RECOIL IQ

BY ADVANCED PRECISION DEVICES

USER GUIDE AND EXAMPLE USES

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Introduction

Congratulations on your purchase of the Recoil-IQ by Advanced Precision Devices. The Recoil-IQ is a scientific instrument that greatly enhances the ballistic laboratory of the serious shooter. By measuring the recoil event as transmitted to your shoulder you will gain the knowledge to improve your accuracy, comfort, repeatability, follow-up shot placement, reduce cycle time, and much more. It will improve your component and ammunition selection abilities to optimize for every scenario. The recoil IQ will help you select optimal muzzle brakes, recoil pads, buffer springs and carrier group components for given bullet weight, powder charge, barrel length, etc. combinations. Not only will the data enhance your performance as a shooter, but will shed light on the mechanics of the firearm itself – revealing dynamic events occurring at the sub-millisecond level that are not distinguishable by the user. This knowledge will improve your shooting performance and cut the guesswork from firearm design and optimization.

Recoil-IQ Operating Principle, Specifications, and User Requirements

Warning!: The Recoil-IQ is designed for use on a firearm held ONLY against the shoulder. It is a sensitive instrument designed specifically to measure forces transmitted to the human shoulder. The human shoulder is a compliant biological structure that dissipates recoil forces over time. Attempts to measure recoil while holding the buttplate against a rigid surface such as a tree, brick wall, or vehicle will result in massive forces that may destroy the Recoil-IQ and potentially even destroy your firearm. (Trust us on this).

The Recoil-IQ Is a high performance scientific laboratory grade recoil recoil measurement sensor that mounts to the stock of a rifle or shotgun. It is a complete package seamlessly integrating a purpose-built force sensor, data acquisition system, and software interface working together to provide data thus far unavailable to the serious firearm user. Until now, recoil force data has been available only to organizations with the means to develop and invest tens of thousands of dollars into large, clumsy, bench mounted systems that use off-the-shelf force sensors, expensive commercial signal conditioning data acquisition systems generating mountains of data to filter, postprocess, and evaluate manually. Unfortunately, the publicly available data generated from these systems only tells a partial story of recoil since they use a bench mounted frame to absorb the recoil, and not the shoulder of a shooter. The Recoil-IQ tells the entire story as it integrates the entire firearm/shoulder system. It automatically detect the recoil event, records it, and plots the force over the entire duration of the recoil event. The Recoil-IQ specifications are shown in Table 1.

Table 1: Recoil-IQ operating specifications. (Specifications are liable to change at any time with updates to Recoil-IQ, or new Recoil-IQ models)

Recoil-IQ Specification	Value
Sensor Material	High Strength Aluminum Alloy
Full Scale Measured Force (lbf)	400
Maximum Recoil Force Without Damage (lbf)	550
Calibrated Accuracy Min. (% of Full Scale)	+/-1.0%
Resolution (lbf)	0.095
Sampling Rate (samples/second)	4000
Samples Per Shot	500
Shot Detection Duration Window (seconds)	0.125
Sensor Weight (lbf)	1.0
Sensor Thickness (inches)	1.12
Sensor Length (inches)	5.0
Sensor Width (inches)	1.8
Sensor Cable Length (ft)	5.5
USB Cable Length (ft)	5.5
Threaded Insert Outer Thread Type	3/8-16
Threaded Insert Inner Thread Type	10-24
Threaded Insert Spacing (inches)	3.125

To use it the user must simply install the software on their computer that has a windows 10 (or newer) operating system equipped with the specifications shown below().

Table 2: User PC System Requirements (system requirements are subject to change)

User PC System Requirement	Value
Operating System	Windows 10 or newer
RAM	8+ GB
CPU	Dual Core or Better
USB	2.0+
Mac OS Support	None. Future Versions Will Support OS
Firearms Included	None
SKU	AD-BK-0001

Component Overview

The Recoil-IQ consists of a high performance recoil sensor, a Sensor Control Module (SCM), and User Interface Software (Figure 1). The recoil sensor attaches to the firearm using either the velcro strap, or by mounting directly using screws. Both mounting strategies are outlined in this User Guide. The device is device is designed for ultimate ease of use and has only one button which is on the SCM and can be used to reset the device to facilitate setup.

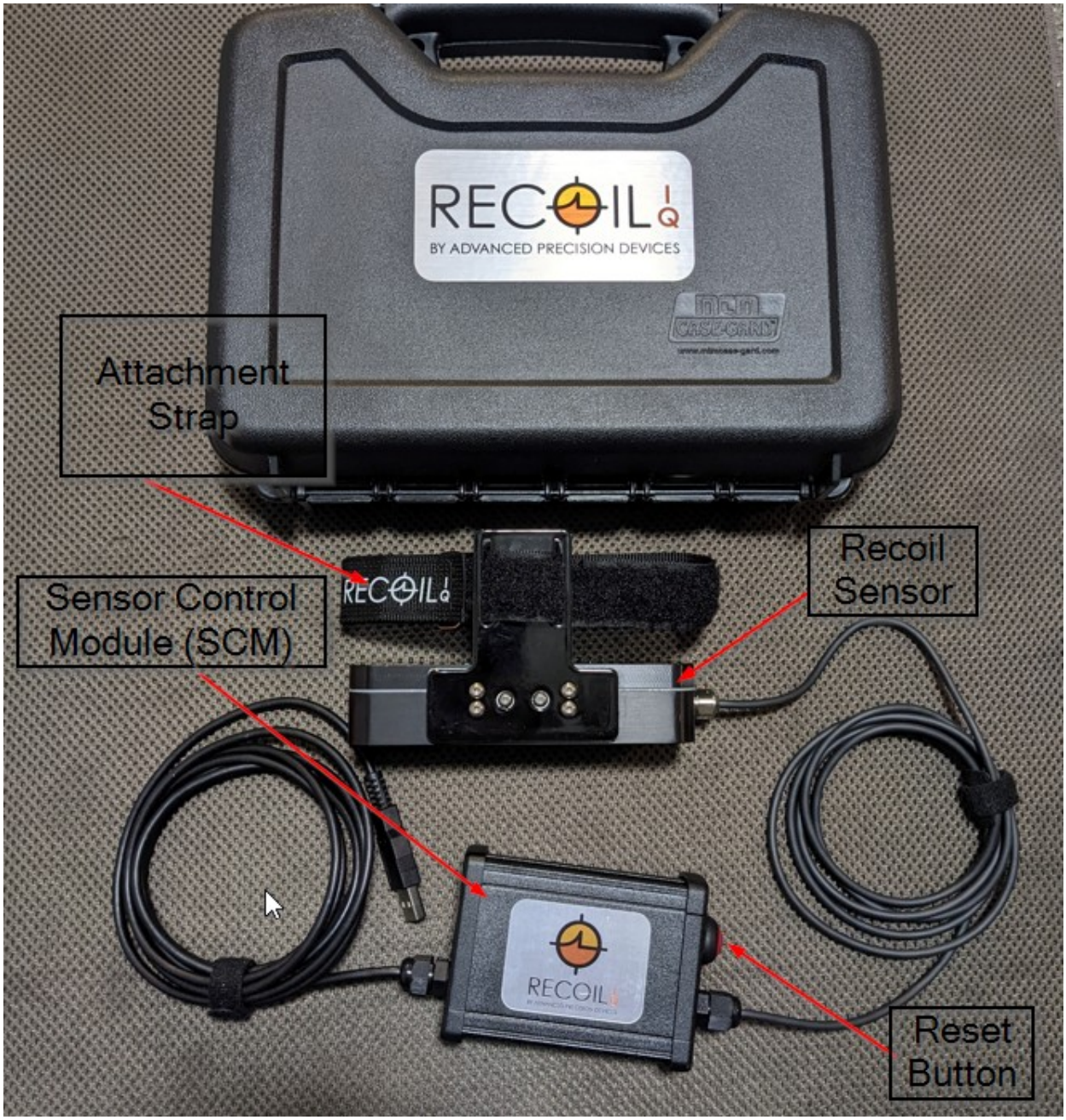


Figure 1: Component Overview

Installation Methods

Quick-Strap

In Quick-Strap mode, the Recoil-IQ is placed against the buttplate of the firearm. The user may orient the cable upward or downward depending on their preference. Securely cinch the Recoil-IQ to the stock using the velcro straps (Figure 2). Note, this attachment mode will increase the pull length by just over one inch - the thickness of the Recoil-IQ.

Figure 2: Quick-Strap Attachment Method

Be sure to make sure the Recoil-IQ is well centered from top to bottom of your stock. Also make sure the Recoil-IQ is well centered from side to side on your stock (Figure 3).

Figure 3: Mount Recoil-IQ well-centered from side to side.

