



(51) International Patent Classification:

G21B 1/05 (2006.01) H05H 1/16 (2006.01)
G21B 3/00 (2006.01) H05H 1/54 (2006.01)
G21B 1/13 (2006.01) H05H 3/06 (2006.01)
G21C 13/087 (2006.01)

(21) International Application Number:

PCT/US2017/062009

(22) International Filing Date:

16 November 2017 (16.11.2017)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

62/423,662 17 November 2016 (17.11.2016) US

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(54) Title: FUSION REACTOR

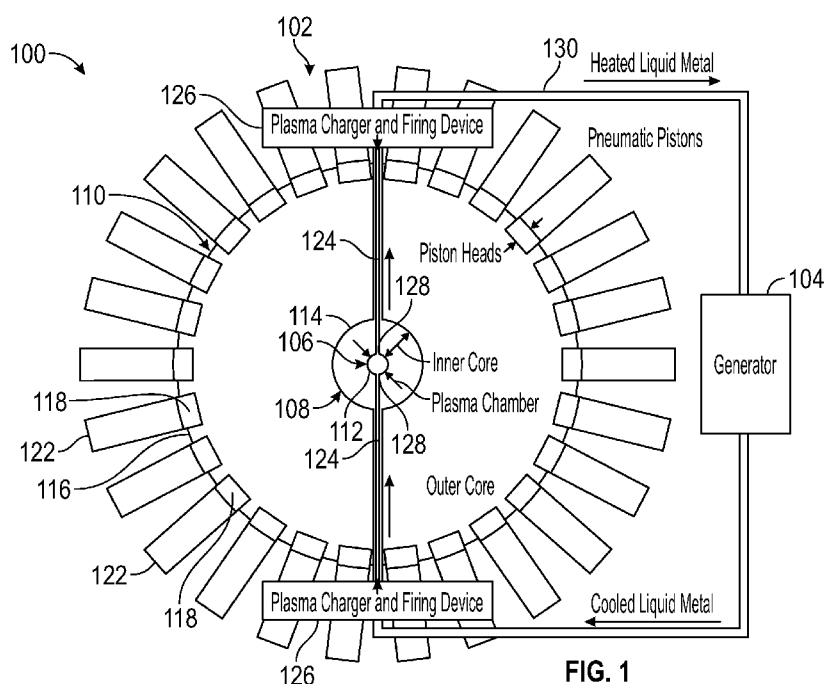


FIG. 1

(57) Abstract: A reacting system for performing a fusion reaction and harvesting thermal energy from the fusion reaction includes a reactor. The reactor includes an outer core, an inner core, a central opening, and a compressor. The outer core contains liquid metal. The inner core contains liquid metal and defines an external surface including a force transferring barrier that is configured to separate liquid metal in the outer core from liquid metal in the inner core. The central opening is configured to receive plasma. The compressor is configured to compress the liquid metal in the outer core. The force transferring barrier is configured to transfer force from the compression of the liquid metal in the outer core to the liquid metal in the inner core thereby causing displacement of the liquid metal in the inner core and compressing the plasma within the central opening.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

- *with international search report (Art. 21(3))*
- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

FUSION REACTOR

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present Application claims the benefit of and priority to U.S. Provisional Patent Application No. 62/423,662, filed on November 17, 2016, the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] Electrical energy is utilized throughout modern society. One of the ways through which electrical energy may be produced involves utilizing a fusion reaction. The fusion reaction may fuse a plurality of atomic nuclei into a final product. The final product may have a lower mass than the combined mass of the plurality of atomic nuclei, thus producing a net product of energy according to mass-energy equivalence theory.

SUMMARY

[0003] Systems, methods, and apparatuses for a reacting system are provided. One embodiment relates to a reacting system for performing a fusion reaction and harvesting thermal energy from the fusion reaction. The reactor includes an outer core, an inner core, a central opening, and a compressor. The outer core contains liquid metal. The inner core contains liquid metal and defines an external surface including a force transferring barrier that is configured to separate liquid metal in the outer core from liquid metal in the inner core. The central opening is configured to receive plasma. The compressor is configured to compress the liquid metal in the outer core. The force transferring barrier is configured to transfer force from the compression of the liquid metal in the outer core to the liquid metal in the inner core thereby causing displacement of the liquid metal in the inner core and compressing the plasma within the central opening.

[0004] Another embodiment relates to a reacting system for performing a fusion reaction and harvesting thermal energy from the fusion reaction. The reacting system includes a reactor. The reactor includes an outer core, an inner core, a compressor, and a central opening. The outer core contains liquid metal. The inner core contains liquid metal and defining an external surface. The inner core includes a barrier that is configured to separate liquid metal in the outer core from liquid metal in the inner core. The compressor is

configured to compress the liquid metal in the outer core. The central opening is configured to receive plasma. The barrier is configured to contain the thermal energy of the fusion reaction in the liquid metal in the inner core.

[0005] Yet another embodiment relates to a reacting system. The reacting system includes a reactor. The reactor includes an outer core, an inner core, a compressor, and a plasma chamber. The outer core contains liquid metal. The inner core contains liquid metal and includes a first flexible membrane that is configured to separate liquid metal in the outer core from liquid metal in the inner core. The compressor is configured to compress the liquid metal in the outer core. The plasma chamber is positioned within the inner core. The plasma chamber contains plasma and includes a second flexible membrane that is configured to separate the plasma from liquid metal in the inner core. The first flexible membrane is configured to transfer displacement of liquid metal in the outer core to liquid metal in the inner core. The first flexible membrane is configured to contain thermal energy of the liquid metal of the inner core. The second flexible membrane is configured to transfer displacement of liquid metal in the inner core to the plasma in the plasma chamber.

[0006] Yet another embodiment relates to a reacting system. The reacting system includes a reactor. The reactor includes an outer core, an inner core, and a plurality of pistons. The outer core contains liquid metal. The outer core defines a casing including a plurality of openings. The inner core is homocentric with the outer core. The inner core contains liquid metal and defines an external surface including a membrane that is configured to separate liquid metal in the outer core from liquid metal in the inner core and to transfer displacement of liquid metal in the outer core to liquid metal in the inner core. Each of the plurality of pistons includes a piston head that is positioned in one of the plurality of openings.

[0007] These and other features, together with the organization and manner of operation thereof, may become apparent from the following detailed description when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE FIGURES

[0008] FIG. 1 is a schematic view of a reacting system, according to an exemplary embodiment;

[0009] FIG. 2 is a block diagram for a process of using the reacting system shown in FIG. 1, according to an exemplary embodiment;

[0010] FIG. 3 is a schematic view of a reacting system, according to another exemplary embodiment; and

[0011] FIG. 4 is a block diagram for a process of using the reacting system shown in FIG. 3, according to an exemplary embodiment.

DETAILED DESCRIPTION

[0012] Referring to the figures generally, systems, methods, and apparatuses for performing a fusion reaction are provided.

[0013] Energy producing reactions may occur through a fusion of a plurality of atomic nuclei, such as two deuterium (e.g., 2H , heavy hydrogen, etc.) atoms, into a final product, such as helium-4 (e.g., 4He , etc.). The plurality of atomic nuclei may include two incident reactant species, such as, by way of example only, deuterium and tritium (e.g., 3H , hydrogen-3, triton, etc.) that are each positively charged. Because of their positive charges, the reactant species are repelled by an electrostatic repulsion that may be overcome in the fusion reaction. This electrostatic repulsion, also known as a coulombic barrier, may have an energy on the order of 0.1 Megaelectron volts (MeV).

[0014] Some current fusion reactions are accomplished using magnetized target fusion systems. Typically, magnetized target fusion systems require large amounts of energy to compress plasma. For example, it is common for magnetized target fusion systems to utilize between fifty and one-hundred Megajoules of energy to compress plasma. As a result, the energy output by conventional magnetized target fusion systems is lower than the large amount energy required to operate these systems. Conventional fusion reactors may employ one core to contain a liquid metal, which is used to absorb heat from a fusion reaction and also apply pressure. However, this single core design does not efficiently capture and create energy at an optimal output because the energy needs to be absorbed and

transferred throughout the entire core, and the volume of the core must be a certain volume to optimally apply pressure, thus this increased size from a single core design does not allow for maximum storage of energy because of the dissipation of energy through the full volume of the liquid metal core.

[0015] The reacting system described herein provides a dual core design where a smaller core functions primarily to store the thermal energy from the fusion reaction and a larger core with a primary function to transfer pressure created from the pistons to the smaller core. The volume of the smaller core facilitates storing and transferring the thermal energy more efficiently than with the conventional single core designs. The relative size of the larger core facilitates efficiently and effectively applying pressure to the smaller core. Additionally, because the outer core does not have to store thermal energy, the outer core can be larger and, thus, even greater pressure is able to be applied to plasma than in single core designs. Further, the outer core may thermally insulate the inner core, thereby increasing the efficiency of the reacting system. By utilizing this dual core design, the reacting system described herein is capable of obtaining a larger net output of energy than in conventional single core designs.

[0016] The reacting system described herein is capable of applying greater pressure and concentrated heat to magnetized toroidal plasma than conventional magnetized target fusion systems, while providing improved energy storage within the inner core. This facilitates increased frequency of catalyzing plasma atoms (e.g., deuterium, tritium, helium-3, lithium-6, lithium-7, etc.), allowing the reacting system described herein to produce a positive net energy output. In contrast with conventional fusion reactors, the reacting system described herein facilitates the expansion and contraction of a relatively large volume of liquid metal under piston firing action. Through the use of a comparatively small inner core to absorb energy and a relatively larger outer core to apply pressure, the reacting system described herein is capable of more efficiently producing electrical energy than fusion reactors today.

[0017] Referring to Fig. 1, a system, shown as reactor system 100, includes an apparatus, shown as reactor 102, and a generator, shown as generator 104. Reactor system 100 utilizes reactor 102 and generator 104 to produce electrical energy (e.g., electricity, etc.). Reactor system 100 may be implemented to provide electrical energy to a power grid. For example, reactor system 100 may provide electrical energy to residential, commercial, and industrial properties. Similarly, reactor system 100 may be implemented to provide electrical energy

on various mobile applications, such as maritime vessels (e.g., submarines, aircraft carriers, barges, floating platforms, etc.) and for space applications (e.g., space stations, etc.).

