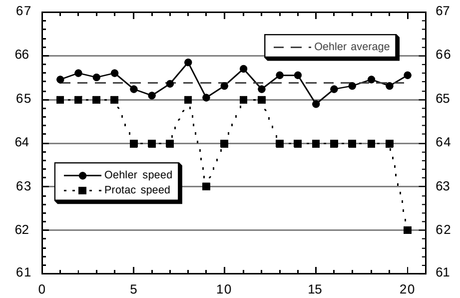
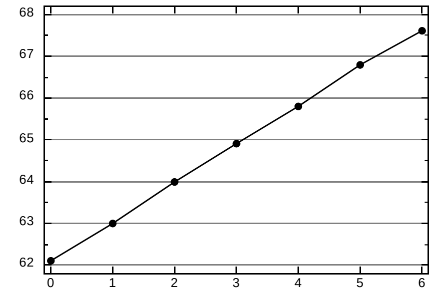
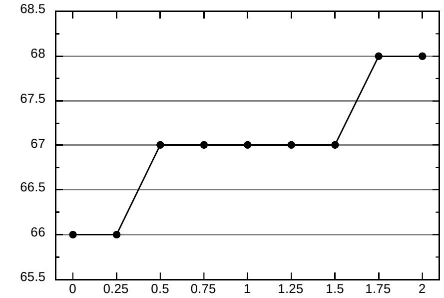


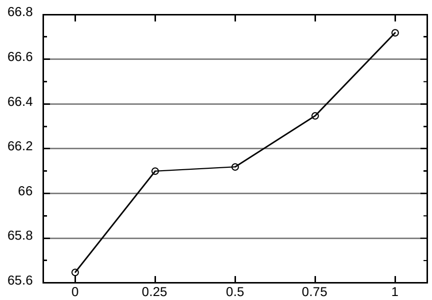


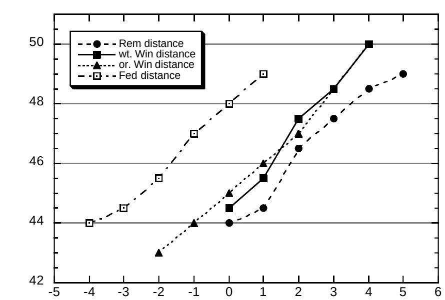


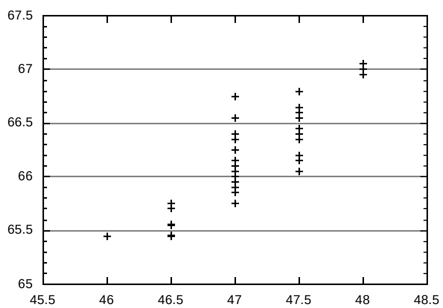
Chronographs & Clay Targets

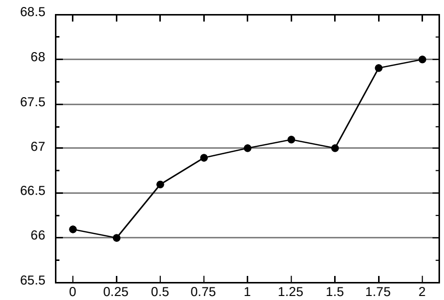
by Neil Winston

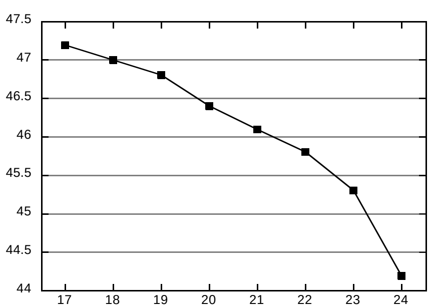
August 1999

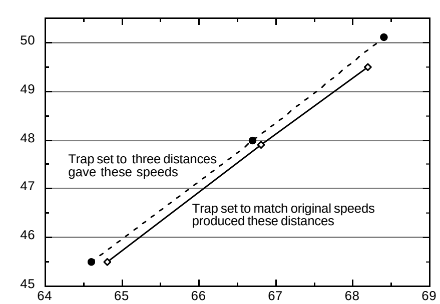












	Trap 1	Trap 2	Trap 3	Trap 4
Target #1	65	66	65	66
Target #2	66	66	65	66
Target #3	65	65	65	65
Target #4	66	66	65	62
Target #5	65	75	65	66
Target #6	66	66	65	64
Target #7	65	66	65	66
Target #8	65	66	65	66
Target #9	65	66	65	64
Target #10	65	66	65	66
Average	65	66	65	66

Introduction

"The demons of target-setting – wind, heavy air, machine variation, no landing area, judgment – have finally met their match and it is the chronograph. We can set a target in any conditions, then we can trot down the line and set all the traps the same and the targets will be just alike so it's fair for everyone, then we can define a "Standard Chronographed Legal Target" and get those western discs up to proper speed, then we can..."

You've heard all this and more. And now what do you bet? True? Half true? Horsefeathers? And what did you base your wager on? A few relied on experience, more on rumor or common sense, but none of you relied on systematic tests of the strengths and weaknesses of the instruments themselves, their proper use, and the effects of variables other than initial target speed which might affect where a target actually lands.

In a letter in the Feb. 1998 issue of Shotgun Sports I called for "years of systematic experimentation" to establish the validity of some of the claims in the first paragraph. This report is the start of such a program. It leaves a lot out, gives too little attention to some effects and too much to others, and, being but a start, no doubt makes some mistakes. I offer it as a "sketch of the outlines" and hope that others will, in time, complete the rest of the picture.

SECTION 1

•CHRONOGRAPHS
•SPEED
•DISTANCE

ProChrono+ and Oehler chronographs

"The ProChrono+ chronograph which is becoming popular as an aid in setting trap targets is an inexpensive and practical instrument, but anyone who buys a chronograph for any purpose must ask "Is it accurate?" Accuracy is really the last question to ask about chronographs. Before we can judge accuracy we have to know four other properties of the instrument:

1) **Validity** (Does it really measure target speed?)

2) **Precision** (What's the smallest difference in readings I can count on?)

3) **Repeatability** (Does using it give consistent targe flight?)

4) **Generality** (Do the results apply across different brands of traps, targets, weather conditions?)

