
Unpack the system including the **SetupSys89** program included on the USB flash drive. Alternatively, you can find and download any latest revision of the program from the oehler-research.com web site. Run **SetupSys89**. The program automatically installs four programs and four desktop shortcut icons. If you are in a great hurry to play with the software you can delay installation of the device drivers and go directly to the **Sys89Demo** section.

The main Sys89 program will not run until device drivers have been installed.

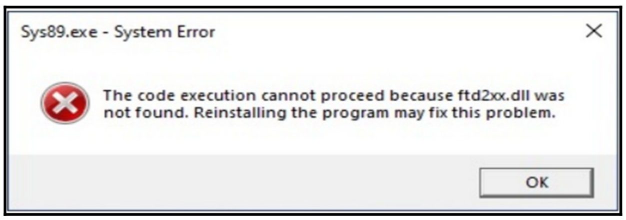
If you run the main **Sys89** program before you install USB drivers you will see an error message telling you that you must install the drivers.

Device Driver Installation

Connect either controller unit to your PC using the USB cable provided (USB A-Male to B-Male, commonly called a printer cable). If the PC is running Windows 10, it will install the proper driver. If prompted, allow Windows to search on-line for the latest driver. Once Widows reports "Device driver software installed successfully," you can run the **Sys89** program. The message may be different on different versions of Windows. Windows 10 may show no message. If there is no message, plug in either unit and attempt to run the **Sys89** program.



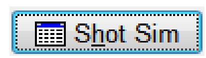
If the driver is not installed then you'll see the following message when you try to run the System 89 program.



You need not reinstall the System 89 software, but you must install the required driver. If the PC has no internet connection or if Windows failed to install the driver, then you must locate and install the driver. Open the **ReadMe.Txt** file found in the **Drivers** folder under the location selected for installation. Select and run the proper driver setup file for your operating system. After running the driver setup file connect the controller unit and turn it on. Run the **Sys89** program to verify proper installation. The program will ask if you want to register units. You may go through the registration procedure, or click **No** and close the main program.

Sys89Demo

The **SetupSys89** program installed **Sys89Demo** with a shortcut icon on your desktop. The **Sys89Demo** program is ready to run as installed. It needs no extra hardware or drivers. We urge you to open and run the **Sys89 Demo** program as an introduction to the system. The demo program resides in the folder with the regular Sys89 program and they share the settings. Do not try to open them both at the same time. Peek ahead to **Enter Test Setup Data** located on page 17 for specific information regarding program operation. The demo program behaves the same as the regular Sys89 program, but you need not worry about radios, USB cable, skyscreens or microphones. You can even fire simulated shots by pushing a button.



The **Shot Sim** button is located at the top of the test window. This button is found only in the demo version of the program. You can fire one or many shots with varying characteristics and forced random variations. It is much easier to use the system in the field if you have learned to use the demo program at your desk.

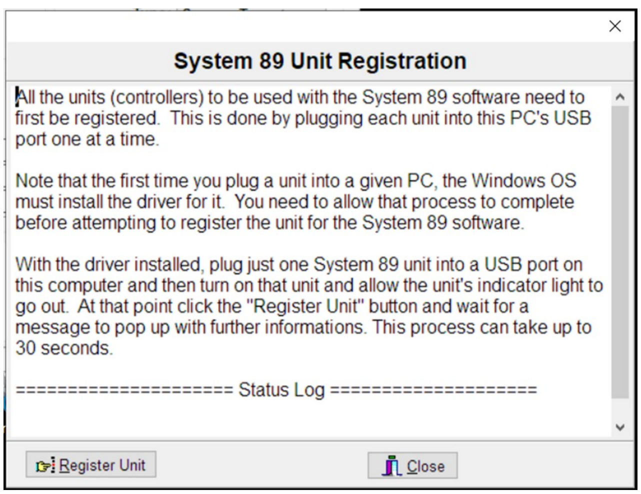
Experiment and work with the demo program until you are comfortable with it. Set up hypothetical experiments, save the test setup templates, fire simulated shots, observe the data, look at the raw times of individual shots, print the reports, export the data to the Excel files.

Don't go to the range until you are comfortable with the demo program. We try to make things simple, but the System 89 is doing a job considered impossible just a short time ago.

Controller Unit Registration

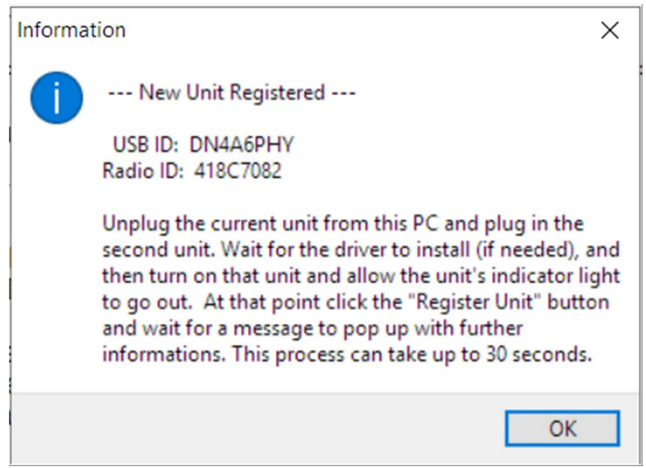
The USB port of each controller unit has a unique preassigned name and each radio has a preassigned name. There are millions of similar radios in use. Your two radios must ignore all others as they communicate only with each other. Your PC must learn the names of your controllers and radios. The preassigned names are long and clumsy, so we must let the PC and controllers introduce themselves.

For the proper introductions the PC must be running the regular **Sys89** program. The first time you run the program you will automatically be directed to the Unit Registration. (If registration is required later, you can select **Unit Registration** under **Tools.**) Connect a controller to the PC using the provided USB cable. Turn **ON** controller power. You will see:



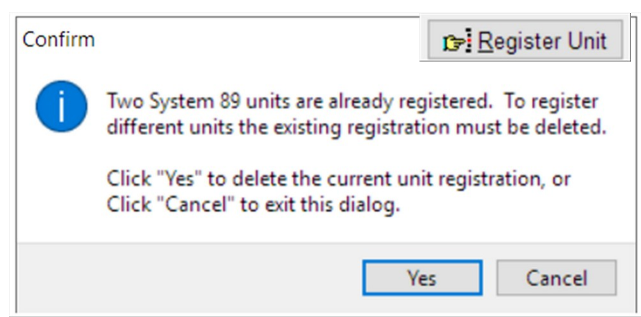
Plug one System 89 unit into a USB port on the computer and then turn on the System 89. Wait until the indicator light stops blinking.

Click the **Register Unit** button. You will see the following message.



Follow the instructions using the second unit. The unit connected to the computer via the USB cable is always recognized as the "gun" unit. Every unit powers on as a "target" unit, but then turns into a "gun" unit when it is connected to the PC. Don't worry if you swap the two units; the PC automatically assumes that the unit connected to the computer is at the gun and the second unit is at the target.

To change radio registrations, you must select **Unit Registration** under **Tools.** You will then see:



Delete the current unit registration and then re-do the registration procedure for both units. Even if you use one previously registered unit , you must delete all registrations and start over.

Firing Line Position

One controller unit is located at the gun. This unit uses three Skyscreen III detectors to measure initial velocity and the start of the time-of-flight measurement. Skyscreens should be properly mounted on the EMT rail. The optimum spacing is usually determined by the longest rail that you can transport to the range in one piece. We urge you to make your own long mounting rail for improved accuracy. Multiple piece rails require special care in fabrication and set-up. A droop or sag of less than an inch at the center of the rail can cause significant velocity measurement error. The 4’ *quick start* rail fits into a carrying case and is within shipping size limitations. The 4’ spacing is the absolute minimum suggested for measuring ballistic coefficients. A 6’ rail will conveniently fit into a pickup truck for transport to the range. An 8’ or 9’ rail can usually be carried with minimal overhang or can often be stored near the range. Velocity measurement errors with the 8’ rail are expected to be half the errors typical with the 4’ rail.

A wooden wedge with a series of 9/32 inch holes drilled along the slanted edge provides varied skyscreen mounting height on sloping ground. For a lower mount, place the tail through a 9/32” hole drilled through a short piece of lumber or PVC pipe. We usually place the first skyscreen approximately 10 feet from the gun.

Skyscreens can provide accurate muzzle velocities only if there is adequate light. Skyscreen III detectors expect to see bright and direct sunlight on the tops of each diffuser. The skyscreens also work well under fully cloudy skies during mid-day if you omit the orange diffuser. Those overhead clouds are actually the best diffuser you can get.

Performance of the skyscreens is monitored and indicated by the ***Proof*** channel of the testing display. This channel shows the difference in velocity measured between start and middle skyscreen and the reported velocity measured between start and stop skyscreens. With good light and adequate screen spacing, the proof numbers should have a variation of only a few feet per second.

Plug the skyscreens into the unit. The start skyscreen connects to **EVENT A**, the middle skyscreen connects to **EVENT B** and the stop skyscreen connects to **EVENT C.** If not familiar with Oehler chronographs and skyscreens, please refer to the Skyscreen section in the Afterthoughts chapter.

Down range distances are referenced to the start skyscreen.

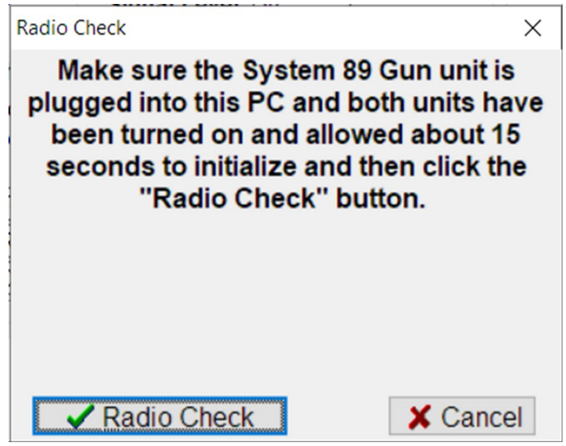
If you expect to use the range again, mark the location of the first or start screen with a permanent monument. At least secure some survey flagging tape or colored plastic to the ground with a large nail. **The initial velocity is measured at the midpoint of the start and stop screens.** The the time-of-flight start is referenced to this midpoint. Distance from the muzzle to the first screen is of secondary importance. Exact location of the controller unit is not critical but it should not be subjected to muzzle blast. (We like to have the laser reflector of the gun unit adjacent to the start screen as we measure distance back from the target.)

Mount unit on a tripod with the stick antenna pointing straight up and skyscreen cables going down to the ground. Keep the skyscreen cables away from the radio antenna. The furnished tripods are convenient stands for the radios; they are not intended for spotting scopes or photography. Connect the unit to the PC and turn it on. The light on the unit will blink momentarily and then go off.

Place gun unit even with start skyscreen and with laser reflector aimed toward target. Measure range from target back to gun; range measured both ways checks accuracy of your measurement. Move unit away from muzzle blast before shooting.

The supplied straight stick antennae have been used at two miles. A Yagi antenna may be used for extreme range. The antenna elements should be vertical and the antenna aimed at the distant radio. Place the antenna as high as possible. Use a high quality cable.

Turn on the target radio and conduct a radio check with the gun unit. Select **Radio Check** from the **Tools** drop-down menu.



Click **Radio Check** to start.

The radio check window will show activity as the radios link to each other. After the test is completed, the window will show the radio signal level received at the gun and battery voltage at both gun and target. The **Signal Level** is measured with standard RSSI notation where -40 db represents maximum signal and -100 db approximates the weakest usable signal under good “clear channel” conditions. The **Signal Quality** indicates difficulties caused by stray radio signals and noise at your location. Accuracy is not degraded by lower signal quality, but the system must sometimes work longer to process a shot.

Leave **Radio Check** running while you take the second unit downrange to install the target equipment. After you install the target radio, the blinking light indicates that you have good communication with the gun unit. Even if you forgot to leave **Radio Check** running at the gun, make sure that you switch the target unit **ON** before you return to the gun.

Downrange Target Considerations

You have a choice of three target arrangements. You can use a simple *flyover* acoustic target, an impact target, or a square acoustic target. For bullets still supersonic at the target, the flyover acoustic target is the easiest to deploy. This target is our default choice to measure a single ballistic coefficient giving the best fit from gun to maximum supersonic range. An impact target (think of a sheet or plywood or drywall with a couple of mics attached) is suitable for both subsonic and supersonic bullets. Impact targets are necessary for subsonic bullets (as 22RF) or at extreme long range. We have used three sheets of plywood to form an 8x12' target at two miles. We consider that to be the maximum practical size. Do you really need to measure the ballistic coefficient if you can't hit that target? The square acoustic target provides better target scoring accuracy and operation in the transonic velocity region at the cost of more difficult set-up at the range.

Downrange Radio Considerations

Locate the controller unit at a convenient position. It is prudent to place the unit to the side of the target with the laser reflector pointed toward the gun. Keep the antenna as high as possible. It must extend above any barrier.

While you are at the target, you can check for proper communications by momentarily turning the controller unit off. When switched back **ON**, the LED will flash a few times and then go dark until communication is re-established. This process normally completes within thirty seconds. Successful communications are indicated by the LED blinking approximately 100 times per minute. The gun unit must be **ON** in the Radio Check mode if you expect to communicate with it.

If communications problems are encountered, possible causes and suggestions are:

- Antenna elements must be vertical.
- Elevate the antennae at both the gun and target to provide better line-of-sight between radios. Having the line-of-sight just skimming the top of the ground causes signal loss. Radios work better if they are not under a metal roof or behind a wall.
- Downrange radios need ***radio line of sight*** back to the firing line. *Radio line of sight* means more than peeking through a small hole in timber and terrain. You want to see through a wide band and clearly over the terrain. Having dense timber adjacent to the path or allowing the radio signal to skim just above the ground soaks up radio signals.
- When quoting range, radio manufacturers assume that both transmitter and receiver are located at the tops of high towers. They further assume that there are no interfering radios in the area. For example, the '89 radios operate near the frequency band of some common cell-phone signals. What the manufacturers specify as *line of sight* might

be better described as a *football of sight* with transmitter on one end of a huge football and the receiver on the other end. *Radio line of sight* is not just a *line* joining transmitter and receiver, but they assume a large volume of empty space. For example, shooting from hill-side to hill-side provides an unobstructed path for the signals almost as if the radios were on towers. Shooting across a flat field with radios near the ground gives up half the *football of sight.* Shooting across flat terrain with timber along the sides of the firing lane causes even more signal loss.

- The radios of the System 89 operate in the 900 MHz band. A replacement stick antenna can be found locally or on the internet. These antennae are often used with cell-phone booster amplifiers. To fit the radio connector on the System 89, look for the magic description of *"900 MHz with RP-SMA male connector"*. The radio connector on the System 89 includes a center pin. It expects to see a small center hole on the mating antenna or cable.
- If the Signal Level is between -40 db and -80 db, you probably have no radio problem.

Battery

Each controller unit is powered by an internal 18650 lithium battery. A fully charged battery should provide a full day of operation at the range. The battery is recharged through the USB Type B connector located on the front panel. Any common 5-volt USB or cell phone charger can be used with a *USB Type A to Type B* or "printer" cable. Older chargers should completely charge a battery overnight while a 2.0 amp charger may fill the battery faster. The battery of the gun unit is trickle recharged through the USB connection to the PC. The battery voltage of the units is displayed during the radio check; don't expect a radio to operate with voltage less than 3.3 volts. If one unit shows marginal battery voltage, then use it at the gun where it can steal power from the computer. We suggest a full charge of both units before you go to the range. A portable cell-phone charger [battery] can be connected to the target unit using a USB printer cable.

Warning

If you must replace the battery located inside the controller unit, please be careful. The 18650 battery includes no polarity protection. A battery installed with reversed polarity may damage the unit beyond repair. Such damage is not covered by the warranty. Oehler will provide and install a proper battery for a reasonable charge.

Flyover Target Array

The System 89 flyover target uses four microphones equally spaced along a straight line. Target scoring accuracy is diminished compared to a square array, but the observed arrival times of the bullet still provide reliable time-of-flight measurements. It is much easier to place four mics in a straight line on the ground than to mount a square array in the air.

We make our array using three 40 inch sections of 3/4” PVC pipe joined with Tee fittings. Two Tee fittings are glued to each ends of two pipe sections. The center pipe section without fittings should remain unglued so the array is easy to take down and transport. The shorter pipes illustrated keep the main rail from rolling and also serve as handles when you need to twist the sections apart.

You can change the length of the array. Just make sure the mics are equally spaced along a straight line. Measure between the two end mics to determine the length or size of your array. An overall array length between 6 and 16 feet is usually practical.

The microphones are designed to mount directly to a PVC Tee. Pipe size is optional. We favor nominal ¾ inch for flyover arrays because it is compact and convenient. Nominal 1 ¼ inch is appropriate for square arrays; it is more rigid.

Microphones should be oriented so that Mach cone of the bullet slaps the face of the mic. The sensitive portion of the mic is located at the bottom of the “doodle-bug” hole on the mic face. This face side of the mic should be aimed at the gun or the center of a square target.

PVC Tee fittings must be drilled with a 9/32" diameter hole passing through both sides of the fitting where the pipe centerlines intersect. Microphones are mounted to the PVC with ¼"-20 carriage bolts and wing nuts. The shoulders of the carriage bolt will meet resistance the first time a mic is mounted. You will probably have to use pliers to tighten the wing nuts the first time as you force the shoulders of the bolt to bite into the PVC.

Microphones should be oriented so that recessed sensitive element faces toward the expected source of the Mach cone. You want the Mach cone to slap the face of the microphone. Most sensitivity problems will occur at low velocities and with the bullet path far from the microphones. The microphones should face the gun as is shown in the photo. **Event A** is connected to the microphone on the left as viewed from the gun. Other mics follow in order.

This flyover array is protected by a wall of railroad ties. Do not place the array immediately adjacent to the wall, but allow at least twice the height of the wall. The Mach cone does not travel straight down.

We prefer to place the target radio on a tripod located off the end of the mic array. Place radio as far from the array as the cables will allow and keep the antenna pointing up. For best radio link, keep radio high. Let microphone cables fall straight down from unit. Keep microphone cables away from antenna. Orient radio so that the laser reflector on the top of the unit faces the gun.

As a rough rule-of-thumb, you can detect bullets passing no higher above the microphones than the array length. Accuracy of apparent impact locations is diminished when the shot is fired too high, too low or beyond the ends of the array. Accuracy of the arrival time remains adequate for computing ballistic coefficients. The mathematical solver that converts microphone signals to hit location breaks down if you shoot either too far from the array or too close. Target scoring is most accurate if you keep shots no farther than half the array length above the array.

Shots that are too high or too near the microphones will still be scored. Vertical position of these shots may be uncertain, but horizontal position is adequate to confirm your wind call. Shots falling left or right of the array will given a numerical score, but will not be shown in the picture. If the shot is recognized by the microphones, the time-of-flight and ballistic coefficients are valid.

Target scoring accuracy of the flyover target is diminished as the velocity drops to the speed of sound. You should strive for terminal velocities above Mach 1.2.

Square Target Array

We suggest 1 ¼” Schedule 40 PVC pipe. If 1 ¼” PVC pipe and fittings are not readily available, either 1” or 1 ½” PVC can be used. The 1” pipe will be flimsy if you make a large square target without extra support (such as a steel T-post planted behind each vertical PVC). The PVC pipe maintains spacing between mics; it is not a strong structure or bulletproof.

