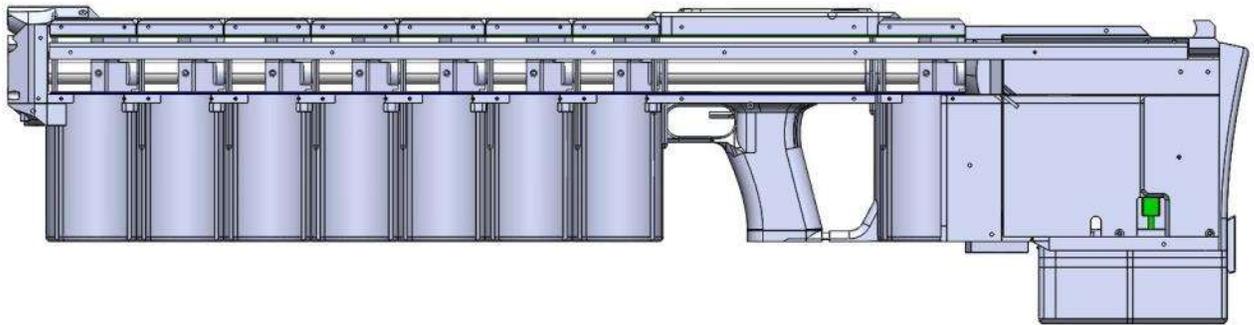


GR-1 “ANVIL” High Energy Gauss Rifle

User Manual



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IT IS STRONGLY ADVISED TO READ THIS ENTIRE MANUAL
FAILURE TO ADHERE TO THESE PROCEDURES COULD RESULT IN
DAMAGE TO THE PROTOTYPE AS WELL AS
RISK OF PERSONAL INJURY, INJURY TO OTHERS, OR DEATH



- TREAT THE GR-1 AS YOU WOULD A FIREARM.
- NEVER POINT THE GR-1 AT ANYTHING OR ANYONE YOU DO NOT INTEND TO DESTROY.
- THE GR-1 PRODUCES A POWERFUL MAGNETIC FIELD. DO NOT OPERATE THE GR-1 AROUND ANYONE WHO USES A PACEMAKER OR AROUND OTHER SENSITIVE EQUIPMENT.
- NEVER STICK FINGERS OR ANY FOREIGN METAL OBJECT INTO THE REAR VENT HOLES



1. Overview

1.1. General

The Arcflash Labs GR-1 “ANVIL” (Gauss Rifle 1, Alpha prototype) is an 8 stage high voltage semi-automatic reluctance accelerator. The GR-1 is the most powerful coilgun ever sold to the public, and also (very likely) the most powerful handheld coilgun ever built.

The GR-1 has a ½” bore which configured to fire any ferromagnetic projectile between 10-12mm in diameter and between 30-50mm in length (using a variable chamber). Arcflash Labs recommends the use of 1232, 1242E, or 1252 Magnetic Armatures (sold separately) but any 12mm steel dowel pin between 30-50mm should work. The GR-1 is sold separately from its magazines, allowing the user to choose which armature size which they would like to chamber.

The GR-1 ships standard with its own hard polymer carrying case and (1) 6S 3300mAh battery which can provide power for over 40 full-power shots before needing to recharge.

As an alpha tester of the GR-1, you are privileged to join an exclusive community of electromagnetic gun developers and enthusiasts around the globe. Until now, only a handful of individuals have ever seen an electromagnetic gun, let alone fired one. Congratulations on being selected to own a piece of history.

1.2. Safety

1.2.1. Correct use

The GR-1 is intended for use in research, testing, and pest control, similar in functionality to an air rifle.

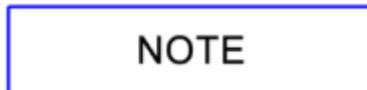
The following terminology is used throughout this manual for the purpose of denoting important and safety critical information:



An operation, procedure, or practice which if not correctly followed could result in personal injury or loss of life.



An operation, procedure, or practice which if not strictly observed, could result in damage to the device and/or voiding of the device's warranty.



A recommended procedure, suggested practice, or point of additional information which may facilitate the ease of use for the operator, or point out a feature of particular importance which is useful to know, but not safety-critical.

1.2.2. Limits

WARNING: The GR-1 is NOT WATER RESISTANT AND NOT IMPACT SAFE. Exposure to water or dropping from distances greater than 1 foot may cause irreversible damage to the gun, fire, explosion, electrical shock or venting of toxic gas from the battery or capacitors. If the GR-1 is dropped or exposed to water: discontinue use immediately and return the gun to its manufacturer for repairs.

WARNING: DO NOT STICK FINGERS OR FOREIGN OBJECTS INTO REAR VENT HOLES. Risk of severe and potentially lethal electrical shock may result. Keep all clothing or metal objects clear of vent holes during operation.

WARNING: NEVER exceed the barrel red-line temperature at any time.

CAUTION: It is strongly advised to shut down the gun once barrel temperature exceeds yellow-line. The red-line temperature indicates the temperature at which irreversible damage will be done to the barrel. Exceeding this temperature, even briefly, could result in fracture, melting or catastrophic damage to the barrel. Therefore, it is advised to not operate the unit and allow the barrel to cool, once it reaches the yellow-line temperature.

CAUTION: Do not fire chipped, broken or imbalanced ammunition, or non-OEM ammunition larger than 12mm in diameter. Barrel damage, ricochet or jams may result.

CAUTION: Disconnect battery from gun when not in use. Main power switch may accidentally activate, even when the unit is stored properly in its case. Always disconnect the battery for storage.