[0018] Reactor 102 includes a first chamber, shown as plasma chamber 106, a second chamber, shown as inner core 108, and a third chamber, shown as outer core 110. In many applications, plasma chamber 106, inner core 108, and outer core 110 may be spherical in shape. According to various embodiments, inner core 108 has a diameter of between approximately 0.304 meters (e.g., one foot, etc.) and approximately 9.14 meters (e.g., thirty feet, etc.), and outer core 110 has a diameter of between approximately 0.91 (e.g., three feet, etc.) meters and approximately 60.96 meters (e.g., two-hundred feet, etc.). In other embodiments, outer core 110 has a diameter of between approximately 1.52 meters (e.g., five feet, etc.) and approximately 76.2 meters (e.g., two-hundred and fifty feet, etc.). However, other shapes (e.g., cylinder, cube, tetrahedron, hexahedron, octahedron, dodecahedron, etc.) for any of plasma chamber 106, inner core 108, and outer core 110 may be utilized. According to various embodiments, plasma chamber 106, inner core 108, and outer core 110 may be homocentric. In other words, plasma chamber 106 may be centered from every point on the exterior circumference of outer core 110. In one embodiment, plasma chamber 106 is configured to selectively hold (e.g., contain, receive, etc.) plasma (e.g., heated gas without electrons, etc.), and inner core 108 and outer core 110 are configured to hold liquid (e.g., molten, etc.) metal. Reactor system 100 creates a fusion reaction in plasma chamber 106 through shock waves (e.g., acoustic waves, vibratory waves, pressure waves, etc.) transferred through liquid metal in outer core 110 and inner core 108.

[0019] Plasma chamber 106 includes a containment surface (e.g., force transferring barrier, membrane, casing, outer surface, barrier, etc.), shown as membrane 112. Membrane 112 separates (e.g., divides, partitions, etc.) plasma chamber 106 from inner core 108 and is deformable (e.g., capable of changing shape, etc.). Similarly, inner core 108 includes a wall (e.g., force transferring barrier, membrane, casing, outer surface, barrier, etc.), shown as membrane 114. Membrane 114 separates (e.g., divides, partitions, etc.) inner core 108 from outer core 110 and is deformable (e.g., capable of changing shape, etc.). Membrane 112 and membrane 114 are external surfaces of plasma chamber 106 and inner core 108, respectively. In an exemplary embodiment, membrane 114 insulates liquid metal in outer core 110 from liquid metal in inner core 108 while membrane 112 is relatively

highly thermally conductive to facilitate heat transfer between plasma in plasma chamber 106 and liquid metal in inner core 108.

[0020] In an exemplary embodiment, membrane 112 has a relatively high thermal conductivity to facilitate energy transmission (i.e., via thermal energy) from the fusion reaction to the liquid metal in inner core 108. The liquid metal in inner core 108 is configured to absorb energy (e.g., heat, etc.) from the fusion reaction in plasma chamber 106. For example, the liquid metal in inner core 108 may be selected based on target heat transfer properties (e.g., heat capacity, thermal conductivity, etc.).

[0021] Outer core 110 includes a wall (e.g., outer surface, barrier, shell, metal containment layer, composite containment layer, lattice or patterned containment layer, selectively portioned containment layer with multiple lining materials, etc.), shown as exterior casing 116. In some embodiments, exterior casing 116 is constructed from metal (e.g., alloys, composite metals, etc.). Exterior casing 116 includes a plurality of openings (e.g., holes, bores, selectively positioned voids, etc.), shown as openings 118. Openings 118 may be equally distributed around exterior casing 116. For example, openings 118 may be distributed equidistant from one another and cover a majority of exterior casing 116. Accordingly, the number of openings 118 may be related to a spacing distance between openings 118. In other examples, openings 118 are equally spaced apart at some regions of exterior casing 116 (e.g., near a middle line of outer core 110, etc.) and more concentrated in other regions of exterior casing 116 (e.g., near a top and/or bottom of outer core 110, etc.).

[0022] Openings 118 are configured to receive piston heads, shown as piston heads 120. Piston heads 120 are configured to selectively interface with the liquid metal in outer core 110. Each of piston heads 120 is selectively driven by a piston (e.g., actuator, driver, motor, ram, rod, pneumatic device, steam device, hydraulic device, controlled heat device, fuel electric device, etc.), shown as piston 122, of a compressor. As utilized herein, pistons 122 are an exemplary configuration of a compressor that is configured to compress liquid metal in outer core 110. It is understood that the compressor may include other compressing mechanisms such as, for example, a plurality of panels configured to selectively collapse exterior casing 116. According to various embodiments, pistons 122 selectively drive piston heads 120 between a first position, outside of outer core 110 such that piston head 120 does not substantially extend into outer core 110, and a second position, inside outer

core 110 such that piston head 120 extends into outer core 110 and displaces the liquid metal in outer core 110. In some embodiments, the compressor may include explosive devices (e.g., blast directors, combustion pistons, etc.) instead of, or in addition to, pistons 122.

[0023] Piston heads 120 may have various shapes depending on the application of reactor system 100. For example, piston heads 120 may be generally flat, may be rounded (e.g., hemispherical, triangular, three-dimensional, patterned, etc.), or have another shape tailored to displace a maximum amount of the liquid metal in outer core 110. Piston heads 120 may have a surface area of between 92.9 square centimeters (e.g., 0.1 square feet, etc.) and 0.93 square meters (e.g., ten square feet, etc.).

[0024] Pistons 122 may be at least partially mounted (e.g., fixed, secured, attached, etc.) to outer core 110 via an interface with exterior casing 116. In some applications, reactor system 100 may include between six and five-thousand pistons 122 and the same number of piston heads 120. In other applications, reactor system 100 may include between sixteen and ten-thousand pistons 122 and the same number of piston heads 120. In some embodiments, piston heads 120 are mounted behind (e.g., relative to within the outer core 100, etc.) a metal casing or lining, where piston heads 120 may push through the lining when fired. The metal casing may isolate piston heads 120 from the liquid metal in outer core 110 when the piston heads are in the retracted second position.

[0025] Pistons 122 are configured to cause piston heads 120 to selectively enter outer core 110 and interface with the liquid metal in outer core 110 through openings 118. For example, pistons 122 may be configured to facilitate a travel of piston heads 120 into outer core 110 of between 0.03 meters (e.g., 0.1 feet, etc.) and 1.51 meters (e.g., five feet, etc.). Piston heads 120 may be configured to collectively cause a displacement of between 0.03 cubic meters (e.g., one cubic foot, etc.) and 1,132.67 cubic meters (e.g., forty-thousand cubic feet, eighty-thousand cubic feet, etc.) of liquid metal in outer core 110. In various applications, pistons 122 may be driven by compressed air, steam, pneumatic devices, hydraulically operated devices, electronically driven devices, fuel driven devices (e.g., operated by gas fuels, liquid fuels, solid fuels), and/or other working fluids. Pistons 122 may be driven at relatively high speeds such that piston heads 120 move at between, for example, ten meters per second and over one-thousand meters per second.

[0026] As piston heads 120 are driven into outer core 110, the liquid metal in outer core 110 is displaced, causing a shock wave to propagate through the liquid metal in outer core 110. In this way, the liquid metal in outer core 110 acts as a conductive medium for the shock wave. An outer core 110 of a larger volume and diameter may produce a greater focusing action on the shock wave created. The shock wave may be magnified and intensified as it travels through outer core 110 and inner core 108 through the shrinking volume of the interior of the outer core 110 and inner core 108, such as an outer core 110 of a larger diameter may produce a greater magnified shock wave, such that when the shock wave reaches the inner core the pressure applied from the shock wave is magnified, as the shock wave would otherwise be if the diameter of the outer core 110 was smaller, resulting in greater compression force applied to plasma chamber 106. In order to achieve improved magnification of the shock wave force, the liquid metal in outer core 110 and inner core 108 may be formulated to meet viscosity requirements that conduct the shock wave. When this shock wave encounters membrane 114, membrane 114 transfers the shock wave to the liquid metal in inner core 108 due to the deformable nature of membrane 114. Similar to the liquid metal in outer core 110, the liquid metal in inner core 108 acts as a conductive medium for the shock wave. As the shock wave encounters membrane 112, membrane 112 transfers the shock wave to the plasma in plasma chamber 106 due to the deformable nature of membrane 112 thereby compressing the plasma. In some embodiments, membrane 112 at least partially returns to its uncompressed state due to the shock wave reversing after the fusion reaction occurs, which facilitates more simplified firing of plasma into plasma chamber 106. Because plasma chamber 106 may be homocentric with inner core 108 and outer core 110, the shock waves from piston heads 120 encounter membrane 112 substantially simultaneously, thus leading to substantially equal compression of plasma chamber 106 from all directions and increasing the probability of a fusion reaction.

[0027] Pistons 122 are controlled (e.g., cooperatively, sequentially, etc.) to selectively drive piston heads 120 to control this shock wave. According to an exemplary operation, pistons 122 are controlled such that the shock wave produced by each piston head 120 is synchronized to selectively collapse (e.g., deform, compress, shrink, etc.) plasma chamber 106 when the plasma is in the center of plasma chamber 106. This collapse of plasma chamber 106 causes nuclei within the plasma to undergo a fusion reaction resulting in the production of energy. In various applications, reactor system 100 is capable of producing between one and one-hundred megajoules (MJ) of energy. In other applications, reactor

system 100 is capable of producing between ten and fifty-thousand megawatts. In still other embodiments, reactor system 100 is capable of producing between one-thousand and fifty million MJ every twenty-four hours.

[0028] Reactor system 100 includes at least one conduit (e.g., pipe, tube, channel, etc.), shown as plasma conduit 124. Plasma conduit 124 is configured to facilitate selective transmission of plasma through outer core 110, through inner core 108, and into plasma chamber 106. In various applications, plasma conduit 124 has a length of between 1.83 meters (e.g., six feet, etc.) and 30.48 meters (e.g., one-hundred feet, etc.). According to an exemplary embodiment, plasma conduit 124 terminates on a first end at a device, shown as plasma charging and firing device 126, and terminates on a second end, opposite the first end, at plasma chamber 106. In various embodiments, reactor system 100 includes two plasma conduits 124, each including a plasma charging and firing device 126.

[0029] According to various embodiments, plasma charging and firing device 126 is located outside of exterior casing 116. Plasma charging and firing device 126 is configured to be selectively charged with plasma and to selectively accelerate and fire the plasma into plasma chamber 106. In this way, plasma fired from two plasma charging and firing devices 126 may be propelled, each in a separate plasma conduit 124, towards plasma chamber 106. The two plasma shots fired from the two conduit 124 may have trajectories such that the two plasma shots collide within plasma chamber 106.

[0030] Plasma charging and firing device 126 is configured to fire the plasma based on timing required for the shock wave created by pistons 122 to collapse plasma chamber 106, such that the firing of the pistons 122 is adjusted based on various factors, including but not limited to, the diameter of the reactor and the distance the plasma travels. In an exemplary operation, plasma charging and firing device 126 may be configured to fire the plasma such that the plasma is in the center of plasma chamber 106 when the shock wave collapses membrane 112, thereby causing the plasma to be evenly compressed on all sides by membrane 112.