This “parade ground” configuration shows a target frame on flat ground and no wind. In the real world, expect to provide support posts behind each vertical side.

The mics should be mounted so that each recessed microphone element faces the impacting Mach cone. Cables can be routed through the hole in the mic base and wrapped around the vertical pipes. Use duct tape to secure cables to the pipe so that they do not flop in the wind. (Cables banging the frames may cause false mic triggers.) We have found it convenient to permanently glue the Tee fittings to both top and bottom pipes. Side pieces can remain unglued; gravity will hold them in place. Supporting legs and feet can also be made from PVC pipe. Glue a Tee between each pair of horizontal feet. Leave the vertical legs unglued.

Here is more detail of a microphone mounted at the corner of the array. The recessed element faces toward the Mach cone.

The exact size of the finished microphone array (measured from center of microphone element to center of adjacent microphone element) is best measured after you build the array and attach the mics. The actual scoring plane of the target is located at the microphone centers.

We suggest a maximum size of 121 inches on a side. That is the largest you can get using a 10 foot pipe. Larger arrays become very floppy and the cables from the microphones will be too short. An array is much more convenient if you keep the square to 6 feet or less.

We name the microphones and events in the order shown as viewed from the gun.

A D

B C

Connect the microphones to the corresponding event inputs of the controller unit.

For accurate group measurements you must assure that the array is stable and normal to the bullet path. With a paper target you never notice a slight fore-aft tilt of the target. With paper, the slight tilt does not significantly affect the hit location with respect to the aiming point. With the acoustic target, such fore-and-aft tilt will significantly change the calculated impact location. As a very rough rule of thumb, *If the top of the acoustic target drifts one inch toward the gun, then the apparent bullet hole will be reported an inch too high.* This very rough approximation depends on bullet velocity and the location of the hit in the target frame, but you get the general idea. If the small tilt is constant throughout a group, then the shape and size of the group is relatively accurate, but the apparent group center will be shifted by the tilt.

The accuracy of the acoustic target is influenced by the velocity of the bullet passing through the array. With bullets at Mach 1.2 and above, scoring accuracy of a 10’ square target is expected to be within a couple of inches. Absolute scoring of the group center depends on the arrival angle of the bullet and is difficult to determine. Observed impact points will be reported for slower bullets but the accuracy diminishes as the velocity approaches the speed of sound. At velocities within 30 feet per second of the expected speed of sound, hit locations are no longer displayed. At velocities below the speed of sound, the microphones will no longer hear the passage of the bullet.

Although the blunt angle of the Mach cone prevents accurate scoring of hit locations at low velocities, the system still records accurate arrival times. The sharp Mach cone of higher velocities decays to a flatter cone and then to a flat shock wave at the speed of sound. Times-of-flight along with the corresponding ballistic coefficients will be reported until the bullet is subsonic .

Impact Target

If the microphones are forced to listen to impact sounds, we can provide an arrival time signal to measure time of flight. A Mach cone is not required; either supersonic or subsonic bullets will trigger the stop time, but we can't tell you the impact point.

The arrival time signal is generated when the bullet strikes a physical target plane. We often use a sheet of ½ inch plywood. Any hard and dense wall-board or drywall can be used. A large steel plate can be used in a permanent installation. Black powder cartridge riflemen might use their steel buffalo silhouette.

The same microphones used for fly-over or fly-by arrays may be used. The sensitive element of the microphone (located in circular indention of the microphone case) is placed adjacent to the target panel. The acoustic coupling between the element and the panel can be improved by placing a common 5/16-18 nylon hex nut between element and plywood. We secure the nut inside the indention with a piece of cellophane tape. The nut barely protrudes above the microphone case and provides solid acoustic coupling between impact panel and microphone element. The microphone is attached to the plywood sheet with a C-clamp pressing the nut snugly to the sheet.

Although only one microphone is needed, we urge the use of multiple mics at an impact target. We routinely use two or more microphones even on smaller targets. If a mic cable is accidentally shot, you still have at least one working microphone. Having two or more working mics will provide two simultaneous event signals for each impact as a clear indication of a valid signal.

The arrival time at the target is the time at which the impact signal is first detected from one or more microphones. Sound from the bullet's impact is transmitted through the target with very little delay. (Sound travels approximately twenty times as fast through wood or steel compared to air.) The transit time from impact point to microphone is negligible compared to time-of-flight.

If you require a billboard sized target for extreme long range testing, you must use several sheets of plywood. This billboard target is made with three sheets of plywood and with one mic attached to each sheet.

The photo shows both an impact array and a flyover array. For supersonic bullets results from flyover mic array on the ground were identical to results from the impact array. Note the laser rangefinder reflector hanging on the edge of the target. Controller units are shielded behind the white steel target plate located at the end of the flyover array.

Fly-thru and fly-over target arrays provide large target areas, but impact targets are favored for several applications.

- To determine the uniformity of ballistic coefficients of .22 rimfire bullets used in long range competition.
- To determine the effective drag function of handgun bullets when they become subsonic at long range.
- To determine the effective ballistic coefficient of the bullets commonly used in black powder cartridge rifles.
- To determine the chained or stepped ballistic coefficient of a bullet having decayed below the transonic level.
- To determine the ballistic coefficient of subsonic bullets such as from handguns or air rifles.
- A small plywood impact target is easy to take to the range and set up. It works with either supersonic or subsonic bullets.

General Target Observations

The target function of the System 89 is intended to provide approximate hit location. The mics of the '89 were designed to be rugged, inexpensive and appropriate for measuring ballistic coefficient. The mics are not intended for high-accuracy reduced-size target arrays. It is difficult to compete with a paper target and spotting scope at 100 yards. Square arrays allow ballistic coefficient measurements down to Mach 1 even if no target impact location is shown.

Keep your downrange arrays as simple as possible. They will eventually be damaged and you want easily replaceable parts. Be selective in which joints are glued and which are left to be a slip fit. A small amount of PVC cement is adequate for the glued joints. Grease or wax on slip fit joints may make things easier.

You will be tempted to leave microphone arrays outdoors overnight. The system was not designed to be weatherproof, but a little dampness or sprinkle of rain is not catastrophic. Rabbits and other rodents have an appetite for the cable jacket. Don't leave the cables on the ground overnight. Livestock such as cattle will eat cables just for spite.

One problem with disassembling and reusing the arrays is the handling of the microphone cables. They quickly become tangled. Our preferred solution is a pocket full of rubber bands. Bands 3/8 inch wide and 3 inches in diameter work well. Gather the cables into a hank by wrapping them around a microphone on one end and your hand on the other. Secure the hank with at least two turns of the rubber band. Lift one turn of the band and use it to secure the hank to a microphone or pipe connector. You might prefer to use duct tape; it works well and also has other uses. We've been known to simply tie a clove hitch around the folded hank of wires.

Tale of an Impact Target

Many test rounds were fired during the development of the System 89. Most shots were aimed above fly-over acoustic targets at ranges from 800 yards to a mile. Some tests were made at ranges up to two miles to verify radio range and performance. Short range impact target tests of subsonic .22RF loads were also included.

A square of inexpensive particle board was used for the short-range target. It was convenient to set up for the tests at 50, 100 and 200 yards.

Here is the board as viewed from the gun side. We haven't bothered to count the bullet holes after testing was completed. Most holes are from .22RF, but the impact target also worked well with larger calibers.

Two steel targets are clamped at the lower corners of the board. A few impact splashes are visible on the steel plates. The microphones were clamped to the back side of the board with the steel plates protecting them from accidental shots.

The effects of repeated shooting are more apparent on the exit side of the board. Two microphones are clamped at each lower corner and were protected by the steel targets on the front. The system will function with only one mic attached to the board, but redundancy is better. When more than one mic hears a signal at almost the same instant, the computer knows that it was a valid impact. Even with all the extra bullet holes, we saw no failures to detect impact of the bullet.

If you don't have C-clamps handy, you can fasten each mic to the target board using a 1x2x5" block of wood. Drill 3/16" thru holes 1" from each end. Use 2 ½" or 3" screws to sandwich the mic between block and target board. Make sure that the mid element faces the target board.

Enter Test Setup Data

By now you should have the System 89 program installed on your computer. Most of our tests have used Windows 10. Earlier versions of Windows have worked, but may require manual installation of USB driver.

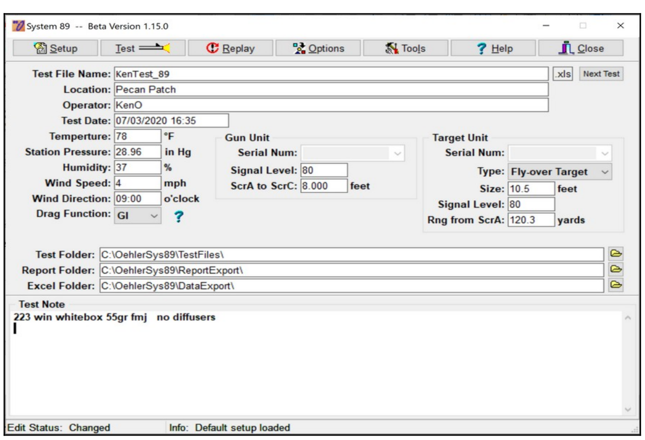
Acrobat Reader must be installed to open and read PDF files, such as the User's Manual, but the System 89 software generates PDF reports without any other software being installed.

The Event time from the first skyscreen is reported as seconds after midnight from the PC clock. Other Event times for the shot are reported in seconds relative to this first event. The date and time of the PC should be checked before any tests. This date cannot be edited without losing the *Original* status of a completed test.

Start the program and play along while reading these instructions. You won't hurt anything and everything you do can be erased.

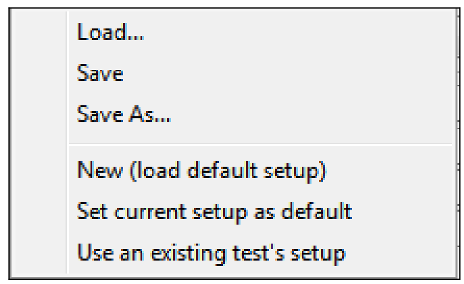
Main Screen Buttons

The program opens with this screen.



Understanding the functions of the buttons arrayed across the top of the window is handy for you to gain a sense of program and data flow. You need not remember all the details, but you must know why they are there and what they do.

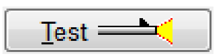
The **Setup** button allows you to control *which* test you run, replay, edit, and save. Its function is closely related to the **Test File Name** which follows each unique test from test firing to archival storage.



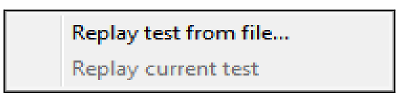
The drop-down from the Setup button describes several functions

- **Load** brings up a list of named tests stored in the **TestFile** folder. These may be tests you've already fired or simply test setup templates of tests you intend to fire. Selected tests may be edited.
- **Save** writes the test template data and any associated data to the named file in the **TestFile** folder. If you edit the setup of a previously recorded test, you must **Save** your changes to keep them.
- **Save As …** allows you to rename the test file of an edited test and to save the results without over-writing the original. We typically append an A to the test name for a test we edit and save. This preserves the original test data in its unedited state.

- **New (load default setup)** loads in a default test setup screen for you to edit, rename, and save.
- **Set current setup as default** allows you to make the default file just what you want.
- **Use an existing test's setup** lets you go back and fire additional test groups using a previously used name and setup.

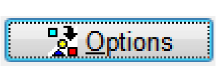


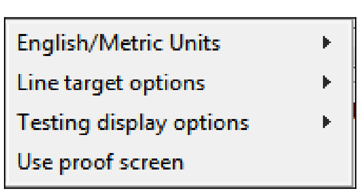
The Test button sends you to the test screen used during actual firing. You can go there after we talk about the other buttons and set up our test.



The **Replay** button brings up a choice of **Replay test from file** or **Replay current test**. The tests from the Test Folder file are those tests you've already fired. After selecting the named test, you will immediately see the testing screen results for that test. If you want to print an old test you must first replay it and then request a printout from the testing screen. Printout can only be made from the testing screen.

The **Replay current test** allows you to quickly look back at the results of the test you just fired. You can make trial edits of drag function, distance or array size and see the results of those edits. With care you can see the effect of the edits without over-writing the original data.



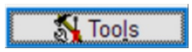


Under **Options** you can choose between **English/ Metric Units**. If you change your selection, the program automatically converts all data to the desired system. You can operate the system in either metric or English. If you replay or print a report from a recorded test, the display and printed report will reflect the units selected at the time of replay or print. You can conduct a test in metric units and replay or print in English units, or you can conduct a test in English units and replay or print in metric units. The System 89 is bilingual. It switches with ease, but don't expect it to operate with mixed units.

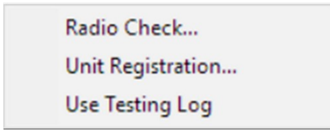
Line target options allows you to **Show areas of reduced accuracy** by shading of the displayed target area. Vertical scoring errors increase near to the microphones and the microphones may not hear bullets passing too high.

The **Testing display options** allow you to select screen colors and font used in the testing display. It all depends on personal preference, lighting, and the size of available computer screen.

Use proof screen should always be selected. An accurate measure of muzzle velocity is essential to the accurate measurement of ballistic coefficient. You should always use a proof screen. Strive to get single digit proof numbers. Uniform, but large, proof numbers usually indicate an error in screen spacing. Erratic proof numbers usually indicate poor light conditions.



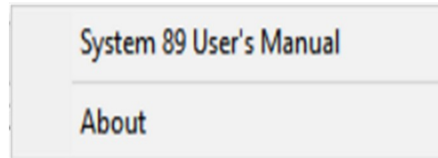
The drop-down menu of the **Tools** button provides three essential functions.



Radio Check and **Unit Registration** functions have already been covered.

The **Use Testing Log** function was used during development and is used only for extreme troubleshooting. If option is checked, the system displays and records a log file showing tracks of many internal system operations. The log will be active during both **Radio Check** and **Test** modes. Resulting text files will be named and stored in your **Test Folder**.

An **Auto Reset Target Unit** function is provided but is not shown. If the target unit fails to respond to normal commands from the gun unit the system automatically begins a remote "reboot" of the target unit. The system first recovers any existing gun or target data. The gun unit is then reset and the program attempts to sync with the target unit. If no sync response is received from the target unit, the target unit is sent a reboot command. If the system remains locked, you must do a manual "off-on" reboot of the target controller.



The **Help** button displays a PDF copy of this **System 89 Manual**. The customary **Help About** shows the usual name, version number, and copyright.

Exits the program gracefully.

Test Conditions

Test File Name. Plan ahead with your naming scheme, the computer will use its standard rules to sort and display the file names when you are trying to recover test data. During initial trials of the System 89, we had accumulated results from only a few dozen tests. We could easily track them all. After accumulating more tests of our own, and then receiving test results from many users, we were overwhelmed. You can apply proper computer discipline and organize all the files into their proper folders; we find this difficult. You can structure your file names to include info such as bullet and gun, but avoid special characters and use no more than 30 characters.

We prefer to use a simple naming system for test files, and rely on the **Test Log** to provide an index to the test names used. The preferred form for test names is

DRF160305xxx_nn

The initial few characters, such as **DRF**, are selected by a user for all his test names. They become his permanent identification. When test results are shared between users, the recipient always knows the source. The numbers are the current date code of **YYMMDD**. We usually have a reasonable idea of date and sequence. You can insert any identification or message **xxx...xxx** following the date. The suffix **_nn** will automatically be supplied by the System 89 as it increments groups. The program searches for any previous use of the test name and then applies the next available suffix number.

All test info files will default to the Excel **.xls** format and will be stored in the indicated **Test Folder**

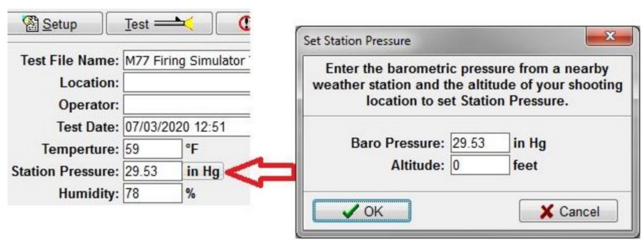
You must rely on the **Test Log** or similar record to include detailed info on the gun and ammo. It is in addition to the information recorded in the System 89.

The **Location** and **Operator** fields are for your records only. They are not used by the program.

Test Date is stored as part of the test results. The date and time furnished by the computer are used for the report.

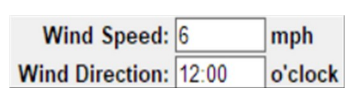
Temperature entry is critical. This value of estimated air temperature along the bullet flight path is used in all ballistic calculations including air density and speed of sound. For accurate data and results, you must observe local air temperature and enter the correct value immediately prior to each test group.

Station Pressure is important, but is less variable than temperature. The pressure varies slowly except during the passage of a weather front. Enter the station pressure as usually measured with a Kestrel.



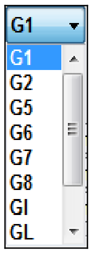
If measured station pressure is not available, click on the pressure dimensions to bring up a supplemental window. Enter the pressure reported from a local weather station and your altitude into this window. The system will estimate and complete the station pressure.

There is provision for entering **Humidity**, **Wind Speed**, and **Wind Direction;** these variables are less significant. When compared to muzzle velocity, time-of-flight, distance, pressure and temperature, the effects of humidity and wind are small.

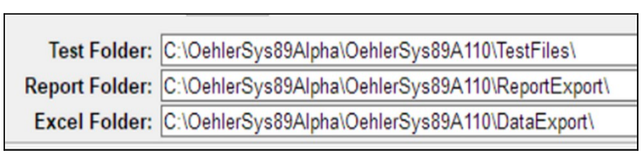


The wind direction is entered in "from clock" format. 12:00 o'clock is from the target. You must use a colon between hour and minutes.

The **Drag Function** allows you to select which of the drag function tables you choose to use. You must select a drag function expected to fit your bullet prior to a test. Ballistic Coefficients will be reported relative to the chosen drag function.



We prefer to select and use G7 with all tests. It not only provides better estimates for the usual long range bullets, but it appears to provide reasonable estimates for subsonic 22LR bullets. You may select G1 if it gives you more comfort. If you later want to change the drag function used, you can replay the test using the desired new drag function. The ballistic coefficients generated during the replay will be those associated with the new drag function. You need not refire the test. You may add your own custom drag table. Drag tables used in the System 89 are in the same format as used by Ballistic Explorer.



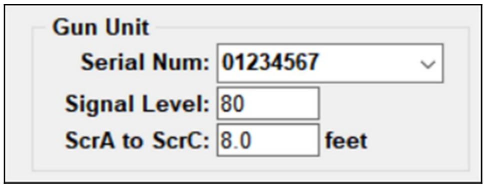
In the **Test Folder** field enter the complete folder address in which you want the archival copy of the test data stored at the conclusion of the test. The data is stored the Excel .xls format. Attempts to edit the data are permitted, but discouraged. Because only the set-up information and raw event times are stored in this file, editing is difficult. Any editing will set an obvious **Edited** flag. If you must edit the file, make a renamed work copy and preserve the original data with its original name. When a test is initially run and completed the program stores a number of CRC (cyclic redundancy check) values in the test file. If a test is replayed the program compares the test data with the stored CRC values. If the CRC values match you will see **Edit Status Original** . If no match, **Edited** is displayed. If you must edit the test set-up, you are encouraged to record the reasons for changes in the **Test Note**. Changes to the **Test Note** and shots omitted from the summary do not change the **Original** status of a test.