CAUTION: Always store the GR-1 in its included carrying case or similar hard case to avoid damage to its polymer structure.

CAUTION:

1.2.3. Electrical

Above and throughout this manual is a summary of the major hazards associated with the device, but is NOT ALL INCLUSIVE. There are many other hazards associated with the device which are not laid out in this manual. We recommend wearing high voltage, flame retardant gloves at all times when using the device as well as goggles and thick clothing. Do not use the device around flammable materials or volatile chemicals, and always have a fire extinguisher on standby.

1.2.4. EMP Issues

The GR-1 produces a sizable magnetic field and EMP when fired. While internal and external reviews have found that it produces no significant EMP, we still caution users that it is **NOT SAFE TO FIRE THE GR-1 WITHIN 50 FEET OF ANYONE WHO USES A PACEMAKER OR OTHER SENSITIVE OR SAFETY-CRITICAL ELECTRICAL EQUIPMENT.**

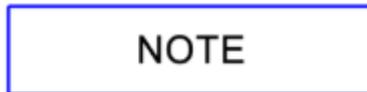
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 *A recommended procedure, suggested practice, or point of additional information which may facilitate the ease of use for the operator, or point out a feature of particular importance which is useful to know, but not safety-critical.*

2.1 Barrel



- The GR-1 max muzzle energy is roughly that of a .22lr. This is a lethal weapon. Never point the gun at anyone or anything you do not intend to destroy.
- Never fire projectiles longer than 2" or larger than 12.5mm – firing projectiles other than Arcflash 12X2 series Magnetic Armatures could result in fire or explosion.



- The GR-1 produces a powerful magnetic field. Do not operate near sensitive electronic or medical devices.

The GR-1 is a semi-automatic Gauss Rifle – its core component is a sequence of optically gated, SCR switched high voltage driver solenoids. As a projectile passes through the barrel, it triggers optical gates which send signals back to the microcontroller. The microcontroller quickly interprets these signals and directs the coils to turn on in a precise sequence. This accelerates the projectile down the barrel and out of the gun with an exit velocity between 40-80m/s (120-240fps).

A 1 oz round traveling at such velocities has roughly equivalent muzzle energy to a .22lr firearm. While this muzzle energy may be “restricted” (i.e. ‘less lethal’) using software programming- such programs are not always reliable and even when the device is set in “restricted energy” mode, it is still capable of delivering lethal energy on target.

The barrel is equipped with sensors that are designed to detect blockages and damage to the photogates but such sensors may not detect all sources of barrel blockage, especially if the blockage is small or the photogates are damaged in an unexpected way. The only way to reliably detect barrel blockages is to fully power down the GR-1 and insert a long plastic or non-magnetic rod down the barrel, observing the tip through the magazine well.

During a shot, the coils are energized with several thousand amperes of current and they create a transient magnetic field between 5-8 Teslas (for comparison, most MRI machines generate a magnetic field of only 1-3 Teslas). The GR-1 bore field is mostly confined to the inside of the barrel and it is concentrated within the gap between the active coil and the armature. The field outside of the barrel is far lower than inside the barrel, and is under 1 Tesla on all external surfaces of the gun, even during a shot. Nonetheless, this powerful magnetic field may affect nearby sensitive electronics or medical devices. It may generate low-frequency EM interference (under 10kHz) or other transient electromagnetic effects. It is recommended to never operate the GR-1 in the vicinity of safety-critical electronics or medical equipment (such as electronic pacemakers, insulin pumps, etc.)

2.2 Capacitors



The GR-1 contains high voltage capacitors which are capable of storing up to 3.3kJ of combined energy. This is roughly equivalent to two standard M-80 fireworks.



- Discharging of the capacitor bank is performed when the main switch is turned off.
- Repeated discharges of the bank, or discharging the bank when it is charged to full capacity may result in electrical damage to the DCL's, or may melt the GR-1's outer structural panels



It is not recommended to hold high voltage in the GR-1 for long periods of time (more than a few seconds). Such a condition is inherently dangerous for the user.



Charging the capacitor bank on a Gauss Rifle is analogous to switching off the safety, racking a round, and/or putting the hammer in half-cock (all at the same time).

Once high voltage is put into the capacitor bank, one way or another, that energy is GOING to come back out, usually in a violent fashion.

The GR-1 contains a large bank of electrolytic capacitors (27,000 uF total capacitance). They are capable of delivering several thousand amps burst current through the coils and hundreds of thousands of amps during a dead-short condition.

Upon powering up the GR-1 via the main switch, the capacitors will remain uncharged until positive input is received from the user. When the user squeezes the trigger (see section 2.5), the microcontroller (MCU) enters charging mode. While in charging mode, the primary MCU signals the charge controller (via the low voltage cable) to begin the charging process. The charge controller actuates two high current relays which allow 60-80A from the battery to flow into the Clamped Quasi-Resonant (CQR) chargers which step up the battery voltage from ~25V to 500V. This 500V flows through the high voltage cable back into the charge controller and into the capacitors where it is stored until one of four conditions are met:

- 1) If the user releases the trigger, the MCU will halt the charging process until the user depresses the trigger again.
- 2) If the voltage in the capacitors exceeds the voltage setpoint computed by the the MCU in "restricted energy" mode, the MCU halts the charging process until either the voltage falls below the setpoint, a shot is fired or the gun is shut down.
- 3) If the voltage in the capacitors ever exceeds 99% of the capacitors' rated voltage (495V), the MCU automatically halts the charging process until either a shot is fired or the gun is shut down.
- 4) If the voltage in the capacitors ever exceeds 110% of the capacitors' rated voltage (540V), a hard wired secondary safety circuit triggers an emergency override and halts the charging process until the voltage falls below 100% of the capacitors' rated voltage.