[0031] Plasma fired by plasma charging and firing device 126 may enter plasma chamber 106 at a first pressure, density, and temperature. However, after being compressed by membrane 112 in plasma chamber 106, the plasma may have a second pressure, density, and temperature. Any of the second pressure, density, and temperature may be greater than

the first pressure, density, and temperature. This difference and/or these differences may be a multiple, an order of magnitude, or greater.

[0032] Plasma from plasma charging and firing device 126 enters plasma chamber 106 through openings (e.g., apertures, etc.), shown as input points 128. In an exemplary embodiment, plasma chamber 106 has two input points 128, one for each of two plasma charging and firing devices 126. In other embodiments, plasma chamber 106 has one input point 128, and one plasma charging and firing devices 126. In other applications, plasma chamber 106 includes more than two input points 128. For example, plasma chamber 106 may include two input points 128 for a single plasma charging and firing device 126. According to an exemplary embodiment, plasma chamber 106 includes two input points 128 diametrically opposed on membrane 112. However, in other embodiments, plasma chamber 106 includes two or more input points 128 otherwise angled relative to each other (e.g., angled at ninety degrees from each other, etc.). Depending on the application, plasma charging and firing device 126 may fire plasma into plasma chamber 106 at speeds up to or over 3219 kilometers per hour. In some embodiments, plasma conduit 124 is configured to radially compress the plasma as it travels towards plasma chamber 106.

[0033] In some embodiments, input points 128 are selectively reconfigurable between an open state and a closed state. For example, input points 128 may be open to receive a shot of plasma from plasma charging and firing device 126, and closed once the shot is inside of plasma chamber 106.

[0034] Reactor system 100 includes another conduit (e.g., pipe, tube, channel, etc.), shown as liquid metal circuit 130. Liquid metal circuit 130 is configured to facilitate the selective transmission of liquid metal through outer core 110 and into inner core 108 as well as from inner core 108 and through outer core 110. Liquid metal circuit 130 may include one or more conduits through which liquid metal may move from inner core 108 and through outer core 110. Liquid metal conduit 130 may protrude through outer core 110 and extend into inner core 108 at various relative orientations such as the top of outer core 110 and inner core 108, the bottom of outer core 110 and inner core 108, and other similar orientations. In one exemplary embodiment, liquid metal enters outer core 110 and inner core 108 from the top and exits inner core 108 and outer core 110 from the bottom. According to various embodiments, plasma conduit 124 is contained within (e.g., surrounded by, etc.) liquid metal circuit 130. According to other embodiments, plasma

conduit 124 is parallel and separated from liquid metal circuit 130 by a small distance (e.g., 1mm, 5mm, 100mm, etc.). Plasma conduit 124 may be configured to prohibit contact between plasma in plasma conduit 124 and liquid metal in liquid metal circuit 130. In some embodiments, plasma conduits 124 are connected to liquid metal circuit 130.

[0035] Generator 104 is disposed along liquid metal circuit 130. Generator 104 is configured to receive heated liquid metal, via liquid metal circuit 130, remove heat from the heated liquid metal to produce energy (e.g., via a boiler and/or turbine, etc.), and provide cooled liquid metal via liquid metal circuit 130. Generator 104 may function to harvest thermal energy from the heated liquid metal to provide electrical energy. For example, generator 104 may utilize thermal energy from the heated liquid metal to convert water into steam to drive a turbine and produce electrical energy. The temperature change in the liquid metal entering generator 104 and the liquid metal leaving generator 104 may be related to the efficiency of reactor system 100. Generator 104 may function as and/or include a pump to draw liquid metal through liquid metal circuit 130.

[0036] According to various embodiments, liquid metal is circulated in inner core 108. In some applications, liquid metal is circulated at speeds of between zero and one-thousand rotations per minute. In other embodiments, either or both of inner core 108 and plasma chamber 106 are configured to rotate independent of outer core 110, pistons 122, plasma conduit 124, plasma charging and firing device 126, liquid metal circuit 130. In other embodiments, either one of or both the liquid metal of inner core 108 and the liquid metal of outer core 110 are configured to rotate within the interior of their respective cores, where membrane 112, membrane 114, and exterior casing 116 are stationary, and the liquid metal in inner core 108 and/or outer core 110 are rotated by other means. In other embodiments, either one of or both the liquid metal of inner core 108 and the liquid metal of outer core 110 are configured to rotate within the interior of their respective cores, where membrane 112, membrane 114, and exterior casing 116 are stationary and such rotation is independent of pistons 122, and the liquid metal in inner core 108 and/or outer core 110 are rotated by other means. For example, paddles or wheels positioned within inner core 108 and/or outer core 110 may cause rotation of the liquid metal of inner core 108 and/or the liquid metal of outer core 110 independent of pistons 122.

[0037] Rotation of inner core 108 and/or outer core 110 may assist in dissipating shock waves after each compression of pistons 122. For example, inner core 108 may be

configured to rotate to increase heat transfer from plasma chamber 106 to liquid metal in inner core 108. In order to rotate inner core 108 and/or outer core 110, inner core 108 and/or outer core 110 may be mounted on a rotating system such as a plasma firing device, a generator, and/or other systems. In these embodiments, plasma conduits 124 and liquid metal circuit 130 may rotate with inner core 108 and/or outer core 110. For example, inner core 108 and/or outer core 110, or only the liquid metal in inner core 108 and/or only the liquid metal in outer core 110, may rotate about plasma conduits 124 and liquid metal circuit 130. In this example, a device may be coupled to plasma conduits 124 and/or liquid metal circuit 130 that facilitates rotation of inner core 108 and/or outer core 110 without loss of liquid metal from inner core 108 and/or outer core 110. In some of these embodiments, reactor system 100 does not include membrane 112. Rather, inner core 108 is rotated to create a vortex into which plasma conduits 124 provide plasma selectively discharged from plasma charging and firing device 126. In some embodiments, plasma conduits 124 form an opening in the liquid metal in inner core 108, through which the plasma is propelled into the vortex, using a burst of air (e.g., fired in unison by plasma charging and firing devices 126). Thus, when the shock wave encounters inner core 108, the liquid metal in inner core 108 is compressed around plasma in the vortex.

[0038] In some embodiments, it is desired to alter characteristics of the plasma before it is fired into plasma chamber 106 by plasma charging and firing device 126 such that when the plasma is fired it has altered characteristics. Plasma charging and firing device 126 may, independently or cooperatively with additional plasma charging and firing devices 126, charge (e.g., create a positive charge, create a negative charge, etc.), magnetize, shape, transform, heat, cool, accelerate, and/or otherwise alter the characteristics of the plasma. Altering some characteristic(s) of the plasma may cause corresponding alterations in other characteristics of the plasma. For example, changing the shape of the plasma may cause changes in a magnetic field associated with the plasma, potentially resulting in magnetic confinement of the plasma.

[0039] In some applications, plasma charging and firing device 126 forms the plasma into a low-density, low-temperature spheromak ring. Following this example, plasma may be fired into plasma chamber 106 in a spheromak ring held together by self-generated magnetic fields. In other examples, plasma charging and firing device 126 forms the plasma into a field-reversed configuration (FRC), compact toroid, and/or other toroidal shapes.

[0040] To alter the characteristics of the plasma, plasma charging and firing device 126 may include additional components, devices, or machines, such as, for example, a magnetized coaxial gun. In some applications, plasma charging and firing device 126 is configured to heat to charge and heat the plasma. For example, plasma charging and firing device 126 may charge and heat the plasma to between five and two-hundred kiloelectron Volts (keV), inclusive. In another example, plasma charging and firing device 126 may charge and heat the plasma to between five and one-hundred keV, inclusive. By charging and heating the plasma, some of the atoms in the plasma may have energies that exceed the coulombic barrier before being fired into plasma chamber 106. In some applications, plasma charging and firing device 126 includes a fusor (e.g., Farnsworth fusor, etc.) to electrostatically confine the plasma. In other applications, plasma charging and firing device 126 includes a tokamak to magnetically confine the plasma.

[0041] In some applications, plasma charging and firing device 126 includes an acceleration device to accelerate the plasma, thus resulting in further heating and compression of the plasma. In this way, the plasma may be compressed in a higher temperature and higher density compressed toroidal plasma. The acceleration device may have a length of up to or over forty meters. The acceleration device may include an electromagnetic accelerator. In some embodiments, electrical current from the acceleration devices provides magnetic and/or electromagnetic forces on the plasma that further compress the plasma.

[0042] Depending on the application, plasma charging and firing device 126 may utilize various plasmas. In some applications, reactor system 100 utilizes any plasma having a weight of between one and two-hundred kilograms, inclusive. For example, plasma charging and firing device 126 may utilize various combinations of the plasmas of deuterium, tritium, helium-3, lithium-6, lithium-7, and/or other plasmas. In some embodiments, the plasmas utilized in reactor system 100 have a surface that is coated in a second material such as lithium or deuteride or more coatings. This coating may reduce impurities in the plasma.

[0043] Similarly, depending on the application, reactor system 100 may utilize various types of liquid metals in inner core 108 and/or outer core 110. The liquid metal in inner core 108 and/or outer core 110 may be various combinations of molten lead-lithium. In one example, the liquid metal in inner core 108 and/or outer core 110 may be molten lead-

lithium with approximately seventeen percent (e.g., by mass, by volume, etc.) lithium. In other examples, the liquid metal in inner core 108 and/or outer core 110 may be lead-lithium mixtures with other lithium percentages (e.g., zero percent, five percent, ten percent, fifteen percent, twenty percent, twenty-five percent, etc.). In one embodiment, the liquid metal in inner core 108 and/or outer core 110 is substantially pure liquid lithium and/or enriched liquid lithium. In other embodiments, the liquid metal in inner core 108 and/or outer core 110 may be one or more lithium isotopes which can absorb neutrons and/or produce tritium. In other applications, the liquid metal in inner core 108 and/or outer core 110 may include various combinations of iron, nickel, cobalt, copper, aluminum, and/or other metals or alloys thereof.

[0044] In some embodiments, the liquid metal in inner core 108 is selected to have sufficiently low neutron absorption such that a useful flux of neutrons escapes the liquid metal. In one embodiment, the liquid metal in inner core 108 is selected to have a density of approximately 11.6 grams per cubic centimeter. In one embodiment, the liquid metal in outer core 110 is selected to have a density of approximately 11.6 grams per cubic centimeter. In some embodiments, the liquid metal in inner core 108 is heated to between ten and ten-thousand keV.

[0045] In applications where reacting system 100 includes a plurality of plasma charging and firing devices 126, the plasma fired from one plasma charging and firing device 126 may differ from the plasma fired by another plasma charging and firing devices 126. For example, one plasma charging and firing device 126 may form muonic tritium from a muon and a tritium atom and fire the muonic tritium into plasma chamber 106, and another plasma charging and firing device 126 may fire deuterium into plasma chamber 106. Because the muonic tritium has a reduced Bohr radius, the columbic barrier may be reduced and helium-4 and a neutron may be produced.

