Professional Ballistics Lab
System 85

User's Manual

Oehler Research System 85 Version 1.2.0 01/25/2012

Thanks for choosing to use the Oehler System 85. This system is well suited to modern test methods that include databases and local networks.

Our manuals have evolved over forty years. Many industrial users have so much experience that they often don't need a manual to use conventional chronographs and peak pressure equipment. The System 85 is different; it is intended for a variety of users. System 85 users may be first-time ballistic testers, or they may have been doing tests to SAAM, NATO, or CIP specs for thirty years. If we've told you the obvious, please forgive us. If we've left out something, please give us a call.

We suggest that everyone starts with the Quick Tour Instructions found on page 10.

Ken Oehler
April 2010

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Revision History:

09/23/2010 Added discussion of test names and templates. Added information on filters. Software Version 1.0.1.

05/19/2011 Added English/Metric switch to Options reflecting software Version 1.1.0.

07/20/2011 Removed Schematics and Parts List Appendix

10/10/2011 Added Appendix for Simulator

01/25/2012 Reflect Version 1.2.0 software with added filter options. Revised filter appendix. Velocity reference correction is active in all modes.

12/16/2015 Add comment reflecting correspondence of PSI/V to equivalent mV/unit.

CHAPTER 1

Background Information

Why This Chapter ?

For many years I was the junior kid among the gray-beards of SAAMI. Most of those who patiently tutored me for many years have now retired. Because they retired without writing down much of that they know, I'll presume to write a few introductory paragraphs for those new to the game. The System 85 combines chamber pressure, port pressure, action time, muzzle velocity, target, time-of-flight, and ballistic coefficient measurements into a tightly integrated form. Parameters are measured together just as they occur together in the real world.

Along with bits of historical fact and scientific background, I try to communicate a philosophy or attitude. Chamber pressure measurement is a blend of science, black art, and common sense. There are few absolutes; the best we can expect is to reliably distinguish between the safe and the unsafe. Pressure measurements are tedious, but they must be made. Pressures will literally rise up to smite the unwary.

Pressure Measurements

Beginning with the first firearms, shooters have had two big questions. What happens at the target? Did firing the shot damage the gun? Shooters have studied downrange results for centuries. They have plotted trajectories by observing impact points at various ranges, and they have been able to see the effects of the bullet by examining the targets. Recently chronographs and exterior ballistics programs have become common, and most shooters can better understand exterior ballistics.

Shooters have a good idea of what happens in front of the gun, but they have no idea of what is going on inside the gun. If nothing breaks, it's OK; if the cartridge case can't be reloaded, it's borderline; if the gun blows up the load was a little hot. This is completely unacceptable from the viewpoint of personal safety. The wiser shooters try to "read" the indications of excess pressure by paying particular attention to the condition of the cartridge case after a shot is fired. What they don't realize is that many of the fired cases of *proof ammo* would be considered to be reloadable if judged by the visible characteristics commonly observed by handloaders. There are no signs of brass flow or enlarged primer pockets. Proof ammunition is special test ammo loaded to generate distinctly higher pressures than will ever be generated by factory ammo. Each new gun is tested with one round. Shooters claim concerns about pressure, but they often don't give pressure the respect it deserves. They have had no equivalent to a chronograph to help them.

The first practical pressure gauge for measuring the pressure inside a gun was invented by Sir Alfred Nobel in the 1860s. This gauge is commonly known as a "crusher gauge". To make a crusher gauge, drill a hole through the barrel into the chamber, fit the hole with a sliding piston, and let the sliding piston crush a small piece of lead against an anvil when the shot is fired. The higher the pressure, the more the lead cylinder is deformed. The crusher gauge is calibrated by using pure lead cylinders of specified height and diameter. Cylinders from each lot are subjected to static compression tests. A chart is made showing the deformed height versus the applied force or pressure equivalent. After a shot is fired and the deformed crusher is measured, this chart is used to translate the height of the crusher to the pressure of the shot.

A century later, the lead crusher gauge remains a reasonable way to measure peak pressures typical of black powder guns and shotgun. Readings made with lead crushers correspond remarkably well with readings made with modern transducers. There are slight differences, and the measurements made with the lead crushers are tagged with the units of LUP (Lead Units of Pressure) instead of PSI. For most practical purposes and handloader decisions you need not worry about the differences between the two.

With the advent of modern cartridges and smokeless powders, pressures went higher. At higher pressures the lead cylinders deformed too much. Cylinders made of pure copper replaced the lead cylinders. The higher pressures occur faster, and they are harder to measure. During the last twenty years piezoelectric transducers have replaced copper crushers in most chamber pressure measurements. With two different methods to measure chamber pressure, users had two sets of pressure readings, and the readings did not agree. Pressure readings that had been accepted as the exact gospel truth for decades became suspect. Copper crusher readings had been assumed to represent peak pounds per square inch for many generations, but now there was another system also measuring peak pounds per square inch. Copper crusher readings and *peak* PSI readings from transducers are *not* interchangeable. Regardless of conversion charts or graphs you may have seen which pretend to offer a conversion between CUP readings and transducer *peak* PSI, there is no easy conversion. Ballisticians have fired hundreds of thousands of rounds seeking an easy correlation. They haven't found it yet, and they won't. As a result, readings taken with copper crushers are tagged with the designation CUP for Copper Units of Pressure and the PSI designation is reserved for readings taken with transducers.

It is possible to predict CUP readings from transducer data, but you must use the <u>total transducer pressure-time curve</u> and not just its <u>peak</u> value. The prediction of CUP values from transducer data is available only with the Oehler System 82.

Ideally, chamber pressure readings should be absolute. We are all spoiled and accustomed to absolute measurements of common items. If you buy a pound of powder you expect to get an amount that weighs exactly the same as a pound of butter from the grocery store or a pound of nails from the hardware store. Within close tolerances you will be right. All three of the items mentioned can be taken to a scale and weighed; you can repeat the comparison by weighing each item on a second scale. You can even "calibrate" the scales; it's simple to use a check weight.

Chamber pressure readings are more complicated than weighing a brick of butter. You can weigh and measure a loaded cartridge all you want to, you can fire dozens of loaded cartridges from the same lot in tightly specified pressure guns under controlled conditions, you can plead with the gods and IRS, but you still can't tell how much pressure the load will generate when fired in your gun.

You may read that the pressure of a certain load is 56,000 psi. You must not assume that the 56,000 psi is an absolute number. If the number is quoted for factory ammo you know that similar ammo was tested in accordance with ANSI/SAAMI standards and that there is little chance that the pressure of the ammo fired under ANSI/SAAMI specified conditions will exceed the 56,000 psi. The 56,000 psi number by itself does not tell you the pressure that will be generated when you fire the ammo in any specific test barrel or gun. The pressure generated by the round depends greatly on the gun in which it is fired and the test conditions. Individual chamber and barrel tolerances are critical. Even if you use three "identical" rifles with consecutive serial numbers or three SAAMI spec test barrels, I'll wager that you will get three different average velocities and average pressures. The pressure numbers so casually mentioned with great authority are not absolute; they are approximate and they depend greatly on the gun or barrel used!

The ANSI/SAAMI test procedures used by the major US gun and ammo makers have evolved over many decades of gun and ammo testing. The ultimate purpose of these procedures is to assure that all the ammunition loaded by the ammo makers will function **safely** in all guns which have been produced in accordance with the same family of specifications. The ANSI/SAAMI specifications define a system of measurement techniques and very specific test procedures, tight specifications for test barrels, and cooperative assessment procedures in which samples of large lots of selected uniform ammunition are fired under ideal conditions in many different labs. What you don't find in the ANSI procedures is any claim that the pressure numbers are absolute even under laboratory conditions, and you certainly won't find any claims that the quoted pressure values are directly applicable to any individual gun.

Relative Pressures

The pressures measured in any specific gun with the either piezo transducer or strain gage apply only to that gun. You can use the pressure numbers to compare different ammo fired in the same gun with the same instrumentation. Pressures in sporting guns will typically be lower than pressures of the same ammo fired in a standard test barrel because the test barrel is intentionally made tighter than typical sporting barrels. Just as some barrels shoot accurately and some won't, the same ammo builds different pressures in different barrels.

We've already discussed the unresolved differences between copper units of pressure and transducer *peak* PSI. Separate standards and procedures have been established for crusher and transducer measurements, and either can be acceptable. The British have long had their way of measuring pressure, but translating to American units is more than simply translating tons per square inch to pounds per square inch. Similarly the members of the CIP (the organization of European proof houses) have their own procedures and standards. Their results will not directly translate to either the American or British results. Proponents of each of the standards may claim that theirs is the final word, but the fact remains that there is no real translation between them. Each can be used to make valid comparisons *within one system*, and none is accepted by all others as being the gospel truth. In other words, each standard is really relative. You can make valid comparisons between numbers gathered using any one standard, but you are asking for trouble if you try to make translations between systems or compare results gathered using different standards.

There is one common denominator linking common pressure measurement standards. You must use a special breech or you must drill a hole in the barrel at the chamber to mount a transducer or install a piston for a crusher. Many systems also require a hole to be drilled in the brass cartridge case. Strain gages may be used on many sporting guns, and it does not require any holes be drilled. The strain gage *estimates* the pressure by observing how much the barrel stretches over the chamber. The strain gage is not intended to replace standard ANSI/SAAMI procedures and equipment. The strain gage with a System 83 is intended for use to estimate chamber pressure in sporting guns. The Model 83 and a strain gage can be used in industrial applications to estimate chamber pressure in sporting guns when the conventional test barrels and transducers are not available or applicable. It will closely estimate pressure *in that specific gun*. Nothing else will.

Reference Ammo

Reference ammo is widely used within the ammunition industry. It is typically a uniform and large lot of common production ammo that is designated as reference ammo only after its pressure and velocity have been properly assessed at several different test facilities *using ANSI/SAAMI approved equipment and procedures.* The aggregate value of both pressure and velocity, as determined by the many tests, is assumed as the standard. Reference ammo is then fired in each individual test barrel to determine the correction factor that must be applied to tests using that particular barrel. Reference ammo is not proof ammo. The pressure and velocity of reference ammo normally falls within the range of that allowed for production ammo. The pressure of proof ammo is normally at least 30% greater than that expected from any production ammo.

When hearing about the measurement of pressures with sporting barrels and strain gages, some users want to use reference ammo to calibrate their system. ***The assessed pressure and velocity of the reference ammo is valid only when the reference ammo is fired in test barrels meeting all ANSI/SAAMI specs, using ANSI/SAAMI procedures and instruments.*** The value of reference ammo is not simply the ammo itself, but in its controlled use within the framework of the ANSI/SAAMI specs.

Reference ammo used in testing does not establish a reference of pressure. Instead, it establishes the response expected from the mythical "average" test barrel. That is why the corrections derived from the use of reference ammo are referred to as *barrel corrections* and not *transducer corrections*, *measurement corrections*, or *absolute corrections*.

Firing reference ammo in a sporter as a calibration for the strain gage is only marginally better than using readily available commercial ammo. What can be more important to you is the use of your own *private reference* ammo. After you have installed a strain gage on your gun and have tested a few lots of ammo, select several boxes of one uniform lot to be your own *private reference* ammo. Save this ammo with its firing records for future use whenever you question the performance of your system. If you then fire a few more rounds of your *private reference* ammo, and the results are consistent with earlier results, you will have renewed confidence in your measurement. If the ammo gives results that are inconsistent with earlier data, you know that there's a problem.

CAUTION

Stay alert for the classic indications of excess pressure (head expansion, expanded primer pockets, difficult extraction, or other evidence of yielding brass). Do not push your loads to approach the published pressures if you see <u>any</u> indications of excess pressure. If your readings taken in a sporting barrel ever exceed what is reported as "maximum product average", you may be approaching the pressure of proof ammunition fired in that same gun.

BACK OFF!

Factory Pressure Limits

In books or magazines you may see reference to the working pressure, maximum product average pressure, or other terms gleaned from ANSI/SAAMI standards. While the numbers quoted may be correct, they can be misleading if you don't abide by all the fine print included in the actual standards. The fine print defines the procedures and equipment which must be used to measure the pressures and it defines the required statistical analysis. Unless you are prepared to spend the price of a new luxury automobile on test equipment, and are willing to follow ANSI/SAAMI procedures exactly, you cannot use their numbers to justify increasing the pressures of handloads.

Offset

The term *offset* has just come into the pressure measurement vocabulary with the widespread use of the conformal piezoelectric transducer. The conformal transducer is commonly used at the ammunition factories for pressure measurements. The conformal transducer is mounted in a test barrel with the sensitive face of the transducer actually forming a portion of the chamber wall. When the cartridge is fired, the case expands to push on the chamber wall. The case must contain a significant pressure before it stretches enough to press against the chamber wall. The pressure required to expand the case and push it against the conformal transducer is called the offset and is added to the measured pressure as a correction. In industrial applications this offset correction is measured with hydraulic pressure for each lot of cases.

References

For more information, we suggest that you read the sections *Chamber Pressures in Handloading* and *Measurements of Chamber Pressure* by William C. Davis, Jr., contained in the NRA ***Handloading*** book, 1981.

Industrial users must become intimately familiar with the appropriate standards ANSI/SAAMI Z299.1, Z299.2, Z299.3 and Z299.4.

Factors Affecting Pressure Measurements

We all think we know what influences chamber pressure. Bullet weight and diameter, seating depth and freebore, powder weight, type and lot, case capacity, ambient temperature, and primers are known to influence the pressure. Now consider the extra items that influence the *measurement* of pressure. The following list was taken directly from the ANSI/SAAMI standards, and the standards refer to the list as the *principal* items in each category, which may cause difficulties.

<u>*INSTRUMENTATION*</u>

1. *Condition of test barrel (whether minimum or maximum bore, chamber size and headspace, amount of erosion at throat and bore.).*
2. *Fit of transducer in barrel.*
3. *Location of transducer in barrel.*
4. *Tightness of barrel mounting.*
5. *Shape, size and protrusion of firing pin beyond breech face.*
6. *Force of firing-pin blow.*
7. *Characteristics of transducer.*
8. *Quality of transducer.*
9. *Quality of Read-Out System.*

<u>*AMMUNITION*</u>

1. *Condition of cartridge.*
2. *Position of powder in case.*
3. *Temperature of ammunition.*

<u>*PROCEDURE*</u>

1. *Failure to properly mount pressure barrel in Universal Receiver or other test action to assure minimum headspace.*
2. *Failure to rotate cartridge and close breech carefully to assure proper powder positioning.*
3. *Failure to fire warming shots.*
4. *Overheating barrel by excessive rate of fire.*
5. *Failure to clean bore and control metal fouling.*
6. *Failure to protect transducer against contamination, such as oil or water.*
7. *Transducer calibration.*
8. *Read-Out System calibration.*

The preceding list applies to measurement of chamber pressure using conformal transducers in test barrels under laboratory conditions. They worry about problems most shooters have never considered. Note that the list doesn't begin to address differences between different measuring systems. And we thought 56,000 psi was an absolute and reproducible number!

Powder Position

Any cartridge containing less than a settled full case of powder may produce *drastic* differences in pressure depending on powder position. The industry standard requires that powder be gently positioned near the primer end by using the following procedure:

1. Ammo is placed in a loading block with primer down.

2. Grasp test cartridge between thumb and forefinger, lift from block, pause, rotate cartridge slowly in a vertical plane until the primer is up, pause, and rotate until the primer is again down.

