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United States Patent Application Publication 20250257722
Kind Code A1
Publication Date August 14, 2025
Inventor(s) Thomas; Micheal Cole et al.

FLUID END

Abstract

A fluid end made of a plurality of fluid end sections positioned in a side-by-side relationship. Each fluid end section is made of a housing having a discharge bore and an intake bore formed therein. A fluid routing plug is installed within each housing and is configured to route fluid throughout the housing and between the discharge and intake bores. The fluid routing plug carries seals that engage sealing surfaces formed within the housing. A number of features, including the location of seals within bore walls and carbide inserts within valve guides, aid in reducing or transferring wear within each housing.

Inventors: **Thomas; Micheal Cole (Azle, TX), Barnett; Christopher Todd (Stratford, OK), Foster; Kelcy Jake (Sulphur, OK), Son; Nicholas (Davis, OK), Keith; John (Ardmore, OK), Nowell; Mark S. (Ardmore, OK)**

Applicant: **Kerr Machine Co.** (Sulphur, OK)

Family ID: **1000008563498**

Appl. No.: **19/195010**

Filed: **April 30, 2025**

Related U.S. Application Data

parent US continuation 19077200 20250312 parent-grant-document US 12338815 child US 19195010
parent US continuation 18736090 20240606 parent-grant-document US 12276276 child US 19077200
parent US continuation 18313515 20230508 parent-grant-document US 12012955 child US 18736090
parent US continuation 17550552 20211214 parent-grant-document US 11644018 child US 18313515
parent US continuation 16951741 20201118 parent-grant-document US 11162479 child US 17515707

parent US continuation-in-part 17515707 20211101 parent-grant-document US 11359615 child US 17550552
us-provisional-application US 62936789 20191118
us-provisional-application US 62940513 20191126
us-provisional-application US 62953763 20191226
us-provisional-application US 62957489 20200106
us-provisional-application US 62959570 20200110
us-provisional-application US 62960194 20200113
us-provisional-application US 62960366 20200113
us-provisional-application US 62968634 20200131
us-provisional-application US 62990817 20200317
us-provisional-application US 63008036 20200410
us-provisional-application US 63018021 20200430
us-provisional-application US 63019789 20200504
us-provisional-application US 63027584 20200520
us-provisional-application US 63033244 20200602
us-provisional-application US 63040086 20200617
us-provisional-application US 63046826 20200701
us-provisional-application US 63053797 20200720
us-provisional-application US 63076587 20200910
us-provisional-application US 63089882 20201009
us-provisional-application US 63148065 20210210
us-provisional-application US 63150340 20210217
us-provisional-application US 63155835 20210303
us-provisional-application US 63168364 20210331
us-provisional-application US 63283487 20211128
us-provisional-application US 63125459 20201215

Publication Classification

Int. Cl.: **F04B7/02** (20060101); **F04B1/0452** (20200101); **F04B1/0538** (20200101); **F04B7/00** (20060101); **F04B15/02** (20060101); **F04B53/00** (20060101); **F04B53/10** (20060101); **F04B53/16** (20060101); **F16K15/02** (20060101)

U.S. Cl.:

CPC **F04B7/0208** (20130101); **F04B53/007** (20130101); **F04B53/1022** (20130101); **F16K15/02** (20130101); F04B1/0452 (20130101); F04B1/0538 (20130101); F04B7/0088 (20130101); F04B15/02 (20130101); F04B53/1032 (20130101); F04B53/164 (20130101); Y10T137/7915 (20150401)

Background/Summary

RELATED APPLICATIONS [0001] This application is a Continuation of U.S. Ser. No. 18/313,515, authored by Thomas et al. and filed on May 8, 2023, which has issued as U.S. Pat. No. 12,012,955. application Ser. No. 18/313,515 is a Continuation of U.S. Ser. No. 17/550,552, authored by Thomas et al. and filed on Dec. 14, 2021, which has issued as U.S. Pat. No. 11,644,018. application Ser. No. 17/550,552 is a Continuation-in-Part of U.S. Ser. No. 17/515,707, authored by Thomas et al. and filed on Nov. 1, 2021, which has issued as U.S. Pat. No. 11,359,615.

application Ser. No. 17/515,707 is a Continuation of Ser. No. 16/951,741, authored by Thomas et al. and filed Nov. 18, 2020, which has issued as U.S. Pat. No. 11,162,479. [0002] application Ser. No. 16/951,741 claims the benefit of the following provisional patent applications: Ser. No. 62/936,789, authored by Thomas et al. and filed on Nov. 18, 2019; Ser. No. 62/940,513, authored by Thomas et al. and filed on Nov. 26, 2019; Ser. No. 62/953,763, authored by Thomas et al. and filed on Dec. 26, 2019; Ser. No. 62/957,489, authored by Foster et al. and filed on Jan. 6, 2020; Ser. No. 62/959,570, authored by Thomas et al. and filed on Jan. 10, 2020; Ser. No. 62/960,194, authored by Foster et al. and filed on Jan. 13, 2020; Ser. No. 62/960,366, authored by Foster et al. and filed on Jan. 13, 2020; Ser. No. 62/968,634, authored by Foster et al. and filed on Jan. 31, 2020; Ser. No. 62/990,817, authored by Thomas et al. and filed on Mar. 17, 2020; Ser. No. 63/008,036, authored by Thomas et al. and filed on Apr. 10, 2020; Ser. No. 63/018,021, authored by Thomas et al. and filed Apr. 30, 2020; Ser. No. 63/019,789, authored by Thomas et al. and filed on May 4, 2020; Ser. No. 63/027,584, authored by Thomas et al. and filed on May 20, 2020; Ser. No. 63/033,244, authored by Thomas et al. and filed Jun. 2, 2020; Ser. No. 63/040,086, authored by Thomas et al. and filed on Jun. 17, 2020; Ser. No. 63/046,826, authored by Thomas et al. and filed on Jul. 1, 2020; Ser. No. 63/053,797, authored by Thomas et al. and filed on Jul. 20, 2020; Ser. No. 63/076,587, authored by Thomas et al. and filed on Sep. 10, 2020; and Ser. No. 63/089,882, authored by Thomas et al. and filed on Oct. 9, 2020. The entire contents of all of the above listed provisional and non-provisional patent applications are incorporated herein by reference. [0003] This application also claims the benefit of the following provisional patent applications: Ser. No. 63/125,459, authored by Thomas et al. and filed on Dec. 15, 2020; Ser. No. 63/148,065, authored by Thomas et al. and filed on Feb. 10, 2021; Ser. No. 63/150,340, authored by Thomas et al. and filed on Feb. 17, 2021; Ser. No. 63/155,835, authored by Thomas et al. and filed on Mar. 3, 2021; Ser. No. 63/168,364, authored by Thomas et al. and filed on Mar. 31, 2021; and Ser. No. 63/283,487, authored by Thomas et al. and filed on Nov. 28, 2021. The entire contents of all of the above listed provisional patent applications are incorporated herein by reference.

BACKGROUND

[0004] Various industrial applications may require the delivery of high volumes of highly pressurized fluids. For example, hydraulic fracturing (commonly referred to as “fracking”) is a well stimulation technique used in oil and gas production, in which highly pressurized fluid is injected into a cased wellbore. As shown for example in FIG. **1**, the pressured fluid flows through perforations **10** in a casing **12** and creates fractures **14** in deep rock formations **16**. Pressurized fluid is delivered to the casing **12** through a wellhead **18** supported on the ground surface **20**. Sand or other small particles (commonly referred to as “proppants”) are normally delivered with the fluid into the rock formations **16**. The proppants help hold the fractures **14** open after the fluid is withdrawn. The resulting fractures **14** facilitate the extraction of oil, gas, brine, or other fluid trapped within the rock formations **16**.

[0005] Fluid ends are devices used in conjunction with a power source to pressurize the fluid used during hydraulic fracturing operations. A single fracking operation may require the use of two or more fluid ends at one time. For example, six fluid ends **22** are shown operating at a wellsite **24** in FIG. **2**. Each of the fluid ends **22** is attached to a power end **26** in a one-to-one relationship. The power end **26** serves as an engine or motor for the fluid end **22**. Together, the fluid end **22** and power end **26** function as a hydraulic pump.

[0006] Continuing with FIG. **2**, a single fluid end **22** and its corresponding power end **26** are typically positioned on a truck bed **28** at the wellsite **24** so that they may be easily moved, as needed. The fluid and proppant mixture to be pressurized is normally held in large tanks **30** at the wellsite **24**. An intake piping system **32** delivers the fluid and proppant mixture from the tanks **30** to each fluid end **22**. A discharge piping system **33** transfers the pressurized fluid from each fluid end **22** to the wellhead **18**, where it is delivered into the casing **12** shown in FIG. **1**.

[0007] Fluid ends operate under notoriously extreme conditions, enduring the same pressures, vibrations, and abrasives that are needed to fracture the deep rock formations shown in FIG. **1**. Fluid ends may operate at pressures of 5,000-15,000 pounds per square inch (psi) or greater. Fluid used in hydraulic fracturing operations is typically pumped through the fluid end at a pressure of at least 8,000 psi, and more typically between 10,000 and 15,000 psi. However, the pressure may reach up to 22,500 psi. The power end used with the fluid end typically has a power output of at least 2,250 horsepower during hydraulic fracturing operations. A single fluid end typically produces a fluid volume of about 400 gallons, or 10 barrels, per minute during a fracking operation. A single fluid end may operate in flow ranges from 170 to 630 gallons per minute, or approximately 4 to 15 barrels per minute. When a plurality of fluid ends are used together, the fluid ends collectively deliver about 4,200 gallons per minute or 100 barrels per minute to the wellbore.
[0008] In contrast, mud pumps known in the art typically operate at a pressure of less than 8,000 psi. Mud pumps are used to deliver drilling mud to a rotating drill bit within the wellbore during drilling operations. Thus, the drilling mud does not need to have as high of fluid pressure as fracking fluid. A fluid end does not pump drilling mud. A power end used with mud pumps typically has a power output of less than 2,250 horsepower. Mud pumps generally produce a fluid volume of about 150-600 gallons per minute, depending on the size of pump used.
[0009] In further contrast, a fluid jetting pump known in the art typically operates at pressures of 30,000-90,000 psi. Jet pumps are used to deliver a highly concentrated stream of fluid to a desired area. Jet pumps typically deliver fluid through a wand. Fluid ends do not deliver fluid through a wand. Unlike fluid ends, jet pumps are not used in concert with a plurality of other jet pumps. Rather, only a single jet pump is used to pressurize fluid. A power end used with a jet pump typically has a power output of about 1,000 horsepower. Jet pumps generally produce a fluid volume of about 10 gallons per minute.
[0010] High operational pressures may cause a fluid end to expand or crack. Such a structural failure may lead to fluid leakage, which leaves the fluid end unable to produce and maintain adequate fluid pressures. Moreover, if proppants are included in the pressurized fluid, those proppants may cause erosion at weak points within the fluid end, resulting in additional failures.
[0011] It is not uncommon for conventional fluid ends to experience failure after only several hundred operating hours. Yet, a single fracking operation may require as many as fifty (50) hours of fluid end operation. Thus, a traditional fluid end may require replacement after use on as few as two fracking jobs.
[0012] During operation of a hydraulic pump, the power end is not exposed to the same corrosive and abrasive fluids that move through the fluid end. Thus, power ends typically have much longer lifespans than fluid ends. A typical power end may service five or more different fluid ends during its lifespan.
[0013] With reference to FIG. **3**, a traditional power end **34** is shown. The power end **34** comprises a housing **36** having a mounting plate **38** formed on its front end **40**. A plurality of stay rods **42** are attached to and project from the mounting plate **38**. A plurality of pony rods **44** are disposed at least partially within the power end **34** and project from openings formed in the mounting plate **38**. Each of the pony rods **44** is attached to a crank shaft installed within the housing **36**. Rotation of the crank shaft powers reciprocal motion of the pony rods **44** relative to the mounting plate **38**.
[0014] A fluid end **46** shown in FIG. **3** is attached to the power end **34**. The fluid end **46** comprises a single housing **48** having a flange **50** machined therein. The flange **50** provides a connection point for the plurality of stay rods **42**. The stay rods **42** rigidly interconnect the power end **34** and the fluid end **46**. When connected, the fluid end **46** is suspended in offset relationship to the power end **34**.
[0015] A plurality of plungers **52** are disposed within the fluid end **46** and project from openings formed in the flange **50**. The plungers **52** and pony rods **44** are arranged in a one-to-one relationship, with each plunger **52** aligned with and connected to a corresponding one of the pony

rods **44**. Reciprocation of each pony rod **44** causes its connected plunger **52** to reciprocate within the fluid end **46**. In operation, reciprocation of the plungers **52** pressurizes fluid within the fluid end **46**. The reciprocation cycle of each plunger **52** is differently phased from that of each adjacent plunger **52**.