[0046] According to various embodiments, membrane 112 is constructed from a deformable material that returns to its original shape when not under pressure from the compression caused by the shock wave. Membrane 112 may be flexible and may be configured to substantially evenly deform in all directions when impacted by the shock wave. Membrane 112 may be spherical, cubic, cylindrical, polygonal, tetrahedron, hexahedron, octahedron, dodecahedron, or have some other similar shape or combination thereof. In some embodiments, membrane 112 includes a number of openings to facilitate

heat transfer from the fusion reaction to the liquid metal in inner core 108. For example, membrane 112 may be of a mesh construction. Membrane 112 may have various textures on the interior face (i.e., the membrane face in the direction of the fusion reaction).

[0047] According to various embodiments, membrane 114 is configured to withstand temperature of between approximate ten and one-thousand keV without deforming due to heat. Membrane 114 may be flexible and durable to withstand repeated expansion and contraction from the shock waves imparted by piston heads 120. In an exemplary embodiment, membrane 114 is constructed from a material capable of expanding and contracting at a high frequency (e.g., once every half a second, once every second, once every three seconds, etc.) while exposure to high heated liquid metal during operation of reactor system 100. Depending on the liquid metal in inner core 108, membrane 114 may have different properties. For example, if the liquid metal in inner core 108 is a lead-lithium mixture, membrane 114 may be configured to have relatively high insulating properties such that heat is retained in inner core 108.

[0048] According to various embodiments, membrane 112 has different material properties than membrane 114. Similarly, the liquid metal in outer core 110 may be different, and have different properties, than the liquid metal in inner core 108. In an exemplary embodiment, the liquid metal in outer core 110 is configured to transfer pressure from the shock wave created by piston heads 120 to inner core 108. In one embodiment, the liquid metal in outer core 110 is selected to optimize transmission (e.g., decrease losses, increase speed, etc.) of the shock wave. For example, the liquid metal in outer core 110 may have a relatively low density.

[0049] Other components of reactor system 100, such as, for example, exterior casing 116, piston heads 120, plasma conduit 124, and liquid metal circuit 130, may be constructed from various materials such as, for example, stainless steel coated with tungsten. However, these components may be constructed from other materials so long as deformation of the components is reduced or does not occur. In some embodiments, components of reactor system 100 may be subjected to temperature on the order of one-hundred keV.

[0050] According to some embodiments, plasma charging and firing device 126 is configured to fire the plasma and an auxiliary shot. The auxiliary shot may be a burst of compressed gas (e.g., air, etc.) that may function to reopen plasma chamber 106 after each

shock wave. In other embodiments, the plasma discharged from plasma charging and firing device 126 may be discharged with sufficient force to reopen plasma chamber 106 independent from an auxiliary shot. Alternatively, if inner core 108 and/or outer core 110 are configured to rotate, plasma chamber 106 may at least partially reopen due to centripetal force that draws liquid metal away from plasma chamber 106 after each shock wave compression.

[0051] In one embodiment, reactor system 100 includes a suction line positioned along at least one of plasma conduit 124 and liquid metal circuit 130. The suction line may function to draw used plasma shot material from plasma chamber 106 between cycles of reactor system 100. For example, the suction line may remove used plasma shot material from plasma chamber 106 after a target number of cycles (e.g., every two cycles, every five cycles, every ten cycles, etc.). By removing used plasma shot material, reactor system 100 may obtain higher efficiencies. In some applications, the used plasma shot material may be reused (e.g., recharged, etc.) by plasma charging and firing device 126.

[0052] According to alternative embodiment, reactor system 100 does not include plasma conduit 124 or plasma chamber 106. Rather, inner core 108 and/or outer core 110 are rotated to create a vortex in the center of the liquid metal in inner core 108 and/or the liquid metal in outer core 110. Plasma is then fired directly into this vortex where it is compressed directly by the liquid metal in inner core 108. In some of these alternative applications, inner core 108 is not separated from outer core 110 by membrane 114.

[0053] In another alternative embodiment, reactor system 100 includes two plasma charging and firing devices 126 on the bottom of outer core 110 and inner core 108 but only one of the two plasma charging and firing devices 126 is contained within liquid metal circuit 130. In this embodiment, liquid metal circuit 130 additionally connects to another location in inner core 108 and/or outer core 110, such as the top.

[0054] In another alternative embodiment, liquid metal may enter and leave inner core 108 through the same location in liquid metal circuit 130. For example, a single partitioned conduit (e.g., tube, pipe, etc.) may extend through outer core 110 and into inner core 108. Following this example, liquid metal may be introduced to inner core 108 via one section of the partitioned conduit and removed from inner core 108 via another section of the partitioned conduit. This single partitioned tube may be extended through either the top or

bottom of outer core 110. The single partitioned tube facilitates thermal insulation of hot liquid metal extracted from inner core 108 by the cooled liquid metal entering inner core 108.

[0055] In another alternative embodiment, reactor system 100 does not include membrane 114. Rather, the liquid metal in inner core 108 and the liquid metal in outer core 110 may contact but, due to the repulsive properties of the liquid metals, they may not mix. This allows the liquid metal of outer core 110 to insulate the liquid metal of inner core 108. In other applications where reactor system 100 does not include membrane 114, insulating metal or liquid suspension material are positioned between the liquid metal in inner core 108 and the liquid metal in outer core 110.

[0056] In yet another alternative embodiment, membrane 112 and/or membrane 114 are solid and not flexible. For example, membrane 112 and/or membrane 114 may be configured to contract (e.g., collapse, etc.) with compression from the liquid metal in outer core 110. This contraction may be facilitated by, for example, a contraction mechanism (e.g., telescoping chamber, etc.) coupled to a device (e.g., actuator, piston, etc.) disposed on or extending through exterior casing 116.

[0057] In some embodiments, plasma chamber 106 are held within inner core 108 by a mechanism other than plasma conduits 124. In some of these applications, plasma conduits 124 may be configured to retract and disconnected from input points 128. For example, plasma conduits 124 may be rapidly inserted to connect with input points 128 prior to firing plasma (e.g., within one to three seconds of firing plasma, etc.).

[0058] In some embodiments, exterior casing 116 is collapsible (e.g., able to decrease in internal volume, etc.). As exterior casing 116 collapses, exterior casing 116 substantially maintains a spherical shape (e.g., a perfect sphere, an imperfect sphere, etc.). As exterior casing 116 collapses, a shock wave (e.g., a pressure shock wave, etc.) is transferred through liquid metal in outer core 110 which is subsequently transferred to liquid metal in inner core 108 and thereby to plasma in plasma chamber 106. In this way, exterior casing 116 may expand and contract to cause compression of plasma in plasma chamber 106. In some embodiments, this configuration of exterior casing 116 eliminates the need for pistons 122 in reacting system 100. In other embodiments, pistons 122 compliment collapsing of

exterior casing 116. For example, pistons 122 may further compress plasma in plasma chamber 106 after exterior casing 116 has fully collapsed.

[0059] In applications where exterior casing 116 is collapsible, exterior casing 116 may be constructed from a plurality of overlapping panels (e.g., segments, etc.) which slide together to collapse exterior casing 116. The overlapping between the panels creates a seal therebetween such that liquid metal is maintained within exterior casing 116. This seal is maintained before, after, and during collapsing of exterior casing 116. The panels may be, for example, one foot wide by four feet tall. In other examples, the panels may be one foot wide by more than four feet tall. Each of the panels may be, for example, flat, curved, or rounded (e.g., arc shaped, etc.).

[0060] Collapsing of exterior casing 116 may be also be accomplished through the use of contracting members (e.g., contracting rods, contracting beams, contracting plates, etc.) which are positioned around inner core 108. The contracting members are configured such that liquid metal in outer core 108 causes the contracting members to expand and shrink. In some applications, the contracting members may be configured such that liquid metal may only contact an interior side of the contracting members. For example, the contracting members may be positioned along an interior surface of exterior casing 116. During collapsing and expanding of exterior casing 116, liquid metal remains sealed within exterior casing 116.

[0061] It is understood that while only two plasma charging and firing devices 126 are shown in Fig. 1, reactor system 100 may incorporate three, six, ten, or more plasma charging and firing devices 126. In such applications, all plasma charging and firing devices 126 would be configured as described herein and would be positioned equidistant about exterior casing 116.

[0062] Referring to FIG. 2, reactor system 100 is controlled according to a process (e.g., operating sequence, etc.), shown as reacting process 200. Reacting process 200 may include an energy producing stage and an energy harvesting stage. Reacting process 200 causes a fusion reaction of plasma in plasma chamber 106 thereby producing thermal energy that is absorbed by liquid metal in inner core 108 and transferred via liquid metal circuit 130 to generator 104, where it is harvested to produce electrical energy. According to various embodiments, reacting process 200 occurs over a duration of between 0.1 second

and five seconds, inclusive. During reacting process 200, liquid metal may be continuously pumped through liquid metal circuit 130. The reacting process employed by reactor system 100 begins (step 202) with altering characteristics of the plasma by plasma charging and firing device 126. For example, the plasma may be charged (e.g., positively, magnetically, etc.) in plasma charging and firing device 126. In some applications, reactor system 100 does not alter the characteristics of the plasma.

[0063] Reactor system 100 then (step 204) fires all pistons 122 thereby causing all piston heads 120 to simultaneously displace the liquid metal in outer core 110. Each piston 122 creates a shock wave that travels towards inner core 108. The firing of pistons 122 may be synchronized, coordinated, or otherwise cooperatively programmed such that the shock waves impact plasma chamber 106 at substantially the same time. As the pistons 122 are fired, plasma charging and firing device 126 prepares to fire plasma (step 206). Plasma charging and firing device 126 may concurrently prepare multiple shots of plasma (e.g., two, five, ten, fifty, etc.) to be sequenced and fired. This may include reusing previously fired plasma shot materials.

[0064] Reactor system 100 then fires plasma from plasma charging and firing device 126 (Step 208). In an exemplary embodiment, reactor system 100 includes two plasma charging and firing devices 126. Both of the two plasma charging and firing devices 126 simultaneously fire plasma towards plasma chamber 106. The time difference between when pistons 122 are fired (step 204) and when plasma is fired (step 208) may be between 0.2 and five seconds. The firing of plasma charging and firing devices 126 may be controlled by a processor, processing circuit, computer, or other controller. Heat from a fusion reaction in plasma chamber 106 may then be harvested as previously described, and reacting process 200 may repeat.