3. Seat the cartridge gently into a horizontal chamber keeping the primer end as low as possible.

This procedure is commonly called the "SAAMI Twist" and is followed religiously. Typically, powder positioned at the primer end will give higher pressures and velocities, but exceptions have been noted.

Ballistic Coefficient

With the proliferation of exterior ballistics programs for personal computers, you now see a lot of discussion about ballistic coefficients. You can make the idea of BC very complicated or keep it simple. We like the simple version.

Years ago the commercial firearms and ammo people decided on a standard model to describe the exterior ballistic performance of sporting ammo. They chose a drag function named **G1** to represent typical performance of a sporting bullet. While "G1 drag function" sounds impressive, it's only a table showing how fast the standard projectile is losing velocity versus the momentary velocity of the projectile. If a tested bullet loses velocity twice as fast as does the standard bullet, it has a BC of 1/2 or 0.500. If the tested bullet loses velocity three times as fast as does the standard bullet, it has a BC of 1/3 or 0.333. If the tested bullet loses velocity at the same rate as the standard bullet, it has a BC of 1/1 or 1.000. If the tested bullet retains its velocity better than the standard bullet it has a BC of greater than 1.000.

To measure BC you must know both how fast your bullet is going and how fast the bullet is losing velocity. Suppose that your bullet starts at 2500 fps and loses 312 fps in 100 yards. The standard bullet loses only 84 fps starting at the same velocity under the same atmospheric conditions. The BC of your bullet is approximately 84/312 or 0.269.

BC computations are complicated because ballisticians don't just talk about a standard bullet. They also assume the bullet is flying in a standard atmosphere (pressure, temperature, and humidity). When you measure how fast your bullet is losing velocity at your local conditions, you must correct the readings to estimate how much it would lose under the standard conditions. This gets very messy and is best left to the computer program. Your responsibility is to tell the computer the exact atmospheric conditions at the time of the test, and to make sure all test distances are exactly what you tell the computer.

The System 85 computes ballistic coefficients normalized to the standard conditions of:

Altitude:	Sea Level
Barometric Pressure:	29.53 inches Hg
Temperature:	59 degrees F
Relative Humidity:	79 %

The user should be particularly aware of entering the correct values for these properties during BC tests. An error 1000 feet in altitude, 1 inch Hg in barometric pressure, or 10 degrees in temperature can each cause a 3% error in the measurement of BC. The user surely knows altitude (and it won't change in the lab), the barometric pressure will hardly change an inch under any conditions and normally varies slowly unless a drastic weather front passes, but changes in either outdoor temperatures or ventilation can easily swing test tunnel temperatures by over 10 degrees. Be aware of temperature changes!

The definition and computation of BC hinges around your measurements of muzzle velocity and either the velocity lost over a specified distance or the time required to travel that distance. If you measure velocity lost to an accuracy of 5%, your ballistic coefficient will have an accuracy of approximately 5% at the velocity tested. As an example, assume that you have a velocity loss of 200 fps representing a typical big-game bullet traveling 100 yards. To measure the velocity loss with 5% accuracy requires an error of less than 10 fps out of 200 fps. Using chronographs at both the muzzle and at 100 yards, you have an error budget of only 5 fps at each chronograph. That's an accuracy requirement of 0.17% at 3000 fps! It can be done, but it takes good equipment, a wide screen spacing, and a careful operator. It is often preferable to measure ballistic coefficient using the muzzle velocity and measured time-of-flight. It is usually easier to measure time-of-flight to an accuracy of better than 0.17% than it is to measure velocity at a long range to the same accuracy.

You will find that making reliable ballistic coefficient measurements is approximately ten to twenty times more difficult than making routine velocity measurements. What is an insignificant error in technique or recording conditions for normal velocity measurements can destroy the integrity of your measurement of ballistic coefficients. If you doubt it, just measure the ballistic coefficients from the same box of bullets with three setups on three different days.

You will sometimes see mention of BC varying with velocity. Don't worry; your bullet is not changing as it flies through the air. It's just a mathematical trick. Measuring a BC at a particular velocity forces the theoretical drag to fit the observed drag at that velocity. Just because you've forced the measured and theoretical drag curves to fit at one velocity doesn't mean that they will fit at other velocities. If BCs measured at two velocity levels differ significantly, it means that the G1 drag function doesn't fit your bullet exactly. Even though the G1 drag function doesn't fit each bullet perfectly, it is the common standard and it is the only way we can make meaningful comparisons. Sometimes we hammer a square peg into a round hole and admit that we only get a tight fit at the corners. Though we may have different BCs over a velocity range, it's usually adequate to use an average BC. Don't worry about the third decimal place of the BC number; it's like quibbling if an estimated range is 391 or 392 yards.

An unexpected can of worms is opened as more shooters begin to measure ballistic coefficients. If ballistic coefficients are measured over short ranges (less than 100 yards), the observed ballistic coefficients are often lower than published values. Some of this loss can be attributed to the fact that at short ranges the bullet may not be fully stabilized and the yaw causes extra aerodynamic drag and a lower ballistic coefficient. The apparent ballistic coefficient for the same bullet will be higher if measured after the bullet is fully stabilized.

Even with a perfectly stabilized bullet, the observed ballistic coefficient may be different at different velocities because the G1 drag function doesn't fit every bullet fired with every load. While exterior ballistics programs may compute exterior ballistics precisely in accordance with the G1 drag table, the G1 drag table may not fit your bullet.

This doesn't mean that the G1 drag table should be abandoned. No other table fits all bullets either. You should use as long a distance as possible in measuring ballistic coefficient. Measuring hunting rifle bullet ballistic coefficients over a range of 300 yards is reasonable if you expect to use the rifle at that distance. Measuring the ballistic coefficients of long-range match bullets over 600 yards is reasonable if you expect to shoot that range. By measuring the ballistic coefficients over a long range, the BC is forced to fit over that range, and it may fit “good enough” over twice that range. On the other hand, if you measure ballistic coefficients over only 50 yards and then try to extrapolate out to 1000 yards, you can expect significant errors.

Don't let anyone tell you that ballistic coefficients aren't important. With a 200 yard zero, a significant change in ballistic coefficient may change the impact point only slightly at 400 yards. But, the same change in ballistic coefficient can change 400-yard energy and wind deflection significantly, and can make a very large difference at 1000 yards..

Acoustic Target

Oehler has been making acoustic targets for measuring the apparent impact points of supersonic bullets since 1982. These systems are used extensively by the military and major defense contractors.

The principle of the acoustic target is simple. Any supersonic projectile carries with it a Mach cone or "sonic boom." Four microphones detect the time at which the Mach cone arrives at the target. Given the location of each microphone, the speed of sound in air, and assuming that the bullet travels perpendicular to the target, it is possible to compute the apparent path of the bullet.

The System 85 records the initial velocity of the bullet with a set of photoelectric screens and it also records the time required for the bullet to travel from the muzzle screens to the target. Knowing the *exact* distances involved we can compute the remaining velocity at the target and accurately compute the ballistic coefficient.

Accuracy of the acoustic target is best with higher velocities (typically over 1800 fps). At higher velocities the Mach cone is sharp and skinny; this allows good accuracy in computing the target impact coordinates. We observe typical accuracies for the four-microphone system to be in the order of 0.15% of the side of the microphone square. For example, if each side is 60 inches, the coordinates are typically accurate to 0.1 inches. If each side is 120 inches, the coordinates are typically accurate to 0.2 inches. At lower velocities (say 1400 fps) the system still works, but accuracy is reduced.

A major benefit of the acoustic target is in the measurement of ballistic coefficients. The shooting window at the target is huge when compared to photoelectric screens. Although the window is big, you must still measure distances from muzzle screens to the target with high accuracy. It's desirable to measure these distances to an accuracy of 0.1% or 1 part per 1000. If you don’t know your 100 yard distances to within a couple of inches, or your 1000 yard distances within a couple of feet, it’s not good enough.

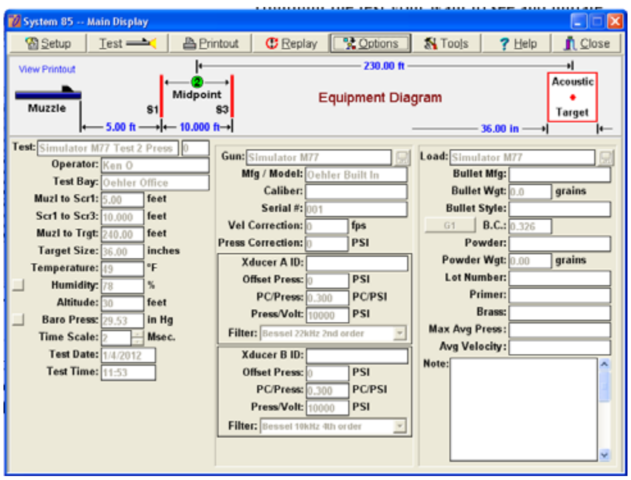
CHAPTER 2

Quick Tour Instructions

The best way to learn this system is to install the program in your computer and play along as you read these instructions. Replay some of the tests we've already fired, print them out, and then pretend you're setting up and firing tests of your own. You won't break anything.

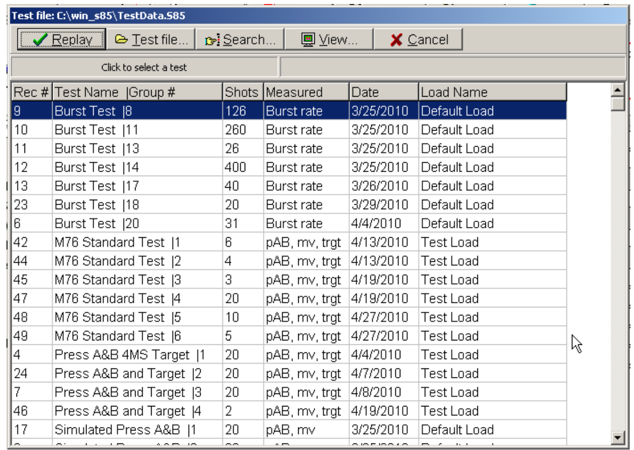
Operating from Windows 98, NT, 2000, XP, ?Vista?, or 7, exit from all other applications and install the System 85 software provided.

The System 85 program will start with a title window over the main display. Just hit the OK button to remove the title window.



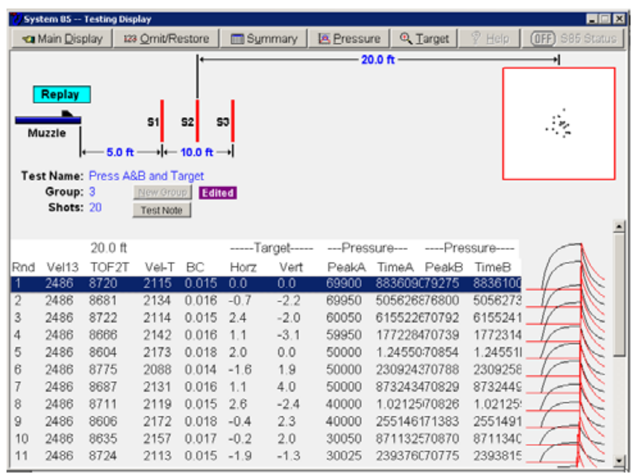
Main Display

The main display shows the test set-up and conditions, the description of the gun and description of the tested load. From the main display you can select the **Replay** action with the pushbutton.



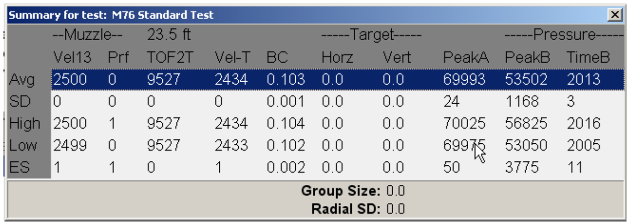
Replay Test List

Here is a list of the previously fired tests. Highlight the test your want to see and initiate the replay of that test with either a double-click on the selected test or a click on the **Replay** button after a test is selected.



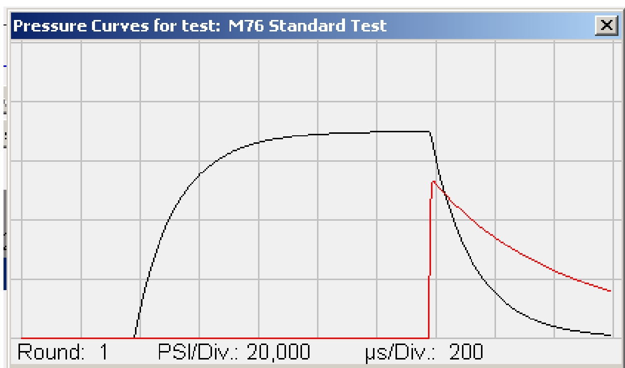
Replay Test Window

This is the test screen that you would have seen at the completion of the firing. You can see the schematic of the test setup, the group on the target, the numeric value of each test parameter of each shot, and each pressure curve. Use the scroll bar to see up to twenty rounds of the test.



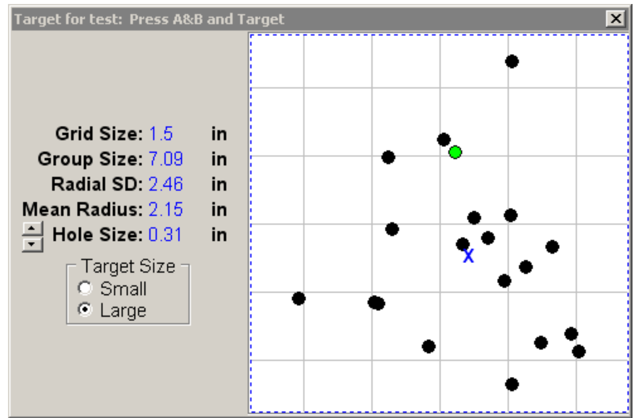
Summary

Here is the statistical summary of all parameters just as if you had requested the summary at the end of the test. If the size and resolution of your display permits, you can move the summary window to uncover the primary test window. Leaving the summary window open during an actual test provides an up-to-date running summary after each shot is fired.



Pressure

Clicking on the Pressure button opens the pressure window. This provides a better view of the pressure curves from the highlighted shot. If the size and resolution of your display permits, you can move to uncover the rpimary test window. Leaving the pressure window open during a test provides a much better view of the latest pressure curves.

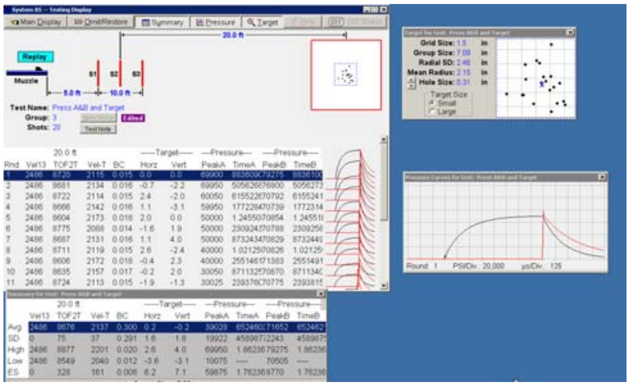


Target

Clicking on the Target button opens a window with a larger view of the acoustic target. Within this window, you can select the hole size to provide a realistic view of the target and you can select between two sizes of target windows. Again, the window can be left open during an actual test to watch the target develop. The last shot is colored green and the X denotes the group center. Clicking on any hole will select and highlight the corresponding round in the test data.