[0016] With reference to FIG. **5**, the interior of the fluid end **46** includes a plurality of longitudinally spaced bore pairs. Each bore pair includes a vertical bore **56** and an intersecting horizontal bore **58**. The zone of intersection between the paired bores defines an internal chamber **60**. Each plunger **52** extends through a horizontal bore **58** and into its associated internal chamber **60**. The plungers **52** and horizontal bores **58** are arranged in a one-to-one relationship.

[0017] Each horizontal bore **58** is sized to receive a plurality of packing seals **64**. The seals **64** are configured to surround the installed plunger **52** and prevent high-pressure fluid from passing around the plunger **52** during operation. The packing seals **64** are maintained within the bore **58** by a retainer **65**. The retainer **65** has external threads **63** that mate with internal threads **67** formed in the walls surrounding the bore **58**. In some traditional fluid ends, the packing seals **64** are installed within a removable stuffing box sleeve that is installed within the horizontal bore.

[0018] Each vertical bore **56** interconnects opposing top and bottom surfaces **66** and **68** of the fluid end **46**. Each horizontal bore **58** interconnects opposing front and rear surfaces **70** and **72** of the fluid end **46**. A discharge plug **74** seals each opening of each vertical bore **56** on the top surface **66** of the fluid end **46**. Likewise, a suction plug **76** seals each opening of each horizontal bore **58** on the front surface **70** of the fluid end **46**.

[0019] Each of the plugs **74** and **76** features a generally cylindrical body. An annular seal **77** is installed within a recess formed in an outer surface of that body, and blocks passage of high pressure fluid. The discharge and suction plugs **74** and **76** are retained within their corresponding bores **56** and **58** by a retainer **78**, shown in FIGS. **3**, **5**, and **6**.

[0020] The retainer **78** has a cylindrical body having external threads **79** formed in its outer surface. The external threads **79** mate with internal threads **81** formed in the walls surrounding the bore **56** or **58** between the installed plug **74** or **76** and the surface **66** or **70** of the fluid end **46**.

[0021] As shown in FIG. **3**, a single manifold **80** is attached to the fluid end **46**. The manifold **80** is also connected to an intake piping system, of the type shown in FIG. **2**. Fluid to be pressurized is drawn from the intake piping system into the manifold **80**, which directs the fluid into each of the vertical bores **56**, by way of openings (not shown) in the bottom surface **68**.

[0022] When a plunger **52** is retracted, fluid is drawn into each internal chamber **60** from the manifold **80**. When a plunger **52** is extended, fluid within each internal chamber **60** is pressurized and forced towards a discharge conduit **82**. Pressurized fluid exits the fluid end **46** through one or more discharge openings **84**, shown in FIGS. **3-5**. The discharge openings **84** are in fluid communication with the discharge conduit **82**. The discharge openings **84** are attached to a discharge piping system, of the type shown in FIG. **2**.

[0023] A pair of valves **86** and **88** are installed within each vertical bore **56**, on opposite sides of the internal chamber **60**. The valve **86** prevents backflow in the direction of the manifold **80**, while the valve **88** prevents backflow in the direction of the internal chamber **60**. The valves **86** and **88** each comprise a valve body **87** that seals against a valve seat **89**.

[0024] Traditional fluid ends are normally machined from high strength alloy steel. Such material can corrode quickly, leading to fatigue cracks. Fatigue cracks occur because corrosion of the metal decreases the metal's fatigue strength—the amount of loading cycles that can be applied to a metal before it fails. Such cracking can allow leakage that prevents a fluid end from achieving and maintaining adequate pressures. Once such leakage occurs, fluid end repair or replacement becomes necessary.

[0025] Fatigue cracks in fluid ends are commonly found in areas that experience high stress. For example, with reference to the fluid end **46** shown in FIG. **5**, fatigue cracks are common at a corner **90** formed in the interior of the fluid end **46** by the intersection of the walls surrounding the horizontal bore **58** with the walls surrounding the vertical bore **56**. A plurality of the corners **90** surround each internal chamber **60**. Because fluid is pressurized within each internal chamber **60**, the corners **90** typically experience the highest amount of stress during operation, leading to fatigue cracks. Fatigue cracks are also common at the neck that connects the flange **50** and the housing **48**. Specifically, fatigue cracks tend to form at an area **92** where the neck joins the housing **48**, as shown for example in FIGS. **4** and **5**.

[0026] For the above reasons, there is a need in the industry for a fluid end configured to avoid or significantly delay the structures or conditions that cause wear or failures within a fluid end.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] FIG. **1** is an illustration of the underground environment of a hydraulic fracturing operation.

[0028] FIG. **2** illustrates above-ground equipment used in a hydraulic fracturing operation.

[0029] FIG. **3** is a left side perspective view of a traditional fluid end attached to a traditional power end.

[0030] FIG. **4** is a top plan view of the fluid end shown in FIG. **3**.

[0031] FIG. **5** is a sectional view of the fluid end shown in FIG. **4**, taken along line A-A.

[0032] FIG. **6** is a front perspective view of a fluid end. A plurality of stay rods are attached to the fluid end.

[0033] FIG. **7** is a rear perspective view of the fluid end shown in FIG. **6**, but the plurality of stay rods have been removed.

[0034] FIG. **7**A is a side elevational view of the fluid end shown in FIG. **6**, but with another embodiment of intake and discharge manifolds.

[0035] FIG. **7**B is a front perspective view of the fluid end shown in FIG. **7**A.

[0036] FIG. **8** is a front perspective view of one of the fluid end sections making up the fluid end shown in FIG. **6**.

[0037] FIG. **9** is a cross-sectional view of the fluid end section shown in FIG. **8**, taken along line D-D.

[0038] FIG. **10** is a perspective view of a first surface of a connect plate used with the fluid end shown in FIG. **6**.

[0039] FIG. **11** is a perspective view of a second surface of the connect plate shown in FIG. **10**.

[0040] FIG. **12** is an elevational view of the first surface of the connect plate shown in FIG. **10**.

[0041] FIG. **13** is an elevational view of the second surface of the connect plate shown in FIG. **10**.

[0042] FIG. **14** is a perspective view of a second surface of a housing making up the fluid end section shown in FIG. **8**.

[0043] FIG. **15** is an elevational view of the second surface of the housing shown in FIG. **14**.

[0044] FIG. **16** is a cross-sectional view of the fluid end and stay rods shown in FIG. **6**, taken along a plane that includes the line B-B.

[0045] FIG. **17** is a cross-sectional view of the fluid end and stay rods shown in FIG. **6**, taken along a plane that includes the line C-C.

[0046] FIG. **18** is a top plan view of the housing shown in FIG. **14**.

[0047] FIG. **19** is an enlarged view of area E shown in FIG. **9**.

[0048] FIG. **19**A is a front perspective view of another embodiment of a fluid end having upper and lower discharge manifolds.

[0049] FIG. **19**B is a side elevational view of the fluid end shown in FIG. **19**A.

[0050] FIG. **19**C is a front perspective view of the fluid end shown in FIG. **19**A but uses another embodiment of upper and lower discharge manifolds.

[0051] FIG. **19**D is a side elevational view of the fluid end shown in FIG. **19**C.

[0052] FIG. **19**E is a front and top perspective view of one of the fluid end sections shown in FIGS. **19**A and **19**C.
[0053] FIG. **19**F is a front and bottom perspective view of the fluid end section shown in FIG. **19**E.
[0054] FIG. **19**G is a cross-sectional view of the fluid end section shown in FIGS. **19**E and **19**F, taken along line CA-CA.
[0055] FIG. **19**H is an enlarged view of area CB shown in FIG. **19**G with the addition of arrows indicating fluid flow.
[0056] FIG. **20** is the cross-sectional view of the fluid end section shown in FIG. **17** with the upper and lower intake manifolds shown attached to the housing.
[0057] FIG. **21** is a rear perspective view of the fluid end section shown in FIG. **20**, but the plunger has been removed.
[0058] FIG. **22** is a top plan view of a stuffing box shown attached to the housing in FIG. **20**.
[0059] FIG. **23** is a perspective view of a first surface of the stuffing box shown in FIG. **22**.
[0060] FIG. **24** is an elevational view of the first surface of the stuffing box shown in FIG. **22**.
[0061] FIG. **25** is a cross-sectional view of the stuffing box shown in FIG. **24**, taken along line F-F.
[0062] FIG. **26** is a cross-sectional view of the stuffing box shown in FIG. **24**, taken along line G-G.
[0063] FIG. **27** is a perspective view of a second surface of the stuffing box shown in FIG. **22**.
[0064] FIG. **28** is an elevational view of the second surface of the stuffing box shown in FIG. **22**.
[0065] FIG. **29** is a cross-sectional view of the stuffing box shown in FIG. **28**, taken along line H-H.
[0066] FIG. **30** is a top plan view of a retainer shown attached to the stuffing box in FIG. **20**.
[0067] FIG. **31** is a perspective view of a first surface of the retainer shown in FIG. **30**.
[0068] FIG. **32** is an elevational view of the first surface of the retainer shown in FIG. **30**.
[0069] FIG. **33** is a cross-sectional view of the retainer shown in FIG. **32**, taken along line I-I.
[0070] FIG. **34** is a cross-sectional view of the retainer shown in FIG. **36**, taken along line J-J.
[0071] FIG. **35** is a perspective view of a second surface of the retainer shown in FIG. **30**.
[0072] FIG. **36** is an elevational view of the second surface of the retainer shown in FIG. **30**.
[0073] FIG. **37** is a cross-sectional view of the retainer shown in FIG. **36**, taken along line K-K.
[0074] FIG. **38** is a top plan view of a plunger packing shown installed within the stuffing box and retainer in FIG. **20**.
[0075] FIG. **39** is a perspective view of a first surface of the plunger packing shown in FIG. **38**.
[0076] FIG. **40** is an elevational view of the first surface of the plunger packing shown in FIG. **38**.
[0077] FIG. **41** is a cross-sectional view of the plunger packing shown in FIG. **40**, taken along line L-L.
[0078] FIG. **42** is a perspective exploded view of the plunger packing shown in FIG. **38**.
[0079] FIG. **43** is a top plan view of a packing nut shown installed within the retainer in FIG. **20**.
[0080] FIG. **44** is a perspective view of a first surface of the packing nut shown in FIG. **43**.
[0081] FIG. **45** is an elevational view of the first surface of the packing nut shown in FIG. **43**.
[0082] FIG. **46** is a cross-sectional view of the packing nut shown in FIG. **45**, taken along line M-M.
[0083] FIG. **47** is a perspective view of a first surface of a retainer shown installed within the housing in FIG. **20**.
[0084] FIG. **48** is an elevational view of the first surface of the retainer shown in FIG. **47**.
[0085] FIG. **49** is a cross-sectional view of the retainer shown in FIG. **48**, taken along line N-N.
[0086] FIG. **50** is the cross-sectional view shown in FIG. **9**, but the suction valve is spaced from the fluid routing plug.
[0087] FIG. **51** is the cross-sectional view shown in FIG. **50**, but the plunger has extended into the housing, the suction valve is sealed against the fluid routing plug, and the discharge valve is spaced from the fluid routing plug.

[0088] FIG. **52** is a perspective view of a second surface of a fluid routing plug shown installed within the fluid end section in FIG. **50**.
[0089] FIG. **53** is a perspective view of a first surface of the fluid routing plug shown in FIG. **52**.
[0090] FIG. **54** is an elevational view of the second surface of the fluid routing plug shown in FIG. **52**.
[0091] FIG. **55** is a cross-sectional view of the fluid routing plug shown in FIG. **54**, taken along line O—O.
[0092] FIG. **56** is an elevational view of the first surface of the fluid routing plug shown in FIG. **52**.
[0093] FIG. **57** is a top plan view of the fluid routing plug shown in FIG. **52**.
[0094] FIG. **58** is a cross-sectional view of the fluid routing plug shown in FIG. **57**, taken along line P-P.
[0095] FIG. **59** is an enlarged view of area Q shown in FIG. **57**.
[0096] FIG. **60** is the top plan view of the fluid routing plug shown in FIG. **57**, but the plug has been slightly rotated.
[0097] FIG. **61** is a cross-sectional view of the fluid routing plug shown in FIG. **60**, taken along line R-R.
[0098] FIG. **62** is a cross-sectional view of the fluid routing plug shown in FIG. **60**, taken along line S-S.
[0099] FIG. **63** is a cross-sectional view of the fluid routing plug shown in FIG. **60**, taken along line T-T.
[0100] FIG. **64** is an enlarged view of the fluid routing plug shown in FIG. **60**.
[0101] FIG. **65** is the cross-sectional view shown in FIG. **50**.
[0102] FIG. **66** is an enlarged view of area U shown in FIG. **65**.
[0103] FIG. **67** is an enlarged view of area V shown in FIG. **65**.
[0104] FIG. **68** is an enlarged view of area W shown in FIG. **65**.
[0105] FIG. **69** is an enlarged view of area X shown in FIG. **65**.
[0106] FIG. **70** is an enlarged view of area Y shown in FIG. **65**.
[0107] FIG. **71** is an enlarged view of area Z shown in FIG. **65**.
[0108] FIG. **72** is a top plan view of a suction valve shown installed within the housing in FIG. **50**.
[0109] FIG. **73** is a perspective view of a second surface of the suction valve shown in FIG. **72**.
[0110] FIG. **74** is an elevational view of the second surface of the suction valve shown in FIG. **72**.
[0111] FIG. **75** is a perspective view of a first surface of the suction valve shown in FIG. **72**.
[0112] FIG. **76** is a cross-sectional view of the suction valve shown in FIG. **74**, taken along line AA-AA.
[0113] FIG. **77** is a top plan view of a suction valve guide shown installed within the housing shown in FIG. **50**.
[0114] FIG. **78** is a perspective view of a first surface of the suction valve guide shown in FIG. **77**.
[0115] FIG. **79** is an elevation view of the first surface of the suction valve guide shown in FIG. **77**.
[0116] FIG. **80** is a cross-sectional view of the suction valve guide shown in FIG. **79**, taken along line AB-AB.
[0117] FIG. **81** is a perspective view of a second surface of the suction valve guide shown in FIG. **77**.
[0118] FIG. **82** is an elevational view of the second surface of the suction valve guide shown in FIG. **77**.
[0119] FIG. **83** is a perspective view of the suction valve guide shown in FIG. **77** engaged with the suction valve shown in FIG. **72**. A spring is shown positioned between the suction valve guide and the suction valve.
[0120] FIG. **84** is a top plan view of the suction valve guide, suction valve, and spring shown in FIG. **83**.
[0121] FIG. **84**A is a top plan view of another embodiment of a suction valve guide.