In the **Reports Folder** field enter the address of the folder in which you want the *.pdf* format test report stored. In the **Excel Folder** field enter the folder address for the complete exported Excel file describing the test. This file will include results in addition to the event times. All files written to this Excel folder will have ***Exp*** appended to the test name.

The **Test Note** area allows entry of memo information describing the test in more detail. Enter as little as you like, but months or years later you never complain of too much data. Total length of the note is limited to approximately 200 characters. You can edit the contents of the note during the time you are firing a test. If you edit test data or setup after firing, you should note the reason for the edit.

Gun Unit

This area shows the identification and settings for the gun unit.



The gun unit is dedicated to measuring muzzle velocity and to providing the start time for all time-of-flight measurements. **It is assumed that all downrange distances are referenced to the location of the first or start Skyscreen.** The exact time after test start is recorded when the start screen is triggered. All other raw event times will be displayed relative to this start time. The velocity reported is the instrumental velocity measured at the midpoint of the skyscreens. Times-of-flight are reported as referenced to the midpoint of the skyscreens. The indicated distance to the target on the test screen and reports will be the distance from the middle skyscreen to the plane of the target. In other words, the displayed initial velocity, the displayed distance, and the displayed time-of-flight form a consistent set to be used with any ballistics program.

The **Serial Num** is a unique eight-character identification code embedded in the USB port of each unit. Only the PC knows the identity of each unit, and it learns it only through the registration procedure. If you have used the program with your units, the PC will assign the unit plugged into the computer as the gun unit and the other unit remains as a target unit.

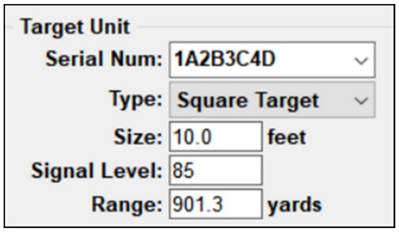
The **Signal Level** represents the threshold level at which an event is recognized. Lower settings let the system recognize smaller signals, but makes it more sensitive to electrical noise. Higher settings require a larger signal from the event sensors, but make the system less sensitive to noise. Signal level settings can range between 50 and 255. The default setting of 80 is usually good. If you must change the setting, don't just nibble. We suggest steps of roughly 30 percent or 50, 80, 110, 150, 200, or at 255. Settings below 50 may cause "false trigger" events.

ScrA to ScrC is the distance measured between the centers of the first and third skyscreen. It is assumed that Screen B is located midway between Screen A and Screen C. For best accuracy in the measurement of the initial velocity, use the longest practical screen spacing. If you can store an 8 or 9 foot rail near the shooting position, that's best. If you can readily transport a 6-foot rail to the range, use that. If you must carry a rail in a carrying case, use at least 4 feet. "Take-down" rails are nice, but you should always verify screen spacing with each use.

If for some reason you want to measure time-of-flight without measuring muzzle velocity, you must set the distance between screens to zero. You can use either a skyscreen or microphone at the Event A input to trigger the start of the time-of-flight and you must use an impact target to stop the time-of-flight.

You can use a muzzle velocity chronograph other than the skyscreens, but you must provide the "start" signal for the time-of-flight measurement. The System 89 will measure and record the time-of-flight to an impact target, but all further calculations are up to the user.

Target Unit



Entry of data for **Target Unit** is only slightly more complicated. Select the function of the downrange unit. From the pull-down menu under **Type** select the desired function.

None indicates that you will measure muzzle velocity only; no target unit is required. The **Fly-over Target** easy to set up and is required for subsonic bullets. The square target provides the best accuracy for both target scoring and time-of-flight measurement and can be used. The **Impact Target** provides only the arrival time signal for time-of-flight. It is used to determine the effective ballistic coefficients of bullets which have fallen below sonic velocity at the target. In this mode all event times will be recorded in the Excel data file. It can be used for special tests for which the user analyzes his own time data.

The **Size** is the length between microphone centers on a side of the target square or between the end microphone centers of the line target array. Size is not relevant to the subsonic target.

The **Signal Level** is the threshold or sensitivity setting for the sensors. Start with a setting of 80. Increase setting if you encounter excessive false triggers. Reduce setting if you miss seeing expected events. Again, we suggest steps of roughly 30 percent or at 50, 80, 110, 150, 200, or 255.

Range

Exact range is critical for computing ballistic coefficient. For accurate ballistic coefficients, the range (measured from start screen at the gun to the plane of the downrange target) should have an error of no more than 0.1%. You must have less than 1 yard error in 1000 yards or less than 1 foot error in 300 yards. The range is best measured by a professional surveyor, but surveyors are expensive and often are not available. Survey equipment may be available for rent, but you still need a trained operator.

We have measured range to target in many ways. A steel tape is economical and accurate, but it is difficult over rough terrain. High-quality laser rangefinders are used by the military to find the approximate range to uncooperative targets without benefit of reflectors. These expensive rangefinders use a tightly focused beam to pick a target from the background clutter but are usually not tested to measure ranges to an accuracy of one part per thousand..

If you use your own laser rangefinder, we urge you to verify its accuracy over a measured long range. Surveyors virtually always use a reflector for laser range measurements and you should too. A reflector is provided with your system.

Use of the proper reflector is critical. The prisms used by surveyors yield the highest accuracy. These prisms are usually small to allow precise measurement of angle. The prisms are small; they collect and reflect only a small portion of the laser light. In our application we are interested only in the range measurement and can use a larger reflector. The larger reflector bounces much more laser light back to the rangefinder. You must use a tripod with your rangefinder to get consistent readings. If the reading is not stable, you are probably not aiming the laser properly.

Military rangefinders rely on a tight beam to select a passive target from the background clutter. Rangefinder aim must be precise because of the tight beam. These rangefinders typically provide range display with one meter resolution. The beam of the Leupold Rx-1200i is in the order of 1.3 milliradians (approximately four feet at a thousand yards). This larger sensitive area is an advantage when used with a highly reflective target. Exact aim is not as critical. The signal from the reflective target dominates the signal returned from typical background clutter. With the reflective target, target lock-on is quick and apparent if the rangefinder is braced.

At ranges beyond 400 yards, it is best to use a reflector made of Avery T-11500 OmniCube White. This material (a film surface of many tiny corner-reflector prisms) is a replacement for the older "beaded" or "Scotchlite" material used for reflective safety tapes and highway signs. It is not available at your local store, but we include a reflective target glued to the top of each controller. Place controllers even with the start screen and with the target array so that you can make accurate measurements from both directions.

We've found that a large sheet of matte white paper is a reasonable target at ranges up to 600 yards. Our experience indicates that you should use the sheet of white paper so long as you can readily get consistent and repeatable readings. If you cannot get consistent readings from the white paper, then switch to using the reflector.

To determine the range to the target we suggest the following procedure. First find the desired locations for the start skyscreen and the downrange target. It is usually easier to accurately measure the distance between gun and target than to place the target an an exact predetermined distance.

Permanently mark these locations so that you can use them for future tests. On our home range we use large 40d nails driven through colored patches cut from scrap plastic bottles. They are easy to see but avoid problems with mowers and grazing animals. (Animals love to eat survey tape.)

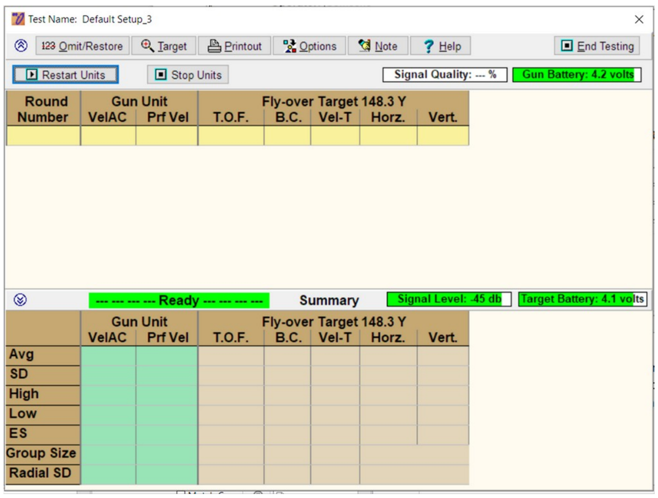
The distance to target need not be an exact round number, but you must tell the System 89 the actual measured distance. If your actual measured distance is 798.6 yards, then you must enter 798.6 yards. Your desire for an approximate 800 yards, or your recollection of an earlier measurement to the 800-yard target line, means little.

For an accurate laser measurement, you must use a reflector. For an accurate ballistic coefficient, the distance measurement is equally as important as the flight time and muzzle velocity.

Modified Leupold Rx-1200i rangefinders work well. Oehler can provide modified Rx-1200i units that give 0.1 yard resolution and better than 0.1 percent accuracy to 1500 yards. For more details see the Modified Leupold Rx-1200i section in the Afterthoughts chapter. The standard Leupold Rx-1200i rangefinder provides 0.1 yard resolution to 125 yards and 1 yard resolution at longer ranges.

Actual Testing

After both the units have been set up, you can begin actual testing. Click on the **Test** button of the main screen to advance to the **Test Screen**.



Working and Ready Flags

Located at the left side between the test data and summary area are the all-important **--- Working ---** and **--- Ready ---** flags.

As you begin testing, you will see **WORKING** as the controller units synchronize their timers. After timers are synchronized, the flag will change to **READY** indicating that the system is ready for shot. **You must wait for the green READY flag before you shoot.** After the shot is fired, the flag returns to **WORKING** as the system waits for the bullet to get to the target and collects data from the gun and target units. After the shot is displayed the flag will go back to **READY**. While the system is working you may see cryptic messages indicating work progress adjacent to the flag. The system typically requires fifteen to twenty seconds between shots.

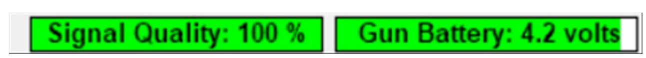
Test Screen Buttons

At the left top there is a "chevron" or  button. This button activates the radio network monitoring and controls. It is normally not used until you encounter problems with the radio network or until you miss readings from a downrange target during a test.

The radio network area includes the following:

This forces a restart of all controller units. It will usually take several minutes to complete the restart.

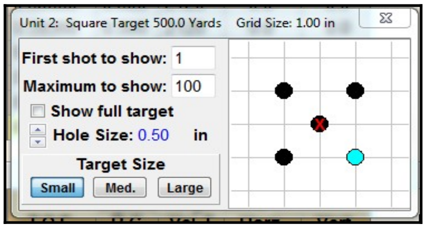
This button stops radios for "hot"restart.



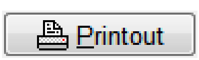
The radio network window includes display of the signal quality and the gun battery voltage. This window is normally left closed.

The **Omit/Restore** button is used to temporarily omit data from recognized bad shots. Use the cursor to highlight the data line of interest and then click the button. The **Omit** function will draw a dashed line through the data and will omit it from the summary. Highlighting an omitted shot and clicking the button will remove the dashed line and will **Restore** the data to be included in the summary. If a succeeding shot has been recorded, the shot data will remain permanently. If the last shot is omitted before a succeeding shot is fired, the omitted data will be over-written.

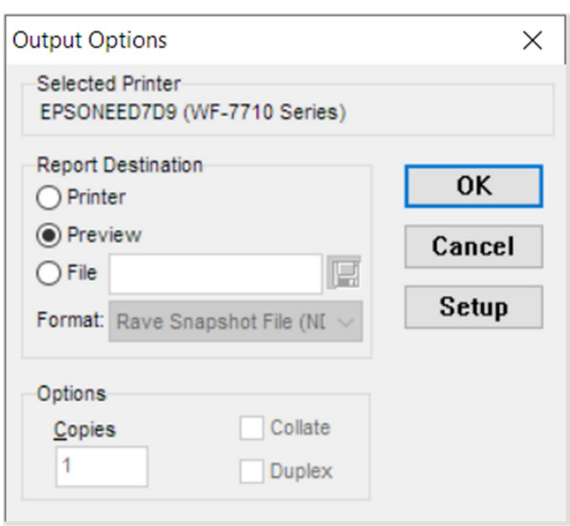
The **Target** button enables a graphical display of the targets showing apparent hit locations.



In the target window you can select **Show full target** area to see the group location within the target frame or your can just look at the group. For the line target, the display will include only those hits falling within the length of the array. Shots falling "Off-the-end" or at excessive distance from the microphones may be scored numerically, but are not shown in the window. The highlighted hole in the target window corresponds to the highlighted shot in the numeric display. Clicking on a shot hole in the target highlights the corresponding numeric display line. The **Target Size** buttons change the size of the window. The **X** marks the group center. The acoustic target function lets you keep shots in the middle of the window at long range when you can't spot impacts.



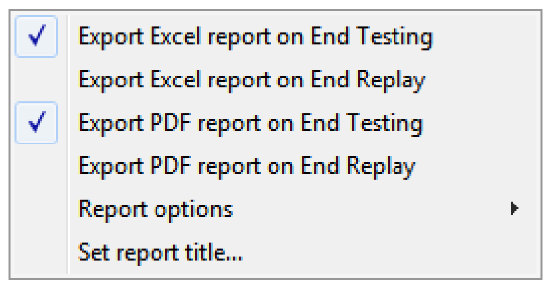
The **Printout** button brings up a window showing various print options.



The **Output Options** window allows selection of the print destination. The customary Windows printer selection window is available with the **Setup** button. You may select the **Preview** button to display a preview of the report. Selecting the **File** button lets you write the report to a selected file in the format selected in the drop-down list.

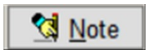
Report printing is only available using this button. Only the report of the test shown in the test window can be printed. If you want to print the report of an earlier test, you must go to the main window and **Replay** the test prior to printing.

The **Options** button primarily governs when the reports and Excel output are generated and written.

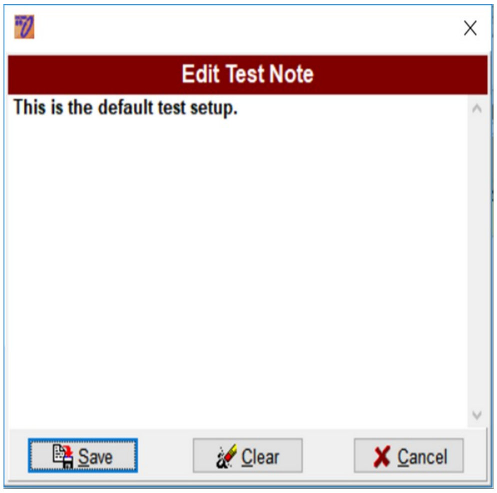


We suggest that you select to export both Excel and PDF reports only on End Testing. This automatically provides you with a report of "as done" tests. If you elect to play the "what if" game and edit your tests during a replay, you don't want to automatically overwrite your earlier like-named reports with an edited version. It is best to modify the test name, request export on End Replay to write reports of the edited test, and then disable the export on End Replay. The **Report options** button allows selection of several parameters controlling the appearance of the printed report and its preview.

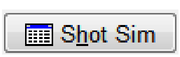
The **Set report title** allows you to place your name in the default title of all printed reports.



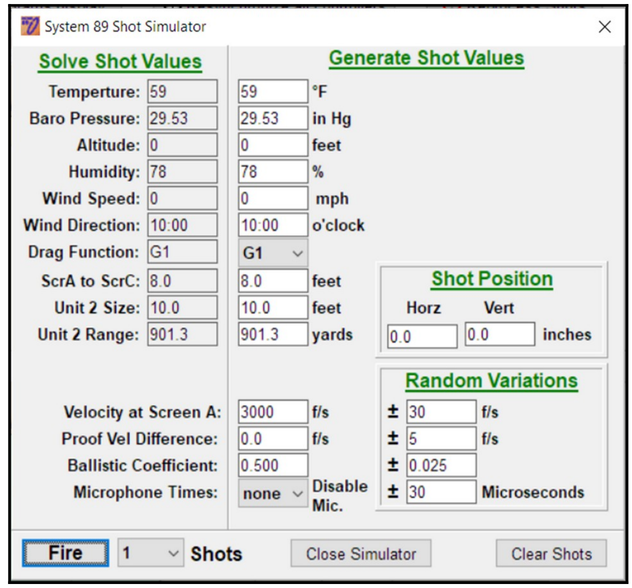
The **Note** button allows you to edit the contents of the test note during a test.



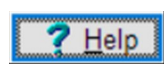
You may enter any alibis or changes in the test notes. You must **Save** the contents of the edited note to close the window. Saving the note contents immediately places the edited note on the main page and also saves it to the test info file. Notes are limited to approximately 200 characters.



The **Shot Sim** button opens a firing simulator used during program development. **This button and function are available only in the "Demo" version of the program.** This simulator will "fire" one or more test shots. The computer generates appropriate event times to accurately simulate the results you would get from actual firing tests. This simulator is not essential to your testing, but it is an excellent training aid and remains for your entertainment and amazement. It is interesting to use one drag function (representing the tested bullet) to generate the data and use a different drag function to observe the test results. We used the simulator to generate some of the data shown in this instruction book.



Note that **Shot Position** of the simulated shots defaults to the center of the square target. For flyover targets, the vertical shot position should be adjusted 30 inches above the microphone line. **Random Variations** are used to add scatter to the input parameters and to add "noise" to microphone times. (Random variations of 50 microseconds reflects typical microphone timing and position errors.)

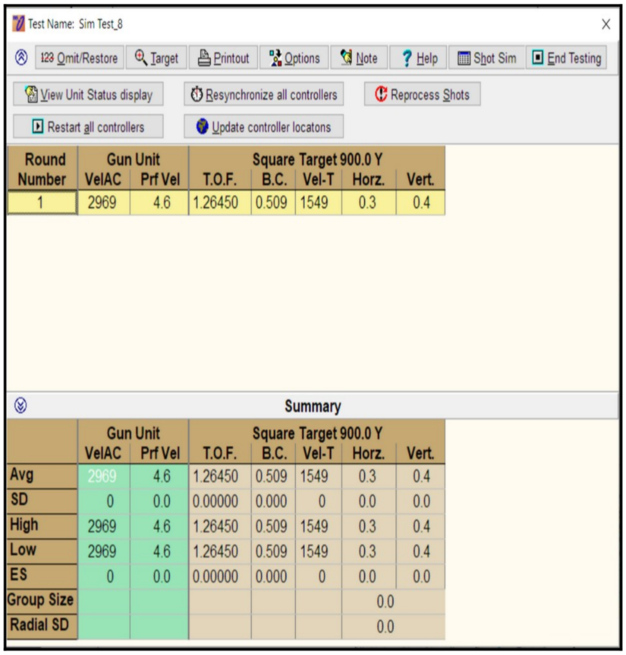


The Help button provides access to a pdf version of this manual and to the customary program name and version number.