The Omit/Restore pushbutton will alternately omit the data from a round from the summary, or it will restore the data from a round to the summary. Omitted rounds will have a line drawn through the numeric data and will have no pressure curves.

The Main Display pushbutton returns you to the Main Display window. In this window you can observe the complete set-up conditions for the test you just replayed. The left-hand column contains the administrative information on the test. The middle column includes all the essential information on the gun and transducers. The right-hand column contains the information about the ammunition.



1280x800 Display

The size of the primary windows is fixed at 800x600. They are not scalable. If your display is at least 1280x800, you can take advantage of the extra room by leaving the summary, target, and pressure windows open. The latest pressure curves and shot location are much easier to interpret and the statistical summary is also available.

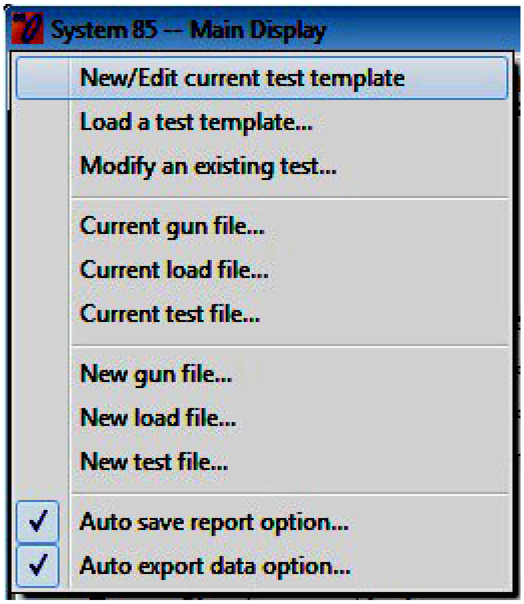
Go back to the Main Display and replay a few more different tests. Play with all the buttons just to become familiar with the actions.

To print a previously fired test, follow a similar procedure. You just hit the Printout button instead of the replay button while you are in the Main Display window. Select the test to be printed with a double-click, push the Printout button. The Preview button is selected by default, and an OK will show the preview on your screen. If you really want the report printed on paper, select the Printer pushbutton instead of the Preview button.

Now that you've replayed some of our tests, and printed copies of our reports, it's time to do your own test. Start from the Main Display window using the Setup pushbutton. The setup pushbutton will pull down a list of confusing terms. (If you've used the Oehler 43, 83, or 84 you will be right at home.)

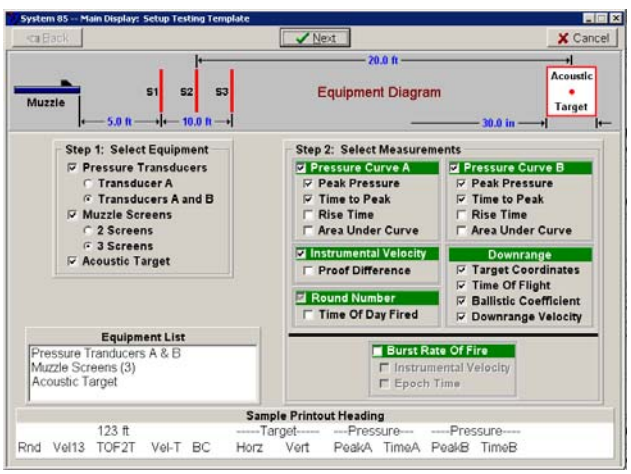
In the System 85 program, we refer to the description of a test as a template. A test template is the complete description of a test *excluding* the actual firing data. The template describes what parameters are to be tested (pressure, muzzle velocity, ...), what test equipment is used and how it is arranged (screen spacing, pressure scale factor, …), environment (temperature, wind, barometric pressure, …), gun description, and load description. *You must have a test template prior to each test. You can continue using an existing test template, you can modify an existing template, or you can edit an existing template and rename it to make a new template.*

When you are testing, each test will probably be very much like the previous one. You might change powder charge between tests, or the temperature may change, or you might grab a different gun, but chances are you won't change the whole setup. The program works just like that.



Setup Pull-down List

From the Setup pull-down list, choose the Edit current test template option. This will bring up the Setup Testing Template window.

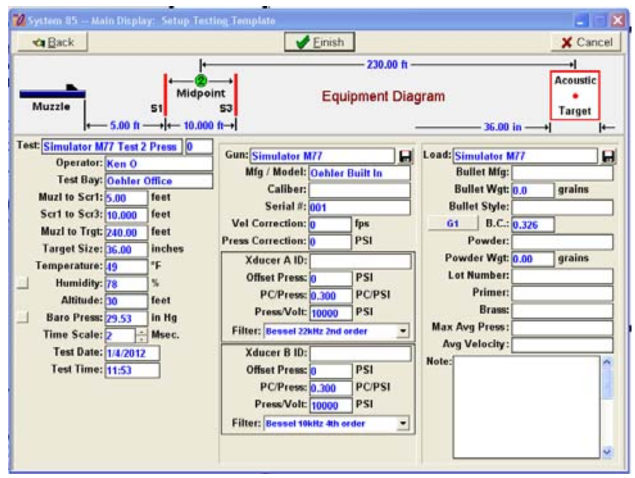


Setup Testing Template

In this window you first select the equipment to be used for the test. Indicate transducers, muzzle velocity screens, and acoustic target that are to be used for the test. Then pick the measurements you wish to make during the test. The System 85 can make more measurements on each shot than there is room for displaying and printing the numeric values. Select those channels of primary interest to you. When the page is full you can't select more.

There are a few restrictions. If you want only one pressure measurement; you must use Pressure A or Transducer A. If you select to make a pressure measurement, the pressure curves will be displayed. Pressure time-to-peak readings are referred to the fire signal. If there is no fire signal, then the times-to-peak are referred to the time that the Pressure A signal crosses the 0.95 volt threshold. If you select Burst Rate of Fire, then the equipment will revert to having only two velocity screens and you have no other options.

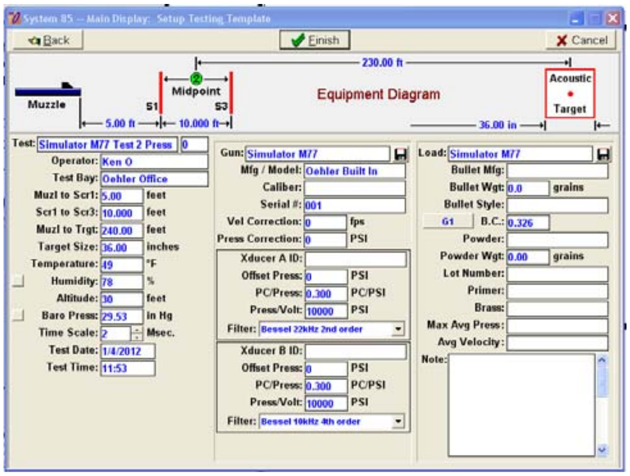
Proceed to the next screen with the Next button.



Setup Testing Template

You will now see a Main Display window, but the parameter boxes are now open for editing.

Note that this is the only place in the program that you can enter or modify the test conditions, gun information, or load information.



Main Display – Parameter Entry

We check and change the parameters from top-to-bottom, left-to-right. The tab key naturally moves you this way.

The test name is very important. The name, with the group number, is used as the file name when the test data is stored in Excel or .pdf format. The appropriate generic extension is appended to the test name. The test name is limited to thirty characters to prevent bloated file names. It is the responsibility of the user to define a naming convention. You may end up with hundreds or thousands of test reports stored in a single folder. When you look for a report or data for a particular test, it will be more convenient if the computer sorts the file names into similar groups. We suggest that the ammo headstamp name (without spaces or punctuation) form the initial part of the test name. Following the headstamp, we suggest that you indicate the nature of the test. For instance PV could indicate chamber pressure and velocity, PPV would indicate chamber pressure, port pressure and velocity, PVT would indicate pressure, velocity and target. Following the nature of the test, we'd suggest the bullet weight in grains. Each user and installation will have its own preference of the hierarchy in test names. It's your decision. The computer doesn't care what names you use, but it will use its standard rules to sort them. Think about it before you start.

Enter the test conditions in the left column. Don't worry about correct date and time; they will update when a test is fired.

Advance to the Gun column. Again, plan ahead when choosing a gun name. We always start with the first few letters of the headstamp (no punctuation or spaces) and then add descriptors as needed. Getting all your 308W barrels in one group helps you locate any specific gun. Mfg/Model, Caliber, and Serial # are memo fields to the System 85, but you might use them in Excel to analyze the Excel data to determine such information as total rounds fired through a barrel. The Vel Correction and Press Correction are assumed to be the results of barrel assessments and are included in the numeric peak pressure and velocity results reported by the System 85. The Xducer A ID is a memo. The Offset Press is from the conformal transducer calibration and is included in the peak pressure numbers. The PC/Press is a memo so that the gunner can set the charge amp properly. The Press/Volt is used to convert input voltage to an apparent pressure. The Filter pull-down menu allows you to select an appropriate low-pass filter for the pressure curve. After you have completed the gun column, click on the little diskette button and Save your gun in the gun file. Next time you want to test with that gun, use the same button and Load the gun information.

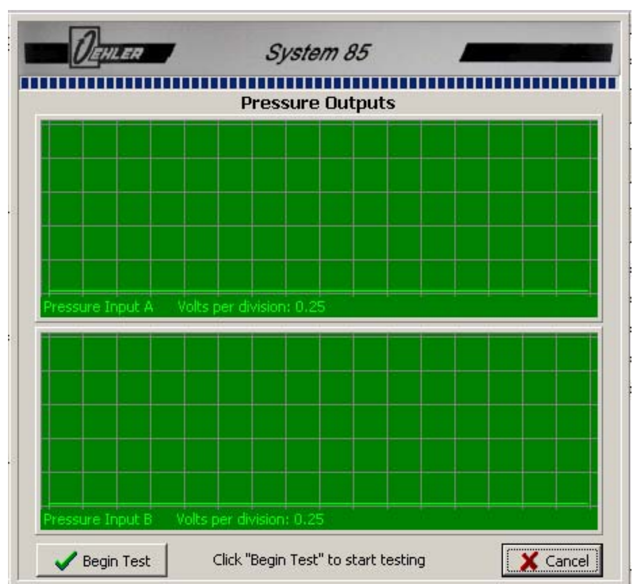
As with the guns, we assign load names starting with the headstamp. We usually enter bullet weight as the second item of the load name, and we don't bother with entering decimal points, hyphens, mms, or grains. You might want to use product numbers or similar. After a load is entered, use the diskette button and Save it. It's easier to use the diskette button and Load a similar load and change one parameter than to enter a new load from scratch. The button adjacent to B. C. selects the drag function used in the B.C. computation. We urge you to stay with **G1** unless you have urgent reason to change.

All other entries for the load are considered memo.

Much of the information entered for gun and load is not critical for testing, but it is critical for test documentation. You may not appreciate it now, but you will bless it months and years from now when you review your recorded data.

After completing the entry of data into the boxes of the parameter entry screen, finish the process with the Finish *pushbutton. This will typically bring up a warning that the test name already exists. You have the choice of either over-writing an existing test template (appropriate only if you are authorized to change the master template) or proceeding with the test using the edited template. Note that this will not change the template or raw data from a previously fired test, and it will not change the master template.. As each test is fired and recorded, template in effect at the time of the test is recorded along with the raw data.*

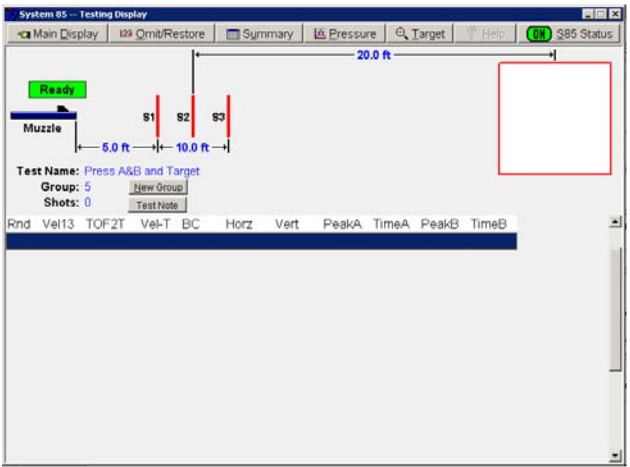
After the template is successfully accepted, you will be returned to the Main Display window. Push the Test pushbutton to start the test. This will establish and check the USB connection to the System 85.



Monitor Screen

The monitor screen will be displayed. You will see a dotted completion bar under the picture of the System 85 front panel as initial checks are performed. If pressures are expected, oscilloscope snapshots of the quiescent pressure signals are shown. Quiescent pressure signals should be flat lines at the bottom of the display. If there are “haystacks” indicating power-line interference or if there are stray shapes indicating noise, the problem should be corrected. After the completion bar finished, push the Begin Test button. You must allow the completion bar to finish.

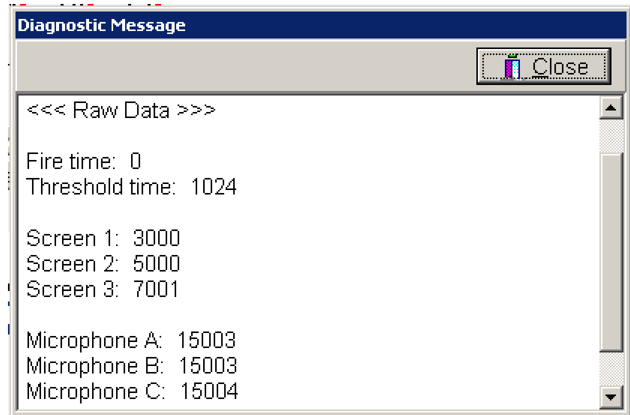
Leaving the diagnostic window shows the testing display.



Testing Display

The testing display is your window for actual shooting. You see the graphic picture of your test setup along with the picture of the target frame and you group. Pay attention to the green ready light in the upper left of the screen. If the light shows steady green and Ready, the system is ready for you to shoot; if it's red or flashing, there are false triggers.

Fire the first shot and you should see the parameter value appear in each column along with the pressure curve and a bullet hole in the target. To get a diagnostic window, select and double-click on the round in question.



Diagnostic Message

The diagnostic message shows the times at which various critical events occurred. It is especially useful for isolating problems with sensors. All the times shown are in microseconds, and are referenced to the first recognized event. If a Fire signal is used, the time at this event will be zero. The next event expected is Pressure A crossing it's detection threshold. These signals will be followed by signals from the muzzle screens and the target microphones. Any expected event that did not occur is represented by **- - - -.**

If any line of shot data is overwritten by lines or dashes, it is considered to be omitted from the summary. When the System 85 detects known abnormal data, it will automatically omit that shot. We use a special logic on the Omit function. If the last shot is shown as omitted on the display, the next shot will erase and overwrite it. This allows you to cleanly forget those shots obviously caused by warming rounds or by a false trigger or other such goof. Any previous shot can be omitted (removed from the summary), but it will not be erased. You can't remove all evidence of a shot just because you later decide that you don't like it. The data may be trying to tell you something even if you don't recognize it now.