[0065] After a number of cycles, it may be desirable to replace membrane 112 and/or membrane 114 (step 210). For example, membrane 112 and/or membrane 114 may be removable from plasma chamber 106 and/or inner core 108, respectively. Replacing membrane 112 and/or membrane 114 may occur regularly (e.g., during maintenance cycles, etc.). By replacing membrane 112 and/or membrane 114, reactor system 100 may be reconfigured for different applications (e.g., the use of different liquid metals, different plasmas, etc.).

[0066] In some embodiments, liquid metal is not continuously pumped through liquid metal circuit 130 while a reaction is occurring and is instead only pumped through liquid metal circuit 130 after a reaction has been completed. For example, liquid metal may not be pumped through liquid metal circuit 130 during step 202, step 204, step 206, or step 208.

[0067] Referring to FIG. 3, reactor system 100 is shown according to another embodiment. In this embodiment, reactor system 100 is structured such that inner core 108 and membrane 114 are divided into a first half, shown as first half 300, and a second half, shown as second half 302. As shown in FIG. 3, first half 300 and second half 302 are separated. However, first half 300 and second half 302 are movable such that first half 300 and second half 302 can selectively mate to encapsulate (e.g., surround, cover, etc.) plasma chamber 106 after a reaction within plasma chamber 106. In this way, pressure can be applied directly (e.g., without losses due to passing through structure such as membrane 114, etc.) from outer core 108 to plasma chamber 106, when first half 300 and second half 302 are separated, and thermal energy can be harvested from within first half 300 and second half 302, when first half 300 and second half 302 are mated (e.g., after a reaction within plasma chamber 106, etc.). In some embodiments, reactor system 100 is structured such that membrane 114 is a continuous panel that is folded to establish an internal volume housing inner core 108 and unfolded to reduce the internal volume housing inner core 108. In this way, membrane 114 may wrap around a fusion reaction after it occurs. Membrane 112 may similarly fold, unfold, and wrap around the fusion reaction.

[0068] In this embodiment, liquid metal circuit 130 includes a first portion, shown as a first arm 304, and a second portion, shown as a second arm 306. First arm 304 and second arm 306 are selectively repositionable within outer core 110. For example, first arm 304 and second arm 306 may be telescopic. First arm 304 is coupled to first half 300, and second arm 306 is coupled to second half 302. In this way, first arm 304 may be selectively extended or retracted to cause repositioning of first half 300 within outer core 110. Similarly, second arm 306 may be selectively extended or retracted to cause repositioning of second half 302 within outer core 110. Further, first arm 304 and second arm 306 are fluidly connected to liquid metal circuit 130 such that liquid metal may be circulated between first arm 304, second arm 306, first half 300, and second half 302 when first half 300 is mated to second half 302.

[0069] First half 300 and second half 302 may mate by insertion and/or rotation facilitated by first arm 304 and/or second arm 306. For example, first half 300 may include a plurality of posts that are received in a plurality of holes or slots in second half 302. One of first half 300 and second half 302 may be rotated relative to the other of first half 300 and second half 302 such that the posts are secured within the holes or slots. In other applications, first half 300 and second half 302 include corresponding threads such that first half 300 and second half 302 may be rotated together.

[0070] Reactor 102 includes a first mechanism, shown as a first drive 308, and a second mechanism, shown as a second drive 310. First drive 308 is configured to (e.g., is structured to, operable to, etc.) selectively extend and retract first arm 304, and second drive 310 is configured to selectively extend and retract second arm 306. First drive 308 and second drive 310 are communicable with a controller, shown as a controller 312. Controller 312 may include various processors, memories, and circuits configured to communicate with first drive 308, second drive 310, and external systems (e.g., external computers, external sensors, etc.).

[0071] In an exemplary, first half 300 and second half 302 are hemispherical. In other embodiments, first half 300 and second half 302 are conical or frustoconical. In still other embodiments, first half 300 and second half 302 are cylindrical. In various applications, first half 300 and second half 302 may be prismatic, rectangular, square, and otherwise similarly shaped.

[0072] First arm 304 and second arm 306 may be extended and retracted along plasma conduits 124, as shown in FIG. 3. In other applications, first arm 304 and second arm 306 may be extended and retracted independent of plasma conduits 124. For example, first arm 304 and second arm 306 may be offset relative to plasma conduits 124. In these applications, first drive 308, second drive 310, and liquid metal circuit 130 would be correspondingly offset.

[0073] In some applications, inner core 108 is configured to extend or retract only from a single arm (e.g., first arm 304, second arm 306, etc.). In these embodiments, inner core 108 may contain a mechanism for receiving plasma chamber 106 and subsequently sealing plasma chamber 106 within inner core 108. For example, inner core 108 may contain a closable aperture that is opened to receive plasma chamber 106. In these embodiments,

liquid metal circuit 130 circulates within the arm such that liquid metal flows into the arm, into inner core 108 around plasma chamber 106, and back through the arm towards liquid metal circuit 130.

[0074] Reacting system 100 is configured such that thermal energy is harvested from first half 300 and/or second half 302. In some embodiments, reacting system 100 is configured such that thermal energy is harvested from both first half 300 and second half 302. In other embodiments, reacting system 100 is configured such that thermal energy is harvested from only one or first half 300 and second half 302.

[0075] In some embodiments, first half 300 and second half 302 are collapsible (e.g., into a more narrow form, etc.). In these embodiments, first half 300 and second half 302 may be in a collapsed state when first half 300 is not mated to second half 302, such as when first half 300 and second half 302 are moving within outer core 108. In this way, first half 300 and second half 302 may move more easily (e.g., with less force from first drive 308 and second drive 310, etc.).

[0076] In some embodiments, plasma chamber 106 are held within inner core 108 by a mechanism other than plasma conduits 124. In some of these applications, plasma conduits 124 may be configured to retract and disconnected from input points 128. For example, plasma conduits 124 may be rapidly inserted to connect with input points 128 prior to firing plasma (e.g., within one to three seconds of firing plasma, etc.). This movement of plasma conduits 124 may be facilitated by first drive 308 and second drive 310.

[0077] It is understood that while only first drive 308 and second drive 310 are shown in Fig. 3, reactor system 100 may incorporate three, six, ten, or more drives similar to first drive 308 and second drive 310 described herein. In such applications, all drives could be positioned equidistant about exterior casing 116.

[0078] Referring to FIG. 4, reactor system 100 is controlled according to a process (e.g., operating sequence, etc.), shown as reacting process 400. Reacting process 400 is similar to reacting process 200, and includes similar steps. Reacting process 400 may include an energy producing stage and an energy harvesting stage. Reacting process 400 causes a fusion reaction of plasma in plasma chamber 106 thereby producing thermal energy that is absorbed by liquid metal in inner core 108 and transferred via liquid metal circuit 130 to

generator 104, where the thermal energy is harvested to produce electrical energy. First half 300 and second half 302 are extended to mate so as to encapsulate plasma chamber 106 after the fusion reaction is initiated. According to various embodiments, reacting process 400 occurs over a duration of between 0.1 second and five seconds, inclusive. During reacting process 400, liquid metal may be continuously pumped through liquid metal circuit 130. For example, liquid metal may flow out of second half 302 and into first half 300 from outer core 110. The reacting process employed by reactor system 100 begins (step 402) with altering characteristics of the plasma by plasma charging and firing device 126. For example, the plasma may be charged (e.g., positively, magnetically, etc.) in plasma charging and firing device 126. In some applications, reactor system 100 does not alter the characteristics of the plasma. At this stage, first half 300 and second half 302 are in a retracted state and do not encapsulate plasma chamber 106.

[0079] Reactor system 100 then (step 404) fires all pistons 122 thereby causing all piston heads 120 to simultaneously displace the liquid metal in outer core 110. Each piston 122 creates a shock wave that travels towards plasma chamber 106. The firing of pistons 122 may be synchronized, coordinated, or otherwise cooperatively programmed such that the shock waves impact plasma chamber 106 at substantially the same time. As the pistons 122 are fired, plasma charging and firing device 126 prepares to fire plasma (step 406). Plasma charging and firing device 126 may concurrently prepare multiple shots of plasma (e.g., two, five, ten, fifty, etc.) to be sequenced and fired. This may include reusing previously fired plasma shot materials.

[0080] Reactor system 100 then fires plasma from plasma charging and firing device 126 (step 408) and a fusion reaction in plasma chamber 106 occurs. Both of the two plasma charging and firing devices 126 simultaneously fire plasma towards plasma chamber 106. The time difference between when pistons 122 are fired (step 404) and when plasma is fired (step 408) may be between 0.2 and five seconds. The firing of plasma charging and firing devices 126 may be controlled by a processor, processing circuit, computer, or other controller, such as the controller 312.

[0081] Heat from the fusion reaction in plasma chamber 106 may then be harvested by first extending first arm 304 and second arm 306 until first half 300 and second half 302 mate and encapsulate plasma chamber 106 (step 410). In some embodiments, the liquid metal within outer core 110 is spun at a relatively high speed prior to extending the first half

300 and the second half 302 (step 410). Such spinning may increase pressure of the liquid metal.

[0082] Once plasma chamber 106 has been encapsulated, the reaction will provide thermal energy to liquid metal within inner core 108 which has now been formed by the mating of first half 300 and second half 302. Liquid metal can then be circulated by liquid metal circuit 130 as previously described. To repeat reacting process 400, first half 300 and second half 302 are separated and retracted.

[0083] After a number of cycles, it may be desirable to replace membrane 112 and/or membrane 114 (step 412). Replacing membrane 112 and/or membrane 114 may occur regularly (e.g., during maintenance cycles, etc.). By replacing membrane 112 and/or membrane 114, reactor system 100 may be reconfigured for different applications (e.g., the use of different liquid metals, different plasmas, etc.).

[0084] The present disclosure contemplates methods, systems, and program products on any machine-readable media for accomplishing various operations. The embodiments of the present disclosure may be implemented using existing computer processors, or by a special purpose computer processor for an appropriate system, incorporated for this or another purpose, or by a hardwired system. Embodiments within the scope of the present disclosure include program products comprising machine-readable media for carrying or having machine-executable instructions or data structures stored thereon. Such machine-readable media can be any available media that can be accessed by a general purpose or special purpose computer or other machine with a processor. By way of example, such machine-readable media can comprise RAM, ROM, EPROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to carry or store desired program code in the form of machine-executable instructions or data structures and which can be accessed by a general purpose or special purpose computer or other machine with a processor. When information is transferred or provided over a network or another communications connection (either hardwired, wireless, or a combination of hardwired or wireless) to a machine, the machine properly views the connection as a machine-readable medium. Thus, any such connection is properly termed a machine-readable medium. Combinations of the above are also included within the scope of machine-readable media. Machine-executable instructions include, for example, instructions and data which cause a general purpose computer, special

purpose computer, or special purpose processing machines to perform a certain function or group of functions.