This mounting style relies on the strap to hold the Recoil-IQ to the firearm. Make sure the strap is snug. A properly mounted Recoil-IQ strapped on should in theory be snug enough to hold the firearm on while hanging upside down (Figure 4).

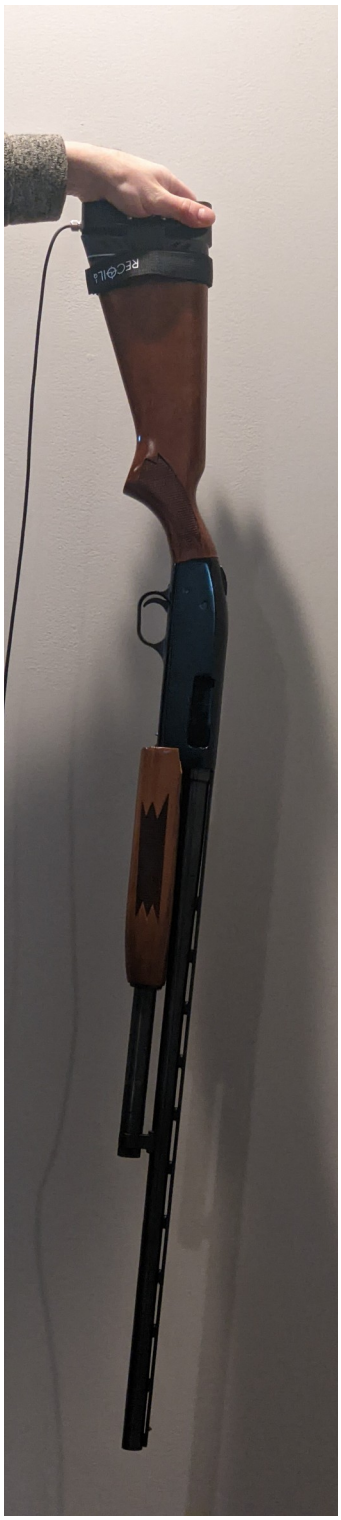


Figure 4: Recoil-IQ with well-mounted straps (for demonstration only, do not attempt)

Notes on Quick-Strap Method

The quick-strap method is the most popular, fastest, and easiest way to acquire recoil data from your firearm. In our experience, the Quick-Strap method is the optimal attachment method for 90% of customers. In firearms that have recoil pads the quick-strap method places the ***recoil pad*** between the firearm and the Recoil-IQ and not against the shoulder where it normally is. This method is the best configuration for measuring the effectiveness of a recoil pad, muzzle brake, buffer system, or as it measures the force at the shoulder side of the recoil pad (where you would feel it), and not the firearm side of the recoil pad. Obviously, with the recoil pad against the shoulder the recoil feels different because the Recoil-IQ is flat aluminum and a recoil pad can be a multitude of shapes and material compostions. A user can also bolt the recoil pad to the back of the Recoil-IQ while in Quick-Strap mode, but this will produce a slightly different recoil signature than with the recoil pad on the firearm side of the Recoil-IQ. This is for several reasons. With the recoil pad on the shoulder side of the Recoil-IQ, the Recoil-IQ is measuring the raw force on the firearm side of the recoil pad. This force is a dynamic combination of elastic, viscous, and inertial forces which are different than on the other side (shoulder side) of the recoil pad. The curious user can use both methods to evaluate the way that their recoil pad acts as a mechanical filter for reducing, filtering, and changing recoil forces as they are transmitted through the recoil pad. Ultimately, if you want to evaluate what is transmitted to your shoulder through a recoil pad, placing the Recoil-IQ behind the recoil pad will most optimally collect that information. The shoulder side of the Recoil-IQ has threaded inserts set at the popular 3 1/8" bolt spacing that accept 10-24 fasteners. If your recoil-pad does not have standard 3 1/8" spacing, the user may contact Advanced Precision Devices to discuss a custom adapter plate, or purchase a recoil pad with the standard 3 1/8" spacing.

Figure 5: 3 1/8" buttplate hole spacing as shown on stock recoil pad removed from firearm.

Hard Mount

Hard mounting allows the user to attach the Recoil-Iq to the firearm in a more semi-permanent manner and is best used to determine the raw forces entering the recoil pad, which are then absorbed inertially, viscously, and elastically before being transmitted to your shoulder. Again, as mentioned above, the Quick-Strap method is the optimal method for 90% of users, but the hard mount method is provided as an option for the curious user.

The hard mount method involves bolting the Recoil-IQ to the firearm. The Recoil-IQ is equipped with 3 1/8" holes to bolt directly to a 3 1/8" hole pattern. This is a very common hole pattern, but may not fit on your specific gun. Adapter

plates can be made to adapt the recoil IQ pattern to fit on other patterns. Please contact Advanced Precision Devices to discuss a custom stock adapter plate. To do this:

Confirm whether your stock has a 3 1/8" buttplate hole spacing. Figure 5 shows a photo of a factory recoil pad with a standard 3 1/8" pad spacing. This recoil pad will fit on many firearms, but not all of them.

Warning!: The following hard-mount process should only be attempted by a gunsmith or a very capable firearm tuner. Stripping a screw head, scratching your stock, or damaging a stock, recoil pad, or even the Recoil-IQ itself, are all possible outcomes of attempting the following modifications to a firearm. Advanced Precision Devices is not responsible for any damages or harm from attempting this.

Once you have confirmed 3 1/8" hole spacing, carefully remove your recoil pad or buttlplate using a gunsmith or a responsible and careful adult. If desired, the sideplates and strap can be removed using a 2mm allen key – only remove the four fasteners bordered in red (Figure 6), the other two fasteners are environmentally sealed and if removed could compromise or destroy the Recoil-IQ. After the sideplates are removed, reinstall the four fasteners to keep them from getting lost, and to keep debris from fouling the holes. It is not absolutely necessary to remove the sideplates and straps for hard-mount, but many users prefer it. Finally, remove the threaded inserts from the back of the Recoil-IQ. Keep these inserts nearby for reinsertion.

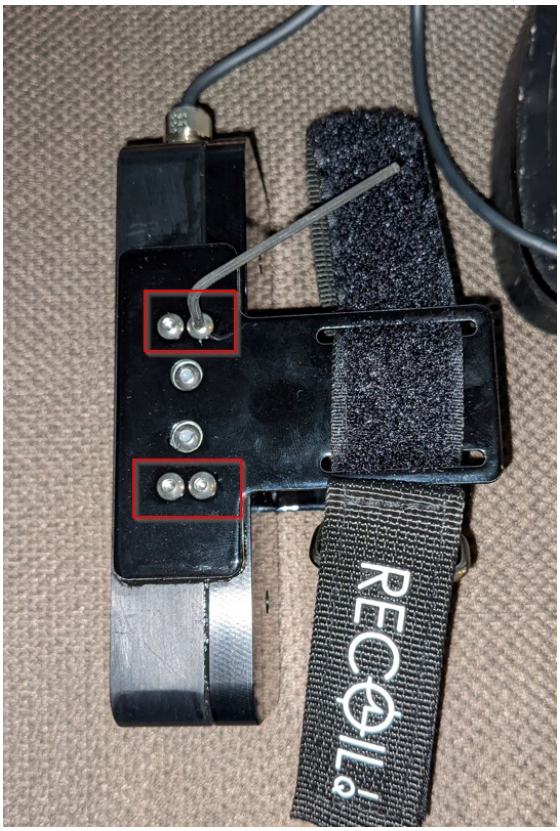


Figure 6: For Hard-Mount method, the sideplates and straps may be removed by removing screws bordered in red in this image. Replace the screws after the sideplates are removed to avoid losing them, and to keep debris out of the exposed holes.

Having Removed the Threaded inserts, study the details regarding the mechanics of hard mounting the Recoil-IQ (Figure 7). The threaded inserts must be removed so that screws can be inserted. The diameter of the Thru-hole through which the screws insert is 0.195;. The minor diameter of the threaded hole for the threaded insert is 0.307”. This means that whatever screw you select must have threads no greater than 0.195” in major diameter, and with a head no greater than 0.307 in diameter. If the screws you reused from the firearm are appropriate, use them. If not, then find a suitable screw. The screw should extend into the stock the same distance as the stock screw. Select your screw appropriately.

