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(54) **Title:** NOVEL MODULAR VALVE AND SEAL ASSEMBLY AND MANUFACTURING PROCESS

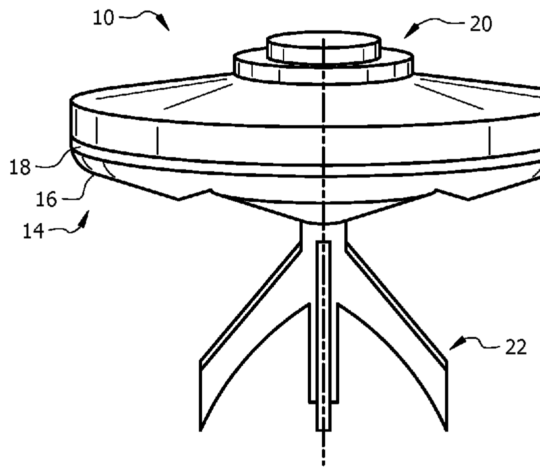

FIG. 3A

(57) **Abstract:** A valve with a modular seal is described herein. The valve includes a metal valve body defining at least one seal-receiving slot, at least one modular seal including an annular dampening member coupled to an annular metal member is configured to fit within the at least one seal-receiving slot so that the at least one modular seal forms a sealing interface with a valve seat configured to receive the valve.

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[Continued on next page]

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NOVEL MODULAR VALVE AND SEAL ASSEMBLY AND MANUFACTURING PROCESS

FIELD

The present disclosure relates to a novel valve assembly and manufacturing process, and in particular, to a modular valve and seal assembly and manufacturing process.

BACKGROUND

Hydraulic fracturing (a.k.a. “fracking”) is a process to obtain hydrocarbons such as natural gas and petroleum by injecting a fracking fluid or slurry at high pressure into a wellbore to create cracks in deep rock formations. The hydraulic fracturing process employs a variety of different types of equipment at the site of the well, including one or more positive displacement pumps, slurry blender, fracturing fluid tanks, high-pressure flow iron (pipe or conduit), wellhead, valves, charge pumps, and trailers upon which some equipment are carried.

Positive displacement pumps are commonly used in oil fields for high pressure hydrocarbon recovery applications, such as injecting the fracking fluid down the wellbore. A positive displacement pump may include one or more plungers driven by a crankshaft to create a high or low pressure in a fluid chamber. A positive displacement pump typically has two sections, a power end and a fluid end. The power end includes a crankshaft powered by an engine that drives the plungers. The fluid end of the pump includes cylinders into which the plungers operate to draw fluid into the fluid chamber and then forcibly push out at a high pressure to a discharge manifold, which is in fluid communication with a well head. The fluid end employs a number of valves that regulate fluid flow. These valves typically include a metal valve body with one or more seals fabricated from a dampener material. Because the valves are subject to high pressure fluid flow that are corrosive and abrasive, they often leak and fail prematurely and require costly servicing and replacement.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1 and 2 are cross-sectional side views of exemplary embodiments of a novel valve with modular seal assembly according to the teachings of the present disclosure;

FIG. 3 is a flowchart of an exemplary process for manufacturing a novel valve with modular seal assembly according to the teachings of the present disclosure;

FIG. 4 is a partial cross-sectional view of an exemplary fluid end of a hydraulic fracturing pump according to the teachings of the present disclosure; and

FIG. 5 is a perspective view of an exemplary hydraulic fracturing pump according to the teachings of the present disclosure.