CHAPTER 3

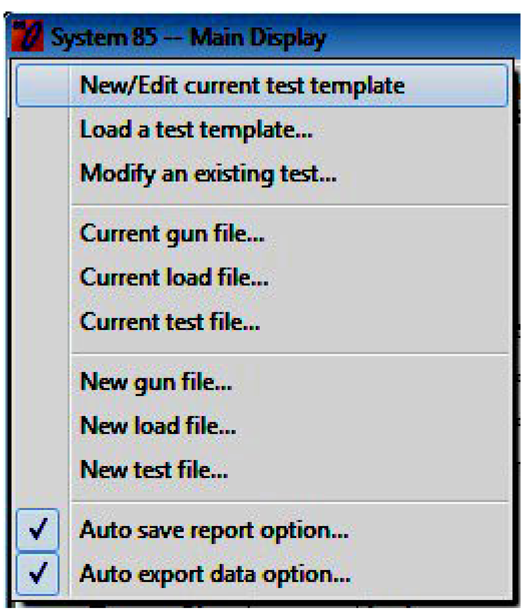
Main Display

This chapter provides more details on setting up a test. For those who don't really believe in Windows, here are some old-fashioned printed instructions. If you are a Windows purist, we apologize for some of the constraints left in the program. For standardization, we have chosen to restrict some of the options sometimes available in Windows.

If you haven't taken the quick tour described in Chapter 2, we urge you again to take it now. It will help if your have your M85 program running as you read these explanations.

The Main Display widow is the center of the System 85 software. Everything starts and ends at this window. You leave this window by pushing one of the buttons at the top, and the only controlled exit from the program is back through this window.

The Setup button will bring up a list of options.



Setup Options

You must go through the setup options prior to any test *except* when you are firing another group with the same gun and ammo under exactly the same conditions. It's the only place you can enter test information!

The New/Edit current test template option lets you define what you want to measure, how your equipment is set up, the environmental conditions, gun information, and load information.

The Load a test template option allows you to load any previously defined template. You can add new groups to an earlier test, or you can load an earlier similar test to form the basis for editing. It is anticipated that users will keep common tests in a networked file to assure consistency between gunners and firing bays.

The Modify an existing test is a dangerous option. It allows you to correct a previously fired test for information or conditions entered in error. For example, you can correct the distance from gun to target on a ballistic coefficient test or the offset on a pressure test. Upon any subsequent replay or printing, the test results will reflect the changes you make. You can edit test conditions, fill in extra blanks about the load, or make similar corrections; you can also demolish the validity of a test if you put in the wrong numbers. To note possible alteration of your original recorded data, any replay or print subsequent to a modification will include an "edited" flag in place of the date.

The Current gun file, Current load file, and Current test file options allow you to specify the files currently in use by the program. The program will typically search a folder for files with the

.s85 suffix and allows you to select the desired files for use. As a matter of habit, we use .s85 as the suffix for all of these files, and reflect the type of file in the prefix name. For instance, we would use Gundata.s85, GunRifles.s85, GunGage.s85, TestBarrels.s85 or similar names for gun files.

Here you must also enter the locations for Auto save report option ... and Auto export data option ... These folders will receive the *pdf* and *Excel* reports automatically generated at the end of each firing test.

The New gun file, New load file, and New test file options allow you to create the new files for any of the three functions. If you do a lot of tests, you will probably want to start segregating different types of guns, loads and test data into different test data files. For example, you may want to reserve certain names for networked files of standard test barrels [guns], standard cataloged ammo [loads], and output data from standard tests. Users may generate local files for nonstandard tests and conditions.

Test Button

The Test pushbutton starts an actual firing test. It will establish handshaking between the PC and the System 85. If handshaking cannot be established, the most common causes are USB cable not properly connected, or the S85 not powered. After communications are established, you will see the diagnostic screen. By the time you get to the actual test screen, there isn't much to do except shoot when the light is green.

Printout Button

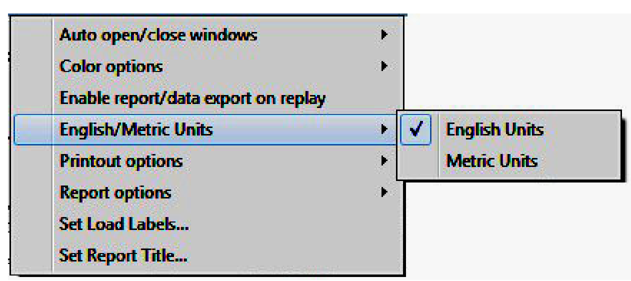
The Printout button of the main display is used to print or to view the results of fired tests. Select the test your want to print or view from the list. ***Hint: The right mouse button will easily take you back to the last test you selected. You often want to go there.*** After one or more tests are selected for printing, hitting the PrintOut button will bring up the Report Setup screen. It will default to showing a preview of the printed report on the screen. *If you want a real printed copy of the report, hit the printer icon at the top of the preview screen. If you don't hit the printer icon now, you'll have to go through the select process again and select the Printer pushbutton instead of the default Preview button.*

Replay Button

The Replay button of the main display is similar in function to the printout button. It allows you to select from a test list and shows the screen of the actual test results with summary and ballistics available. The setup, gun, and load information for the selected test will be displayed on the Main Display when you return from the replay. You can get a consolidated report of both test results and the setup conditions with a printout.

Options Button

Under the Options button of the main display, you can change several appearance items. More important, you can change the system from English to metric units.



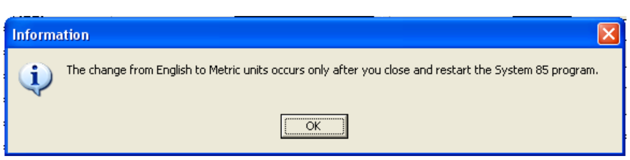
Options

Auto open/close windows provides for automatic opening and positioning of the Target, Summary, and Pressure windows during a test.

The Color options affect the display of the testing screen used during actual shooting.

The Enable report/data export on replay option allows you to generate and export new .pdf and Excel files when you replay a test. Usually you will want to generate these new files only if you have made changes to the setup prior to replay and you want a new report reflecting these corrections or change between English/metric.

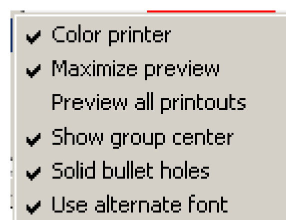
The English/Metric Units is a powerful feature hidden in this menu. If you customarily work in English units, you will leave it set for English. If you customarily work in metric units, you will leave it set for metric. The same software is used for both. Observed times and voltages are recorded independent of the desired display units. Even if you customarily work in English units, you can select Metric Units, exit the program, and then restart. The program will restart in metric units and any subsequent tests or replays will appear with the display, report, and export data in metric units. You can get reports and exported data in the proper form expected by your continental buddy. Similarly, if you customarily work in metric units, you can generate reports to please your U.S. friend.



You must close and restart to convert between systems of units.

Printout options affect the content and appearance of the printed reports. Enable report/data export on replay allows the export of both report and data during replay. This function is especially useful if the test template has been changed to include measurement channels not included in the original report.

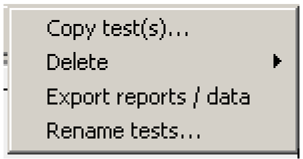
Report options allow choice between the standard report, a raw data report useful in diagnosing malfunctions, and a multi-report summary to summarize data from more than one test. The multi-report summary is most useful if a test of more than twenty rounds if required. For such a test, fire the test in twenty-round groups and then print using the multi-report summary. The statistics from all included reports will be combined and the summary sheet will reference all included reports. The Set Load Labels allows the entry of optional labels for two data fields in the load information. The Set Report Title option allows you to put your own report title (for instance, company name can automatically appear as the major heading of each printed report).



Printout Options

Under the printout options you can make several significant selections. Checking the Color printer option allows jazzed up printouts from a color printer. Unchecking the option assures that Pressure A is printed in black and Pressure B curve is printed in grey. Checking the Maximize preview spreads the report preview over the entire screen. Checking Preview all printouts makes you look at a screen before it wastes a sheet of paper on a printout; it also slows you down when you know what you want to print or want to print multiple reports. Checking Show group center will put an X at the group center. Solid bullet holes normally look like a real target with round bullet holes to scale; unchecking it will show circles instead of holes so you can see individual shots in a one-hole group. Checking Use alternate font may help older printers.

Tools Button
(Includes Export to Database)



Tools Options

Under the Tools pushbutton of the main display, there are several useful options. The Copy test(s) allows you to reorganize your tests and put test results into different test data files. The Delete function allows you to delete or scrap tests, guns, loads, or test templates. The Export reports / data option allows you to export test data to in both *pdf* and *Excel* format to the folders specified in Setup. The Rename tests ... option allows you to rename your tests. **Renaming tests can be dangerous!** If you rename tests, you assume responsibility that the changed names of the tests are reflected in all data files and reports.

Close Button

The Close button lets you exit the program gracefully.

The Equipment Diagram of the main display gives you a picture of the test equipment used for the displayed template. It is automatically updated to show the distances and equipment specified in the setup.

Entering Test Setup

For adequate documentation of each test, you should fill in all the little boxes of the main display. Some boxes are essential to the measurements, and some are simply desired for memo. Just fill them all in; we guarantee that you won't have too much data years from now.

Test:

Name the test with a unique name. Tests can be alpha-numerically sorted on all lists, so choose the first few characters carefully. This will determine the test order and grouping on all displayed lists. The box to the right of the test name is the group number of all those tests performed with this same template.

Operator:

The name of the gunner or operator is an optional bit of data.

Test Bay:

The number or name of the test bay is optional.

Muzl to Scr1: feet

Enter the distance in feet from the muzzle of your gun to the first skyscreen (the start screen). This distance should be measured and maintained within 0.1 ft if you use the Acoustic Target to measure ballistic coefficients, or if you are measuring pressure

Scr1 to Scr3: feet

Enter the distance between the start and stop muzzle screens. The standard distance is 20 feet.

Muzl to Trgt: feet

Enter data here only when the Acoustic Target is used. This distance must be accurate to within a few tenths of a foot if the Ballistic Coefficient is to be valid. If you guess this distance, don't be *surprised at ridiculous ballistic coefficients and downrange velocity numbers. We find it most convenient to record the distance measured from the front of the shooting bench to the permanent target mounting face, and adjust this distance to obtain the distance from muzzle to microphone.*

Target Size: inches

Enter data here only when the Acoustic Target is used. Enter the size of the target in inches. Measure one side of the microphone mounting square, from center of red ball to center of red ball.

Temperature: F

Enter the current temperature in degrees Fahrenheit. Temperature affects air density and the speed of sound, both of which are essential to accurate ballistics calculations. If you are making ballistic coefficient measurements, the temperature should be updated at each test to an accuracy of 2 degrees or better. If not measuring BC's, then temperature is optional.

Humidity: %

Enter the relative-humidity percentage. Humidity affects air density and the speed of sound. Humidity has only a slight effect on ballistic calculations.

Altitude: feet

Enter the altitude at the firing range in feet above sea level. An accuracy of 100 feet is normally sufficient for ballistic coefficient calculations.

Baro Press: in Hg

Enter the current reported barometric pressure in inches of mercury. If you do not know the current pressure, use the standard value of 29.92. Reported pressures are corrected to sea level. The program corrects the reported pressure to the actual pressure at your altitude. If you know the raw pressure at your location, hit the button to the left of the box and the program will then accept the raw pressure.

Time Scale

The time scale for the overall length of the pressure curve is normally set at 2 milliseconds for handguns and rifles. It is typically set at 4 milliseconds for shotguns or long barrel guns.

Date: Time:

The program automatically picks up the time and date from the computer when a test is fired. If the displayed time and date are not correct on your test report, you must reset your computer's clock.

Entering Gun Data

Most gun data is entered only one time for any gun, but it can be edited. Learn to use the little load and store icon located immediately to the right of the gun name box. It will save much time.

For the purposes of this program, we consider a test barrel with its associated transducer as a gun. The entries saved in the networked gun file should be entered by the personnel responsible for transducer calibration and reference ammo corrections.

The various entries in the gun file are.

Gun Name:

Enter the name of your gun. We find it most convenient to use the headstamp caliber numbers as the initial characters. That way it's easier to find guns in a list.

Mfg/Model:, Caliber:, Serial #:

These entries are optional.

Vel Correction:

Enter the barrel correction as determined by assessment. Otherwise zero. This correction is applied to muzzle velocity only. It is not applied to estimated velocity at the downrange target.

Press Correction:

Enter the barrel correction as determined by assessment. Otherwise zero. Applied to peak pressure.

Xducer A ID:

Enter the Pressure A transducer model and serial number. Optional.

Offset PSI: PSI

For conformal transducer, use the offset value from the transducer calibration. For gas transducers, offset is usually zero.

PCPres: PC/PSI

Enter the transducer sensitivity. This optional value is recorded for the convenient use by the gunner in setting the charge amplifier.

Press / Volt: PSI / V

Enter the output voltage scale factor of the charge amplifier in PSI per volt. This value is essential. It need not be restricted to the typical 2000, 5000, or 10000 values, but can be set at "odd" values to accommodate voltage mode transducers.

The System 85 uses the legacy notation of PSI/V. Many modern charge amplifiers use the notation of "millivolts per measurement unit". The values are mathematic reciprocals of each other.

The pressure measurement unit is PSI.

For example
0.1 mv/unit → 0.1 mv/PSI → 10000 PSI/volt
0.2 mv/unit → 0.2 mv/PSI → 5000 PSI/volt
0.5 mv/unit → 0.5 mv/PSI → 2000 PSI/volt
1.0 mv/unit → 1.0 mv/PSI → 1000 PSI/volt.

Filter:

Use the pull-down to select the appropriate low-pass filter for each pressure curve. Unless otherwise directed, we strongly suggest using the Bessel 22 kHz 2nd order filter.

Entering Load Data

Load data will be reused many times. Again, it will be to your advantage to learn how to save and store loads in the load file. We would expect normal production loads to be stored in a networked load file.

Load Name:

As with guns, we prefer to start load name with the numerals of the headstamp designation, followed by any required alpha character, a space and the bullet weight in grains. This grouping makes it easier to find loads in the list. You may want to use catalog numbers or other product identification.

Bullet Mfg:

This is optional.

Bullet Wgt: Gr

This is optional.

Bullet Style:

This is optional.

BC:

The button to the left of B.C. can be used to select the drag function used. Use the G1 function unless you understand drag functions and have good reason to use another. (See Appendix A) The actual number entered in the box is the estimated ballistic coefficient of your bullet. If in doubt, enter a B.C. of 0.200.

Do not use a B.C. of zero. If you use a B.C. of zero, the computer expects the bullet to fall to the floor immediately after it leaves the muzzle.

NOTE: If you measure the actual BC, using the acoustic target, the load BC value is automatically updated.

Powder:

This is optional.

Powder Wgt: Grains

This is optional.

Lot Number:

This is optional, but almost as important for your records as powder type and weight.

Primer:

This is optional.

Brass:

This is optional.

Max Avg Press:

This is optional and is simply for convenient reference.

Avg Velocity:

This is optional and is simply for convenient reference.

Note that the last two above headings can be altered to record any other parameter of regular interest. See Set Load Labels under the Options list of the Main Display.

