MODULAR REACTOR SYSTEM FOR EXOTHERMIC REACTIONS

TECHNICAL FIELD

[001] The present disclosure relates generally to the field of exothermic reactor systems and, more particularly, to a low cost, modular reactor for use in producing exothermic reactions under a wide variety of conditions and using a wide variety of materials.

BACKGROUND

[002] Over the past 30 years, scientists have observed the phenomena of excess heat being generated when a transition metal or metal alloy such as palladium, nickel or platinum, is exposed to hydrogen gas, or one of its isotopes under pressure. This phenomena is sometimes referred to as excess heat reactions. While much research is being conducted to better understand the excess heat reactions, the technology is not developed to the point of being commercially viable. Therefore, there is a need for further research to develop commercially viable reactor systems.

[003] A great deal of the current research is focused on identifying the combination of materials and triggering conditions needed to cause and sustain exothermic reactions. Researchers test a variety of theories, ranging from solid state reactors with pressure or magnetic triggers to wet electrolytic cells with voltage triggers and more. Most researchers develop their own costly test reactors specially designed for their unique requirements. This makes quickly analyzing a variety of combinations very cost and time prohibitive, and thus holds back the progress of exothermic reaction technology.

BRIEF SUMMARY

[004] The present disclosure comprises a modular reactor system for carrying out exothermic reactions. The modular reactor system comprises of a standard base plate and two or more interchangeable top plates configured to meet the requirements of different energy production processes, or different phases of an energy production process. In some embodiments, different top plates may be provided for solid-state reactors, plasma reactors, and electrolytic reactors, all of which are configured for use with the same standard base plate. In other embodiments, different top plates may be configured for use with the standard base plate during different phases of an energy production process. Such phases could include a preparation phase and an operation phase. The different phases may include sub-phases that require different top plates. For example, the preparation phase may comprise a cleaning phase and an activation phase.

[005] Through the interchangeability of the top plates, design complexity and overall cost of the reactor system can be reduced.

BRIEF DESCRIPTION OF THE DRAWINGS

[006] Figures 1A and 1B illustrate an exemplary modular reactor system according to one embodiment.

[007] Figure 2 illustrates an exemplary base plate for the modular reactor system.

[008] Figure 3 illustrates an exemplary top plate for the modular reactor system.

[009] Figure 4 is an exploded perspective view of the modular reactor system.

[010] Figure 5 illustrates an exemplary top plate used in the modular reactor system during a cleaning phase of an energy production process.

[011] Figure 6 illustrates an exemplary top plate used in the modular reactor system during an activation phase of an energy production process.

[012] Figure 7 illustrates an exemplary top plate used in the modular reactor system to create a solid-state reactor.

[013] Figure 8 illustrates an exemplary top plate used in the modular reactor system to create a plasma reactor.

[014] Figure 9 illustrates an exemplary top plate used in the modular reactor system to create an electrolytic reactor.

DETAILED DESCRIPTION

[015] Referring now to the drawings, exemplary embodiments of a modular exothermic reactor system10 are shown. It should be noted that throughout the specification and drawings, similar elements in the exemplary embodiments are indicated by similar reference numbers.

[016] Figures 1A and 1B show an exemplary reactor system 10. The modular reactor system 10 comprises two or more plates that are stacked together to form a reactor housing 12. The plates on each end of the stack are referred to herein generally as end plates. Plates between the two end plates are referred to herein as intermediate plates or expansion plates. In one embodiment, the modular reactor system 10 comprises a standard base plate 20 and two or more interchangeable top plates 40 configured to meet the requirements of different energy production processes, or different phases of an energy production process. Additional expansion plates 60 may be added between the base plate 20 and interchangeable top plate 40 as shown in Figure 1B. One or more of the plates include a cavity so configured that, when the plates are stacked together, a sealed chamber is formed inside the reactor housing 12. Alternatively, the modular reactor system 10 may comprise a standard top plate 40 and two or more interchangeable base plates 20. In some embodiments, the reactor system 10 may comprise two or more base plates 20, each of which can be used with two or more top plates 40. The expansion plates 60 may also be interchangeable in order to accommodate different instrumentation.

[017] The plates 20, 40, 60 of the reactor housing 12 are constructed of a material that can sustain high temperatures, vacuum, and/or high pressure, such as stainless steel.

The material should not react with the fuel materials of interest. For reactors where low thermal conductivity is desired, materials such as stainless steel, nickel alloys (e.g., Inconel, Incoloy), or titanium may be used. Where high thermal conductivity is desired, materials such as aluminum alloys, copper alloys, and silver alloys can be used. Aluminum alloys are better suited for heat sink applications but have low strength and a relatively low melting point. Copper alloys have higher melting points and offer good corrosion resistance, but may not be suited for the certain fuel materials. Silver alloys have higher melting points than aluminum alloys and are not implicated in contamination of exothermic reactions, but would be more expensive. If strength is a concern, coatings with high thermal conductivity, e.g., DLC, could be used in conjunction with lower thermal conductivity materials that provide better strength.