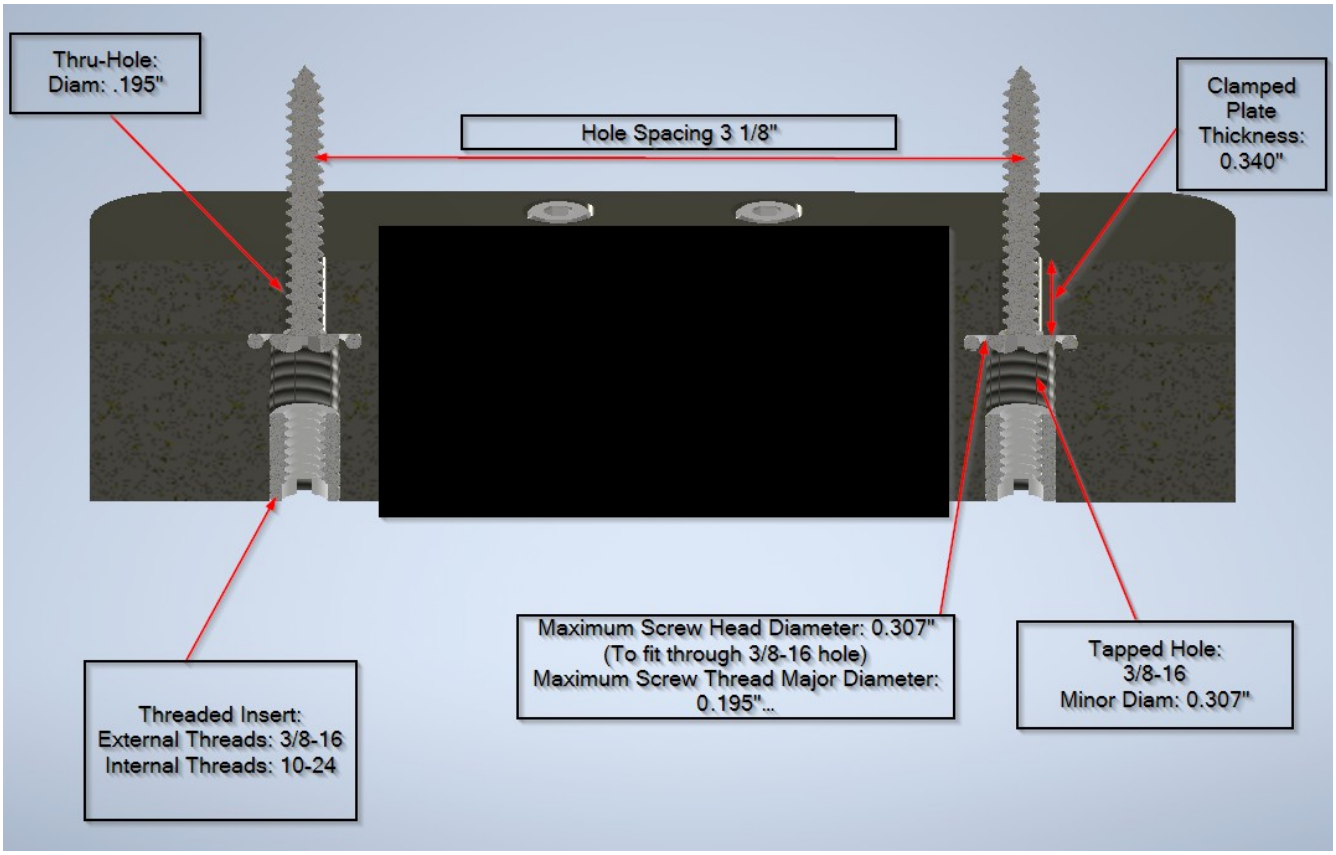
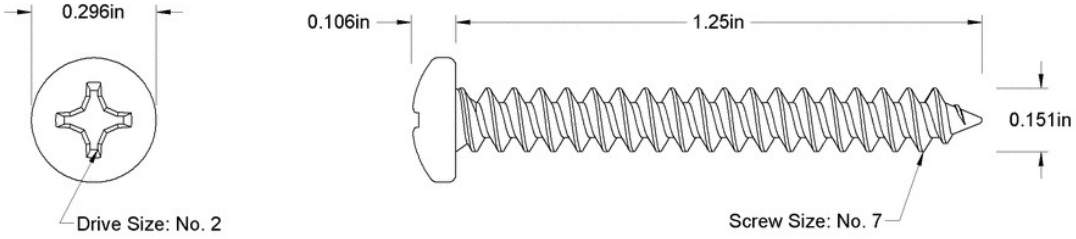


Figure 7. Cross section of Hard-Mount screws and threaded inserts.

The screw shown in the manual figures is the model shown in Figure 8. It may or may not be appropriate for your application but we have found decent success with it. Use caution when selecting a screw. A good screw will meet the dimensional requirements without being much larger or much smaller than the original screws. Ideally the factory screws should be used if possible, but they will not always be sized to fit. It is generally good practice to use a screw that is slightly smaller thread diameter than the stock screw because it will be easier to screw in, and you do not want to have any trouble removing the screw from once you want to unmount the Recoil-IQ. The right screw should have the same pitch as the original. The user should understand that if they use a screw that has a different pitch than the factory screw then the threads will be cutting a new path into the stock.



Drill Bit Size: No. 30 (0.1285in)

Approximate Threads per Inch: 16

Maximum Drilling Thickness: 0.025in

McMASTER-CARR® CAD
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Information in this drawing is provided for reference only.

PART NUMBER 90190A178

Phillips Rounded Head Screws for Sheet Metal

Figure 8: Example Hard-Mount Screw that fits through Recoil-IQ

Gently and carefully attach the Recoil-IQ to the firearm (Figure 9). Tighten until gently snug. Do not under any circumstances overtighten. If you overtighten and strip a screw head trying to remove it then you may either have to damage the firearm or the Recoil-IQ to remove it. Further, it is possible that the Recoil-IQ screw thread will have identical threads to the factory screw, so by gently tightening you will deform and stress the stock material minimally as it screws into the stock. Further, the Recoil-IQ is a scientific instrument and it and the gun should be handled more carefully and gently than during normal usage. Further, the fact that the Recoil-IQ works very well in quick-strap mode, is proof that it does not need to be screwed on to the stock with great force in order to perform well.

Figure 9: Hard Mount Screw Insertion

After both screws are installed, reinstall the threaded inserts. Install them just far enough so are recessed slightly into the sensor (Figure 10). Do not thread them deep into the sensor because if you do, the insert could push with large force on the sensing component of the sensor and you could cause damage to the Recoil-IQ. Once installed on the recoil-IQ, a recoil-pad can now be installed on the shoulder side of the Recoil-IQ.

Figure 10 Threaded inserts installed until just recessed below surface.

After the inserts are installed you are ready to either intall a recoil pad or begin shooting with no recoil pad. Since the threaded inserts are 10-24 internal threads, you need to use 10-24 fasteners to install your recoil pad. Additionally, the hole spacing on the threaded inserts is 3.125″ so only a recoil pad with that mounting hole pattern will work. When you select your 10-24 screw, **it is critical that the screw does not extend deep into the hole and push with great force on the wood screw holding the Recoil-IQ to the stock. If this happens it can destroy the Recoil-IQ. Best practice is to select a screw that engages only the length of the threaded insert (3/8″ long) or less. Meaning if your recoil pad is 1/4″ thick, then you should select a screw that is between 1/2″ and 5/8″(Figure 11).**

Figure 11: Recoil Pad Attached using 10-24 fasteners. Note fastener length protruding beyond the surface of the recoil pad is approximately 1/4". That is plenty of length to engage the threaded inserts in the Recoil-IQ. Screwing in longer screws could bottom out on the wood screw and destroy the Recoil-IQ.

Alternative Hard Mount

There are numerous styles of stocks with many different bolt spacings. In many situations where the existing stock doesn't have a 3 1/8" bolt spacing, an adapter plate can be bolted directly to the stock, and then the Recoil-Iq can be bolted directly to the adapter plate. Similarly, a custom adapter plate could be made to adapt a recoil pad without 3 1/8" bolt spacing to fit on the shoulder side of the Recoil-IQ Please contact Recoil-Iq for questions regarding alternative hard mount and custom adapter plates. Experienced and capable users may create their own adapter plates at their own risk.

Software Installation

With the Recoil-IQ attached to the firearm visit the website for Advanced Precision Devices (https://www.recoiliq.com/) and download the software. Install the software. The minimum system requirements are show in Table 2.

Software Guide

Firearm Configuration

Open the software and connect your Recoil-Iq. To use the software you must read and agree to the Recoil-IQ safety agreement. Once connected click on the Firearms Tab and click +Add New (Figure 12).

