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(54) **GROUNDING SABOT AND METHODS OF USE**

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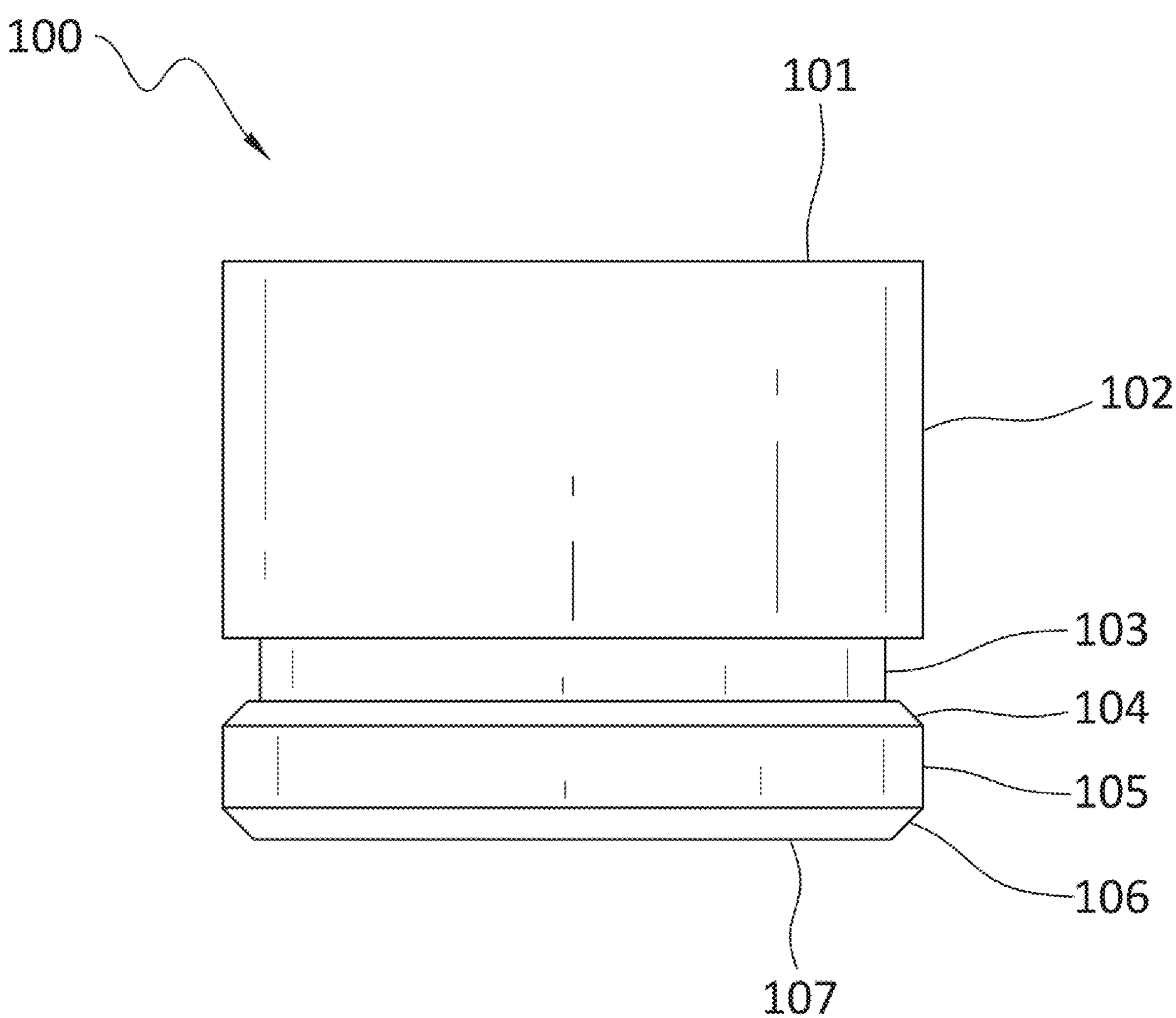
(57) **ABSTRACT**

A sabot that includes a body configured to be partly received within a propellant chamber of a perf gun, and the body includes an interface configured to engage a projectile, a divider that defines part of the interface, an ignition pass through that extends through the divider, an ignition stack electrically connected to the ignition pass through, a ground terminal electrically connected to the ignition pass through, a deflector defined by the divider and having a cup-shaped configuration, and the deflector is configured to expand diametrically upon ignition of a propellant in the propellant chamber when the sabot is positioned within the propellant chamber, a gas valve configured and arranged to be actuated by expansion of the deflector, and a compensator positioned between the interface and the gas valve.



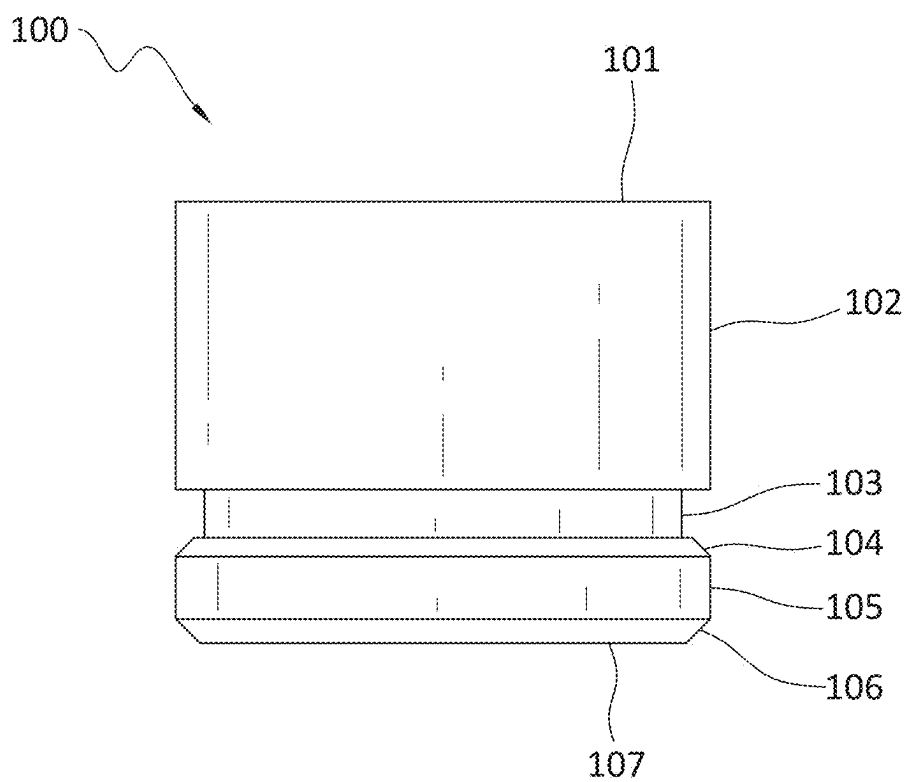



FIG. 1

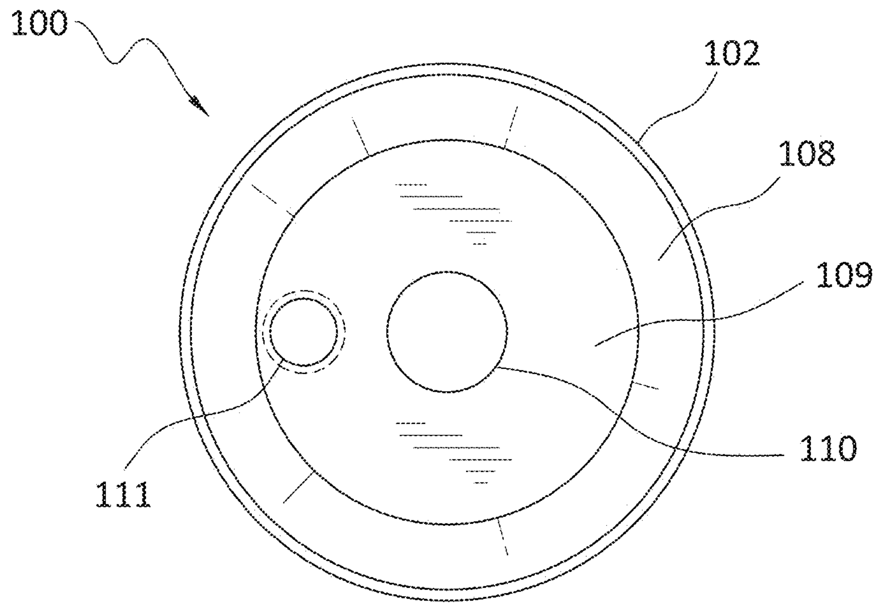



FIG. 2

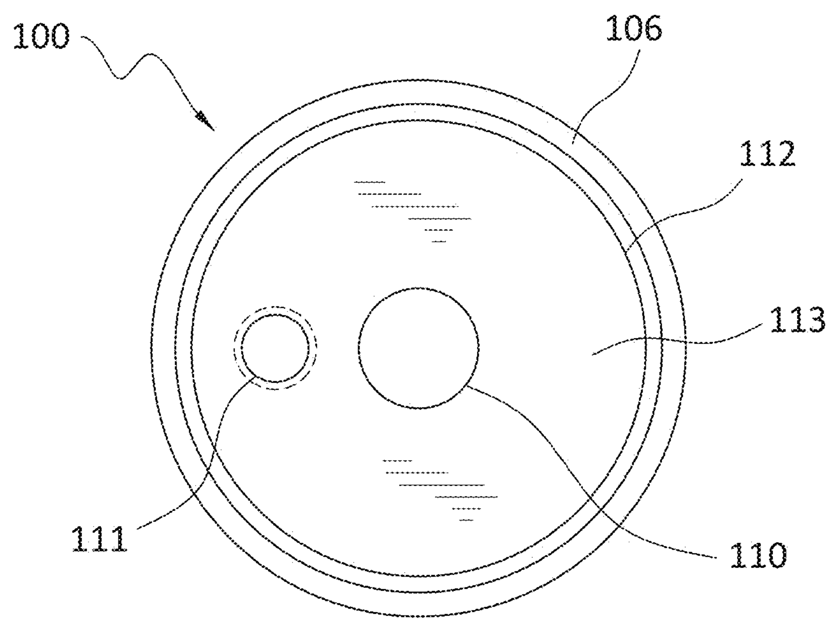



FIG. 3

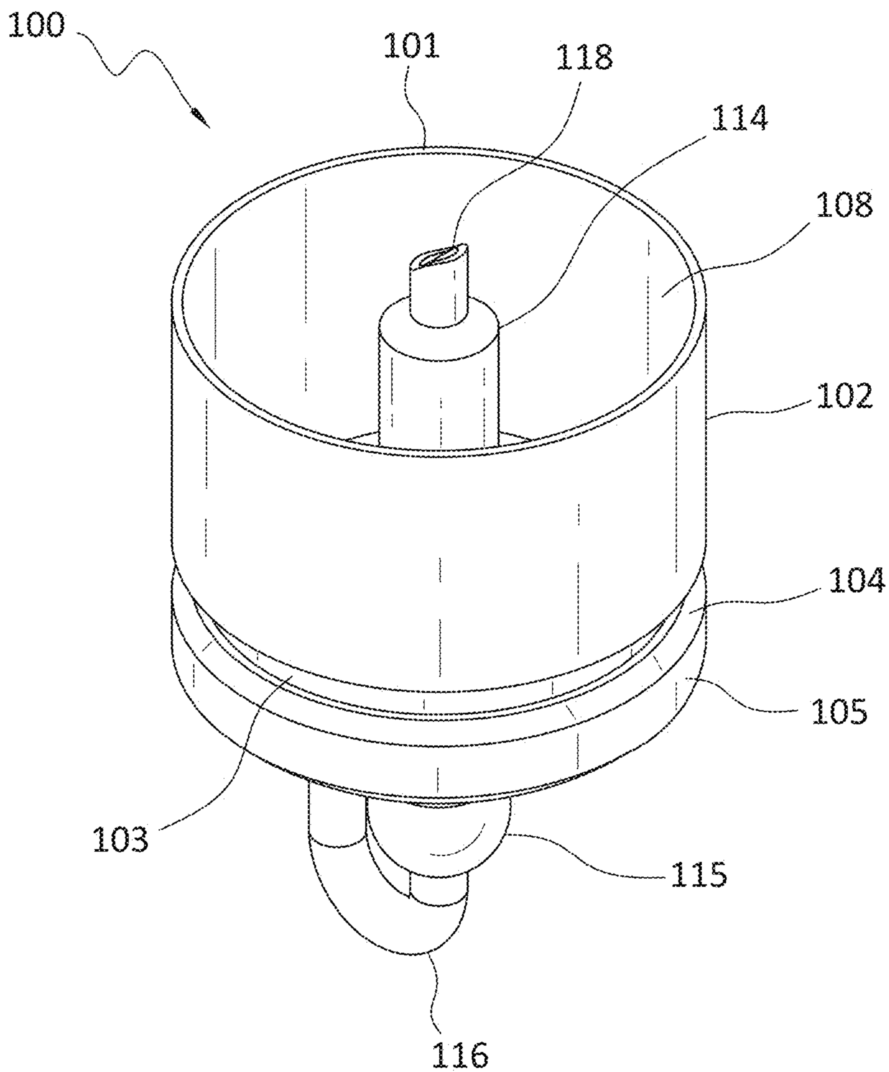



FIG. 4

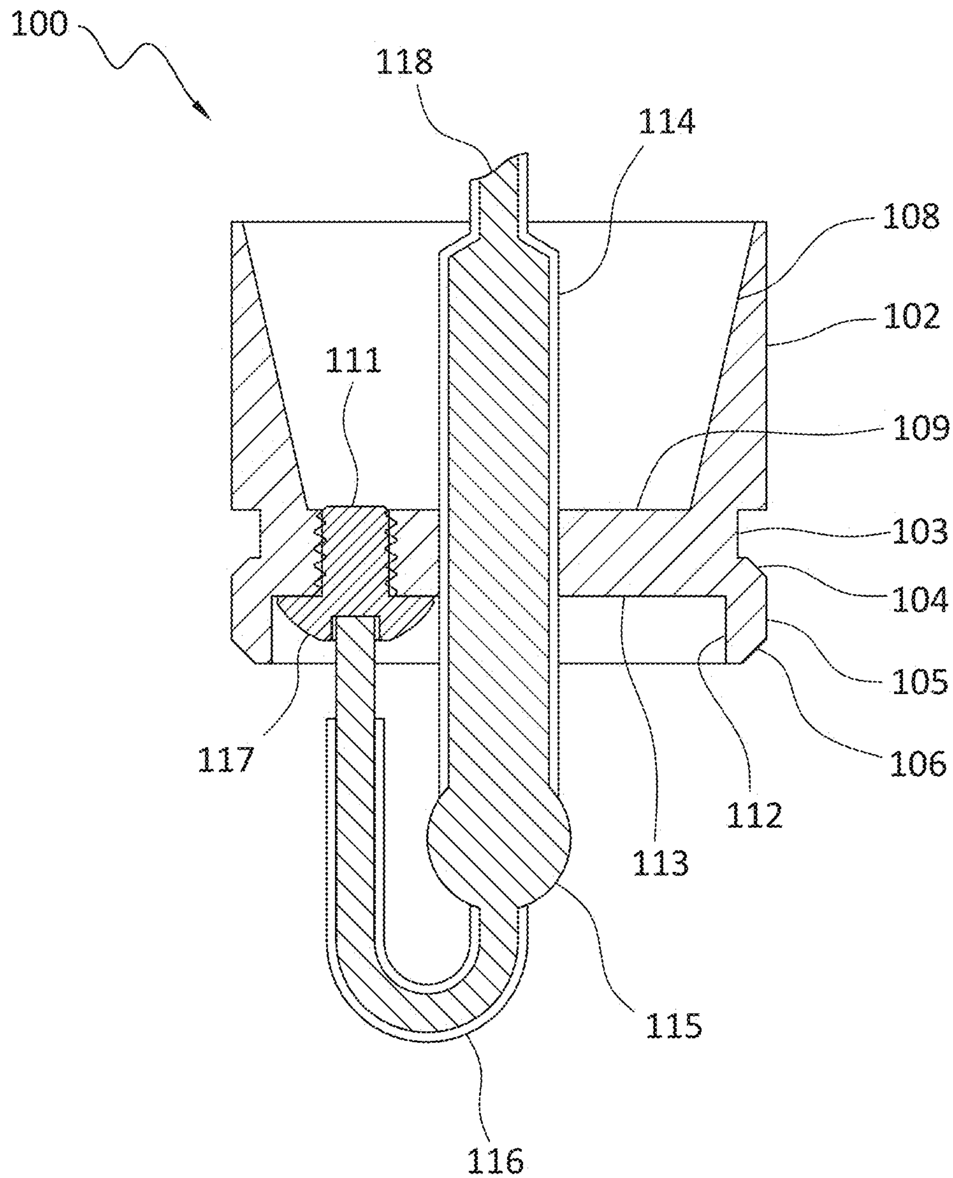



FIG. 5

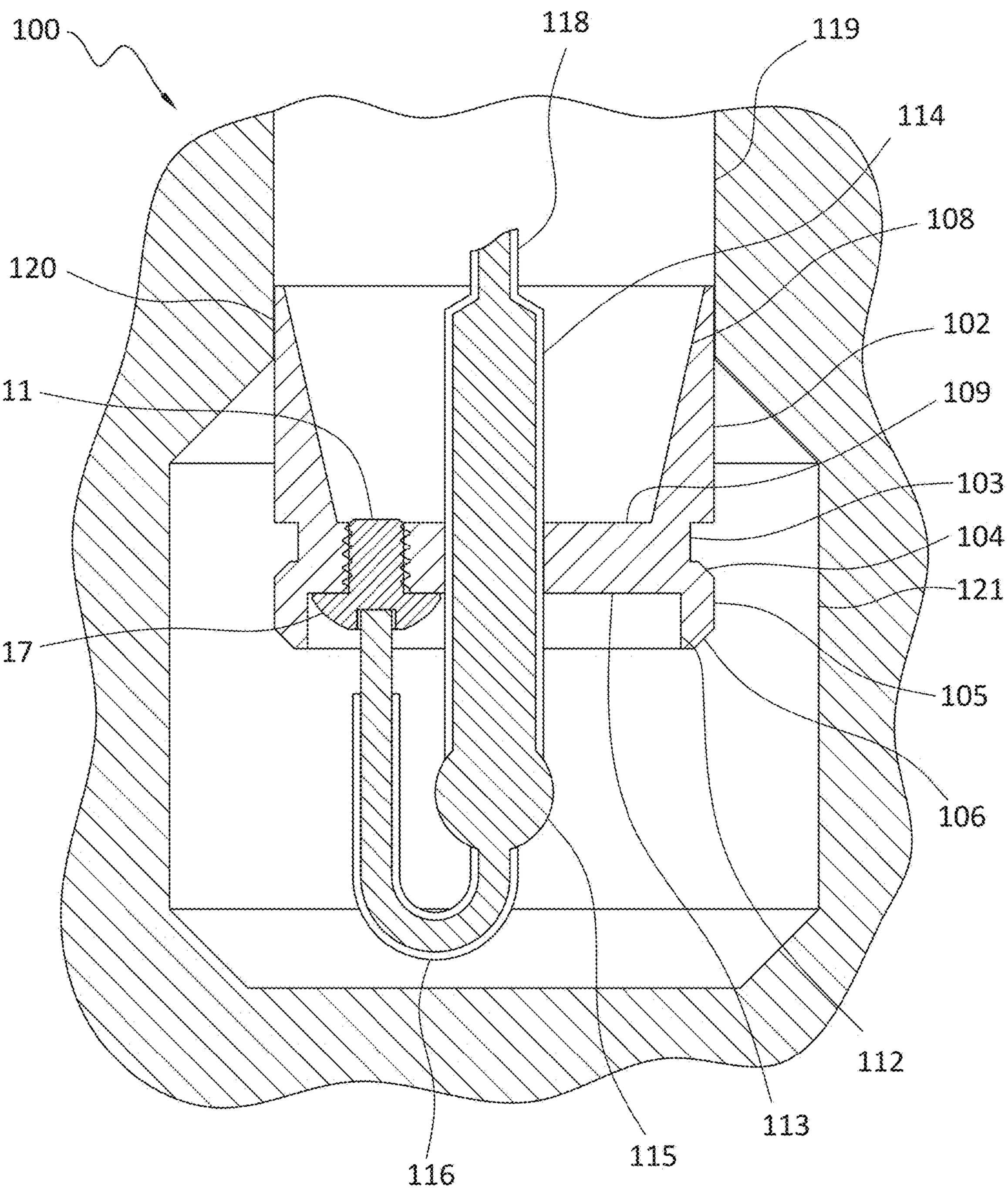

100
118
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FIG. 6

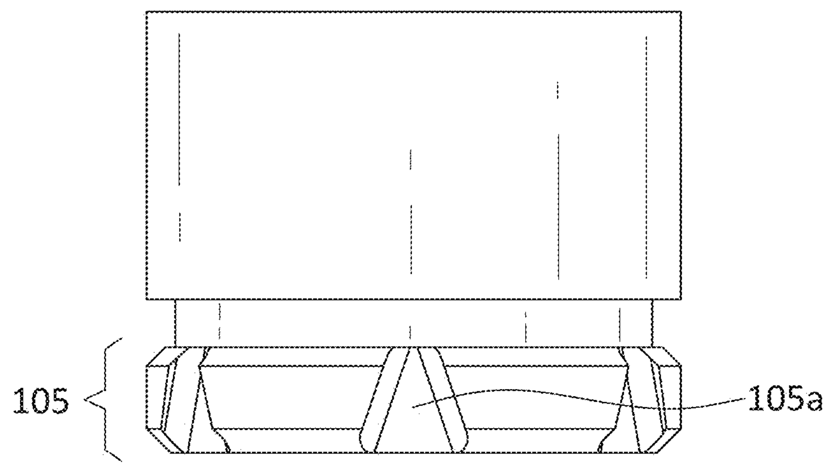


FIG. 7

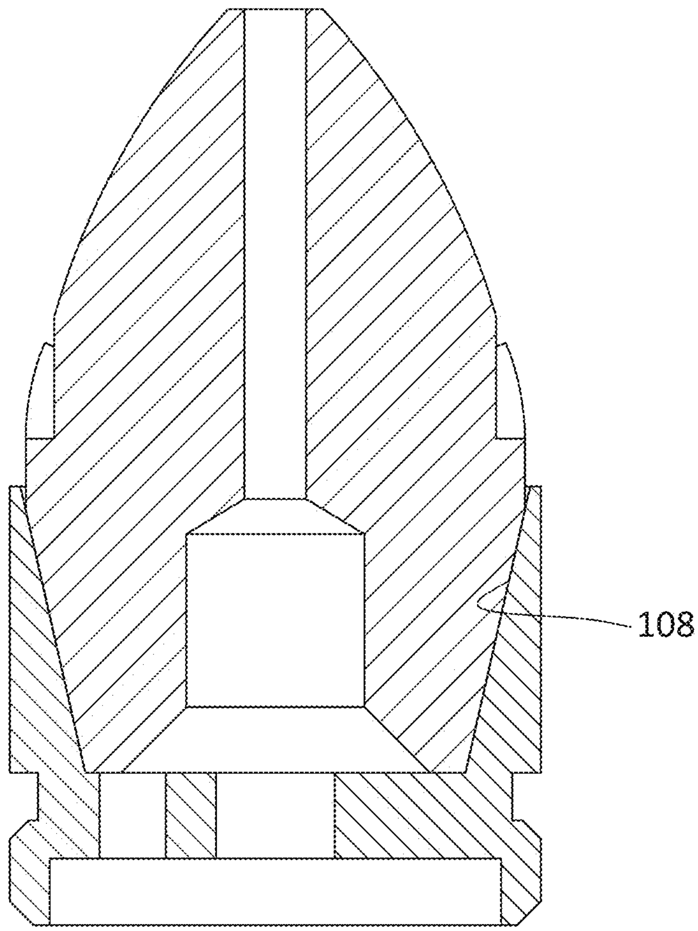


FIG. 8

# GROUNDING SABOT AND METHODS OF USE

## TECHNOLOGICAL FIELD OF THE DISCLOSURE

**[0001]** One or more example embodiments disclosed herein are directed to projectiles and associated components such as may be employed in downhole perforation operations. More specifically, example embodiments comprise a grounding sabot, and a method for using the same.

## BACKGROUND

**[0002]** Perforating is a process used to create holes in a well casing disposed in a wellbore. Perforation may be implemented using shaped charges. After perforation of the casing, and possibly the surrounding formation, fluids such as oil and gas may flow from the formation into the wellbore.

**[0003]** After perforating, hydraulic fracturing is employed to enhance the production of oil or gas. Fracturing may involve pumping fluid and proppant, such as sand, into the perforations in the well casing at high pressure to create fractures in the formation, which improves the permeability of the formation to the flow of gases and liquids from the formation into the wellbore.

**[0004]** Perforation guns are used in oil and gas well completion operations to create holes in the casing, cement, and formation, to enable hydrocarbons to flow into the wellbore. A disposable perforation gun tube is an element of the perforation gun assembly that carries the shaped charges that create the perforations.

**[0005]** While conventional perforation approaches have proven useful, the systems, devices, and methods for implementing perforation processes nonetheless leave room for improvement. For example, conventional approaches are relatively inefficient in terms of transferring forces resulting from propellant ignition to a projectile. As another example, the aerodynamic drag associated with conventional devices may reduce their velocity and, thus, the kinetic energy available for perforation.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0006]** The appended drawings contain figures of various example embodiments to further illustrate and clarify the above and other aspects of example embodiments. It will be appreciated that these drawings depict only example embodiments and are not intended to limit the scope of this disclosure or of any claims. Example embodiments will be described and explained with additional specificity and detail through the use of the accompanying drawings.

**[0007]** FIG. **1** is a side view of an example grounding sabot according to one embodiment.

**[0008]** FIG. **2** is a top view of the example grounding sabot disclosed in FIG. **1**.

**[0009]** FIG. **3** is a bottom view of the example grounding sabot disclosed in FIG. **1**.

**[0010]** FIG. **4** is an isometric view of the example grounding sabot disclosed in FIG. **1**, and further including an ignition device.

**[0011]** FIG. **5** is a side cross-sectional view of the example grounding sabot disclosed in FIG. **1**.

**[0012]** FIG. **6** is a side cross-sectional view of the example grounding sabot disclosed to FIG. **1**, chambered in a device such as a perf gun.

**[0013]** FIG. **7** is a side view of the gas channels of a grounding sabot according to one embodiment.

**[0014]** FIG. **8** is a side view of an interface of a grounding sabot, according to one embodiment, with a kinetic energy perforating round (KEPR).

## ASPECTS OF SOME EXAMPLE EMBODIMENTS

**[0015]** One or more example embodiments disclosed herein are directed to projectiles and associated components such as may be employed in downhole perforation operations. More specifically, one or more example embodiments comprise a grounding sabot, associated devices and components, and a method for using the same.

**[0016]** Embodiments may be implemented in various ways. One embodiment comprises a grounding sabot, part or all of which may be electrically conductive, and/or which may include one or more electrically conductive components, that includes elements such as, but not limited to: a body configured to be partly received within a propellant chamber of a perf gun, wherein the body defines an interface by way of which the sabot is engageable with a projectile; a divider that defines part of the interface; an ignition pass through that extends through the divider; an ignition stack electrically connected to the ignition pass through; a ground terminal electrically connected to the ignition pass through; a deflector having a cup-shaped configuration that is partly defined by a bottom portion of the divider, and the deflector is configured to expand diametrically upon ignition of a propellant in the propellant chamber when the sabot is received within the propellant chamber; a gas valve configured and arranged to be actuated by expansion of the deflector; and, a compensator positioned between the interface and the gas valve.

**[0017]** Another embodiment comprises a jacket that may implement one, some, or all, of the same functions as a grounding sabot. As well, a jacket may comprise many, or all, of the same components as a grounding sabot. However, in contrast with a grounding sabot which engages a projectile, the jacket may be swaged to a projectile, such as a KEPR for example. For example, a jacket may comprise an electrically conductive terminal, such as a grounding terminal or other terminal, that enables an electrical component, wire, or any device requiring power and or communication signals, such as an ignition device for example, to electrically connect to the jacket. In an embodiment, this electrical connection comprises a grounding connection, or simply a 'ground.' Other example electrical connections that may be implemented by way of a jacket, or sabot, include, but are not limited to, an ignition signal connection, a control signal connection, and a sensor connection.

**[0018]** As will be apparent from this disclosure, example embodiments of the invention may be advantageous in various respects. For example, an embodiment may be more efficient, relative to conventional approaches, in transferring forces resulting from propellant ignition to a projectile. As another example, an embodiment may be associated with a reduced aerodynamic drag, relative to conventional devices, that may enable projectiles to achieve higher velocities, and kinetic energies which, in turn, may provide more effective and reliable perforations. Various other advantages of some embodiments of the invention will be apparent from this disclosure.

[0019] It should be noted that nothing herein should be construed as constituting an essential or indispensable element of any invention or embodiment. Rather, and as the person of ordinary skill in the art will readily appreciate, various aspects of the disclosed embodiments may be combined in a variety of ways so as to define yet further embodiments. Such further embodiments are considered as being within the scope of this disclosure. As well, none of the embodiments embraced within the scope of this disclosure should be construed as resolving, or being limited to the resolution of, any particular problem(s). Nor should such embodiments be construed to implement, or be limited to implementation of, any particular effect(s).

## DETAILED DISCUSSION

### A. Context for One or More Embodiments—Methods and Processes

[0020] As noted earlier herein, embodiments may be employed in perforation processes in which a well casing, and possibly a formation within which the well casing is disposed, may be perforated using projectiles fired by a perforation gun. Following is a discussion of some considerations that may apply to one or more embodiments.

#### A.1 Purpose of Perforating the Casing

[0021] A well casing may be perforated for various reasons, one of which is reservoir access. In particular, a perforating a well casing may be performed to create channels or perforations in the well casing, enabling fluid communication between the reservoir and the wellbore. This enables hydrocarbons, for example, such as oil and gas, to flow from the reservoir into the wellbore, where they can be recovered. It is noted that as used herein, a 'fluid' embraces, gases, liquids, entrained particulates, and any combination of the foregoing.

#### A.2 Staged Approach to Perforating

[0022] One perforation process comprises a "plug-and-perf" method. In many hydraulic fracturing operations, a staged approach is employed using a plug-and-perf method. This involves perforating specific sections of the wellbore in stages, which may be isolated from each other by temporary isolation plugs that prevent the flow of fluids from one stage to another. In this approach, each stage corresponds to a specific depth interval in the well.

#### A.3 Plug-and-Perf Process

#### A.3.1 Staging

[0023] In preparation for a plug-and-perf process, various staging operations may be performed. These may included defining the number of stages, as well as various parameter values for the perforations. Staging operations may be useful for a variety of reasons. For example, staging enables more targeted and controlled access to different sections of a reservoir. This optimization may be important to enable maximization of hydrocarbon recovery and ensuring uniform production across the entire wellbore. As another example, staging operations may enhance In particular, a staged approach facilitates a more effective hydraulic fracturing process by isolating and treating specific reservoir intervals individually. This can lead to better fracture initiation and propagation.

[0024] The number of perforation stages may vary depending on factors such as the length of the horizontal well section, geological characteristics, and reservoir properties. Wells may have anywhere from a few to several dozen stages. The number of perforations per stage can also vary, and may depend on factors such as the desired production rate, reservoir characteristics, and the overall completion strategy. Each perforation creates a flow path for hydrocarbons to enter the wellbore during production.

#### A.3.2 Plug-and-Perf Processes

[0025] After staging has been completed, a plug-and-perf process may be performed. Such a process may comprise various operations. This process may begin with the drilling of the well. After the well has been drilled, a steel casing is installed and cemented in place to isolate and support the wellbore.

[0026] When the wellbore has been cased, a multistage perforation process may be performed in which the well is perforated in multiple stages. Each stage may comprise the following operations:

[0027] a. Setting an isolation plug—in this stage, a dissolvable or drillable isolation plug is set at a specific depth within the wellbore. This plug isolates the subsequent perforation zone from the previous ones.

[0028] b. Perforating—in this stage, perforating guns, equipped with shaped charges, are lowered into the wellbore opposite the targeted reservoir interval. The charges are fired, creating perforations in the casing and extending into the surrounding formation.

[0029] c. Repeating for each stage—the process of setting plugs, followed by perforating, is repeated for each designated stage.

[0030] d. Post-perforation clean-out and evaluation—after all of the stages are perforated, a workover rig such as a hydraulic workover or coiled tubing unit, may come in and drill out the remaining plugs in the well, clean/flush the wellbore of debris, and use a data collection system to ensure the effectiveness of the perforations and gather data on the wellbore conditions.

### B. Context for One or More Embodiments—Shaped Charges

[0031] As discussed earlier herein, a conventional perf process may employ shaped charges. A shaped charge may comprise various components, each of which are addressed in turn below.

#### B.1 Liner

[0032] A liner is a metal cone or cylinder that is shaped in such a way that, upon detonation, it collapses and forms a high-velocity jet of molten metal. This jet is directed towards the target material, such as a casing, and a formation.

#### B.2 Case

[0033] The case contains the explosive material, such as RDX and or HMX, and provides structural support for the shaped charge. The case is typically made of a material that can withstand conditions in a downhole environment without a material effect on the functionality of the shaped charge.

B.3 Detonation Cord (Det Cord)

**[0034]** Det cord is a flexible explosive cord that surrounds the outside of the case. The det cord acts as the initiator and ensures that the explosive material in the case detonates uniformly and symmetrically.

B.4 Energetic and Explosives

**[0035]** Shaped charges are sometimes referred to as energetic devices because they convert stored chemical energy of an explosive into kinetic energy of a projectile or jet. The detonation of the explosive material creates a high-velocity metal jet that penetrates the casing and cement to create perforations.

B.5 Consumable Item

**[0036]** Upon detonation of an explosive, the shaped charge exerts extreme forces and temperatures. This leads to the destruction of the carrier and the tube, making them unsuitable for reuse. Thus, the use of a shaped charge is a one-time use process. That is, a shaped charge can only be used once.

C. Detailed Discussion of Aspects of One or More Embodiments

**[0037]** An example grounding sabot (GS) according to one embodiment is disclosed in FIGS. **1** through **6**. Following are various considerations relating to one or more embodiments of a sabot.

C.1 Introduction

**[0038]** In an embodiment, a GS **100** may comprise a grounding terminal that enables an electrical component, wire, or device such as an ignition device to electrically ground to the GS **100**. As collectively shown in the Figures, the GS **100** may comprise various components. These are each discussed in turn below.

**[0039]** An embodiment of the GS **100**, as exemplified in FIG. **1**, may comprise a body in the form of a single piece of material, such as metal. The body of the GS **100** may be created in various ways, such as, but not limited to, machining, additive manufacturing processes, casting, and molding.

**[0040]** In general, a GS, such as the GS **100**, may help to optimize the performance of a KEPR (kinetic energy perforating round) (examples of which are disclosed in United States Utility Application (atty docket 22464.26.1), entitled KINETIC ENERGY PERFORATING ROUND AND METHODS OF USE, and filed the same day herewith) by one or more of the mechanisms discussed below.

**[0041]** In contrast with shaped charges, for example, an embodiment of the GS **100** may be reusable multiple times, in which multiple KEPRs or other projectiles are fired from the same GS **100**. As such, in one embodiment, the GS **100** is not a consumable item.

C.1.1 Ensuring Efficient Transfer of Force From the Propellant

**[0042]** In an embodiment, the GS **100** may have a snug fit inside the barrel of a penetrating charge dispenser (PCD), which may be carried by a perf gun, that creates a seal that helps contain and channel the expanding gases produced by the ignition of propellant. By preventing, or mitigating, gas leakage around the KEPR, the GS **100** may ensure that the maximum amount of force generated by the propellant is directed toward accelerating the GS **100** and KEPR. As well, the GS **100** may minimize gas blowby by closely conforming to the shape of the KEPR and barrel. This containment of gases ensures that more energy is harnessed to propel the GS **100** and KEPR forward.

C.1.2 Enhancing the Kinetic Energy of the KEPR

**[0043]** In an embodiment, the GS **100** may help streamline the KEPR shape, reducing aerodynamic drag as the KEPR travels through the barrel of a perf gun. By minimizing, or at least reducing, air resistance, the GS **100** may enable the KEPR to maintain higher velocities and, thus, kinetic energies, as the KEPR exits the barrel. Further, since kinetic energy is proportional to the square of the velocity, even small increases in velocity result in a significant enhancement of kinetic energy.

C.1.3 Increasing Velocity of the KEPR

**[0044]** In an embodiment, the GS **100** facilitates efficient acceleration by ensuring that the force generated by the propellant is transmitted directly to the KEPR and GS **100**. This efficient acceleration, coupled with the minimized air resistance provided by the GS **100**, may result in a more rapid increase in velocity of the KEPR.

C.1.4 Non-Discarding Sabot

**[0045]** In an embodiment, the GS **100** may, but need not necessarily, comprise a non-discarding configuration and mode of operation. That is, a non-discarding GS **100** may remain attached to the KEPR, rather than being discarded or ejected, as the KEPR leaves the barrel. Put another way, unlike a discarding sabot, which may fall away, or be discarded, after it exits the muzzle of a barrel, a non-discarding GS **100** stays with the KEPR throughout the trajectory of the KEPR.

**[0046]** A sabot according to one embodiment, such as a non-discarding sabot for example, may contribute to an increase, relative to a circumstance where the sabot is not employed or where a conventional sabot is employed, in kinetic energy of the associated projectile. Kinetic energy (KE) is the energy an object possesses due to its motion. In the example context of a KEPR, increasing kinetic energy may enhance the perforating capabilities of the KEPR. The non-discarding GS **100** may play a role in this improvement in the kinetic energy of the KEPR by ensuring a tight fit of the GS **100** with the KEPR, and with the barrel of a penetrating charge dispenser from which the KEPR may be fired, reducing air resistance, and maximizing the transfer of energy from the propellant to the KEPR.

**[0047]** A sabot according to one embodiment may help to improve the velocity of a projectile, such as a KEPR for example. Velocity is a contributing factor to the kinetic energy of a KEPR. The non-discarding GS **100** may contribute to improved velocity of the KEPR by minimizing drag forces during as the KEPR travels through a barrel of a perf gun or other device.

**[0048]** A sabot according to one embodiment may improve, relative to a circumstance where the sabot is not employed or where a conventional sabot is employed, the work exerted on a projectile, such as KEPR for example. In this regards, 'work' is the product of force and displacement. In the context of a non-discarding GS **100**, the force exerted by the expanding gases from the propellant is transmitted efficiently to the KEPR. The GS **100** assists in converting this force into acceleration of the KEPR, enabling the KEPR to achieve higher speeds. The work done on the KEPR may thus be maximized by an embodiment of a sabot, resulting in increased kinetic energy of the KEPR.

C.2 Discussion

**[0049]** With attention now to the examples of FIGS. **1** through **6**, details are provided concerning aspects of example components of an example grounding sabot (GS), referenced in the Figures at **100**, according to one embodiment. In an embodiment, the GS **100** may house, encase, or surround, a KEPR. In an embodiment, a jacket may be similar to a sabot except that the jacket may be swaged to the projectile. In an embodiment, a jacket may serve the same purpose(s) as a sabot.

**[0050]** As noted above, another embodiment comprises a jacket that may implement one, some, or all, of the same functions as a grounding sabot. As well, a jacket may comprise many, or all, of the same components as a grounding sabot. However, in contrast with a grounding sabot which engages a projectile, the jacket may be swaged to a projectile, such as a KEPR for example. For example, a jacket may comprise an electrically conductive terminal, such as a grounding terminal or other terminal, that enables an electrical component, wire, or any device requiring power and or communication signals, such as an ignition device for example, to electrically connect to the jacket. In an embodiment, this electrical connection comprises a grounding connection, or simply a 'ground.' Other example electrical connections that may be implemented by way of a jacket, or sabot, include, but are not limited to, an ignition signal connection, a control signal connection, and a sensor connection.

C.2.1 Apex

**[0051]** The apex **101** of the GS **100** is the upper most portion of the GS **100**, or the top of the GS **100**. As shown in the particular example of FIG. **4**, the apex **101** may comprise an upper rim of a bearing surface **102**.

C.2.2 Bearing Surface

**[0052]** A bearing surface **102** according to one embodiment may provide various functions. For example, the bearing surface **102** may be configured to conform closely to the outer profile of a KEPR. This precise fit may help to ensures that the GS **100** provides maximum support to the KEPR during acceleration of the KEPR through a barrel (see reference **119**), discussed below.

**[0053]** A bearing surface **102** may serve as a sealing device within a gun barrel. It may create a gas-tight seal around the KEPR, preventing gas blowby, or the escape of high-pressure propellant gases around the KEPR. This sealing action may maximize the transfer of propellant energy to the KEPR, contributing to efficient acceleration of the KEPR.

**[0054]** In an embodiment, the bearing surface **102** may incorporate grooves, compensators, or drive bands that may capture gas that may be trying to blow by the GS **100** as it accelerates through the barrel **119**. These features may enhance the overall performance and perforating capability of the KEPR.

**[0055]** In an embodiment, the bearing surface **102** may be configured to distribute the pressure generated by the propellant gases evenly across the contact area of the bearing surface **102** with a gun barrel. This distribution may help prevent localized wear and deformation, ensuring the GS **100** maintains its structural integrity throughout the firing process.

**[0056]** In an embodiment, as the GS **100** travels down a gun barrel, it may experience significant heat generated by the rapid combustion of propellant. The bearing surface **102** may be configured, and comprise material(s), to dissipate this heat efficiently and may prevent overheating and degradation of material properties of the GS **100**. Heat-resistant materials and heat dissipation features contribute to maintenance of the GS **100** structural integrity, and examples of such materials include, but are not limited to, aluminum, titanium, copper, and brass.

**[0057]** In an embodiment, an outside diameter of the bearing surface **102** may closely match the inside diameter of a gun barrel. Such a precise fit may reduce the amount of surface area of the GS **100** that is in contact with a barrel, minimizing friction. That is, because the GS **100** may comprise aluminum or other relatively low friction material, and/or because the outside diameter of the GS **100** may be greater than that of the projectile, the bearing surface **102** may keep the projectile from touching the barrel. The material of the GS **100**, with the additional surface contact, reduces the friction that may otherwise result if the projectile were to come into contact with the barrel **119**. This may create a tight seal without unnecessary interference, enabling the GS **100**, which may comprise aluminum and/or other material(s), to travel through the barrel with lower friction than if some other materials were used for the GS **100**.

C.2.3 Compensator

**[0058]** In an embodiment, a compensator **103** may act as a sealing component within the GS **100**, creating a gas-tight seal between the GS **100** and the KEPR. This seal may be useful in containing the high-pressure propellant gases behind the GS **100** and KEPR, preventing gas blowby past the KEPR and ensuring that the majority of the propellant energy is used to propel the GS **100** and KEPR forward.

**[0059]** By creating this gas-tight seal, the compensator **130** may minimize the escape of propellant gases around the GS **100**. This may help to maximize the efficiency of the propulsion system, as any gas leakage results in energy loss of the KEPR and, correspondingly, reduced overall performance of the KEPR.

**[0060]** In an embodiment, the use of a compensator **103** in a non-discarding GS **100** may provide one or more advantages. For example, the compensator **103** may ensure that the propellant gases are effectively harnessed to drive the GS **100** and KEPR. By containing the gases and minimizing blowby, the compensator **103** may contribute to a more efficient transfer of energy from the propellant to the GS **100** and to the KEPR, leading to enhanced acceleration and velocity of the KEPR.

**[0061]** As another example, the compensator **103** may reduce fouling and wear within the gun barrel by containing the propellant gases and preventing direct contact between the GS **100** and the barrel. This may help in maintaining the longevity of the barrel and preserving the consistency of ballistic performance over multiple firings.

**[0062]** As another example, the compensator **103** may ensure a consistent and controlled environment for the GS **100** and KEPR, regardless of external conditions. By maintaining a secure seal, the compensator **103** may minimize the impact of factors such as temperature and pressure variations on the performance of the KEPR.

**[0063]** Yet another advantageous aspect of an example compensator **103** concerns the gas jetting that occurs when high-pressure gases escape unevenly around the GS **100** and KEPR, leading to asymmetrical forces that can affect performance of the assembly. The compensator **103** may minimize gas jetting effects by providing a uniform seal, promoting a more symmetrical and predictable flight path for a projectile.

**[0064]** In an embodiment, the compensator **103**, by effectively containing and utilizing propellant gases, contributes to the optimization of kinetic energy. The enhanced acceleration and velocity achieved through proper gas sealing may result in higher kinetic energy upon impact, improving the ability of the KEPR to perforate multiple layers of confined target such as wellbore casing, cement, and formation.

C.2.4 Conducive Angle

**[0065]** In an embodiment, a conducive angle **104** on the body of the GS **100** may enable optimal expansion of propellant gases into the compensator **103**. The angle, that is, the conducive angle **104**, at which gases are channeled into the compensator **103** may be important for enhancing performance and mitigating potential issues such as flame gouging. In an embodiment, the conducive angle **104** may be in a range of 15 degrees to 100 degrees, inclusive.

**[0066]** In an embodiment, the conducive angle **104** may configured to facilitate the smooth and controlled flow of propellant gases into the compensator **103**. This conducive angle **104** may be configured to minimize turbulence and resistance, ensuring that gases can efficiently fill the space within the compensator **103**. For example, the conducive angle **104** may enable a gradual expansion of gases as they move from the confined space of the gun barrel **119** into the compensator **103**. A gradual expansion helps maintain a controlled environment, reducing the likelihood of sudden pressure differentials that could impact the structural integrity of the GS **100** or the compensator **103**.

**[0067]** The definition, configuration, and implementation, of the conducive angle **104** in the body of the GS **100** may be beneficial. For example, the conducive angle **104** may promote the efficient transfer of energy from the expanding gases to the GS **100**. By enabling gases to fill the compensator **103** uniformly, the conducive angle **104** may help to ensure that the force generated by the propellant is evenly distributed, contributing to effective acceleration and velocity of the GS **100** and the KEPR.

**[0068]** As well, the conducive angle **104** may enable controlled gas expansion into the compensator **103** to help minimize gas blowby. This may be important for preventing the escape of high-pressure gases around the GS **100**, which could result in energy loss and reduced overall performance. Further, an embodiment of the conducive angle **104** may contribute to creation and maintenance of a secure seal between the GS **100** and the barrel **119**. The correct conducive angle **104** may help establish a gas-tight environment, optimizing the efficiency of the propulsion system. As noted below, the conducive angle **104** may help to mitigate various issues that can arise during the firing of a projectile that includes a GS **100**.

**[0069]** For example, flame gouging is a phenomenon where hot propellant gases erode or damage the surfaces of the GS **100**. In an embodiment, the conducive angle **104** may help mitigate flame gouging by directing gases in a way that minimizes direct impingement on surfaces. The conducive angle **104** may enable a more controlled interaction between gases and material surfaces, reducing the risk of erosion. As another example, an embodiment of the conducive angle **104** may play a role in regulating the temperature and pressure within the compensator **103**. A conducive angle **104** may help prevent sudden spikes in pressure or temperature that could lead to adverse effects on the GS **100** or compensator **103** material, contributing to a more controlled and predictable environment.

C.2.5 Gas Valve

**[0070]** The configuration of an embodiment of a gas valve **105** may facilitate a balance between maintaining an initial seal for efficient energy transfer and enabling, in a controlled way, some gas to bypass the KEPR, contributing to optimal propulsion. An embodiment of a gas valve **105** with controlled gas bypass may have various characteristics.

**[0071]** For example, an embodiment of the gas valve **105** may be, or comprise, one or more gas channels **105*a*** which may be sized and configured to enable controlled amounts of gas to flow over the conducive angle **104** and into the compensator **103**. This configuration may help to ensure management of gas flow during the firing sequence. In an embodiment, the guides and/or channels may be circumferential.

**[0072]** As another example of an aspect of an example gas valve **105**, rather than being a permanent, hermetic seal, the gas valve **105** may be configured to act as a controlled valve. This configuration may enable small amounts of gas to bypass the initial seal formed between the gas valve **105** and the barrel, typically over/past the conducive angle **104**, and enter the compensator **103**. The behavior of an embodiment of the gas valve **105** serves to capture as much energy, from propellant gases, as possible while maintaining stability of the GS **100** in flight. In more detail, the gas valve **105** may conform uniformly to the barrel, and allow gas to expand into the compensator **103**. As the GS **100** travels up the barrel, the gas valve **105** may eventually seal and close off the barrel, thus capturing all of the gas while the compensator **103** captures the gas that has bypassed the gas valve **105**.

**[0073]** In one embodiment, the controlled gas bypass enabled by the gas valve **105** may contribute to optimization of energy transfer from the propellant gases to the GS **100** and KEPR. By enabling gas flow over the conducive angle **104** in a controlled way, the configuration of the gas bypass **105** may capture additional energy that would otherwise be lost in a fully sealed system, maximizing the efficiency of the propulsion system. While allowing controlled gas bypass, the gas valve **105** may still maintain an effective initial seal, minimizing the risk of significant gas blowby past the KEPR and/or other components of the GS **100**. This controlled bypass may balance the need for capturing energy with the requirement of preventing excessive gas leakage around the KEPR or other projectile.

**[0074]** In an embodiment, the valve-like behavior of the gas valve **105** provides dynamic adaptability to changing conditions during firing. It allows the system to adjust the amount of gas bypass based on factors such as pressure, temperature, and KEPR velocity, ensuring optimal performance across different scenarios. Moreover, controlled gas bypass helps mitigate the risk of flame gouging by allowing gases to flow in a regulated manner. This can prevent excessive heat and pressure from directly impinging on surfaces, reducing the likelihood of erosion or damage to the GS **100** or compensator **103**. Finally, by allowing small amounts of gas to bypass over the conducive angle, an embodiment of the gas valve **105** may serve to enhance stability during its trajectory through the barrel. The controlled bypass helps manage asymmetrical forces and disturbances, contributing to a more predictable and stable trajectory of the KEPR.

C.2.6 Engagement Angle

**[0075]** An engagement angle **106**, positioned below the gas valve **105**, comprises a section of the outer diameter of the GS **100** that comes into contact with the propellant gases. This engagement angle **106** may be useful in initiating the controlled interaction between the GS **100** and the propellant gas, leading to efficient energy transfer and propulsion. In one embodiment, the engagement angle **106** may be in a range of 10 degrees to 50 degrees, inclusive.

**[0076]** In an embodiment, the engagement angle **106** is the first part of the outer diameter of the GS **100** that the propellant gases encounter, and the engagement angle **106** may be configured and arranged to be the primary point of contact where the gas begins to interact with the outer diameter of the GS **100**. The engagement angle **106** may be configured to facilitate a controlled and gradual entry of gas into the gas valve. Its configuration ensures that gas flow commences in a manner that allows for efficient energy capture while maintaining stability.

**[0077]** In an embodiment, the engagement angle **106** plays a role in initiating the process of energy transfer from the propellant gases to the GS **100** and associated projectile. In particular, as propellant gases come into contact with the engagement angle **106**, the controlled interaction begins, setting the stage for optimal energy capture and subsequent propulsion. As the initial point of contact with the propellant gases, an embodiment of the engagement angle **106** configuration enables a gradual expansion of gases. This configuration may ensure that the pressure buildup due to gas generation and expansion is controlled, contributing to a more stable and predictable acceleration of the GS **100** and KEPR.

**[0078]** Among other things, an embodiment of the engagement angle **106** may help to ensure controlled entry of gas into the gas valve **105**, preventing sudden or uneven pressure differentials. This controlled environment contributes to stable propulsion and minimizes the risk of issues such as turbulence or erratic forces. Further, the configuration and arrangement of an embodiment of the engagement angle **106** may be optimized to minimize abrasion and wear as the gas begins to interact with the GS **100**. This may be important for preserving the structural integrity of the GS **100** and maintaining consistent performance over multiple firings of one or more instances of a GS **100**.

**[0079]** In an embodiment, the engagement angle **106** serves as a transitional zone that directs gas flow towards the gas valve. This ensures that the gas valve **105** operates effectively, capturing as much energy as possible while maintaining a degree of control over gas flow. As well, by guiding the initial interaction between the GS **100** and propellant gases, the engagement angle **106** contributes to the overall enhancement of propulsion, and optimizes the efficiency of the kinetic energy transfer process, leading to improved performance of the GS **100** and KEPR.

C.2.7 Base

**[0080]** The base **107** of the GS **100** is the bottommost section of the example GS **100**. FIG. **1** discloses an example configuration and arrangement of a base **107** according to one embodiment.

C.2.8 KEPR Interface

**[0081]** In an embodiment, the interior wall of the GS **100**, referred to as the KEPR interface **108**, and shown in FIG. **2**, directly interacts with the KEPR. As such, the KEPR interface **108** may play a role in ensuring stability, alignment, and efficient energy transfer during the KEPR firing sequence.

**[0082]** The KEPR interface **108** may be constructed from high-strength materials capable of withstanding the intense forces and pressures generated during the firing of the GS **100** and KEPR. Common materials include metals, alloys, or composite materials chosen for their durability and structural integrity. An embodiment of the KEPR interface **108** may be constructed using precision machining to achieve the desired dimensions and geometry. This machining may help to ensure a snug fit with the KEPR, minimizing play and maintaining alignment between the KEPR and the GS **100**. In an embodiment, the KEPR interface **108** may be configured to conform closely to the outer profile of the KEPR. This close fit aids stability and may help to prevent any unnecessary movement or misalignment during the KEPR and GS **100** travel through the barrel **119** and upon exit. In one embodiment, the fit between the KEPR interface **108** and the outer profile of the KEPR may be an intentional negative press fit in a range of −0.001" to 0.010", inclusive.

**[0083]** In an embodiment, the KEPR interface **108** is configured to stabilize the KEPR within the GS **100**. It prevents undesirable movements, rotations, or wobbling, ensuring that the KEPR maintains a consistent orientation during its entire trajectory. A precise interface between the KEPR interface **108** and a projectile helps in maintaining proper alignment between the GS **100** and the KEPR. This alignment helps in achieving accuracy and stability in flight, ultimately influencing the KEPR impact energy on the target.

**[0084]** An embodiment of the KEPR interface **108** may contribute to improved energy transfer from propellant gases to the GS **100** and projectile. For example, an embodiment of the KEPR interface **108** may facilitate the efficient transfer of energy from the GS **100** to the KEPR. During the firing sequence, the KEPR interface **108** ensures that the forces generated by the propellant are transmitted directly to the KEPR, contributing to effective acceleration. As well, a relatively close fit and precise interface between the KEPR interface **108** and KEPR minimize energy losses within the

GS **100**. By reducing play and maintaining a secure connection, the KEPR interface **108** may ensure that the maximum amount of energy generated by the propellant is transferred to the KEPR, maximizing the kinetic energy of the KEPR.

C.2.9 Divider Top

**[0085]** In an embodiment, a divider top **109** may comprise a base plate that separates the KEPR from a propellant chamber (reference **121**, discussed below). The divider top **109** may comprise two openings in the bottom through which a ground terminal (reference **111**, discussed below) and an ignition pass through and/or ignition stack (reference **114**, discussed below), respectively, may pass, as shown in the example of FIG. **5**.

**[0086]** In an embodiment, the divider top **109** may be integral with the body of the GS **100** and, as such, may be constructed from materials chosen for their strength, durability, and ability to withstand the forces and pressures experienced during the firing sequence. Such materials include metals or alloys, with considerations for factors such as weight and structural integrity.

**[0087]** In an embodiment, the divider top **109** may comprise a flat and circular design, such as in the shape of a round disk for example. This geometry enables ease of manufacturing, uniform distribution of forces, and contributes to the overall energy capturing capabilities of the GS **100**. In one embodiment, the divider top **109** may have a thickness of approximately 0.080 inches to 0.115 inches. This thickness may be selected to provide the necessary structural support for a KEPR and the elements of GS **100**, while considering weight constraints and considerations

**[0088]** One example function of an embodiment of the divider top **109** is to provide structural support to the KEPR system. Positioned between the KEPR and the propellant, the divider top **109** helps distribute and withstand the forces generated during the firing process, ensuring the integrity of the assembly that comprises the KEPR and GS **100**. As well, the divider top **109** acts to isolate the KEPR and the propellant from each other. The divider top **109** may prevent direct contact between these components, maintaining the required configuration for efficient energy transfer during the KEPR acceleration.

**[0089]** In an embodiment, the divider top **109**, along with other GS **100** components, contributes to creating a gas-tight seal within the GS **100**. This seal may help in directing the propellant gases toward propelling the KEPR and GS **100** forward, minimizing gas blowby within the inside of the GS **100**, and optimizing the efficiency of the propulsion system. By serving as a barrier between the KEPR and the propellant, the divider top **109** helps prevent gas leakage around the KEPR. This may be important for ensuring that the maximum amount of propellant energy is utilized for accelerating the KEPR.

**[0090]** In terms of its relation to the GS **100**, an embodiment of the divider top **109** may be securely attached, as a separate and discrete component, to the GS **100**, or manufactured as an integral element of the GS **100**, forming a stable connection. The area of the divider top **109** that is integrated into the GS **100**, or attached, may be configured to withstand the forces exerted during firing and to ensure that the divider top **109** remains in place throughout the KEPR travel through a barrel.

**[0091]** In an embodiment, the configuration of the divider top **109** is compatible with the configuration of the propellant. Particularly, an embodiment of the divider top **109** may help to ensure that the propellant gases are directed efficiently toward the GS **100** while maintaining the necessary structural considerations. A thickness of the divider top **109** may be such as to balance structural strength with weight considerations. This optimization ensures that the KEPR achieves the desired performance characteristics without unnecessary weight penalties.

C.2.10 Ignition Pass Through

**[0092]** In an embodiment, the GS **100** comprises an ignition pass through **110**, which may be in the form of a hole or opening, that may serve as a pass through for an ignition stack or ignition device that may be located in the center of the GS **100**. The ignition pass through **110** may comprise materials suitable for conducting electrical current safely and reliably. Possible materials include metals with good electrical conductivity.

**[0093]** With regard to its configuration, the example ignition pass through **110** may comprise a conductive rod or hole that extends through the bottom of the divider top divider **109** and into the propellant chamber (reference **121**, discussed below. The ignition pass through **110** configuration helps to ensure a secure connection and pass through for an ignition device or ignition stack (reference **114**, discussed below).

**[0094]** In an embodiment, the portion of the ignition pass through **110** that passes through, and possibly contacts, the divider top **109** may be insulated to prevent unintended electrical contact and electrical current conduction with the surrounding GS **100** components. This insulation may help maintain electrical integrity and ensures that ignition is initiated only when intended or by eliminating potential intermittence or grounding of the ignition device or ignition stack.

**[0095]** With regard to some example functionalities, an embodiment of the ignition pass through **110** serves as the pathway, and or housing, for an ignition device or ignition stack that may be used to initiate the ignition of the propellant. Thus, the ignition pass through **110** may be configured to house, or enable pass through of, an internal ignition system, such as an electrical firing mechanism, or ignition device. As best shown in FIG. **6**, the ignition pass through **110** extends into the propellant chamber (reference **121**, discussed below) and/or through to the bottom of the divider top **109**, ensuring that the electrical energy is delivered through the GS **100** and directly to the propellant. This integration may be important for achieving consistent and reliable ignition, as the energy is applied at the point where it is needed for propelling the KEPR.

**[0096]** An embodiment of the ignition pass through **110** may comprise various safety features. For example, the portion of the ignition pass through **110** passing through the divider top **109** may be insulated to prevent unintended electrical contact with other components. This insulation enhances safety by minimizing the risk of electrical discharge before intentional ignition. As another example, the ignition pass through **110** may be defined in the divider top **109** and may be situated in the center of the divider top **109**, to ensure stability and reliable electrical connection. This arrangement is configured to withstand the forces and vibrations experienced during the firing sequence.

**[0097]** In an embodiment, the ignition pass through **110** may be positioned in or near the center of the GS **100** or in a location, passing through the divider top **109**, that may enable an ignition device to deliver electrical energy directly into the propellant chamber **121**, ensuring that ignition occurs in the proper location of the propellant charge. This location of the ignition pass through **110** helps to maximize the effectiveness of the GS **100**. In an embodiment, the configuration of the example ignition pass through **110** takes into account the configuration of the propellant chamber **121**, and also ensures that the ignition pass through **110** is appropriately positioned to allow an ignition device to initiate ignition in a manner that optimally utilizes the propellant energy for accelerating the KEPR.

C.2.11 Ground Terminal

**[0098]** A ground terminal **111**, which may be offset to the ignition pass through, plays a role in providing a pathway for electrical grounding within the GS **100** assembly. In an embodiment, the ground terminal **111** ensures a controlled and safe discharge of electrical energy, contributing to the overall safety and reliability of the ignition system.

**[0099]** In one embodiment, the ground terminal **111** is positioned at a distinct location, separate, and spaced apart, from the ignition pass through **110**. Similar to the ignition pass through **110**, an embodiment of the ground terminal **111** may be made of conductive materials with good electrical conductivity, so as to ensure a reliable pathway for grounding and/or passing electrical current. The ground terminal **111** may comprise a pass through for a grounding device, extending, or passing through, from a specific point in the GS **100** assembly to facilitate the grounding function. The configuration of the ground terminal **111** provides stability, reliability, and ease of integration within the overall assembly.

**[0100]** In one embodiment, a primary function of the ground terminal **111** is to provide a designated pathway for grounding the ignition system. This helps to ensure the safe and controlled discharge of electrical energy during the firing sequence. The offset position, as shown in FIG. **2**, of the ground terminal **111**, relative to the ignition pass through **110**, may ensure that a grounding process facilitated by the ground terminal **111** is electrically isolated from, and unaffected by, the ignition process facilitated by the ignition pass through **110**. This intentional separation prevents unintentional grounding and contributes to the overall safety of the system.

**[0101]** An embodiment of a ground terminal **111** may provide various safety features. For example, an embodiment may prevent unintended discharge of electrical energy. The offset configuration between the ground terminal **111** and the ignition pass through **110** ensures that grounding occurs only when intentionally initiated, reducing the risk of accidental activation. In an embodiment, the ground terminal **111** may comprise insulation or isolation features to prevent unwanted electrical contact/communication with other selected components. This feature further enhances safety by minimizing the potential for electrical discharge in unintended areas of the GS **100** assembly.

**[0102]** As suggested above, a ground terminal **111** may be integrated with an ignition system. For example, an embodiment of the ground terminal **111** is configured to connect to an external grounding system or component, or to enable the transfer of electric current from the GS **100** and through the barrel **119** to ground. This connection ensures that the electrical current is safely discharged to the ground, completing the circuit and preventing the accumulation of charge. In one embodiment, the configuration of the ground terminal **111** takes into account the configuration of the ignition device. It ensures compatibility and effective integration to establish a reliable grounding pathway from the GS **100**, to the barrel, and to ground as part of the overall ignition system.

**[0103]** With regard to safety considerations, the ground terminal **111** may be securely attached to the GS **100** assembly, ensuring stability and reliability. This attachment is configured to withstand the forces and vibrations experienced during the firing sequence.

**[0104]** Finally, in an embodiment, the ground terminal **111** may incorporate redundancy features to ensure the reliability of the grounding system. For example, the ground terminal **111** may comprise multiple ground terminals or backup mechanisms to guarantee a consistent and fail-safe grounding process.

C.2.12 Deflector

**[0105]** As best shown in FIGS. **5** and **6**, deflector **112**, situated at the bottom of the GS **100**, is a component of the GS **100** that may optimize the capture of energy generated during the firing of the GS **100** and KEPR system. The configuration of the deflector **112** may enable it to deflect outward and conform to the barrel **119**, ensuring efficient utilization of propellant energy. In particular, the gas pressure expands the deflector **112** outward and conforms the deflector **112** to the ID (internal diameter) of the barrel. This element captures the gas in the cup shape of the bottom of the GS **100**. The deflector **112** may be analogous to the walls of the cup and the gas is forcing the deflector **112** outwards towards the ID of the barrel **119**.

**[0106]** With regard to some of its example physical characteristics, an embodiment of the deflector **112** may be made from materials known for their durability, heat resistance, and ability to withstand the forces generated during the firing sequence. Such materials include metals or alloys capable of maintaining structural integrity under high pressures and temperatures. In one embodiment, the deflector **112** is integral with the GS **100**, and has a configuration resembling an upside down cup with a wall that is located at the bottom of the GS **100**. The deflector **112** is positioned to interact with the propellant gases and contribute to the overall efficiency of the propulsion system. In an embodiment, the deflector **112** comprises a shape that enables it to conform to the interior shape of the gun barrel **119**. This conforming configuration may help in maximizing the capture of propellant energy by directing gases in a controlled manner.

**[0107]** An embodiment of the deflector **112** may be configured to deflect, or flex, outward, such as under the influence of the temperature and pressure of the gas, during a firing sequence. This outward deflection that may optimize the interaction, such as by increasing the contact area, between the GS **100** and the gun barrel **119**, ensuring that propellant gases are efficiently captured. By conforming to a barrel for example, the deflector **112** maximizes the transfer of energy from the propellant gases to the GS **100**. This configuration of the deflector **112** contributes to enhanced acceleration and velocity of the GS **100** and KEPR by capturing as much energy as possible during the initial phase of propulsion.

**[0108]** In an embodiment, the deflector **112** guides the propellant gases in a controlled manner as they expand within the cup-like structure of the deflector **112**. This controlled gas flow may be helpful in preventing turbulence and ensuring that energy is efficiently transferred to the GS **100**. Further, the conforming, or conformable, shape and configuration of the deflector **112** enhances the efficiency of the gas-to-GS **100** energy transfer, and may also help create a more directed and focused flow of propellant gases, reducing energy losses and optimizing the overall performance of the GS **100**.

**[0109]** An embodiment of the deflector **112** may lend a degree of stability to the GS **100**. For example, the deflector **112** maintains structural integrity during the outward deflection. This stability may ensure that the GS **100** remains intact and that the deflector **112** effectively channels the energy without compromising the overall structural integrity of the assembly that comprises the KEPR and GS **100**.

**[0110]** In an embodiment, the configuration of the deflector **112** takes into account its compatibility with other GS **100** components, such as the divider bottom (reference **113**, discussed below) and gas valve **105**. This ensures a cohesive interaction between components and contributes to the stability of the entire system.

**[0111]** An embodiment of the deflector **112** may be heat and abrasion resistant. For example, the deflector **112** may comprise elements such as heat-resistant coatings or materials to withstand the high temperatures generated during the firing process. Additionally, abrasion-resistant properties help maintain the longevity of the deflector **112** under repeated use. Example abrasion-resistant materials and coatings include PTFE (polytetrafluoroethylene) coatings, polymer and plastic coatings, anodization, and electroless nickel.

**[0112]** Finally, while able to deflect outwardly, the deflector **112** may also contribute to implementing and maintaining an initial gas seal to close the gas valve **105** by deflecting outward and forcing the gas valve closer to the gun barrel **119** wall. This is useful in preventing gas blowby and ensuring that the expanding propellant gases are directed toward the KEPR.

C.2.13—Divider Bottom

**[0113]** In an embodiment, and as shown in FIGS. **5** and **6** for example, a divider bottom **113** disposed opposite the divider top **109**. That is, the divider top **109** and divider bottom **113** may comprise respective opposing faces of a divider.

**[0114]** Thus, the divider bottom **113** may be located at the base of the GS **100** assembly, situated beneath the KEPR and forming the lower part of the GS **100**. As one of the initial components exposed to the ignited propellant gases, the divider bottom **113** helps in capturing and directing these gases to drive the propulsion system.

**[0115]** As with all of the other elements of the GS **100** body, the divider bottom **113** may be an integral element of the GS **100** body which, as noted elsewhere herein, may comprise a single piece of material. More particularly, an embodiment of the divider bottom **113** may be formed as an integral part of the GS **100**, forming a lower section that interacts directly with the ignited propellant gases.

**[0116]** Accordingly, an embodiment of the divider bottom **113** may comprise robust and heat-resistant materials to withstand the high pressures and temperatures generated during the firing sequence. Such materials include metals or alloys chosen for their durability and stability under extreme conditions. As well, the divider bottom **113** may be configured to maintain structural rigidity under the significant forces experienced during firing. This stability may enable the divider bottom **113** to withstand the pressure generated by the propellant, that is, the propellant gases that result from ignition of the propellant, and to provide a reliable foundation for the entire GS **100** assembly.

**[0117]** In one embodiment, a role of the divider bottom **113** is to capture the propellant gases and channel them in a controlled manner. As one of the first components exposed to the expanding gases, the divider bottom **113** plays a role in initiating the propulsion process. For example, by capturing and directing the propellant gases, the divider bottom **113** contributes to the efficient transfer of energy from the propellant to the GS **100** so as to propel the KEPR with optimal velocity.

**[0118]** To this end, an embodiment of the divider bottom **113** is configured to confine and direct the propellant gases in a way that optimizes energy transfer. The shape and configuration of the example divider bottom **113** may help create a controlled environment within the GS **100**, guiding the gases toward the desired path, that is, toward the KEPR or other projectile. In an embodiment, the divider bottom **113** contributes to enhancing gas pressure within the GS **100** assembly. Particularly, by capturing and confining the gases, an embodiment aids in creating a high-pressure environment that drives a projectile.

**[0119]** In addition to aiding with control of gas flow, the divider bottom **113** may provide support for a projectile. In one embodiment, for example, the divider bottom **113** is connected to the divider top **109** to form an integral unit, that is, a divider, that supports and secures the KEPR. This integration may ensure that the entire GS **100** assembly functions as a unified system during the firing sequence. The interface between the divider bottom **113** and other components, such as the divider top **109** and deflector **112** walls, is configured to enable creation of a gas-tight seal during firing of a projectile. This seal may prevent gas blowby and may ensure that the expanding propellant gases are directed effectively for propulsion of the projectile. A well, the configuration of the divider bottom **113** may minimize energy loss by maintaining a tight seal and directing the propellant gases with efficiency. This contributes to optimization of the overall performance of the GS **100** and KEPR system.

C.2.14 Ignition Stack

**[0120]** As best shown in FIGS. **4** and **5**, an ignition stack **114** passes electrical current, for ignition of a propellant, from an external source through the GS **100** assembly and to the ignition pass through **110**. The ignition stack **114**, passing through the ignition pass through **110**, divider top **109**, and divider bottom **113**, serves to deliver the necessary electrical current to the ignitor **115** located in the propellant chamber **121**.

**[0121]** In an embodiment, the ignition stack **114** may comprise a stacked configuration. Thus, an ignition stack **114** may comprise multiple components stacked together to form a continuous electrically conductive pathway from the external ignition source, and electrical contact that may be connected to an ignition source, to the ignitor **115** within the propellant chamber **121**. In an embodiment, the ignition stack **114** may incorporate insulation at certain points to prevent unintended electrical contact with surrounding GS **100** components and the KEPR. In one embodiment, a function of the ignition stack **114** is to act as a conduit for transmitting electrical current from an external ignition source to the ignitor **115** within the propellant chamber **121**. It facilitates the controlled transfer of energy to initiate the ignition of the propellant.

**[0122]** In an embodiment, the ignition stack **114** is configured to mate with the ignition pass through **110**, ensuring a secure electrical connection. In particular, an uppermost part of the ignition stack **114** extends through the divider top **109**, maintaining continuity and connection to the external ignition source. The ignition stack **114** then passes through the divider bottom **113**, extending into the propellant chamber **121**.

**[0123]** The ignition stack **114** may be configured for proper alignment and stability as it passes through the divider top **109** and divider bottom **113**. That is, alignment of the ignition stack **114** to the center of the GS **100** may be important as such alignment may center the ignition point of the ignitor (reference **115**, discussed below) with the propellant. In an embodiment, it may be important that the propellant is ignited in the correct location in the propellant chamber.

**[0124]** As shown, for example, in FIG. **6**, the ignition stack **114** terminates at the ignitor **115** within the propellant chamber **121**. The interface between the ignition stack **114** and the ignitor **115** may ensure a secure and efficient connection for the initiation of the propellant ignition. The ignition stack **114** may be securely attached to the ignitor **115**, such as by welding or brazing for example, to withstand the forces and vibrations experienced during a firing sequence. This secure attachment may help to maintain the integrity of the ignition system.

**[0125]** An embodiment of the ignition stack **114** may comprise insulation within the ignition stack **114** to enhance safety and avoid inadvertent electrical contact between components. This insulation prevents unintended electrical contact with other GS **100** components, minimizing the risk of accidental discharges. As well, an embodiment of the ignition stack **114** may incorporate features that facilitate controlled energy, that is, electrical current, transfer to the ignitor **115**. This ensures that ignition occurs only when intended, reducing the likelihood of premature or unintended firing.

**[0126]** In an embodiment, an uppermost part of the ignition stack **114** is configured to connect to an external ignition system, or may have an electrical contact that may connect to an electrical firing mechanism. This connection allows for a controlled and deliberate initiation of a projectile firing process. In an embodiment, the ignition stack **114** may be adaptable for use with different ignition systems, ignitors, ignition components, and external energy sources. This adaptability contributes to the versatility and reliability of the overall ignition process.

C.2.15 Ignitor

**[0127]** As shown in the example of FIGS. **4**, **5** and **6**, an ignitor **115** may comprise a device that ignites the propellant in the propellant chamber. Ignitor plugs are one example embodiment of an ignitor **115** that may be used to initiate the combustion of propellants. Ignitor plugs may comprise a pyrotechnic composition or an electrically heated element. An ignitor **115** may comprise a hot-wire ignitors that may include a resistive wire that heats up rapidly when an electric current passes through it. This heated wire, in turn, ignites the propellant. In still another example, an ignitor **115** may comprise pyrotechnic initiators which may take the form of small devices containing pyrotechnic compositions that generate intense heat or flame when ignited. Such a pyrotechnic initiator may be used to initiate a chain reaction leading to propellant ignition. Various other embodiments of an ignitor **115** are possible as well.

**[0128]** For example, an ignitor **115** may comprise squibs and detonators which are explosive devices that produce a shockwave or heat capable of igniting propellants. An ignitor **115** may comprise an ignition cartridge that is a self-contained unit that may include both an ignition source and the necessary propellant for initiating combustion. An ignitor **115** may comprise a hypergolic ignition systems. Hypergolic propellants spontaneously ignite upon contact with each other. Hypergolic ignition systems may use this specific property to eliminate the need for a separate ignition device, relying on the inherent reactivity of the propellants. In another embodiment, an ignitor **115** may comprise a laser ignition system that may use a high-energy laser to ignite propellants. In one example, a laser beam is focused on a specific point to initiate combustion of a propellant. As a final example, an ignitor **115** may comprise an electrically ignited initiator that may use electrical current to generate heat or sparks, initiating the combustion of propellants. Such ignitors may include resistive elements or spark-gap designs.

C.2.16 Ground Wire

**[0129]** As best shown in FIGS. **4**, **5** and **6**, an embodiment of a GS **100** may comprise a ground wire **116**. In an embodiment, ground wire **116** may comprise an insulated wire that comes off of the ignitor **115** and connects to the GS **100** at the ground terminal **111**. The outer layer of the ground wire **116** may be insulated to prevent unintended contact with other components, the propellant, and or surfaces. This insulation may be necessary for maintaining electrical integrity and preventing short circuits or unintentional grounding. The end of the ground wire **116** may be equipped with a ground terminal contact that securely attaches to the GS **100** at the ground terminal **111**, or another grounding point within the assembly.

**[0130]** In one embodiment, a function of the ground wire **116** is to provide an electrically conductive pathway for the safe discharge of electrical energy from the ignitor **115**. By grounding the ignitor **115**, the ground wire **116** completes the electrical circuit, allowing controlled energy transfer during the ignition process. As well, the ground wire **116** may serve as a safety mechanism by providing a designated and controlled path for electrical discharge. This helps prevent unintended electrical events, contributing to the overall safety of the GS **100**.

**[0131]** In an embodiment, the ground wire **116** connects to the ground terminal **111** within the GS **100** assembly. This connection ensures that the electrical current is safely discharged to the ground, completing the circuit. The connection point of the ground wire **116** is securely attached to the designated ground terminal **111**, ensuring reliable contact to ground.

**[0132]** In an embodiment, insulation on the ground wire **116** prevents unintended contact with other components, surfaces, or conductive materials. This protective layer minimizes the risk of electrical interference and helps maintain a safe operating environment. An embodiment of the ground wire **116** may be robust and durable, capable of withstanding the forces and vibrations experienced during a firing sequence. Its robust configuration ensures that the wire remains intact and functional under various conditions.

**[0133]** The ground wire **116** may be adaptable to different ignitor **115** configurations. Its configuration and arrangement enables compatibility with various types of ignitors used in GS **100** and KEPR systems. Further, the ground wire **116** is versatile in its ability to connect to different grounding points within the GS **100** assembly. This versatility allows for flexibility in the overall design of the ignition and grounding system.

C.2.17 Ground Terminal Contact

**[0134]** As shown in the examples of FIGS. **5** and **6**, an embodiment of a GS **100** may include ground terminal contact **117** that may establish a secure and reliable electrical connection between the ground wire **116** and the GS **100**, specifically, at the ground terminal **111**. In an embodiment, this contact is necessary for completing the electrical circuit and providing a controlled pathway for the discharge of electrical energy, contributing to the safety and reliability of the GS **100** and KEPR system. In an embodiment, the ground terminal contact **117** may comprise a machine screw or similar fastener, but need not take any particular form or configuration.

**[0135]** An embodiment of the ground terminal contact **117** comprises an electrical connector, such as a fastener for example, that securely mates with the ground terminal **111** on the GS **100**. The configuration and arrangement of the ground terminal contact **117** may ensure a snug and stable connection with the ground terminal **111**, preventing unintended disconnection during the firing sequence. The contact surface of the ground terminal contact **117** is configured to maximize contact area and conductivity, such as a threaded contact for example. The ground terminal contact **117** may help to reduce electrical resistance and ensure efficient energy transfer, that is, electrical current, between the ground wire and the GS **100**.

**[0136]** In the ignition system, the ground terminal contact **117** is the point at which the ground wire from the ignitor **115** connects to the GS **100** assembly. This connection completes the electrical circuit and establishes a pathway for the safe discharge of electrical energy. The ground terminal contact **117** serves as a grounding mechanism by providing a designated point for the controlled discharge of electrical energy. This contributes to the safety and reliability of the GS **100** and KEPR system during the ignition process.

**[0137]** In more detail, with respect to the interface between the ground terminal contact **117** and the GS **100**, connector of the ground terminal contact **117** securely attaches to the ground terminal **111** on the GS **100**. This attachment may provide stability and reliability, ensuring that the connection remains intact under the forces and vibrations experienced during firing. The configuration of the ground terminal contact **117** accommodates the specific configuration of the ground terminal **111** on the GS **100**. This compatibility ensures that the ground terminal contact **117** aligns correctly, establishing a proper electrical connection.

**[0138]** The ground terminal contact **117** may comprise various safety features. For example, the ground terminal contact **117** may comprise a secure locking mechanism, such as a fastener for example, to prevent unintended disconnection. This feature enhances safety by ensuring that the connection remains stable and reliable throughout the firing sequence. Also, while the ground terminal contact **117** comprises an electrical conductor, it may include features to minimize unintentional contact with other conductive components, reducing the risk of electrical interference or short circuits.

**[0139]** The ground terminal contact **117** is adaptable to different ground wire configurations. This adaptability allows for compatibility with various ignitors and grounding systems used in GS **100** and KEPR assemblies. Further, the configuration of the ground terminal contact **117** considers the variability in ground terminal designs among different GS **100** assemblies. This versatility ensures that the ground terminal contact **117** can be effectively used with various GS **100** configurations.

**[0140]** Depending on the materials used, the ground terminal contact **117** may comprise corrosion-resistant coatings or features to maintain its functionality over time, especially in challenging environmental conditions. Thus, the ground terminal contact **117** may be well suited for use in downhole environments.

C.2.18 Electrical Contact

**[0141]** In an embodiment, and as shown in FIGS. **4** and **6**, an electrical contact **118** may comprise a connection to the ignition stack **114** that connects the ignition stack **114** and ignition device such as an ignitor **113** to an ignition power source. The electrical contact **118** may be implemented in a wide variety of ways, examples of which are set forth below.

**[0142]** An electrical contact **118** may comprise a pin connector including one or more pins made of conductive materials like copper or gold, ensuring good electrical conductivity. In an embodiment, the entry port has corresponding female sockets with spring-loaded contacts to create a secure connection. Particularly, the male pins are inserted into the female sockets, creating an electrical connection. Spring-loaded mechanisms in a pin connector ensure a tight fit, maintaining electrical contact despite vibrations or movements.

**[0143]** An electrical contact **118** may comprise a coaxial connector with a central conductor, insulator, and outer conductor for shielding against EMI (electromagnetic interference). The inner and outer conductors may be made of materials like copper or aluminum. The coaxial connector may be threaded or pushed into an ignition housing entry port, ensuring a secure connection. The shielding prevents EMI from affecting signals/power passing through the electrical contact **118**.

**[0144]** An electrical contact **118** may comprise a circular connector that includes multiple pins arranged in a circular pattern within the connector. The pins may be made of any suitable conductive materials. The circular connector may interact with an ignition housing entry port. In particular, the circular connector may be twisted and/or pushed into the entry port, aligning the pins for contact. A locking mechanism, such as a bayonet mount, may secure the connection.

**[0145]** An electrical contact **118** may comprise a magnetic connector that includes magnets may embedded in the male and female connectors to facilitate self-alignment of the two connectors with each other. The electrical contacts may be made of materials such as gold for good conductivity. With regard to their interaction with an ignition housing entry port, the magnetic connectors attract and self-align. The magnetic force ensures a reliable connection while allowing for easy disconnection.

**[0146]** An electrical contact **118** may comprise a fiber optic connector that uses optical fibers made of glass or plastic for transmitting light signals. The connectors may have ceramic or metal ferrules to align and protect the fiber ends. To interact with an ignition housing entry port, the fiber optic connectors are aligned and inserted into the entry port. Precise alignment ensures efficient light signal transmission.

**[0147]** An electrical contact **118** may comprise a USB connectors Pins may be made of materials such as copper with gold plating for conductivity. To interact with an ignition housing entry port, USB connectors may be inserted into the entry port, with a distinct design for proper alignment. The connector may feature a locking mechanism for a secure connection.

**[0148]** An electrical contact **118** may comprise pogo pins that use spring-loaded mechanisms for electrical contact. The pins may be made of materials like gold or steel for durability. To interact with an ignition housing entry port, pogo pins may be compressed and inserted into the entry port. The spring-loaded configuration may ensure continuous contact even with minor misalignments.

**[0149]** As a final example, an electrical contact **118** may comprise an insulated wire that includes a conductive core made of copper or aluminum for electrical conduction. Insulation materials such as PVC, Teflon, or rubber protect the conductive core. To interact with an ignition housing entry port, the stripped end of the insulated wire is connected to the entry port. Termination methods such as soldering or crimping may secure the wire in place.

C.2.19 Barrel

**[0150]** As shown in FIG. **6**, a barrel **119**, which may be a barrel of a perf gun, may be configured to hold the GS **100** and fire an associated projectile, such as a KEPR, and may be constructed with materials capable of withstanding extreme pressures and temperatures. The barrel may comprise rifling and precision machining to enhance GS **100** and KEPR stability.

C.2.20 Ground Point

**[0151]** As shown in FIG. **6**, a ground point **120** comprises the contact area of the GS **100** GS **100** with the barrel **119**. The ground point **120** may be located on the bearing surface **102** of the GS **100**. The ground point **120** may enable electrical current to pass from the GS **100** to ground by way of the barrel **119**.

C.2.21 Propellant Chamber

**[0152]** As shown in FIG. **6**, a propellant chamber **121** may be configured to contain and encapsulate propellants and a portion, or portions, of the GS **100**. It is noted that, as best shown in FIG. **6**, the GS **100** may be partly received in the propellant chamber **121** and, as such, when propellant(s) in the propellant chamber **121** are ignited, the gas resulting from that ignition may tend to flow upward—viewed from the perspective shown in FIG. **6**—from the propellant chamber **121** in the direction of, and into, the barrel **119**. Given this flow direction of the gas(es), reference may be made herein to a component as being 'upstream' or 'downstream' with respect to another component. By way of illustration, and with reference again to FIG. **6**, the compensator **103** may be considered as being downstream of the gas valve **105**.

**[0153]** The described embodiments are to be considered in all respects only as illustrative and not restrictive. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

**1**. A sabot, comprising:

a body configured to be partly received within a propellant chamber of a perf gun, and the body comprises an interface configured to engage a projectile;

a divider that defines part of the interface;

an ignition pass through that extends through the divider;

an ignition stack electrically connected to the ignition pass through;

a ground terminal electrically connected to the ignition pass through;

a deflector defined by the divider and having a cup-shaped configuration, and the deflector is configured to expand diametrically upon ignition of a propellant in the propellant chamber when the sabot is positioned within the propellant chamber;

a gas valve configured and arranged to be actuated by expansion of the deflector; and

a compensator positioned between the interface and the gas valve.

**2**. The sabot as recited in claim **1**, wherein the sabot comprises a unified, single-piece, construction.

**3**. The sabot as recited in claim **1**, wherein the projectile comprises a kinetic energy perforating round (KEPR).

**4**. The sabot as recited in claim **1**, wherein the interface is sized and configured to engage projectiles of various different calibers.

**5**. The sabot as recited in claim **1**, wherein the ignition stack comprises an ignitor connected to the ignition pass through and configured to be positioned in the propellant chamber when the sabot is received in the propellant chamber.

**6**. The sabot as recited in claim **1**, wherein an exterior portion of the body defines a bearing surface that contacts an interior of a barrel of the perf gun when the sabot is loaded in the perf gun.

**7**. The sabot as recited in claim **6**, wherein the bearing surface serves as an electrical contact that forms part of a communications circuit and/or a power circuit.

**8**. The sabot as recited in claim **1**, wherein the sabot is reusable for multiple projectile firing operations.

**9**. The sabot as recited in claim **1**, wherein the interface defines a volume that is cylindrical in shape and is configured to receive part of the projectile.

**10**. The sabot as recited in claim **1**, wherein the ignition stack extends out of the interface such that when the sabot is engaged with a projectile, part of the ignition stack extends into the projectile.

**11**. The sabot as recited in claim **1**, wherein the ignition stack comprises an ignitor that is electrically connected to the ground terminal.

**12**. An assembly, comprising:

a projectile; and

the sabot of claim **1**, wherein the sabot is engaged with the projectile.

**13**. The assembly as recited in claim **12**, wherein the projectile comprises a KEPR (kinetic energy perforating round).

**14**. The assembly as recited in claim **12**, comprising a perf gun configured to carry the projectile and the sabot.

**15**. A method, comprising:

using a perf gun to create a perforation in one or more target materials in a wellbore by firing an assembly comprising a sabot within which a portion of a projectile is received, and, prior to the firing, the sabot is partly received within a propellant chamber defined by the perf gun.

**16**. The method as recited in claim **15**, wherein the firing comprises using an ignition stack of the sabot to ignite a propellant in the propellant chamber, and ignition of the propellant causes generation of a gas.

**17**. The method as recited in claim **15**, wherein a deflector of the sabot flexes upon ignition of a propellant in the propellant chamber and actuates a gas valve of the sabot.

**18**. The method as recited in claim **17**, wherein the gas valve operates to control expansion of gas generated by ignition of a propellant in the propellant chamber, and to control flow of the gas into a compensator of the sabot.

**19**. The method as recited in claim **18**, wherein the compensator prevents some of the gas from bypassing the sabot and the projectile.

**20**. The method as recited in claim **15**, wherein the firing is performed using an electrical circuit that comprises the sabot and a ground terminal.

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