[018] Figures 2-4 illustrate an exemplary base plate 20 and a top plate 40 for the modular reactor system 10. The base plate 20 and top plate 40 form a block. The size of the block varies and may be designed in accordance to the desired power output of the reactor. In one embodiment, the block is approximately 3"x3"x3." The base plate 20 includes a contact surface 22 that engages a contact surface 42 on the bottom plate 40 when the base plate 20 and top plate 40 are assembled together. The base plate 20 and top plate 40 each include a cavity, 24 and 44 respectively, that form sealed chamber when the base plate 20 and top plate 40 are assembled together in stacked relationship. The top plate 40 includes a circular wall 46 that surrounds the cavity 44 and projects from the contact surface 42. The base plate 20 includes a circular groove 26 that receives the circular wall 46 of the top plate 40 when the base plate 20 and top plate 40 are assembled. The base plate 20 further includes a recessed surface 28 that surrounds the cavity 24 and is concentrically arranged with the recessed groove 26.

[019] Before the plates 20, 40 are assembled, a first seal 30 (Fig. 4) is placed in the recessed groove 26 on the top plate 40, and a second seal 32 is placed on the recessed surface. When the bottom plate 20 and top plate 40 are assembled, the seals 30, 32 are compressed between the plates 20, 40 to form an air-tight seal surrounding the sealed chamber in the reactor housing 12. Vacuum seals or high pressure seals may be used depending on the particular application. When a high pressure environment in the sealed chamber is required, the inner seal 32 may comprise a high pressure seal and the outer seal 30 may comprise a vacuum seal. In order to create a vacuum in the reaction chamber, the inner seal 32 may comprise a vacuum seal and the outer seal 30 may comprise a high pressure seal. In some embodiments, the inner seal 32 may comprise a seal rated for both vacuum and high pressure and the outer seal 30 can be omitted. In still other embodiments, the outer seal 30 and the inner seal 32 may be omitted.

[020] The base plate 20 and top plate 40 may be secured together by threaded bolts 34 that pass through a series of through holes 48 and thread into aligned bolt holes 36 in the base plate 20. In the embodiment shown in Figures 1-3, the base plate 20 further includes a set of threaded jacking holes 38 for separating the base plate 20 and top plate 40. The jacking holes 38 align with the contact surface 22 on the base plate 20 so that when a jacking screw (not shown) is threaded into the jacking holes 38, the ends of the jacking screw push against the contact surface 22 on the base plate 20 to push the base plate 20 and top plate 40 apart.

[021] In some embodiments, one or more expansion plates 60 may be added between the base plate 20 and top plate 40. The expansion plate 60 includes a first contact surface that engages the contact surface 22 on the base plate 20 and a second contact surface that engages the contact surface 42 on the top plate 40. A cavity is formed in the expansion plate 60 which, together with the cavities 24, 44 in the base plate 20 and top plate 40, form a sealed chamber in the reactor housing 12. Any number of expansion plates 60 could be used depending on the size requirements for the sealed chamber. The same sealing methods as previously described may be used between the expansion plate 60 and base plate 20, and between the expansion plate 60 and top plate 40.

[022] One aspect of the modular exothermic reactor system 10 is that two or more interchangeable top plates 40 may be configured for use with the same standard base plate 20. In some embodiments, the interchangeable top plates 40 may be configured for use in a different type of energy production processes, i.e., for different types of reactors. For example, different top plates 40 may be provided for solid-state reactors, plasma reactors, and electrolytic reactors, all of which are configured for use with the same base plate 20. Solid-state reactors contain hydrogen or deuterium in a solid form which is then released as a gas upon heating. Plasma reactors contain hydrogen or deuterium gas and has a voltage applied across electrodes to create a plasma that contains ionic species. Electrolytic reactors contain electrodes submerged in a solution that have a voltage applied across in order to induce the flow of current through the solution. In other embodiments, different top plates 40 may be configured for use with the standard base plate 20 during different phases of an energy production process.

[023] In some embodiments, the modular exothermic reactor system 10 comprises a base plate 20 and two or more interchangeable top plates 40 configured for use with the base plate 20 during different phases of an energy production process. Such phases could include a preparation phase and an operation phase. The different phases may include sub-phases that require different top plates 40. For example, the preparation phase may comprise a cleaning phase and an activation phase, each requiring a different top plate. The cleaning phase may require a cleaning phase top plate and the activating phase may require an activation phase plate. During the cleaning phase, a base plate 20 and/or other plates used in a previous reaction are cleaned of residual material and byproducts. During the activation phase, a reaction material is treated or prepared to enable an exothermic reaction during a subsequent operation phase. Additional phases may be necessary based on the requirements of the energy-production process. To prevent contamination of the reactor and/or material, the interchanging of top plates 40 could be done in a controlled environment, e.g., a glovebox with an inert atmosphere.