[0085] As utilized herein, the terms “approximately”, “about”, “substantially”, and similar terms are intended to have a broad meaning in harmony with the common and accepted usage by those of ordinary skill in the art to which the subject matter of this disclosure pertains. It should be understood by those of skill in the art who review this disclosure that these terms are intended to allow a description of certain features described and claimed without restricting the scope of these features to the precise numerical ranges provided. Accordingly, these terms should be interpreted as indicating that insubstantial or inconsequential modifications or alterations of the subject matter described and claimed are considered to be within the scope of the invention as recited in the appended claims.

[0086] It should be noted that the terms “exemplary” and “example” as used herein to describe various embodiments is intended to indicate that such embodiments are possible examples, representations, and/or illustrations of possible embodiments (and such term is not intended to connote that such embodiments are necessarily extraordinary or superlative examples).

[0087] The terms “coupled,” “connected,” and the like, as used herein, mean the joining of two members directly or indirectly to one another. Such joining may be stationary (e.g., permanent, etc.) or moveable (e.g., removable, releasable, etc.). Such joining may be achieved with the two members or the two members and any additional intermediate members being integrally formed as a single unitary body with one another or with the two members or the two members and any additional intermediate members being attached to one another.

[0088] References herein to the positions of elements (e.g., “top,” “bottom,” “above,” “below,” “between,” etc.) are merely used to describe the orientation of various elements in the figures. It should be noted that the orientation of various elements may differ according to other exemplary embodiments, and that such variations are intended to be encompassed by the present disclosure.

[0089] Also, the term “or” is used in its inclusive sense (and not in its exclusive sense) so that when used, for example, to connect a list of elements, the term “or” means one, some,

or all of the elements in the list. Conjunctive language such as the phrase “at least one of X, Y, and Z,” unless specifically stated otherwise, is otherwise understood with the context as used in general to convey that an item, term, etc. may be either X, Y, Z, X and Y, X and Z, Y and Z, or X, Y, and Z (i.e., any combination of X, Y, and Z). Thus, such conjunctive language is not generally intended to imply that certain embodiments require at least one of X, at least one of Y, and at least one of Z to each be present, unless otherwise indicated.

[0090] It is important to note that the construction and arrangement of the portable electronic assembly as shown in the exemplary embodiments is illustrative only. Although only a few embodiments of the present disclosure have been described in detail, those skilled in the art who review this disclosure will readily appreciate that many modifications are possible (e.g., variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters, mounting arrangements, use of materials, colors, orientations, etc.) without materially departing from the novel teachings and advantages of the subject matter recited. For example, elements shown as integrally formed may be constructed of multiple parts or elements. It should be noted that the elements and/or assemblies of the components described herein may be constructed from any of a wide variety of materials that provide sufficient strength or durability, in any of a wide variety of colors, textures, and combinations. Accordingly, all such modifications are intended to be included within the scope of the present inventions. Other substitutions, modifications, changes, and omissions may be made in the design, operating conditions, and arrangement of the preferred and other exemplary embodiments without departing from scope of the present disclosure or from the spirit of the appended claims.

WHAT IS CLAIMED IS:

1. A reacting system for performing a fusion reaction and harvesting thermal energy from the fusion reaction, the reacting system comprising:
 - a reactor comprising:
 - an outer core containing liquid metal;
 - an inner core containing liquid metal, the inner core defining an external surface comprising a force transferring barrier configured to separate liquid metal in the outer core from liquid metal in the inner core;
 - a central opening configured to receive plasma; and
 - a compressor configured to compress the liquid metal in the outer core;
 - wherein the force transferring barrier is configured to transfer force from the compression of the liquid metal in the outer core to the liquid metal in the inner core thereby causing displacement of the liquid metal in the inner core and compressing the plasma within the central opening.
2. The reacting system of Claim 1, the force transferring barrier defining a first force transferring barrier and the external surface defining a first external surface, wherein the central opening defines a second external surface comprising a second force transferring barrier configured to separate plasma in the central opening from liquid metal in the inner core.
3. The reacting system of Claim 2, wherein the second force transferring barrier is configured to transfer force from the displacement of the liquid metal in the inner core to the plasma in the central opening thereby causing compression of the plasma in the central opening.
4. The reacting system of Claim 2, wherein the first force transferring barrier is configured to impede heat transfer between liquid metal in the inner core and liquid metal in the outer core; and
 - wherein the second force transferring barrier is configured to facilitate heat transfer between plasma in the central opening and liquid metal in the inner core.

5. The reacting system of Claim 2, further comprising:
 - a generator configured to harvest thermal energy; and
 - a liquid metal circuit communicable with the generator and extending through the outer core and the first force transferring barrier such that the liquid metal circuit is communicable with the inner core;wherein the generator is configured to draw liquid metal in the inner core through the liquid metal circuit and into the generator such that the generator can harvest thermal energy from liquid metal in the inner core.
6. The reacting system of Claim 5, further comprising a casing positioned around the outer core, the casing comprising a plurality of openings;
 - wherein the compressor comprises a plurality of pistons, each of the plurality of pistons comprising a piston head positioned in one of the plurality of openings and configured to apply force to the liquid metal in the outer core.
7. The reacting system of Claim 1, further comprising a casing positioned around the outer core, the casing comprising a plurality of overlapping panels that are configured to uniformly move and collapse the casing to decrease an internal volume of the casing and apply pressure on the liquid metal in the outer core.
8. The reacting system of Claim 7, wherein each of the plurality of overlapping panels is configured to overlap another of the overlapping panels such that a seal is formed therebetween, the seal maintaining the liquid metal in the outer core within the casing.
9. The reacting system of Claim 2, further comprising a casing positioned around the outer core, the casing comprising a plurality of openings;
 - wherein the compressor comprises a plurality of pistons, each of the plurality of pistons comprising a piston head positioned in one of the plurality of openings and configured to apply force to the liquid metal in the outer core.
10. The reacting system of Claim 2, further comprising a casing positioned around the outer core, the casing comprising a plurality of overlapping panels that are configured to uniformly move and collapse the casing to decrease an internal volume of the casing and apply pressure on the liquid metal in the outer core.

11. The reacting system of Claim 10, wherein each of the plurality of overlapping panels is configured to overlap another of the overlapping panels such that a seal is formed therebetween, the seal maintaining the liquid metal in the outer core within the casing.

12. The reacting system of Claim 5, further comprising:

a first plasma charging and firing device configured to be selectively charged with plasma and positioned external to the outer core; and

a first plasma conduit communicable with the first plasma charging and firing device and

extending through the outer core, the first force transferring barrier, and the second force transferring barrier such that the first plasma conduit is communicable with the central opening;

wherein the first plasma charging and firing device is further configured to selectively fire plasma into the central opening through the first plasma conduit.

13. The reacting system of Claim 12, further comprising:

a second plasma charging and firing device configured to be selectively charged with

plasma and positioned external to the outer core; and

a second plasma conduit communicable with the second plasma charging and firing device and extending through the outer core, the first force transferring barrier, and the second force transferring barrier such that the second plasma conduit is communicable with the central opening, the second plasma conduit being aligned with the first plasma conduit;

wherein the second plasma charging and firing device is further configured to selectively fire plasma into the central opening through the second plasma conduit.

14. The reacting system of Claim 1, further comprising:

a first arm extending through the outer core to the inner core;

a first drive configured to selectively extend and retract the first arm and positioned external to the outer core;

a second arm extending through the outer core to the inner core; and

a second drive configured to selectively extend and retract the second arm and positioned external to the outer core;

wherein the inner core is separated into a first half coupled to the first arm and a second half coupled to the second arm; and

wherein the first drive and the second drive are configured to selectively retract the first

arm and the second arm to separate the first half and the second half and to selectively extend the first arm and the second arm to mate the first half and the second half.

15. A reacting system for performing a fusion reaction and harvesting thermal energy from the fusion reaction, the reacting system comprising:

a reactor comprising:

an outer core containing liquid metal;

an inner core containing liquid metal, the inner core defining an external surface and comprising a barrier configured to separate liquid metal in the outer core from liquid metal in the inner core;

a compressor configured to compress the liquid metal in the outer core; and

a central opening configured to receive plasma;

wherein the barrier is configured to contain the thermal energy of the fusion reaction in the liquid metal in the inner core.

16. The reacting system of Claim 15, further comprising:

a generator configured to harvest thermal energy; and

a liquid metal circuit communicable with the generator and extending through the outer

core and the barrier such that the liquid metal circuit is communicable with the inner core;

wherein the generator is configured to draw liquid metal in the inner core through the liquid metal circuit and into the generator such that the generator can harvest thermal energy from liquid metal in the inner core.

17. The reacting system of Claim 15, further comprising a casing positioned around the outer core, the casing comprising a plurality of openings;

wherein the compressor comprises a plurality of pistons, each of the plurality of pistons comprising a piston head positioned in one of the plurality of openings and configured to apply force to the liquid metal in the outer core.

18. The reacting system of Claim 15, further comprising a casing positioned around the outer core, the casing comprising a plurality of overlapping panels that are configured to uniformly move and collapse the casing to decrease an internal volume of the casing and apply pressure on the liquid metal in the outer core.

19. The reacting system of Claim 18, wherein each of the plurality of overlapping panels is configured to overlap another of the overlapping panels such that a seal is formed therebetween, the seal maintaining liquid metal in the outer core within the casing.

20. The reacting system of Claim 15, further comprising:

- a first plasma charging and firing device configured to be selectively charged with plasma and positioned external to the outer core; and

- a first plasma conduit communicable with the first plasma charging and firing device and extending through the outer core, and the barrier, such that the first plasma conduit is communicable with the central opening;

- wherein the first plasma charging and firing device is further configured to selectively fire plasma into the central opening through the first plasma conduit.

21. The reacting system of Claim 20, further comprising:

- a second plasma charging and firing device configured to be selectively charged with

- plasma and positioned external to the outer core; and

- a second plasma conduit communicable with the second plasma charging and firing device and extending through the outer core, such that the second plasma conduit is communicable with the central opening, the second plasma conduit being aligned with the first plasma conduit;

- wherein the second plasma charging and firing device is further configured to selectively fire plasma into the central opening through the second plasma conduit.

22. The reacting system of Claim 15, further comprising:

- a first arm extending through the outer core to the inner core;

- a first drive configured to selectively extend and retract the first arm and positioned external to the outer core;

- a second arm extending through the outer core to the inner core; and

a second drive configured to selectively extend and retract the second arm and positioned external to the outer core;

wherein the inner core is separated into a first half coupled to the first arm and a second half coupled to the second arm; and

wherein the first drive and the second drive are configured to selectively retract the first arm and the second arm to separate the first half and the second half and to selectively extend the first arm and the second arm to mate the first half and the second half.