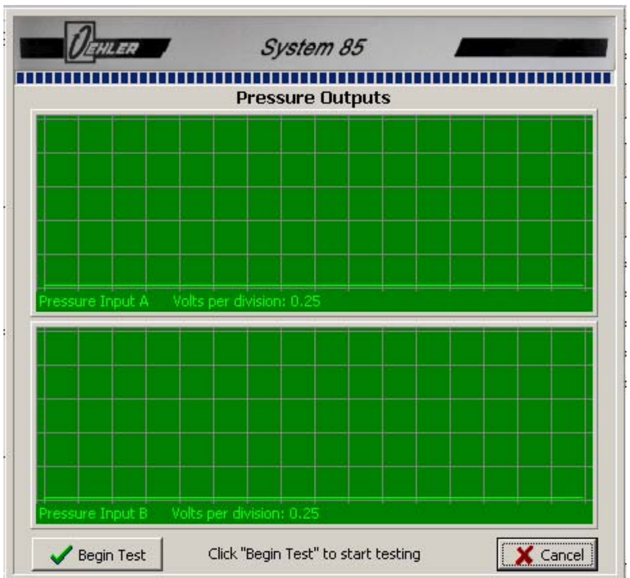
Note:

You can add a short note about this load. Your note will follow the load data as it is stored and used again.

CHAPTER 4

Testing Display

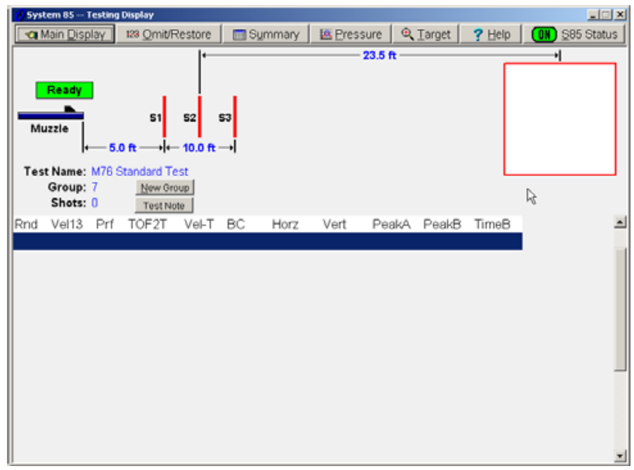
After the template is successfully saved, you will be returned to the Main Display window. Push the Test pushbutton to start the test. This will establish and check the USB connection to the System 85.



Monitor Screen

The monitor screen will be displayed. You will see a dotted completion bar under the picture of the System 85 front panel as initial checks are performed. If pressures are expected, oscilloscope snapshots of the quiescent pressure signals are shown. Quiescent pressure signals should be flat lines at the bottom of the display. If there are "haystacks" indicating power-line interference or if there are stray shapes indicating noise, the problem should be corrected. After the completion bar finishes, push the Begin Test button. You must allow the completion bar to finish.

Leaving the monitor window shows the testing display.



Testing Display

The testing display is your window for actual shooting. You see the graphic picture of your test setup along with the picture of the target frame and you group. Pay attention to the green ready light in the upper left of the screen. If the light shows steady green and Ready, the system is ready for you to shoot; if it's red or flashing, there are false triggers.

Fire the first shot and you should see the parameter value appear in each column along with the pressure curve and a bullet hole in the target. Soon after the shot, the ready light should return to green in anticipation of the next shot.

You can see the schematic of the test setup, the group on the target, the numeric value of each test parameter of each shot, and each pressure curve. Use the scroll bar to see up to twenty rounds of the test.

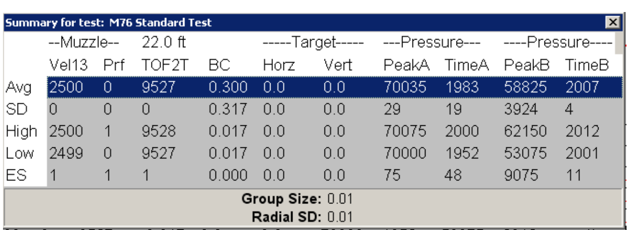
Across the top of the Testing Display are seven buttons.

The Main Display button returns you to the Main Display window.

The Omit/Restore pushbutton will alternately omit the data from a round from the summary, or it will restore the data from a round to the summary. Omitted rounds will have a line drawn through the numeric data and will have no pressure curves.

If any line of shot data is overwritten by lines or dashes, it is considered to be omitted from the summary. When the System 85 detects known abnormal data, it will automatically omit that shot from the summary. We use a special logic on the omit function. If the last shot is shown as omitted on the display, the next shot will erase and overwrite it. This allows you to cleanly forget those shots obviously caused by warming rounds, by a known false trigger or other such goof. Any previous shot, or shots, can be omitted (removed from the summary), but they will not be erased. You can't remove all evidence of a shot just because you later decide that you don't like it. The data may be trying to tell you something even if you don't recognize it now.

The Summary button pops up a window including a summary of all valid rounds fired.



Summary for test: M76 Standard Test

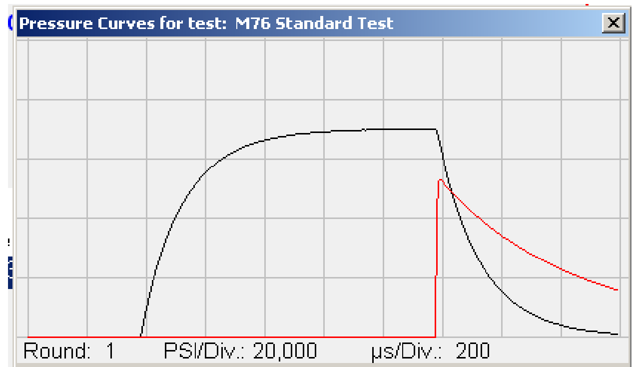
	--Muzzle--		22.0 ft		-----Target-----		---Pressure---		----Pressure----	
	Vel13	Prf	TOF2T	BC	Horz	Vert	PeakA	TimeA	PeakB	TimeB
Avg	2500	0	9527	0.300	0.0	0.0	70035	1983	58825	2007
SD	0	0	0	0.317	0.0	0.0	29	19	3924	4
High	2500	1	9528	0.017	0.0	0.0	70075	2000	62150	2012
Low	2499	0	9527	0.017	0.0	0.0	70000	1952	53075	2001
ES	1	1	1	0.000	0.0	0.0	75	48	9075	11

Group Size: 0.01
Radial SD: 0.01

Summary

If the size and resolution of your display permits, you can move the summary window to uncover the primary test window. It is convenient to leave it just below the testing display so that it shows an extra set of column headings at the foot of the numerical shot data. Leaving the summary window open during an actual test provides an up-to-date running summary after each shot is fired.

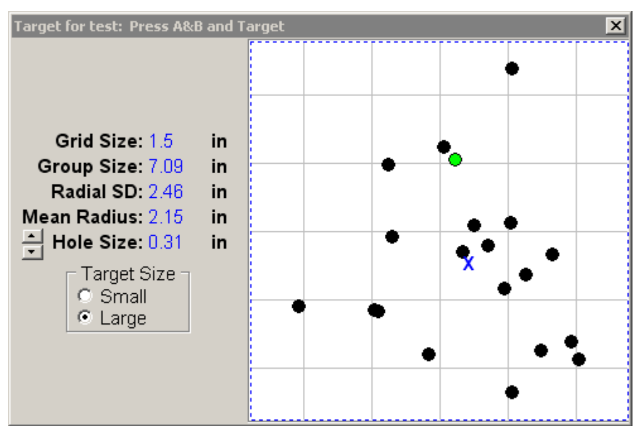
The Pressure button opens a window showing the pressure curves of the last (or highlighed) round.



Pressure

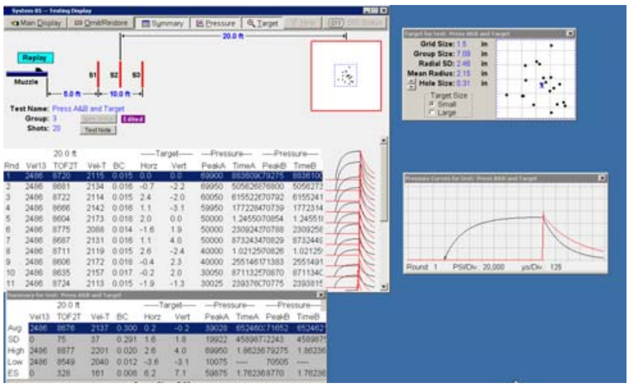
This provides a better view of the pressure curves from the highlighted shot. If the size and resolution of your display permits, you can move it to uncover the testing display window. Leaving the pressure window open during a test provides a much better view of the latest pressure curves.

Clicking on the Target button opens a window with a larger view of the acoustic target.



Target

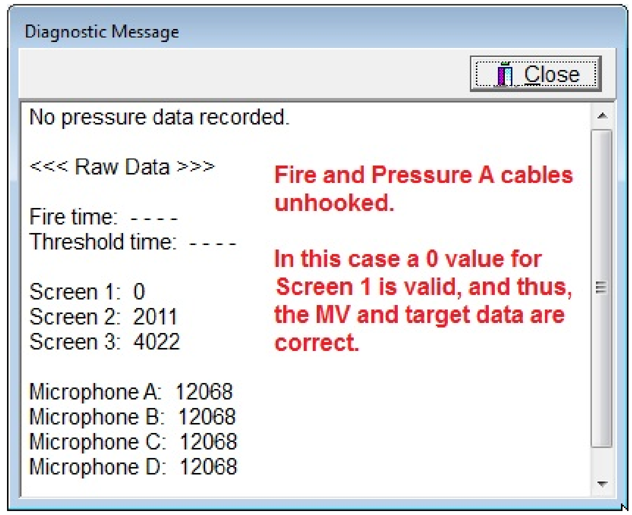
Within this window, you can select the hole size to provide a realistic view of the target and you can select between two sizes of target windows. Again, the window can be left open during an actual test to watch the target develop. The last shot is colored green and the X denotes the group center. Clicking on any hole will select and highlight the corresponding round in the test data.



1280x800 Display

The size of the primary windows is fixed at 800x600. They are not scalable. If your display is at least 1280x768, you can take advantage of the extra room by leaving the summary, target, and pressure windows open. The latest pressure curves and shot location are much easier to interpret and the statistical summary is also available.

The Status button could just a well be labeled the ***Question*** button. If you suspect stray signals on the pressure channel, use the status button to view the oscilloscope snapshots of pressure. Perhaps even more important is the time when you fire a shot and get no response from the System 85. Pushing the status button will force the System 85 to display all the information it knows regarding the last shot. After a response has been forced by the status button, highlight the last shot data and double-click. This will bring up the diagnostic window.



Diagnostic Message

The diagnostic message shows the times at which various critical events occurred. It is especially useful for isolating problems with sensors. All the times shown are in microseconds, and are referenced to the first recognized event. If a Fire signal is used, the time at this event will be zero. The next event expected is Pressure A crossing it's detection threshold. These signals will be followed by signals from the muzzle screens and the target microphones. Any expected event that did not occur is represented by **- - - -.**

The Help button is available for those hints you need to keep going.

The Test Note button can be opened at any time before, during, or after the test. The only restriction is that you must make your notes before you ask for a new group. This is the ideal spot for any alibis or other notes. These notes will be printed on the test report and will be available during any replay. Notes can be added or modified during replay.

If you make any changes in distances or other data during a replay, it is good practice to record such changes and reasons in the notes.

The New group Button. After you fire at least one shot, you can start a new group. The data from all shots is cleared from the screen and the group number increments as soon as you hit [N]. Use [N] to start a new group only if you have no comments to add to your existing group and you have no changes to make regarding conditions, gun, or load. If you hit [N] and then exit to the setup screen, the setup screen will have the group number of the new group.

Any time you end a test with the new group button or otherwise, the system will automatically write the test report in *pdf* and *Excel* to the appropriate folders designated in setup. The test name and group number will be used as the file name. If the "raw" report option has been selected, then "raw" will be included in the file name.

Measurement Channels

The column headings shown on the testing screen are those you previewed on the Setup screen. They may include:

Rnd

The round number of the shot within the test group.

Vel13

The velocity measured from screen #1 to screen #3. It is commonly called the instrumental velocity.

Prf

The velocity proof number. It is computed by subtracting VEL13 from VEL12. Ideally this number is both small and consistent. If the number is large (say more than 5 fps) but consistent, it normally indicates an error in screen spacing. For example, a consistently negative number indicates that screen#2 is too close to screen#3. This column represents the PROOF CHANNEL™ as is described in U.S. Patent 4845690.

TOF2T

The time-of-fight measured in microseconds from Screen #2 (or midpoint between Screen 1 and to the plane of the acoustic target. This time is corrected to compensate for the delay in the bullet's sound hitting the microphone as the bullet passes by the microphones.

Vel-T

The velocity at the target. It is computed from the distance to the target, VEL13, the assumed drag function, and the time-of-flight to the target. The distance to the target is critical to the calculation of the ballistic coefficient. Measure the distance to target carefully, to within a few tenths of a foot, (or 0.1% on longer distances) or you will get meaningless answers.

BC

The ballistic coefficient calculated from your data and is corrected to standard atmospheric conditions. You must take special care to measure and update air temperature to get accurate values of BC. Altitude, barometric pressure, and humidity are also considered, but are less critical.

Horiz

The horizontal impact point of the bullet measured in inches with respect to the center of the acoustic target square. Positive numbers are right and negative numbers are left.

Vert

The vertical impact point of the bullet measured in inches with respect to the center of the acoustic target square. Positive numbers are high and negative numbers are low.

PeakA or PeakB

The observed peak pressure of the two channels. These pressure numbers include the correction for transducer offset and reference firing.

TimeA or TimeB

The time from Fire signal to the peak pressure. If no Fire signal is recognized, the times will be measured with respect to the time that PressureA signal crossed 0.95 volts.

AreaA or AreaB

The area under the pressure curve measured over the duration of the pressure measurement window. Numerical units are psi-milliseconds.

RiseA or RiseB

The time in microseconds from the 25% point to the 75% point of the pressure curve. It is an indication of the powder burning rate.

Pressure Curves

The pressure curves provide information on both the pressure and the instrumentation. You want to see relatively smooth curves without excessive peaks or noise. If you see extra peaks or humps on the pressure curve, fire some ammunition which has proven stable in the past.

Acoustic Target

The large square in the upper corner of the screen represents the acoustic target. As you shoot, a small square shows the location of your group within the large square.

The target popup window shows a zoomed view of your group. The grid squares start at 0.25 inch with your first square and will increase as required to show all the shots in your group. The group size (extreme spread in inches), mean radius, and the group radial standard deviation are shown in the window.

If the system did not recognize proper input signals for any measurement channel, that measurement will be shown as dashes, --- . Highlight the shot and double-click to get the computer's guess of what went wrong on that shot. If a shot record contains dashes instead of data, the shot will be automatically omitted. It can be restored and included with the group data by hitting the Omit/Restore button before the next shot is fired.

Statistical Summary

The line items in the summary are:

Avg

Average is the average or mean value of the valid shots. The average velocity is corrected for reference and the average peak pressure is corrected for reference and offset.

SD

The standard deviation of the valid shots.

High

The highest value among the valid shots.

Low

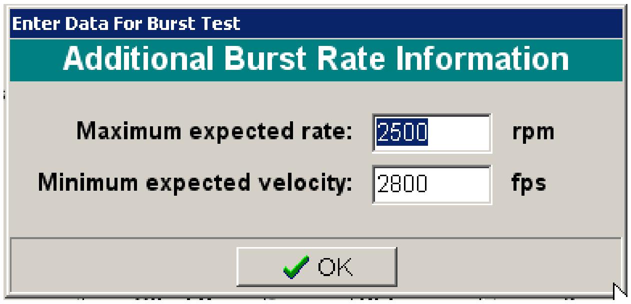
The lowest value among the valid shots.

ES

The extreme spread or the range between the highest and lowest values for the group.