[024] Figure 5 shows an exemplary top plate 40 for use with a modular exothermic reactor during a cleaning phase of an energy production process. The cleaning phase top plate 40, referred to hereinafter as a cleaning plate, may be used with a solid-state reactor, plasma reactor, and/or electrolytic reactor. The cleaning plate can be attached to the base plate 20 to form a sealed chamber as previously described. In Figure 4, the exemplary top plate 40 comprises an electrode 50 in the form of a rod and configured to generate a plasma. The electrode 50 protrudes through the cleaning plate into the sealed chamber. In one embodiment, the electrode 50 is made of molybdenum. In some embodiments, the material of the electrode 50 for the cleaning process is not material so a wide range of materials can be used for the electrode 50. The electrode 50 is electrically isolated from the surrounding material of the cleaning plate by a dielectric material. During a cleaning process, a voltage differential is created between the reactor housing 12 and the electrode 50 in order to generate the plasma. The reactor housing 12 is held at a positive potential to induce an electron flow to reaction material in contact with the inner surface of the sealed chamber. In one embodiment, the cleaning plate includes a heater that can be used to raise the temperature of the reactor according to specification.

[025] The cleaning plate may further include one or more gas ports 52. Two gas ports 52 allow gas flow through the reactor when a plasma is not being generated, which can provide more efficient cleaning. If only one gas port 52 is available due, e.g., to sizing constraints, proper cleaning can still be achieved, but gas introduction and vacuum would be occur in separate steps during the cleaning process. An example cleaning process designed for the top plate 40 described above would be configured to accommodate the continuous flow of an inert gas, e.g. argon, through the reactor housing 12 for a set period of time after which the reactor is vacuumed to a set level. The top plate 40 may be configured to accommodate the flow of a second gas, e.g. hydrogen, which may be introduced into the reactor. The top plate 40 and the base plate 20 should also be configured to allow the chamber to be vacuumed down to an appropriate level.

[026] Figure 6 shows an exemplary top plate 40 for use with a modular exothermic reactor system 10 during an activation phase of an energy production process. In this example, the activation phase top plate 40, referred to herein as an activation plate, is similar to the cleaning plate. The activation plate comprises an electrode 54 and one or more gas ports 52. The electrode 54 is electrically isolated from the material of the activation plate and protrudes through the activation plate and into the sealed chamber. In this example, the electrode 54 generates a plasma for plating the inner surfaces of the sealed chamber with a reaction material. The activation process may require an electrode 54 with a different material than the electrode 50 for the cleaning process, which may necessitate different top plates 40 for the cleaning phase and activation phase. In some embodiments, the same top plate 40 may be used for both the cleaning and activation phases. Those skilled in the art will appreciate that the activation plate is not required for some energy production processes.

[027] In one embodiment, the top plate 40 used for the cleaning phase may be configured to comprise one or more electrodes. When the cleaning plate is replaced with the activation plate, the electrodes of the cleaning plate are switched out by the electrodes of the activation plate. In another embodiment, the electrodes remain in the sealed chamber when the cleaning plate is replaced by the activation plate. In this embodiment, the electrodes are cleaned during the cleaning phase so that the contaminants are pulled out during the cleaning phase and ready for use during the activation phase.

[028] Figure 3 shows an exemplary top plate 40 for use with a modular exothermic reactor system 10 during an operation phase of an energy production process. During the operation phase, an exothermic reaction is triggered and generates heat. In its simplest form, the operation phase top plate 40, referred to herein generically as the operation plate, comprises a cavity 44 as previously described that forms a sealed chamber to contain the solid-state reaction material. The top plate 40 further comprises one or more gas ports 52 to supply and/or evacuate gas from the sealed chamber. In the case of a single gas port 52, the gas port 52 can be selectively connected to a source of vacuum and a source of gas at different times depending on the requirements of the solid-state reaction process. In embodiments with two gas ports 52, a gas flow through the sealed chamber can be maintained during the exothermic reaction.

[029] In some embodiments, the modular exothermic reactor system 10 comprises a base plate 20 and two or more interchangeable top plates 40 configured for use with the base plate 20 for different types of energy production process. For example, different top plates 40 may be provided for solid-state reactors, plasma reactors, and electrolytic reactors, all of which are used with the same standard base plate 20. The embodiment of the top plate 40 shown in Figure 3 is a simple example of a top plate 40 for the operation phase of a solid-state reactor.