To the right, above, is a picture of the two chronographs which I used for this report.

On the right is the familiar ProChrono+. It uses daylight to activate its two sensors which are mounted in a compact case one foot apart. There's an LCD readout on the back surface where you can read and review individual speeds as well as get summary statistics. The numbers are big enough to read from inside the traphouse, a necessary feature. The resolution of the readout is one foot per second, for example 64 or 65, nothing in between.

The light and stable tripod makes transport and setup easy.

fig. 1.1

The big box on the left is my mounting of an Oehler #55 chronograph. The #55 itself consists of two steel frames about 2x3 feet which the user sets up as his use requires. In one short side of each frame is a sixteen inch "Lumiline"single-filament lamp, in the other a row of sensors and appropriate electronics to communicate with an Oehler #34 readout box which provides most-recent speed data and summary statistics but no individual recall of a string of readings.

I orient the Model 55 with the lights on the bottom (so the sensors are looking down); this way there is less chance of daylight degrading the clean light break between the Lumiline lamps and the sensors.

My two frames are mounted in plywood so the sensors are two feet apart. The Model 34 readout treats them as if they were 40 feet apart, giving a theoretical resolution of one-twentieth of a foot per second. An adjustable angle base completes the package.

I would have preferred to use an Oehler Model 35p. It is compact and promises great accuracy but I found it too sensitive to the electrical noise around trap machines to be of any use.

Costly, complicated, and bulky, the Oehler #55 is not for the casually curious, but if you really want to know about the speed of a single target, it is the right instrument to use.

Test 1. Reading the same target with two chronographs

The ProChrono+ is a suspiciously low-cost and simple device. How well does its performance match that of a custom-designed instrument costing many times as much? This test begins to answer that question.

How better to start studying the performance of two chronographs than to have them clock the same target and compare the readings? I arranged the ProChrono inside the case of the Oehler #55 so it was mid-way between the larger instrument's sensors. The angles of Pat Trap #3 at Metro Gun Club in Blaine, Minnesota, and the two chronographs were all set to 19 degrees using a precision bubble level. Twenty targets were thrown and the measured speed of each was recorded. In the graph below the black circle represent the reading by the Oehler chronograph, the black squares the reading of the same target as reported by the ProChrono. The dotted line at

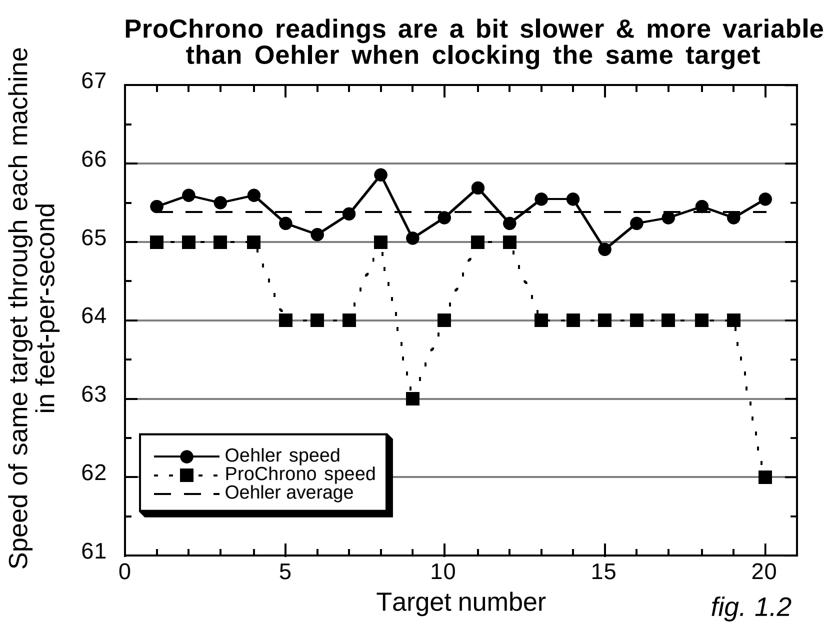


fig. 1.2

65.4 feet-per-second is the average speed of the twenty targets as measured by the Oehler.

The first thing to note about these data is that according to the Oehler, a Pat Trap throws a very consistent target; all twenty flew within a span of only one foot-per-second and three-quarters spanned just one-half foot-per-second. Based on the Oehler readings, we call the speed at this spring setting about 65 and a half feet-per-second.

If we look only at the first dozen targets we see the ProChrono working very well. Ignoring target number nine (an obvious error), when the speed was above average (65.4 ft./sec.) the ProChrono called it 65, when below average, it called it 64. .

Starting with target thirteen the ProChrono's performance is still good enough, but you would no longer say it is tracking above- and below-average discs well at all. And again, one reading (number twenty) is completely wrong. Using the ProChrono data we call the speed 64 or 65 feet per second, which is close enough. I think everyone would just ignore the two deviant readings (63 and 62) as they are simply errors, and do not reflect any problem with the trap. The choice of twenty targets here is instructive, since with only ten we would have given the ProChrono greater credit than it deserved. The lessons are clear: 1) the more data the better and 2) conclusions based on sparse data should be treated with caution.

Test 1 shows that a good trap throws consistent targets whose speed can be measured by either instrument. The ProChrono+ requires some judgement in interpreting its readings; we'll return to this in Test 3.

TEST 2a. Speed and spring tension

"Validity" refers to the ability of an instrument to measure the quantity it purports to. Determining this is usually pretty straightforward. If you have a voltmeter, you can use a battery, if a scale, a calibration weight. There is no such handy standard for chronographs, we can do no better than throw a number of targets at different spring settings and see if the resulting speed readings make sense.

The upper graph at the right relates each of seven trap-spring settings to the average speed of ten targets measured by the Oehler chronograph. The graph at the lower right does the same for the ProChrono.

It is clear that both instruments do a good job of measuring the speed of clay targets. These data put to rest any doubts about the validity of the speed measurements cited in the rest of this report.

Note: The experiments reported in Sections 1 and 2 were all conducted in the summer of 1998 at Metro Gun Club in Blaine, Minnesota. In most cases the time was near dawn to ensure dead-calm conditions. The following atmospheric conditions were typical: temperature 65 degrees, air pressure 29.6 inches of mercury, relative humidity 60%, no wind. Each data point represents the average speed of ten Winchester White Flyer targets set to just clear a nine-foot bar ten-yards in front of the trap.