[0122] FIG. **84**B is a perspective view of the first surface of the suction valve guide shown in FIG. **84**A.
[0123] FIG. **84**C is an elevational view of the first surface of the suction valve guide shown in FIG. **84**A.
[0124] FIG. **84**D is a cross-sectional view of the suction valve guide shown in FIG. **84**C, taken along line CC-CC.
[0125] FIG. **84**E is a perspective view of the second surface of the suction valve guide shown in FIG. **84**A.
[0126] FIG. **84**F is an elevational view of the second surface of the suction valve guide shown in FIG. **84**A.
[0127] FIG. **84**G is a top plan view of another embodiment of a suction valve guide.
[0128] FIG. **84**H is a perspective view of the first surface of the suction valve guide shown in FIG. **84**G.
[0129] FIG. **84**I is an elevational view of the first surface of the suction valve guide shown in FIG. **84**G.
[0130] FIG. **84**J is a cross-sectional view of the suction valve guide shown in FIG. **84**I, taken along line CD-CD.
[0131] FIG. **84**K is a perspective view of the second surface of the suction valve guide shown in FIG. **84**G.
[0132] FIG. **84**L is an elevational view of the second surface of the suction valve guide shown in FIG. **84**G.
[0133] FIG. **84**M is a perspective view of the first surface of another embodiment of a suction valve guide.
[0134] FIG. **84**N is a cross-sectional view of the suction valve guide shown in FIG. **84**M.
[0135] FIG. **840** is a cross-sectional view of another embodiment of a suction valve guide.
[0136] FIG. **84**P is a perspective and exploded view of the first surface of the suction valve guide shown in FIG. **840**.
[0137] FIG. **84**Q is a cross-sectional view of another embodiment of a suction valve guide.
[0138] FIG. **84**R is a perspective and exploded view of the first surface of the suction valve guide shown in FIG. **84**Q.
[0139] FIG. **85** is a top plan view of a discharge valve shown installed within the housing in FIG. **50**.
[0140] FIG. **86** is a perspective view of a second surface of the discharge valve shown in FIG. **85**.
[0141] FIG. **87** is an elevational view of the second surface of the discharge valve shown in FIG. **85**.
[0142] FIG. **88** is a perspective view of a first surface of the discharge valve shown in FIG. **85**.
[0143] FIG. **89** is a cross-sectional view of the discharge valve shown in FIG. **87**, taken along line AC-AC.
[0144] FIG. **90** is a top plan view of a discharge valve guide shown installed within the housing in FIG. **50**.
[0145] FIG. **91** is a perspective view of a first surface of the discharge valve guide shown in FIG. **90**.
[0146] FIG. **92** is an elevation view of the first surface of the discharge valve guide shown in FIG. **90**.
[0147] FIG. **93** is a cross-sectional view of the discharge valve guide shown in FIG. **92**, taken along line AD-AD.
[0148] FIG. **94** is a cross-sectional view of the discharge valve guide shown in FIG. **92**, taken along line AE-AE.
[0149] FIG. **95** is a perspective view of a second surface of the discharge valve guide shown in FIG. **90**.

[0150] FIG. **96** is a perspective cut-away view of a first surface of the fluid end section shown in FIG. **8**.
[0151] FIG. **97** is an enlarged view of area AF shown in FIG. **96**.
[0152] FIG. **98** is a perspective view of the discharge valve guide shown in FIG. **90** engaged with the discharge valve shown in FIG. **85**. A spring is shown positioned between the discharge valve guide and the discharge valve.
[0153] FIG. **99** is a top plan view of the discharge valve guide, discharge valve, and
[0154] spring shown in FIG. **98**.
[0155] FIG. **99**A is a top plan view of another embodiment of a discharge valve guide.
[0156] FIG. **99**B is a perspective view of the second surface of the discharge valve guide shown in FIG. **99**A.
[0157] FIG. **99**C is an elevational view of the second surface of the discharge valve guide shown in FIG. **99**A.
[0158] FIG. **99**D is a cross-sectional view of the discharge valve guide shown in FIG. **99**C, taken along line CE-CE.
[0159] FIG. **99**E is a perspective view of the first surface of the discharge valve guide shown in FIG. **99**A.
[0160] FIG. **99**F is an elevational view of the first surface of the discharge valve guide shown in FIG. **99**A.
[0161] FIG. **100** is the cross-sectional view of the fluid end section shown in FIG. **9**.
[0162] FIG. **100**A is a perspective view of a second surface of another embodiment of a fluid routing plug.
[0163] FIG. **100**B is a perspective view of a first surface of the fluid routing plug shown in FIG. **100**A.
[0164] FIG. **100**C is an elevational view of the second surface of the fluid routing plug shown in FIG. **100**A.
[0165] FIG. **100**D is a cross-sectional view of the fluid routing plug shown in FIG. **100**C, taken along line JA-JA.
[0166] FIG. **100**E is a cross-sectional view of the fluid routing plug shown in FIG. **100**C, taken along line JB-JB.
[0167] FIG. **100**F is the cross-sectional view of the fluid end section shown in FIG. **9**, but the fluid routing plug from FIG. **100**A is shown installed within the housing.
[0168] FIG. **100**G is an enlarged view of area JC from FIG. **100**F.
[0169] FIG. **101** is a perspective view of a first surface of another embodiment of a fluid routing plug.
[0170] FIG. **102** is an elevational view of the first surface of the fluid routing plug shown in FIG. **101**.
[0171] FIG. **103** is a cross-sectional view of the fluid routing plug shown in FIG. **102**, taken along line AG-AG.
[0172] FIG. **104** is a top plan view of the fluid routing plug shown in FIG. **101**.
[0173] FIG. **105** is a perspective view of a second surface of the fluid routing plug shown in FIG. **101**.
[0174] FIG. **106** is an elevational view of the second surface of the fluid routing plug shown in FIG. **101**.
[0175] FIG. **107** is a cross-sectional view of the fluid routing plug shown in FIG. **106**, taken along line AH-AH.
[0176] FIG. **108** is the cross-sectional view of the fluid end section shown in FIG. **50**, but the fluid routing plug from FIG. **101** is shown installed within the housing.
[0177] FIG. **109** is the cross-sectional view of the fluid end section shown in FIG. **51**, but the fluid routing plug from FIG. **101** is shown installed within the housing.

[0178] FIG. **110** is a top plan view of another embodiment of a suction and discharge valve.

[0179] FIG. **111** is a perspective view of a second surface of the suction and discharge valve shown in FIG. **110**.

[0180] FIG. **112** is an elevational view of a second surface of the suction and discharge valve shown in FIG. **110**.

[0181] FIG. **113** is a perspective view of a first surface of the suction and discharge valve shown in FIG. **110**.

[0182] FIG. **114** is a cross-sectional view of the suction and discharge valve shown in FIG. **112**, taken along line AI-AI.

[0183] FIG. **115** is the cross-sectional view of the fluid end section shown in FIG. **65**, but another embodiment of a fluid routing plug is shown installed within the housing.

[0184] FIG. **116** is an enlarged view of area AJ shown in FIG. **115**.

[0185] FIG. **117** is an enlarged view of area AK shown in FIG. **115**.

[0186] FIG. **118** is the cross-sectional view of the fluid end section shown in FIG. **65**, but another embodiment of a fluid routing plug is shown installed within the housing.

[0187] FIG. **119** is an enlarged view of area AL shown in FIG. **118**.

[0188] FIG. **120** is an enlarged view of area AM shown in FIG. **118**.

[0189] FIG. **121** is a top plan view of another embodiment of a fluid routing plug.

[0190] FIG. **122** is a perspective view of a second surface of the fluid routing plug shown in FIG. **121**, with a plurality of second fluid passages formed within the plug shown by phantom lines.

[0191] FIG. **123** is an elevational view of the second surface of the fluid routing plug shown in FIG. **121**, with a plurality of second fluid passages formed within the plug shown by phantom lines.

[0192] FIG. **124** is a cross-sectional view of the fluid routing plug shown in FIG. **123**, taken along line AN-AN.

[0193] FIG. **125** is a cross-sectional view of the fluid routing plug shown in FIG. **121**, taken along line AO-AO.

[0194] FIG. **126** is the top plan view of the fluid routing plug shown in FIG. **121**, with the plurality of second fluid passages formed within the plug shown by phantom lines.

[0195] FIG. **127** is an elevational view of a first surface of the fluid routing plug shown in FIG. **121**, with a plurality of second fluid passages formed within the plug shown by phantom lines.

[0196] FIG. **128** is a perspective view of the first surface of the fluid routing plug shown in FIG. **121**.

[0197] FIG. **128**A is a perspective view of a second surface of another embodiment of a fluid routing plug.

[0198] FIG. **128**B is an elevational view of the second surface of the fluid routing plug shown in FIG. **128**A.

[0199] FIG. **128**C is a cross-sectional view of the fluid routing plug shown in FIG. **128**A, taken along line KA-KA.

[0200] FIG. **128**D is a top plan view of the fluid routing plug shown in FIG. **128**A.

[0201] FIG. **128**E is a perspective view of a first surface of the fluid routing plug shown in FIG. **128**A.

[0202] FIG. **128**F is an elevational view of the first surface of the fluid routing plug shown in FIG. **128**A.

[0203] FIG. **128**G is a cross-sectional view of the fluid routing plug shown in FIG. **128**D, taken along line KB-KB.

[0204] FIG. **129** is a top plan view of another embodiment of a fluid routing plug.

[0205] FIG. **130** is an elevational view of a second surface of the fluid routing plug shown in FIG. **129**.

[0206] FIG. **131** is a cross-sectional view of the fluid routing plug shown in FIG. **130**, taken along line AP-AP.