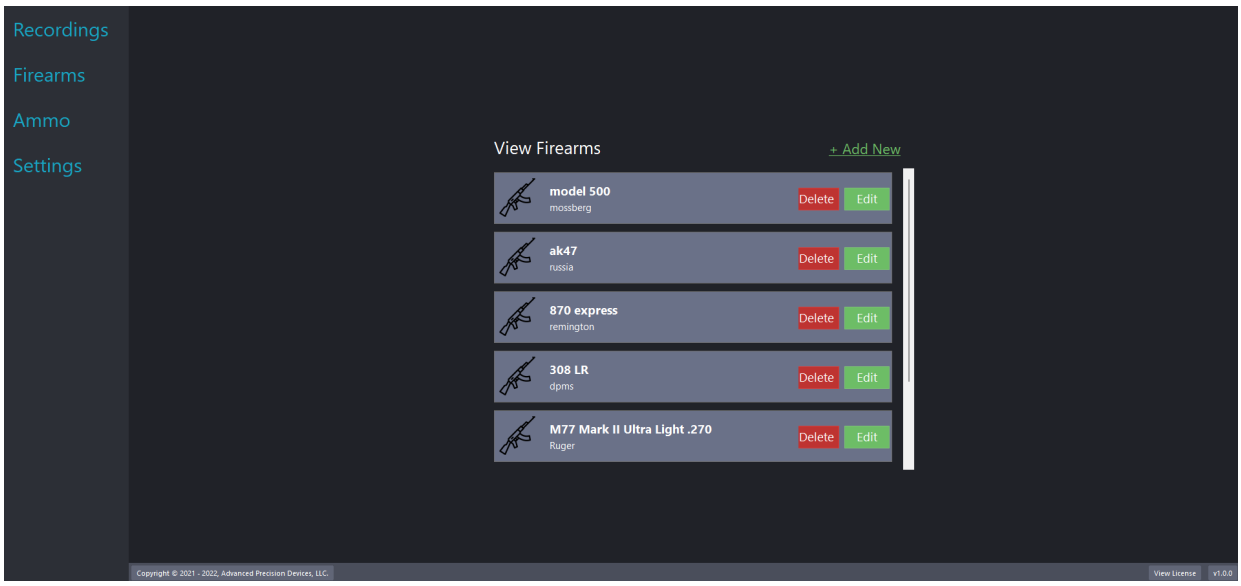


Figure 12: Recoil-IQ Software Firearm Configuration

Fill out the Details for your firearm and click Add Firearm(Figure 13).

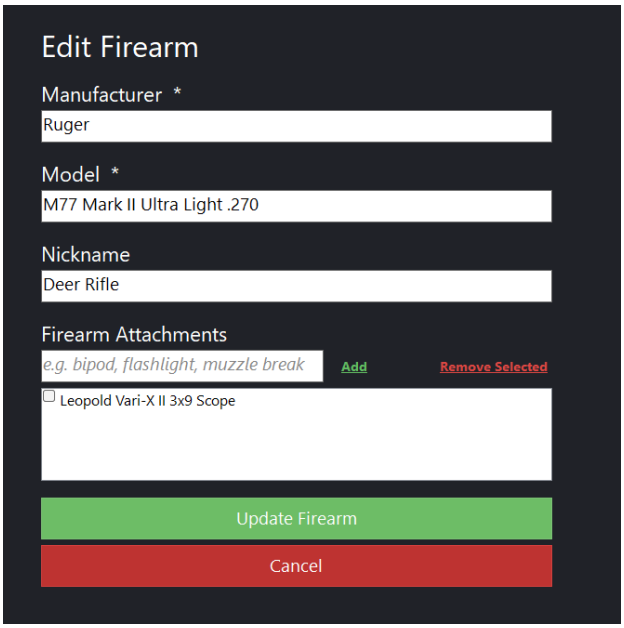


Figure 13: Firearm Configuration Details

Ammo Configuration

Next Click on the Ammo Tab and Click +Add New (Figure 14).

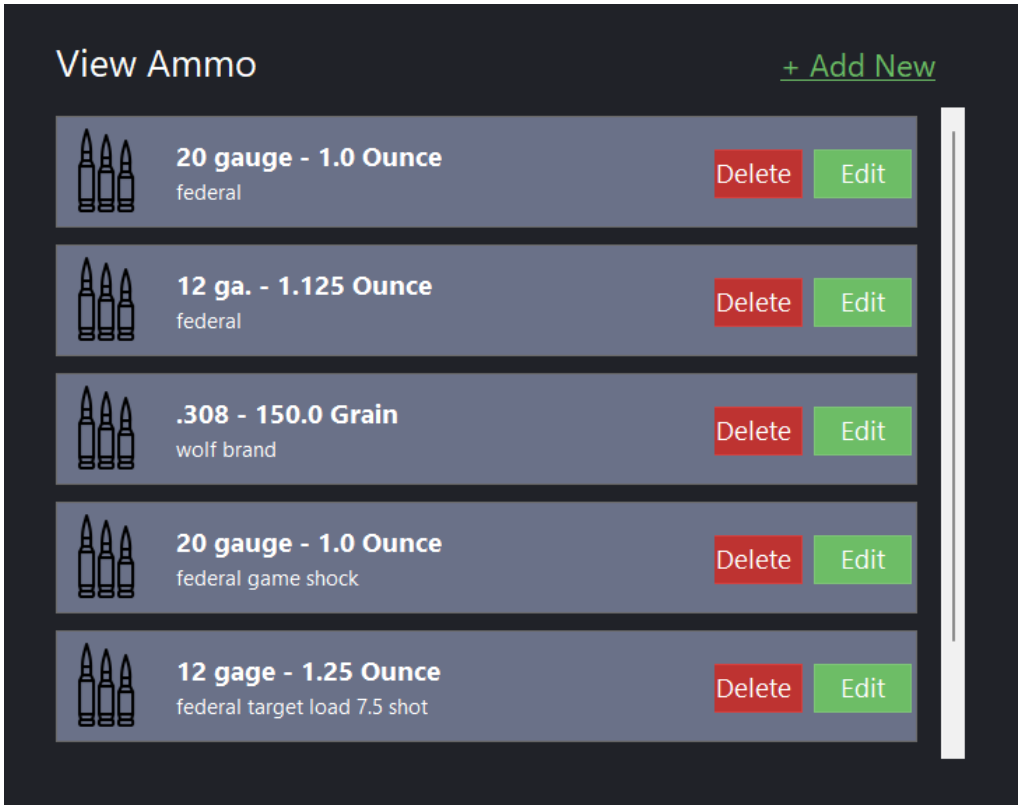


Figure 14: Ammo Configuration

Fill out the Details for your Ammo and click Add Ammo (Figure 15).

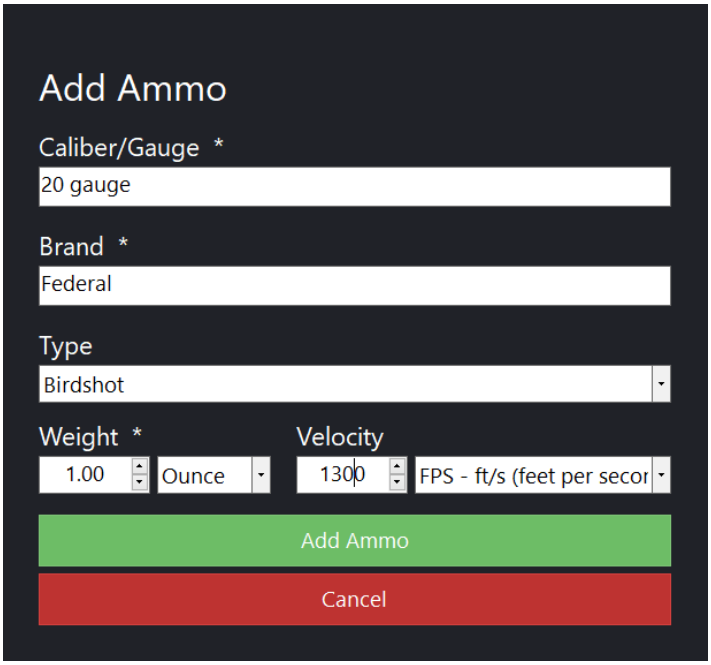


Figure 15: Ammo Configuration

Now you have configured your firearm and ammunition. It is time to connect the device and begin data collection. Plug in the Recoil-IQ into your computer. Click the Recordings tab, the click + Add New (Figure 16).