DETAILED DESCRIPTION

The positive displacement pump commonly deployed at a frac site includes seals on its pony rods in the power end, or flow valves, suction valves, discharge valves, etc. in the fluid end. Such seals operate in harsh conditions, including high pressure (up to 15000 psi), continuous-duty (e.g., full rod load at 120 RPM), and in corrosive (e.g., up to 18% HCl) and highly abrasive liquids. The valves must remain in service for a long life without leakage and other failure and be cost-effective to replace. It is also desirable to be able to replace these seals in the field. Conventionally the valve seals are made of urethane or another elastomer that are directly molded or cast onto the metal valve body retained within a circumferential groove formed on the valve body. The seal is typically disposed at the interface between the valve body and the valve seat and forms at least part of the sealing surface for the valve. A conventional method to manufacture a conventional valve involves machining the valve body, heat treating it, and machining it again. Then a urethane seal is bonded onto the valve body, cured, and the valve body is again machined and the process completed. This fabrication process requires a prolonged curing time in the range of 3-4 weeks after casting or injection molding. This process is typically done in a manufacturing facility off-site. The valve is then shipped to the hydraulic fracturing site for installation in the pump. Hereinafter, the term “valve” is used to refer to the metal valve body and one or more elastomeric seals, which reversibly seals against the valve seat. The term “valve assembly” is used herein to refer to the combination of a valve and a valve seat.

FIG. 1 is a cross-sectional side view of an exemplary embodiment of a novel valve 10 employing one or more modular seals according to the teachings of the present disclosure. The valve 10 includes a valve body 12 constructed of a suitable metal that is configured to engage a valve seat with a cylindrical body defining an inner cylindrical bore. At the interface between the valve body 12 and the valve seat is a modular seal element 14 that is constructed of an annular dampener member 16 affixed to an annular metal member 18. The modular seal element 14 is constructed by fabricating the annular metal member 18 and annular dampener member 16, and then assembling them by affixing (e.g., bonding) them together. The assembled modular seal element 14 is then affixed (e.g., bonded) to a circumferential slot or groove in the valve body 12. The annular dampener member 16 and the annular metal member 18 are dimensioned and configured to form an integral unit. The valve 10 may include one or more modular seal elements 14. The profile and material of the modular metal-dampener seal can be designed and selected according to its desired operating parameters and conditions.

The valve 10 may additionally include other features such as a spring seat 20 upon which a biasing member such as a coiled spring (not shown) may be seated. A lower portion of the valve body 12 further includes a plurality of alignment members 22 that aids in the linear displacement of the valve 10 within the fluid bore between the open and closed configurations.

FIG. 2 is a cross-sectional side view of another exemplary embodiment of a novel valve 30 employing one or more modular seals according to the teachings of the present disclosure. The valve 30 includes a valve body 32 constructed of a suitable metal that is configured to engage a valve seat with a cylindrical body defining an inner cylindrical bore. At the interface between the valve body 32 and the valve seat is a first modular seal element 34 that is constructed of an annular dampener member 16 affixed to an annular metal member 38. The first modular seal element 34 is constructed by fabricating the annular metal member 38 and annular dampener member 36, and then assembling them by affixing (e.g., bonding) them to form an integral unit. The assembled modular seal element 34 is then affixed (e.g., bonded) to an annular groove in the valve body 32. The annular dampener member 36 and the annular metal member 38 are dimensioned and configured to form an integral unit. The valve 30 further include a second modular seal element 40 that is constructed of an annular dampener member 42 affixed to an annular metal member 44, where these two members are dimensioned and configured to form an integral unit. The assembled second modular seal element 40 can then be bonded to an annular groove in the valve body 32.

The valve 30 may additionally include other features such as a spring seat 46 upon which a biasing member such as a coiled spring (not shown) may be seated. A lower portion of the valve body 32 further includes a plurality of alignment members 48 that aids in the linear displacement of the valve 30 within the fluid bore between the open and closed configurations.

Accordingly, the novel valve described herein employs a metal interface for a dampener element to form a modular seal that can be fabricated separately from the valve body. The time required to manufacture the valve is shortened because the modular seal can be fabricated separately in parallel with the valve body and then affixed to the valve on-site. When the modular seal is worn and prone to leakage, the modular seal can be easily removed from the valve body and replaced. With prior conventional valves, when the seal fails, the entire valve has to be replaced, which is time consuming and labor intensive.