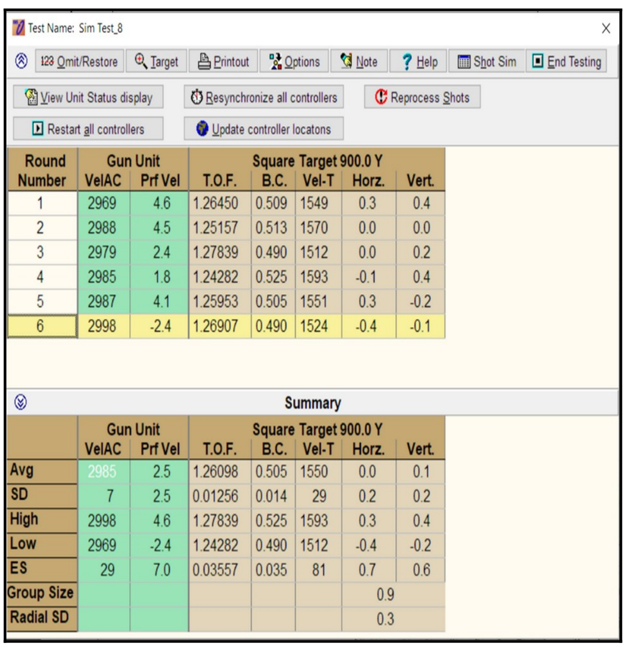
The **End Testing** button ends the test and returns you to the main screen.

The **Summary** portion of the display provides a continually updated statistical summary of the test data. The small "down chevron" button can be used to hide the summary allowing display of more shots on the screen.

Real Test Data

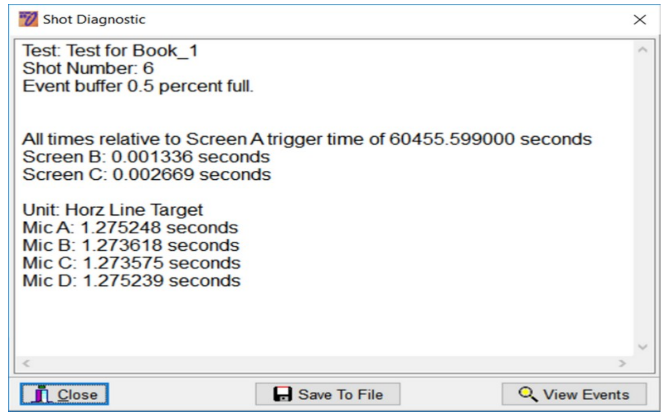


Above is the testing screen after one shot has been fired.



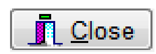
Here is the test screen after five more shots have been fired. The last shot line is highlighted.

If there is a question on any shot, highlight the line by moving the cursor. Double-click on a shot to open a window containing the raw event time data.

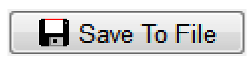


Here are the raw skyscreen times for Shot 6. The first screen triggered at the time of 60455.599 seconds after midnight of the PC clock. All other times are shown relative to the start screen trigger time.

Within this Shot Diagnostic window are three other buttons.

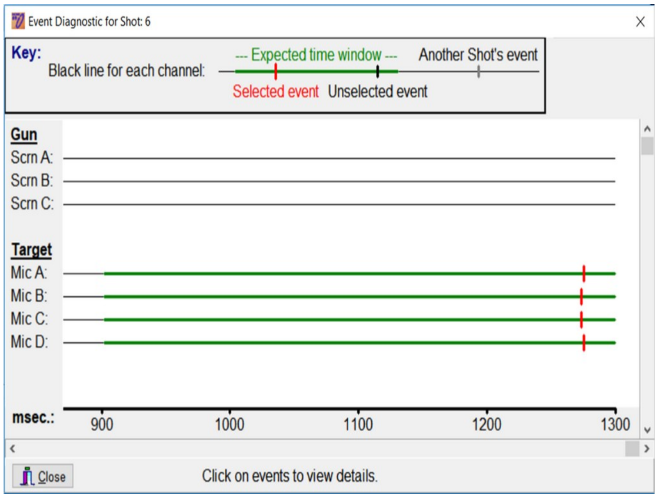


The **Close** button exits the diagnostic window.



The **Save To File** button allows you to save the contents of the diagnostic window for subsequent review.

The **View Events** button brings up a graphic display of all the recorded events for the shot.



This **Event Diagnostic** window illustrates the event times for each unit. The displayed time range is controlled by the horizontal slider. The horizontal green lines show the time range anticipated for a valid response. Selected events falling within the range are indicated by red tic marks. Events outside the expected range are typically spurious responses and are noted by black tic marks. You can click on any black tic mark within the expected range to add it to the processed data, and you can click on any red tic mark to eliminate it from processing. Close the windows to return to testing.

Column headings and displayed results in the testing screen are apparent.

Round Number is the sequential number of the round in the test.

Gun Unit VelAC is the instrumental velocity measured from Start Screen to Stop Screen near the muzzle. Velocity is in feet or meters per second. This is the instrumental velocity measured at the midpoint of the start and stop screens. To convert instrumental velocity to muzzle velocity you must add the velocity loss from muzzle to screen midpoint. If the mid-point is 14 feet from muzzle, this amounts to 7 fps using a muzzle velocity near 3000 fps with a G1 BC of 0.600.

Gun Unit Prf Vel is the difference in velocities as measured between the Start and Middle Screens and between the Start and Stop Screens. It is a reliable indication of the accuracy of the velocity measurement. If the **Prf Vel** is greater than 10 fps, you should recheck the distance between skyscreens and consider omitting this round from the summary. This column represents the *PROOF CHANNEL*™ as is described in U.S. Patent 4845690. Shown in feet or meters per second.

Fly-Over Target XXX.X Y indicates results from a flyover target located XXX.X yards from the midpoint of the Start and Stop Screens. **Y** indicates yards.

T.O.F. is the time of flight in seconds from the midpoint of the muzzle screens to the plane of the acoustic target. T.O.F. is shown in seconds.

B.C. is the ballistic coefficient computed based on the initial velocity, time, and distance. It is based on the drag function specified during setup or edit. Because the legacy drag functions were defined and published for standard Metro conditions, Oehler systems calculate ballistic coefficients referenced to standard Metro conditions. Oehler equipment including the Systems 43, 83, 85 and Ballistic Explorer software all use standard Metro. This reflects the current (2020) SAAMI practice and provides compatibility with legacy data. Some manufacturers of commercial ammunition and bullets publish ballistic coefficients based on ICAO. Oehler uses the Metro based coefficients for compatibility with the accepted tables. Multiplying a standard Metro based ballistic coefficient by 1.018 yields the corresponding ICAO based ballistic coefficient.

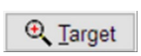
The B.C. values shown by the System 89 depart from the conventional definition of ballistic coefficient. In most literature, a ballistic coefficient is defined as the drag of a reference bullet compared to the drag of the test bullet measured at the same velocity. The System 89 uses the measured initial velocity along with the chosen drag function to predict a time of flight to the target distance. The B.C. is varied until the predicted time-of-flight exactly matches the observed time of flight. This verified B.C. assures that predictions match observed results.

Vel T is the estimated velocity remaining at the target. The estimated remaining velocity may change slightly when you change drag functions. Shown in feet or meters per second.

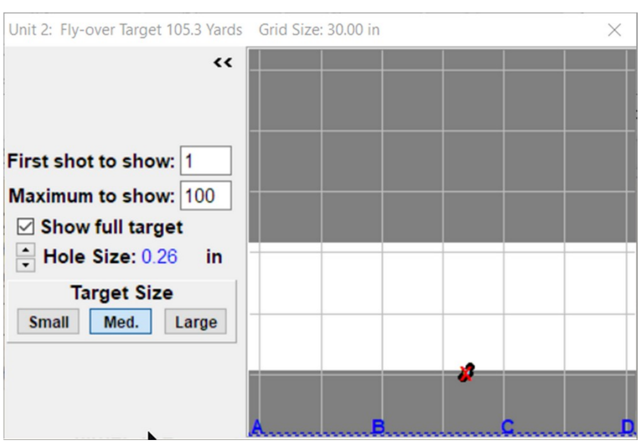
Horiz is the apparent horizontal impact coordinate, measured from center of target square or line. Shown in inches or centimeters.

Vert is the apparent vertical impact coordinate, measure from center of target square or mic line. Shown in inches or centimeters.

Target Graphs

Selecting the 

button displays a picture of the apparent target.



You can choose to show either the full target area or an expanded view of the group. Individual bullet holes are shown with the colored hole representing the last shot. The **X** marks the group center. Shots falling outside the expected array area may still receive a numerical score, but will not be shown on the picture. The displayed shot hole size and the size of the displayed target are adjustable.

The darkened portion of the displayed flyover target indicates areas of questionable scoring accuracy. This shading can be removed under the **Options** pulldown of the main window.

Summary

The following are listed for each of the measured parameters.

Avg is the average or arithmetic mean.

SD is the sample standard deviation.

High is the maximum.

Low is the minimum.

ES is the extreme spread or range.

Group Size is the maximum center to center distance between shots. Optional.

Radial SD is the radial standard deviation of the group. Optional.

Use the **Printout** button to print the results. Use the **Options** to automatically generate a PDF report to be written in the Reports Folder.

At the conclusion of a test group, use the **End Testing** button to end the test and return to the main window. **End Testing** forces storage of the test raw data in the test data file. Depending on the **Option** settings it may also generate and store a PDF report of the test, and it may also store the Excel file containing both raw and processed test data. These optional reports may be generated, stored or printed during any subsequent replay of the test data.

Cowboy Test Log

During the development of the *BC Chrono™* systems, we kept it simple for the operator at the range. We ask for only essential computer entries during actual testing. This simplifies your test duties. Days, weeks or years later when you analyze data, you wish for a modern computer data base containing much more information related to the test. After more than a handful of tests, you are challenged to find the test results in your computer and then you can't recall the exact gun and ammo tested.

We suggest you use our **Test Log** during all your tests. It is a simple procedure that you can quickly complete at the firing range using only a pencil. It is organized so that you can find a test of interest and immediately see the gun, ammo, velocity and ballistic coefficient. The test file name is there if you need to replay the results.

The log appears crude, but its utility and ease of use will become apparent. It has the nickname *Cowboy Test Log* because cowboys detest fixing fences just as shooters dislike recording data at the range. Cowboys often carry a *fence tool.* This tool is used as a hammer, pliers, "steeple" puller, wire stretcher, wire cutter, splice twister and nut cracker. It's not perfect, but it fits in the pocket of their chaps and is there when needed.

Test Name is a critical entry. We use the common test name to link the raw test information file, the exported data file, and the pdf report file generated by each test. Data retrieval and analysis is much easier if you assure that the test name is accurately recorded for each test in your test log. The test name is the only sure link between the test data recorded by the System 89 and your own notes describing what you tested.

Much of the test log can be completed as you prepare for a test or even after you return home from firing. You must record the test name so that you can coordinate your log notes and the computer's memory.

Some users have made Excel adaptations of the test log for use with a computer at the range and back at their desk. We envy their young eyes and nimble fingers but still prefer to use pencil and paper at the range.

Cowboy Fence Tool

***BC Chrono*™ Test Log**

This test log is the minimum external record required while using the *BC Chrono*™. During review and analysis you wish for more data, but during tests you are too busy to write things down. We considered requiring you to enter this information into the computer before the test could proceed, but discarded the idea. We have been both test operator and data analyst. The test file name is critical. If you don't know the test file name, it's hard to find results in your computer.

This procedure was adapted from John Wootters' personal record keeping system for handloads. He developed the system long before computers and called it his *ditto data* system. John dedicated a page to each rifle and a line to each load. Each line allowed him to enter his load data and contained additional columns in which to record firing results such as velocity and group size. You can manually scan the columns of a page to quickly locate or sort the results.

The key to the system is that typically only a few variables are changed between tests. All other entries are simply *dittos* or *dashes* reflecting an unchanged parameter. A blank space indicates unknown or "will complete later". Dashes are quick and easy to enter in the field. You need not repeat the entry of all the data. You must find time to enter the few changed parameters between tests.

In our adaptation we dedicate a page to a specific caliber or bullet diameter and two lines to each named test. For each test we reference a ***BC Chrono*™ Test Name** to connect your log entry to the results stored in your computer. The computer automatically stores a record of test conditions and results; this log describes what you were testing. You need not reenter the root test name as you proceed to different test groups; just note the suffix number of the test as it automatically increments. The test date can be entered below the test name.

You want to know the **Gun** used because different rifles will produce different velocities and different ballistic coefficients. The **Gun ID** can be as simple as the last few digits of the serial number; it allows you to distinguish between otherwise *identical* rifles. The **Case** name is customary even though the bullet needs not know the shape of the case containing the propellant that kicked it out the muzzle. **Barrel** length and **Twist** are important because the length affects velocity and the twist may affect ballistic coefficient as the bullet passes through the sonic region.

You are primarily testing the ammunition and must identify it by **Manufacturer, Type, and Lot #**. The type can be maker's product code or the generic name. Just the last few digits of a lot number can distinguish between lots. The **Bullet manufacturer,** along with **Bullet Style** and **Bullet Weight** must be noted.

The remainder of the line describes test results. These entries can be made from replay of your tests after all tests are completed. The observed velocity and ballistic coefficient are the critical inputs for your ballistic computer. You must make note of which **Drag Function** (G1, … G7 etc.) you used and the **Distance** to the target. The output BC is based on the Army Standard Metro atmosphere and must be multiplied by 1.018 to obtain BC based on ICAO atmosphere. Two untitled columns are provided. These can be used for other information of interest. A tic mark in the **Note** column points to a numbered note written below the table. The numbers also allow quick reference to a line in the table.

The table is cryptic, but it is usable at the range and it fits standard copiers and scanners. Our first generation log sheet used only one line per test, but users demanded more writing space. We choose to print on heavy paper and to bind the sheets on the long edge for added security. A mechanical pencil with 0.5 mm lead and an eraser works well outdoors. Either the Pentel QE-405 or the Zebra M-301 works fine, but bear down if the book is to be copied or scanned.

BC Chrono Test Name / Test Date	#	Gun / Gun ID	Case	Barrel / Twist	Ammo Mfg / Type	Ammo Lot / Bullet Mfg	Bullet Sty / Bullet Wt	Vel Ave / Vel SD	Drag Fn / Dist	Metro BC / BC SD			Note
													1
													2
													3
													4
													5
													6
													7
													8
													9
													10
													11
													12

System 89 Sample Report

OEHLER

Test File Name:	Sim Test_2.xls				
Location:	Shakopee				
Operator:	Rich				
Test Date:	11/30/2018 11:14				
Temperture:	59	**°F**			
Baro Pressure:	29.53	**in Hg**			
Altitude:	0	**feet**			
Humidity:	78	**%**			
Wind Speed:	0	**mph**			
Wind Direction:	10:00	**o'clock**			
Drag Function:	G1				
Edit Status:	Original				
Test Folder:	C:\OehlerSys89\TestFiles\				
Report Folder:	C:\OehlerSys89\ReportExport\				
Excel Folder:	C:\OehlerSys89\DataExport\				
Test Note:	This is the default test setup.				

Gun Unit -----------------------

Serial Num:	01234567	
Signal Level:	80	
ScrA to ScrC:	8.0	**feet**

Target Unit ---------------

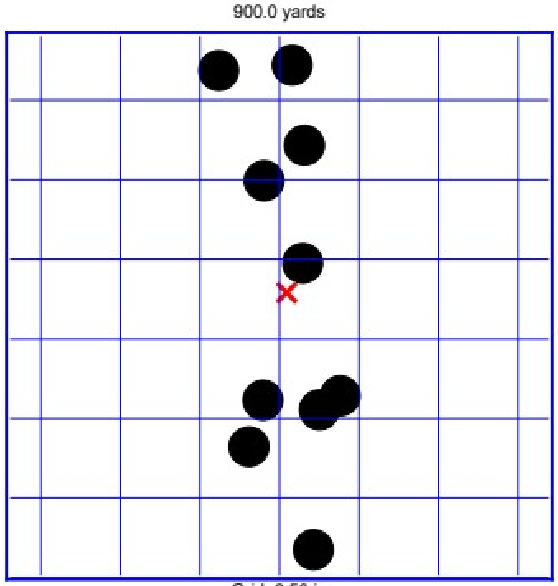
Serial Num:	1A2B3C4D	
Type:	Fly-over Target	
Size:	10.0	**feet**
Signal Level:	85	
Range:	901.3	**yards**

Round	Gun Unit	Fly-over Target 900.0 Y				
Number	VelAC	T.O.F.	B.C.	Vel-T	Horz.	Vert.
1	3016	1.24852	0.502	1563	0.1	40.0
2	3022	1.27339	0.475	1504	-0.3	38.9
3	2981	1.25497	0.513	1565	0.3	39.2
4	3013	1.26381	0.488	1529	0.1	40.8
5	2988	1.27296	0.491	1520	0.2	39.1
6	2969	1.27517	0.498	1524	-0.2	40.6
7	3000	1.23578	0.525	1603	0.1	38.2
8	2975	1.25195	0.520	1575	-0.5	41.3
9	2986	1.25620	0.509	1560	0.0	41.3
10	3001	1.27929	0.479	1500	-0.2	39.2

---------- SUMMARY ----------

	Gun Unit	Fly-over Target 900.0 Y				
	VelAC	T.O.F.	B.C.	Vel-T	Horz.	Vert.
Avg:	2995	1.26120	0.500	1544	0.0	39.9
SD:	17	0.01338	0.017	33	0.2	1.1
High:	3022	1.27929	0.525	1603	0.3	41.3
Low:	2969	1.23578	0.475	1500	-0.5	38.2
ES:	53	0.04350	0.050	103	0.8	3.0
Group Size:					3.1	
Radial SD:					1.1	

900.0 yards



Grid: 0.50 in

Using the Data

Analyzing firing data collected by users of the System 88 over several years has revealed much. For over a hundred years shooters have assumed that a drag function with its associated ballistic coefficient would accurately describe the behavior of a specific bullet. We expected that we could derive one ballistic coefficient based on muzzle velocity and a long time-of-flight and the ballistic coefficient would then provide accurate predictions for that bullet fired in any rifle. **We did not appreciate that the downrange behavior of a bullet can be significantly influenced by the rifle barrel.**

We first observed that the indicated ballistic coefficient of the same bullet varied from tester to tester and it varied from published values. Initially these slight differences were attributed to small errors in measuring either the spacing of the muzzle screens or to small errors in measuring the distance from muzzle screens to target. Later we saw that these small differences exist even when “identical” rifles are tested the same day using the same setup and conditions. Differences are small, seldom exceeding two or three percent, but they are statistically significant and enough to cause misses at long range.

Our observations have been confirmed by Doppler radar tests involving barrels with differing twist rates and differing types of rifling used with the same ammo. These tests indicated differing behavior of the bullets, depending on the barrel used. The differences are most apparent in transonic range.

The observations were confirmed by Hornady’s Doppler radar work with their improved 4DOF program. In an interesting illustration they show multiple drag coefficient curves for different barrels firing the same bullet. Not only do the curves show what would be interpreted as different ballistic coefficients, but they show variations in the shape of the observed drag function. Their excellent 4DOF program, includes a parameter “Axial Form Factor” that can vary between 0.9 and 1.1. The user can adjust this form factor so that the predicted TOF matches the TOF observed with the System 89. This effectively calibrates the radar derived drag function for that bullet for an exact fit to your barrel.

The data leads to the conclusion that you must test the individual rifle/load combination to compare predicted performance to actual performance. This procedure is often referred to as *truing*. Even the custom drag functions derived by exhaustive testing or radar-derived drag functions apply only to the bullet fired from the unique test barrel. At best, drag functions may represent behavior averaged over several barrels. They may be a close fit to your specific barrel, or they may differ by several percent. The prediction process must be trued to make prediction match the real world performance.