It should be noted that neither the MCU, nor the emergency override circuit has the capacity to **initiate a thermal discharge** the capacitor bank. This function is **ONLY performed when the GR-1's main switch is turned off.**

Discharging the energy stored in the capacitor bank without firing an armature may only be accomplished by converting 3.3kJ of electrical energy into heat by discharging the entire bank through the Primary DCLs. This generates significant heat in the DCLs and is only performed upon a full shutdown of the GR-1 (via the main switch) in preparation for storage or in the case of an emergency.

*It is the responsibility of the user to understand that a full discharge of the capacitor bank is **POSSIBLE** through the DCLs, but such an action is not recommended and should only be performed in an emergency or when discharge via firing of an armature is unsafe or impractical.*

While every effort has been made to reduce the safety hazards associated with high voltage in the GR-1 – it is not recommended to store high voltage in the capacitor bank for long periods of time. The user must be aware that holding high voltage in the bank creates an inherently dangerous high energy condition and exposes the user to significantly elevated risk of electric shock, fire, or electrothermal detonation (i.e. Arcflash).

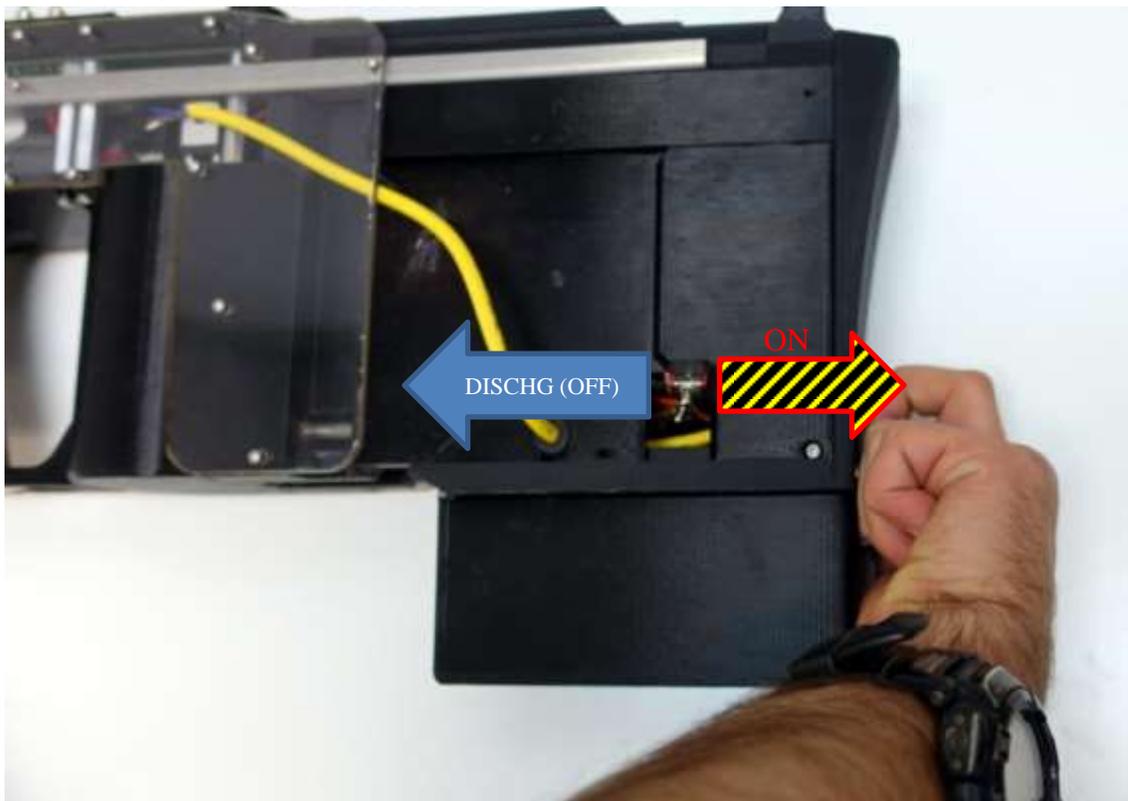
It is advised that you should never touch or insert metal objects into any internal components of the gun, especially those near the barrel. The electrical energy stored in the gun before firing (~3.2kJ) is roughly equivalent to two standard M-80 fireworks (i.e. 500mg of confined pyrotechnic flash powder). The discharge of such energy through the air or through metal objects in an uncontrolled fashion is sufficient to vaporize metal or sear flesh. Discharge of 500V through the human body is potentially lethal via electrocution.

2.3 Main switch



- Always ensure the power switch is set to the discharge (forward) position before inserting the fuse or battery.
- Do not rapidly turn the main switch on and off. If the GR-1 is shut down, it is recommended to wait at least 30 seconds before turning it back on again.

The main switch of the GR-1 controls both the main power electronics and the primary capacitor dump DCLs. It has two modes: Discharge and ON.