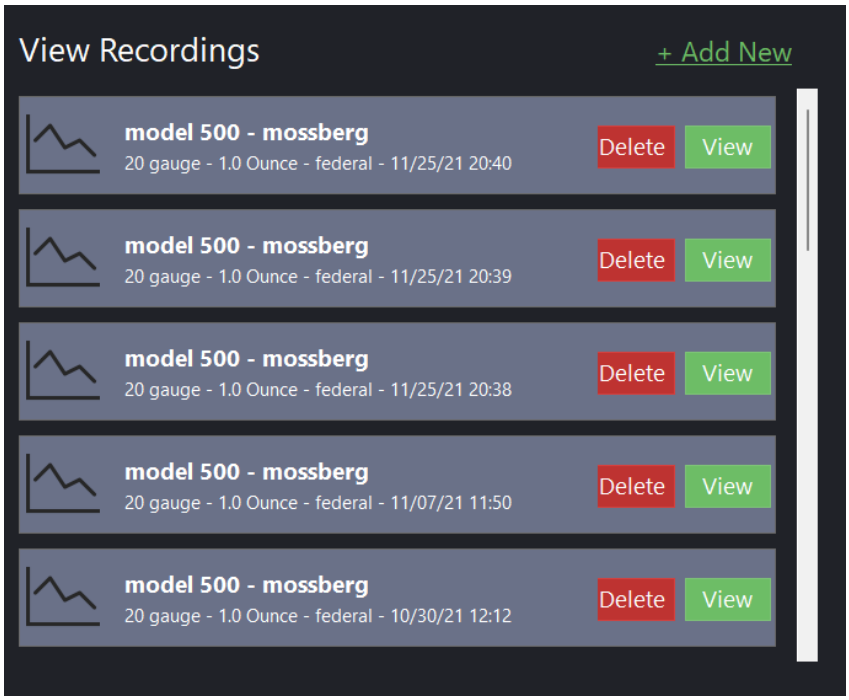


Figure 16: Connection and Recording Setup

Then click Connect. If the device does not connect, then make sure the USB connector is plugged into the computer. If the device still does not conect, press the reset button on the Sensor Control Module (SCM) and press Connect again. After a few seconds, the Recoil-IQ will connect to the software (Figure 17).

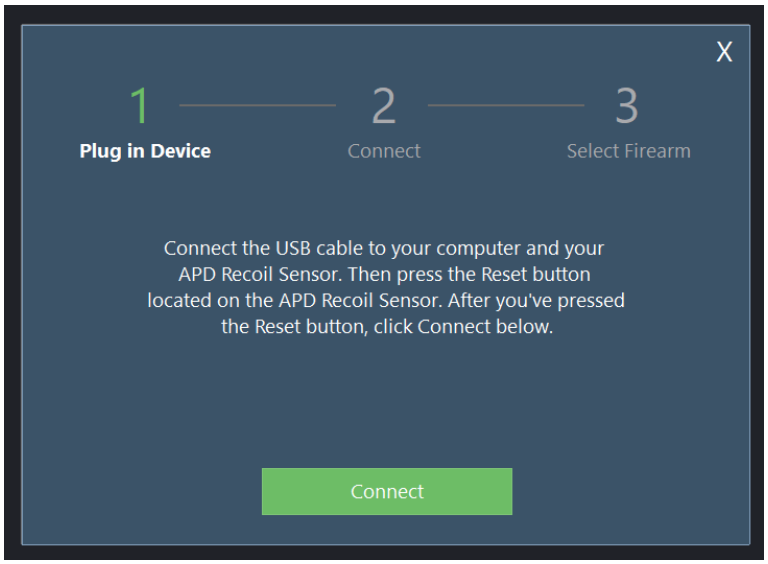


Figure 17: Connect Dialog Box

Once connected, select the appropriate firearm and ammo configuration for this test and press Finish and Start Recording (Figure 18).

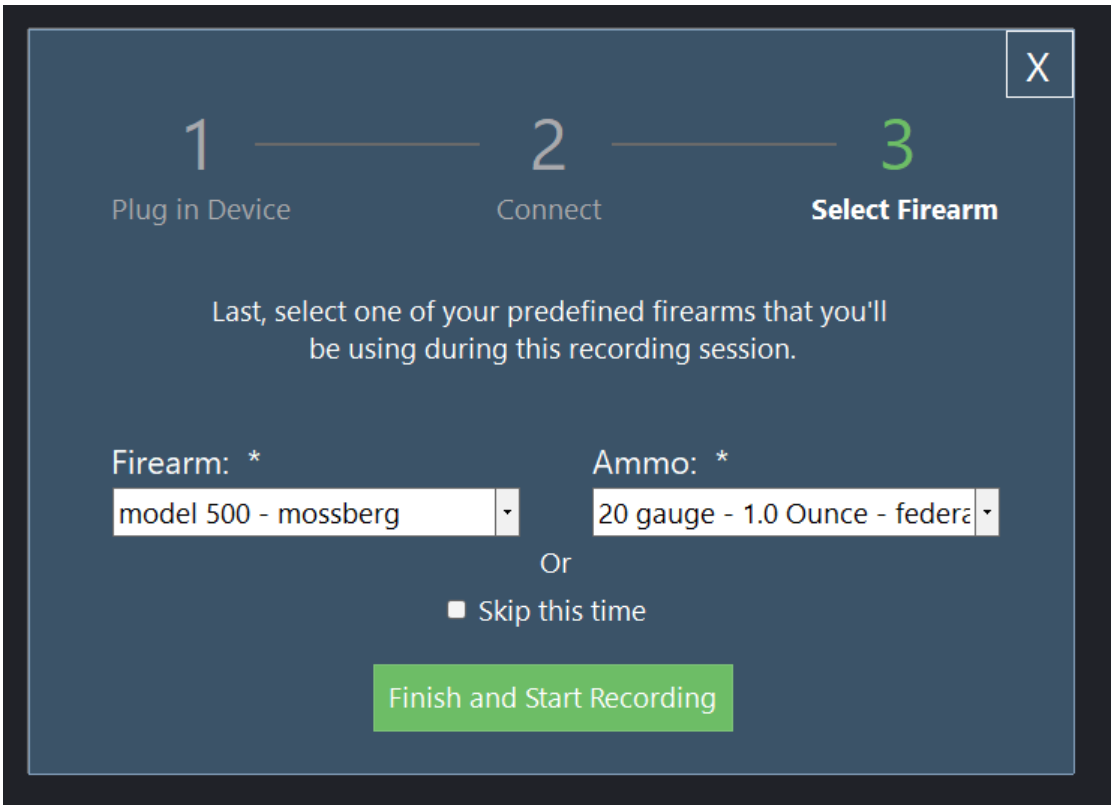


Figure 18: Select Firearm and Ammo Configuration

Data Collection

Notice: The Recoil-IQ is an extremely sensitive sensor equipped with signal amplification and conditioning to measure and record tiny electrical signals from the recoil sensor. The presence of phones, electric motors, current sources, and other sources of electrical noise must be removed from the proximity of the Recoil-IQ to avoid signal contamination. Turn off phones or place at least 10 feet from Recoil-IQ. Turn off running vehicles and other electrical devices except the computer used for testing – make use of the usb cable and sensor cable to maintain a few feet of distance from the test computer.

Having done this, you are ready to start collecting data. **Observing all firearm safety practices according to but not limited to the Advanced Precision Devices safety agreement, local laws, and common sense, place the firearm against your shoulder for firing.** Be careful to place the firearm against your shoulder slowly, holding into your shoulder with normal firmness. The Recoil-IQ detects the fast and sharp forces unique to a firearm recoil and if you jostle the Recoil-IQ sharply into your shoulder it may detect a false shot. You may begin shooting. The Recoil-IQ can detect one shot every two seconds. Faster rates of fire may result in failure to detect shots. The software will collect as many shots as you want, but Advanced Precision Devices recommends approximately 4-12 shots to avoid overcluttering the graph. Every time you shoot, the force data will plot on the graph. **Once you have collected the shots as desired, make your firearm safe, checking the action and magazine to ensure it is unloaded, and press Finish and View Results (Figure 19)**. The results will be shown with Peak Force, and Shoulder Impulse. The peak force is the maximum force reacted by your shoulder during each recoil event. The Shoulder Impulse is the total impulse absorbed by your shoulder during each recoil event.