[0207] FIG. **131**A is a perspective view of the first surface of another embodiment of a fluid routing plug.
[0208] FIG. **131**B is a cross-sectional view of the fluid routing plug shown in FIG. **131**C, taken along line CF-CF.
[0209] FIG. **131**C is an elevational view of the first surface of the fluid routing plug shown in FIG. **131**A.
[0210] FIG. **131**D is a cross-sectional view of the fluid routing plug shown in FIG. **131**C, taken along line CG-CG.
[0211] FIG. **131**E is a top plan view of the fluid routing plug shown in FIG. **131**A.
[0212] FIG. **131**F is a perspective view of the second surface of the fluid routing plug shown in FIG. **131**A.
[0213] FIG. **131**G is an elevational view of the second surface of the fluid routing plug shown in FIG. **131**A.
[0214] FIG. **131**H is a cross-sectional view of the fluid routing plug shown in FIG. **131**E, taken along line CH-CH.
[0215] FIG. **131**I is the cross-sectional view of the fluid routing plug shown in FIG. **131**B having a pair of inserts installed therein.
[0216] FIG. **131**J is a perspective and exploded view of the first surface of the fluid routing plug shown in FIG. **131**I.
[0217] FIG. **131**K is a perspective and exploded view of the second surface of the fluid routing plug shown in FIG. **131**I.
[0218] FIG. **131**L is a perspective view of a first surface of another embodiment of a fluid routing plug.
[0219] FIG. **131**M is a cross-sectional view of the fluid routing plug shown in FIG. **131**N, taken along line CJ-CJ.
[0220] FIG. **131**N is an elevational view of the first surface of the fluid routing plug shown in FIG. **131**L.
[0221] FIG. **1310** is a top plan view of the fluid routing plug shown in FIG. **131**L.
[0222] FIG. **131**P is a cross-sectional view of the fluid routing plug shown in FIG. **1310**, taken along line CK-CK.
[0223] FIG. **131**Q is the top plan view of the fluid routing plug shown in FIG. **1310** having a pair of seals installed therein.
[0224] FIG. **131**R is the cross-sectional view of the fluid routing plug shown in FIG. **131**Q.
[0225] FIG. **131**S is a cross-sectional view of an alternative embodiment of a fluid end section having the fluid routing plug shown in FIG. **131**L installed therein.
[0226] FIG. **131**T is a cross-sectional view of another embodiment of a fluid routing plug.
[0227] FIG. **132** is a perspective view of a first surface of another embodiment of a fluid end section having another embodiment of a housing.
[0228] FIG. **133** is a cross-sectional view of the fluid end section shown in FIG. **132**, taken along a plane positioned on line AQ-AQ.
[0229] FIG. **134** is a top plan view of a retainer shown attached to the housing in FIG. **132**.
[0230] FIG. **135** a perspective view of a second surface of the retainer shown in FIG. **134**.
[0231] FIG. **136** is an elevational view of the first surface of the retainer shown in FIG. **134**.
[0232] FIG. **137** is a cross-sectional view of the retainer shown in FIG. **135**, taken along line AR-AR.
[0233] FIG. **138** is a perspective view of a first surface of the housing shown in FIG. **132**.
[0234] FIG. **139** is an enlarged view of area AS shown in FIG. **138**.
[0235] FIG. **139**A is a front perspective view of another embodiment of a fluid end section.
[0236] FIG. **139**B is a rear perspective view of the fluid end section shown in FIG. **139**A.
[0237] FIG. **139**C is a cross-sectional view of the fluid end section shown in FIG. **139**A, taken

along line CL-CL.
[0238] FIG. **139**D is a cross-sectional view of the fluid end section shown in FIG. **139**A, taken along line CM-CM. A pair of stay rods are shown attached to the fluid end section.
[0239] FIG. **140** is a sectional view of another embodiment of a fluid end section.
[0240] FIG. **141** is a sectional view of the fluid end section shown in FIG. **140**, taken along a different axis.
[0241] FIG. **142** is a top plan view of a first section of the housing shown in FIG. **140**.
[0242] FIG. **143** is a perspective view of a first surface of the first section shown in FIG. **142**.
[0243] FIG. **144** is an elevational view of the first surface of the first section shown in FIG. **142**.
[0244] FIG. **145** is a cross-sectional view of the first section shown in FIG. **144** taken along line AT-AT.
[0245] FIG. **146** is a perspective view of a second surface of the first section shown in FIG. **142**.
[0246] FIG. **147** is an elevational view of the second surface of the first section shown in FIG. **142**.
[0247] FIG. **148** is a cross-sectional view of the first section shown in FIG. **147**, taken along line AU-AU.
[0248] FIG. **149** is a perspective view of a first surface of a second section of a housing shown in FIG. **140**.
[0249] FIG. **150** is an elevational view of the first surface of the second section shown in FIG. **149**.
[0250] FIG. **151** is a cross-sectional view of the second section shown in FIG. **150**, taken along line AV-AV.
[0251] FIG. **152** is a cross-sectional view of the second section shown in FIG. **150**, taken along line AW-AW.
[0252] FIG. **153** is a sectional view of another embodiment of a fluid end section.
[0253] FIG. **154** is a perspective view of a first surface of a housing of the fluid end section shown in FIG. **153**.
[0254] FIG. **155** is a top plan view of the housing shown in FIG. **154**.
[0255] FIG. **156** is an elevational view of the first surface of the housing shown in FIG. **154**.
[0256] FIG. **157** is a side elevational view of the housing shown in FIG. **154**.
[0257] FIG. **158** is a side elevational view of the fluid end section shown in FIG. **153**.
[0258] FIG. **159** is a cross-sectional view of the fluid end section shown in FIG. **158**, taken along line AX-AX.
[0259] FIG. **160** is a sectional view of the fluid end section shown in FIG. **153**, taken along a different axis.
[0260] FIG. **161** is an enlarged view of area AY shown in FIG. **160**.
[0261] FIG. **162** is an elevational view of a first surface of another embodiment of a stuffing box of the fluid end section in FIG. **153**.
[0262] FIG. **163** is a perspective view of the first surface of the stuffing box shown in FIG. **162**.
[0263] FIG. **164** is a top plan view of the stuffing box shown in FIG. **162**.
[0264] FIG. **165** is a cross-sectional view of the stuffing box shown in FIG. **162**, taken along line AZ-AZ.
[0265] FIG. **166** is a perspective view of a second surface of another embodiment of a fluid end section.
[0266] FIG. **167** is a cross-sectional view of the fluid end section shown in FIG. **166**, taken along a plane positioned on line BA-BA.

DETAILED DESCRIPTION

[0267] Turning now to the non-prior art figures, FIGS. **6** and **7** show a fluid end **100**. The fluid end **100** may be attached to the traditional power end **34**, shown in FIG. **3**. Alternatively, the fluid end **100** may be attached to various embodiments of power ends, such as the modular power end described in U.S. Provisional Patent Application Ser. No. 63/053,797, authored by Thomas et al. and filed on Jul. 20, 2020.

[0268] Unlike the traditional fluid end **46**, shown in FIG. **3**, the fluid end **100** comprises a plurality of fluid end sections **102** rather than a single housing **48**. The fluid end sections **102** are positioned in a side-by-side relationship. Preferably, the fluid end **100** comprises five fluid end sections **102**. However, more or less fluid end sections **102** may be used. Forming the fluid end **100** out of multiple fluid end sections **102** allows a single fluid end section **102** to be replaced, if needed. In contrast, the entire housing **48** in traditional fluid ends **46** may need to be replaced if only a portion of the housing **48** fails.

[0269] Turning to FIGS. **8** and **9**, each fluid end section **102** comprises a horizontally positioned housing **104** having a generally cylindrical cross-sectional shape, as shown in FIG. **8**. In alternative embodiments, each fluid end section may have a generally rectangular cross-sectional shape. Unlike the traditional fluid end **46** shown in FIGS. **3** and **5**, each housing **104** does not include a vertical bore intersecting a horizontal bore to form an internal chamber. Rather, each housing **104** only has a single horizontally positioned bore **106**, as shown in FIG. **9**. Removing the internal chamber found in traditional fluid ends from the housing **104** removes common stress points from the housing **104**.

[0270] Eliminating the intersecting bore also reduces the cost of manufacturing the fluid end **100** as compared to traditional fluid ends. The time required to manufacture the fluid end **100** is greatly reduced without the need for machining an intersecting bore, and the fluid end **100** may be manufactured on a lathe instead of a machining center. The fluid end **100** may also be manufactured out of lower strength and less costly materials since it does not include the high stress areas found in traditional fluid ends. Each housing **104** may be manufactured out of high strength alloy steel, such as carbon steel. In alternative embodiments, each housing **104** may be manufactured out of stainless steel.

[0271] Continuing with FIGS. **8** and **9**, each housing **104** comprises a first outer surface **108** joined to an opposed second outer surface **110** by an intermediate outer surface **112**. The horizontal bore **106** extends through the housing **104** along a central longitudinal axis **114** and interconnects the opposed first and second outer surfaces **108** and **110**, as shown in FIG. **9**. Each housing **104** is of single piece construction.

[0272] Since each housing **104** only has a single horizontal bore **106**, fluid must be routed throughout the housing **104** differently from how fluid is routed throughout a traditional fluid end housing **48**. As will be described in more detail herein, a fluid routing plug **116**, shown in FIGS. **52-64**, is installed within each housing **104** and is configured to route fluid throughout the housing **104**.

[0273] With reference to FIGS. **6**, **7**, and **10-16**, each housing **104** is supported on a single connect plate **118** in a one-to-one relationship. A plurality of sets of stay rods **120**, shown in FIG. **6**, are used to attach each connect plate **118** to a power end. The connect plates **118** may each be attached to the corresponding stay rods **120** prior to attaching a housing **104** to a corresponding connect plate **118**. Because the housings **104** are each attached to a connect plate **118**, the fluid end **100** does not include a flange like the flange **50** formed in the fluid end **46** shown in FIG. **3**. In an alternative embodiment, multiple housings may be attached to a single, larger connect plate. In such embodiment, the stay rods are likewise attached to the single, larger connect plate.

[0274] The stay rods **120** shown in FIG. **6** are configured for use with a modular power end, like that shown in U.S. Provisional Patent Application Ser. No. 63/053,797, authored by Thomas et al. and filed on Jul. 20, 2020. A spacer **122** is installed on each stay rod **120** and is configured to engage with a front surface of the power end. In alternative embodiments, the stay rods may be configured like the stay rods **42** shown in FIG. **3**.

[0275] With reference to FIGS. **10-13**, each connect plate **118** has a generally rectangular shape and has opposed first and second surfaces **124** and **126**. A plurality of first passages **128** are formed around the outer periphery of each connect plate **118**. Each first passage **128** interconnects the first and second surfaces **124** and **126** of the connect plate **118** and is configured for receiving a stay rod

120. Each stay rod **120** extends through a corresponding passage **128** in a one-to-one relationship.

[0276] The connect plate **118** shown in FIGS. **10-13** has four first passages **128**. Likewise, four stay rods **120** are shown attached to each connect plate **118** in FIG. **6**. In alternative embodiments, the connect plate may have more than four or less than four first passages, as long as the amount of first passages corresponds with the number of stay rods being used with each connect plate.

[0277] Once each stay rod **120** is installed in a connect plate **118**, a first end **130** of each stay rod **120** projects from the first surface **124** of the connect plate **118**, as shown in FIG. **16**. A nut **132** and a washer **134** are installed on the projecting first end **130** of each stay rod **120** in a one-to-one relationship. The nut **132** is turned until it tightly engages a corresponding washer **134** and the first surface **124** of the connect plate **118**, thereby securing the connect plate **118** to the stay rods **120**.

[0278] With reference to FIGS. **6**, and **14-16**, a plurality of notches **136** are formed around the periphery of the housing **104** at its second surface **110**, as shown in FIGS. **14** and **15**. When the housing **104** is attached to the connect plate **118**, each notch **136** partially surrounds one of the first passages **128** in a one-to-one relationship. The notches **136** provide space to access the washer **134** and nut **132** during operation.

[0279] Continuing with FIGS. **10-13**, a central bore **138** is formed in each connect plate **118** and interconnects the first and second surfaces **124** and **126**. The central bore **138** is configured for receiving a stuffing box **140**, as described in more detail later herein. A plurality of second passages **142** are formed in the connect plate **118** and surround the central bore **138**. Each second passage **142** interconnects the first and second surfaces **124** and **126** of the connect plate **118**. The second passages **142** are configured to align in a one-to-one relationship with a plurality of first threaded openings **144** formed in the second surface **110** of each housing **104**, as shown in FIGS. **14** and **15**.

[0280] Each housing **104** is attached to the first surface **124** of a corresponding connect plate **118** using a fastening system **146**. The fastening system **146** comprises a plurality of studs **148**, a plurality of washers **150**, and a plurality of nuts **152**, as shown in FIGS. **7** and **17**. A first end **154** of each stud **148** is configured to mate with a corresponding one of the first openings **144** formed in the housing **104**. The second passages **142** formed in the connect plate **118** subsequently receive the plural studs **148** projecting from the housing **104**.

[0281] When the housing **104** and the connect plate **118** are brought together, a second end **156** of each stud **148** projects from the second surface **126** of the connect plate **118**. A washer **150** and a nut **152** are subsequently installed on the second end **156** of each stud **148**, in a one-to-one relationship. The nut **152** is turned until it tightly engages the washer **150** and the second surface **126** of the connect plate **118**, thereby securing the housing **104** and the connect plate **118** together.

[0282] In FIGS. **10-15**, the housing **104** and connect plate **118** each have eight corresponding first openings **144** and second passages **142**. In alternative embodiments, more than eight or less than eight corresponding openings and second passages may be formed in the housing and connect plate. In such embodiments, the fastening system may comprise the same number of studs, washers, and nuts as there are openings and passages.

[0283] In further alternative embodiments, the fastening system may comprise different types of fasteners, such as socket-headed screws. In even further alternative embodiments, the connect plate **118** may be integral within the housing **104**, as shown for example in FIGS. **139**A-**139**D.

[0284] Continuing with FIGS. **10-15**, a pair of third passages **158** are formed in the connect plate **118** on opposite sides of the central bore **138**. The third passages **158** are alignable with a pair of pin holes **160** formed in the second surface **110** of the housing **104**. Each third passage **158** and each corresponding pin hole **160** is configured to receive a dowel pin in a one-to-one relationship. The dowel pins are used to help align the housing **104** on the connect plate **118** during assembly. A threaded hole **162** may also be formed in a top surface **164** of each connect plate **118**, as shown in FIGS. **10** and **11**. The threaded hole **162** is configured for receiving a lifting eye (now shown) used to lift and support the connect plate **118** during assembly.