As a very rough rule of thumb, we estimate that a two percent increase in ballistic coefficient provides the same effect as does a one percent increase in muzzle velocity. With a long-range rifle the small difference can easily cause a half mil difference in drop at a mile. Again in general, we estimate that the barrel-to-barrel change in ballistic coefficients is almost as significant as is barrel-to-barrel change in muzzle velocity. We accept that different barrels will likely shoot different velocities with the same load; we must also accept that different barrels will likely yield different ballistic coefficients.

If your shooting is restricted to the customary supersonic range, the System 89 provides the correct ballistic coefficient directly. For the best results, the downrange target should be placed near the range at which the bullet velocity has decayed to approximately Mach 1.2 or 1350 feet per second. The exact velocity at the test range is not critical. Using the G7 drag function will usually provide accurate predictions down to Mach 1.0. This is our preferred technique. If the G7 drag function does not fit the tested bullet exactly, then the System 89 compensates by finding the ballistic coefficient that forces a match between predicted and measured time-of-flight at the tested range. You will have an accurate prediction fitting your gun over what most would consider the longest practical range.

As you interpret the ballistic coefficient provided by the System 89, carefully observe the standard deviation of the individual ballistic coefficients. It is not sufficient to simply look for a high average ballistic coefficient. In many instances it will prove better to sacrifice slightly greater average value for improved uniformity.

If you want your predictions to be accurate into the subsonic range, then you must test into the subsonic range. Remaining spin rate influences a bullet during its transition through the sonic range, therefore testing with the same barrel and reduced muzzle velocity is inadequate. The rotational spin rate is not tied directly to the remaining velocity. The only way to test for the expected transonic behavior is to fire at normal muzzle velocity at a distant target where the bullet velocity has naturally decayed to subsonic velocity.

Subsonic velocities make life difficult. The bullet no longer generates a Mach cone and microphones cannot accurately detect its passage. To detect arrival time for subsonic bullets at a distant target, we must sense the bullet's impact on a wall or plane. Microphones attached to the plane will hear the sound of the impact transmitted through the material of the plane. The target plane can be a steel silhouette target, a sheet of plywood or drywall material. We prefer a sheet of nominal half-inch plywood.

When the System 89 is used with a distant target located in the far subsonic region, it automatically computes a ballistic coefficient providing a match between prediction and observation at the far target. This ballistic coefficient obtained from the distant target will probably not be the same as that observed with the same bullet and gun at the Mach 1.2 target.

Now we have two (or more) ballistic coefficients for the same gun and bullet. How do we use them? Because the ballistic coefficients were measured at different ranges, with different muzzle velocities, and with different air temperatures and densities, we can't simply look directly at only the times-of-flight.

Lacking evidence to the contrary, we suggest using the ballistic coefficient measured at the transonic range for all "normal" shooting out to the sonic range. If your target is at the sonic range or beyond, then use the ballistic coefficient measured at the longer range. It is best if you use "chained ballistic coefficients."

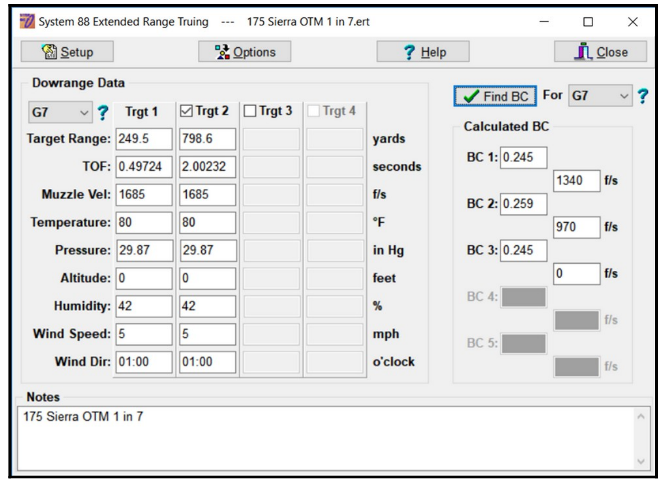
This informal idea can be implemented by using a "stepped ballistic coefficient" as Sierra has used for many years. The first step should occur at the velocity corresponding to the transonic range at which you measure the ballistic coefficient. This measured ballistic coefficient will provide accurate predictions from gun to that point. Using a computer program such as *Ballistic Explorer* that properly handles stepped ballistic coefficients, you can use your measured supersonic ballistic coefficient down to the transonic level. By trial-and-error, and with the atmospheric conditions of your long range test, vary the ballistic coefficient of the **second** step until the predicted time-of-flight to the subsonic target matches the measured time. This provides the proper value of the transonic ballistic coefficient to be used for the second step or the transonic velocity range. If your assumed drag function (probably G7) exactly matches your bullet fired from your gun, then both values of ballistic coefficient will be equal.

Don't expect that to happen! You may see an abrupt change in ballistic coefficient, but don't worry about it. Your solution has been forced to fit at both the transonic and subsonic ranges, and won't be noticeably wrong at any intermediate range. The procedure can be repeated at longer ranges to add additional chained values for ballistic coefficient.

Even with its coarse steps, a *calibrated* ballistic coefficient provides more reliable results than will a radar or custom drag function that has not been calibrated for your individual barrel.

This procedure sounds tedious. It would be nice to place targets at both transonic and subsonic ranges and gather all the data from the same shots. This is fine in theory, but if a long-range bullet is fired so that it naturally decays to subsonic, the mid-range trajectory is very high. The trajectory at the intermediate points will be so high that our microphones cannot accurately measure the event. We are forced to collect transonic and subsonic data with different test set-ups and possibly even on different days and on different ranges.

The Oehler **Extended Range Step BC** computer program solves this tedious problem. With this program you need enter only the average muzzle velocity, range to target, average time-of-flight, and atmospheric conditions for the tests at each range. You tell the program which drag function you want to use for your predictions, and the program will return the values of the chained ballistic coefficients. The program allows data input from up to four tests of the same bullet/gun combination to provide corresponding ballistic coefficients for five steps. Note that the ballistic coefficient of the last step applies beyond the tested range. The ballistic coefficient of the last step defaults to the value obtained in the first step. You can adjust the last ballistic coefficient to match observed and predicted drop at the maximum range.



Extended Range Step BC Program

It is instructive to then apply the **Extended Range Step BC** program on a shot-by-shot basis. Compare each ballistic coefficient value to the value computed using the average inputs. You will find that the agreement is usually very good when comparing the first step. Maximum differences measured with good bullets will often hover at less than one or two percent. Differences observed in the step including Mach 1.2 down to Mach 0.9 may be significantly more erratic. Not only is it more difficult to measure ballistic coefficient in this region, but bullet behavior in this region tends to be less predictable. It appears that the variables of spin rate, the gyro dynamics, the aerodynamic effects, and the smoothness of the engraved bullet cause problems in this region. Large variations in the measured ballistic coefficient in this region indicate unstable behavior. We don't know the causes or cures for the instability, but we can see it and you want to avoid it.

The Extended Range Step BC program with its desktop icon is automatically installed with **SetupSys89**. Detailed instructions for the Extended Range Step BC program are located under its **Help** button.

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Afterthoughts

We've spent the last few years making better predictions for long range ballistics. Over that time, our thinking has evolved. The sections following are not essential to the operation of the BC Chrono™ system, but we believe that the information may be helpful. The topics are in no logical order.

Background

The concept and definition of ballistic coefficient, or BC, has been used for well over a century. We all use it. The G1 drag function and its associated C1 ballistic coefficient have been accepted as the standard ever since a committee of wise men reached an agreement.

> *The G1 drag function may not fit every bullet. It may not fit any bullet. However, we will accept it as the standard for predictions, approximations and comparisons. To know actual bullet behavior, you must shoot it at long range and measure its performance.*

That the accepted G1 drag function does not fit all bullets is not news. By 1943 the military had generated new drag tables to better fit different bullets. Some of the more recognized are G2, G5, G6, G7 and G8. By the early 1960s, the military had abandoned the use of the G*x* family of drag tables and began using drag characteristics measured with Doppler radar for individual cartridges with the summarized results in "firing tables" for the particular weapon. This works well if you require firing tables representing average or typical performance for only a few ammunition types, but individual shooters are faced with a choice of thousands of different bullets fired in many different guns.

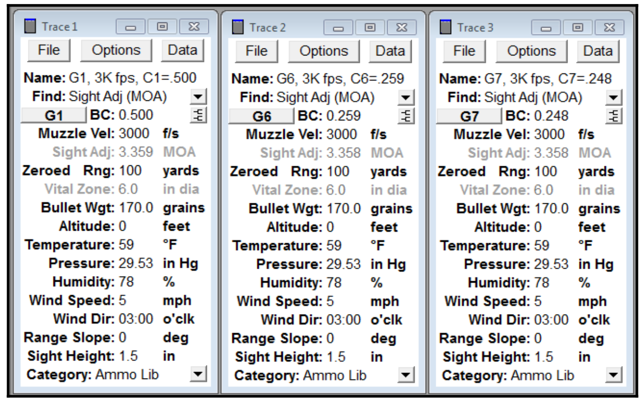
The military may use millions of rounds of one type of ammo. That standardized round is thoroughly tested. Testing is typically done with Doppler radar, and requires an impact zone extending several miles from the gun and a radar system capable of tracking the bullet over a range of several miles. Typically the military radar has a several-man test crew and probably fires fewer than 100 shots per day. You don't casually say, "Here are ten boxes of bullets. Let's start with shooting a few of each." Individual shooters and most bullet makers cannot afford the government procedure.

A drag function (usually G1 by default) with its associated BC are most often used to predict the behavior of the bullet. The typical BC of a bullet is determined by measuring the bullet's muzzle velocity and time-of-flight to a downrange target. You <u>assume</u> that the drag function accurately describes the bullet behavior over all ranges. Current commercial practice is to measure the BC by testing on a range of 100 to 300 yards. This BC is then used to predict the behavior of a similar bullet over longer ranges. The wise men on the committee cautioned long ago that you must verify your description of the bullet with actual shooting. If you make long-range predictions using a BC measured over a short range you are inviting errors. Your firing results will match predictions only if the assumed G1 drag function exactly describes your bullet.

Many personal ballistic programs offer the capability of computing BC from the initial and final velocities measured over a specified range. You must accurately measure the velocity lost. You use a small difference between large quantities. For example, if your chronograph only measures to an accuracy of 1%, then you have an uncertainty of 30 feet per second in a velocity reading of 3000 fps. If you have a velocity loss of 300 fps in 100 yards, then you have an uncertainty of 27 fps at the 100 yard measurement. Add both uncertainties together and you have an uncertainty of 57 fps in your measurement of the 300 fps velocity loss. That translates to an uncertainty of almost 20% in your measurement of the BC. When the range is long enough to lose significant velocity, it is hard to reliably shoot through the small skyscreens.

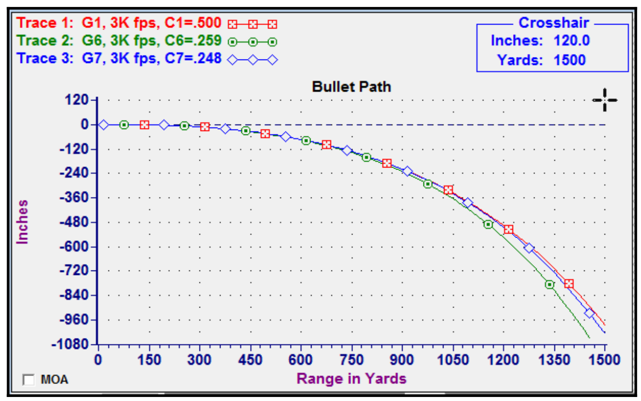
Why doesn't shooting match predictions? You have measured retardation or drag near the muzzle to perfection. You have converted that drag to an equivalent BC. You measured the bullet drag near the muzzle, but you still guess what happens downrange because you don't know what drag function fits the bullet. If you have not measured how your test bullet behaves all the way to the distant target then you cannot reliably predict how the next bullet will behave traveling to the target.

Play *what-if* by using your favored ballistic program. Assume your standard bullet has a G1 BC of 0.500 and a muzzle velocity of 3000 fps. At 100 yards you will see a TOF of 0.10334 seconds. Assume all tests at standard air temperature and pressure. Try three different drag functions, G1 (the agreed standard), G6 (for flat base pointed bullets), and G7 (for very low drag bullets). The initial velocity was 3000 feet per second and you are at the standard atmospheric conditions. Adjust the BCs until the 100-yard TOF equals 0.10334 seconds.



The BCs measured near the gun are C1=0.500, C6=0.259, and C7=0.248. Assume the rifle is zeroed at 100 yards and then look at the long-range bullet path predicted by the software for the three different drag functions.

Here's what you get ---



Or looking at the numbers for bullet path ---

Examine Path: inches

Range:	0 Y	250 Y	500 Y	750 Y	1000 Y	1250 Y	1500 Y
Trace 1:	-1.50	-6.21	-45.02	-132.75	-292.64	-560.33	-983.65
Trace 2:	-1.50	-6.23	-45.72	-137.84	-314.81	-632.95	-1159.9
Trace 3:	-1.50	-6.21	-45.10	-133.19	-294.74	-571.45	-1026.1

Trajectories were reasonably matched out to 500 yards, you're about 5 inches off at 750 yards, about the edge of the target at 1000 yards, and you're way off the paper at even longer ranges. You had "perfect" BCs measured at the muzzle, but our long-range predictions were wrong because you guessed which drag function to use.

Now let's look at the predicted time-of-flight (TOF) for the same three drag functions.

Examine T.O.F: seconds

Range:	0 Y	250 Y	500 Y	750 Y	1000 Y	1250 Y	1500 Y
Trace 1:	0.00000	0.27183	0.59500	0.98462	1.46025	2.04027	2.72457
Trace 2:	0.00000	0.27236	0.60162	1.01280	1.54102	2.21573	3.00351
Trace 3:	0.00000	0.27189	0.59565	0.98694	1.46983	2.08116	2.81200

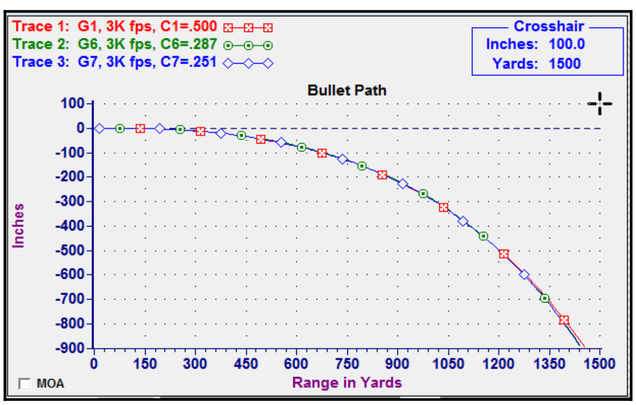
Again you see big differences beyond 500 yards. Our models don't work at the longer ranges where you really need good predictions.

Now adjust the G6 and G7 BCs so that they give the same TOF at 1000 yards as does the standard G1. This is equivalent to computing all the BCs based on muzzle velocity and the 1000-yard TOF instead of the customary shorter-range TOF. You get a new BC=0.287 for G6 and a BC=0.251for G7. Here are the new TOF values. You forced agreement at 1000 yards and have close agreement at other ranges.

Examine T.O.F: seconds

Range:	0 Y	250 Y	500 Y	750 Y	1000 Y	1250 Y	1500 Y
Trace 1:	0.00000	0.27183	0.59500	0.98462	1.46025	2.04027	2.72457
Trace 2:	0.00000	0.26994	0.58936	0.97748	1.46078	2.07182	2.80344
Trace 3:	0.00000	0.27161	0.59430	0.98326	1.46163	2.06506	2.79054

Now look at the bullet path predictions given by the three different drag functions.



The agreement is near perfect out to over 1000 yards. Look at the numbers.

Examine Path: inches

Range:	0 Y	250 Y	500 Y	750 Y	1000 Y	1250 Y	1500 Y
Trace 1:	-1.50	-6.21	-45.02	-132.75	-292.64	-560.33	-983.65
Trace 2:	-1.50	-6.10	-44.08	-130.16	-289.27	-563.97	-1015.5
Trace 3:	-1.50	-6.20	-44.91	-132.37	-292.15	-564.46	-1011.1

The agreement is better than you can expect any shooter to group out past 1250 yards.

We conclude that measuring the ballistic coefficient over a long range is much more important that the choice of drag function.

We've repeated this exercise many times with different drag functions and at different muzzle velocities. The procedure is simple. With the same muzzle velocity, adjust the BCs of the different drag functions to give the same TOF at a range near your maximum expected range. Now use these BCs to predict performance at the maximum range and at intermediate ranges. Using these *adjusted* BCs gives predicted results that are almost independent of the drag function chosen to represent the bullet. If the BC is measured at the longer range, then the choice of drag function is of little consequence!

Why haven't you measured BC at longer ranges before? You can measure muzzle velocity easily. You can accurately measure the distance to a distant target. You can observe the temperature and barometric pressure. **It is difficult to make the time-of-flight measurements over an extended range.** If it were easy, you would see such measurements in the literature. The military uses Doppler radar to track the bullet over very long distances; we cannot afford it. Older Oehler targets can measure long times-of-flight, but they require wires from firing line to the distant target.

Before the Oehler ***BC Chrono™*** systems, there was no practical way to measure ballistic coefficient over longer range. Only after you've measured performance at long range can you confidently predict the behavior of the next shot at long range. The System 89 allows you to measure actual performance over long distance.

Simply using a ballistics program to convert an existing C1 to an equivalent C7 matching the predicted long-range time-of-flight **does not** give you an improved prediction. Such a conversion **assumes** that the bullet's flight is accurately described by G1 and will make the long-range predictions obtained with the equivalent C7 match those predictions from using C1. The new G7 BC makes the new predictions agree with G1 at the long range and assures that predictions will be close at intermediate ranges. *It does not mean that predictions are correct. You have not yet **measured** the time of flight over the long range*.