FIG. 4 is a flowchart of an exemplary process for fabricating a novel valve 10 employing one or more modular seals. The valve body is fabricated by machining, heat treating, and then machining again, as shown in blocks 50-54. The modular seal is fabricated separately by forming the annular metal member (block 56) and bonding the annular dampening member (e.g., urethane, polymer, etc.) to the annular metal member (e.g., such as by injection molding, casting, using an adhesive, or bonding agent, or snap-in-place) (block 58). After curing (if required), the modular seal can then be added to the valve body, as shown in block 60. A number of methods can be used to add the modular seal to the valve body depending on the design of the seal, such as force/interference fit, heat to enlarge the seal, chill to shrink the valve body, brazing, applying an adhesive or epoxy, and employing a mechanical lock or threading. The process is then completed by installing the valve in the pump (block 62). Because the modular seal can be made separately from and in parallel with the fabrication of the valve body, a number of different seal design configurations (different materials and profiles) can be made and selected for installation on the valve body according to specific application or operation parameters, for example. Possible materials for the annular dampening member include, for example, buna-nitrile, ethylene-propylene, perfluoroelastomer, fluorosilicone, neoprene, chloroprene, polyurethane, and silicone. Further, any of the annular dampening members may be fabricated from a metal that may be harder or softer than the valve body.

FIG. 5 is a partial cross-sectional view of a fluid end 70 of a positive displacement pump including an exemplary embodiment of a novel valve configuration according to the teachings of the present disclosure. FIG. 6 is a perspective view of an exemplary embodiment of a positive displacement pump 72. The positive displacement pump 72 has two sections, a power end 74 and a fluid end 70 connected by a stay rod assembly 76. The power end 74 includes a crankshaft powered by an engine and transmission that rotationally drive a crankshaft. A connecting rod, attached to the crankshaft at one end, converts rotational motion into linear motion and terminates at a wrist pin and a series of plungers 78. The plunger piston slides coaxially inside a fluid chamber, alternately increasing and decreasing chamber volume. The plungers 78 operate to draw fluid from a suction manifold 80 into the fluid chamber through an intake or suction valve 82 forming a sealing interface with a suction valve seat 84, and then discharge the fluid at a high pressure through a discharge valve 86 that forms a sealing interface with a discharge valve seat 88 to a discharge manifold 90. The discharged liquid is then injected at high pressure into an encased wellbore. The injected fracturing fluid is also commonly called a slurry, which is a mixture of water, proppants (silica sand or ceramic), and chemical additives. The novel valve with modular seal concept described herein can be employed for a suction valve, a discharge valve, and any valve and seal present in the frac pump, as well as other types of equipment that may be present at an exemplary hydraulic fracturing site and elsewhere in other applications. An exemplary hydraulic fracturing site employs positive displacement pumps, a slurry blender, fracturing fluid tanks, high-pressure flow iron (pipe or conduit), trailers upon which some equipment are carried, valves, wellhead, charge pump (typically a centrifugal pump), conveyers, and other equipment at the site of a hydraulic fracturing operation or other types of hydrocarbon recovery operations.

The features of the present invention which are believed to be novel are set forth below with particularity in the appended claims. However, modifications, variations, and changes to the exemplary embodiments described above will be apparent to those skilled in the art, and the novel valve with modular seal and manufacturing process described herein thus encompasses such modifications, variations, and changes and are not limited to the specific embodiments described herein.

WHAT IS CLAIMED IS:

1. A valve comprising:

a metal valve body defining at least one seal-receiving slot; and

at least one modular seal including an annular dampening member coupled to an annular metal member, where the at least one modular seal is configured to fit within the at least one seal-receiving slot so that the at least one modular seal forms a sealing interface with a valve seat configured to receive the valve.

2. The valve of claim 1, wherein the annular dampening member is bonded to the annular metal member.

3. The valve of claim 1, wherein the annular dampening member is molded to the annular metal member.

4. The valve of claim 1, wherein the at least one modular seal is coupled to the at least one seal-receiving slot of the metal valve body by one of interference fit, brazing, epoxy, adhesive, and threading.

5. The valve of claim 1, wherein the annular dampening member is constructed of a material selected from the group consisting of a urethane, polymer, and an elastomer.

6. A manufacturing process for a valve, comprising:

forming a metal valve body defining a seal-receiving slot;

combining an annular dampening member and an annular metal member into a modular seal unit; and

retaining the modular seal unit within the seal-receiving slot so that it forms a sealing interface with a valve seat configured to receive the valve.