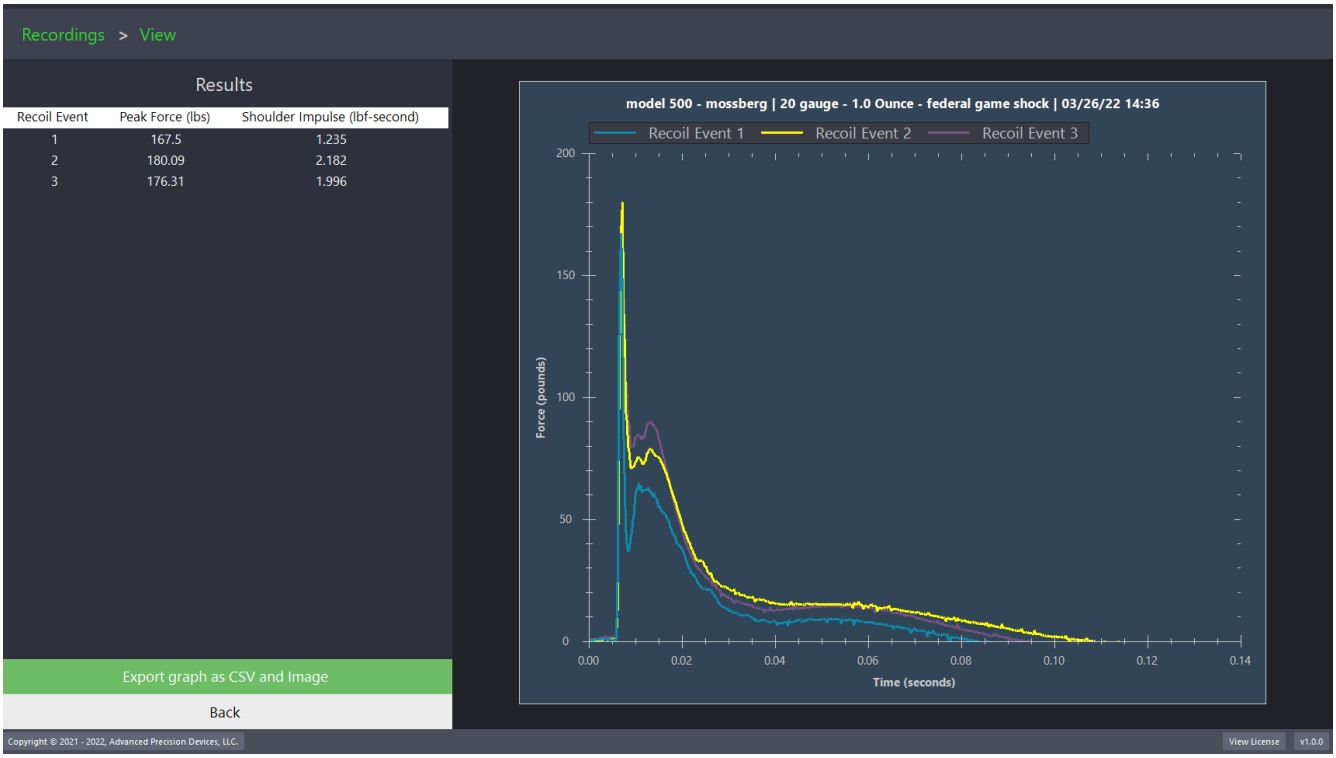


Figure 19: Typical Recoil Results with CSV export option.

If desired you can export the collected data as a CSV file and an image for further analysis.

Interpreting Some Typical Results

This section shows several typical test scenarios and some results with discussion.

Recoil Pad Testing

Every firearm, ammunition, and user combination will produce a different recoil pattern and perceived discomfort is both a function of peak force and total impulse. Non-automatic firearms will usually have a shorter recoil signature and a peak force that is sustained for a longer duration than an otherwise identical automatic weapon of the same caliber. The results below show the difference between a 20-gauge pump action shotgun using 7 ½ shot with 7/8 oz shot, modified choke, and 22″ barrel. The first three shorts are taken using the only the factory recoil pad with the Recoil-IQ mounted in Quick Strap mode (Figure 20). The next three shots are taken using slip-on recoil pad from a major firearm accessories manufacturer.

Figure 20: 20 gauge pump shotgun with factory recoil pad

The recoil results from the factory recoil pad are shown below in Figure 21.

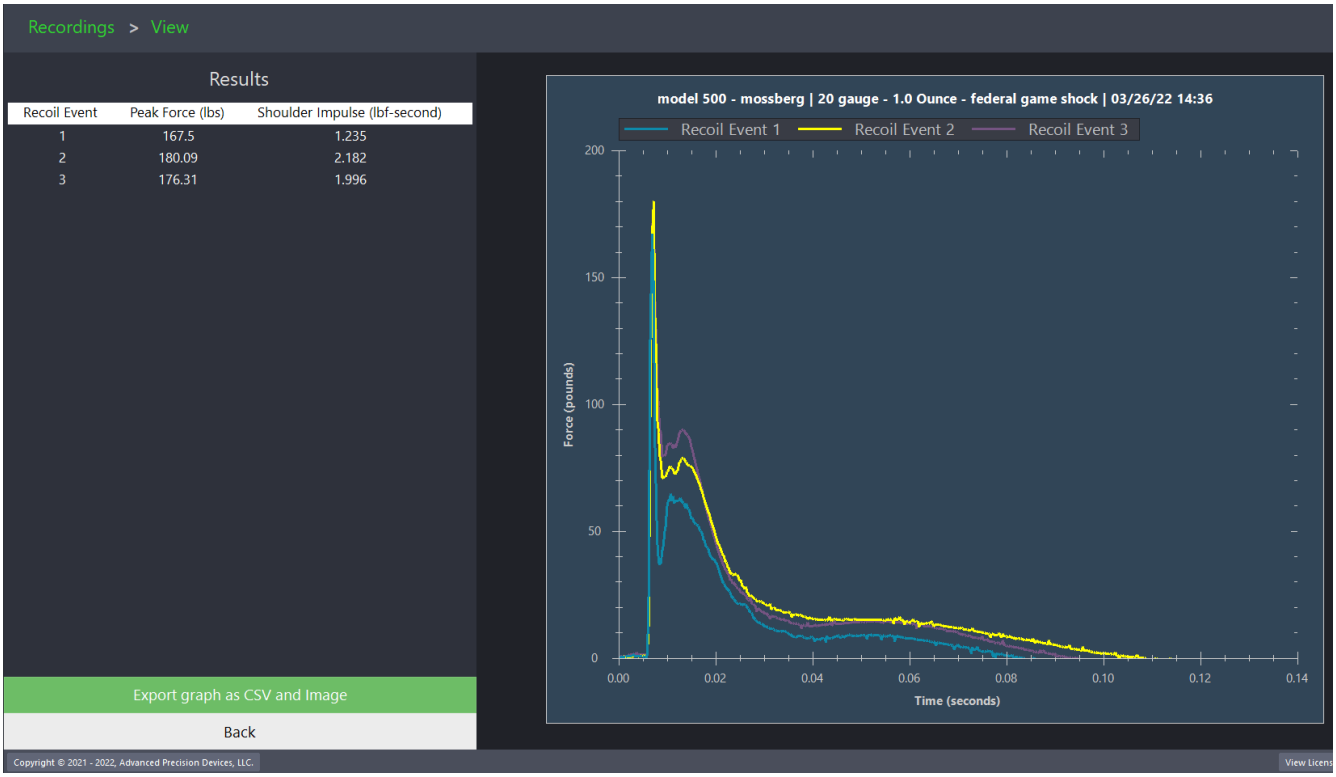


Figure 21: 20 gauge with factory recoil pad used in Quick Strap mode

The next group of results show the same firearm, user, and ammunition, but with a premium recoil pad from a major accessories manufacturer claiming reduction in "felt recoil" of up to 70%.

Figure 22: 20 gauge shotgun with premium aftermarket recoil pad

The results from the factory recoil pad are shown in Figure 23.