[030] Figure 7 shows another example of a top plate 40 configured for use during the operation phase of a solid-state reactor. The top plate 40 in this example is similar to the top plate 40 in Figure 3 with the addition of a heating element 56 to heat the reaction material by conduction and initiate the exothermic reaction in the sealed chamber of the reactor housing 12. The heating element 56 in this example is a resistive heating element 56 that protrudes through the solid-state top plate 40 and into the sealed chamber of the reactor. The resistive heating element 56 may be thermally insulated from the surrounding material of the top plate 40 so that the reactor is heated from inside and the heat flows outward from the sealed chamber. In other embodiments, the heating element 56 may be embedded in the top plate 40 or base plate 20 as shown in Figure 2. In still other embodiments, the heating element 56 may comprise a magnetic coil (not shown) that produces magnetic field that heats up ferromagnetic materials inductively, without actually having a heating element inside or even in contact with the reactor chamber. The magnetic coil may be used if the reaction material is ferromagnetic and the reactor housing 12 is non-magnetic, e.g., nickel and austenitic stainless steel. The magnetic coil may be placed, for example, on an outer surface of the top plate 40.

[031] When the base plate 20 is used with the solid-state top plate 40 to form a solid-state reactor, the reaction material is placed in the sealed chamber before the plates are assembled together. The solid-state reaction material may comprise nanoparticles or other solid material loaded with a hydrogen gas, deuterium, or tritium. In some embodiments, the solid-state reaction material may be plated onto the inner surface of the cavities 24, 44 in the base plate 20 and/or top plate 40 respectively.

[032] Figure 8 illustrates an exemplary top plate 40 configured for use during the operation phase of a plasma reactor. The top plate 40 for the plasma reactor comprises a cavity 44 and an electrode 58 that protrudes into the sealed chamber formed when the top plate 40 and base plate 20 are assembled together. The electrode 58 is fed through the top plate 40 and is electrically isolated from the surrounding material of the top plate 40. The top plate 40 further comprises one or more gas ports 52 to supply and/or evacuate gas from the sealed chamber as previously described.

[033] The interior wall of the cavities 24, 44 in one or both of the base plate 20 and top plate 40 may be coated with a reaction material. Alternatively, the reaction material in the form of a foil or mesh can be secured to the inner surface of the cavities 24, 44 in the base plate 20 and/or top plate 40 respectively. The foil or mesh may be electrically isolated from or in direct contact with the surrounding material depending on the preferred set-up.

[034] Figure 9 illustrates an exemplary top plate 40 configured for use in an electrolytic reactor. The top plate 40 for the electrolytic reactor comprises two electrodes 62, 64 and a liquid port for introduction of electrolyte. The electrodes 62, 64 protrude into the sealed chamber formed when the top plate 40 and base plate 20 are assembled together. In the illustrated embodiment, a first electrode 62 in the form of a rod protrudes through the top plate 40 along a central axis of the sealed chamber. A second electrode 64 in the form of a coil surrounds the first electrode 62. Both electrodes 62, 64 are electrically isolated from the material of the top plate 40. In some embodiments, the top plate 40 may further comprise a gas port (not shown) for introducing one or more reactive gases. In one embodiment, the liquid port may be configured as a gas port for gas flow. If no gas port is used, a certain portion of the top plate void wall(s) can be plated with a catalytic material in order to allow for the recombination of generated gases throughout operation. Likewise, a gas port for recirculation of fluid can be coated in the catalytic material if the configuration of the electrodes 62, 64 does not allow for coating of the void wall(s).

CLAIMS

What is claimed is:

1. A modular exothermic reactor system comprising:

a first end plate and two or more interchangeable second end plates configured to be selectively assembled with the first end plate to form a reactor housing; and

a cavity formed in the first end plate, said cavity configured to form, at least in part, a sealed chamber internally within the reactor housing when the plates are assembled to form the reactor housing.

2. The modular exothermic reactor system of claim 1 wherein the two or more interchangeable second end plates are configured for different phases of a multi-phase energy production process.

3. The modular exothermic reactor system of claim 2 wherein the two or more interchangeable second end plates comprise a preparation phase plate for a preparation phase of the energy production process and an operation plate for an operation phase of the energy production process.

4. The modular exothermic reactor system of claim 3 wherein the preparation phase plate comprises a cleaning plate including an electrically isolated electrode configured to generate a plasma in the sealed chamber to clean the first end plate, and at least one

gas port for supplying gas to and/or evacuating gas from the sealed chamber during a cleaning process.

5. The modular exothermic reactor system of claim 4 wherein the cleaning plate comprises two gas ports configured to enable a gas flow through the sealed chamber during the cleaning process.

6. The modular exothermic reactor system of claim 3 wherein the preparation phase plate comprises an activation plate including an electrically isolated electrode configured to generate a plasma in the sealed chamber to plate the cavity of the first end plate with a reaction material, and at least one gas port for supplying gas to and/or evacuating gas from the sealed chamber during an activation process.

7. The modular exothermic reactor system of claim 6 wherein the activation plate comprises two gas ports configured to enable a gas flow through the sealed chamber during the activation process.

8. The modular exothermic reactor system of claim 3 wherein the operation plate is configured to initiate an exothermic reaction in the sealed chamber.