[0285] In alternative embodiments, the connect plate may have various shapes and sizes other than those shown in FIGS. **10-13**. For example, the connect plate may be shaped like the various embodiments disclosed in U.S. Provisional Patent Ser. No. 63/053,797, authored by Thomas et al. and filed on Jul. 20, 2020.

[0286] Turning back to FIGS. **6** and **7**, in contrast to the traditional fluid end **46**, shown in FIG. **3**, the fluid end **100** is configured to receive fluid from two manifolds, rather than just one. The fluid end **100** comprises an upper intake manifold **166** and a lower intake manifold **168**. Each manifold **166** and **168** is in fluid communication with each fluid end section **102**. Using two different manifolds **166** and **168** allows different types of fluid to be delivered to each fluid end section **102**. For example, fluid having a higher level of proppant may be delivered via the upper intake manifold **166**, while fluid having a zero to minimal level of proppant may be delivered via the lower intake manifold **168**.

[0287] Continuing with FIGS. **6** and **7**, the upper and lower intake manifolds **166** and **168** are joined to the fluid end sections **102** via a plurality of conduits **159**. Each conduit **159** is positioned directly below the corresponding manifold **166** and **168** and extends along a straight line between the fluid end section **102** and the corresponding manifold **166** and **168**. Thus, each conduit **159** and corresponding manifolds **166** and **168** have a "T" shape.

[0288] Turning to FIGS. **7**A and **7**B, an alternative embodiment of an upper and lower intake manifold **161** and **163** is shown. The upper and lower intake manifolds **161** and **163** are joined to the fluid end sections **102** via a plurality of conduits **165**. The conduits **165** have an elbow shape. The elbow shape of the conduits **165** causes the corresponding manifolds **161** and **163** to be spaced farther away from a discharge manifold **167**, than the manifolds **166** and **168**. Providing more space between the intake manifolds **161** and **163** and the discharge manifold **167** provides more space for maintenance to different areas of the fluid end **100**, when needed.

[0289] Turning back to FIG. **9**, an upper and lower intake bore **170** and **172** are formed within the housing **104**. Each bore **170** and **172** interconnects the intermediate outer surface **112** and the horizontal bore **106**. The upper and lower intake bores **170** and **172** shown in FIG. **9** are collinear. In alternative embodiments, the upper and lower intake bores may not be collinear.

[0290] With reference to FIGS. **6-9**, the upper intake bore **170** is in fluid communication with the upper intake manifold **166**, and the lower intake bore **172** is in fluid communication with the lower intake manifold **168**. In operation, fluid may be delivered into the housing **104** through both the upper and lower intake bores **170** and **172**. In alternative embodiments, only one intake bore may be formed in the housing and only one intake manifold may be attached to the housing.

[0291] Continuing with FIGS. **6-9**, the fluid end **100** further comprises a plurality of discharge conduits **174**. Each discharge conduit **174** is attached to one of the fluid end sections **102** in a one-to-one relationship. A discharge manifold **176** interconnects each of the discharge conduits **174**, as shown in FIGS. **6** and **7**. In alternative embodiments, the discharge conduits and discharge manifold may be formed as a single unit, like the discharge manifold **167**, shown in FIGS. **7**A and **7**B.

[0292] Continuing with FIG. **9**, a discharge bore **178** is formed in the housing **104** and interconnects the intermediate surface **112** and the horizontal bore **106**. The discharge bore **178** is positioned between the first surface **108** of the housing **104** and the intake bores **170** and **172**. The discharge bore **178** is in fluid communication with the discharge conduit **174**. In operation, fluid to be pressurized enters the housing **104** through the upper and lower intake bores **170** and **172**. Pressurized fluid exits the housing **104** through the discharge bore **178**.

[0293] With reference to FIG. **18**, the discharge bore **178** has an oval cross-sectional shape, as shown by a discharge bore opening **180**. The opening **180** has a length A and a width B. The discharge bore **178** is formed within the housing **104** such that the width B extends along an axis that is parallel to the longitudinal axis **114** of the housing **104**. During operation, high fluid pressure within the discharge bore **178** may cause the walls along the length A to compress, causing the discharge bore **178** to have a more circular cross-sectional shape. Providing room for the walls surrounding the discharge bore **178** to compress, helps reduce stress in the housing **104** and increase fluid flow. In alternative embodiments, the discharge bore may have a circular cross-sectional shape.

[0294] Continuing with FIG. **19**, a counterbore **173** is formed within the housing **104** immediately above the opening **180** of the discharge bore **178**. The discharge bore **178** opens into the counterbore **173**. The counterbore **173** has a circular cross-sectional shape, as shown by the opening **175** in FIG. **18**. A portion of the discharge conduit **174** is installed within the counterbore **173** through its opening **175**. A seal **182** is interposed between the walls of the housing **104** surrounding the discharge bore **178** and an outer surface of the discharge conduit **174**. The seal **182** is installed within a groove **184** formed in the walls of the housing **104**. The seal **182** may be identical to the second seal **376**, described with reference to FIGS. **65** and **70**. In alternative embodiments, the seal may be identical to the first seal **374**, described with reference to FIGS. **65** and **71**.

[0295] The groove **184** is characterized by two sidewalls **185** joined to a base **183**. The sidewalls **185** may join the base **183** via radius corners or at a 90 degree angle. No grooves are formed in the outer surface of the discharge conduit **174** for housing a seal. In operation, the seal **182** wears against the outer surface of the discharge conduit **174**. If the outer surface of the discharge conduit **174** begins to erode, allowing fluid to leak around the seal **182**, the discharge conduit **174** may be replaced with a new discharge conduit **174**. The discharge bore **178** shown in FIG. **9** interconnects a top surface **113** of the intermediate surface **112** of the housing **104** and the horizontal bore **106**. Likewise, the discharge conduits **174** shown in FIGS. **6**, **7**, and **9** are attached to the top surface **113** of the intermediate surface **112** of each housing **104**. In operation, any gas trapped within the housing **104** rises towards the top of the housing **104**. Placing the discharge bore **178** and conduit **174** at the top of the housing **104** allows the gases to naturally escape. Additionally, any wear caused to the components by the rising gas will primarily be imposed on the discharge conduit **174**, rather than the housing **104**. The discharge conduit **174** and corresponding discharge piping **176** are easily replaced, if needed.

[0296] In alternative embodiments, the discharge bore may interconnect a bottom or side surface of the intermediate surface and the horizontal bore, and the discharge conduit may be attached to the corresponding surface of the housing. In further alternative embodiments, the discharge bore may interconnect the first outer surface of the housing and the horizontal bore, and the discharge conduit may be attached to the first outer surface of the housing.

[0297] With reference to FIGS. **6**, **18** and **19**, a rectangular flange **171** is formed around each discharge conduit **174**. Each rectangular flange **171** is attached to the housing **104** using a plurality of threaded studs **186** and nuts **187**, as shown in FIGS. **6** and **19**. A plurality of threaded openings **188** are formed in the housing **104** for receiving the studs **186**, as shown in FIG. **18**. The openings **188** are positioned in a rectangular pattern around the discharge bore opening **180**. Such pattern helps maximize the surface area of the intermediate surface **112** of the housing **104**, helping to reduce the size and weight of the housing **104**.

[0298] With reference to FIGS. **7** and **18**, the intake manifolds **166** and **168** each comprise a plurality of rectangular flanges **189** joined to a plurality of conduits **191** in a one-to-one relationship, as shown in FIG. **7**. Each rectangular flange **189** is attached to the housing **104** using a plurality of threaded studs **190** and nuts **193**, as shown in FIG. **7**. A plurality of threaded openings **192** are formed in the housing **104** for receiving the studs **190**, as shown in FIG. **18**. The openings **192** are positioned in a rectangular pattern around the intake bores **170** and **172** to maximize surface area of the housing **104**. In alternative embodiments, the discharge conduits and intake manifolds may be attached to the housing using different types of fasteners, such as socket-headed screws.

[0299] Continuing with FIG. **18**, the intermediate surface **112** of the housing **104** includes a first portion **194** joined to a second portion **196** by a first tapered portion **198**. The second portion **196** is joined to a third portion **200** by a second tapered portion **202**. The first portion **194** is joined to the first surface **108** and the third portion **200** is joined to the second surface **110**.

[0300] The second portion **196** has a smaller diameter than both the first and third portions **194** and **200**. Providing the second portion **196** with a smaller diameter helps remove unnecessary weight from the housing **104**. The third portion **200** may have a slightly larger diameter than the first portion **194**. The first, second, and third portions **194**, **196**, and **200** are generally cylindrical. Thus, the housing **104** may be characterized as being primarily cylindrical. In alternative embodiments, the housing may be uniform in diameter throughout its intermediate surface. In further alternative embodiments, the housing may have various diameters throughout its intermediate surface other than those shown in FIG. **18**.

[0301] Continuing with FIG. **18**, a threaded hole **204** is formed in the top surface **113** of the intermediate surface **112**. The threaded hole **204** is positioned at the center of gravity of the housing **104** when the housing **104** is fully loaded with the components described herein. The threaded hole **204** is configured to receive a lifting eye (not shown) used to lift and support the housing **104** during assembly and maintenance, as shown in FIG. **9**.

[0302] With reference to FIGS. **19**A-**19**H, an alternative embodiment of a fluid end **99** is shown. The fluid end **99** is generally identical to the fluid end **100** but includes an alternative embodiment of fluid end sections **101** and utilizes upper and lower discharge manifolds **109** and **111**. The fluid end section **101** is generally identical to the fluid end section **102**, shown in FIG. **8**, but includes an alternative embodiment of a fluid end housing **103**.

[0303] Continuing with FIGS. **19**E-**19**H, the fluid end housing **103** is generally identical to the fluid end housing **104** shown in FIGS. **8** and **9** but includes a second discharge bore. The housing **103** comprises an upper discharge bore **105** and a lower discharge bore **107**. The upper and lower discharge bores **105** and **107** are vertically aligned and collinear, as shown in FIGS. **19**G and **19**H. In alternative embodiments, the discharge bores **105** and **107** may be positioned at a non-zero angle relative to one another or may be laterally offset from one another.

[0304] Continuing with FIGS. **19**G and **19**H, the upper discharge bore **105** is generally identical to the discharge bore **178**, shown in FIG. **9**; however, the discharge bore **105** may not include the counterbore **173** or the radial seal groove **184**. Instead, a seal groove **131**, also shown in FIGS. **19**E and **19**F, is formed in the outer surface of the housing **103** for receiving a seal (not shown). A corresponding seal groove is formed on a bottom surface of a manifold or discharge conduit for receiving the seal. The seal installed within the seal groove **131** acts as a face seal rather than a radial seal, like the seal **182**, shown in FIG. **9**.

[0305] The lower discharge bore **107** is identical to the upper discharge bore **105** but is formed in the opposite side of the housing **103**. In operation, fluid exits the housing **103** through both the upper and lower discharge bores **105** and **107**, as shown by arrows **97** in FIG. **19**H.

[0306] Using the two discharge bores **105** and **107** instead of a single discharge bore balances the flow of fluid around the inner components of housing **103** as fluid exits the fluid routing plug **116** and flows into the bores **105** and **107**. Specifically, fluid flow is balanced around the discharge valve **294**, the discharge valve guide **531** and its corresponding seal **520**, discussed later herein. The balanced flow of fluid applies a more even load to these components during operation. The more evenly applied load results in more even wear and an increased life span of such components.

[0307] Turning back to FIGS. **19**A and **19**B, the upper and lower discharge bores **105** and **107** are each in fluid communication with corresponding upper and lower discharge manifolds **109** and **111**. The manifolds **109** and **111** are each formed as a single unit, like the discharge manifold **167**, shown in FIGS. **7**A and **7**B.

[0308] Turning to FIGS. **19**C and **19**D, another embodiment of upper and lower manifolds **115** and **117** are shown. The manifolds **115** and **117** are identical to the discharge manifold **176**, shown in FIGS. **6**, **7**, **8**, and **9**. Like the manifold **176**, the upper and lower manifolds **115** and **117** each comprise a plurality of discharge conduits **119** attached to a corresponding one of housings **103** in a one-to-one relationship.

[0309] The discharge conduits **119** are generally identical to the discharge conduits **174**, shown in FIG. **9**. However, the discharge conduits **119** are not installed within the counterbore **173** and instead abut the outer surface of the housing **103** and aligns with the corresponding discharge bore **105** or **107**. The discharge conduits **119** are attached to the housing **103** in the same manner as the discharge conduits **174**. Fluid is prevented from leaking between the bore **105** or **107** and the conduits **119** or the manifolds **109** and **111** by the face seal installed within the seal groove **131**, shown in FIGS. **19**G and **19**H.