I thank Rick and Rita Wilder, the owners of Metro Gun Club, for their support in this project; without their cooperation none of this could have been done.

I also want to thank my patient editor and target spotter Cindy Thompson. Her help, both on the field and at the editor's desk, has been invaluable.

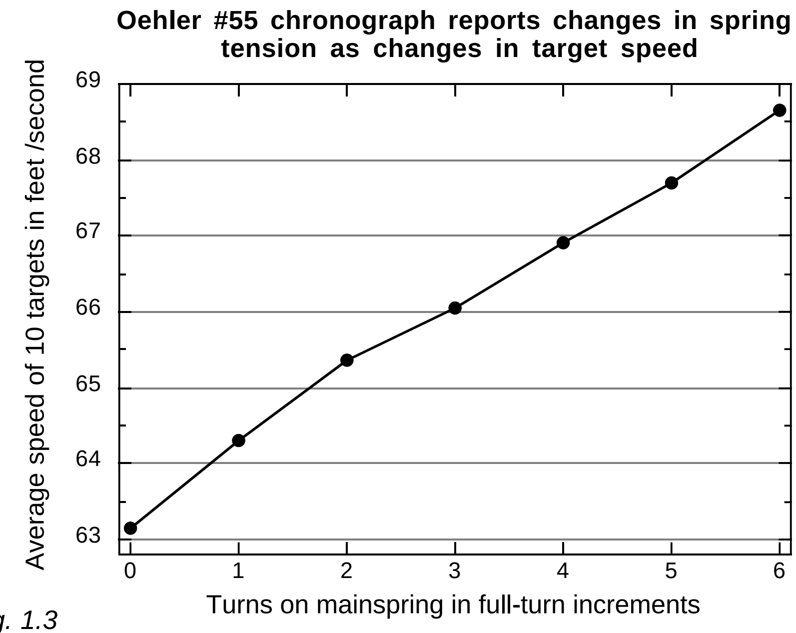


fig. 1.3

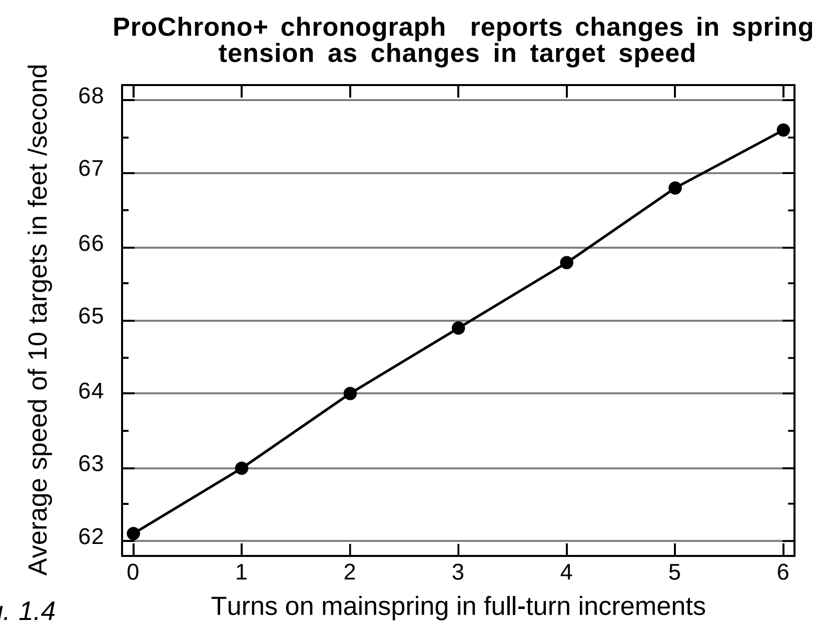
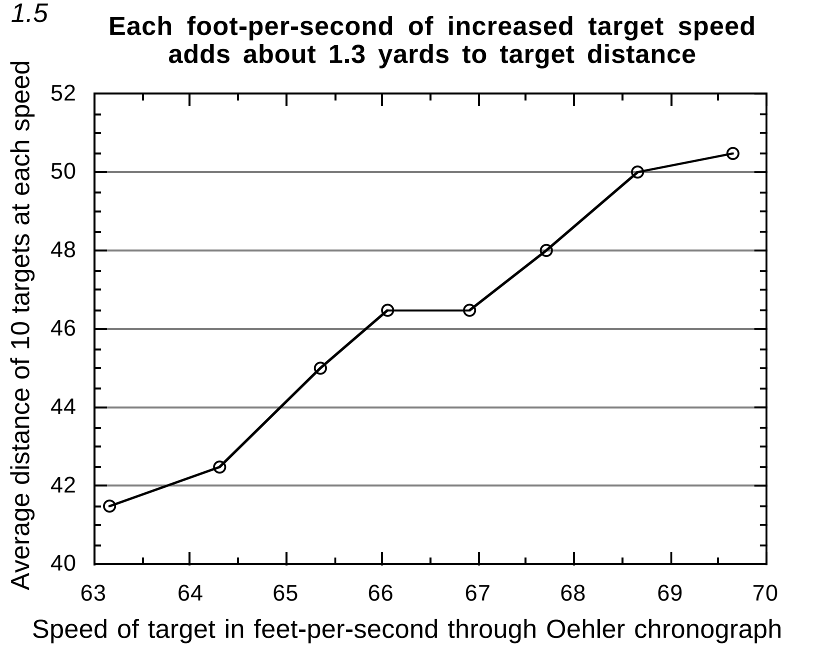


fig. 1.4

TEST 2b. Speed and Distance

The speed of a target by itself is of not much use. What we want to know is whether the chronographed speed is a good predictor of the distance a target will fly. When the previous data were taken, an observer near the 50-yard stake simultaneously reported where each target fell. Four six-foot 1x2 inch wooden sticks, painted and labeled with the appropriate distances, extended from the 50-yard stake toward the traphouse to aid him or her in his or her estimates. Distances were called out by radio, to the nearest half-yard. Records were kept of every target.

fig. 1.5



The landing-place of a target is much more variable than its launching speed and this graph reflects that variability. The general relation is clear: in this example a one foot-per-second increase in target speed adds about 1.3 yards to target flight.