9. The modular exothermic reactor system of claim 8 wherein the operation plate is configured for a solid-state reactor.

10. The modular exothermic reactor system of claim 9 wherein the operation plate comprises a heating element configured to heat a reactive material in the sealed chamber to initiate an exothermic reaction.

11. The modular exothermic reactor system of claim 9 wherein the operation plate comprises a magnetic coil.

12. The modular exothermic reactor system of claim 8 wherein the operation plate is configured for a plasma reactor.

13. The modular exothermic reactor system of claim 12 wherein the operation plate comprises an electrode to initiate an exothermic reaction.

14. The modular exothermic reactor system of claim 8 wherein the operation plate is configured for an electrolytic reactor.

15. The modular exothermic reactor system of claim 14 wherein the operation plate comprises at least two electrically isolated electrodes and a liquid port configured for introduction of electrolyte to the sealed chamber.

16. The modular exothermic reactor system of any one of claims 8 – 15 wherein the operation plate comprises at least one gas port for supplying gas to and/or evacuating gas from the sealed chamber during an operation phase.

17. The modular exothermic reactor system of claim 16 wherein the operation plate comprises two gas ports configured to enable a gas flow through the sealed chamber during the operation phase.

18. The modular exothermic reactor system of claim 1 wherein the reactor housing comprises two or more interchangeable second end plates configured for different energy production processes.

19. The modular exothermic reactor of claim 18 wherein one of said interchangeable second end plates comprises a solid-state reactor plate configured for use in a solid-state reactor.

20. The modular exothermic reactor of claim 19 wherein the solid-state reactor plate comprises a heating element configured to heat a reactive material in the sealed chamber to initiate an exothermic reaction.

21. The modular exothermic reactor system of claim 19 wherein the solid-state reactor second end plate comprises a magnetic coil.

22. The modular exothermic reactor system of any one of claims 18 -21 wherein one of said interchangeable second end plates comprises a plasma reactor plate configured for use in a plasma reactor.

23. The modular exothermic reactor system of claim 22 wherein the plasma reactor plate comprises an electrode to initiate an exothermic reaction.

24. The modular exothermic reactor system of any one of claims 18 -23 wherein one of said interchangeable second end plates comprises an electrolytic reactor plate configured for use in an electrolytic reactor.

25. The modular exothermic reactor system of claim 24 wherein the electrolytic reactor plate comprises at least two electrically isolated electrodes and a liquid port configured for introduction of electrolyte to the sealed chamber.

26. The modular exothermic reactor system of any one of claims 18 - 25 wherein at least one of the interchangeable second end plates comprises a gas port for supplying gas to and/or evacuating gas from the sealed chamber during an operation phase.

27. The modular exothermic reactor system of claim 26 wherein at least one of the interchangeable second end plates comprises two gas ports configured to enable a gas flow through the sealed chamber during the operation phase.

28. The modular exothermic reactor of any one of claims 1-27 wherein the plates includes one or more expansion plates disposed between the first end plate and the second end plate.

29. The modular exothermic reactor of claim 28 wherein the first end plate, second end plate, and one or more expansion plates each include a cavity that form a part of the sealed chamber when the plates are assembled together.

30. The modular exothermic reactor of any one of claims 1 – 29 further comprising one or more seals, each seal disposed between a respective pair of the plates in said reactor housing and surrounding the sealed chamber.

ABSTRACT

A modular reactor system comprises of a base plate and two or more interchangeable top plates configured to meet the requirements of different energy production processes, or different phases of an energy production processes. In some embodiments, a standard base plate and different top plates may be provided for different types of reactors, all of which are configured for use with the same standard base plate. In other embodiments, a standard base plate and two or more different top plates may be provided for different phases for a preparation phase and operation phase of an energy production process.