[0310] With reference to FIGS. **20-29**, each fluid end section **102** further comprises a stuffing box **140** attached to the second outer surface **110** of the housing **104**. The stuffing box **140** has a generally cylindrical shape and comprises a first outer surface **206** joined to an opposed second outer surface **208** by an intermediate outer surface **210**. The intermediate surface **210** includes a cylindrical first portion **212** joined directly to a cylindrical second portion **214**. The first portion **212** is positioned adjacent the first surface **206** and has a reduced diameter from that of the second portion **214**. A threaded hole **215** is formed in a top surface of the second portion **214**. The threaded hole **215** is configured to receive a lifting eye (not shown) used to lift and support the stuffing box **140** during assembly and maintenance.

[0311] A central passage **216** interconnects the stuffing box's first and second outer surfaces **206** and **208**. The walls surrounding the central passage **216** include a first section **218** joined to a second section **220** by a tapered shoulder **222**, as shown in FIGS. **25**, **26**, and **29**. The second section **220** has a larger diameter than that of the first section **218**. As described in more detail herein, the second section **220** and the tapered shoulder **222** are configured for receiving a plunger packing **224**, as shown in FIGS. **20** and **21**.

[0312] Continuing with FIGS. **23-29**, a plurality of passages **226** are formed around the periphery of the second portion **214** of the stuffing box **140**. Each passage **226** interconnects the second surface **208** of the stuffing box **140** and a base **228** of the second portion **214**. The passages **226** are formed parallel to the central passage **216**.

[0313] Turning back to FIGS. **14** and **15**, a plurality of second threaded openings **230** are formed in the second surface **110** of the housing **104**. The openings **230** surround the opening of the horizontal bore **106**. The second openings **230** are surrounded by the first openings **144** used with the connect plate **118**.

[0314] Continuing with FIGS. **20** and **21**, the walls surrounding the horizontal bore **106** adjacent the second surface **110** of the housing **104** are sized to receive the first portion **212** of the stuffing box **140**. The first portion **212** is installed within the horizontal bore **106** such that the base **228** of the second portion **214** abuts the second surface **110** of the housing **104**. A portion of the second portion **214** is disposed within the central bore **138** formed in the connect plate **118**. The stuffing box **140** is aligned on the housing **104** such that the passages **226** align with the second openings **230** in a one-to-one relationship.

[0315] With reference to FIGS. **20**, **21**, and **30-37**, the stuffing box **140** is attached to the housing **104** using a retainer **232** and a fastening system **234**. The retainer **232** has a generally cylindrical shape and comprises opposed first and second outer surfaces **236** and **238** joined by an intermediate surface **240**. A central passage **242** interconnects the first and second outer surfaces **236** and **238**. At least a portion of the central passage **242** has internal threads **244**. A plurality of side passages **246** are formed in the retainer **232**. Each passage **246** interconnects the central passage **242** and the intermediate surface **240**. The passages **246** provide a pathway for lubricating oil to be introduced to the horizontal bore **106** during operation. The oil lubricates the moving parts within the housing **104** during operation.

[0316] Continuing with FIGS. **30-37**, a plurality of passages **248** are formed in the retainer **232** and surround the central passage **242**. Each passage **248** interconnects the first and second outer surfaces **236** and **238**. The first surface **236** of the retainer **232** is positioned on the second surface

208 of the stuffing box **140** such that the passages **248** align with the passages **226** formed in the stuffing box **140**, in a one-to-one relationship.

[0317] A pair of dowel pin holes **241** are formed in the second surface **208** of the stuffing box **140**, as shown in FIGS. **27** and **28**. A corresponding pair of dowel pin holes **243** are formed in the first surface **236** of the retainer **232**, as shown in FIGS. **31** and **32**. The holes **241** and **243** are configured for receiving a dowel pin. The dowel pin aligns the retainer **232** on the stuffing box **140** during assembly.

[0318] Turning back to FIGS. **20** and **21**, the fastening system **234** secures both the retainer **232** and the stuffing box **140** to the housing **104**. The fastening system **234** comprises a plurality of studs **250**, nuts **252**, and washers **254**. A first end **256** of each stud **250** mates with one of the second openings **230** in the housing **104** in a one-to-one relationship. The passages **226** in the stuffing box **140** and the passages **248** in the retainer **232** subsequently receive the plural studs **250** projecting from the housing **104**.

[0319] A second end **258** of each stud **250** projects from the second surface **238** of the retainer **232**. The projecting second end **258** of each stud **250** receives a washer **254** and a nut **252**. The nut **252** is turned until it tightly engages the washer **254** and the second surface **238** of the retainer **232**, thereby securing the retainer **232** and the stuffing box **140** together. The retainer **232**, in turn, holds the stuffing box **140** against the housing **104**. The stuffing box **140** and the retainer **232** may be attached to and removed from the housing **104** without removing the connect plate **118**.

[0320] When the first portion **212** of the stuffing box **140** is installed within the housing **104**, a seal **260** is interposed between the walls of the housing **104** and outer surface of the first portion **212**. The seal **260** is installed within a groove **262** formed in the walls of the housing **104**. The seal **260** may be identical to the first seal **374**, described with reference to FIGS. **65** and **71**. In alternative embodiments, the seal may be identical to the second seal **376**, described with reference to FIGS. **65** and **70**.

[0321] The groove **262** is characterized by two sidewalls **264** joined by a base **266**, as shown in FIG. **21**. The sidewalls **264** may join the base **266** via radius corners or at a 90 degree angle. No grooves are formed in the first portion **212** of the stuffing box **140** for housing a seal. The seal **260** wears against the outer surface of the first portion **212** during operation. If the outer surface of the first portion **212** begins to erode, allowing fluid to leak around the seal **260**, the stuffing box **140** may be replaced with a new stuffing box **140**.

[0322] When the stuffing box **140** is attached to the housing **104** using the fastening system **234**, a first end **256** of the studs **250** may be installed within the housing **104** such that they extend past the seal **260**, as shown in FIG. **20**. An edge of the studs **250** may not be purposely aligned with an edge of the seal **260** in order to prevent areas of high stress from being aligned with one another in the housing **104**, potentially causing a stress riser.

[0323] Continuing with FIGS. **20**, **21**, and **38-42**, a plunger packing **224** is installed within the central passage **216** of the stuffing box **140**. The plunger packing **224** engages the tapered shoulder **222** and is positioned within the second section **220** of the central passage **216**, as shown in FIGS. **20** and **21**. A portion of the plunger packing **224** may extend into the central passage **242** of the retainer **232**. The plunger packing **224** has a central passage **268** that aligns with the central passages **216** and **242** when the plunger packing **224** is installed within the stuffing box **140** and the retainer **232**. In alternative embodiments, the plunger packing may be sized to not extend into the retainer. The plunger packing **224** comprises a pair of outer ring seals **270** and **271** and

[0324] at least one inner ring seal **272**. The outer ring seals **270** and **271** may be made of metal while the inner ring seals **272** may be made of an elastomer material. The outer ring **270** has a tapered outer surface **274** that is sized to engage the tapered shoulder **222** formed in the central passage **216**. The tapered engagement helps reduce stress in the stuffing box **140** during operation. In alternative embodiments, the walls surrounding the central passage of the stuffing box may include an annular shoulder rather than a tapered shoulder. In such embodiment, the plunger packing may have a flat outer ring configured to mate with the annular shoulder. A plurality of holes **275** are formed in the outer ring **271**. The holes **275** are in fluid communication with the side passages **246** formed in the retainer **232** in order to deliver lubricating oil to the housing **104**.

[0325] With reference to FIGS. **20**, **21**, and **43-46**, a packing nut **276** is installed within the retainer **232** and engages the plunger packing **224**. The packing nut **276** comprises a first surface **278** joined to an opposed second surface **280** by an intermediate surface **282**. A central passage **284** extends through the packing nut **276** and interconnects the opposed first and second surfaces **278** and **280**. A plurality of side holes **286** are formed in the packing nut **276** and interconnect the central passage **284** and the intermediate surface **282**. The holes **286** are configured for engaging a tool used to grip the packing nut **276**.

[0326] Continuing with FIGS. **43-46**, external threads **288** are formed in a portion of the intermediate surface **282** of the packing nut **276**. The external threads **288** are configured to mate with the internal threads **244** formed within the retainer **232**, as shown in FIGS. **20** and **21**. The mating threads **288** and **244** are buttress threads. The buttress threads are configured to handle a large amount of load using a low number of threads.

[0327] Using a low number of threads allows the packing nut **276** to be quickly removed or installed within the retainer **232**. In alternative embodiments, the packing nut and retainer may mate using traditional threads.

[0328] When the packing nut **276** is installed within the retainers **232**, the first surface **278** of the packing nut **276** engages an outer ring seal **270** of the plunger packing **224**. Such engagement compresses the plunger packing **224**, creating a tight seal. After the packing nut **276** has been installed within a retainer **232**, the central passage **284** within the packing nut **276** is aligned with the central passage **268** in the plunger packing **224**.

[0329] Continuing with FIGS. **20** and **21**, when the stuffing box **140** and the retainer **232** are attached to the housing **104**, the central passages **216** and **242** align with the horizontal bore **106**. Likewise, the central passages **268** and **284** in the installed plunger packing **224** and packing nut **276** align with the horizontal bore **106**. Thus, the central passages **216**, **242**, **268**, and **284** may be considered an extension of the horizontal bore **106**. A plunger **290** is disposed with the installed plunger packing **224** and the packing nut **276**, as shown in FIG. **20**. In operation, the plunger **290** reciprocates within the horizontal bore **106** in order to pressurize fluid contained with the housing **104**.

[0330] With reference to FIGS. **20**, **21**, and **47-49**, the horizontal bore **106** is sealed at the first surface **108** of the housing **104** by a retainer **300**. The retainer **300** has a first surface **302** joined to an opposed second surface **304** by an outer intermediate surface **306**. A cutout **308** is formed in the second surface **304** for receiving a portion of a discharge valve guide **298**. A central passage **310** is formed in the retainer **300** and interconnects the first surface **302** and the cutout **308**. The walls surrounding the central passage **310** have a polygonal shape. The polygonal shape is configured to mate with a tool used to grip the retainer **300**.

[0331] The intermediate surface **306** of the retainer **300** has external threads **312** that mate within internal threads **314** formed in the walls surrounding the horizontal bore **106** adjacent the first surface **108** of the housing **104**, as shown in FIGS. **20** and **21**. The mating threads **312** and **314** are buttress threads. The buttress threads are configured to handle a large amount of load using a low number of threads. Using a low number of threads allows the retainer **300** to be quickly removed from or installed within the housing **104**. In alternative embodiments, the retainer may mate with the housing using traditional threads. In further alternative embodiments, the retainer may be secured to the housing using a fastening system, as shown for example in FIG. **132**.

[0332] Turning now to FIGS. **50** and **51**, the fluid routing plug **116** is installed within a medial section of the horizontal bore **106**. The fluid routing plug **116** is configured to engage with a suction valve **292** on one side and a discharge valve **294** on the opposite side. In operation, the suction and discharge valves **292** and **294** move axially along an axis that is parallel to or aligned within the central longitudinal axis **114** of the housing **104**, shown in FIG. **9**, as the valves **292** and **294** move at alternating times between an open and closed position. In the closed position, the valves **292** and **294** are pressed against the fluid routing plug **116**, preventing fluid from exiting the plug **116**. In the open position, the valves **292** and **294** are spaced from the fluid routing plug **116**, allowing fluid to flow from the plug **116**.

[0333] The horizontal bore **106** shown in FIGS. **50** and **51** is sized to accommodate a particular fluid routing plug geometry, as shown in FIGS. **52-64**. Accordingly, the bore **106** has a smaller diameter on the suction valve **292** side of the plug **116**, that is, the portion of the bore **106** on a first side of both of the intake **170**, **172** and discharge bores **178**. The bore **106** has a larger diameter on the discharge valve **294** side of the intake bores **170**, **172**—that is, the portion of the bore located between the locations where the intake bores **170**, **172** and discharge bore **178** intersect the horizontal bore **106**. A seal groove may be formed in the bore **106**, having a still larger diameter within the horizontal bore **106** in order to accommodate a seal.

[0334] As will be described in more detail herein, axial movement of the suction valve **292** is limited by a suction valve guide **296** installed within the housing **104**. Likewise, axial movement of the discharge valve **294** is limited by the discharge valve guide **298** installed within the housing **104**.

[0335] Turning now to FIGS. **52-64**, the fluid routing plug **116** comprises a body **316** having opposed first and second outer surfaces **318** and **320** joined by an intermediate outer surface **322**. The first outer surface **318** may also be referred to as the suction side of the fluid routing plug **116**. The second outer surface **320** may also be referred to as the discharge side of the fluid routing plug **116**. A central longitudinal axis **324** extends through the body **316** and both surfaces **318** and **320**, as shown in FIG. **55**.