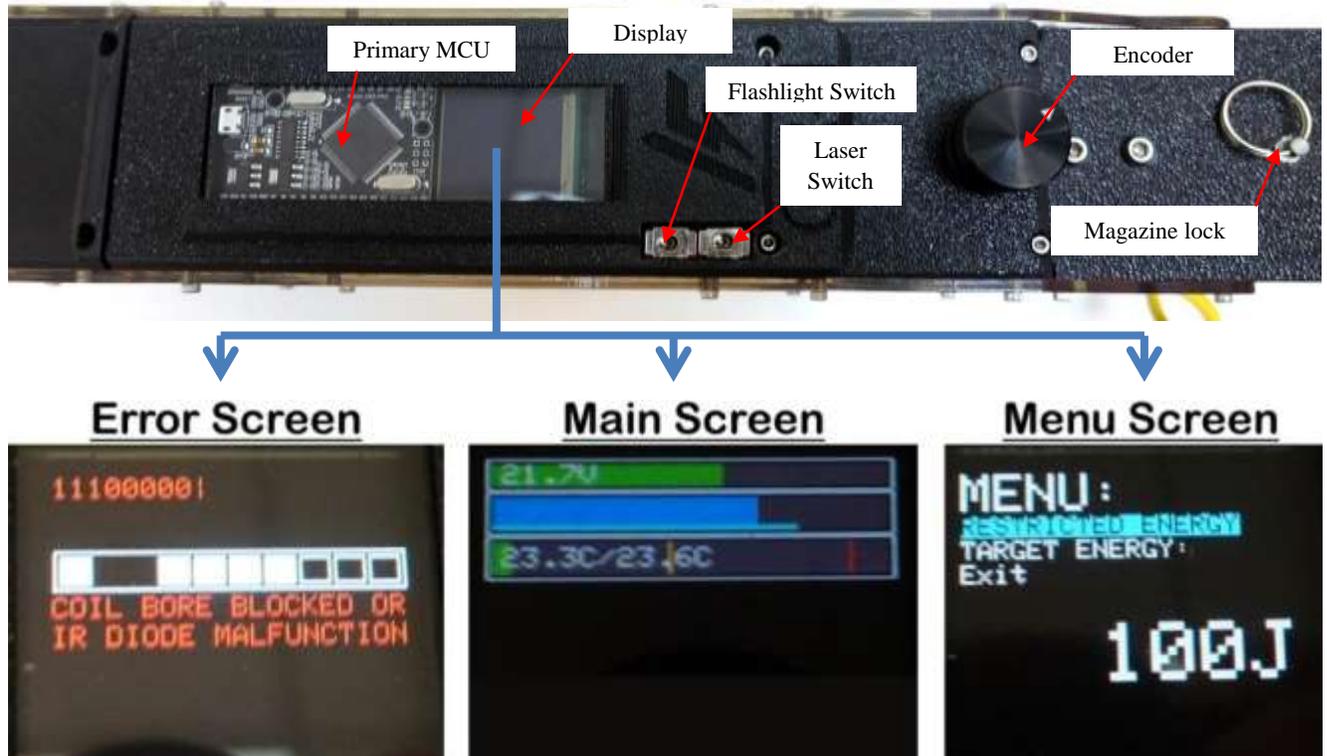


When the switch is placed in the ON (REARWARD) position, the battery will power the gun. When the switch is placed in the DISCHARGE (FORWARD) position, the battery will be disconnected from the gun's systems and a relay (held open by the battery power) will close, allowing the capacitors to discharge their energy into the primary DCLs. If at any point power is removed from the gun's systems, this failsafe relay will discharge the high voltage capacitors in less than 20 seconds through the primary DCLs.

2.4 Display, MCU and Upper Console



- The gun boots into “UNRESTRICTED MODE” by default. Even in “unrestricted” mode, a properly trained operator can differentiate between lethal and less lethal modes by controlling the charge on the capacitors.
- The gun may be placed in a software locked “less lethal” mode by setting gun to “RESTRICTED ENERGY” mode and setting the desired max energy in the menu screen.



The GR-1 Display has three possible display states:

- 1) Error Screen
- 2) Main Screen
- 3) Menu Screen

When the GR-1 is powered on via the main switch, it will enter the (1) Error Screen.

If no optotransistor faults or barrel blockages are detected, the screen will automatically transition to (2) Main Screen.

If there is a problem with the barrel (i.e. a blockage in the bore, or a damaged optotransistor) the Error Screen will display an error code along with a warning message, as well as highlighting the damaged coil on a notional diagram of the gun. In the example above, such an error screen would indicate a blockage (or opto malfunction) in the three coils closest to the muzzle.

The main screen has four main functional areas. From top to bottom, these are:

- A) Battery voltage meter

- B) Capacitor energy meter
- C) Coil temperature meter
- D) Post-shot diagnostics (not shown above)

The (A) battery voltage meter will display the current battery voltage as well as a relative analog bar representing the relative charge of the battery (full green = fully charged battery)

The (B) capacitor energy meter contains two sub-bars. The upper blue bar represents the capacitor ENERGY (in Joules). The lower cyan bar represents the capacitor VOLTAGE (in Volts). The bars will advance at different rates due to the fact that the energy will increase roughly linearly with time, while the voltage will approach the maximum capacitor voltage asymptotically.

During capacitor charging (and during a shot), all other functions of the gun are temporarily paused in order to allow the MCU to check the instantaneous capacitor voltage more rapidly. This is evidenced by the lack of text on the (B) capacitor energy meter and lack of movement on all other bars. As soon as the trigger is released (or fully depressed to initiate firing), the actual voltage and energy will again be displayed on the (B) capacitor energy meter.



- It is recommended to not exceed the (yellow) warning temperature of the barrel.
- Overheating the barrel beyond its (red) maximum service temperature, even briefly, may cause permanent and irreparable damage to the gun.

The (C) coil temperature meter monitors the maximum and average temperature of all coils on the barrel and ensures that no coil exceeds the maximum service temperature of the respective barrel material (85C for acetate barrel, 100C for polycarbonate barrel, and 140C for carbon fiber barrel). Two vertical lines (yellow and red) are displayed on this bar, indicating the warning and overheat (maximum service) temperature of the barrel.