As my experiments progressed I was surprised to find that this particular relationship – the one linking a one foot-per-second change in to a particular change in target distance – is quite variable. The closest estimate I can make is that under a large range of conditions, a foot-per-second speed difference will show up as a yard to yard-and-a-third change in target flight.

Some of you will think that I have spent way too long demonstrating the obvious: chronographs measure target speed and faster targets fly farther. But wait. You have also heard the critics say that chronographs don't work, that if you set a number of traps by distance and then chronograph them, the numbers are all over the map. Or if you set traps by speed, the distances aren't consistent. I'll deal with both these claims in later tests, but what I've shown so far should convince you that however the data come out, the relationship between chronograph readings and target fall can be measured accurately.

But first a short detour to determine the way these instruments should be read.

TEST 3a. Precison of the Oehler #55

In the forgoing pages I've been quoting Oehler readings down to the half-foot or better, while for the ProChrono I been more conservative: "64 or 65 feet per second." The following tests demonstrate why I have made this distinction.

"Precision" is the word I have chosen to describe the smallest difference in speed a chronograph can detect. We'll study this by making small changes in spring tension (and so target speed) and seeing how reliably the instruments track the changes.

The following test was made with Metro Gun Club's Pat Trap #2, throwing Winchester White Flyers at a height of 9 feet measured 10 yards from the trap.

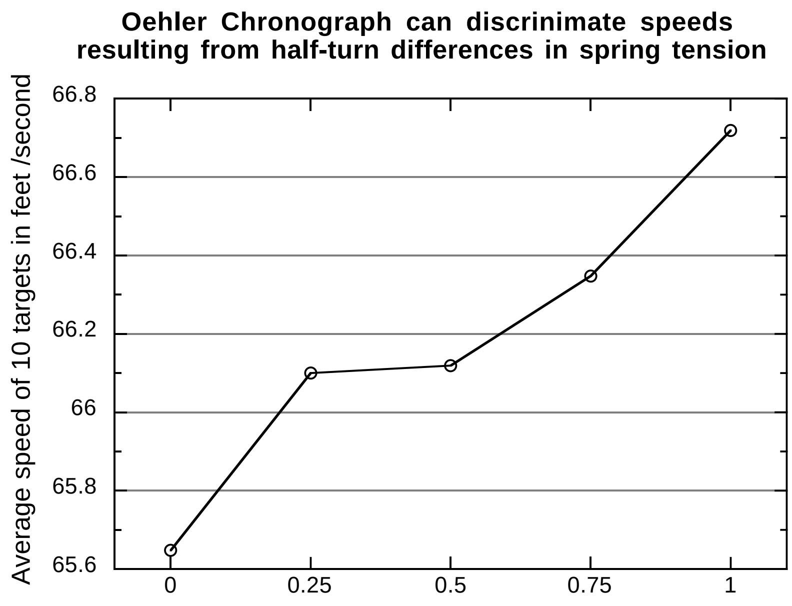


fig. 1.6

All the data points at least one-half turn from each other are clearly different, while the one-quarter turn change from plus 0.25 to 0.50 made hardly any measured difference at all. In other words, the Oehler #55 can discriminate about a half-turn, which on this trap is about half-a-foot per second, the precision I've been using.

This precision is not particularly dependent on the number of targets thrown; a test graph which used data from only the first five targets thrown at each setting looks about the same as the ten-target graph.

Is this half-foot per second precision all we can get, even though the Oehler should be able to do ten times as well? The data from the previous graph can be looked at in greater detail using a scatter plot. The graph below, represents the speed of each target as a cross and shows the spread of speeds at each spring tension.

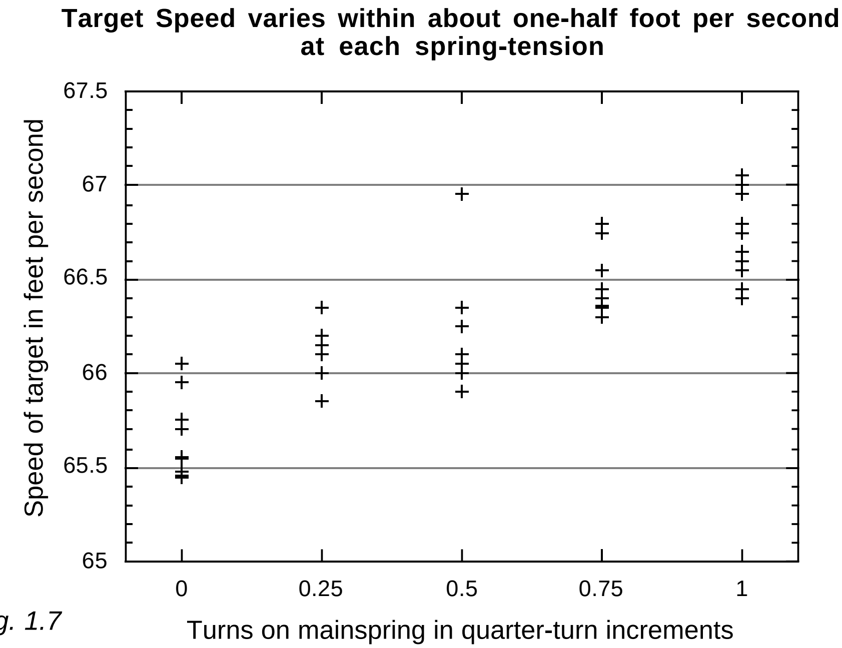


fig. 1.7

Speed readings vary randomly within a range of one-half foot per second. Short of using a second Oehler #55 there is no way to tell if the speeds vary and the chronograph is exactly right, or the other way around (or some of both). This variability persists even if the targets are selected to all weigh the same. Half-a-foot-per-second precision is the best we can do measuring a single target.

TEST 3b. Precision of the ProChrono, small changes

As you use a ProChrono Chronograph to measure the speed of a string of targets you seldom see just one reading. It is far more common to get values which apparently randomly alternate between two numbers, with an occasional detour into clear and recognizable error. Say in a string of ten targets you get nine 64's and one 65 – should you call this 64 or 64.1? And how about half of each? Is it useful to calculate a half-a-foot-per second distinction?