7. The method of claim 6, wherein combining an annular dampening member and an annular metal member comprises bonding the annular dampening member to the annular metal member.

8. The method of claim 6, wherein combining an annular dampening member and an annular metal member comprises molding the annular dampening member to the annular metal member.

9. The method of claim 6, wherein retaining the modular seal unit within the seal-receiving slot comprises retaining by a method selected from the group consisting of interference fit, brazing, epoxy, adhesive, and threading.

10. The method of claim 6, further comprising fabricating the annular dampening member from a material selected from the group consisting of a urethane, polymer, and an elastomer.

11. A method comprising:

fabricating an annular metal member;

fabricating an annular dampening member;

combining the annular dampening member and the annular metal member into a modular seal unit; and

installing the modular seal unit within a seal-receiving slot of a valve body so that it forms a sealing interface with a valve seat configured to receive the valve.

12. The method of claim 11, wherein combining the annular dampening member and the annular metal member comprises bonding the annular dampening member to the annular metal member.

13. The method of claim 11, wherein combining the annular dampening member and then annular metal member comprises molding the annular dampening member to the annular metal member.

14. The method of claim 11, wherein retaining the modular seal unit within the seal-receiving slot of the valve body comprises retaining by a method selected from the group consisting of interference fit, brazing, epoxy, adhesive, and threading.

15. The method of claim 11, wherein fabricating the annular dampening member comprises fabricating the annular dampening member from a material selected from the group consisting of a urethane, polymer, and an elastomer.