If the barrel temperature sensors detect an overheat on any coil, the gun's MCU will prevent it from firing additional rounds until the barrel cools. However, at that point the damage may already be permanent. Therefore, it is strongly recommended that the user NOT fire the gun once the barrel reaches the (yellow) warning temperature, as additional shots may inadvertently overheat the barrel past its (red) maximum service temperature.

While great effort has been made to both monitor and passively cool the barrel, the heating of the barrel will depend on a number of factors including: ambient air temperature, number of shots, frequency of shots, power of shots, and prior activations of the DCLs. Therefore it is difficult to estimate the number of shots which may be fired before temperature becomes a limiting issue. In a carefully controlled, air conditioned environment- we have found that the gun can fire an entire magazine of medium to high power shots in quick succession without thermal concerns. However, high ambient temperatures or aggressive firing conditions may reduce this tolerance.

The (D) Post-shot diagnostics display is a series of data readouts which is intended to help the user or Arcflash Labs technicians troubleshoot and observe the acceleration properties of each shot. In this display you will see the muzzle velocity and timing of each shot inside each stage after firing.

Pressing down and holding the encoder wheel for at least ½ second will enter the (3) Menu screen. The menu screen has three selectable options:

- A) Manual-Restricted/Auto-Restricted/Unrestricted Energy
- B) Target Energy
- C) Exit

Pressing down on the encoder wheel when the first option (A) will toggle between the three modes. The word displayed on line (A) is the mode selected for operation. In Unrestricted energy mode, holding the trigger in the Charge position (see section 2.5) will charge the capacitors until maximum service voltage is reached. Depressing the trigger into the Fire region at any time during the charge process (or after charging has reached max voltage) will initiate the firing sequence.

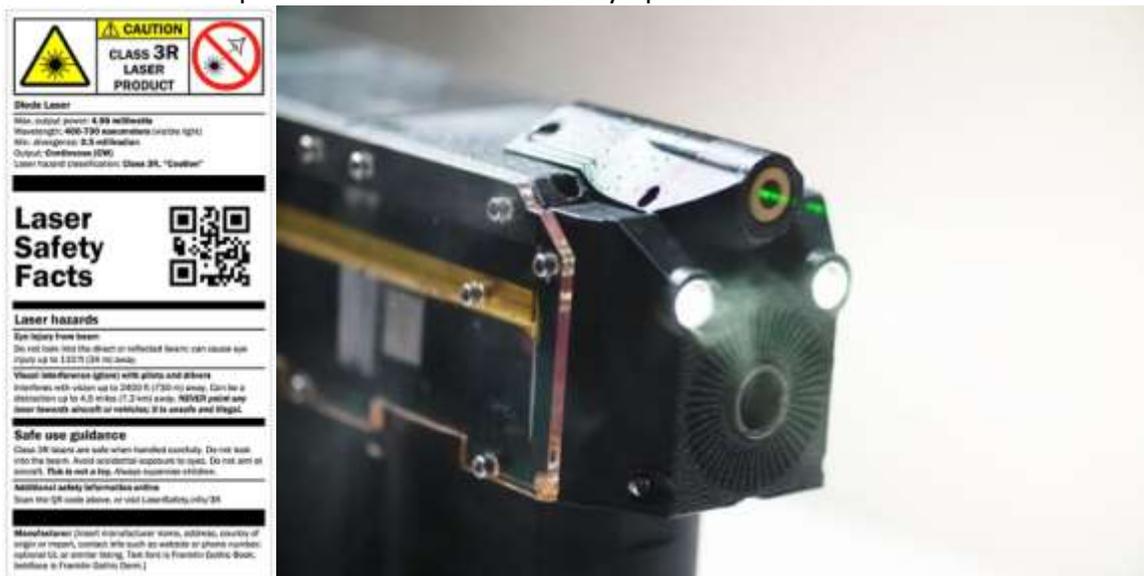
In Manual-Restricted Energy mode, the charging/firing behavior is the same, but instead of capping at the maximum service voltage, the power will be capped at a lower “Target Energy” value displayed at the bottom of the screen.

In Auto-Restricted Energy mode, the capacitors will automatically charge to the “Target Energy” as soon as the menu screen is exited or a shot is fired. The Charge position of the LCT will no longer serve to signal the MCU to begin the charging process, instead charging will proceed immediately after every shot. It is not recommended to use Auto-Restricted Energy mode at Target Energy above 50J as this may cause excessive stress on the capacitors and create inherent dangers for the user.

Scrolling to the (B) Target Energy line and pressing the encoder will enter the user into Energy Selection mode, where the user may select a desired target energy by turning the encoder and pressing down once the desired value is reached.

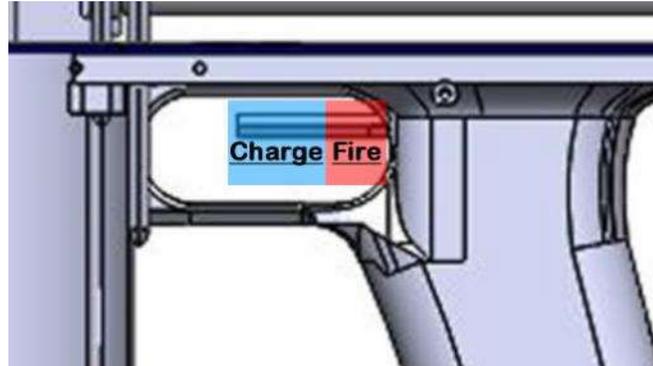
To exit the menu screen, scroll to the (C) Exit option and press the encoder wheel to return to the main screen (2)

The GR-1 features an integrated laser and flashlight system which is operated via manual switch controls independent of the MCU. The switches which control the laser and flashlight are located just below the Display. The integrated flashlights are dual 1W white LEDs. The laser is a 4.9mW (class-3R) green 532nm laser which provides reasonable accuracy up to a distance of 20m.