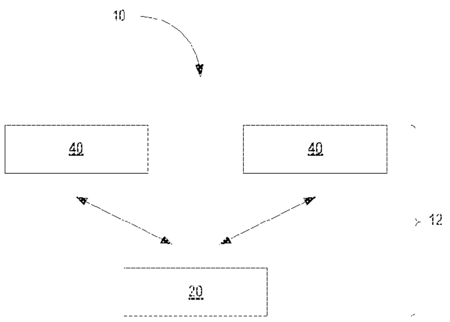

FIG. 1A

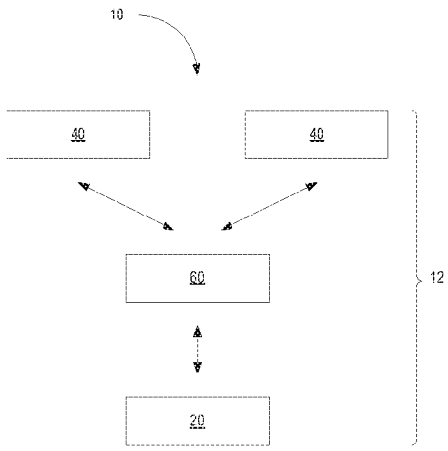

FIG. 1B

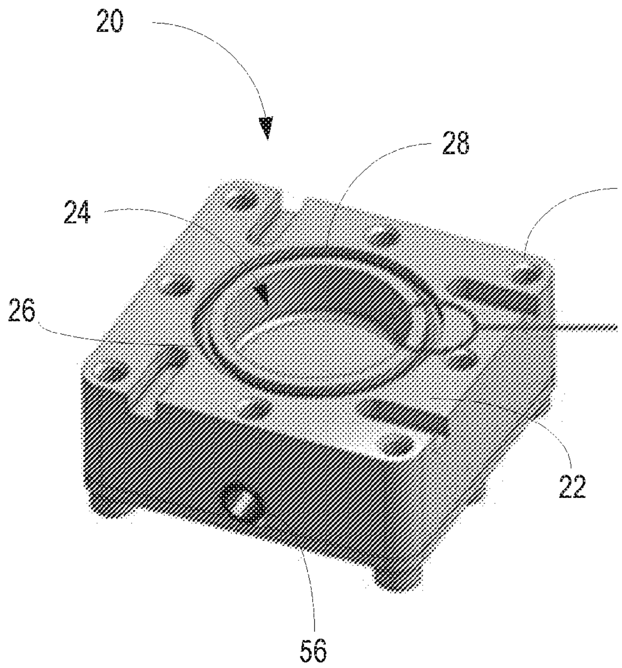

FIG. 2