[0336] A plurality of first fluid passages **326** are formed within the body **316** and interconnect the intermediate surface **322** and the first surface **318**. The first fluid passages **326** interconnect the intermediate surface **322** and the first surface **318** by way of an axial-blind bore **328**, as shown in FIG. **55**. The blind bore **328** extends along the central longitudinal axis **324** of the body **316**. The first fluid passages **326** each open into the blind bore **328** via a plurality of openings **330**. A longitudinal axis **332** of each first fluid passage **326** intersects the central longitudinal axis **324** of the body **316**, as shown in FIG. **58**.

[0337] The fluid routing plug **116** shown in FIGS. **52-64** has four first fluid passages **326** formed in its body **316**. The first fluid passages **326** are equally spaced around the body **316**. In alternative embodiments, more than four or less than four first fluid passages may be formed in the body and may be equally or unequally spaced apart from one another.

[0338] Continuing with FIG. **55**, the first fluid passages **326** extend between the intermediate surface **322** and the blind bore **328** at a non-right angle relative to the central longitudinal axis **324**—the acute angle facing the second surface **320** of the body **316**. Forming the first fluid passages **326** at such angle reduces the amount of stress in the fluid routing plug **116** as fluid flows through the first fluid passages **326**. Forming the first fluid passages **326** at such an angle also helps direct fluid flow towards the blind bore **328** and the first surface **318**.

[0339] With reference to FIGS. **57** and **59**, the first fluid passages **326** have an oval cross-sectional shape, as shown by an opening **334** of each first fluid passage **326** on the intermediate surface **322**. Each opening **334** has a length A and a width B, as shown in FIG. **59**. The first fluid passages **326** are formed in the body **316** such that the length A extends along an axis that is parallel to the central longitudinal axis **324** of the body **316**. Orienting the first fluid passages **326** as such helps reduce the amount of stress in the body **316** as fluid flows through the first fluid passages **326** and helps maximize the rate of fluid flow through the passages **326**. In alternative embodiments, the first fluid passages may have a different cross-sectional shape, such as a circular or oblong shape. In further alternative embodiments, the first fluid passages may be shaped like the first fluid passages **910**, shown in FIGS. **121** and **124**.

[0340] With reference to FIGS. **60-63**, the fluid routing plug **116** further comprises a plurality of second fluid passages **336** formed in the body **316**. The second fluid passages **336** each have a circular cross-sectional shape and interconnect the first and second surfaces **318** and **320** of the body **316**. In alternative embodiments, the second fluid passages may have a different cross-sectional shape, such as an oval or oblong shape.

[0341] Unlike the first fluid passages **326**, the second fluid passages **336** do not intersect an axially blind bore. Rather, each second fluid passage **336** extends between the first and second surface **318** and **320** along a straight-line path. The second fluid passages **336** and the first fluid passages **326** do not intersect and are positioned offset from one another, as shown in FIG. **58**. Positioning the first and second passages **326** and **336** offset from one another helps minimize the stress in the fluid routing plug **116** during operation. The fluid routing plug **116** shown in FIGS. **52-64** has twelve second fluid passages **336** formed in its body **316**. In alternative embodiments, more or less than twelve second fluid passages may be formed in the body.

[0342] Each second fluid passage **336** extends between the first and second surfaces **318** and **320** along a different axis, as shown in FIGS. **60-63**. Each axis is positioned at a non-zero angle relative to the central longitudinal axis **324** of the body **316**. Forming each second passage **336** along a different axis helps alleviate stress in the fluid routing plug **116** during operation and helps maximize the rate of fluid flow through the second passages **336**.

[0343] Turning back to FIGS. **53**, **55**, and **56**, the first surface **318** of the body **316** includes an outer rim **338** joined to a tapered wall **340**. The outer rim **338** may taper slightly between the intermediate surface **322** and the tapered wall **340**, as shown in FIG. **55**. Such taper provides more surface area for the tapered wall **340** without increasing the length of the intermediate surface **322**. The tapered wall **340** extends between an entrance **342** of the blind bore **328** and the outer rim **338** at an angle of at least 30 degrees relative to the central longitudinal axis **324** of the body **316**. Preferably, the tapered wall **340** is formed at an angle of 45 degrees relative to the central longitudinal axis **324** of the body **316**, as is shown in FIG. **55**. As will be described in more detail later herein, the tapered wall **340** forms a cavity **344** within the first surface **318** of the body **316** that is sized to receive a sealing element **346** of the suction valve **292**, as shown in FIGS. **72-76**.

[0344] Continuing with FIGS. **53** and **56**, the second fluid passages **336** open on the outer rim **338** of the first surface **318**, as shown by the openings **348**. The second fluid passages **336** are formed within the body **316** such that the openings **348** are positioned in groups **350** around the outer rim **338**. The first surface **318** shown in FIG. **59** comprises four groups **350** of openings **348**, each group **350** comprising three openings **348**. Adjacent openings **348** within each group **350** are equally spaced. The spacing between the nearest openings **348** of adjacent groups **350** exceeds the spacing between adjacent openings **348** within a single group **350**. Spacing the openings **348** in groups **350** helps achieve the ideal velocity of fluid flow through the fluid routing plug **116** and allows the second fluid passages **336** to be offset from the first fluid passages **326**, as shown in FIG. **58**. In alternative embodiments, the openings may be spaced in differently sized groups or different patterns than that shown in FIG. **56**.

[0345] With reference to FIGS. **52**, **54**, and **55**, the second surface **320** of the body **316** comprises an outer rim **352** joined to a central base **354** by a tapered wall **356**. The tapered wall **356** extends between the central base **354** and the outer rim **352** at an angle of at least 30 degrees relative to the central longitudinal axis **324** of the body **316**. Preferably, the tapered wall **356** is formed at an angle of 45 degrees relative to the central longitudinal axis **324** of the body **316**, as is shown in FIG. **55**. As will be described in more detail later herein, the tapered wall **356** forms a cavity **358** within the second surface **320** of the body **316** that is sized to receive a sealing element **360** of the discharge valve **294**, as shown in FIGS. **85-89**.

[0346] Continuing with FIGS. **52**, **54**, and **55**, a blind bore **362** is formed in the center of the central base **354**. The walls surrounding the blind bore **362** may be configured to mate with a tool used to grip the fluid routing plug **116**. For example, the walls surrounding the blind bore **362** may be threaded. The second fluid passages **336** open on the central base **354** of the second surface **320**, as shown by the openings **364** in FIGS. **52** and **54**. The second fluid passages **336** are formed within the body **316** such that the openings **364** surround the opening of the blind bore **362**. The openings **364** shown in FIG. **54** are all equally spaced from one another around the opening of the blind bore **362**. In alternative embodiments, the openings of the second fluid passages on the central base may not all be equally spaced apart from one another.

[0347] Continuing with FIG. **55**, in order to provide space for the openings **364** on the second surface **320**, the tapered wall **356** has a greater diameter than the tapered wall **340** formed in the first surface **318**. Thus, as will be described in more detail herein, the sealing element **360** of the discharge valve **294** is larger in size than the sealing element **346** of the suction valve **292**, as shown in FIGS. **72-76** and **85-89**.

[0348] Turning back to FIGS. **50** and **51**, the fluid routing plug **116** is installed within the horizontal bore **106** such that the first fluid passages **326** are in fluid communication with the upper and lower intake bores **170** and **172**. The upper and lower intake bores **170** and **172** direct fluid into the first fluid passages **326** of the fluid routing plug **116**. The first fluid passages **326** direct the fluid into the blind bore **328** and towards the first surface **318** of the fluid routing plug **116**.

[0349] When the plunger **290** is retracted from the housing **104**, the fluid flowing through the first fluid passages **326** forces the suction valve **292** to move axially away from the first surface **318**. Such position is considered an open position of the suction valve **292**.

[0350] When the suction valve **292** is spaced from the first surface **318**, fluid flows out of the blind bore **328**, through the gap between the first surface **318** and the suction valve **292**. From there, the fluid flows around the suction valve **292** and the suction valve guide **296** and into the horizontal bore **106**. A first fluid flow path for the fluid to be pressurized is shown by the arrows **366** in FIG. **50**.

[0351] With reference to FIG. **51**, as the plunger **290** extends into the horizontal bore **106**, the plunger **290** forces fluid in the horizontal bore **106** back towards the fluid routing plug **116**. Pressurized fluid forced back towards the fluid routing plug **116** by the plunger **290** forces the suction valve **292** to seal against the first surface **318**, sealing the entrance **342** of the blind bore **328**. Such position is considered a closed position of the suction valve **292**. Once the entrance **342** of the blind bore **328** is sealed, the only place for fluid to flow is through the openings **348** of the second fluid passages **336** on the outer rim **338** of the first surface **318**.

[0352] Fluid flows into the openings **348** on the first surface **318** and through the second passages **336** towards the second surface **320** of the fluid routing plug **116**. The pressurized fluid at the second surface **320** forces the discharge valve **294** to move axially away from the second surface **320**, unsealing the openings **364** of the second fluid passages **336**. Such position is considered an open position of the discharge valve **294**. Pressurized fluid is then allowed to flow around the discharge valve **294** and into the discharge bore **178**. A second fluid flow path for the pressurized fluid is shown by the arrows **368** in FIG. **51**.

[0353] When the plunger **290** retracts from the housing **104**, the fluid pressure on the back side of the discharge valve **294** is greater than the fluid pressure within the fluid routing plug **116**. Such pressure differential causes the discharge valve **294** to seal against the second surface **320**, sealing the openings **364** of the second fluid passages **336**. Such position is considered the closed position of the discharge valve **294**.

[0354] Turning to FIG. **64**, the intermediate surface **322** of the fluid routing plug **116** varies in diameter throughout its length and generally decreases in size from its second surface **320** to its first surface **318**. The intermediate surface **322** comprises a first sealing surface **370** positioned adjacent the first surface **318** and a second sealing surface **372** positioned adjacent the second surface **320**. The first and second sealing surfaces **370** and **372** each extend around the entire intermediate surface **322** in an endless manner and surround the longitudinal axis **324** of the body **316**. The first and second sealing surfaces **370** and **372** shown in FIG. **64** are annular. In alternative

embodiments, the first and second sealing surfaces may have non-annular shape, such as an oval shape.
[0355] The first sealing surface **370** has a smaller diameter than the second sealing surface **372**. As will be described in more detail herein, the first and second sealing surfaces **370** and **372** are configured to engage a first and second seal **374** and **376** installed within the housing **104**, as shown in FIGS. **70** and **71**.
[0356] Continuing with FIG. **64**, the intermediate surface **322** of the fluid routing plug **116** further comprises a first bevel **378** positioned between the opening **334** of the first fluid passages **326** and the first sealing surface **370**. The first bevel **378** extends around the entire intermediate surface **322** in an endless manner and surrounds the longitudinal axis **324** of the body **316**. The first bevel **378** shown in FIG. **64** is annular. In alternative embodiments, the second bevel may have a non-annular shape, such as an oval shape.
[0357] A maximum diameter of the first bevel **378** is greater than the diameter of the first sealing surface **370**. The maximum diameter of the first bevel **378** is positioned adjacent the openings **334** of the first fluid passages **326** and a minimum diameter of the first bevel **378** is positioned adjacent the first sealing surface **370**. As will be described in more detail later herein, the first bevel **378** corresponds with a first beveled surface **380** formed in the housing **104**, as shown in FIGS. **65** and **69**.
[0358] The intermediate surface **322** also comprises a second bevel **382** positioned between the second sealing surface **372** and the openings **334** of the first fluid passages **326**. The second bevel **382** extends around the entire intermediate surface **322** in an endless manner and surrounds the longitudinal axis **324** of the body **316**. The second bevel **382** shown in FIG. **64** is annular. In alternative embodiments, the second bevel may have non-annular shape, such as an oval shape.
[0359] A maximum diameter of the second bevel **382** is positioned adjacent the second sealing surface **372** and a minimum diameter of the second bevel **382** is positioned adjacent the openings **334** of the first fluid passages **326**. The second sealing surface **372** and the maximum diameter of the second bevel **382** both have a greater diameter than the maximum diameter of the first bevel **378** and the diameter of the first sealing surface **370**.
[0360] As will be described in more detail later herein, the second bevel **382** corresponds with a second beveled surface **384** formed in the housing **104**, as shown in FIGS. **65** and **68**. A small transition bevel **386** may extend between the second sealing surface **372** and the second bevel **382**. However, the transition bevel **386** does not engage the second beveled surface **384**, as shown in FIG. **68**. The transition bevel **386** helps reduce friction between the fluid routing plug **116** and the housing **104** during installation.
[0361] As described above, the first and second bevels **378** and **382** are positioned between the first and second sealing surfaces **370** and **372**. The first and second bevels **378** and **382** help alleviate stress in the fluid routing plug **116** during operation. In alternative embodiments, the intermediate surface may only include a single bevel positioned between the first and second sealing surfaces.
[0362] Continuing with FIG. **64**, the various diameters of the intermediate surface **322** are shown in more detail. The first sealing surface **370** has a diameter D**1**. The maximum diameter of the first bevel **378** has a diameter D**2**. The maximum diameter of the second bevel **382** has a diameter D**3**, and the second sealing surface **372** has a diameter D**4**. As described above in detail, D**4** is greater than D**3**, D**3** is greater than D**2**, and D**2** is greater than D**1**.
[0363] With reference to FIG. **65**, in addition to being shaped to alleviate stress, the intermediate surface **322** is shaped to allow for easy installation of the fluid routing plug **116** within the horizontal bore **106**. The fluid routing plug **116** is installed into the horizontal bore **106** at the first outer surface **108** of the housing **104**. The fluid routing plug **116** is installed with the first surface **318** entering the horizontal bore **106** before the second surface **320**. The fluid routing plug **116** is pushed into the horizontal bore **106** until the first sealing surface **370** engages the first seal **374** and the second sealing surface **372** engages the second seal **376**.