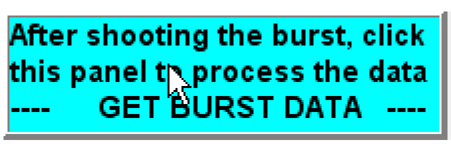
Burst Rate and Muzzle Velocity

If burst rate and muzzle velocity are the selected measurements, you must answer two extra questions.

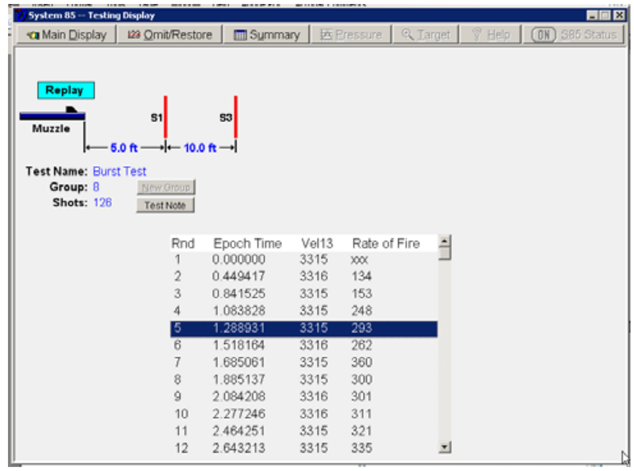


You are asked the maximum expected rate in rounds per minute and the minimum expected velocity in feet per second. Spacing between Screen#1 and Screen#3 must be at least two feet. You must be realistic in answering these two questions. Your answers will be used to compute the minimum time after the first bullet clears the stop screen until the second bullet reaches the start screen. We need at least three milliseconds.

At the testing screen you are instructed to fire the burst.



After the burst is fired, signal the computer by clicking the window. Your data will then be displayed in a window that can be scrolled.



Testing Display, Burst Fire

The column headings are:

Rnd

The number of the round fired. If you fire more than 400 rounds the system will show only the first 400 rounds.

Epoch Time

The elapsed time of each round from the beginning of the burst. If this time exceeds 999 seconds it recycles.

Vel13

The velocity of each round measured between screen#1 and screen#3.

Rate

This rate in rounds-per-minute is calculated based on the time between each round. You can compute the average rates for portions of the burst by using the differences in times and the number of shots between the times.

In the burst rate mode you can still access the summary. In the statistical summary, the average rate of fire is computed as the average of all the individual rates of fire.

CHAPTER 5

Setting Up and Troubleshooting Hints

Connecting the System 85 and the PC

Only one cable is required to connect the System 85 and your PC. Use a standard USB cable with a Male A connector on the PC end and a Male B connector on the System 85 end.

The System 85 gets its power from the USB bus. The System 85 properly negotiates with the USB bus to receive up to 200 ma. It must be connected to either a powered USB adapter or a USB port on the computer.

Fire Signal

In order to measure action time, the System 85 expects to see a Fire signal. This signal can be from an external transducer delivering a nominal +12 volt signal to the Fire input.

A separate input is provided to interface directly with a "short-to-ground" switch located in the test gun. This input is very tender. Applying any voltage (even a +12 volt signal) to this input can damage the System 85. Each System 85 is shipped with a BNC cap on this connector. Uncover this connector only when it is properly used.

Muzzle Screens

Mount the muzzle screens at the desired locations. Use of the third "proof" screen midway between start and stop screens is optional. Connect to the START, MID, and STOP inputs. A nominal +12 volt signal is expected, but the system will accept signals as low as +5 volts and will not be harmed by signals up to +100 volts.

External Source for Pressure Signal

The System 85 accepts pressure signals from an external voltage source. Pressure input is from zero to +10 volts at an impedance of 150K ohms. Prior to the digitizer, high frequency is limited by a single-pole RC filter at 50KHz. The external source is typically a charge mode piezo transducer and charge amplifier, but it may be a voltage mode transducer. Connect the external pressure signal to the BNC PRESSURE connectors located on the back panel. Pressure A is expected to measure to the chamber pressure signal. Pressure B may be connected to either a down-barrel pressure transducer or to a second chamber pressure transducer. If you are measuring only one pressure, you must use Pressure A.

Low-pass Filters

Each pressure channel allows selection of an appropriate low-pass filter located after the digitizer. It is our opinion that the Bessel 22kHz 2nd order filter is most appropriate for routine interior ballistic events and is frequently specified as "required". The filter is properly located after the digitizing process because digitizers themselves often introduce the equivalent of high-frequency noise. Both pressure curves and the numerical readings shown by the System 85 include the effects of these filters. The pressure samples recorded to the Excel data file are raw digitizer output and are unfiltered. If unfiltered data is required, it can be read from the exported data file.

See Appendix G for additional discussion of filtering.

Acoustic Target

The acoustic target is shipped as a set of four microphones, four short BNC/BNC cables, an **8336 Downrange Amplifier** with power supply. You must supply a square wooden frame on which to mount the microphones.

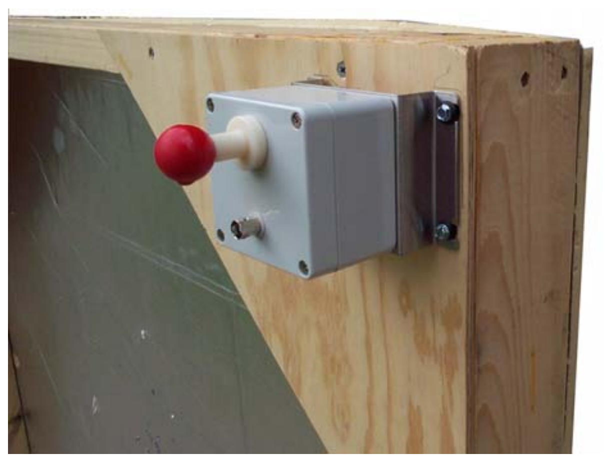
Typical Microphone Frame

The accuracy of the target system is influenced by your choice of target size. If you make the target larger, it will be easier to shoot within the square, but target accuracy will suffer. You can make the target more accurate by making it smaller, but you are more likely to hit a microphone with a stray shot.

If you are shooting in a square or rectangular “walk-in” tunnel, we suggest that the microphones be mounted against the walls or ceiling to form the largest possible square and to allow an armor plate deflector to be mounted in front of each microphone. Microphones must be located sufficiently far back from the armor plate that a 45° Mach cone can strike the microphone.

If you are shooting through a reduced diameter tunnel into a target room, we suggest a frame with the sides of the microphone square is equal to the inside diameter of the tunnel. This will hide the microphones from the shooter.

The actual microphone element is the hemisphere atop the lollipop mounted on the gray box. The microphone element is ceramic and is quite fragile. The Mach cone sound wave must hit each microphone directly. Mount the microphones on a wooden square frame so that the four balls form the corners of the target square. Point each lollypop directly toward the gun.



Microphone Detail

Be sure that the microphones are mounted to wood, and use the rubber grommets to provide isolation from shock waves transmitted through the frame to the microphone. Mounting the microphones on a metal frame or bracket is an invitation to trouble. If paper targets are to be mounted on the same wooden frame with the microphones, use a cardboard or “cellotex” sheet to hold the target. Bullets striking the wooden frame can sometimes cause target errors.

The system can be made to work at over 1000 yards if you use Category 5 cable typically used for computer networks. This cable is readily available and relatively inexpensive for limited use. Connections can be made with the connector pin-out normally associated with local area networks.

If the long-range installation is permanent, we urge the use of the “direct burial, gopher-proof” cable commonly used for telephone service. The Category 5 cable is adequate for indoor use, but is soft and tender. Rodents love to eat it.

The target square should be approximately level and perpendicular to the path of the bullet. If the microphones shift (even fore and aft) as you fire a group, the apparent impact points will also shift and the target system looses accuracy.

Connect the cables from the microphones to the inputs of the downrange amplifier box. As viewed from the gun, the microphones are designated

A	D
B	C

If signals from microphones are crossed, the groups may appear flipped, inverted, rotated, or as a single line.

CHAPTER 6

Miscellaneous Topics

Proof Channel tm

There is nothing more frustrating in testing than having a velocity reading near what was expected, but still questioned. Was it the ammo, or was it the instrumentation. Screens work well under most conditions, but under certain conditions there will be errors. If you haven't yet found these conditions, you will. Errors are seldom, and we expect that users will forgive the system *if* the System 85 indicates those shots that may contain errors. If the numbers in the *Proof Channel* columns, labeled PRF, are unusually large or erratic you know to look for problems in the velocity measurement.

A large number in the *Proof Channel* can be caused by inaccurate screen spacing (more than 0.2 inch error in mounting distance, screens not parallel, shooting a small bullet too high in the screen window, shooting too near the sides of the window instead of centered, **muzzle blast ahead of a subsonic bullet**, inadequate light due to dust and dirt accumulation, abnormally bright muzzle flash or tracers.

The *Proof Channel* is actually a second chronograph. On a standard chronograph with two screens, the first screen (Start) detects the bullet as it enters the screens. The second screen (Stop) detects the bullet as it leaves the screens. The chronograph measures the elapsed time between the signals from the Start and Stop screens, and reads out the velocity in feet-per-second.

The *Proof Channel* adds a middle screen (MID) and a second timing channel. The bullet's velocity is measured twice by each set of three screens, once by the first two screens (the proof velocity) and once by the first and third screens (primary velocity).

If screens are accurately spaced, the proof velocities should be very near the primary velocities and the PRF numbers will be small. If you do a sloppy job spacing the screens, expect larger (but often consistent) differences on each shot. If you have occasional large differences, they are probably due to false triggering from muzzle flash or blast from subsonic loads.

For example, if you move the middle screen just a quarter inch from the exact midpoint, you can see an increased difference between the primary and proof velocities as indicated by a larger PRF number. The *Proof Channel* shows the importance of accurate and adequate screen spacing. The reading of the PRF channel is comparable in size to typical errors in your velocity measurements.

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. The resulting light diffraction can trigger the screens. (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 primary velocities to be abnormally low and the PRF number to be negative. Premature triggering of both start and middle screens will cause the primary velocity to read abnormally low and the PRF number to be large and positive. Premature triggering of all three screens (a rare case) will cause the primary velocity to read near the speed of sound and the PRF to be small.

Subsonic blast problems can occasionally be cured by moving the screens farther from the muzzle. 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. We use a piece of plywood, 2x4 feet, standing on end and leaning on a single hinged leg. Cut a vertical inch-wide shooting slot from gun level to the top of the shield. Place the baffle about halfway between the muzzle and the first skyscreen. **Do not use a metal plate!**

Firing Simulators

The first step in trouble-shooting is to double-click on the high-lighted line of the suspect shot. This will display the times of the critical events of the shot and can be used to diagnose most problems.

The second step is the use of the built-in Oehler firing simulator. These units provides signals of know timing and amplitude to emulate the responses of transducers, screens, and microphones for a complete firing test. It conveniently separates the System 85 and the sensors. If the System 85 provides the expected response to the simulator, look for problems with your input sensors or cables. The the simulator provides automatic fire and detailed acoustic target simulation. If the System 85 does not properly respond to the simulator, call Oehler.

Personal Reference Ammo

You can quickly check the operation of the chronograph portion of the system with an airgun. Velocities will range from approximately 225 fps for a kid's BB gun, to approximately 600 fps for adult match air rifles, up to over 1000 fps for some adult sporter air rifles. BBs and pellets are small, short, and slow. They provide a severe test of screen sensitivity, so you must shoot through the lower half of the screen window. If your system works with an airgun, but fails with larger guns, you can suspect problems related to muzzle blast or flash.

APPENDIX A

Drag Functions

The Drag Functions

The drag functions (G1, G5, G6, G7, GL, Gs, and RA-4) are based on different styles of bullets. These drag functions are derived from the corresponding SAAMI tables and are used with permission. The G1 function is the default in the System 85 program and is universally used in most applications.

The following drag functions are available in the System 85 program:

G1	Standard table for all sporting bullets
G5	Low base drag (boat-tail) bullets
G6	Flat base, sharp nose bullets
G7	VLD bullets
GL	Exposed lead nose & hollow point bullets
Gs	Spherical bullets
RA-4	Standard for rimfire bullets

If you are thoroughly familiar with the various drag functions and want to be able to use other drag functions to calculate ballistic coefficients and do standard atmosphere ballistics, you can enable the other drag tables. During test setup, hit the drag function pushbutton as you are entering the bullet data. Change the drag function to any one desired.

The System 85 will compute the ballistic coefficient appropriate to the drag function selected

Now that you know how to choose alternate drag functions, we urge you to stick with the G1 drag function!

APPENDIX B

Correcting Data

Sooner or later you will have a test record in which you have entered the wrong distances, temperature, load information, or other data. You will want to salvage and correct the data for the actual conditions. It can be done but you should leave clear tracks of the edit in the notes section. The corrections entered will apply only to the one group.

A second application of this procedure is to examine different parameters recorded during the test. You can change the channels displayed during replay and printed on the report. The System 85 will measure and record the data from all transducers specified and connected, but is limited in screen and paper width. Not all measured channels can be displayed and printed on one report. By modifying the test setup to change only the channels to be displayed, you can observe data previously hidden.

Begin the correction process from the Setup pushbutton of the Main Display. From the menu, select Modify an existing test. Load the desired test and make any desired modification.

After you return to the Main Display, we urge you to Replay the test you just modified, and make notes describing the nature of the correction.

The corrected group has now been saved. Replay it for a quick look at the corrected data, or use Printout for a corrected copy of the test.
The procedure makes accurate corrections for small errors in distances and conditions. You cannot change the size or shape of the pressure curves.

You can also use the correction procedure as a tutorial. Change the distance to the acoustic target by a few feet and observe the dramatic change in ballistic coefficients. Change the temperature by a few degrees and you will still see a significant change. Change the altitude by a few feet and you might see a slight change. Change the humidity by a bunch, and you won’t see much change. Moral of story – pay attention to proper measurement of distance to target and to actual temperature.

APPENDIX C

Calibration

The System 85 may be calibrated with the following procedures.

Adjust Peak Pressure Response:

1. Initialize the system software to measure pressure only. In the gun setup, set the gage pressure / volt to 10000. Set pressure offset and barrel correction to zero.

2. Connect source of simulated pressure pulses to the pressure inputs. Proceed to the test display with the signal source for the pulses quiescent at zero voltage. The System 85 adjusts for zero baseline offset as it passes through the monitor window.

3. Simultaneously apply pulses of exactly 7.00 volt peak amplitude to both pressure inputs. These simulated pressure pulses should have a duration of approximately 1 millisecond. The duration of the peak should be at least 20 microseconds.

4. If the peak pressure A does not read between 69900 and 70100 for each shot, adjust the potentiometer R24 located on the circuit board adjacent to pressure inputs.

5. If the peak pressure B does not read between 69900 and 70100 for each shot, adjust the potentiometer R24 located on the circuit board adjacent to pressure inputs.

6. Reduce the peak amplitude of the applied input voltage. The output readings should track within approximately +/- 100 psi or +/-0.1% of full scale.

Verify System Timing:

1. Initialize the system software to measure muzzle velocity only (three screens). Set the distance between screens 1 and 3 to 10 feet.

2. Apply nominal +12 volt pulses to FIRE, START, MID and STOP inputs. The time between pulses should be between 1 and 10 milliseconds and should be precisely known. Select and double-click reported line to view diagnostic screen. Raw times should correspond to input times within 0.1% plus 1 microsecond. Calculate the expected velocity by dividing 10 by the known time. The displayed velocity should agree within 0.1% plus 1 fps.