2.5 Linear Conditional Trigger (LCT)

During pre-alpha testing, we have found a novel and intuitive method to operate the Gauss Rifle which we call a “Linear Conditional Trigger” or “LCT” for short. While the system is quite different from the trigger in an ordinary firearm, it may be familiar to those who have experience with fictional Gauss Rifles in video games. A diagram of the LCT modes can be seen below:



The LCT consists of a linear potentiometer which is connected to a computer which divides the trigger pull into several “zones” during which will perform different functions.

Depressing the trigger lightly into the first “Charge” zone will command the GR-1 to activate the CQR chargers and begin charging the capacitors. Pulling the trigger further, into the “Fire” zone, will command the GR-1 to stop charging and fire a round. Following such a shot, the trigger must be fully released before the cycle can be repeated and another round can be charged and fired. This methodology intuitively conveys to the operator that charging must always precede firing since it is impossible to depress the trigger into the firing region without first passing through the charge region.

If the operator charges the gauss rifle but decides against firing a shot, the trigger may be released from the charge region and a shot will not be fired. However, the capacitors will remain charged and if the operator decides to fire a shot, the GR-1 will require a much shorter charge time to achieve a desired muzzle energy from this condition.

If the trigger is released from the charge position, charge will remain on the capacitors until either a round is eventually fired, or the GR-1 is shut down via the main switch.

2.6 Adjustable Magazine Lock

The GR-1 uses a proprietary magazine locking mechanism, allowing the gun to accept 3 different size magazines which in-turn allows it to fire any magnetic ammunition within a broad window of acceptable lengths and diameters using three different magazine sizes: the GR-1232, 1242, and 1252. This allows the gun to accept any magnetic armature between 10-12mm in diameter and between 25-52mm (1-2”) in length. The GR-1232 accepts armatures between the length 25-32mm, the 1242 accepts armatures between 32-42mm in length, and the 1252 between 42-52mm in length. Armatures must have a solid rear plate or sufficient cross sectional area for the loading solenoid to push them into the barrel, but they may be hollow (in the case of 1242E armatures) or otherwise unusually shaped so long as they do not exert abrasion on the barrel and the maximum diameter of the round is under 12mm in diameter.



To insert differently sized magazines, the GR-1 uses an adjustable magazine locking magazine. The procedure for operating the magazine lock is depicted below:

	<p>Step 1: Remove existing magazine and lift magazine lock ring.</p>
	<p>Step 2: With one hand, pull firmly on the magazine lock ring and maintain upward pressure. With your other hand, pull or push on the rear section of the GR-1 to the desired position.</p>
	<p>Step 3: Release the magazine lock ring and hold the body of the gun with one hand while moving the rear section with the other hand until the locking ring clicks into place and the pin moves downward.</p>
	<p>Step 4: Insert new magazine. Check fitment. Re-adjust and/or repeat procedure from step 1 as needed.</p>

2.7 Battery



- The GR-1 contains a large 6S Lithium Polymer battery. Large lithium polymer batteries can catch fire or release gas if stored improperly. Always store in a cool, dry environment.



- Take care not to pinch the wires when closing the battery compartment.

The GR-1 contains a Lithium Polymer battery. As with any device containing a large lithium battery, it presents a number of hazards including shock, fire, explosion, or venting of toxic gas. Always store the gun and battery in a cool, dry environment indoors, away from any flammable materials.

It is recommended to disconnect the battery wires from the gun when not in use.

3. Operation

3.1 Startup



- Always ensure the gun is pointed in a safe direction prior to inserting the battery and powering the gun.

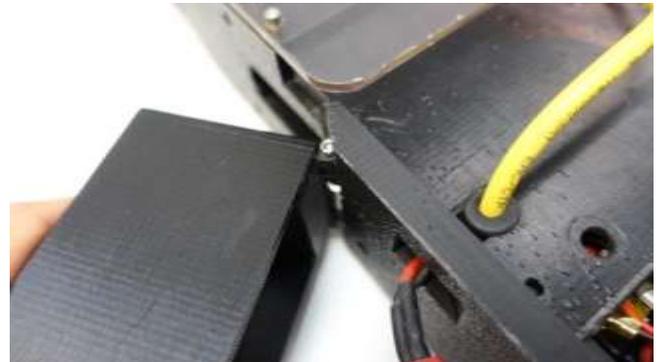


- Always ensure the power switch is set to the discharge (forward) position before inserting the fuse or battery.