> *When you say bullet, you include not only the perfectly smooth physical bullet launched to achieve perfect stability. You also include any deformations caused by its trip down the bore, the imperfect stability resulting from different barrel twists, any yaw introduced by an imperfect barrel crown or less than perfect bullet balance, and other things that influence the actual flight of the bullet. This discussion applies to rifle fire over customary and practical velocities and ranges.*

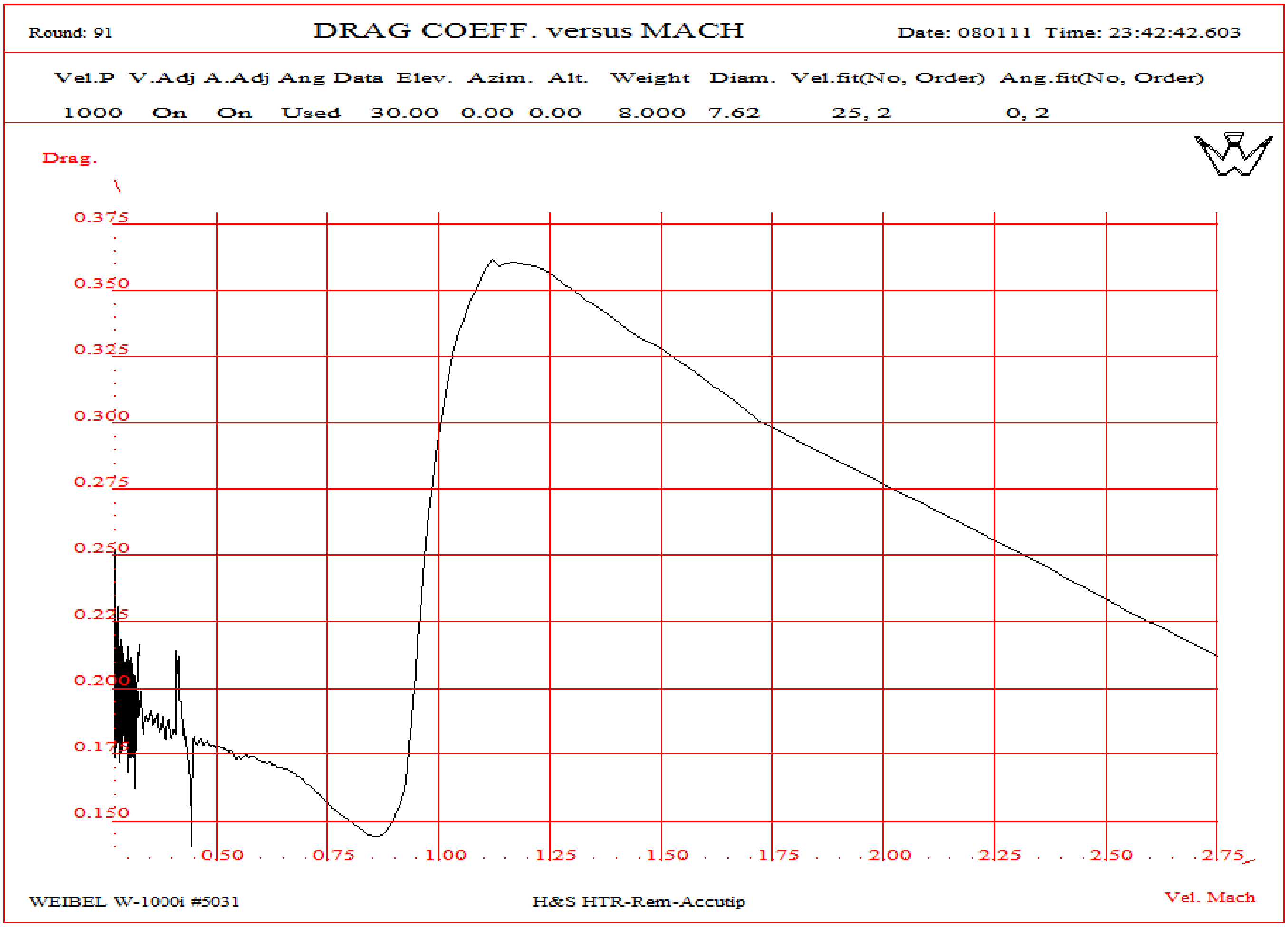
Authorities agree that almost any reasonable drag function can give predictions that are more accurate than you can read the wind or shoot, **<u>but</u> you must use the correct ballistic coefficient**. The same authorities don't give you the magical ballistic coefficient for your load and gun; they can't even tell you where to find it.

You can get the correct ballistic coefficient for your bullet fired in your gun by

1. Testing with Doppler radar.
2. Measuring drop at different ranges, long and short.
3. Testing with the Oehler System 89.

Traditional short-range measurements of ballistic coefficient are not adequate. If you must predict what happens out to 1000 meters or beyond, you must measure to 1000 meters or beyond.

There's no doubt that the Doppler radar tests provide the most extensive and detailed data. However, there are few test sites available, and the tests are expensive. A Doppler radar capable of the long range testing may cost a hundred times that of a System 89. With the detailed data collected on a single Doppler shot, it might seem that only one shot is required. As soon as you collect the results from a second Doppler shot, and compare it to the first shot, you will see shot-to-shot variation. Before you can use the data for reliable predictions you must know both average behavior and uniformity. It takes more shots and data analysis to make reliable predictions. With the Doppler it's easy to see exact behavior of one shot, but good predictions still require many shots. Even with extensive Doppler testing, the results apply only with the guns used for the tests. Your gun may give different results from the same bullet.



Doppler radar output showing actual bullet drag coefficient versus Mach number.

The plot shown was generated on a proving ground with an expensive radar operated by an experienced crew. The Doppler radar tracked the 150 grain .30 caliber spitzer bullet for 26 seconds as it traveled to a range of 3600 meters. Velocity was 936 m/s at muzzle and 26 seconds later the bullet had slowed to 36 m/s. The range and times sound improbable, but the bullet was launched at an elevation angle of 30 degrees. It reached maximum height of approximately 1100 meters at a range of 2500 meters 11 seconds into its flight. At this point it had retained velocity of only 100 m/s and took the next 15 seconds to fall below the radar. Each Doppler shot yields many pages of graphs and numbers. Don't expect this performance from all radars.

Most long-range shooters have been forced to use observed drop. They test with many shots over varied short and long distances and record their results. As they shoot, the temperature and pressure may change significantly. They go home to their computer program where they seek that one mystical BC that makes all their data come together. You've all played that game because you had no alternative. This procedure is perfectly valid, but it takes many shots under good shooting conditions to find the effective ballistic coefficient of the one load fired from the one gun. The preferred solution is testing with the System 89. With the System 89 you can measure muzzle velocity and time-of-flight over a long range. These measurements combined with the air density yields an effective ballistic coefficient measured over the long range. It makes little difference which drag function you choose. That drag function used with its calibrated BC is forced to fit what you actually measured over the long range. Instead of having a BC made to fit 200 meter results, you have a BC made to fit 1000 meter results. When the prediction is forced to fit exactly at 1000 meters, the fit is still close at 900, 800, 700, or 600 meters. The scientist would say that you are *interpolating* between known data points. As you go beyond 1000 meters you are still confident at 1100 meters because you know the fit was made at 1000 meters. However, you are *extrapolating* or guessing what happens outside the range you actually measured. The choice of an appropriate drag function becomes more important when you extend your prediction beyond where you measured. If you want to know what will happen at 1100 meters, it's much better to extrapolate from 1000 meters than from 200 meters. If you decide that you've assumed an incorrect drag function, you can always "replay" your test data using your System 89 program with a different drag function to get a new ballistic coefficient for use with the new drag function.

You will record slightly different ballistic coefficients if you measure over different ranges or different muzzle velocities. This does not say that ballistic coefficients vary with velocity or range, but it says that your assumed drag function does not perfectly match your bullet. If the drag function truly matches the bullet, then the ballistic coefficients are independent of initial velocity and the range over which it is measured. The actual measurement of the ballistic coefficient over the maximum anticipated range is more important than the choice of drag table. Practically speaking, nearly all long range rifle bullets are launched in the relatively narrow velocity range of Mach 2.5 to Mach 3 and are most effectively used in the supersonic range. Testing at a range roughly corresponding to a remaining velocity of Mach 1.2 is logical.

Drag Functions and Ballistic Coefficients

I've learned to measure what happens in the real world before trying to predict what will happen on the next shot. When I duplicate the experiment, I expect to see similar results. *Ken Oehler*

The shooter uses the ballistic coefficient with the drag table to predict long range performance. The shooter assumes that the drag function accurately describes the behavior of the bullet throughout its flight, even though actual drag was checked only near the gun at the higher velocities. The prediction often does not match the measured results. What happens as the perfectly pointed plastic tip melts halfway to the target? How does twist rate effect drag? Does deeper engraving or a cannelure cause more drag? Was the drag measurement influenced by bullet yaw and instability? You can only guess *why* things happen, but you can measure the result if something unexpected happened.

Given muzzle velocity, distance, and time-of-flight, you can use a ballistics program to determine which ballistic coefficient accurately predicts the measured time of flight. If the time-of-flight is predicted accurately at that distance, then the drop and wind drift can be predicted accurately. You force your predictions to fit at that long distance by choosing the ballistic coefficient. If you use a different drag table, you get a different ballistic coefficient, but you have still forced your predictions to fit measured data at the long distance. Your choice of drag tables matters significantly only when you make predictions beyond the distance at which you determined the ballistic coefficient. In this case, the drag table better matching the bullet will give better predictions at extended ranges. Remember, your predictions are forced to be accurate at the tested distance and muzzle velocity regardless of the drag table chosen.

Which drag table should I use with the System 89? For informal testing, there is no problem sticking with G1. Most literature and our built-in mental library of approximate ballistic coefficients are based on G1. If you measure your BC at a long range, and the bullet is still supersonic at that range, then the G1 predictions are excellent at the long range and very good at intermediate and even slightly longer ranges. If you play the long-range game using low-drag bullets, and use the G7 drag table for your predictions, then use the G7 table in your tests. It will provide slightly better predictions at longer ranges where your bullet has fallen subsonic. If you later want a ballistic coefficient corresponding to a different table, just choose the new drag function as you replay the test.

We have included relative humidity in our computations, but in our opinion it is not significant until you reach extremely high temperatures. Wind is likewise included, but is of little significance in the measurement of ballistic coefficient. A reasonable guess at the prevailing wind is an adequate estimation of the average wind from muzzle to target.

Do not expect the ballistic coefficient of nominally identical bullets to remain the same! Don't be surprised at different BCs from different guns and barrels, different barrel crowns, different bullet lots, or other variables you haven't recognized or measured. As a very rough rule don't be surprised at a change of 2 to 5 percent from published values. Don't be surprised by shot-to-shot BC variations of greater than 1 or 2 percent from your ammo fired from your gun.

We've made our accuracy estimates based on experience and actual testing. The accuracy of the muzzle velocity measurement is approximately 0.1 percent if you use a screen spacing of at least 8 feet, have good light, and make no errors in your measurements. If you cut screen spacing in half, you double the error. Time-of-flight measurements made with the square acoustic target are accurate to better than 0.1 millisecond. Flight time measurements made with the "line" acoustic target are within 1 millisecond. We look for similar 0.1% accuracy in the distance to the target. Many rangefinders claim adequate accuracy, but reflective targets must be used at longer ranges. Rangefinders should be checked for accuracy comparing their readings to actual surveyed distances. Kestrel readings are adequate for measuring air density.

Thanks to computers and digital instruments, many people have a very optimistic sense of accuracy. You see velocities reported to the better than one foot per second and bullet drop at extended range to tenths of an inch. You expect to see ballistic coefficients quoted to three significant figures; some even insist that the last digit is significant. When asked how accurately we can measure ballistic coefficients, our usual answer is, "Oh, within one or two percent." The usual response is a look that translates into, "That's horrible. Can't you do better?"

How accurately must you measure each variable? For purposes of comparison, just look at how much error you can tolerate on each variable until it causes an error of one percent on a ballistic coefficient measurement. For purposes of discussion, assume a bullet with a G1 ballistic coefficient of 0.500 fired with a muzzle velocity of 3300 fps tested over 1000 yards at standard conditions. For each of the variables, the error shown will vary the ballistic coefficient by approximately one percent. The errors may compensate, or they may add.

- Muzzle velocity --
  error of *12 fps*
- Time-of-flight.
  error of *5 milliseconds*
- Distance
  error of *3 yards in 1000 yards*
- Barometric pressure
  error of *0.27" Hg*
- *Temperature*
  error of 6 degrees F

Muzzle velocity, time-of-flight, distance, and air density are the primary factors. Humidity and winds of less than 10 mph matter little. We've worked many years to assure that you get good muzzle velocity and time-of-flight readings. You must establish distances with care; call a surveyor if you must. Take your station pressure reading from your Kestrel and enter the altitude as zero. A reasonable guess on prevailing wind is adequate.

Temperature variations are very significant; observe and record temperature for each test group!

Considering that any one of the individual errors noted can yield one percent error in the ballistic coefficient number, our estimate of a "couple of percent" looks quite reasonable. Using the same rifle and ammo from the same lot, you can often get "repeatability" or "precision" less than one percent. This does not mean that your absolute accuracy is better than one percent, or that ballistic coefficient is an inherent and constant characteristic of a bullet with a given label. Your set up must be perfect before you can claim one percent accuracy.

Skyscreens

Skyscreen Background

Oehler's Skyscreen III units have been proven to be accurate and reliable over many years by thousands of users. They can be frustrating, but we have found nothing better. Oehler's *Proof Channel* uses three screens to make two measurements of velocity on each shot; you get a verification of accuracy with each shot fired.

The distance between skyscreens is always a compromise. Longer is better, but shorter is convenient. You'd like to use 4' rail because it is convenient to ship and easy to haul to the range. For the precise velocity measurements required for accurate ballistic coefficients, you need an 8' rail. An 8' rail is more difficult to store and is almost impossible to ship. Some users will opt to use the 4' rail for convenience even though the inherent accuracy of the 4' spacing is only 0.2%.

Make a Long Mounting Rail

For critical applications where longer screen spacing is required, or for native metric dimensions, you must fabricate your own rail. Use half-inch EMT (thin-wall electrical conduit) cut at least an inch longer than the desired screen spacing. We suggest a maximum length that fits your vehicle for transport to the range or that can be stored at the range. Most users opt to use a spacing of 8 or 9 feet or metric 3 meters. Regardless of the length of the rail, the third screen mounts midway between the two primary screens.

Mount each screen to the rail with a 1/4-20 x 1" hex head bolt. Place the rail and skyscreens on the floor or on a long workbench with the skyscreens looking down. Measure screen spacing. It makes no difference if you measure front-to-front, middle-to-middle, or back-to-back, but you must be consistent. Tighten bolts snugly to hold screens in place. Recheck spacing (tolerance better than 1/32 inch or 1 millimeter) and make sure that each screen is square on the floor. Use a C-clamp or vice-grip wrench to hold the two plastic halves of each skyscreen together around the bolt. (If you don't hold the halves together, the embedded nut will pop out.) Tighten each bolt at least one and a half turns, but no more than two complete turns. Fewer turns won't make a good dimple and more turns will flatten the conduit so that the skyscreen tends to bind. You now have dimples at the correct locations. Remove bolts and replace the long-tailed screws and thumbscrew. Spacing between screens is critical !

Mount skyscreens using the 1/4"-20 x 3" threaded stud with attached wing-nut for start and stop screens. Use a 1/4"-20 thumb-screw at the middle screen. As you mount a screen on the rail you must wobble it to feel and locate the dimple as you tighten the screw. Tighten each mounting screw carefully as you seat the screw into the dimple. The dimples are only an aid to proper spacing; they are not a guarantee.

If you are tempted to simply drill holes into the conduit instead of making dimples, don't bother. The mounting screws will thread into the drilled holes and skyscreens will still wobble.

Take special care if you use a multiple-piece rail. Short pieces are convenient but can cause problems. Such rails may sag at the joint and cancel the benefit of longer spacing. To make a long and sturdy rail, see the section "**Skyscreens, Multi-piece Rail"** for detailed instructions.

As you prepare to shoot under bright sun, you must mount a diffuser over each skyscreen.   Slip a black side-rail into your skyscreen, hook one end of an orange diffuser into the standing side-rail, hook a second side-rail onto the diffuser, and then slip the last end into the skyscreen.

Actual Shooting

After you mount the skyscreens for the first time, actual shooting is simple.   Improper alignment not only leads to missed velocities, but often leads to bullet holes in the skyscreens.   Place the assembled skyscreens approximately eight to ten feet in front of the muzzle.

The triangular light diffusers should form a "triangle-within-a-triangle" sight picture as you look down the barrel at the target from your normal shooting position.

If you are shooting from prone position, place the rail assembly on the ground. It is convenient to support the rail using a board or stick approximately two feet long with a quarter-inch hole drilled thru the middle. Place the supporting stick crosswise and drop the tail of the skyscreen mounting screw into the hole.

If the ground slopes away from the firing position then the stop screen must be higher. We use a piece of lumber cut diagonally from a 1x10 or 1x12. Place the long edge on the bottom and drill a series of 9/32" holes up the slanting edge. Insert the skyscreen tail in the appropriate hole.

In Case of Trouble

The System 89 relates all event times and distances to the START skyscreen. If the display does not change within a few seconds after you shoot, it means that no start signal was received. Possible causes are the bullet passing too near the top or side of the skyscreen window, the orange diffuser not being directly illuminated by the sun, the skyscreen not having an unobstructed view of the sky overhead, or having too little light for proper skyscreen operation. Make a deliberate effort to shoot through the middle of the triangular window of the Skyscreen III. Be sure the skyscreen cables are plugged firmly into the jacks on front panel of the System 89 unit; if you see a band of metal near the plug handle, then push harder.

Dust and dirt can accumulate on the lens. To clean lens you must remove diffuser side-rails and then wipe lens with a dampened cloth.

Wipe plugs with rough cloth (blue jeans) to remove any oily or dirt residue. Use alcohol if required. **Do not use steel wool or sandpaper.** If you remove the nickel plating you will be forever plagued with corroded plugs.
Observe the velocity “proof” numbers. These numbers reflect the differences between the primary velocity measured between START and STOP screens and the proof velocity measured between START and MID screens. If the proof numbers are consistently high and positive, then the middle screen is probably mounted too near the start screen. If the proof channel velocities are consistently too negative, then the middle screen is probably mounted too far from the start screen. If the proof numbers are erratic, it is often caused by muzzle flash or blast. Strive to keep your proof numbers less than ten.

Orange Diffusers Don’t Always Help

The orange diffusers shade the lenses from noonday sun and make the hot-spot light from the sun into a uniformly bright orange background against which the eye can see the bullet. If you are shooting under cloudy skies, with heavy overcast, or in the shade, then no direct light strikes the diffuser. What little light is available is already diffused, and the diffuser can't make it any brighter. If the orange diffusers don't cast a shadow, and you have problems, leave them off. You can still use the black side-rails as aiming guides.

Expect trouble if you try to shoot under the shade of a tree. The sun can cast a spotted shadow on the diffuser; the bullet may go through a bright spot and be detected or the bullet may go through a shaded spot and be missed. With no diffuser, the eye may see the bullet silhouetted against a spot of sky, or the bullet might be silhouetted only against the black bottom of a limb.

Subsonic Velocities

With velocities below the speed of sound, the muzzle blast wave reaches the screen before the bullet. This muzzle blast wave is like a lens traveling through the air at the speed of sound, and the resulting light diffraction can trigger the skyscreens. (The speed of sound is approximately 1060 plus the air temperature in degrees Fahrenheit, or 1130 fps at room temperature.) Premature triggering of only the start screen will cause the velocity to be low and the proof number to be high. Premature triggering of both start and middle screens will also cause the velocity to read abnormally low and the proof number to read high. Premature triggering of all three screens (a rare case) will cause the system to indicate the speed of sound with a low proof number.

If you see the effects of blast, the only sure solution is to install a blast baffle midway between muzzle and first screen. This baffle should be a piece of plywood with a small hole or vertical slot to shoot through. Shown below is a baffle made at the range with locally available materials. It worked well.

Proof Channel Background

Professional users have long recognized the convenience of skyscreens. These same users have also recognized limitations in the reliability of skyscreens. With skyscreens you are at the mercy of the light conditions existing at the range. Skyscreens work well under most conditions, but under certain rare light conditions there will be errors. If you haven't yet found these conditions, you will. The size of the differences on each shot is comparable to the size of errors in your velocity measurements. The proof channel tells you when to trust the chronograph velocity reading, and when the system is fooled by light conditions. The configuration of the three skyscreens was chosen so that an error at any one or two skyscreens causes a *significant difference* in velocity readings. This difference is your warning of a measurement error. Large numbers in the *Proof Channel* indicate error conditions in the muzzle velocity measurements. These errors may be caused by muzzle flash (visible and infrared) or other unrecognized problems.