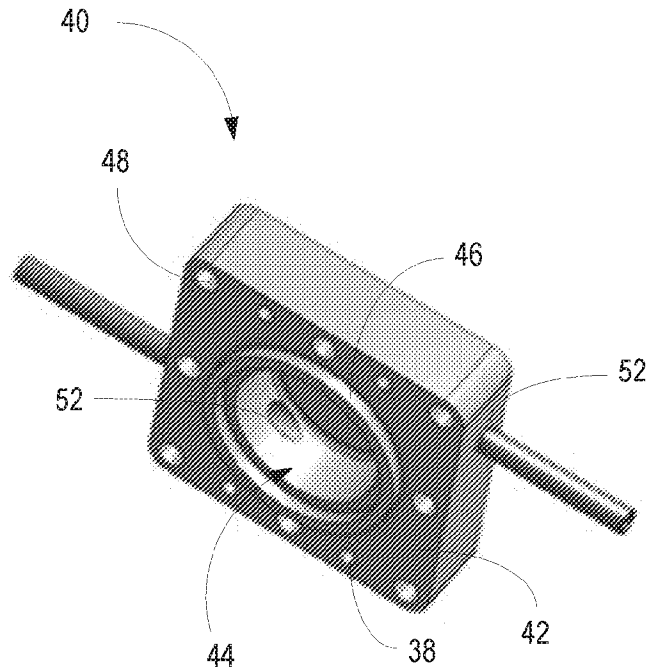

FIG. 3

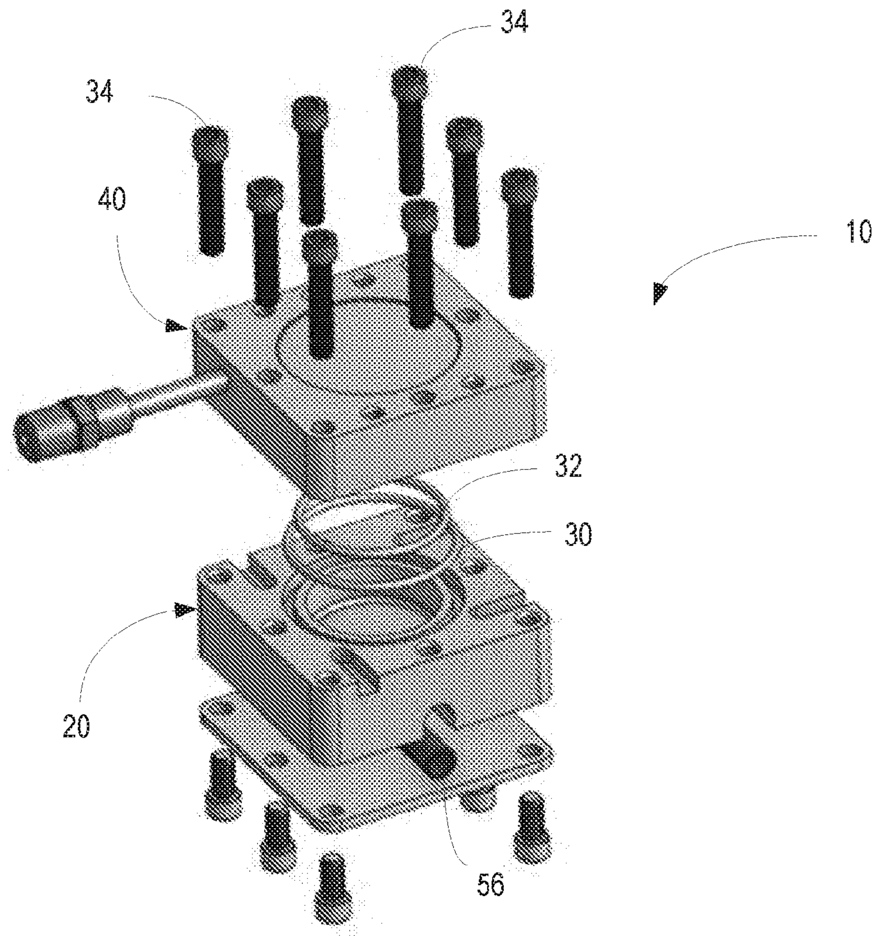

FIG. 4

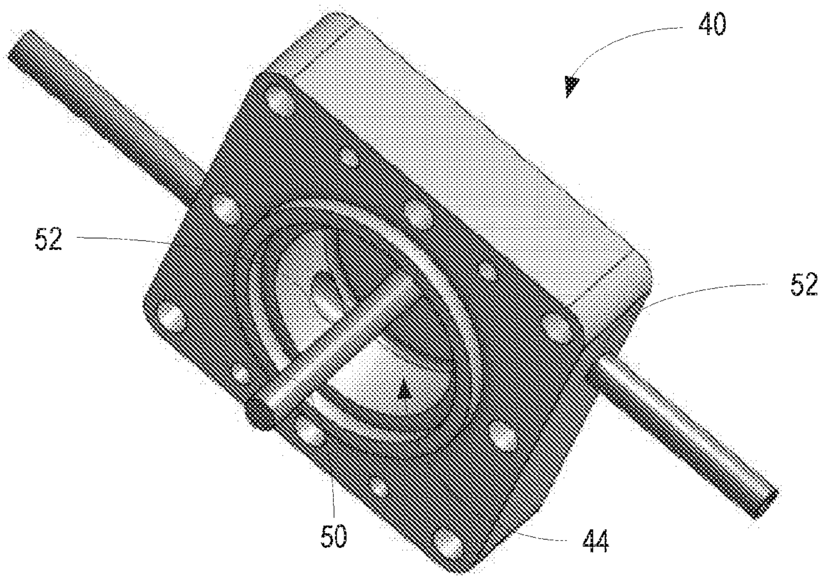

FIG. 5

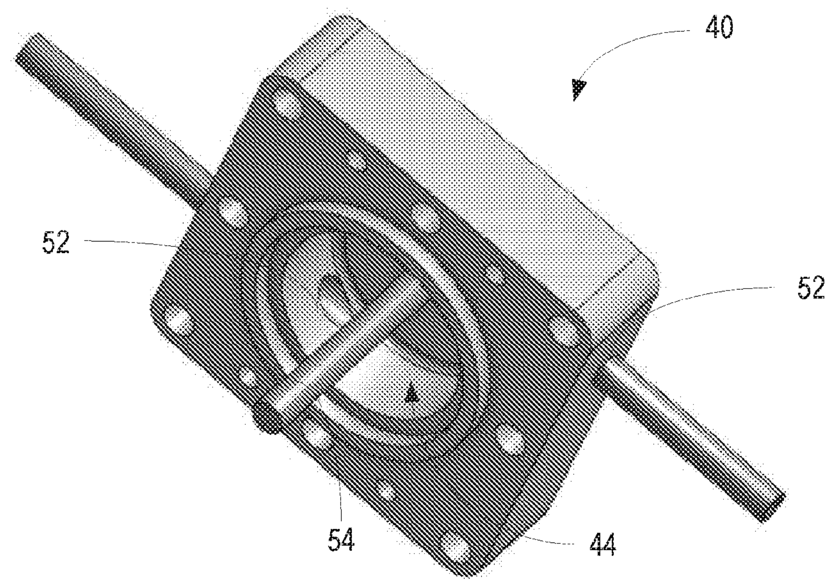