The data graphed to the right were obtained starting with a Pat Trap throwing White Flyers at about 66 feet-per-second. Ten targets were thrown and the results recorded. A quarter turn was added to mainspring tension and ten more targets thrown and recorded. This continued until a span of two full turns on the spring had been measured.

The graphs at the right plot the data in two ways. In the upper figure the common way of expressing average, the arithmetic mean. The speeds of ten targets were summed. (In this case there was no need to ignore any suspiciously deviant readings.) The sums were divided by ten, and the results plotted in figure.

In the lower graph, the speed was determined by inspecting the readings and selecting the most common value, the mode, as the average.

Using the mean, that is making fine distinctions between speeds, leads to a set of numbers which don't make much sense. Are we really to believe, for example, that in two instances the speed went down as the spring was tightened? The graph using the mode, the most common reading, makes more sense.

My decision has been to use the mode, and call the cases which really do vary about 50/50 between 64 and 65 not "64.5" but "64 or 65."

This rule only applies when relatively small changes are made in spring tension, for example when actually setting targets. As detailed in the next test, when big changes are studied, it is the mean which does a better job of summarizing the data.

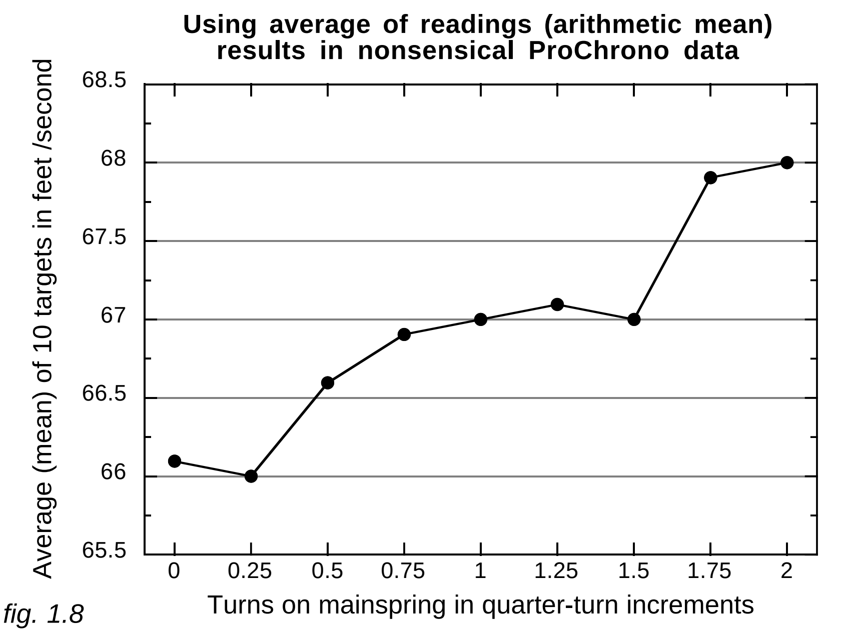


fig. 1.8

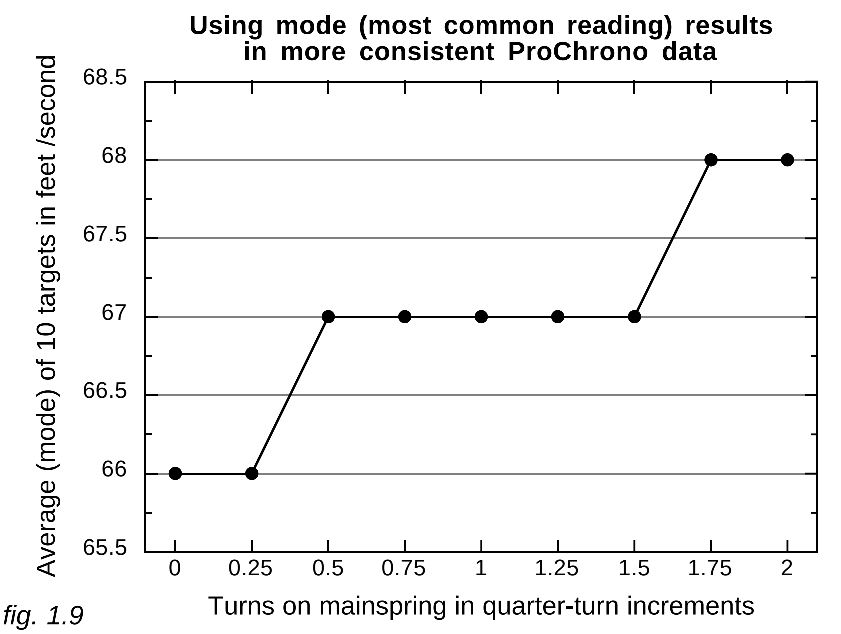


fig. 1.9

TEST 3c. Precision of the ProChrono, larger changes

The breakdown in the correlational relationship between spring-tension and speed which we saw on the previous page is a well-known statistical artifact and occurs with almost any data if the variables are divided into fine enough bits (in that case one-quarter-turn increments of spring-tension). It's only when we have a reasonably wide range of speeds that we begin to enjoy the benefits of throwing all ten targets and doing the work involved in calculating the arithmetic mean. Conditions in this test were the same as in Test 3b, except the trap spring was tensioned in full-turn increments instead of quarter-turn, and the full range was six turns.

The upper graph on the right plots the arithmetic mean of speed *vs* turns on the spring. It shows that a full-turn increase in spring tension produces a 0.9 foot-per-second speed change.

The lower graph plots the mode, and describes a one-foot-per-second change in speed per turn on the spring. Using the mode here throws away some interesting data and leads to a 10% mis-estimation of the relationship.

Comparing the Oehler's data in figure 1.7 with the ProChrono's in figures 1.8 and 1.9 shows that the former is capable of much finer distinctions when small changes are being made.

But now go back and compare figure 1.3 (Oehler's mean over a big range) with figure 1.12 (ProChrono's mean over a similarly big range). In this test the ProChrono is performing even better than the more complicated and expensive Oehler.

I've included the present test to encourage others who might want to replicate, challenge, or extend the data I am presenting in this report. If an investigator is willing to throw enough targets over a wide enough range of conditions, the ProChrono is capable of some very nice science indeed.