ICAO vs Metro

The drag functions supplied with the System 89 program originated from work done at the U.S. Army Aberdeen Proving Ground. The following dates were gleaned from Chapter 1 of Modern Exterior Ballistics by Robert L. McCoy

Drag Function	Compiled
G1	1918
G2	1922 - 1925
G5	before 1960
G6	1929 - 1931
G7	1943
G8	1943

In chapter 8 McCoy states that U.S. Army Ordnance used the Army Standard Metro (Metro) atmosphere until 1962. The standard drag functions were long in use and were calibrated to standard Metro conditions. We have found no record of any of these drag functions being revised when the International Civil Aviation Organization (ICAO) atmosphere was adopted by Army Ordnance in 1962. By this date the military was using Doppler radar to create drag functions specific to each type of ammunition issued by the U.S. military.

William C. Davis writes in the instructions to the ATRAG program that "The ARMY STANDARD METRO atmosphere was established at the U.S. Army Aberdeen Proving Ground and was used for many years by the U.S. Army as the atmosphere for which all standard firing tables were computed. This standard atmosphere was also adopted by the manufacturers of commercial ammunition, and it is still in use by the major manufacturers of commercial ammunition and bullets."

The G1, G5, G6, G7, GL, GS, and RA-4 drag functions included with Oehler software were, with permission, derived from the SAAMI Tables Of Siacci Functions And Drag Coefficients of June 1976. This document references SAAMI Exterior Ballistics Centerfire And Rimfire Ammunition of June 1976. This reference document specifically states in equation 19 that the standard atmospheric pressure to be used is 29.5275 in Hg for an air density of 0.0751265 lb/ft^3, which is the Metro standard pressure and air density.

Because the long-used drag functions were defined and published for standard Metro conditions, Oehler systems calculate ballistic coefficients referenced to standard Metro conditions. Oehler equipment including the Systems 43, 83, 85 and Ballistic Explorer software have used Army Standard Metro since 1992. This reflects the current (2020) SAAMI practice and provides compatibility with legacy data and drag tables.

The measurements from the System 89 provide a solution. Use the ballistic coefficient indicated by your measurements as the input to your ballistic prediction program. After compensating for the atmosphere, your prediction should match the time-of-flight you observed.

If the predicted times-of-flight don't match the measured times, then change the BC until they do. This assures that you have calibrated your entire system.

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Measurement Accuracy

It is difficult to quantify the accuracy of the downrange parameters measured by the System 89 The system actually measures the times at which the specified events occur. You can see these raw times when you double-click on a displayed result line. Other parameters (time-of-flight, remaining velocity, ballistic coefficient, along with the horizontal and vertical impact points are computed from the event times. This computation is not straight-forward; it is described by mathematicians as an "iterative solution". Simply stated it means that we keep refining our guesses until our latest guess matches the actual measured data.

As the target is placed farther from the gun to record performance all the way down to the transonic velocities, the Mach cone angle becomes larger. The cone theoretically becomes a flat shock wave at Mach 1.0. Practically, as the Mach cone becomes flatter, the correction between microphone event times and arrival time at the microphone plane becomes smaller and less important. This means that accurate time-of-flight measurements can be made all the way down to remaining velocities of Mach 1.0.

As the Mach cone becomes flatter, the target scoring accuracy is degraded. We typically quote Mach 1.3 or 1500 feet per second as the lower limit for good scoring accuracy. Even at lower velocities approaching Mach 1.0, the scoring accuracy remains adequate to tell the user approximate hit locations as he determines flight times and ballistic coefficients. At Mach 1.0, acoustic scoring becomes completely dysfunctional.

Note that the displayed values for the downrange parameters may change slightly as you change your assumed drag function from G1 to G7 to G whatever. *The values displayed will correspond to the drag function you specified.*

Although the system uses an accurate clock to precisely measure the times at which the events occur, the accuracy of the output parameters is usually determined by the accuracy of the physical spacing of the skyscreens and microphones. Errors in skyscreen spacing lead directly to errors in muzzle velocity; a spacing of 0.1% too long yields an indicated velocity 0.1% too low. Errors in the location of microphones can cause subtle errors in both arrival time and apparent impact position. Square arrays must be square and line arrays must be straight. Square arrays should not only be square, but they should be “square” to the bullet path and tilted to match the arrival angle of fall. Line arrays should also be “square” to the bullet path.

Errors in spacing and alignment are usually not reflected in the precision or repeatability of the readings. For example, the picture of your group may look identical to your paper group and show the same dispersion, but it may be displaced a few inches above the target center instead of being perfectly centered.

If you use another exterior ballistics program to confirm the accuracy of the ballistic coefficients determined with the System 89, please remember that the time-of-flight is measured from the mid-point of the skyscreens to the plane of the target!

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Barely Supersonic Bullets with Flyover Array

The scoring of target impact location from the flyover array is not as robust as is the scoring from the square array. With the square array, we stop showing impact locations slightly above Mach 1, but we continue to show arrival times and BC. We continue to show arrival times and BCs because the array window is relatively small and we know that the correction between the time of a bullet passage through the plane of the target and its Mach cone reaching the nearest microphone is small. (At the barely supersonic velocities the Mach cone is relatively flat.) With the flyover target, we no longer know if the bullet passes near a microphone and therefore do not report arrival time or BC if the location "solver" flags that the scored location is questionable.

Experimenters are interested in the behavior of the bullet as its velocity falls through the zone of Mach 1.2 down to Mach 1.0. The distance to target must be selected based on the expected velocity at the target. If the expected distance is slightly farther than the actual distance, then some (or all) of the bullets may be too slow to properly trigger all four microphones. In this case, the flyover target will appear not to respond. You can check for any hidden microphone responses by double-clicking on the shot line and hitting the "View Events" button at the bottom of the diagnostic window. Make sure you scan through the entire recorded time; if target events are present, they will show as small black "tic" marks in the window. This indicates that the shot was still supersonic because one or more mics heard the Mach cone, but the black color of the tics indicates that they were not selected for a displayed solution. In this case, we suggest that you continue the test and recover the data later. It is difficult to collect data in the Mach 1.0 region and we lucked into a good setup.

To recover the data, you must edit the **TestInfo** file using Excel and then replay the edited file using the **Sys89** program. We suggest the following procedure.

1. Load the **TestInfo** file into Excel.
2. Immediately do a "Save As" after you append "Subsonic" or some other flag to the root name of the file. Always preserve your original file in its "unedited" or virgin state.
3. On the first sheet of the Excel book, find the notation "Horiz Line Target" and replace it with "Subsonic Target".
4. Use the "Delete Sheet" under the "Edit" pulldown to delete the "Event Comb" sheet.
5. Use the "Save" function to save your edited file.
6. Replay the edited file using **Sys89**.
7. Compare your outputs to that of the unedited file. For those shots previously missing, you should see TOF and BC results if at least one microphone heard the Mach cone. For those shots previously properly scored by the flyover solver, you will probably see a very slight increase in TOF and decrease in BC.

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Increased Resolution

In developing the System 89, we chose the number of digits displayed after the decimal point to be consistent with expected field accuracy. Although inputs and outputs are restricted to a few decimal digits in the standard program, these same numbers are stored and used to higher precision within the program. Some users have requested increased resolution for input and output values.

This increased resolution is available to users if they manually modify the "s89param.ini" file. This file must be in the same folder as the program's **Sys89.exe** file. If the file is missing the Sys89 program issues an error message and then closes. The file may be opened and edited with Windows Notepad. Make a backup copy of the **s89param.ini** file in case your edits do not work. You open and edit this file at your own risk. If the program does not work after your edits, you may have to delete the edited file and reinstall the program.

The basic element contained in an INI file is the key. Every key has a name and a value, delimited by an equals sign (=). The name appears to the left of the equals sign.

name=value

Keys are grouped into named sections. The section name appears on a line by itself, in square brackets ([and]). All keys after the section declaration are associated with that section. There is no explicit "end of section" delimiter; sections end at the next section declaration, or the end of the file. Sections may not be nested.

```
[section]
a=a
b=b
```

Key names must be unique within a section, but the same key name can be used in more than one section. Section and Key names are not case sensitive.

Semicolons (;) at the beginning of the line indicate a comment. Comment lines are ignored.

; comment text

Blank lines are allowed anywhere in the INI file.

Range and Format:

The System 89 has two range and format sections in the INI file, one for use when English units are selected and one for use when Metric units are selected from the Options menu. This allows optimum setting for each measurement system.

The parameters are under the **[English Range and Format]** section and a duplicate set are under the **[Metric Range and Format]** section. There are four keys for each numerical parameter in the program's main display. The keys start with an abbreviation of the parameter followed by one of four types as shown.

MinRange Sets the minimum value for the parameter
MaxRange Sets the maximum value for the parameter
Default Sets the default value for the parameter
DPFormat Sets the number of places to the right of the decimal point to display

For example, in the section for English values you'll see the following for the Temperature parameter.

TempMinRange=0
TempMaxRange=120
TempDefault=59
TempDPFormat=0

In the section for Metric values you'll see the following for the Temperature parameter.

TempMinRange=-15
TempMaxRange=65
TempDefault=15.0
TempDPFormat=0

The program enforces the minimum and maximum range of each parameter and uses the default value when the program is first started or when "New (load default setup)" is selected from the Setup menu.

The default parameter is set to the current value when "Set current setup as default" is selected from the Setup menu. The program sets the default values in both the English and Metric sections regardless of what measurement system is currently selected. Conversions are done as needed.

In addition to the setup parameters, the "DPFormat" value of several types of displayed data is set using with the following keys.

TargetDPFormat Target strike location (inches or centimeters)
VelocityDPFormat Bullet Velocity (feet per second or meters per second)
TOFDPFormat Time of Flight in seconds
BCDPFormat Ballistic Coefficients

Date Format:

The format of the "Test Date" in the setup display and in reports is controlled by the DateFormat key in the [Program Settings] section. Users have different requirements for date format, so the information for setting the format is included in the INI file as comments. Note that changing the format does not alter the format in existing tests, only in new tests. Below is the information found in the INI file along with the default setting.

; Date Format information
; yy for 2 digit year or yyyy for 4 digit year
; mm for 2 digit month with leading 0 or m for no leading zero
; mmm for abbreviation of month name
; dd for 2 digit day with leading 0 or d for no leading zero
; hh for 2 digit hour with leading 0 or h for no leading zero
; nn for 2 digit minute with leading 0 or n for no leading zero
; ss for 2 digit second with leading 0 or s for no leading zero
; examples: mm/dd/yyyy -for- 09/01/2013 -or- m/d/yy -for- 9/1/13 -or- yyyy/mm/dd -for- 2013/09/01
; examples with time: mm/dd/yyyy hh:nn -for- 09/01/2013 7:35 -or- m/d/yyyy hh:nn:ss -for- 9/1/2013 19:35:20
; example with different date separator: mm-dd-yyyy hh:nn -for- 09-01-2013 19:35
; example for 12 hour clock: mm/dd/yyyy hh/nn am/pm -for- 09/01/2013 7:35 pm -or- mm/dd/yyyy hh/nn AM/PM -for- 09/01/2013 7:35 PM
; example for Military format: dd/mmm/yyyy hh:nn -for- 09/Sep/2013 19:35
DateFormat=mm/dd/yyyy hh:nn

Hidden Parameters:
Some parameters are not found in the **s89param.ini** file. They are set to a default value in the code and should not be altered by the user.

Editing Test Data

Most edits of the TestData files can be made on the main screen as you replay a test. Replaying a test displays the **Test** screen immediately. To edit the main screen, you must exit the test results screen with the **End Replay** button. At the main screen, you may edit many of the parameters such as metro conditions, distances, sensor spacing, or even choose a different drag function. For an immediate replay of the edited test, you must select the **Replay current test** option; replay will use the changes you have made on the main screen. **End Replay**; as you leave the main screen and you will be given option to change the TestData file to include the changes you have made. Edits made with this procedure are anticipated and handled by the program.

A cursory examination of an Excel TestData file shows a simple structure. Every **Replay** begins with the recorded Test Data Excel file and recomputes all results using the information from the data file. You can use Excel to edit this raw data, but there are many traps. We've given you rope; you can swing or hang.

The first sheet contains the setup information, both questions and answers. Beware of answer format.

The second sheet shows a record of each event recognized by the gun unit near the muzzle. The **System 89** considers an event from the start skyscreen as the beginning of a shot. The time for this starting event is read from the PC clock and is recorded in seconds after midnight. (You must make columns wider to show extra digits after the decimal place.)

The third sheet displays the results from the target. As an example pf use, if the cables connecting the sensors to the event inputs are crossed, then the time data will be recorded in the incorrect column. This can be remedied by editing the sheet in Excel to swap the recorded times so that they are in the columns of the proper sensor.

The fourth sheet records shots that have been manually omitted from the test. The fifth sheet labeled **Event Comb** requires more explanation. The computer collects all the event times from both gun and target controllers as they are recognized. The computer is smarter than the individual controllers. It knows that the start skyscreen should be the first recognized event from a shot; the shot starts there. It knows that signals from the mid and stop skyscreens should follow shortly. Knowing the distance to the downrange target and the muzzle velocity, the computer can establish a rough time window into which the microphone response events should occur. It must scan through the event times received from each microphone at the target to find those having reasonable time delays. We've named this process the "event comb" where we comb through all the received data and patch it together.

The results of the **Event Comb** scan are recorded on the **Event Comb** sheet. Column A is the shot number in the group. Column B contains the line number of the event times for the start skyscreen. Column C contains the line number event times for the mid skyscreen. The columns proceed for the various events at gun and target expected to be recorded for each shot. If no appropriate event time is found, there is a zero.

Your edits may change the event comb results. Richard Larson, who has written Oehler's software for almost forty years, provides a way out. Edit the TestData file to delete the **Event Comb** sheet. On the next replay, the program will automatically "re-comb" the data and make a new **Event Comb** sheet.

If all sensors worked perfectly and recognized every bullet and they never gave a false trigger, life would be easy. It doesn't happen that way. We have made each controller operate under a very simple set of rules.

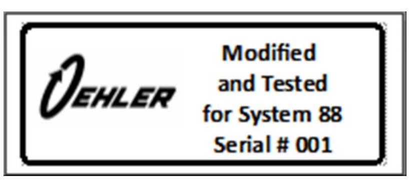
- Record the time of the first recognized of the four events.
- Record the time of any other events recognized within fifty milliseconds of the first event. All valid events must occur within this fifty millisecond window.
- Bundle all the recorded times into a "shot" package to be sent back to the computer when requested.
- Immediately reset all event inputs and wait for another event to be recognized.

If anything triggers the false recognition of an event, the stupid controller unit does not know that it is a false event and reports it anyway. If the unit doesn't recognize a bullet it should have recognized, there is no event to report. The computer receives a mixed basket of information, valid data, false data, and some data might be missed.

Modified Leupold RX-1200i

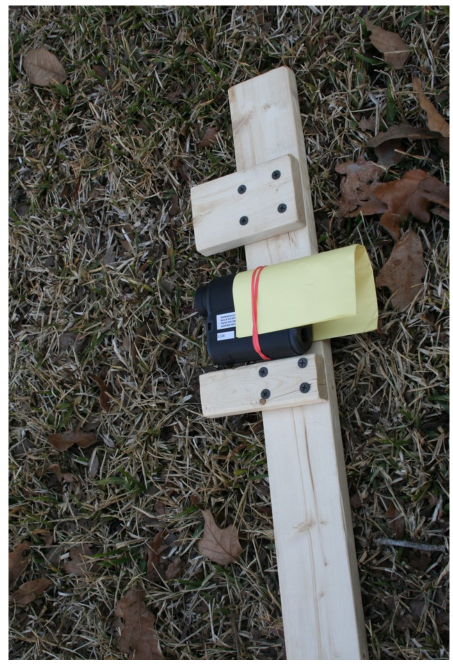
Operate your rangefinder in the **LOS** or "line of sight" mode. We want to measure the direct line of sight. The rangefinder should indicate **LOS** at the bottom portion of the display; you should not see **TBR** or **BOW** at the top of the display. Aim the rangefinder at the reflective target using the **+** index and hold the top **POWER** button down. Lock on the reflective target becomes obvious when the indicated range stabilizes for repeated readings. If the repeated readings vary a few digits, then you can use the most frequent reading from a series of tests.

Note that the modified rangefinder has only a four-digit display for range. For measured ranges over 999.9 yards or meters, there is no display of the thousands digit. Like an odometer, the display will simply roll over. For example, if the measured distance is 1256.7 yards, you will see only 256.7 yards in the display. The meter is not expected to function at ranges over 1500 yards. The modified and tested units have a supplemental label attached.



The Leupold Rx-1200i rangefinder has no provision for tripod mounting. An adapter clamp such as is commonly used to mount a smart phone to a tripod works well. If the rangefinder is used with a tripod, make sure that the rangefinder is plumb above the mark on the ground.

Because we must measure to 0.1 yard resolution, it is important that the front edge of the rangefinder be aligned over the mark on the ground. You can use a plumb bob, but we prefer to use a *Buford Stick*.



The *Buford Stick* is a board with a cleat installed square and at a convenient height. The stick shown has two cleats, one convenient for standing and the other convenient for sitting on the Gator seat. Rest the rangefinder on the cleat with front edges matching the stick, and place the toe of the stick on the mark. This assures that the rangefinder is aligned to the mark. The photo also shows our improvised sun shield. Because we were aiming into the sun, we strapped a piece of paper around the rangefinder with a rubber band. The sun can no longer shine on the objective lens.

The clamp used to fasten a smart-phone to a camera tripod can be used to to steady the rangefinder.

The following segments have been extracted from the Leupold instruction manual. The complete manual is available in pdf form on their website www.leupold.com.

Enter the setup mode.

To initiate rangefinder setup mode, press the POWER button to activate the unit, then press and hold the MODE button for 2 seconds to enter the Quick Set Menu™.

To manipulate a function, press and release the MODE button until that function is flashing, then use the POWER button to change the setting. If this is the last function to be changed, you can allow the rangefinder to sit idle for 20 seconds which will cause an automatic power-off, saving all selections. If additional functions require manipulation, simply press MODE to continue through the Quick Set Menu. Pressing and holding MODE for 1 second at any time will save all changes, exit the Quick Set Menu, and prepare the rangefinder for immediate use.

To reset your RX-1200*i* to factory settings, Press POWER to activate the rangefinder, press and hold MODE, then press and hold POWER. A 10-second countdown timer will appear; factory reset will occur after 0 has been reached.

Note: *Activating certain modes automatically disables other modes. For example activating the yards mode will automatically deactivate the meters mode.*

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The rangefinder must be set to the LOS mode.

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FUNCTION 1: TBR, BOW OR LOS

To activate TBR, BOW, or LOS, activate the RX-1200*i* by pressing the POWER button, then press and release the MODE button to enter the menu. While "Out Put" is shown in the display, press and release the POWER button to rotate through TBR, BOW, and LOS modes. Once the desired mode is displayed, press the MODE button for >1 and release.
The inclinometer output is shown beside the battery status indicator.

NOTE: LOS is always active on non-TBR models.

The rangefinder can be set for either yards or meters.

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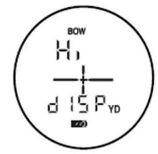
FUNCTION 3: DISPLAY INTENSITY

This mode is used to adjust the brightness of the display, allowing you to match the intensity to current conditions. Your RX-1200*i* has three display intensity settings; low, medium, and high.