3. Initialize the system to measure both muzzle velocity and acoustic target. Apply nominal +12 volt pulses to FIRE, START, MID, STOP, and MIC inputs. If the timing of the signals is not consistent with expected exterior ballistic behavior, then the system will not display target information directly. You must highlight the observed line of test results and double-click to view the diagnostic screen. The times reported on the diagnostic screen should be consistent with the input pulse timing to a tolerance of 0.1% plus one microsecond.

The firing simulator built into each System 85 is an ideal source of test signals for calibration.

Built-in Firing Simulator

General

The built in firing simulator provides a source of know test signals for ballistic instrumentation systems. These signals can be used in the routine checkout and calibration of ballistic instrumentation. Timing accuracy is approximately 0.01% and voltage accuracy is approximately 0.05%

Signals Provided

FIRE
The fire signal indicates the initiation of a test shot. In testing, the fire signal is typically generated using an action-time switch in the universal receiver. It can also be generated using the electrical fire signal for electrically primed ammunition. The pulse is +8 volts, one millisecond long, via BNC connector.

PRESSURE
A simulated pressure signal is provided 1 millisecond after the fire signal. The peak amplitude of this voltage signal defaults to 7.00 volts and is automatically reduced in 1 volt steps as a 20 round-per-minute burst is fired. The stepped cycle is repeated starting at 8.00 volts until the burst is ended. The nominal duration is 1 millisecond with rise and fall curve shapes approximated by simple RC circuit with a time constant of 130 microseconds. Output via BNC connector. This signal represents chamber pressure and can be used to verify the accuracy of the voltage [pressure] measurement.

To test the Pressure Channel B, the user must supply an appropriate BNC "T" to apply the pressure signal to both inputs.

START
The start signal represents the signal generated by the first muzzle velocity screen. It occurs 3 milliseconds after the fire signal. The pulse is +8 volts, one millisecond long, via BNC connector.

No provision is made for a separate signal for the middle velocity screen. Proper operation of the middle channel can be observed by using a BNC "T" to connect middle and stop screen inputs. This will cause the indicated "proof" velocity to be approximately one-half the observed primary velocity between start and stop screens.

STOP
The stop signal is represents the signal generated by the last or stop velocity screen. The pulse occurs 7 milliseconds after the fire signal. The pulse is +8 volts, one millisecond long, via BNC connector.

MICROPHONES
This set of four signals represents the response of the four microphones of an acoustic target located downrange. The four signals occur 15 milliseconds after the fire pulse and represent a center hit on the acoustic target. The pulses are +8 volts, one millisecond long, via RJ-45 connector.

APPENDIX D

Firmware Protocols

The System 85 Ballistics Measurement System supports the action time, rate of fire, dual pressures (PS A, PS B), muzzle velocity, and down range targeting/time of flight.

Event Timing and Capture

The following time events are captured from one of four synchronized 32 bit hardware timers with a resolution of 1uS. Raw times are referenced to activation of the green "Ready" light.

• Fire Signal:	Latched Rise Edge	Timer 1	
• PS A:Sample 81	Software Read	Timer 1	Threshold
• Velocities			
Start	Latched Rise Edge	Timer 2	
Mid	Latched Rise Edge	Timer 3	
Stop	Latched Rise Edge	Timer 4	
• Targeting			
Microphone A	Latched Rise Edge	Timer 1	
Microphone B	Latched Rise Edge	Timer 2	
Microphone C	Latched Rise Edge	Timer 3	
Microphone D	Latched Rise Edge	Timer 4	

Pressure Conversion and Capture

The System 85 simultaneously samples two 12 bit analog-to-digital converters. Either a 5uS or a 10uS sample interval can be selected. This yields either 2mS or 4mS of pressure data.
The pressure measurement routine returns time stamps for the **Fire** and **PS A Threshold** events followed by 400 ordered sample pairs of the voltage measurements. .

```
←--- 20% ---→←------------------- 80% ---------------------------→
|-----------------|-------------------------------------------------------|
1                81                                                  400 samples
              Threshold
```

Figure 1, Pressure Samples

The sample window is triggered when Pressure A increases above 0.95 volts referred to a full scale input of 10 volts. The a/d conversion is scaled so that an integer reading of 0 to 4000 corresponds to a full scale input of 0 to 10 volts. The converter can over-range up to a reading of 4095. The first 80 readings occur before Pressure A crosses the threshold and the following 320 readings occur after Pressure A crosses the threshold.

Muzzle Velocity

The muzzle velocity routine returns four time stamps corresponding to Fire, Start, Mid, and Stop.

Burst rate of Fire

The Burst rate of Fire routine returns two time stamps, Start and Stop, for each of the first 400 rounds fired.

Targeting

The targeting routine returns eight time stamps. They are Fire, Start, Mid, and Stop plus the four times stamps from each of the four microphones.

Communication Interface

Hardware Interface

The hardware interface to the PC is an industry standard USB. The USB module is a Future Technology UM232R. The appropriate driver can be downloaded from their website, http://www.ftdichip.com

The RS232 control signals from the UM232R have been modified from usual convention. The DTR line is used to provide a "hard reset" to the System 85 hardware. To absolutely reset the System 85, set DTR line low for 5 milliseconds and then restore it to high.

Application Programming Interface

The control characters used in the System 85 are ASCII upper-case alpha. Communications are master-slave protocol with the System 85 measurement unit as slave to the PC. The command and response character set is defined in Table 1 below.

Character	Software Command	Firmware
A	All	Measure Pressure, Velocity and Targeting
B	Burst Rate of Fire	Measure Burst Rate of Fire and Velocities
C	Quiescent Pressure	Measure Quiescent Pressure - Hardware Diagnostics
D	Dump Data Set	Send Full Data Set from last operation
E	Echo	Echo Last Command "E" - Verify USB Communications
F	Build Test Data Set	Worst Case File size Data = 100000000 + Data field #
G	Measure at the Gun	Measure Pressure and Velocity Only
N	Send Next Data Block	Hand shaking within the Data Dump Routine
P	Pressure	Measure Pressures Only
R		Respond - Ready for Command
T	Targeting	Measure Muzzle Velocity and Down Range Microphones
V	Velocity	Measure Muzzle Velocity Only
X	Abort current Task	Abort Task and Return to Ready
Z	Data Transfer Complete/Terminated	Hand shaking within the Data Dump Routine

Table 1 Command control Character set

After reset, the System 85 enters the **Ready** state. It sends an **R,** and then continually polls the input for a command. The System 85 always returns to the **Ready** state after completing a command.

Upon receipt of a character the firmware determines if it is a valid command.
Invalid commands are echoed back. The firmware then loops back into the **Ready** state.
Valid commands are echoed back. The program executes the appropriate measurement routine.

Three tasks require further information from the PC: **All**, **Measure Pressure**, and **Measure Burst Rate of Fire**. Upon entering one of these routines the System 85 polls for an 8 bit binary integer value.

The **All** and **Measure Pressure** routines accept only the values of 2 or 4 corresponding to the desired pressure measurement time window in milliseconds. All values are echoed.

The **Burst** routine accepts values from 3 to 255. All other values (0, 1, and 2) are rejected. All values are echoed. This value in milliseconds is used as a delay or hold-off time between rounds of a burst.

Upon completion any command. the System 85 returns to the **Ready** state.

During the execution of any command, the System 85 frequently checks for an **Abort** command. Upon receipt of the **Abort** command, the System 85 builds an appropriate **Data Dump Set** for return to the PC, signals the PC with an **R**, and enters the **Ready** state in anticipation of a command to dump data.

Communication Protocol for Data Dump
The date file is organized in Blocks and Fields. Each block contains four Fields. See file format definition below.

|<------------------- Block 1-------=------------→|----------------=---- Block 2------------------→|
|<Field 1>, <Field 2>, <Field 3>, <Field 4>, |<Field 5>, <Field 6>, <Field 7>, <Field 8>,|

Figure 2

All Fields are comma separated. All data is formatted ASCII alpha or a formatted 32bit positive integer value, (0 through 999999999).

The System 85 transfers a Block of data, then waits for a command **N** to transfer the next Block or a **Z** to abort Data Dump. The software can request multiple Blocks to be transferred by issuing multiple block transfer commands.

After transfer of the final block, the System 85 will poll for an acknowledgment **Z** indicating that the file transfer is complete.

Data File Format

Block 1:
Field 1 = Last Command / Measurement completed
Field 2 = PS A Time Stamp at (Sample 81) or (Threshold Crossed)
Field 3 = 0
Field 4 = Field Count = 816

Block 2:
Field 5 = Fire Time Stamp
Field 6 = Start Time Stamp
Field 7 = Mid Time Stamp
Field 8 = Stop Time Stamp

Block 3:
Field 9 = Microphone 1 Time Stamp
Field 10 = Microphone 2 Time Stamp
Field 11 = Microphone 3 Time Stamp
Field 12 = Microphone 4 Time Stamp

Block 4 => 103:
Field 13 = PS A Sample 1 or Burst Start Shot 1 Time Stamp
Field 14 = PS A Sample 2 or Burst Start Shot 2 Time Stamp
Field 15 = PS A Sample 3 or Burst Start Shot 3 Time Stamp
Field 16 = PS A Sample 3 or Burst Start Shot 4 Time Stamp
.

.
Block 104 => 203:
Field 413 = PS B Sample 1 or Burst Stop Shot 1 Time Stamp
Field 414 = PS B Sample 2 or Burst Stop Shot 2 Time Stamp
Field 415 = PS B Sample 3 or Burst Stop Shot 3 Time Stamp
Field 416 = PS B Sample 3 or Burst Stop Shot 4 Time Stamp
.
-----.
.
Block 204
Field 813 = Reserved Status Code 1 =Q
Field 814 = Firmware Revision =100
Field 815 = Check Sum Field 2 => Field 812
Field 816 = “Z”

APPENDIX E

System 85 Organization

The purpose of the System 85 is to measure various parameters of tested ammunition and preserve the results of these measurements in a form that is easily interpreted by the operator and is recorded for archives and future interpretations.

The System 85 uses test names for each test. The test name consists of a root test name plus a successive group number of various tests fired using this name. You must be able to locate the results of previous tests, either by shuffling through many printed test reports or by searching in a computer. Fortunately, the gun and ammo industry has the names and a way to make the first sort of test results, test guns, and test ammunition. The headstamp name is unique, concise, and universally recognized. We urge that test names, gun name, and ammunition names use a headstamp name as the initial characters. To conserve space on lists and displays, we suggest that only numerals and letters be used without spaces or symbols. For instance, 308Win, 7RemMag, 7RemExp, 300WSSM, and 223Rem are recognizable and unique identifiers. If all test names begin with these characters, any search is narrowed considerably.

After a space, the nature of the test can be described. For instance, we'd suggest the following abbreviations.

PV	Pressure and Velocity
PPV	Pressure, Pressure and Velocity
VT	Velocity and Target
PPVT	Pressures, Velocity and Target

If you see a test name of 3006Spr PV xxxxxxxx, you know it is a routine pressure and velocity test of a 30-06 Springfield.

The System 85 will allow root test names of up to 30 characters. Following the headstamp and nature of the test, the user may add to the test name at his discretion.

It is recognized that the gunner should enter minimal information into the computer before firing the test. However, you want to see complete information on any test reports and data. If the gunner doesn't provide all the desired archival information, it must come from somewhere and be properly associated with the test.

The System 85 uses what we call "templates" to define the test name and conditions and to describe just what is to be measured. In the System 83 and the beta version of the System 85, these templates were made to be adaptive. Before any test, the template must be defined. If you were repeating a test with no changes in conditions, you could either call up an old template or call up an old test for replay and use that template. If you made any changes to the test, the revised template was automatically written over the existing template. (The templates are stored in the System 85 TestData file as a "group zero" test.) This protocol worked well for independent systems where convenient adaptability to current conditions was the highest priority.

In the environment of multiple test tunnels shared by many operators, standardization of the tests becomes the higher priority. Operator data-entry with the associated errors must be minimized, yet the operator must retain the capability to properly record any departures from the provided script.

The traditional means of minimizing data entry errors is allowing choice from a predetermined list. For instance, each test tunnel would include its own set of templates. Given a sample of 30-06 ammo for the standard pressure and velocity test, the operator would look for and load the template labeled "3006Spr PV xxxxxxx". The template would already include entries for tunnel designation, appropriate screen locations, environment,, etc. The operator would probably insert his name. The template would default to a particular gun, but this could be readily changed by selecting and loading a new gun, filed under "3006 . . ." that new gun file would include all the appropriate transducer settings and reference corrections. The template would include a default load file. That file too can be readily changed by selecting from a list of "3006 . . ." standard load files. After making the appropriate selections, the operator will have the freedom to make changes to the templates; any changes made will be reflected in the printed test report and exported data.

If changes are made to the template, the operator will be given an option to save (overwrite) the existing template. If the operator elects to overwrite, he will be prompted "Are you authorized to make this change?" Only if the operator claims authorization will the original template be altered. The operator may use the edited template during his test session without saving it, but the template will revert to its original form for later tests.

We envision a structure of test templates, gun files, and load files in which the operators have the freedom to make required changes, but are restricted from making inadvertent changes. Just as Windows has administrators, users and guests, we envision a similar protocol for use of the System 85. We feel ham-strung by the Vista requirements for administrator permission for relatively minor changes, but we do appreciate the warning that we are making potentially damaging changes. The System 85 will give the warning, but it won't tie you hands.

We envision that the "master" test templates would be established by supervisors or proven capable operators. These templates will be stored locally in the tunnel where they are used (and can provide information unique to that tunnel or setup). Test data and any special templates will be written to folders local to the tunnel. Reports and exported test data stored in folders at each tunnel will be periodically "mined" and reviewed by an administrator and then placed in appropriate archives.

We suggest that the gun files be created and maintained by the person responsible for transducer calibration and installation along with determining the reference corrections for the barrel. These gun files can be stored at one common network location and need not be stored at individual tunnels. It a barrel is available for use, the most current data is automatically available. The operator must still make the appropriate gain settings on the charge amplifier.

Load data files are not critical. Again, we suggest that files for common catalog and production items be established and maintained in one common network folder. The System 85 makes practically no use of the information included in the load data; it is required as a "memo" to assure a complete record of your test.

APPENDIX F

Pressure Filtering

The question of filtering has been debated through the history of electronic pressure transducers. Users want to see pressure-time curves that accurately reflect the pressure being observed. Users want to remove spurious noise and artifacts from the curves so that they can be reliably interpreted. The overzealous application of filters to remove the offending noise may also distort or mask the display of the actual pressure event.

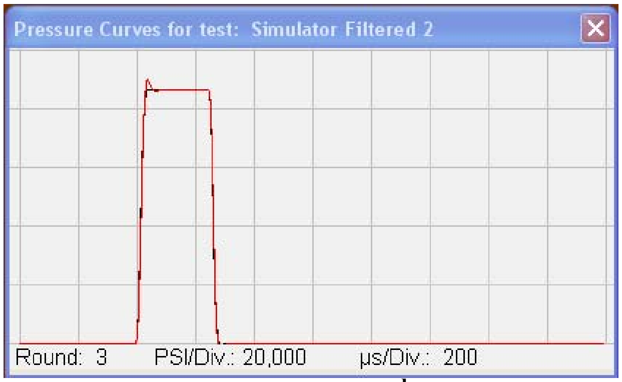
Pioneers in the development of the electronic transducers for ballistic testing advocated use of a low-pass 22 kHz Butterworth filter in the charge amplifier. We consider this to be sound advice. The first order Butterworth filter is typically well behaved and does not tend to overshoot in response to a step-function (abrupt rise time) input signal. The first order configuration does not exhibit a sharp cut-off at 22 kHz, and it may do a less than perfect job of attenuating higher frequency noise. Higher order Butterworth filters and not as well behaved.