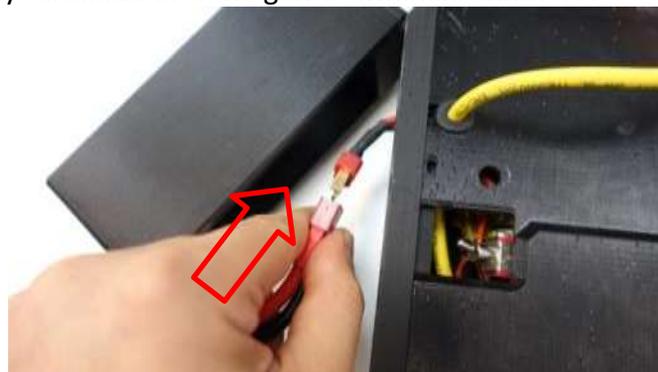
1. Ensure battery is charged to its nominal voltage of 25.2V
2. Ensure main switch is in the DISCHG (OFF/Forward) position



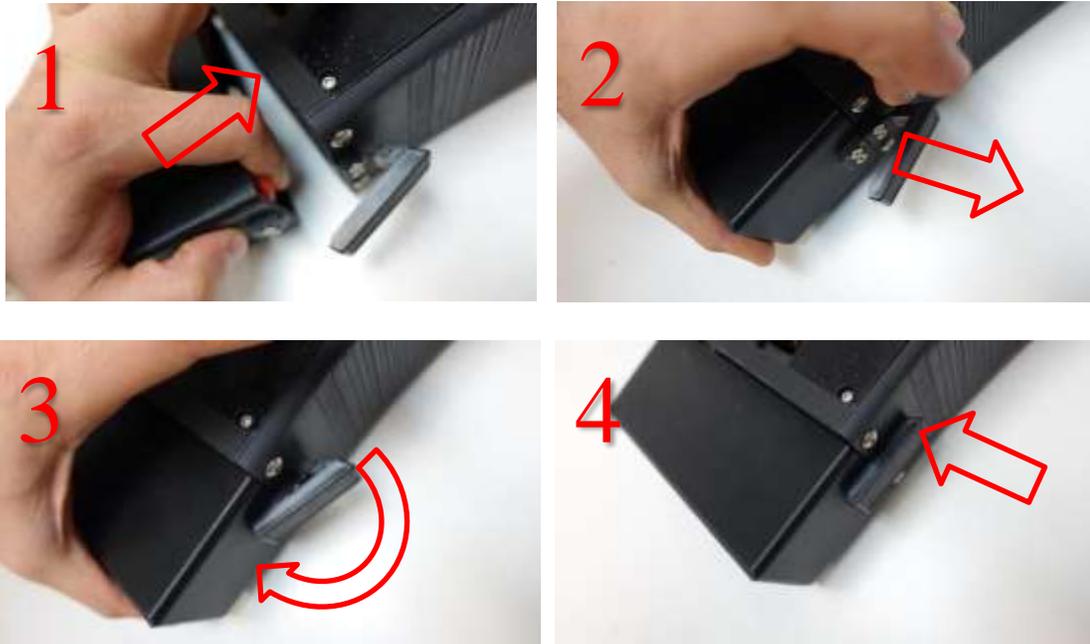
3. Insert battery onto metal catch



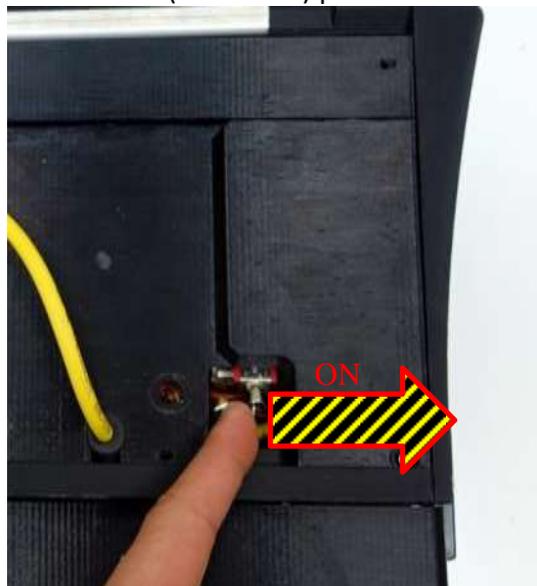
4. Connect the battery terminals into the gun's terminal connector.



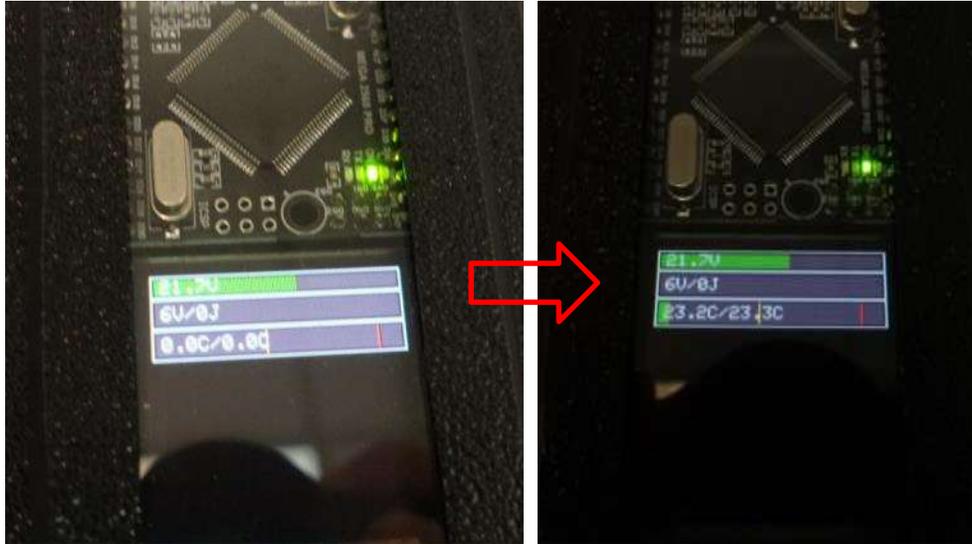
5. Stuff the connector and excess wires into the battery compartment. Ensure wires clear pinch points and close the compartment by tilting the rear end of the battery into position close to the rear latch. The battery should fit smoothly onto the latch with minimal force. If excessive force is required, STOP. Check for pinched wires. Do not exert excessive force onto the battery component as this could damage the wires or the latch. Once the compartment is seated and closed, actuate the latch. *ENSURE THAT THE WIRES ARE NOT PINCHED BEFORE CLOSING THE COMPARTMENT*



6. Turn the main switch to the ON (Rearward) position



7. Upon powering on, the MCU will enter a diagnostic procedure. If the diagnostic procedure shows a barrel blockage or optotransistor failure, see section 2.4. Otherwise, if the barrel sensors clear diagnostics, the main screen will appear below. After approx. 5-10 seconds, the secondary MCU will begin receiving thermocouple data and transmit it to the primary MCU which will display it at the bottom of the screen.