23. A reacting system comprising:

a reactor comprising:

an outer core containing liquid metal;

an inner core containing liquid metal and comprising a first flexible membrane configured to separate liquid metal in the outer core from liquid metal in the inner core;

a compressor configured to compress the liquid metal in the outer core; and

a plasma chamber positioned within the inner core, the plasma chamber containing plasma and comprising a second flexible membrane configured to separate the plasma from liquid metal in the inner core;

wherein the first flexible membrane is configured to transfer displacement of liquid metal in the outer core to liquid metal in the inner core;

wherein the first flexible membrane is configured to contain thermal energy of the liquid metal of the inner core; and

wherein the second flexible membrane is configured to transfer displacement of liquid metal in the inner core to the plasma in the plasma chamber.

24. The reacting system of Claim 23, wherein the outer core, the inner core, and the plasma chamber are homocentric.

25. The reacting system of Claim 23, further comprising:

a first arm extending through the outer core to the inner core;

a first drive configured to selectively extend and retract the first arm and positioned external to the outer core;

wherein the first drive is configured to selectively interface with the first arm to cause the plasma chamber to be exposed to liquid metal in the inner core.

26. The reacting system of Claim 23, further comprising:

a plasma conduit extending from the plasma chamber, through the second flexible membrane, into the inner core, through the first flexible membrane, into the outer core, and out of the outer core, the plasma conduit configured to facilitate injection of plasma into the plasma chamber from outside of the outer core; and

a liquid metal circuit extending from the inner core, through the first flexible membrane, into the outer core, and out of the outer core, the liquid metal circuit configured to facilitate communication of liquid metal into the inner core from outside of the outer core.

27. The reacting system of Claim 26, wherein the plasma conduit and a portion of the liquid metal circuit are aligned.

28. The reacting system of Claim 26, wherein the plasma conduit is contained within a portion of the liquid metal circuit.

29. The reacting system of Claim 23 wherein the first flexible membrane has a first coefficient of thermal conductivity and is configured to insulate liquid metal in the outer core from liquid metal in the inner core; and

wherein the second flexible membrane has a second coefficient of thermal conductivity greater than the first coefficient of thermal conductivity and is configured to facilitate heat transfer between plasma in the plasma chamber and liquid metal in the inner core.

30. A reacting system comprising:

a reactor comprising:

an outer core containing liquid metal, the outer core defining a casing comprising

a plurality of openings;

an inner core homocentric with the outer core, the inner core containing liquid

metal and defining an external surface comprising a membrane configured to separate liquid metal in the outer core from liquid metal in the inner core and to transfer displacement of liquid

metal in the outer core to liquid metal in the inner core; and

a plurality of pistons, each of the plurality of pistons comprising a piston head positioned in one of the plurality of openings.

31. The reacting system of Claim 30, further comprising:
an arm extending through the outer core and coupled to the inner core; and
a drive positioned external to the outer core configured to selectively reposition the arm.

32. The reacting system of Claim 31, wherein the drive is configured to selectively reposition
the arm to cause the inner core to separate such that liquid metal in the inner core is communicable with liquid metal in the outer core.

33. The reacting system of Claim 31, wherein the drive is configured to selectively reposition
the arm to reconfigure the inner core such that liquid metal in the inner core is communicable
with liquid metal in the outer core.

34. The reacting system of Claim 30, wherein a diameter of the outer core is approximately
three times a diameter of the inner core.

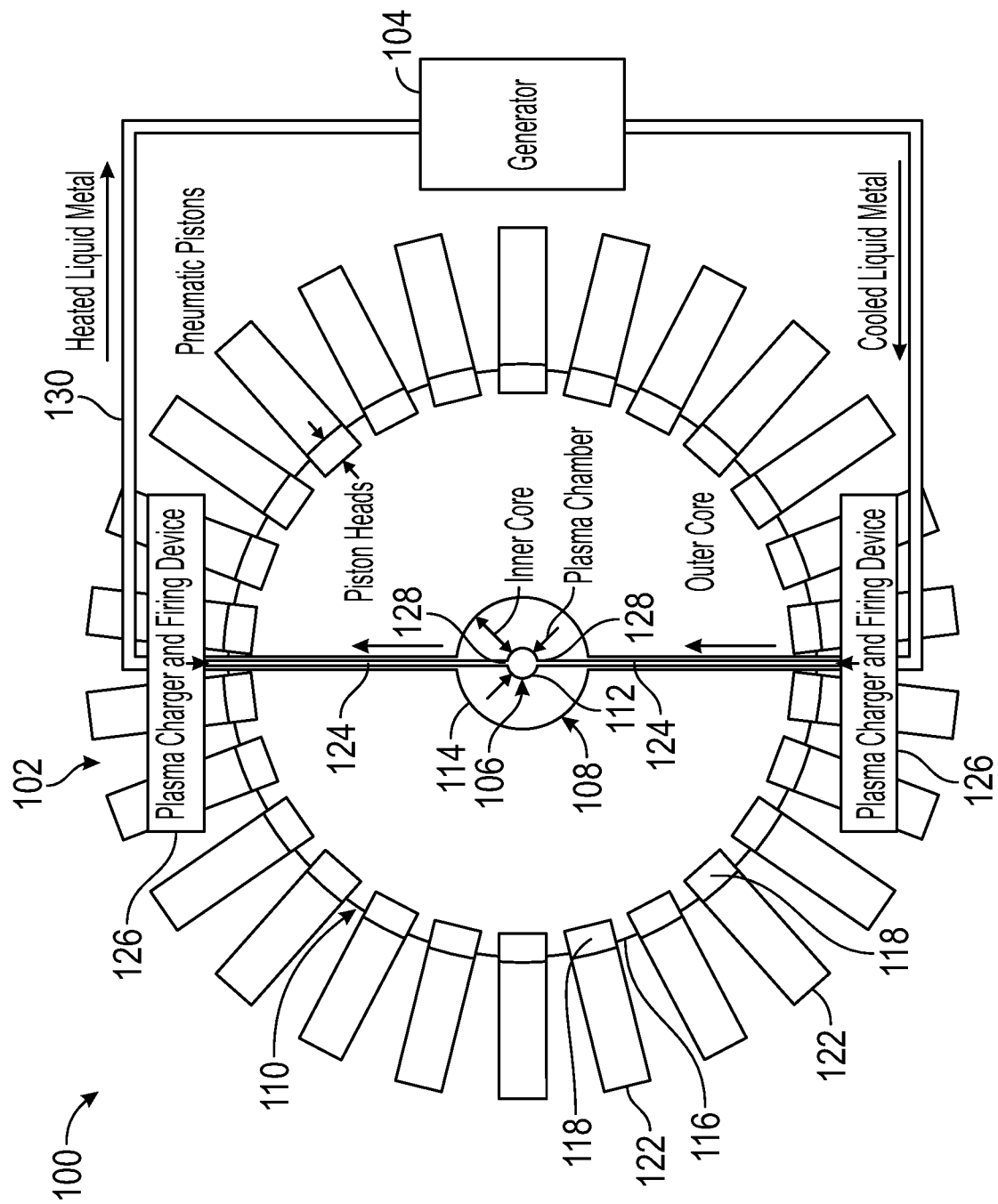
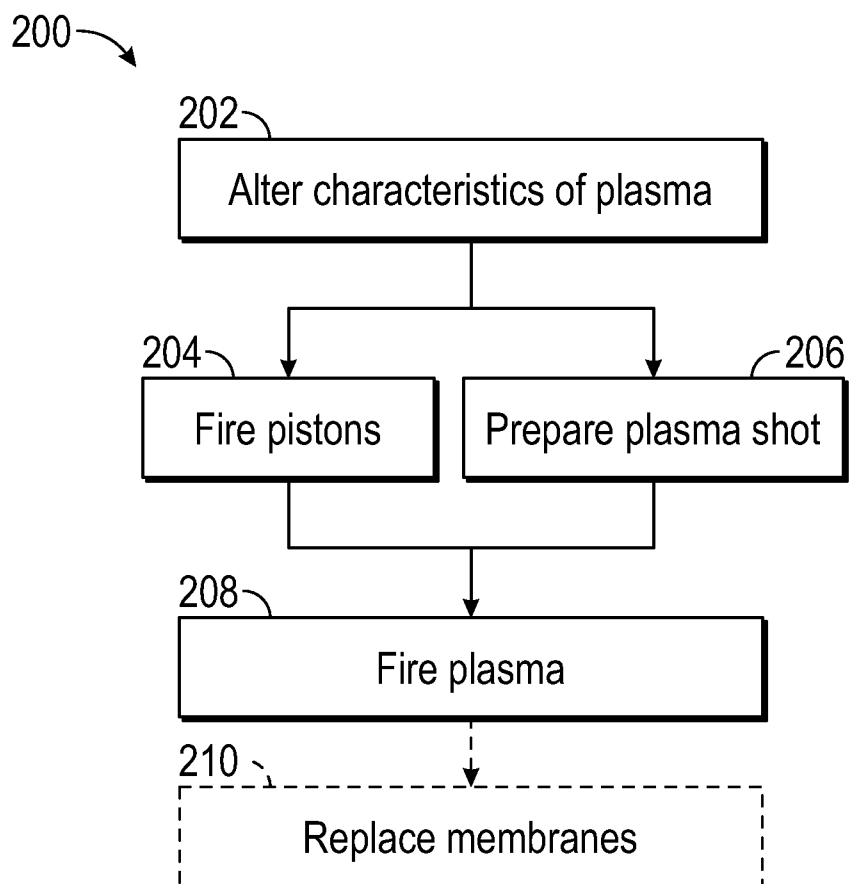
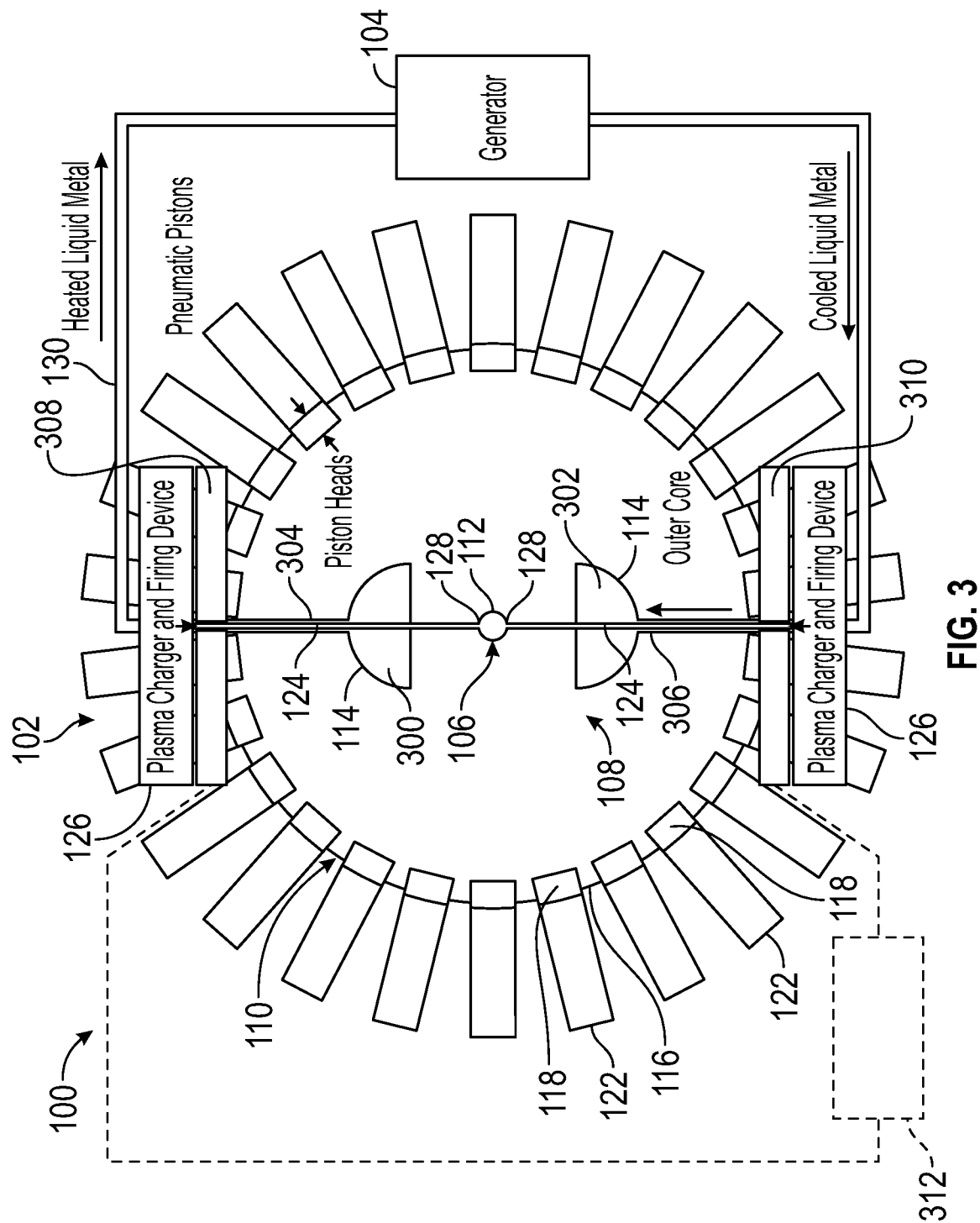
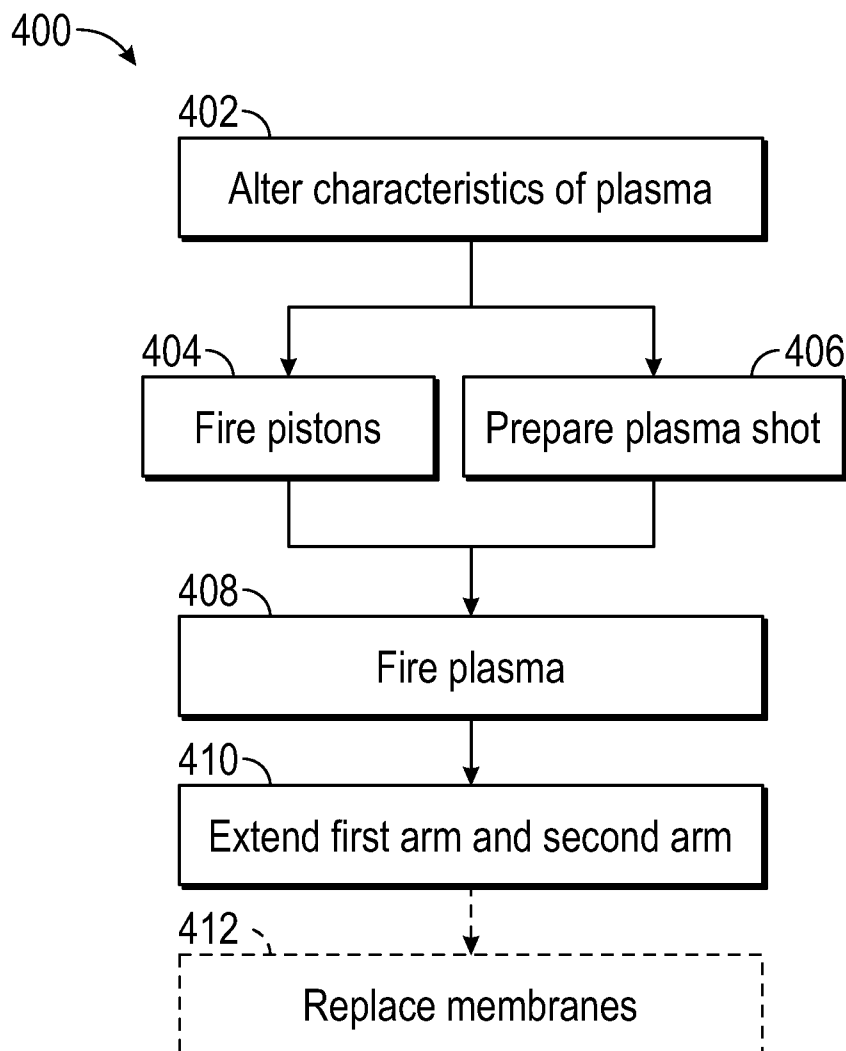