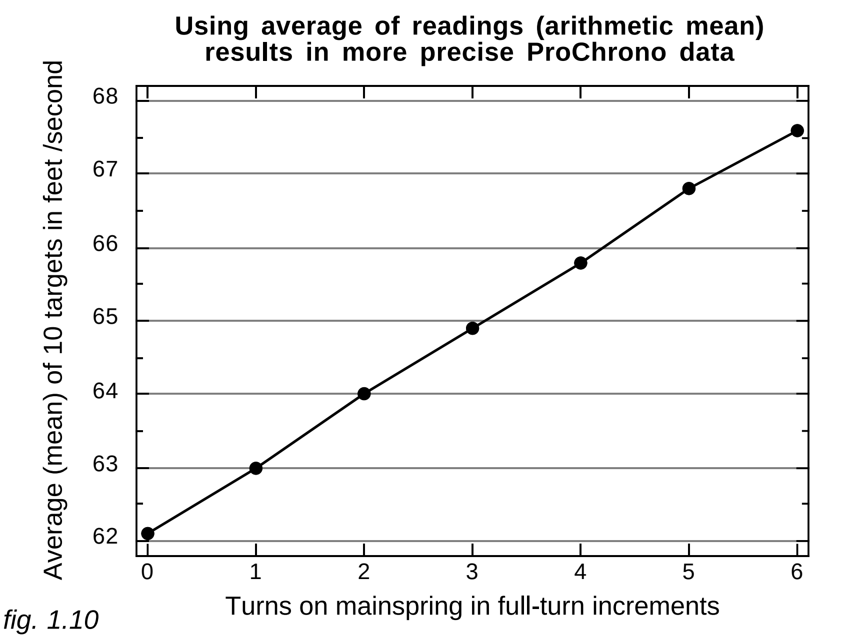


fig. 1.10

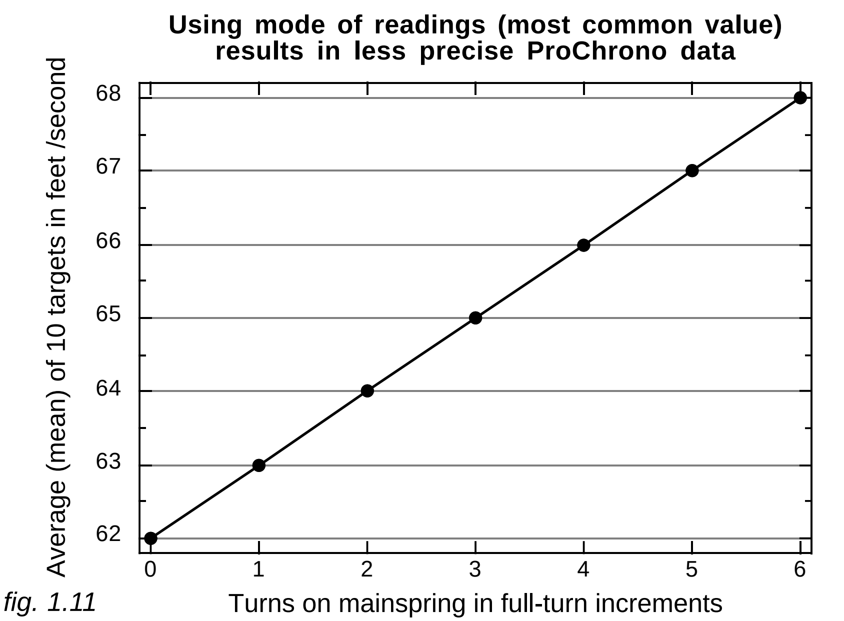


fig. 1.11

TEST 3d. Precison of the Target distance

How sensitive is target flight to spring tension? In the graph below the spring was tightened in 1/4-turn increments and the effect reported by the observer at the 50-yard line. A full-turn difference is clear, but a change of only half a turn can't be reliably discriminated.

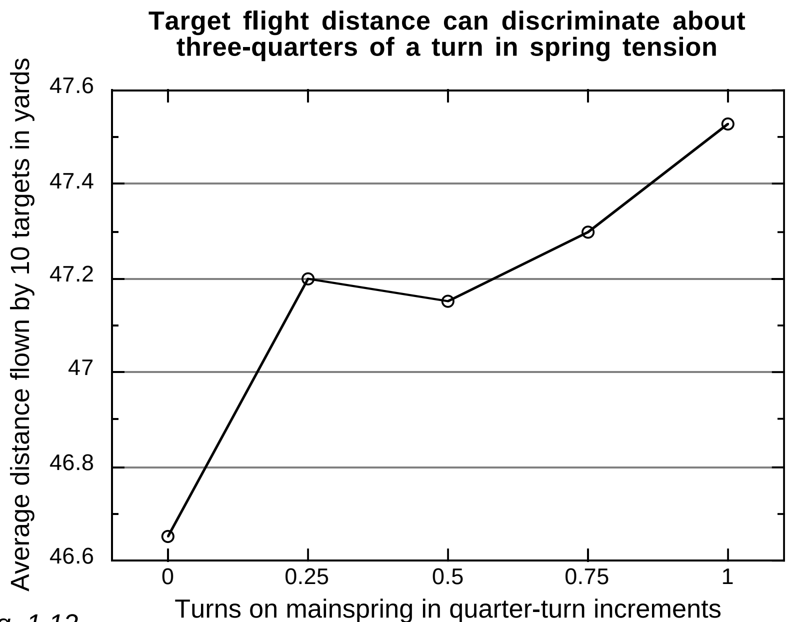


fig. 1.12

This graph represents the same targets as in figure 1.7. The small change in speed between 0.25 and 0.5 turns we saw there has carried through to the target flight. If speed is so well reflected in distance can we say that a slightly faster individual target will go slightly farther? Not really. The data above are averages which dampen out individual deviations; on a target-by-target basis the relationship largely breaks down. The scatter plot of distance *vs* speed shows that there is too much overlap in the readings to say with confidence how far a particular target will fly.