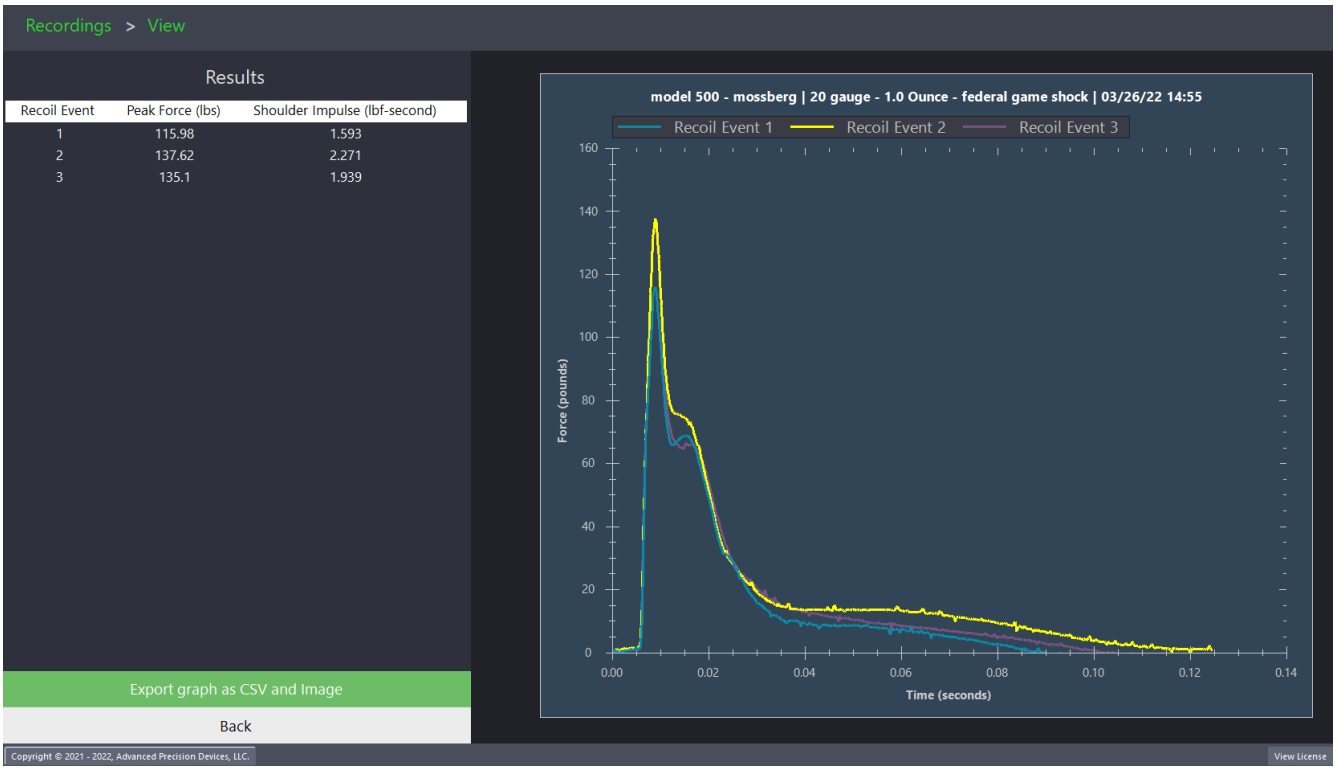


Figure 23: Recoil Signature from 20 gauge using premium aftermarket recoil pad

The results comparing both tests are summarized in Table 3

	Factory shot 1	Factory shot 2	Factory shot 3	Average	
Total Impulse (lbf-second)	1.24	2.18	2.00	1.80	
Peak Force (lbf)	167.50	180.09	176.31	174.63	
	Premium shot 1	Premium shot 2	Premium shot 3	Average	Reduction (%)
Total Impulse (lbf-second)	1.59	2.27	1.94	1.93	7.20%
Peak Force (lbf)	115.98	137.62	135.62	129.74	-25.70%

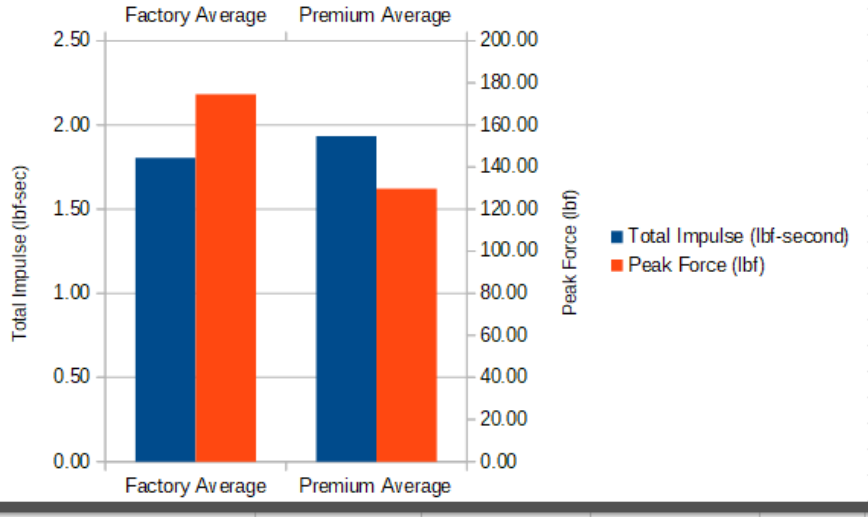


Table 3: Comparison summary between factory recoil pad and premium aftermarket recoil pad.

The results speak for themselves. The premium recoil pad resulted in a reduction in peak force of 25.7%. This is a significant reduction but it is nowhere near the “up to 70%” claimed by the manufacturer. Curiously, the total impulse actually increased by 7.2% for the aftermarket recoil pad.

Automatic Testing with Buffer Spring Comparison

In this test, an AR-10 with 150 grain .308 ammunition is tested in Quick-Strap mode with the factory buffer spring, and then in comparison with a premium aftermarket flat-wire buffer spring. The setup is shown in Figure 24

Figure 24: AR-10 in Quick-Strap mode

The results results are shown below in Figure 25 and show a wealth of information related to the cycling of this particular firearm and ammunition.

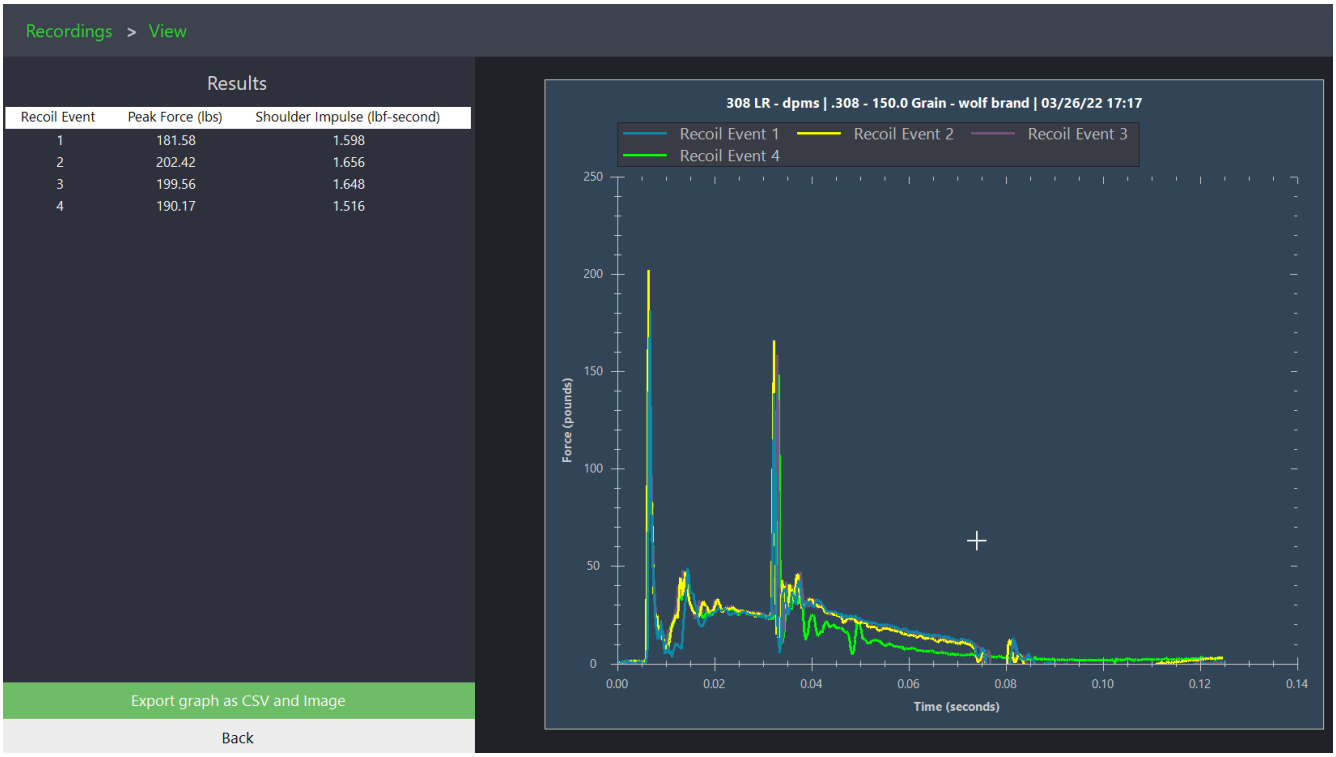


Figure 25: AR-10 Recoil Results with .308 150 grain and factory buffer spring

The data is shown zoomed in between 0 and 80 milliseconds for clarity on the cycle (Figure 26). The recoil signature for this automatic weapon is extremely complex. The initial spike occurs instantly in a similar fashion to the pump action shotgun shown earlier. There is a rapid initial rearward acceleration of the firearm when the round is initially fired. The force diminishes down quickly once the dwell time is complete. Before the rotating bolt is actuated by the gas routed through the gas port, the entirety of the recoil force is transmitted from the bolt to the firearm frame and into the shoulder. Once the gas port is exposed and the bolt unlocks, then the bolt carrier group begins to accelerate backwards under gas pressure – resisted by the buffer spring. At this time, the majority of the recoil force is transmitted through the buffer spring into the shoulder. This allows for the very gentle recoil force plateau present between .005 seconds and .03 seconds. After this force plateau there is a major secondary recoil spike that is almost as large as the initial spike. This is due to the bolt carrier group slamming the buffer against the hard stop. This massive secondary spike of averaging 150 lbf is a disorienting, uncomfortable event superposed in an already violent recoil event. Further, it is hard on components, causing unnecessary wear. This firearm is overgassed for this ammunition and is in desperate need of tuning. This tuning may include gas block port size reduction, buffer spring changes, buffer changes, and perhaps ammunition changes. A properly tuned AR-10 should minimize the size of the secondary spike while retaining enough energy to ensure reliable cycling. After the secondary spike, the buffer spring begins to accelerate the carrier group forward to battery, with the force diminishing gradually as the spring elongates and its force diminishes. At the .075 second point, the bolt is back to battery and the cycle is complete. The average cycle time for this factory buffer spring with this ammunition is 70 milliseconds (.076 minus .006).