FIG. 1

**FIG. 2**



**FIG. 4**

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 17/62009

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - G21B 1/05, G21B 3/00, G21B 1/13, G21C 13/087, H05H 1/16, H05H 1/54, H05H 3/06 (2018.01)
CPC - G21B 1/057, G21B 1/11, G21B 1/13, G21B 3/008, G21C 1/328, G21C 13/087, G21C 15/247,
G21C 19/31, H05H 1/16, H05H 1/30, H05H 1/32, H05H 1/54, H05H 3/06, H05H 2001/469, H05H
2277/13, Y02E 30/10, Y02E 30/122, Y02E 30/14, Y02E 30/128, Y02E 30/14, Y02E 30/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

See Search History Document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

See Search History Document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

See Search History Document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2016/0314855 A1 (GENERAL FUSION INC.) 27 October 2016 (27.10.2016), Fig. 1B; para [0051], [0052], [0047], [0052]	1-22
A	WO 95/03611 A1 (ORELLANA HURTADO) 02 February 1995 (02.02.1995), English Abstract	1-22
A	US 5,015,432 A (KOLOC) 14 May 1991 (14.05.1991), Fig. 12; col 20, ln 4-22	1-22
A	US 4,749,540 A (BOGART et al.) 07 June 1988 (07.06.1988), Fig. 2; col 19, ln 21-43	1-22
A	US 4,305,784 A (OHKAWA) 15 December 1981 (15.12.1981), Fig. 4; col 2, ln 50-65	1-22

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

13 March 2018

Date of mailing of the international search report

27 MAR 2018

Name and mailing address of the ISA/US

Mall Stop PCT, Attn: ISA/US, Commissioner for Patents
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Authorized officer:

Lee W. Young

PCT Helpdesk: 571-272-4300
PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 17/62009

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I: Claims 1-22, drawn to reacting systems comprising barriers.

Group II: Claims 23-34, drawn to reacting systems comprising membranes and pistons.

-- Please See Supplemental Box --

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-22

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

Continued from Box No. III, Observations where unity of invention is lacking,

The inventions listed as Groups I and II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

Special Technical Features

Group II does not require a reacting system for performing a fusion reaction and harvesting thermal energy from the fusion reaction, the reacting system comprising: an inner core defining an external surface comprising a force transferring barrier configured to separate liquid metal in the outer core from liquid metal in the inner core; a compressor configured to compress the liquid metal in the outer core; wherein the force transferring barrier is configured to transfer force from the compression of the liquid metal in the outer core to the liquid metal in the inner core thereby causing displacement of the liquid metal in the inner core and compressing the plasma within the central opening (as in Claim 1); and a reacting system for performing a fusion reaction and harvesting thermal energy from the fusion reaction, the reacting system comprising: an inner core defining an external surface and comprising a barrier configured to separate liquid metal in the outer core from liquid metal in the inner core; a compressor configured to compress the liquid metal in the outer core; and wherein the barrier is configured to contain the thermal energy of the fusion reaction in the liquid metal in the inner core (as in Claim 15), as required by Group I.

Group I does not require a reacting system comprising: an inner core comprising a first flexible membrane configured to separate liquid metal in the outer core from liquid metal in the inner core; a compressor configured to compress the liquid metal in the outer core; and a plasma chamber positioned within the inner core, the plasma chamber containing plasma and comprising a second flexible membrane configured to separate the plasma from liquid metal in the inner core; wherein the first flexible membrane is configured to transfer displacement of liquid metal in the outer core to liquid metal in the inner core; wherein the first flexible membrane is configured to contain thermal energy of the liquid metal of the inner core; and wherein the second flexible membrane is configured to transfer displacement of liquid metal in the inner core to the plasma in the plasma chamber (as in Claim 23); and a reacting system comprising: an outer core defining a casing comprising a plurality of openings; an inner core homocentric with the outer core, the inner core defining an external surface comprising a membrane configured to separate liquid metal in the outer core from liquid metal in the inner core and to transfer displacement of liquid metal in the outer core to liquid metal in the inner core; and a plurality of pistons, each of the plurality of pistons comprising a piston head positioned in one of the plurality of openings (as in Claim 30), as required by Group II.

Shared Common Features

The only feature shared by Groups I and II that would otherwise unify the groups is a reactor comprising: an outer core containing liquid metal; an inner core containing liquid metal and defining an external surface, a central opening configured to receive plasma; thermal energy; a compressor; and displacement of the liquid metal in the inner core. However, this shared technical feature does not represent a contribution over prior art, because the shared technical feature is anticipated by US 2016/0314855 A1 (General Fusion Inc.). General Fusion Inc. discloses a reactor (para [0051]), comprising: an outer core containing liquid metal (Fig. 1B; para [0052], liquid metal funnel, 8.); an inner core containing liquid metal and defining an external surface (Fig. 1B; para [0052], liquid metal reservoir, 18.), a central opening configured to receive plasma (para [0047], plasma toroid, 13.); thermal energy (para [0058]); a compressor (para [0049], funnel compresses plasma.); and displacement of the liquid metal in the inner core (Fig. 1B; para [0052], liquid metal supplied from reservoir, 18, to toroid, 13, through liquid guide, 22, as shown.).

As the technical features were known in the art at the time of the invention, this cannot be considered a special technical feature that would otherwise unify the groups.

Groups I and II therefore lack unity under PCT Rule 13 because they do not share a same or corresponding special technical feature.