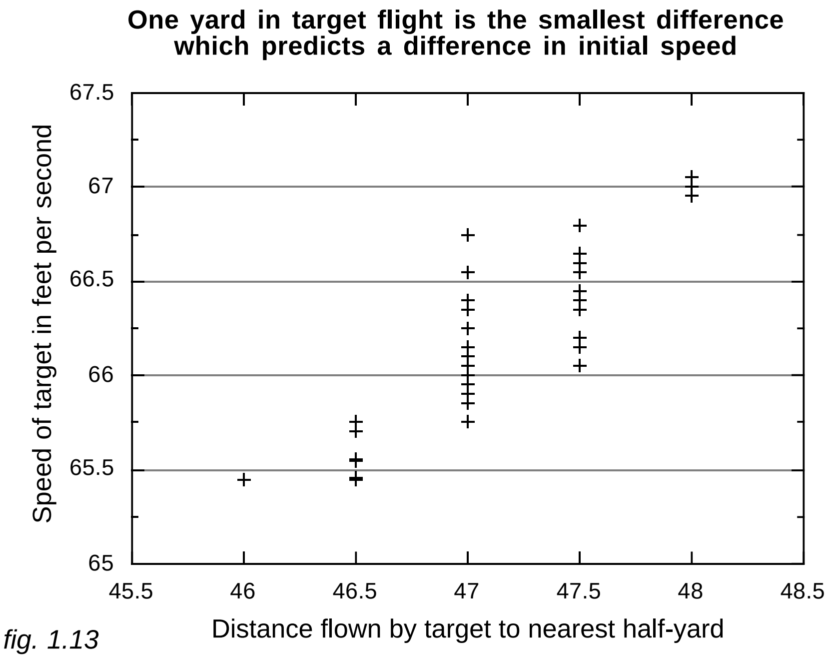


fig. 1.13

Recall the conditions which were used to get this one-foot-per-second accuracy. An observer marked the targets from the 50 yard stake using rules on the ground as a guide. Ten targets were thrown at each setting and the results recorded. Just one warmed-up trap was used, so the angle of flight was always the same and the speed didn't change. There wasn't a breath of wind.

Now consider the less ideal conditions under which targets are usually set. How close can we expect the speeds on two adjacent traps to be? Remove the observer and set the targets from the trap-house – decrease the speed accuracy. Throw fewer targets and use several cold traps set at somewhat different angles – add inaccuracy at each step. Now add even a light breeze and then you can just forget it.

Earlier I promised to explain how it is possible to set a line of traps by eye and then find that speeds "are all over the map." *It's because setting traps in the usual way does not produce all the same target speeds.* Using the kind of care described above can narrow the spread, but the chronograph which tells us that the traps we just set are not all throwing the same-speed targets is not misleading us, it's telling us the truth.

TEST 4a. Setting targets by speed using one trap

There is still one criticism to deal with, the assertion that if traps are set the same speed, the targets don't go the same distance. This test asks the question in the most conservative possible way: "Using a single trap can you produce consistent distances based on target speed?"

Conditions are as before: a Pat Trap set in the #3 notch (about 19 degrees), a dead-still morning, an observer radioing target landings from the 50-yard stake, ten White Flyers thrown under each test condition.

Using the Oehler chronograph a series of ten targets was thrown and each target's speed and distance recorded. A couple of turns were put on the mainspring and the series repeated. Then two more turns, another series of targets.

The chronograph was then removed and replaced, care being taken to put it back the way it had been. The mainspring was loosened and retightened to an indeterminate setting.

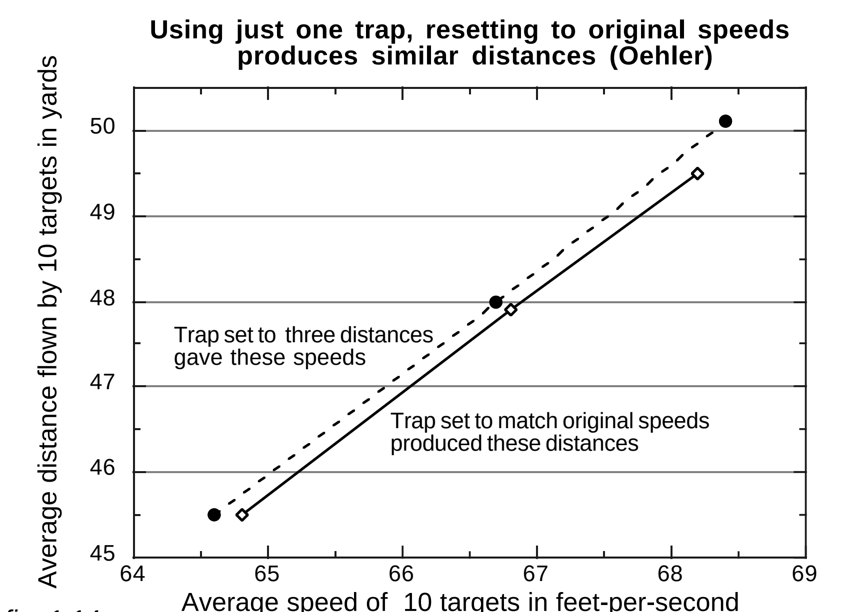


fig. 1.14

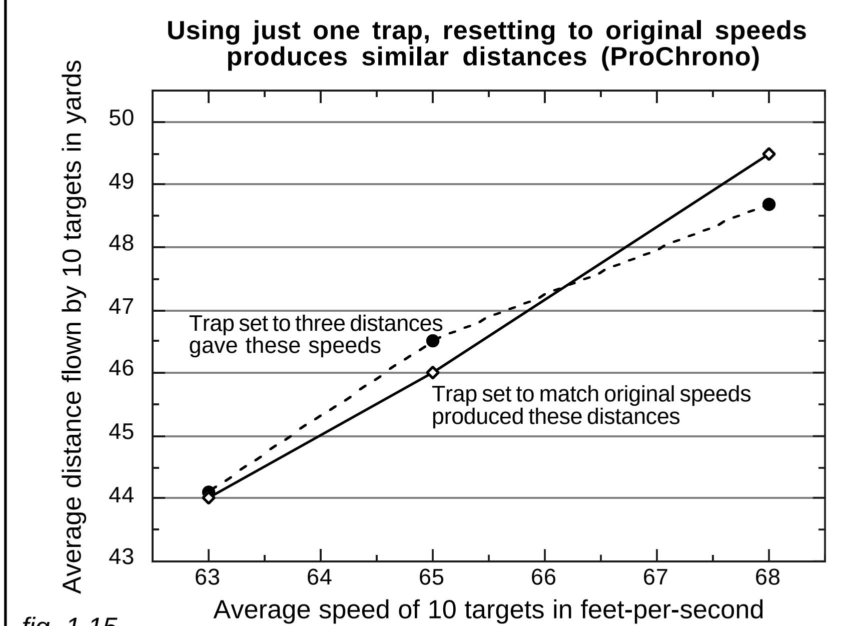


fig. 1.15

Averages were calculated for the first speeds, and the trap adjusted to reproduce each of those original speeds. Then the landing spots of ten more targets at each speed-setting were recorded. The same procedure was followed using the ProChrono.