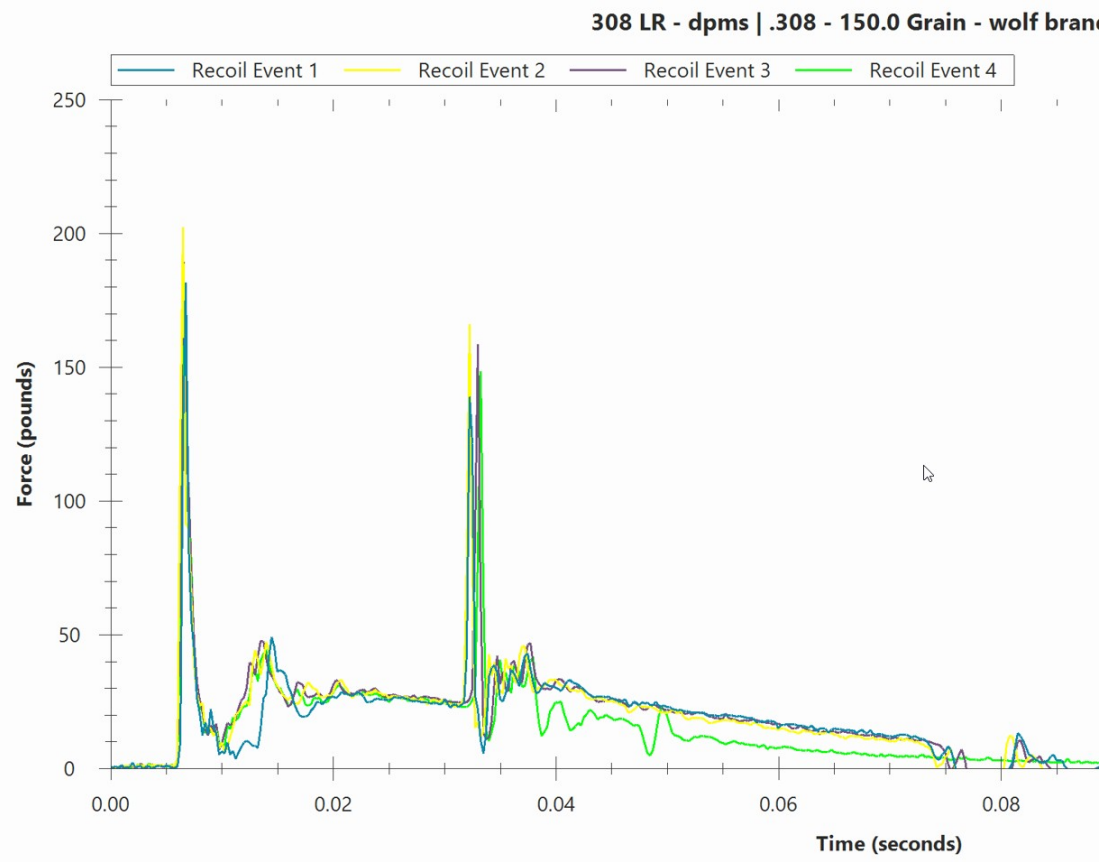
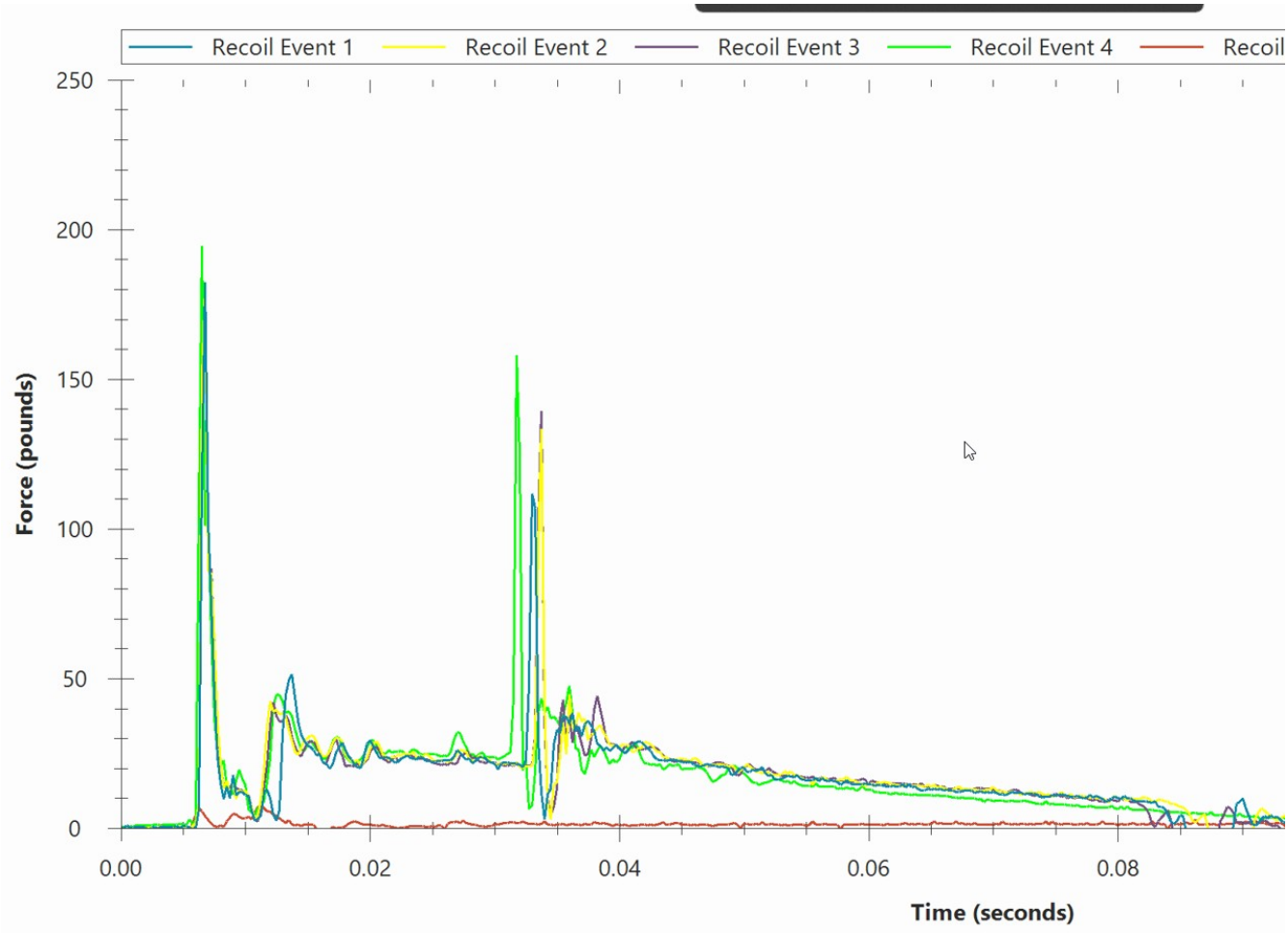


Figure 26: AR-10 .308 150 grain, factory buffer spring, zoomed in.

The next dataset for this firearm is collected using identical ammunition, identical shooter, but with a premium flatwire buffer spring. Flatwire buffer spring manufacturers claim in improvement of life, with minimal spring degradation over time compared to traditional round springs. They also claim improvements in harmonics, more constant spring force over the spring range, lighter maximum spring force, more controlled rebound. The physics of a flatwire spring supports some of these claims.



Overall, the recoil signature using the premium flatwire spring is almost identical to that of the factory spring. The initial spike is virtually identical in magnitude, as is the secondary spike. One would hope that the performance improvements of the premium spring would be a reduction of the secondary recoil spike but the data does not support that. The major difference between the two springs is the premium flatwire spring has a cycle time of 78 milliseconds (.084 -.006). **This is an 11.5% longer cycle time than with the factory spring.** In certain circumstances such as military or competition, this longer cycle time may be the difference between victory and defeat and the user may think twice about using a flatwire spring despite claims of other less tangible, less measureable improvements.