Navigate through the Quick Set Menu by pressing and releasing the MODE button until "DISP" is shown in the lower display. Press and release the POWER button to toggle between high, medium, and low. Press MODE to save the selection.

FUNCTION 4: UNIT OUTPUT

This mode is used to choose between yards and meters as the preferred unit of measure. To choose between yards and meters, navigate through the Quick Set Menu by pressing and releasing the MODE button until "Unit" is shown in the lower display. Press and release the POWER button to alternate between yards and meters. Press MODE to save the selection.

Unit set to Yards (YD)

You can select the desired reticle.

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FUNCTION 6: 3 SELECTABLE RETICLES

This mode allows you to choose any one of the 3 preloaded reticles as the primary aiming point for the RX-1200*i* digital laser rangefinder. To select a reticle, press and release MODE until the current reticle is blinking. Press and release POWER to scroll through the available reticles, then press MODE when the preferred reticle is shown. The reticle choices are as follows:

Plus Point™ | Duplex® with Plus Point™ | Duplex® without Plus Point™

Skyscreens, Multi-piece Rail

This section was contributed by Buford Boone after years of experience with chronographs and skyscreens.

Skyscreen Notes – YOU have control over the accuracy of the measurements.

We recommend using a minimum of 8’ spacing for BC measurements. Short spacings are convenient…and less accurate.

We strongly recommend using three screens. Doing so results in two velocity measurements per shot. One measurement is from start to stop screen and the second measurement is from start screen to the middle screen. The difference between the measurements is reported as the *prf* (Proof) number. Ideally, the *prf* number would be 0 or 1. You should not expect to see *prf* of “0” often. Both positive and negative *prf* numbers are normal. A properly functioning system will show consistent *prf* numbers.

Oehler skyscreen precision is best described as 1/8” uncertainty in screen spacing. The longer the spacing, the better the accuracy of the velocity. For example, expected error for a 2500 fps shot on a 4’ spacing is 6.5 fps. Increase the spacing to 9’ and the expected error shrinks to 2.9 fps.

The *prf* number on an 8’ spacing compares a velocity taken over a 4’ spacing to the velocity measured over 8’. The larger error of the 4’ spacing will dominate and the expected error over the 8’ spacing value is only half of the *prf* number.

Since YOU choose the length of your rail, YOU are in total control of the accuracy of the measurement. Want more accuracy? Use a longer spacing. Longer spacing means longer rail, or multi-piece rail. Multi-piece rail means you have to have a method of joining the pieces.

The software requires the user to input the screen spacing in feet. This spacing DOES NOT have to be in whole feet. We recommend that the user measure the actual spacing between start and stop screens EVERY TIME. Input the actual distance into the program. If measurement is 96 1/8”, divide 96.125 by 12 and enter 8.010 feet in the program.

We recognize that this means the middle screen is not exactly in the middle and the proof value would be slightly affected. For a 3,000 fps measurement, the added 1/8” would cause a *prf* error of less than 4 fps. This is inconsequential because the *prf* number is intended solely to provide confidence in the primary number. Small and consistent *prf* numbers instill confidence while large or inconsistent prf numbers imply something wrong with your setup or light conditions.

Your chosen skyscreen rail length will be a compromise between desired accuracy and convenience. How long a rail can you easily transport and store?

Making Multi-Part Skyscreen Rails:

We have a workable method of coupling two or three pieces of rail together. Best results will be obtained if the rail is supported at all three screens.

Required Materials and Tools

- Electrical conduit (EMT), nominal ½”.
  Note that 1/2” EMT is usually available in 10’ length. Both ends of new conduit are smooth and square. Connect these ends to keep the rail as straight as possible.
- Conduit coupling
  (Pro Connex ½” Compression Coupling, Lowes Item 44260, works well. Whatever coupling you choose will add length to the setup. The Pro Connex adds between 1/8” and 1/16”.)
- 5/8” (.625”) threaded rod at least 16” inches long. Length is not critical.
- 1/4-20 x 2” hex head bolts (3 each)
- Wrench to fit above bolt.
- “C” clamp or Vice-Grip wrench.
- Drill with 15/64” bit.
- Sharpie marker.
- Masking tape.

If you make a 3 piece rail, use a tubing cutter to obtain a square cut.

<u>Two-Piece Assembly:</u>

Decide the length of your rail. For this example, we will make a system capable of a 9’ (108”) spacing.

Replace the skyscreen bolts with the hex head bolts you purchased.

Cut the 10’ rail at 64”. Place start screen and mid screen (no diffusers) on 64” rail. The start screen should be approximately 3/4” from the cut end of the rail. The mid screen should be toward the smooth factory end.

Place the rail with screens upside down on a flat surface, like workbench or garage floor. Slide the mid screen so that it is **exactly** 54” from the start screen. Measure more than once, from center-to-center or between leading edges. Hand tighten the two bolts to secure the skyscreens. Measure again. After measurement is exact, use a “C” clamp to hold the plastic halves of the skyscreen housing together. Tighten the bolt of the start skyscreen exactly 1.5 turns. (Too many turns will flatten the EMT so screen won’t slide; too few turns will leave no locating dimple.) Turn the bolt of the mid screen exactly 1 turn. This creates dimples in the rail. Mark the screen near each rail with “S” for the start screen and “M” for the mid screen. Remove both skyscreens.

Using a drill with 15/64” bit, drill the dimple of the mid screen thru one side of the tubing only.

Slide a piece of threaded rod into the EMT tubing near the mid dimple leaving half the rod sticking out. The drilling likely left big burrs on the inside of the drilled hole. Expect to twist the threaded rod to get it deep enough.

Reinstall the Start and Mid screens on the rail using the original 3” bolts with fastened wing-nuts. The screw of the Start screen should settle into its dimple. The screw of the Mid screen will go thru the drilled hole and tighten against the threaded rod.

Install the compression coupling on the first rail, ensuring you have it as square as possible. Tighten the end that is nearest the Mid screen. Tightening about ¼ turn past hand tight and mark it with masking tape so you’ll not undo it.

Install remaining screen on remaining piece of EMT, estimating correct location but don’t tighten the screw. Slip the milled end of the second rail onto the threaded rod and into the compression coupling.

Tighten the compression coupling hand tight.

Using the same tape measure as before, slide the stop screen so that it is exactly 108" from the start screen and 54" from the mid screen. MEASURE a couple of times. You've only got one chance at this. Once measurement is perfect, clamp the skyscreen sides with "C" clamp and create dimple with exactly 1 ½ turns of the bolt.

Cut excess rail off, if you want to.

Three-Piece Assembly

Same supplies except you will need an additional EMT coupling and an additional threaded rod.

Cut one piece of EMT at 37". This will become the middle section. Cut the remaining piece of EMT in half.

Replace skyscreen screws of the screens with the hex head screws.

Place the mid screen at the middle of the 37" rail. Using "C" clamp or Vice-Grip, clamp the two halves of the skyscreen together near the bolt. Create a dimple by tightening the bolt exactly 1 ½ turns past hand-tight.

If you are using 16" threaded rod, place a dimple 8.5" from each end to be joined by coupling. (This keeps threaded rod from getting lost inside the EMT.) Use a skyscreen (reinforced with "C" clamp) and 1 ½ turns of the bolt to make each dimple.)

Join the rails using the conduit couplings with the reinforcing rod inside the EMT. Tighten the coupling nuts located on the center section approximately ¼ turn past hand-tight. Mark these nuts with masking tape to remind you that they need not be loosened in the field.

Secure the mid screen so that it is exactly in the center of its support rod. Place all skyscreens on the rail and place assembly on a flat surface such as garage floor.

Ensure you have everything snugged up with EMT sections pushed together and coupling nuts secure.

Measuring from the center screen, tighten the start and stop screens so that each is exactly 54" from the mid screen and exactly 108" from each other. Measure carefully and often. Once satisfied that you have the setup exact, install the "C" clamps and create the dimples with exactly 1 ½ revolutions of the hex head bolt.

Trim the excess rail from the start and stop screens.

Make a couple of wraps of masking tape around both sides of both couplings. Using the Sharpie, mark both sides of the coupling nearest the start screen with "1" and mark both sides of the coupling nearest the stop screen with "2". This will ensure you reassemble correctly.

Replace the original screen mounting screws.

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Measure Twice

Measurement errors happen. We tolerate these errors and forgive them when they are recognized. Recognition of errors is essential.

You are concerned when any measurement doesn't fall within your expected range. Whether you are looking at muzzle velocity, group on the target or ballistic coefficient, your first question of an apparent outlier is, "Was it a measurement error?" If you decide that it was a measurement error, you believe that your gun and load were good and you cuss the instrumentation system. If you discard the reading, and there was no measurement error, you just ignored the bad news. Was there an error?

To get maximum benefit from your tests, any error must be recognized . There is a difference between a measurement you don't like and certainty that a measurement error occurred. After sixty years, we have found nothing better than making redundant measurements. If two or more measurements of the same parameter agree, there is a good chance that the measurements are valid. If the measurements don't agree, then you know that at least one measurement is wrong. Both measurements may be wrong. Often your best alternative is to disregard all the data and check your instrumentation.

To measure a ballistic coefficient accurately, you need three accurate measurements. You need the initial velocity, the distance to the target, and the time-of-flight to the target. The System 89 includes redundant measurement for all three.

Some may consider the Skyscreen III system archaic, but we consider it to be the most accurate and reliable field system for measuring initial velocity. The three skyscreens allow two measurements of velocity for each shot, and we display the *Proof* number so that you can easily see comparisons of the measurements on each shot. A single large proof number indicates that at least one velocity measurement is in error, but you don't know which one. Consistent, but large, proof numbers usually indicate errors in the spacing of the three skyscreens. Very erratic proof numbers usually indicate poor light conditions, muzzle blast with subsonic ammo, excess muzzle flash, or not shooting through the centers of the skyscreens. If skyscreens are spaced properly and you have either cloudy skies or have direct sun on each orange diffuser, you expect to see single-digit proof numbers agreeing within a few feet per second. Three skyscreens provide the required redundancy.

The distance over which you measure the time-of-flight is just as important as is the measured time and velocity. We put a laser reflector on *each* System 89 unit; use your rangefinder to make *two* measurements on each target set-up. Place the gun unit adjacent to the start skyscreen before you go downrange to set up the target. Measure the distance from target back to gun. Leave the target unit with its reflector even with the target when you go back to the gun. Measure distance from start skyscreen to target and compare. If the measurements don't agree, find out why. Have you verified the readings from your rangefinder over accurately surveyed long distances? Have you compared readings from two rangefinders? Unless you can match the two distance measurements to better than one-part-per-thousand, you are asking for errors.

The time-of-flight measurement of the System 89 includes built-in redundancy. Each of the four microphones gives its own time measurement. Tiny inconsistencies in the times recorded by the multiple microphones will show up as either an abnormal target reading or no target reading at all. You should use multiple microphones when you use an impact target. When you look at the raw time data and see multiple impact times very close together, the recorded impact time is confirmed. If the proper stop signal is detected at the target, then the accuracy of the time-of-flight measurement is probably better than the accuracy of your distance measurement.

The benefits of redundant measurements become most apparent during the post-test analysis of the data. The System 89 not only makes redundant measurements, but it saves the results. Just as you can't measure group size after firing only one or two shots, you should complete your test before you exclude or *omit* data. The System 89 shows the redundant data during replay or during post-test examination of the raw data files.

Sooner or later you will be making a test to determine the uniformity of a batch of bullets. You know that average ballistic coefficient is correct because your predicted come-ups match reality at long ranges. This "truing" confirms that distance to target and screen spacing were probably correct.

As you scan the column of measured BCs, there may be one value that seems to jump out of the group. Was this an abnormal bullet, or did the '89 screw up? We know that the distance didn't change as the test group was fired, so we worry about the time-of-flight and muzzle velocity measurement. The most critical part of the time-of-flight measurement is properly stopping the clock at the target. If you used an acoustic target then any shot that scored at the target caused microphone event times yielding accurate time-of-flight measurement. If you used an impact target, you should have used two or more mics. Double-click on the shot in question to bring up the *Shot Diagnostic* window and look at the time reading to each microphone. Click the *View Events* button to see a plot of all the recorded events. Do you see two coincident events at the target? If so, you better believe the target data. If everything looks good at the target, examine the initial velocity and proof numbers. If the proof numbers are consistently small, you can bet that your velocity readings are accurate. If the velocity number is within the expected range, you can consider it verified. After you've cross-checked all the supporting measurements you can be confident that something was amiss with the bullet. There probably was no measurement error.

Old-timers say, *"Measure twice, you only cut once."*

The redundant measurement technique can be applied to an entire system instead of only one characteristic. When measured ballistic coefficients vary from shot to shot, the first question asked is, "Did the BC actually change or was it just a sloppy measurement?" To answer this reasonable question, you make two measurements of the BC of each bullet. If the measurements don't agree, there is a problem with the instrumentation. If the measurements do agree, you have high confidence in the instrumentation. The obvious solution is to use two independent systems on the same shot.

As the beta tests of the System 89 ended, two systems were set up for simultaneous use. 22RF ammo was used with an impact target. The photo shows the two sets of three skyscreens mounted on single rail. Two microphones from each system were mounted on the impact target board located at a nominal 100 meters. Two controllers with two laptop computers were used at the gun and two more controllers at the target. The experienced user took exceptional care to assure the accuracy of all distance measurements. The G7 drag function was used because it had been demonstrated to provide similar BCs when subsonic 22RF ammo was tested at different ranges. (That implies that the G7 drag function provides a reasonable fit to the typical ammo.) The software was tweaked to provide four-digit printout of the observed BC numbers even though four-digit accuracy is not expected.

The unedited test results for the initial twenty-round test are included as the next two pages. The agreement between primary and proof velocities is shown by tiny values indicated for the Proof Velocity of each round. There is a small difference in the range to target caused by the nine-inch offset required to mount two sets of skyscreens on the single rail. This results in an approximate 0.8 millisecond difference in the time-of-flight of each round, but the ballistic coefficients agree to the third decimal place on each round. Round 1 went over the impact plate so no target information is shown. Rounds 7 and 8 were missed with the first system and were omitted on the printed results for the second system. (Skyscreens B and C missed readings on these two shots. We suspect premature false triggers on screen A.)

Comparison of the measured BCs showed almost perfect agreement between the two systems. The third digit always agreed and the fourth digit usually agreed. The disagreement between systems was significantly smaller than the differences between individual rounds of ammo.

Down Range Farm (Boone Ballistics, LLC) - System 89 Report

BC CHRONO™ System 89 OEHLER

Test File Name: 05222021 Simo test square units_1.xls
Location: DRF
Operator: Boone
Test Date: 05/22/2021 15:36
Temperture: 90 **°F**
Station Pressure: 30.17 **in Hg**
Humidity: 44 **%**
Wind Speed: 0 **mph**
Wind Direction: 05:00 **o'clock**
Drag Function: G7

Gun Unit ------------------------
Serial Num: BOONE001
Signal Level: 80
ScrA to ScrC: 9.000 **feet**

Target Unit ---------------
Serial Num: OEHLER01
Type: Impact Target
Size: 1.0 **feet**
Signal Level: 80
Range: 106.345 **yards**

Edit Status: Original
Test Folder: C:\OehlerSys89\TestFiles\
Report Folder: C:\OehlerSys89\ReportExport\
Excel Folder: C:\OehlerSys89\DataExport\
Test Note: RWS Subsonic. From Ruger American with Gemtec silencer. Screens B and C missed shots 6 and 7. No idea why.

Round	Gun Unit		Impact Target 104.845 Y	
Number	VelAC	Prf Vel	T.O.F.	B.C.
1	1010	0.1	---	---
2	1006	0.1	0.33731	0.0531
3	1012	0.1	0.33433	0.0558
4	951	0.1	0.35558	0.0534
5	1024	0.1	0.32955	0.0591
6	1034	0.2	0.32738	0.0568
~~7~~	—	—	—	—
~~8~~	—	—	—	—
9	1001	0.3	0.33867	0.0534
10	1021	0.1	0.33072	0.0576
11	1033	0.0	0.32683	0.0588
12	1037	0.0	0.32619	0.0578
13	1032	0.2	0.32870	0.0553
14	995	0.2	0.34293	0.0491
15	986	0.2	0.34241	0.0556
16	1010	0.1	0.33435	0.0568
17	975	0.1	0.34761	0.0529
18	994	0.1	0.34013	0.0551
19	1010	0.2	0.33542	0.0548
20	1006	0.1	0.33415	0.0610

---------- SUMMARY ----------

	Gun Unit		Impact Target 104.845 Y	
	VelAC	Prf Vel	T.O.F.	B.C.
Avg:	1008	0.1	0.33601	0.0557
SD:	22	0.1	0.00798	0.0028
High:	1037	0.3	0.35558	0.0610
Low:	951	0.0	0.32619	0.0491
ES:	86	0.3	0.02939	0.0119

Test Report from System Using Two Controllers from First Beta Run

Down Range Farm (Boone Ballistics, LLC) - System 89 Report

Test File Name: 05222021 Simo test Slimline units_1.xls
Location: DRF
Operator: Boone
Test Date: 05/22/2021 15:36
Temperture: 90 **°F**
Station Pressure: 30.17 **in Hg**
Humidity: 44 **%**
Wind Speed: 0 **mph**
Wind Direction: 05:00 **o'clock**
Drag Function: G7

Gun Unit ------------------------
Serial Num: S89-0004
Signal Level: 80
ScrA to ScrC: 9.000 **feet**

Target Unit ---------------
Serial Num: S89-0003
Type: Impact Target
Size: 1.0 **feet**
Signal Level: 80
Range: 106.611 **yards**

Edit Status: Original
Test Folder: C:\OehlerSys89\TestFiles\
Report Folder: C:\OehlerSys89\ReportExport\
Excel Folder: C:\OehlerSys89\DataExport\
Test Note: RWS Subsonic From Ruger American with Gemtech silencer. Shots 7 and 8 missed on other system so are omitted here.

Round	Gun Unit		Impact Target 105.111 Y	
Number	VelAC	Prf Vel	T.O.F.	B.C.
1	1011	0.2	---	---
2	1007	0.3	0.33809	0.0531
3	1012	0.1	0.33511	0.0558
4	952	0.3	0.35636	0.0534
5	1024	0.3	0.33028	0.0591
6	1035	0.4	0.32814	0.0568
~~7~~	~~1030~~	~~0.4~~	~~0.33016~~	~~0.0553~~
~~8~~	~~998~~	~~0.2~~	~~0.33905~~	~~0.0571~~
9	1002	0.6	0.33946	0.0534
10	1022	0.3	0.33140	0.0578
11	1034	0.4	0.32758	0.0590
12	1037	0.2	0.32694	0.0578
13	1032	0.2	0.32942	0.0554
14	995	0.4	0.34372	0.0491
15	987	0.2	0.34315	0.0558
16	1011	0.3	0.33508	0.0570
17	975	0.3	0.34840	0.0529
18	994	0.4	0.34089	0.0553
19	1010	0.6	0.33620	0.0548
20	1006	0.3	0.33491	0.0611

---------- SUMMARY ----------

	Gun Unit		Impact Target 105.111 Y	
	VelAC	Prf Vel	T.O.F.	B.C.
Avg:	1008	0.3	0.33677	0.0557
SD:	22	0.1	0.00800	0.0029
High:	1037	0.6	0.35636	0.0611
Low:	952	0.1	0.32694	0.0491
ES:	85	0.5	0.02942	0.0121

Test Report from System Using Two Controllers from Second Beta Run

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