The problem of filter overshoot is not apparent with conformal transducers or with drilled-case gas transducers. In these applications, the frequency spectrum of the pressure signal is sufficiently low that the 22 kHz filter is essentially transparent. Looking at the filtered pressure-time curve you often see little effect other than the desired attenuation of high frequency signals normally considered noise.

The problem of overshoot becomes much more significant with case-mouth transducers. Instead of ignition and a smooth build-up of pressure, the fast rise-time of the pressure curve now approximates a step-function input. Often filters are visualized in what engineers call the frequency domain. Their holy grail is uniform frequency amplitude response over a specified bandwidth and rejection of frequencies outside this band. This concept is appropriate if you are looking for the spectral response of a repeating or cyclic signal. The filter may display appropriate behavior with respect to frequency, but the shape of the output waveform may be changed. In the case of ballistic pressure measurements, we are primarily interested in the shape and amplitude of the "one shot" curve. We are not primarily interested in the frequency spectrum. Application of the wrong filter can lead to overshoot in the response.

Butterworth filters are most often used. They are appropriate to vibration analysis or other cyclic events often measured with quartz transducers or strain gages. Butterworth filters exhibit the often desired flat frequency response in the pass band and higher order Butterworth filters have relatively steep skirts but higher order Butterworth filters will have significant overshoot in response to a step-function input characteristic of a case-mouth transducer. This leaves only the first order Butterworth filter appropriate for use with case-mouth transducers. Higher order filters lead to the "overshoot" peak often observed in the response of case-mouth transducers.

An alternative to the Butterworth type filters are known as Bessel filters. Bessel filters are designed to minimize distortion of the shape of the signal even at the expense of giving up the flat frequency response. Even higher order Bessel filters display negligible overshoot in response to a step-function input.



Step Response of 22kHz 2nd Order Filters
Bessel (Black) and Butterworth (Red)

Note that the Butterworth response (red) includes an overshoot of approximately 5 percent while the Bessel response (black) has negligible overshoot.

Our general filter recommendations are

1. Use the 22kHz Bessel Second Order filter for normal testing, including conformal, drilled-case, and case-mouth..

2. Use the 22kHz Bessel Forth Order filter for case-mouth testing only if there is excessive high-frequency noise or oscillations near the peak pressure.

3. Use the 10kHz Bessel Second Order filter if a 10kHz filter is required by specification.

4. If specifications require use of 22kHz Butterworth filter, use only the first order filter.

5. With conformal or drilled-case transducers, any of the provided filters are appropriate. If your system includes a single-pole filter, then leave it in place. The 22 kHz filter normally does not interfere. If your system includes a higher order filter, beware of overshoot.

6. With the 9mm Luger (or similar) cartridge, do not expect any filter to compensate for the fact that the peak chamber pressure may occur prior to the pressure reaching the case-mouth transducer.

With most bottle-neck cartridges, the response of the case-mouth transducer essentially begins at a pressure 70 to 80% of the observed peak. In this situation, the pressure curve has adequate time to recover from most filter-induced overshoot and reasonably represents the peak pressure observed. When the 9 mm Luger (or similar) cartridges (with some combinations of propellant and bullet) are tested with a case-mouth transducer, the overshoot can degrade the accuracy of the observed peak. The overshoot can occur at approximately the time of the pressure peak, or even after the pressure peak, and the two cannot be separated. If the case-mouth transducer is not exposed to the peak pressure significantly before and during the peak, no amount of filtering or faster rise time can improve measurement accuracy.

The available filters and default filter selection is controlled in the *Sys85param.ini* file. This file is located in the Win_S85 folder containing the Sys85 executable file. Filters can be made unavailable to the operator by editing the filter name from "=true" to "=false". The available filters can be listed in any order, but the first filter listed will become the default filter selection.

APPENDIX G

Firing Simulator

Oehler has provided firing simulators for use with their ballistic instrumentation systems beginning with the Model 75 Simulator thirty-five years ago. The 8225 Test Module was an important component of the Model 82 modular system. Oehler hastily built a firing simulator used in the development and demonstrations of the System 85. This simulator provided an adequate representation of firing signals generated during pressure and velocity testing, but simulation of the acoustic target was minimal and there was no provision for simulation of automatic fire.

The initial users of the System 85 were unanimous in expressing their need for a firing simulator. Firing simulators are used at every workbench where we test System 85 units and even simpler instruments. When we needed a better firing simulator for development tests of the new machine-gun-chronograph/target system, we were forcibly reminded that a firing simulator is an essential part of any modern ballistic test system. The firing simulator is now built-in as standard in both the System 85 and System 87.

The built-in firing simulator is independent of the System 85 processor and computer. It is powered by an internal battery and is activated only when the user pushes the BANG button. It is controlled by its own microprocessor to generate a fire signal, a pressure signal, muzzle velocity start and stop four signals from an acoustic target.

The simulator must be connected to the System 85 inputs just as you would connect other input sensors. A short Ethernet cable along with four short BNC/BNC cables are provided. If you want to connect both pressure channels, use an extra BNC cable and T.

Operation of the simulator is controlled by the BANG pushbutton along with the settings of two toggle switches. Pushing the BANG button powers the simulator; hold it down firmly until the firing test is completed. There will be a three-second delay as the system stabilizes, and then the red LED will blink at each shot.

The SHOTS toggle switch controls the number of simulated shots provided in response to one continual push of the BANG button.

- A setting of 1 SHOT is the single-shot or most basic mode. Only one shot is fired in response to the BANG input. If the button is held for more than three seconds after the shot is fired, the pressure signal assumes a value of exactly +7.00 volts dc. This can be verified with an external dc voltmeter to assure calibration. If required, the internal potentiometer R8 should be adjusted to provide the exact +7.00 volts dc.
- A setting of 20 SHOTS conveniently fills the output screen and page with a 20 shot test.
- A setting of 200 SHOTS demonstrates capability of handling longer burst of automatic fire.

The RPM toggle switch controls the firing rate of repeated simulated shots provided in response to one continual push of the BANG button.

- A setting of 20 RPM must be used for all shots for which FIRE or PRESSURE signals are expected. If the RPM is set at 20 for a test of 20 SHOTS, then a special set of pressure signals are generated. The first pressure signal will be at +7 volts, the second will be at +6, the third at +5, and they will continue to step down one volt with each shot. The 8th shot will go to +8 volts and the sequence will be repeated. The 16th shot will begin a new partial sequence. This repeated sequence can verify the accuracy of the pressure readings over the common operating range.

- A setting of 1000 RPM corresponds to the highest rate of fire most individual automatic weapons. The simulator will generate appropriate START and STOP muzzle velocity signals along with acoustic target microphone signals for each shot of a burst.

- A setting of 6000 RPM corresponds to rates of fire expected from the Vulcan or Mini-gun. The simulator will generate appropriate START and STOP muzzle velocity signals along with acoustic target microphone signals for each shot of a burst.

Users will find that the firing simulator makes a wonderful training aid for system operators. Using the simulator, the novice operator can practice connecting the system, setting up tests, firing tests, manipulating test reports and exported data, and can perform all the operations required of an operator. Supervisors can familiarize themselves with system operation before they must train the gunners.

Experienced operators can use the simulator to replace questioned input sensors with known valid signals to isolate problems or simulate faults. A bad cable is still a bad cable even if used with a simulator. A missing sensor signal will show up as bad on the raw time display of the '85 in response to a missing connection to the simulator.

Proper system response to the known signals from the simulator provides a realistic check and verification of system function and performance. In the practical world, such verification is often more valuable than formal calibration.

Battery

We chose a battery power supply because we tired of finding the proper adapter and plugging in a simulator each time we wanted to use it. Borrowing power from the system under test voids the independence between simulator and test system. A 9-volt lithium battery is required for proper operation.

The first symptom of low battery voltage will be a lower than expected reading on the 8-volt pressure pulse. If you fire a 20-shot pressure test sequence and the 8-volt reading is low while pressure readings of 7 volts and below appear to be correct, it is likely a battery problem. Remove the system cover and replace the battery with a known fresh lithium battery.

Please observe the battery polarity during installation. There is no power switch, and the circuit is not "idiot proof".

Using the Firing Simulator

A report generated with the firing simulator is shown on the next page. The user has no options to set the times and voltages generated by the firing simulator. This means that the user must input the proper distances, temperature, pressure scale factors, and filter choice to see outputs that correspond to a typical ballistics test.

Study the report presented. Of special importance are

- Muzl to Scr1: 5.00 feet
- Scr1 to Scr4: 10.00 feet
- Muzl to Trgt: 240.00 feet
- Target Size: 36.00 inches
- Temperature: 49 ˚F
- Baro Press: 29.53 in Hg
- Vel Correction: 0
- Press Correction 0
- Offset Press 0
- Press/Volt 10000
- Filter: Bessel 22kHz
- B.C. 0.300

This choice of input parameters should yield a muzzle velocity of 3333 fps, time-of-flight to target of approximately 72 ms, velocity at target of 3088 fps, an observed BC of approximately 0.325, targeted shots arranged in a 20-inch square, and pressures of 70K, 60K, 50K, 40K, 30K, 20K, 10K, 80K, 70K, …

It is not uncommon for the first shot at 70K to be slightly low. This is a characteristic of the simulator not being completely stabilized before the first shot is fired and does not reflect an error on the part of the measuring system.

If the pressure reading expected to be 80K is low while all lower readings are as expected, it is probably due to low voltage on the battery of the simulator module.

Remember, there is a delay of approximately three seconds between BANG button actuation and the simulated shot. This time is required for the simulator to power-up and stabilize. You must push and hold the button for the duration of the test. The red indicator light will blink as each shot is fired.

Test Using Model 77 Firing Simulator

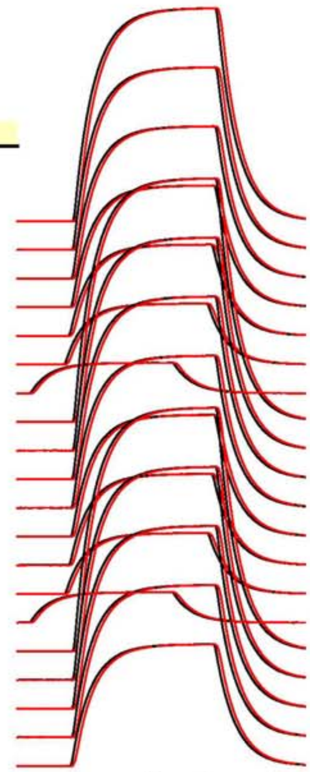
Test: Simulator M77 Test 2 Press 3
Operator: Ken O
Test Bay: Oehler Office
Muzl to Scr1: 5.00 **feet**
Scr1 to Scr3: 10.000 **feet**
Muzl to Trgt: 240.00 **feet**
Target Size: 36.00 **inches**
Temperature: 49 **°F**
Humidity: 78 **%**
Altitude: 30 **feet**
Baro Press: 29.53 **in Hg**
Time Scale: 2 **Msec.**
Test Date: 1/4/2012
Test Time: 11:54
File: C:\Documents and Settings\Ken...
Reports: C:\win_s85\ExportedReports\
Excel: C:\win_s85\ExportedReports\

Gun: Simulator M77
Mfg/Model: Oehler Built In
Caliber:
Serial #: 001
Vel Correction: 0 **fps**
Press Correction: 0 **PSI**
Xducer A ID:
Offset Press: 0 **PSI**
PC/Press: 0.300 **PC/PSI**
Press/Volt: 10000 **PSI**
Filter: Bessel 22kHz 2nd order
Xducer B ID:
Offset Press: 0 **PSI**
PC/Press: 0.300 **PC/PSI**
Press/Volt: 10000 **PSI**
Filter: Bessel 10kHz 4th order

Load: Simulator M77
Bullet Mfg:
Bullet Wgt: 0.0 **grains**
Bullet Style:
B.C.: 0.325 **G1**
Powder:
Powder Wgt: 0.00 **grains**
Lot Number:
Primer:
Brass:
Max Avg Pre...
Avg Velocity:
Note:

SYSTEM 85 SHOT DATA

		230.0 ft			----Target----		----Pressure------		------Pressure------	
Rnd	**Vel13**	**TOF2T**	**Vel-T**	**BC**	**Horz**	**Vert**	**PeakA**	**RiseA**	**PeakB**	**RiseB**
1	3333	71681	3089	0.327	-9.95	-9.94	69950	150	69900	149
2	3333	71681	3089	0.328	-5.95	-9.99	59975	149	59950	149
3	3333	71678	3090	0.328	-1.98	-10.01	50000	148	49950	148
4	3334	71678	3088	0.325	1.98	-10.01	39975	147	39925	146
5	3333	71684	3089	0.327	5.94	-9.99	30025	146	29975	146
6	3334	71687	3088	0.324	9.93	-9.94	20050	145	20000	145
7	3333	71685	3089	0.327	9.98	-5.94	10000	142	9975	142
8	3333	71682	3089	0.327	10.01	-1.98	79975	151	79950	150
9	3333	71684	3089	0.327	10.00	1.98	69975	150	69950	150
10	3333	71688	3089	0.327	9.99	5.94	60025	149	59975	149
11	3334	71692	3087	0.323	9.94	9.94	50025	148	49975	148
12	3334	71691	3087	0.324	5.94	9.99	40000	147	39950	147
13	3334	71687	3088	0.324	1.97	10.01	30025	146	29975	145
14	3334	71688	3088	0.324	-1.98	10.01	20050	145	20000	145
15	3334	71693	3087	0.323	-5.95	9.99	10025	143	9975	142
16	3334	71697	3087	0.323	-9.94	9.94	79975	150	79950	150
17	3333	71695	3088	0.326	-10.00	5.95	69975	150	69950	150
18	3333	71692	3088	0.326	-10.01	1.98	60025	149	59975	149
19	3333	71693	3088	0.326	-10.02	-1.98	50025	148	49975	148
20	3334	71698	3087	0.323	-9.99	-5.94	40000	147	39950	147

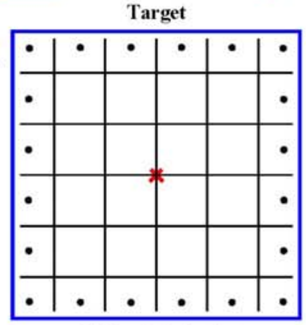


SUMMARY

		230.0 ft			----Target----		----Pressure------		------Pressure------	
	Vel13	**TOF2T**	**Vel-T**	**BC**	**Horz**	**Vert**	**PeakA**	**RiseA**	**PeakB**	**RiseB**
Avg	3334	71688	3088	0.325	0.00	0.00	47004	148	46961	147
SD	1	6	1	0.002	8.44	8.44	22010	2	22015	2
HI	3334	71698	3090	0.328	10.01	10.01	79975	151	79950	150
LO	3333	71678	3087	0.323	-10.02	-10.01	10000	142	9975	142
ES	1	20	3	0.005	20.03	20.03	69975	9	69975	8

Rad SD: 11.93
Group: 28.11
Mean Radius: 11.54

Target



Grid: 4.0 **inches**

Comment: