



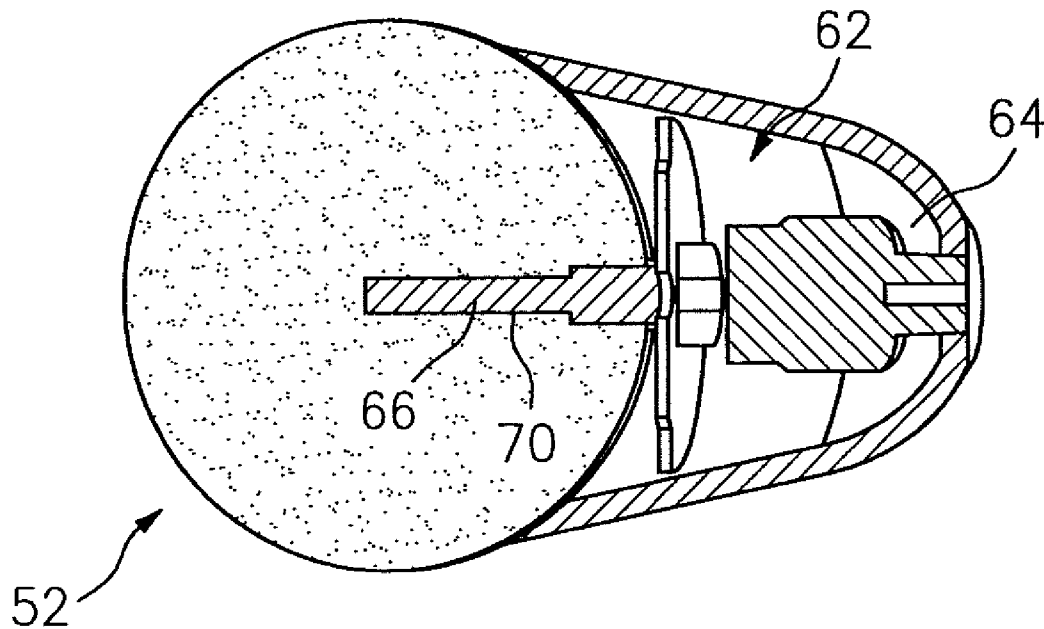
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(19) **United States**(12) **Patent Application Publication**
Garvey et al.(10) **Pub. No.: US 2016/0130906 A1**(43) **Pub. Date: May 12, 2016**(54) **DESTRUCTIBLE FRAC-BALL AND DEVICE
AND METHOD FOR USE THEREWITH***E21B 47/14* (2006.01)*E21B 47/06* (2006.01)*E21B 47/12* (2006.01)(71) Applicant: **Ensign-Bickford Aerospace & Defense
Company, Simsbury, CT (US)**(52) **U.S. Cl.**CPC *E21B 33/12* (2013.01); *E21B 47/06*(2013.01); *E21B 47/065* (2013.01); *E21B**47/122* (2013.01); *E21B 47/14* (2013.01);*E21B 47/18* (2013.01)(72) Inventors: **Alan J. Garvey, Suffield, CT (US);
Marc A. Morris, Clarksville, TN (US)**(21) Appl. No.: **14/935,114**(22) Filed: **Nov. 6, 2015****Related U.S. Application Data**(60) Provisional application No. 62/076,934, filed on Nov.
7, 2014.**Publication Classification**(51) **Int. Cl.***E21B 33/12* (2006.01)*E21B 47/18* (2006.01)

(57)

ABSTRACT

A destructible frac-ball is provided that includes a body and a rupture mechanism, and a method for selectively initiating fluid flow within a casing segment is provided that utilizes one or more of the aforesaid frac-balls. The rupture mechanism is in communication with the body, and is operable to selectively initiate and break the body into the plurality of discrete pieces.



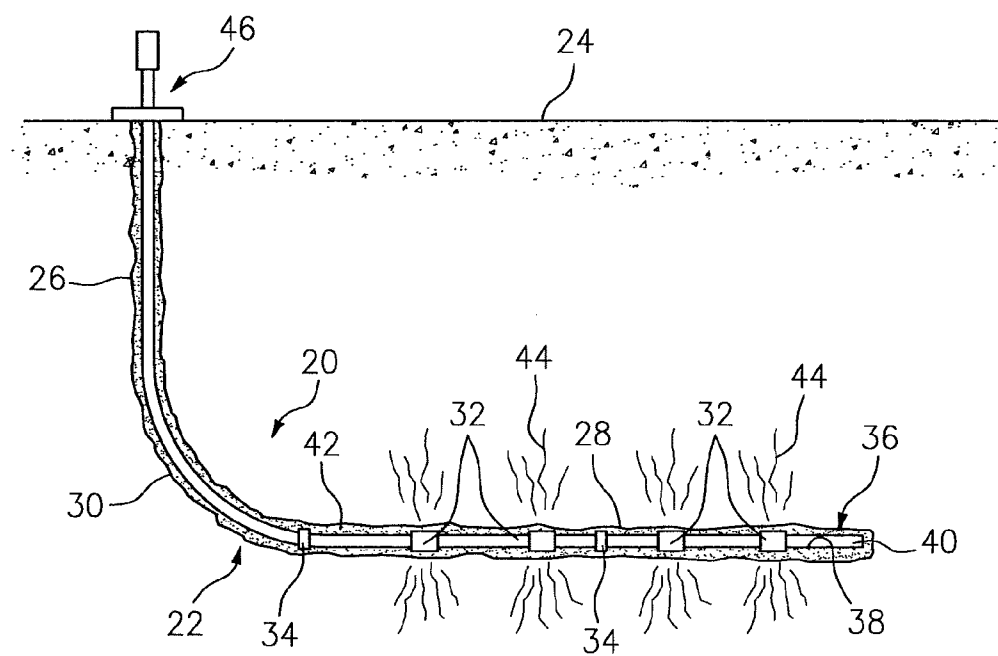


FIG. 1

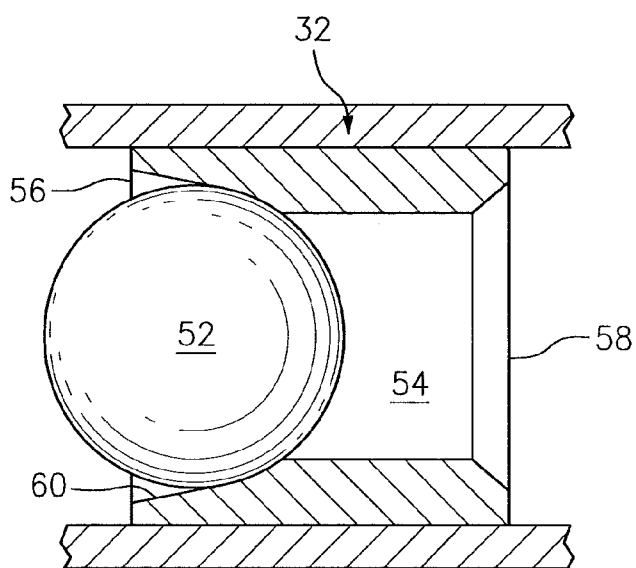


FIG. 4

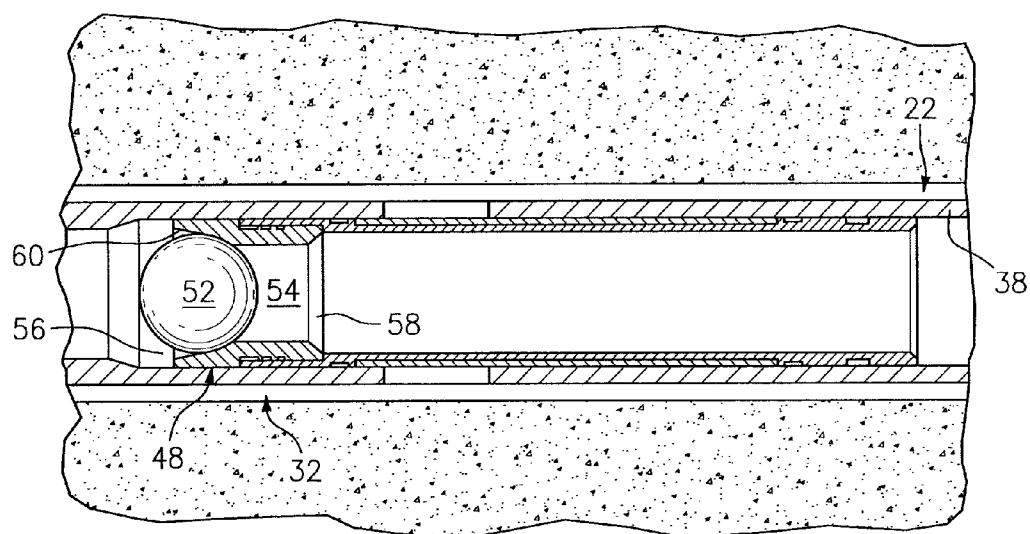


FIG. 2

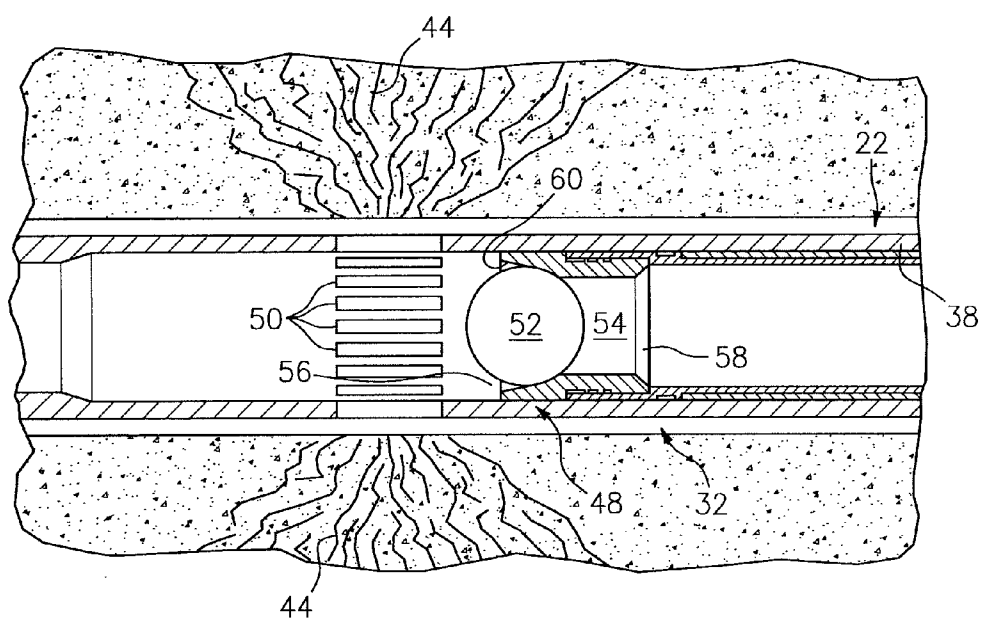


FIG. 3

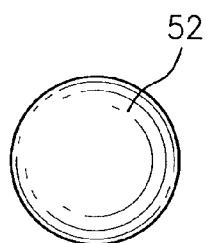


FIG. 5

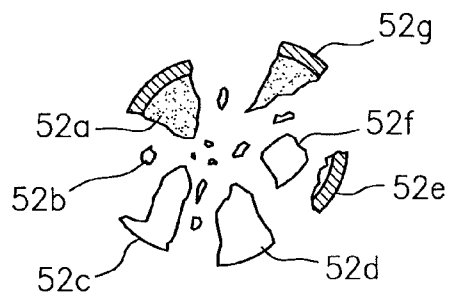


FIG. 6

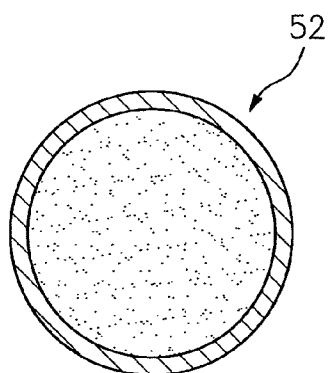


FIG. 7

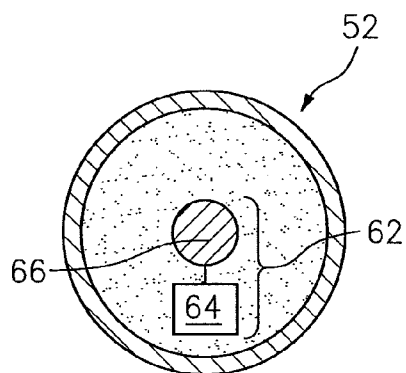


FIG. 8

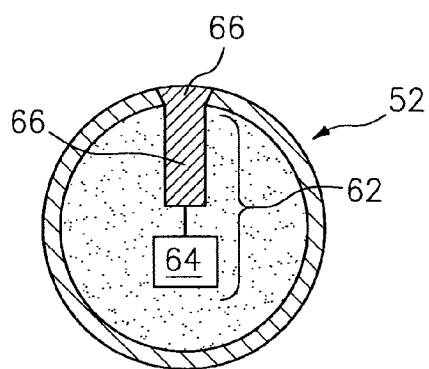


FIG. 9

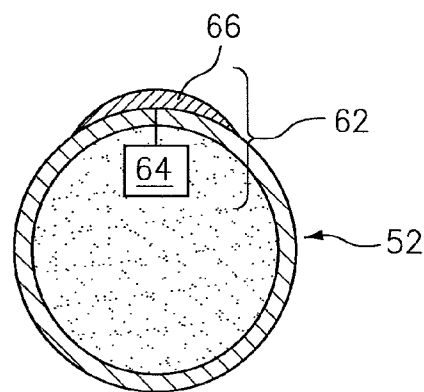


FIG. 10

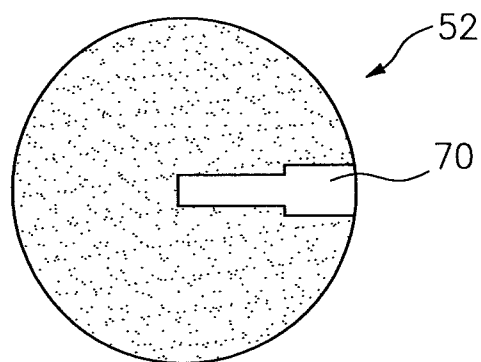


FIG. 11

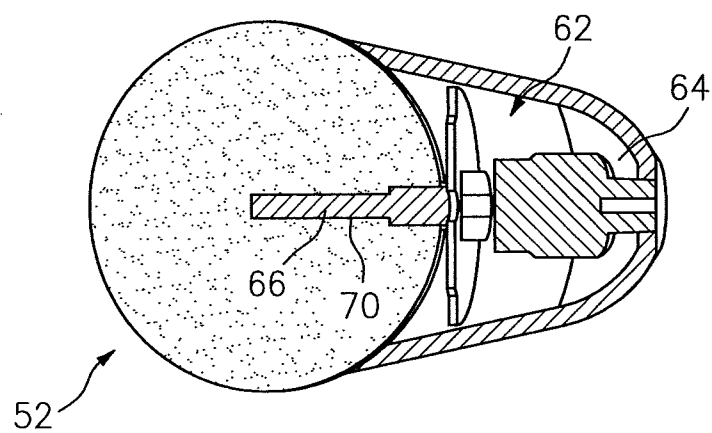


FIG. 12

DESTRUCTIBLE FRAC-BALL AND DEVICE AND METHOD FOR USE THEREWITH

[0001] This application claims priority to U.S. Patent Appin. No. **62/076,934** filed Nov. 7, 2014, which document is hereby incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] 1. Technical Field

[0003] The present disclosure relates to subterranean well casing segmentation devices in general, and to frac-balls used with casing segmentation devices in particular.

[0004] 2. Background Information

[0005] Subterranean wells can be used to locate and extract subterranean disposed raw materials. For example, wells may be used to locate and extract hydrocarbon materials (e.g., hydrocarbon fluids such as oil, and gases such as natural gas) from subterranean deposits. A water well may be used for locating and extracting potable or non-potable water from an underground water table. A well configured and located to locate and extract hydrocarbon materials typically includes a tubular casing disposed subsurface within the well, and pumping system for injecting materials into and for extracting materials out of the well. The casing may be oriented to have vertically disposed sections, horizontally disposed sections, and sections having a combined vertical and horizontal orientation.

[0006] The term “hydraulic fracturing” refers to well formation techniques (sometimes referred to as “well completion” techniques) that create fractures within the subterranean ground to facilitate extraction of hydrocarbon materials disposed within the subterranean ground. There are several hydraulic fracturing techniques currently used, including techniques that utilize fluid flow segmentation devices.

[0007] For example, “plug and perforation” techniques may utilize one or more plugs (a type of casing segmentation device) that are positionable within the well casing. The plugs are used to fluidically isolate (i.e., segment) casing sections for a variety of reasons; e.g., to permit specific casing sections to be radially perforated, etc. The perforations in the casing provide fluid paths for materials to selectively exit and enter a fluid passage within the casing. In some instances, the plugs are designed to include a fluid flow passage that permits fluid flow through the plug; i.e., between a forward end of the plug and an aft end of the plug. The passage has a ball seat disposed at the forward end of the passage. The term “forward end” refers to the end of the passage disposed closest to the well head when disposed within the casing, and the term “aft end” refers to the end of the passage disposed farthest from the well head when disposed within the casing. The passage ball seat is configured to receive a spherical ball (typically referred to as a “frac-ball”). To segment the well casing, a frac-ball is introduced into the casing and the frac-ball is carried with fluid flow until it reaches the ball seat. Once the frac-ball is seated properly within the seat, the frac-ball closes the plug fluid passage and prevents fluid passage through the plug. The fluid on one side of the plug may then be increased dramatically in pressure; e.g., to perform the perforation/fracturing process. Subsequently, the frac-ball and plug may be machined out to remove the isolating structure, or the frac-ball may be of a type that dissolves to permit fluid flow through the plug. There are several disadvantages associated with frac-balls that must be machined out or dissolved; e.g., cost and time.

[0008] Another hydraulic fracturing technique utilizes a sliding sleeve type device (another type of casing segmentation device). In this approach, the casing typically includes multiple stages (e.g., each with a sliding sleeve assembly and a packer assembly) that are built into the casing. Each sliding sleeve assembly includes an inner component and an outer component, and the inner component may be biased to reside in a forward located closed position. The inner component includes a fluid flow passage that permits fluid flow through the sliding sleeve; e.g., between a forward end of the inner component and an aft end of the inner component. The passage has a ball seat disposed at the forward end of the passage. When a frac-ball is properly seated within the seat and sufficient pressure is created on the frac-ball side of the sliding sleeve, the inner component will travel axially aft ward relative to the outer component. The axial travel allows pressurized fluid to perforate the casing and create the fractured subterranean structure. The frac-balls used to activate the sliding sleeves (and the associated frac-ball seat) may be arranged in a particular order for use in the casing; i.e., the smallest diameter frac-ball is introduced into the casing first and passes through the sliding sleeves having progressively smaller diameter seats until it reaches a seat that it cannot pass through and is consequently seated, thereby closing the fluid passage through the sliding sleeve. Each progressively larger frac-ball is introduced and the process is repeated until all the zones are fractured. Once the high pressure source is removed, it may be possible to use subterranean fluids entering the casing to unseat the frac-balls. In some instances, however, it may be necessary to remove the frac-balls via machining or dissolution. Sliding sleeve arrangements are not appropriate for all applications, and as indicated above there are disadvantages to frac-ball machining and dissolution should it be necessary to clear the casing.

SUMMARY OF THE DISCLOSURE

[0009] According to an aspect of the present disclosure, a destructible frac-ball is provided that includes a body and a rupture mechanism. The rupture mechanism is in communication with the body, and is operable to selectively initiate and break the body into the plurality of discrete pieces.

[0010] According to another aspect of the present disclosure, a segmentation device is provided for use within a casing. The segmentation device includes a seat for receiving a frac-ball, and at least one rupture mechanism disposed relative to the seat. The rupture mechanism is operable to act upon a frac-ball disposed within the seat and cause the frac-ball to rupture into discrete pieces.

[0011] According to another aspect of the present disclosure, a method for selectively initiating fluid flow within a casing segment is provided. The method includes the steps of: a) providing a segmentation device operable to be disposed within the casing, which segmentation device includes a seat for receiving a frac-ball; b) providing a frac-ball having a body and a rupture mechanism in communication with the body, which rupture mechanism includes a trigger mechanism operable to selectively cause the rupture mechanism to initiate and break the body into the plurality of discrete pieces; and c) causing the rupture mechanism to initiate and break the frac-ball body into the plurality of discrete pieces based on input from the trigger mechanism, and thereby selectively initiating fluid flow through the segmentation device.

[0012] In a further embodiment of any of the foregoing aspects, the frac-ball body may include a core encased within a shell.

[0013] In a further embodiment of any of the foregoing aspects and embodiments, the frac-ball core may include a fluid soluble material.

[0014] In a further embodiment of any of the foregoing aspects and embodiments, the frac-ball shell may include a fluid non-soluble material or a fluid soluble material.

[0015] In a further embodiment of any of the foregoing aspects and embodiments, the frac-ball rupture mechanism may include an energetic material.

[0016] In a further embodiment of applicable foregoing aspects and embodiments, the frac-ball body may be a solid body substantially consisting of a homogeneous material, which homogeneous material may be a fluid soluble material.

[0017] In a further embodiment of any of the foregoing aspects and embodiments, frac-ball rupture mechanism may include a trigger mechanism having a sensor, and the trigger mechanism is operable to cause the rupture mechanism to initiate based on input from the sensor. The sensor may be operable to sense at least one of pressure, temperature, or conductivity proximate the frac-ball. Alternatively, the sensor may be operable to sense at least one of magnetic, electromagnetic, pressure, electrical, RF, or ultrasonic signals.

[0018] In a further embodiment of any of the foregoing aspects and embodiments, the frac-ball rupture mechanism may include a trigger mechanism that includes a timer.

[0019] In a further embodiment of any of the foregoing aspects and embodiments, the frac-ball rupture mechanism may include a trigger mechanism that includes a first metallic alloy and a second metallic alloy, wherein the first metallic alloy has a first melting temperature and the second metallic alloy has a second melting temperature, which second melting temperature is higher than the first melting temperature, and wherein the first metallic alloy and the second metallic alloy are exothermically reactive with one another.

[0020] In a further embodiment of any of the foregoing aspects and embodiments, the frac-ball rupture mechanism may include a receiver operable to receive at least one of a radio frequency energy type signal, or an acoustic energy type signal, an electrical energy type signal, or a pressure pulse type signal.

[0021] In a further embodiment of any of the foregoing aspects and embodiments, the frac-ball rupture mechanism may include a trigger mechanism that is operable to be selectively deployed into a state where it may be activated to selectively cause the rupture mechanism to initiate and break the body into the plurality of discrete pieces.

[0022] In a further embodiment of any of the foregoing aspects and embodiments, the frac-ball rupture mechanism may include a trigger mechanism that is operable to be selectively activated via electromagnetic inductive coupling.

[0023] In a further embodiment of any of the foregoing aspects and embodiments, the frac-ball may include a safety inhibit operable to prevent the rupture mechanism from initiating and breaking the body into the plurality of discrete pieces unless a predetermined condition is met.

[0024] The foregoing features and the operation of the invention will become more apparent in light of the following description and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] FIG. 1 is a sectional diagrammatic illustration of a portion of a well casing.

[0026] FIG. 2 is a diagrammatic illustration of a sliding sleeve type casing segmentation device shown in a closed configuration.

[0027] FIG. 3 is a diagrammatic illustration of a sliding sleeve type casing segmentation device shown in an open configuration.

[0028] FIG. 4 is a diagrammatic illustration of the casing segmentation device.

[0029] FIG. 5 is a diagrammatic illustration of a frac-ball embodiment.

[0030] FIG. 6 is a diagrammatic illustration of a ruptured frac-ball, shown in discrete pieces.

[0031] FIG. 7 is a sectional diagrammatic illustration of a frac-ball embodiment.

[0032] FIG. 8 is a sectional diagrammatic illustration of a frac-ball embodiment, including a rupture mechanism embodiment.

[0033] FIG. 9 is a sectional diagrammatic illustration of a frac-ball embodiment, including a rupture mechanism embodiment.

[0034] FIG. 10 is a sectional diagrammatic illustration of a frac-ball embodiment, including a rupture mechanism embodiment.

[0035] FIG. 11 is a diagrammatic illustration of a frac-ball embodiment.

[0036] FIG. 12 is a sectional diagrammatic illustration of a frac-ball embodiment, including a rupture mechanism embodiment.

DETAILED DESCRIPTION OF THE INVENTION

[0037] Now referring to FIG. 1, an exemplary embodiment of a wellbore 20 disposed in a subterranean formation is shown. The wellbore 20 includes a fluid conduit (typically referred to as a “casing”; e.g., casing 22) disposed within a drilled bore extending below surface level 24. The wellbore 20 is diagrammatically shown as having a substantially vertical oriented section 26, a substantially horizontal oriented section 28, and an arcuate section 30 connecting the vertical and horizontal sections 26, 28. For purposes of describing aspects of the present disclosure, the casing 22 is described herein as including casing segmentation devices 32, packers 34, and pipe sections 36. The pipe sections 36 include a wall 38 surrounding a flow passage 40. The described well casing configuration reflects a typical configuration and the present disclosure is not limited to any particular well casing configuration. The casing 22 is disposed within the well after the well is drilled. The wellbore 20 is shown as having cement 42 disposed between the outer diameter of the casing 22 and the inner diameter of the drilled bore, which cement 42 secures the casing 22 within the drilled bore. Not all wellbores include cement or other material disposed outside of the casing 22.

[0038] As indicated above, a well completion process that utilizes hydraulic fracturing involves creating fractures 44 (e.g., cavities) within the subterranean ground adjacent the casing 22 to facilitate extraction of hydrocarbon materials (or water) disposed within the subterranean ground. The fracturing process is typically performed in segments (sometimes referred to as “stages”); e.g., a first segment of the casing 22 may be created adjacent the portion of the wellbore 20 fur-

thrust from the wellhead 46, and the casing 22 in that segment “perforated” to create a fluid path between the casing flow passage 40 and the subterranean environment adjacent the segment. Once the first segment is fractured, that segment may be isolated, and the process may be repeated for the next segment in line, until all of the desired segments of the wellbore 20 are fractured. The term “perforated”, as used herein, refers to the creation of the aforesaid fluid paths between the casing flow passage 40 and the subterranean environment adjacent the segment. In some instances, a pipe section 36 of the casing 22 is perforated by creating holes in the wall 38 of the pipe section 36 (e.g., using a perforating gun). In other instances, a casing section may be “perforated” by manipulating a sliding sleeve 48 (e.g., see FIGS. 2 and 3) or other valve-type casing segmentation device 32 into an open configuration, wherein apertures 50 in the sliding sleeve 48 are exposed to create the fluid paths between the casing flow passage and the subterranean environment adjacent the segment. FIG. 2 diagrammatically illustrates a sliding sleeve type casing segmentation device 32 disposed in a closed configuration; e.g., preventing fluid flow radially through the casing. FIG. 3 illustrates a sliding sleeve type casing segmentation device 32 disposed in an open configuration; e.g., allowing radial fluid flow through the casing via apertures 50. The present disclosure is not limited to use with any particular device or method for creating the fractures within the subterranean environment.

[0039] Aspects of the present disclosure include destructible frac-balls 52, casing segmentation devices 32 that are configured for use with destructible frac-balls 52, and methods for completing a well using destructible frac-balls 52. The present disclosure is not limited to use with any particular type casing device that uses a frac-ball 52. In addition, the present disclosure is described herein in the context of a well formed to extract hydrocarbon based materials. The present disclosure is not limited to applications for extracting hydrocarbon based materials; e.g., oils and gases.

[0040] Referring to FIG. 4, the casing segmentation devices 32 (e.g., sliding sleeves, plugs, etc.) are designed to be positionally located within the casing 22. These devices 32 may include an internal passage 54 with a forward end 56, and aft end 58, and a ball seat 60 disposed at the forward end. Once a frac-ball 52 is seated properly within the ball seat 60, the frac-ball 52 closes the fluid passage 54 and prevents fluid passage there through.

[0041] Referring to FIGS. 5 and 6, according to an aspect of the present disclosure a destructible frac-ball 52 is provided. The destructible frac-ball 52 is adapted to be selectively ruptured into a plurality of discrete pieces (e.g., depicted in FIG. 6 as pieces 52a, 52b, 52c, 52d, 52e, 52f, 52g, etc.), with each discrete piece smaller in volume than the frac-ball 52. At the time of rupture, or some time thereafter, each discrete frac-ball piece is of a size inadequate to prevent fluid flow through the fluid passage 54 disposed within the casing segmentation device 32. The term “discrete pieces” is used herein to describe that the pieces, created as a result of the frac-ball 52 being ruptured, are physical portions of the frac-ball 52, as opposed to granular sized material eroded or dissolved from the frac-ball 52 that may go into solution within surrounding fluid.

[0042] Frac-balls 52 according to the present disclosure may be in a spherical geometry, but are not limited to a spherical geometry. The ball seat 60 (e.g., see FIG. 4) included in the casing segmentation device 32 is configured to

complement the frac-ball geometry for sealing purposes. In those applications wherein a plurality of destructible frac-balls 52 are used, some or all of the plurality of frac-balls 52 may have the same geometry (e.g., same diameter spherical shape). In other applications, the plurality of frac-balls 52 may have graduated sizes; e.g., “n” number of spherical frac-balls 52, progressively smaller/larger in diameter that may be used in a sliding sleeve type casing segmentation device 32.

[0043] In some embodiments, the destructible frac-ball 52 includes a rupture mechanism 62 (e.g., see FIGS. 8-10) that is operable to selectively break the frac-ball 52 into the plurality of discrete pieces described above. As indicated below, in some embodiments a portion or all of each frac-ball piece may at least partially erode or dissolve, but such erosion or dissolution is not the rupture mechanism 62. An example of a rupture mechanism 62 is one that includes an energetic material 66 (e.g., an explosive) and a trigger mechanism 64. Another example of a rupture mechanism 62 is a mechanical device, etc., coupled with a trigger mechanism 64. The present disclosure therefore is not limited to any particular type of rupture method or devices for rupturing the frac-ball 52.

[0044] The trigger mechanism 64 may assume a variety of different forms, and the present disclosure is not limited to any particular type of trigger mechanism 64. The trigger mechanism 64 may include one or more processors capable of processing instructions stored in a memory, one or more sensors (e.g., temperature sensors, pressure sensors, magnetic, electromagnetic, conductivity, etc.), timing devices, receivers (e.g., adapted to RF signals, ultrasonic signals, pressure pulse signals, etc.), etc. In those embodiments that include one or more sensors, timing devices, receivers, etc., such sensors, devices, or receivers may be in communication with the processor. The trigger mechanism 64 may be implemented in a variety of different forms (e.g., in a hardware form, or a programmable medium, etc.). As will be explained below, different applications may favor the use of different types of trigger mechanisms 64, or combinations of trigger mechanism types.

[0045] A first example of a type of trigger mechanism 64 is one that is temperature related. Some wells have well portions where the subterranean environment is at elevated temperature. In these applications, the fracturing fluid that is being pumped from the surface may be no warmer than a known temperature (e.g., 80° F.) and during fracturing the aforesaid fluid will maintain a frac-ball 52 at a temperature that is cooler than the surrounding well environment; e.g., the fracturing fluid acts as a coolant. Once the fracturing operation at a stage is complete, the warmer temperature reservoir fluids and gases will raise the temperature of the frac-ball 52 via thermal conduction and/or convection. In this instance, the trigger mechanism 64 may be an aspect that is disabled below a predetermined temperature, and enabled at temperatures above the predetermined temperature. For example, an electronic component may be embedded within or attached to a frac-ball that includes a temperature sensor. Once the temperature sensor detects a predetermined temperature (e.g., “a trigger temperature”), the electronic component (e.g., a processor) may directly or indirectly initiate an energetic material adequate to rupture the frac-ball.

[0046] In instances where the temperature within a well likely exceeds an electronic component operating temperature (e.g., above 120° C.), an alternative temperature related trigger mechanism may be used. For example, a bimetallic

device may be used that combines a rupture mechanism and trigger mechanism. The bimetallic device includes a first metallic alloy, a second metallic alloy, and an energetic material. The first metallic alloy has a first melting temperature and the second metallic alloy has a second melting temperature, which second melting temperature is higher than the first melting temperature. The first metallic alloy and the second metallic alloy are exothermically reactive with one another, and are initially separated from one another within the device. The first metallic alloy is selected to have a melting temperature that coincides with the desired trigger temperature for rupturing the frac-ball. When the first metallic alloy reaches the trigger temperature it melts, begins to flow, and contacts the second metallic alloy, thereby triggering an exothermic reaction between the two alloys. The exothermic reaction between the alloys generates sufficient thermal energy to ignite the energetic material. The ignition of the energetic material causes the frac-ball to rupture.

[0047] A second type of trigger mechanism **64** is one that activates upon receipt or termination of a selectively emitted signal. For example, the trigger mechanism **64** may be selectively activated by radio frequency energy type signal, or an acoustic energy type signal (e.g., ultrasonic signal), a pressure pulse type signal traveling through the fracturing fluid, etc.

[0048] Mud pulse telemetry (“MPT”) is a non-limiting example of a communication technique that can be used. In a MPT system, a downhole located valve may be operated to restrict the flow of the drilling fluid in a manner acceptable to transmit digital information; e.g., opening and closing the valve to allow or restrict, respectively, the fluid flow within the drill pipe. The valve operation creates pressure fluctuations indicative of the information. The pressure fluctuations propagate within the drilling fluid towards the surface where they are received from pressure sensors. The signals received by the pressure sensors are subsequently processed to produce the information. As another example, a “wired drill pipe system” may be used, wherein electrical wires are incorporated into the casing. Electrical signals may be conducted through the wires and received by the frac-balls.

[0049] A third type of trigger mechanism **64** is one that actuates based on timing; e.g., the trigger mechanism **64** can be programmed to detonate at a particular time, or after a predetermined interval of time (e.g., a time delay period starting from when the frac-ball **52** is deployed into the well).

[0050] A fourth type of trigger mechanism **64** is one where the frac-ball **52** is physically processed prior to deployment. For example, the trigger mechanism **64** can be configured to activate upon the frac-ball **52** being spun at a predetermined rotational speed (e.g., “X” rotations per minute—“RPMs”) to arm the device prior to deployment.

[0051] A fourth type of trigger mechanism **64** is one that may be selectively activated via electromagnetic inductive coupling; e.g., selectively activated by the application or removal of a magnetic field. For example, an electromagnetic trigger mechanism may include an electrical insulator incorporated into the casing. To transmit data, the device may generate an altered voltage difference between the top part (e.g., the main casing, above the insulator), and a second part (e.g., a drill bit, or other tools located below the insulator). On the surface, a wire is attached to the wellhead, which makes contact with the casing at the surface. A second wire is attached to a rod driven into the ground some distance away. The wellhead and the ground rod form the two electrodes of

a dipole antenna. The voltage difference between the two electrodes is used as a signal that is received and processed.

[0052] A fifth type of trigger mechanism **64** is one that is activated by pressure; e.g., when the trigger mechanism **64** senses a predetermined environmental pressure, the trigger mechanism **64** is activated. The predetermined pressure could be the high pressure resultant from a fracturing operation or it could simply be the hydrostatic pressure exerted by the column of fluid in the well.

[0053] In some embodiments, a frac-ball **52** may be configured to include one or more safety features. For example, a frac-ball **52** may be configured to include an activating sequence that includes an inhibit whereby prior to rupture initiation, the trigger mechanism **64** will query its surroundings to verify certain predetermined conditions. If the condition is satisfied, then the trigger mechanism **64** will initiate rupture of the frac-ball **52**. Non-limiting examples of safety features include the trigger mechanism **64** sensing to determine if the frac-ball **52** is surrounded by ferrous material (e.g., the well pipe) or a fracturing fluid (e.g., via conductivity). If the safety condition is not met, the triggering mechanism will not initiate rupture of the frac-ball **52**.

[0054] A non-limiting example of how a trigger mechanism **64** may be configured is provided hereinafter. In this example, a frac-ball **52** includes a rupture mechanism **62** with a trigger mechanism **64** that includes an electronic circuit (e.g., including the processor and one or more of the sensors described above) powered by a battery. The electronics are maintained in a claimant state until the frac-ball **52** is exposed to a predetermined pressure (e.g., 500 psi). The pressure normally exerted on a frac-ball **52** at about 1100 feet below surface is about 500 psi. Fracturing operations are almost always conducted at depths below 1100 feet, so a frac-ball **52** will always be subjected to at least 500 psi. From a safety standpoint, there is no credible scenario on the surface where the ball can be accidentally subjected to a predetermined pressure such as 500 psi, hence the predetermined pressure can be used as a safety condition. When the frac-ball **52** is subjected to the predetermined pressure, the frac-ball electronics activate and initiate a timer set for a predetermined time period (e.g., 10 hours). Once the predetermined time period expires, a second safety feature may be initiated. For example, once the predetermined time period expires, the trigger mechanism **64** may sense the surrounding environment to determine the presence of ferrous material around the frac-ball **52**. If the safety condition is met, then the triggering mechanism causes the frac-ball **52** to rupture. If the trigger mechanism **64** determines the safety condition is not met, then the electrical energy is bled from the circuit, thereby disarming the ball and rendering it safe. As indicated above, the above example is provided to illustrate an example of a triggering mechanism; e.g., one that is operable to evaluate safety conditions. The present disclosure is not limited to this example.

[0055] In those embodiments wherein the rupture mechanism **62** includes an energetic material **66**, the energetic material **66** may be constructed from or otherwise include an amount of energetic material **66** such as, but not limited to, lead azide, zirconium potassium perchlorate (ZPP), gasless ignition powders such as AlA (e.g., comprising Zirconium powder, Ferric oxide, and diatomaceous earth), pentaerythritol tetranitrate (PETN), cyclotrimethylenetrinitramine (RDX), and diazodinitrophenol (DDNP). The energetic material **66** may be adapted to energize (e.g., activate and

explode) upon receiving or otherwise being subjected to a command signal such as, but not limited to, a radio wave trigger. Alternatively, the energetic material 66 may also include a detonator adapted to energize the energetic material 66 upon receiving a command signal. In this manner, a controller or human operator may selectively activate the energetic material 66 and thereby selectively cause the frac-ball 52 to rupture.

[0056] Referring to FIGS. 7-10, in those embodiments wherein the rupture mechanism 62 includes an energetic material 66, the energetic material 66 may be included in a variety of different configurations, and the present disclosure is not limited to any particular configuration. For example, the energetic material 66 may be disposed internally within the frac-ball 52 (e.g., see FIG. 8), or the energetic material 66 may be configured in a form (e.g., a pin, a plug, etc.) that extends (e.g., radially) into the frac-ball 52 (e.g., see FIG. 9), or the energetic material 66 may be attached to an outer peripheral surface of the frac-ball 52 (e.g., see FIG. 10), or the energetic material 66 may be mixed with and/or configured to form a component of the frac-ball 52, or combinations thereof.

[0057] In some embodiments, the destructible frac-ball 52 includes a core 50 encased (e.g., covered) within a shell 52. The present disclosure is not limited to frac-balls 52 having a core and shell configuration. The core 50 may be constructed from a fluid soluble material; e.g., soluble in a fluid such as water, fracking fluid, etc. Examples of such a core material include, but are not limited to, salt, calcium carbonate, and polyglycolic acid. A core 50 constructed from a fluid soluble material may partially or totally dissolve after the destructible frac-ball 52 is ruptured; e.g. once the core material is exposed to fluids within the casing. The shell 52 may be constructed from a fluid non-soluble material; e.g., non-soluble in a fluid such as water, fracking fluid, etc. Examples of a non-soluble shell material include, but are not limited to, alumina (Al_2O_3), zirconia (ZrO_2), and silicon nitride (Si_3N_4). Alternatively, the shell 52 may be constructed from a fluid soluble material that dissolves in the fluid at a slower rate than the core material. Examples of such alternative shell materials include, but are not limited to, an aluminum alloy with micro-galvanic electrochemical cells, a controlled electrolytic metallic, and a nano-composite material. In those embodiments wherein the frac-ball 52 includes a core 50 disposed within a shell 52, an energetic material 66 may be disposed within or form a part of the core 50 portion or the shell 52 portion of the frac-ball 52, or combinations thereof.

[0058] In those embodiments wherein the frac-ball 52 includes a core 50 disposed within a shell 52, the shell 52 prevents fluids within the casing from reaching the core 50. The shell 52 therefore may prevent the frac-ball 52 and, more particularly, the core 50 from degrading prior to the frac-ball 52 being ruptured. However, upon the frac-ball 52 being ruptured into a plurality of discrete pieces, the core 50 is exposed to the surrounding fluid.

[0059] In some embodiments (e.g. see FIGS. 11 and 12), the destructible frac-ball 52 may comprise a solid configuration; e.g. comprised of a material that is substantially homogeneous throughout the frac-ball 52. The term “homogeneous” is used herein to describe a frac-ball material that is uniformly distributed within the frac-ball 52; i.e., the frac-ball “material” may include a plurality of materials, all of which are substantially uniformly distributed within the frac-ball 52. A solid homogeneous material frac-ball 52 may include a cavity 70 sized to receive at least a portion of a rupture

mechanism 62 similar to those described above, which rupture mechanism includes a trigger mechanism 64 as described above. FIG. 12 shows the trigger mechanism 64 attached to the exterior surface of the frac-ball 52, and energetic material 66 disposed in the frac-ball cavity 70. In some embodiments, the homogeneous material of the solid frac-ball may be a fluid soluble material (e.g. such as those types identified above) that may partially or totally dissolve after the destructible frac-ball 52 is ruptured; e.g. once the core material is exposed to fluids within the casing. The solid homogeneous material destructible frac-ball 52 is adapted to be selectively ruptured into a plurality of discrete pieces (e.g., as described above), with each discrete piece smaller in volume than the frac-ball 52. At the time of rupture, or some time thereafter, each discrete frac-ball piece is of a size inadequate to prevent fluid flow through the fluid passage 54 disposed within the casing segmentation device 32. To be clear, in those instances wherein the solid homogeneous material frac-ball 52 comprises a fluid soluble material, it is the rupture mechanism 62 that ruptures the frac-ball into “discrete pieces” of a size inadequate to prevent fluid flow through the fluid passage 54 disposed within the casing segmentation device 32.

[0060] In some embodiments, the destructible frac-ball 52 may comprise a solid shell and a core comprising a non-solid material; e.g. comprised of a liquid that may be considered to be incompressible as used within a frac-ball. The shell is configured such that it may be ruptured into the aforesaid “discrete pieces” of a size inadequate to prevent fluid flow through the fluid passage 54 disposed within the casing segmentation device 32. In some embodiments, the destructible frac-ball 52 may include a trigger mechanism 64 and an energetic material 66 disposed within a fluid core frac-ball. Upon initiation, energy created by an energetic material 66 is transmitted into the fluid core, which would (e.g., via shock wave) cause the solid shell to break the shell into the aforesaid discrete pieces. The core fluid would subsequently mix with the fluid disposed within the casing. Non-limiting examples of fluid core materials include water, mineral oil, ballistic gelatin, and silicon oil. Fluid materials (e.g., oils, ballistic gelatin, etc.) that have no adverse effect on trigger mechanism electronics are particularly useful. The shell may comprise materials as disclosed above.

[0061] In some embodiments, a casing segmentation device 32 that is configured for use with a destructible frac-ball 52 may include one or more rupture mechanisms 62; e.g., rupture mechanisms 62 disposed at positions where they can act upon a seated frac-ball 52 and cause the destructible frac-ball 52 to rupture into the aforesaid discrete pieces. For example, a rupture mechanism 62 included with a casing segmentation device 32 may selectively cause a mechanical feature (e.g., a pin, blade, etc.) to strike the frac-ball 52 and thereby cause the frac-ball 52 to rupture into the aforesaid discrete pieces.

[0062] In some embodiments, a plurality of rupture mechanisms 62 may be used, with at least some of the rupture mechanisms 62 actuatable independent of the other rupture mechanisms 62. For example, the rupture mechanism 62 of a first frac-ball 52 may be activated at a first frequency whereas the rupture mechanism 62 of a second frac-ball 52 may be activated at a second frequency.

[0063] In some embodiments, the frac-balls 52 may be configured having different sizes; e.g., diameters. In this manner, a first frac-ball 52 may have a diameter smaller relative to the diameter of other frac-balls 52, which smaller diameter

permits the first frac-ball **52** to pass through one or more ball seats **60** before seating against a downstream located ball seat **60** sized to receive and hold the first ball frac-ball **52**.

[0064] While various embodiments of the present invention have been disclosed, it will be apparent to those of ordinary skill in the art that many more embodiments and implementations are possible within the scope of the invention. For example, the present invention as described herein includes several aspects and embodiments that include particular features. Although these features may be described individually, it is within the scope of the present invention that some or all of these features may be combined with any one of the aspects and remain within the scope of the invention. Accordingly, the present invention is not to be restricted except in light of the attached claims and their equivalents.

What is claimed is:

1. A frac-ball, comprising:
 - a body;
 - a rupture mechanism in communication with the body, which rupture mechanism is operable to selectively initiate and break the body into the plurality of discrete pieces.
2. The frac-ball of claim 1, wherein the body includes a core encased within a shell.
3. The frac-ball of claim 2, wherein the core comprises a fluid soluble material.
4. The frac-ball of claim 3, wherein the shell comprises a fluid non-soluble material.
5. The frac-ball of claim 2, wherein the shell comprises a fluid soluble material.
6. The frac-ball of claim 2, wherein the rupture mechanism includes an energetic material.
7. The frac-ball of claim 2, wherein the core comprises a fluid.
8. The frac-ball of claim 1, wherein the body is a solid body substantially consisting of a homogeneous material.
9. The frac-ball of claim 8, wherein the homogeneous material is a fluid soluble material.
10. The frac-ball of claim 1, wherein the rupture mechanism includes a trigger mechanism having a sensor, and the trigger mechanism is operable to cause the rupture mechanism to initiate based on input from the sensor.
11. The frac-ball of claim 10, wherein the sensor is operable to sense at least one of pressure, temperature, or conductivity proximate the frac-ball.
12. The frac-ball of claim 10, wherein the sensor is operable to sense at least one of magnetic, electromagnetic, pressure, electrical, RF, or ultrasonic signals.
13. The frac-ball of claim 1, wherein the rupture mechanism includes a trigger mechanism that includes a timer.
14. The frac-ball of claim 1, wherein the rupture mechanism includes a trigger mechanism that includes a first metal-

lic alloy and a second metallic alloy, wherein the first metallic alloy has a first melting temperature and the second metallic alloy has a second melting temperature, which second melting temperature is higher than the first melting temperature, and wherein the first metallic alloy and the second metallic alloy are exothermically reactive with one another.

15. The frac-ball of claim 1, wherein the rupture mechanism includes a receiver operable to receive at least one of a radio frequency energy type signal, or an acoustic energy type signal, an electrical energy type signal, or a pressure pulse type signal.

16. The frac-ball of claim 1, wherein the rupture mechanism includes a trigger mechanism that is operable to be selectively deployed into a state where it may be activated to selectively cause the rupture mechanism to initiate and break the body into the plurality of discrete pieces.

17. The frac-ball of claim 1, wherein the rupture mechanism includes a trigger mechanism that is operable to be selectively activated via electromagnetic inductive coupling.

18. The frac-ball of claim 1, further comprising a safety inhibit operable to prevent the rupture mechanism from initiating and breaking the body into the plurality of discrete pieces unless a predetermined condition is met.

19. A segmentation device for use within a casing, comprising:

- a seat for receiving a frac-ball;
- at least one rupture mechanism disposed relative to the seat, which rupture mechanism is operable to act upon a frac-ball disposed within the seat and cause the frac-ball to rupture into discrete pieces.

20. The segmentation device of claim 19, wherein the rupture mechanism includes a mechanical feature operable to strike the frac-ball and thereby cause the frac-ball to rupture into the discrete pieces.

21. A method for selectively initiating fluid flow within a casing segment, comprising:

- providing a segmentation device operable to be disposed within the casing, which segmentation device includes a seat for receiving a frac-ball;
- providing a frac-ball having a body and a rupture mechanism in communication with the body, which rupture mechanism includes a trigger mechanism operable to selectively cause the rupture mechanism to initiate and break the body into the plurality of discrete pieces;
- causing the rupture mechanism to initiate and break the frac-ball body into the plurality of discrete pieces based on input from the trigger mechanism, and thereby selectively initiating fluid flow through the segmentation device.

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