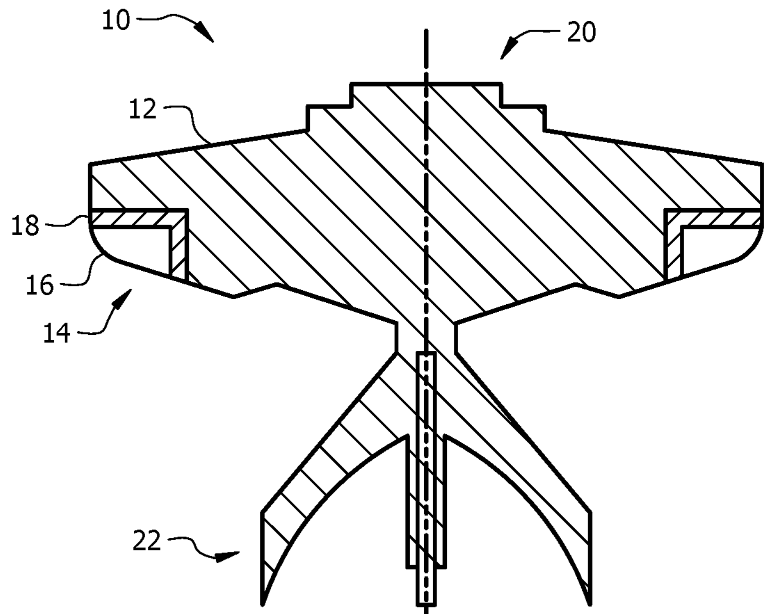

FIG. 1

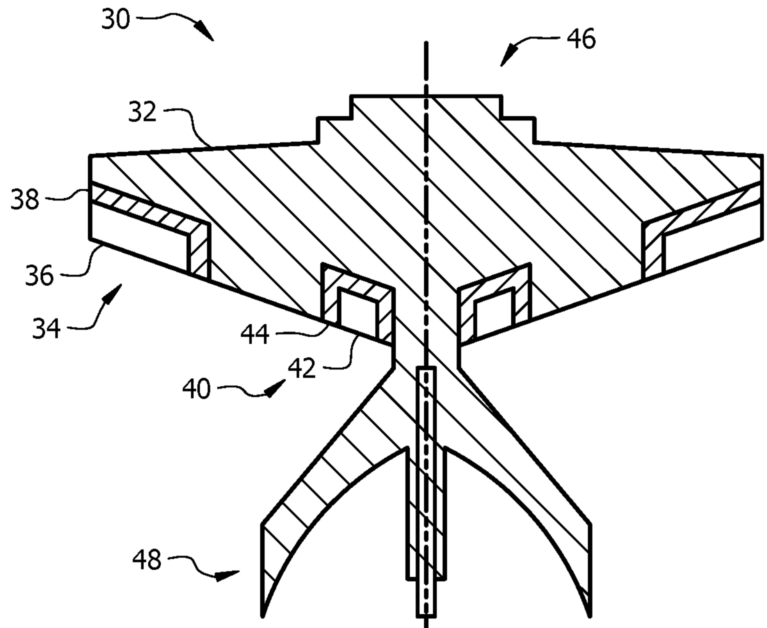

FIG. 2

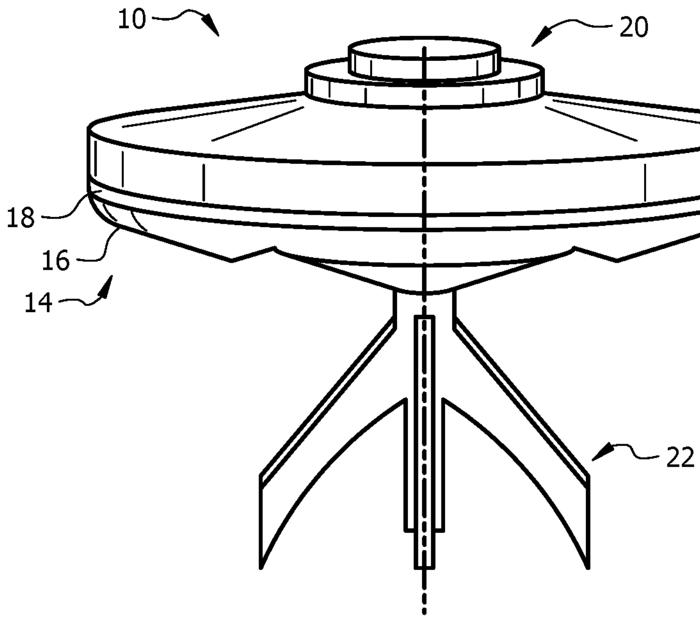

FIG. 3A

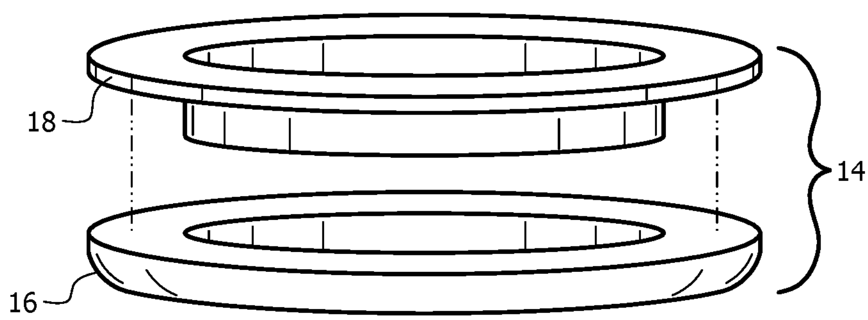

FIG. 3B

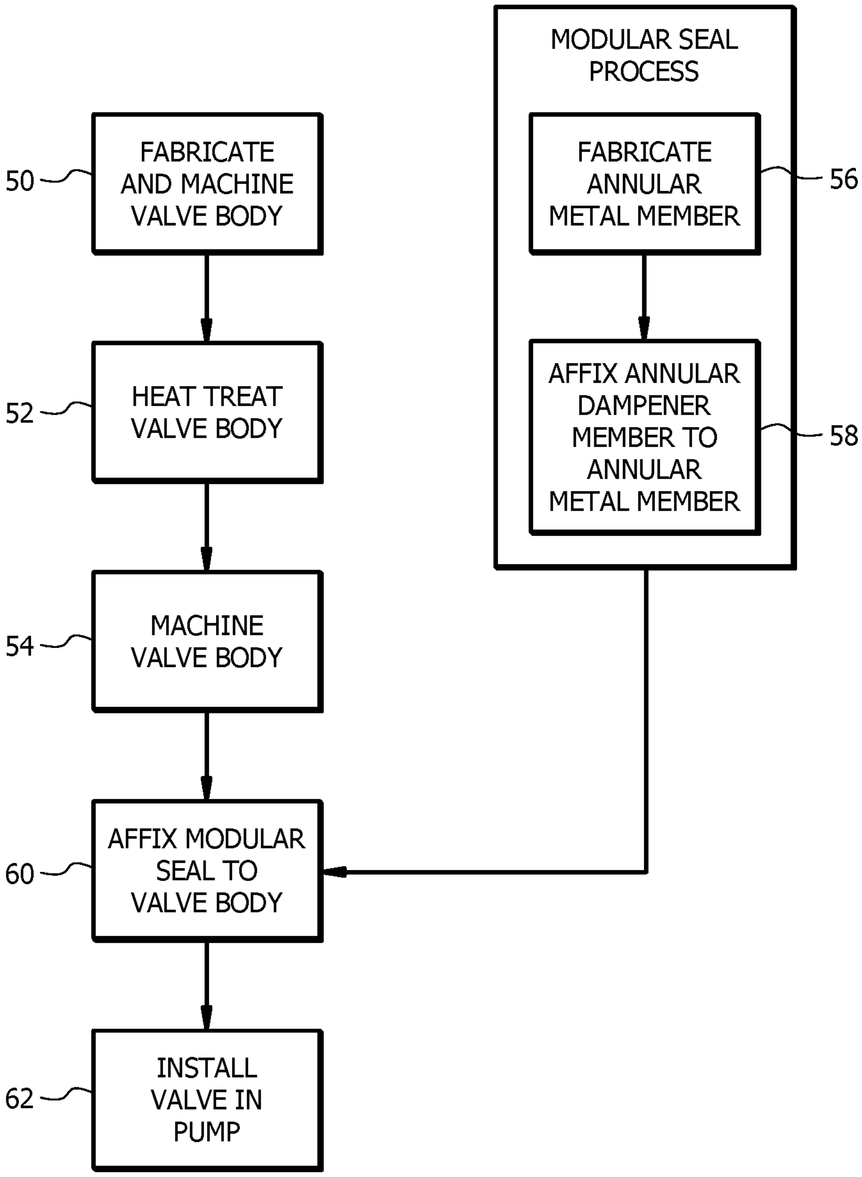
MODULAR SEAL PROCESS
FABRICATE AND MACHINE VALVE BODY
50
HEAT TREAT VALVE BODY
52
MACHINE VALVE BODY
54
AFFIX MODULAR SEAL TO VALVE BODY
60
INSTALL VALVE IN PUMP
62
FABRICATE ANNULAR METAL MEMBER
56
AFFIX ANNULAR DAMPENER MEMBER TO ANNULAR METAL MEMBER
58

FIG. 4

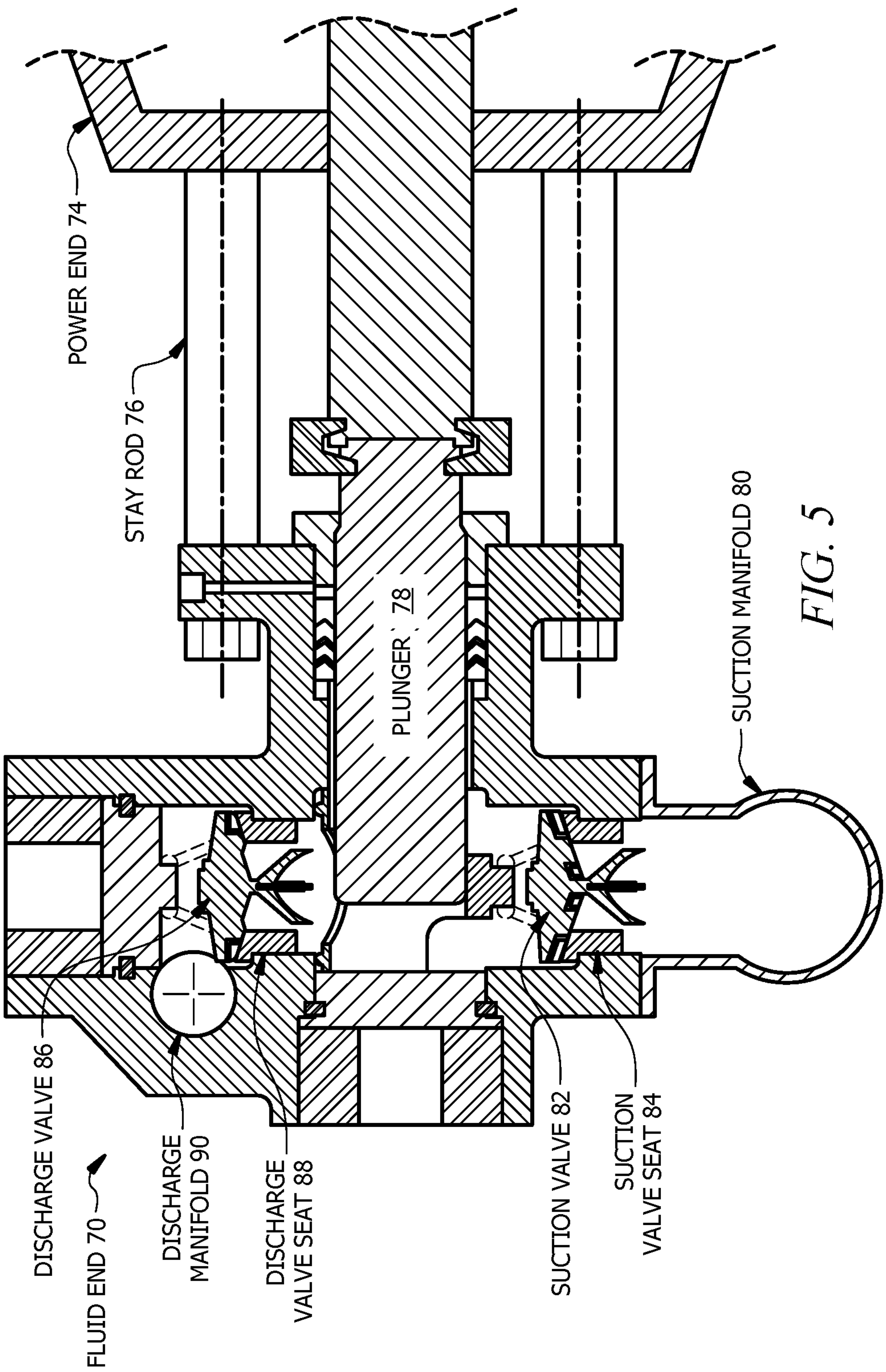
POWER END 74
STAY ROD 76
PLUNGER 78
SUCTION MANIFOLD 80
DISCHARGE VALVE 86
FLUID END 70
DISCHARGE MANIFOLD 90
DISCHARGE VALVE SEAT 88
SUCTION VALVE 82
SUCTION VALVE SEAT 84