FIG. 6

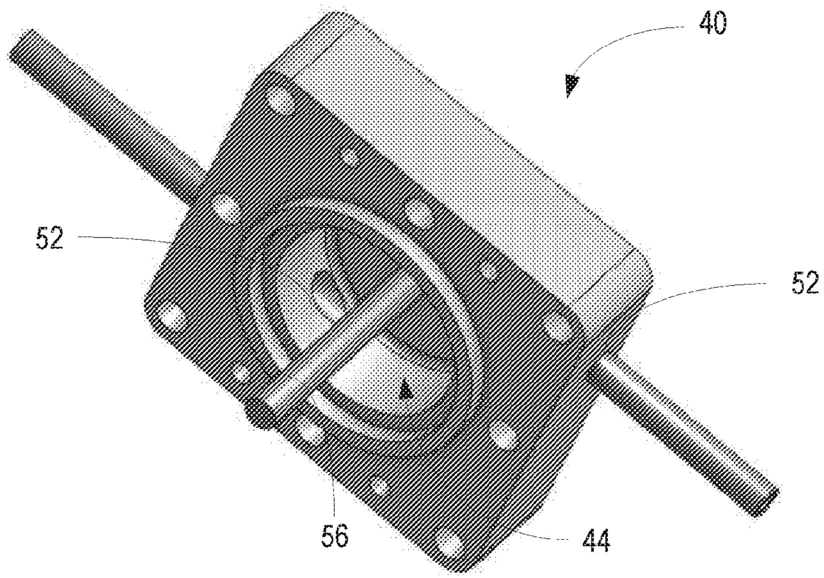

FIG. 7

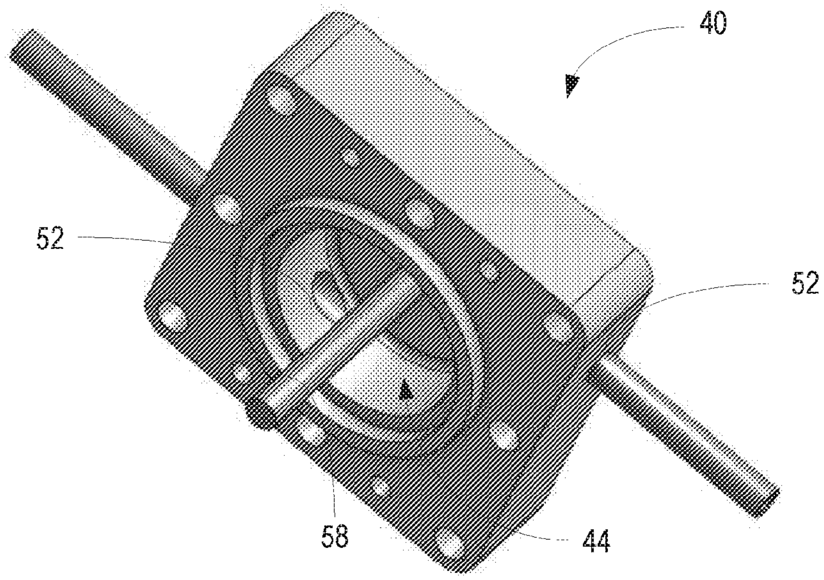

FIG. 8

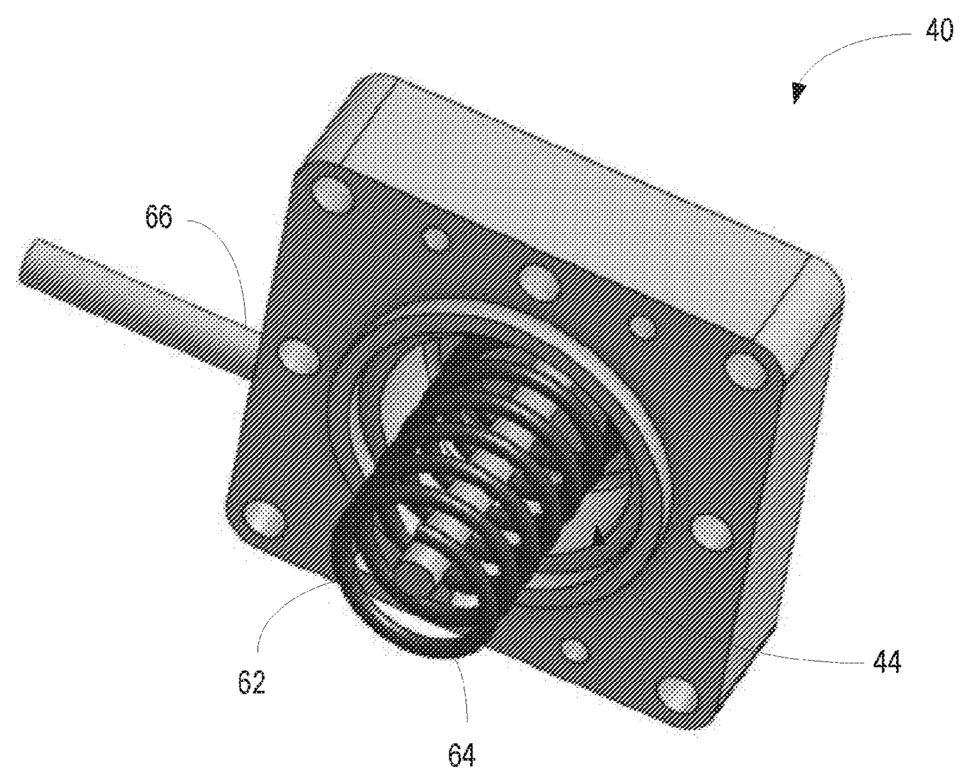

FIG. 9