8. (If necessary) adjust magazine lock (see section 2.6).
9. Ensure the gun is powered up and pointed in a safe direction, then insert magazine.



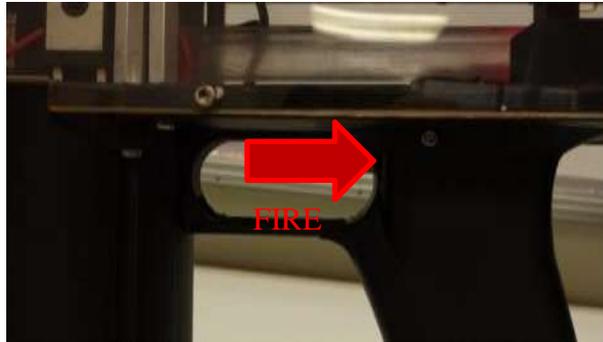
3.2 Charging and firing

1. Always ensure the gun is powered up and pointed in a safe direction before charging. There is no slide or chamber on the GR-1. The active round in the magazine itself acts as the chambered round.

- (If the mode is set to Unrestricted or Manual-Restricted) Press the trigger lightly, roughly half-way to the stop, you will hear a light whine of the CQR chargers and several light clicks as the charging relays are activated. The capacitor energy display will begin rising with 2 blue bars advancing at different rates. If the trigger is released before the target or maximum energy is reached, the blue bar will display the voltage and capacitor energy in digital form. It is not necessary to release the trigger at the end of charging. It is possible to fire directly from the Charge mode by depressing the trigger all the way to the stop.

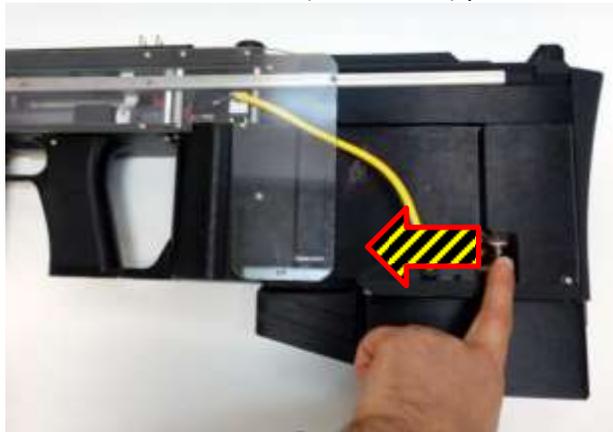


- Depressing the trigger fully to its stop will fire the GR-1.

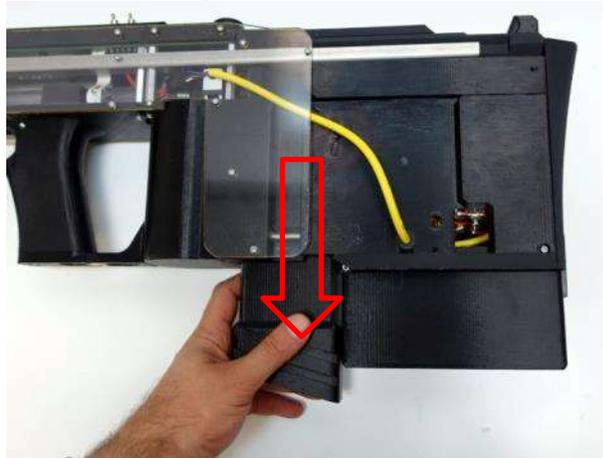


3.3 Shutdown

- Flip the Main Switch to the DISCHARGE (FORWARD) position.



2. Remove the magazine from the gun.



3. Place the gun on a safe, stable surface and point the gun in a safe direction, then open the locking latch on the battery enclosure, and disconnect the battery connector from the terminal.



4. The GR-1 is now safe for storage.

4. Software

The GR-1 is equipped with firmware Temp_v6, Encoder_Signal_v1, and MCU Proto_one_v9

The software in this device is not intended to be user-serviceable. In fact, tampering with the GR-1 software is expressly discouraged and will immediately void any express or implied warranties. Any attempt to modify the software may render the gun unusable or unsafe. Arcflash Labs, LLC assumes absolutely no responsibility for units which have had their software modified by the end user.

5. Hardware Specifications

Accelerator Specifications

Primary power source	6S LiPo – 25.2V
Power supply	1000W (CQR)
Capacitors	8x HV electrolytic
Switches	9x HV SCR
Projectile	10-12mm x[variable] alloy steel
Armature Capacity	10 rounds (standard)
Rate of fire	Up to 100 rounds/min
Muzzle velocity	Up to 80 m/s
Muzzle energy	Up to 100J
Efficiency	2.8%

Physical Dimensions

Barrel length	26.0"
Bore	0.5"
Physical Dimensions	38.0" x 8.0" x 3.0"
Overall Weight (unloaded, no battery)	20 lbs