FIG. 5

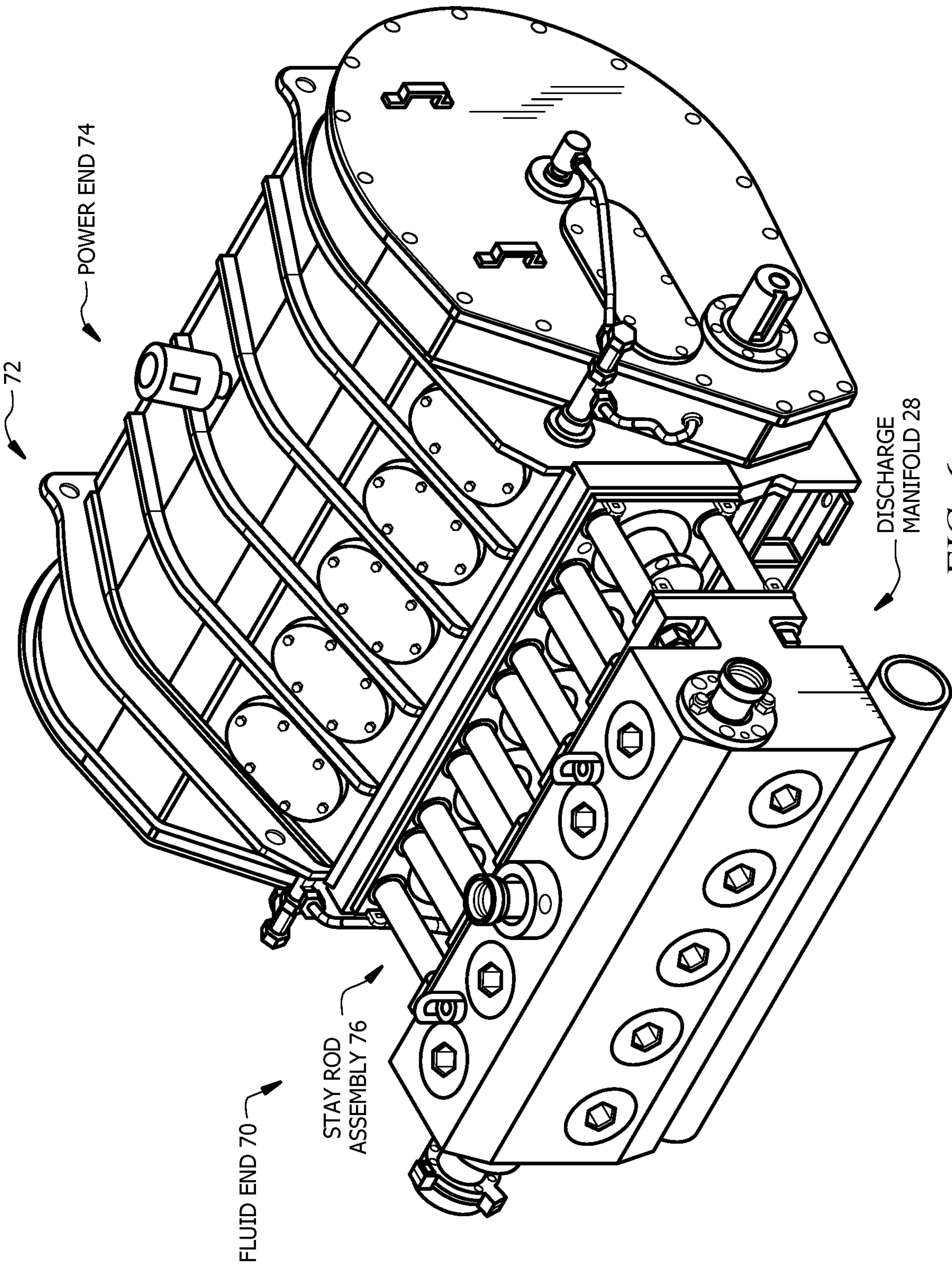
POWER END 74
72
FLUID END 70
STAY ROD ASSEMBLY 76
DISCHARGE MANIFOLD 28

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2019/020447

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - F16K 15/06; E21B 21/01; F04B 53/10; F16K 1/36; F16K 1/46 (2019.01)

CPC - F16K 15/063; E21B 21/01; F04B 53/1087; F16K 1/465 (2019.02)

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
USPC - 29/890.12; 137/516.29; 137/543.23; 137/902; 251/332; 251/333; 251/363; 251/368 (keyword delimited)

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.
X --- Y	US 5,088,521 A (JOHNSON) 18 February 1992 (18.02.1992) entire document	1, 2, 4-7, 9-12, 14, 15 --- 3, 8, 13
Y	US 4,479,508 A (BREED) 30 October 1984 (30.10.1984) entire document	3, 8, 13
A	US 2009/0278069 A1 (BLANCO et al) 12 November 2009 (12.11.2009) entire document	1-15
A	US 5,052,435 A (CRUDUP et al) 01 October 1991 (01.10.1991) entire document	1-15
A	US 3,324,880 A (ROBERTS et al) 13 June 1967 (13.06.1967) entire document	1-15

☐ 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
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"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	Date of mailing of the international search report
09 April 2019	03 May 2019

Name and mailing address of the ISA/US	Authorized officer
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, VA 22313-1450 Facsimile No. 571-273-8300	Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774