As figures 1.15 and 1.16 indicate, both chronographs were able to reproduce target distances based on speed. Five of six measurements were within eighteen inches; the maximum deviation from standard was only a yard. There was no difference in the ability of either chronograph to do the job.

TEST 4b. Setting targets by speed 4 traps

Under the by-now standard conditions (perfect weather, 50-yard-line observer) four Pat Traps were set to specific speeds and the length of target flight recorded. Though Traps 1 and 4 couldn't be slowed down enough to contribute data to the slower condition there is enough here to show that the findings from one trap (Test 4a) can be generalized to a multi-trap layout. The largest deviation was one-half yard, which is a good result indeed.

fig. 1.16 **Setting traps to same speeds results in similar target flight (distances in yards)**

Oehler speed	Prochrono Speed	Trap 1 distance	Trap 2 distance	Trap 3 distance	Trap 4 distance
65 feet/sec	64 feet/sec		46	46.	
68 feet/sec	67 feet/sec	49.5	49.5	49.5	50

Contrary to a previously-cited criticism, if you set several traps by chronograph you *do* get consistent target distance.

TEST 5. Measuring speed of 12 traps set by distance

All of the previously reported data were collected under ideal, even unworldly conditions – never any wind, well-tuned and warmed-up traps, no squads itching to get started with the real business of a trapshoot. This test addresses the fourth factor in chronographing: generality. To what extent can all of the foregoing be applied to the practical problem of setting traps for an event?

In July 1998 we used a 48-yard standard to set the twelve traps at the Minnesota State Shoot at Del Tone in St. Cloud. Then we went back and checked the whole line with a ProChrono. I had been the 50-yard-line observer so there was no appearance that I was checking someone else's work.

The table below reports the speed of every target as we checked them down the line. Ten of twelve traps were within one foot-per-second (65 or 66), one was a foot-per-second fast, one was a foot-per second slow. *continued on next page*

Speeds in feet-per-second of twelve traps set to throw targets 48 yards *fig. 1.17*

	Trap 1	Trap 2	Trap 3	Trap 4	Trap 5	Trap 6	Trap 7	Trap 8	Trap 9	Trap 10	Trap 11	Trap 12
Target #1	65	66	65	66	65	65	64	66	65	66	66	66
Target #2	66	66	65	66	65	66	65	65	66	66	66	65
Target #3	65	65	65	65	66	65	64	65	66	67	66	66
Target #4	66	66	65	62	66	66	64	65	66	65	66	66
Target #5	65	75	65	66	65	65	64	65	66	67	66	66
Target #6	66	66	66	64	65	65	64	65	66	67	66	65
Target #7	65	66	65	66	65	65	65	66	66	66	66	65
Target #8	65	66	65	66	64	64	64	66	67	67	66	66
Target #9	65	66	65	64	65	65		65	67	67		66
Target #10	65	66	65	66	64			65	67	67		66
Average	**65**	**66**	**65**	**66**	**65**	**65**	**64**	**65**	**66**	**67**	**66**	**66**

There are two ways to look at the data in this table. Unbelievers will cite these data as proof that chronographs don't really tell you how far a target is going to fly – "the same" targets are not all going the same speed.

I see it differently. But first a caution: the test is seriously, perhaps even fatally, incomplete. There should have been someone at the 50-yard line to recheck target distance. As a result, we can't say if these are "the same" targets or not. This is just one of the ways the pressures of reality – in this case, waiting squads – can prevent us from getting the data we want.

With that caution in mind I will still call these data (provisional) evidence that setting targets by distance is a pretty good, but by no means perfect, way of setting targets to the same speed.

The "Big Question", whether distance or chronographing is a better route to consistent targets, deserves a much better and well-thought-out test than this. It might begin like this:

1) Set all the traps by distance, check them by speed and distance to determine the consistency of speed and stability of the previously set distance.

2) Set all the traps by speed, check them by speed and distance to determine the consistency of distance and stability of the previously set speed.

3) Refine the test based on problems uncovered in phases 1) and 2).

4) Do all of this over again in different conditions of wind.

It is the lack of the above-suggested (and other) data that makes this report a continuing, and perhaps permanent, "work in progress."

Summary of Section 1

I started this section by steering my readers away from the apparent first question about chronographs, their accuracy. (In fact I never have addressed accuracy at all.) Instead I covered the four other questions about chronographs that my ten-year study of shotshell speed and recoil has led me to.

1) **Validity** (Does it really measure target speed?): Test 1 and 2a established that both the Oehler #55 and the ProChrono read the speed of targets to a useful extent. Test 2b confirmed that speed is a reliable predictor of the length of target flight.

2. **Precision** (What's the smallest difference in readings I can count on?): The series of tests 3a-d led to the following conclusions: In setting targets the ProChrono is best read to the nearest whole number. The Oehler is capable of finer distinctions as is the ProChrono when range of readings is extended. In measuring target flight precision of half-a-yard in distance is about right.

3. **Repeatability** (Does using it give consistent target flight?): The high repeatability of speed and distance is clear throughout all the experiments; the tests which addressed this specific question were 4a-b and Test 5. As may be inferred from the rest of the data, target distances set by chronograph are highly repeatable.

4. **Generality** (Do the results apply across different brands of traps, targets, weather conditions?): Test 5 touched on the topic of generality which will be covered in greater detail in the following segment. Section 2 will cover a) important controls which must be observed to get the kind of consistent data I have presented, b) details involved with different brands of traps and targets, and c) other aspects of the general confusion which is slowing progress in getting chronographs widely accepted (or rejected).