[0364] The first sealing surface **370** and first bevel **378** have smaller diameters than the second seal **376** and the second beveled surface **384**. Thus, clearance exists between these features as the fluid routing plug **116** is installed into the horizontal bore **106**. Providing such clearance during installation avoids unnecessary wear to both the housing **104** and fluid routing plug **116** during installation.

[0365] With reference to FIGS. **65** and **67**, once the fluid routing plug **116** is installed within the housing **104**, an annular chamber **388** is formed between the walls of the housing **104** and the intermediate surface **322**. The intake bores **170** and **172** open into the chamber **388**. Only a couple of the openings **334** of the first fluid passages **326** may align with the intake bores **170** and **172**. Alternatively, the fluid routing plug **116** may be installed within the housing **104** such that none of the openings **334** directly align with the intake bores **170** and **172**. The chamber **388** provides a pathway for fluid from the intake bores **170** and **172** to flow around the fluid routing plug **116** and into the openings **334** of the first fluid passages **326**. The chamber **388** also provides space for proppant or other debris to collect during operation.

[0366] Continuing with FIG. **67**, the walls of the housing **104** surrounding the horizontal bore **106** immediately adjacent the intake bores **170** and **172** are beveled, as shown by bevels **390** and **392**. The bevels **390** and **392** help reduce stress in the housing **104** during operation and increase the size of the annular chamber **388**. In alternative embodiments, the bevels **390** and **392** may be larger than those shown in FIG. **67** in order to increase the size of the chamber **388**, as shown for example in FIG. **100**F. Similarly, the walls of the housing **104** surrounding the horizontal bore **106** immediately adjacent the discharge bore **178** are also beveled, as shown by the bevel **394** in FIG. **66**. The bevel **394** reduces stress in the housing **104** during operation and helps direct fluid into the discharge bore **178**.

[0367] Continuing with FIGS. **65** and **68**, the second bevel **382** and the second beveled surface **384** are shown in more detail. The second beveled surface **384** is positioned between the second seal **376** and the intake bores **170** and **172**. The second beveled surface **384** has an annular shape and surrounds the horizontal bore **106** in an endless manner. In alternative embodiments, the second beveled surface may have a shape that conforms to the shape of the second bevel formed in the fluid routing plug.

[0368] When the fluid routing plug **116** is installed within the horizontal bore **106**, the second bevel **382** seats against the second beveled surface **384**, as shown in FIG. **68**. The bevels **382** and **384** meet at a non-right angle. Such angle reduces stress in the fluid routing plug **116** and the housing **104** during operation. The bevels **382** and **384** remain engaged during the forward and backwards stroke of the plunger **290**.

[0369] Turning to FIGS. **65** and **69**, the first bevel **378** and the first beveled surface **380** are shown in more detail. The first beveled surface **380** is positioned between the intake bores **170** and **172** and the first seal **374**. The first beveled surface **380** has an annular shape and surrounds the horizontal bore **106** in an endless manner. In alternative embodiments, the first beveled surface may have a shape that conforms to the shape of the first bevel formed in the fluid routing plug.

[0370] In contrast to the second bevel **382**, the first bevel **378** is sized to be spaced from the first beveled surface **380** when the fluid routing plug **116** is initially installed within the housing **104**, as shown by a gap **398**. The gap **398** provides space for the fluid routing plug **116** to expand during operation.

[0371] As the plunger **290** retracts backwards away from the housing **104**, a significant amount of load is applied to the second bevel **382**. The applied load causes the fluid routing plug **116** to slightly compress, forcing the intermediate surface **322** at the first bevel **378** to expand outwards. As the first bevel **378** expands, it eventually engages with the first beveled surface **380**. Upon engaging the first beveled surface **380**, the load being applied to the second bevel **382** is shared with the first bevel **378**, thereby decreasing the load applied to the second bevel **382**. Without the gap **398**, the fluid routing plug **116** would not have room to expand, potentially causing damage to the fluid routing plug **116** and the housing **104** over time.

[0372] As the plunger **290** extends forward into the housing **104**, the first bevel **378** will return to its un-expanded state, re-creating the gap **398**. The gap **398** will repeatedly be created and closed during operation as the plunger **290** reciprocates. In addition to providing space for the fluid routing plug **116** to expand, the gap **398** also provides a gas and fluid relief area during the forward stroke of the plunger **290**.

[0373] Continuing with FIGS. **68** and **69**, because the second bevel **382** carries the majority of the load experienced by the fluid routing plug **116** during operation, the second bevel **382** is longer than the first bevel **378**. In alternative embodiments, the first bevel may be longer than that shown in FIG. **69** or be equal in length to the second bevel. In such embodiments, the first beveled surface formed in the housing may correspond with the chosen size of the first bevel. In further alternative embodiments, the first bevel may be sized to mate with the first beveled surface when the fluid routing plug is first installed within the housing.

[0374] With reference to FIGS. **65**, **70**, and **71**, in order to prevent fluid from leaking around the fluid routing plug **116** during operation, the first and second seals **374** and **376** are positioned between the sealing surfaces **370** and **372** and the walls of the housing **104** surrounding the horizontal bore **106**.

[0375] The first seal **374** is positioned within a first annular groove **400** formed in housing **104** and surrounding the horizontal bore **106** in an endless manner. The first groove **400** is positioned between the intake bores **170** and **172** and the second outer surface **110** of the housing **104**, as shown in FIG. **65**. The first groove **400** is characterized by two sidewalls **402** joined by a base **404**, as shown in FIG. **71**. The sidewalls **402** may join the base **404** via radius corners or at a 90 degree angle. In alternative embodiments, the first groove may have a non-concentric shape that corresponds with the shape of the first sealing surface.

[0376] The second seal **376** is positioned within a second annular groove **406** formed in the housing **104** and surrounding the horizontal bore **106** in an endless manner. The second groove **406** is positioned between the discharge bore **178** and the intake bores **170** and **172**, as shown in FIG. **65**. The second groove **406** is characterized by two sidewalls **408** joined by a base **410**. The sidewalls **408** may join the base **410** via radius corners or at a 90 degree angle. In alternative embodiments, the second groove may have a non-concentric shape that corresponds with the shape of the second sealing surface.

[0377] The second groove **406** has a larger diameter than that of the first groove **400** due to the diameter of the horizontal bore **106** at each groove, as shown in FIG. **65**. Likewise, the second seal **376** has a larger diameter than that of the first seal **374**. Because the first and second grooves **400** and **406** are formed in the housing **104**, no grooves are formed in the intermediate surface **322** of the fluid routing plug **116** for receiving a seal.

[0378] When the fluid routing plug **116** is installed within the horizontal bore **106**, the first and second seals **374** and **376** tightly engage the corresponding first and second sealing surfaces **370** and **372**, as shown in FIGS. **70** and **71**. During operation, the first and second seals **374** and **376** wear against the first and second sealing surfaces **370** and **372**. If the first or second sealing surface **370** or **372** begins to erode, allowing fluid to leak around the fluid routing plug **116**, the plug **116** may be removed and replaced with a new plug **116**. The first or second seal **374** or **376** may also be replaced with a new seal, if needed.

[0379] The first groove **400** shown in FIG. **71** is wider than the second groove **406** shown in FIG. **70**. As described below, each groove **400** and **406** is sized to correspond with the size of the seal installed within the groove. In alternative embodiments, the first and second grooves may be wider or narrower than those shown in the figures in order to accommodate the size of the seal installed within the groove.

[0380] As discussed above, the fluid routing plug **116** may repeatedly stretch and contract in response to the changing fluid pressure. For example, when the plunger **290** is retracted out of the housing **104**, the fluid pressure at the first surface **318** is equal or approximately equal to the pressure of fluid delivered to the housing **104** from the intake manifolds **166** and **168**. Such fluid pressure may be around 100-200 psi, for example. When the plunger **290** extends into the housing **104**, the fluid at the first surface **318** may be pressurized to around 10,000 psi, for example.

[0381] The first seal **374**, being positioned adjacent the first surface **318** of the fluid routing plug **116** experiences the constant change in fluid pressure. In contrast, the second seal **376**, being positioned adjacent the second surface **320**, experiences more static fluid pressure. The fluid pressure at the second surface **320** of the fluid routing plug **116** may remain at or close to 10,000 psi, for example.

[0382] Continuing with FIGS. **70** and **71**, because the first seal **374** experiences more pressure fluctuations during operation than the second seal **376**, the first seal **374** may be more robust than the second seal **376**. For example, the first seal **374** is larger than the second seal **376** and has a generally square cross-sectional shape, while the second seal **376** has a circular cross-sectional shape. The first seal **374** may also have a higher durometer value than the second seal **376**. As described below, both seals **374** and **376** are bi-directional seals. In alternative embodiments, the second seal may be of the same construction as the first seal.

[0383] Continuing with FIG. **71**, the first seal **374** is shown engaged with both side walls **402** of the first groove **400**. In operation, as the plunger **290** extends into the housing **104**, pressurized fluid pushes against the right side of the first seal **374**, helping to activate the first seal **374** and create a tight seal between the first seal **374** and the first sealing surface **370**. As the plunger **290** retracts from the housing **104** and the fluid pressure drops, the fluid pressure is greater on the left side of the first seal **374**. Thus, the fluid pressure may push against the left side of the first seal **374**, helping to activate the first seal **374**. Therefore, in operation, the first seal **374** may move slightly between its left and right side.

[0384] Continuing with FIG. **70**, the second seal **376** is shown engaged with both side walls **408** of the second groove **406**. In operation, pressurized fluid within the housing **104** helps to activate the second seal **376**, thereby creating a tight seal between the second seal **376** and the second sealing surface **372**. Because the second seal **376** experiences primarily static fluid pressure, the second seal **376** may not move within the second groove **406**, as much as the first seal **374** moves within the first groove **400**.

[0385] Continuing with FIGS. **70** and **71**, the first seal **374** also takes up approximately 97% of the open volume within the first groove **400**. Likewise, the second seal **376** takes up almost 97% of the open volume within the second groove **406**. Normally, seals are configured to take up around 70% of the open volume within the groove the seal is installed within. The remaining open volume provides space for the seal to expand and move. However, in operation, fluid and proppants can fill the open volume and wear against the groove, eventually causing the walls of the groove to erode. If the walls of the groove are damaged, the housing **104** may need to be replaced.

[0386] By sizing the grooves **400** and **406** so that the seals **374** and **376** take up almost all of the open volume within the corresponding grooves **400** and **406**, there is less room for fluid or proppants to fill any open space within the grooves. Specifically, fluid and proppants are prevented from entering any open volume on the back side of the seals **374** and **376**, thereby protecting the first and second grooves **400** and **406** from erosion. In alternative embodiments, the first seal may take less volume of the first groove than is shown in FIG. **70**. Likewise, in alternative embodiments, the second seal may take up less volume of the second groove than is shown in FIG. **71**. The other grooves formed in the housing and described herein may also be configured so that the corresponding seals take up approximately 97% of the open volume within the groove.

[0387] Continuing with FIG. **71**, the first sealing surface **370** may extend up to immediately adjacent the first surface **318** of the body **316**. A first portion **412** of the intermediate surface **322** between the first bevel **378** and the first sealing surface **370** faces the housing **104** walls. A very small gap exists between the first portion **412** and the housing **104**. The gap may be as small as

0.001 inches in width. Such gap provides clearance to reduce friction between the fluid routing plug **116** and the housing **104** during installation and operation. Such gap also provides space for excess proppant to collect during operation.

[0388] Continuing with FIG. **70**, a second portion **416** of the intermediate surface **322** between the second sealing surface **372** and the second surface **320** may face the walls of the housing **104**. A third portion **418** of the intermediate surface **322** between the second sealing surface **372** and the transition bevel **386** may also face the walls of the housing **104**. Like the first portion **412**, a very small gap exists between the second and third portions **416** and **418** and the housing **104**. The gaps may be as small as 0.001 inches in width. Such gaps provide clearance to reduce friction between the fluid routing plug **116** and the housing **104** during installation and operation. Such gaps also provide space for excess proppant to collect during operation.

[0389] Turning back to FIG. **65**, as discussed above, the walls of the housing **104** surrounding the horizontal bore **106** are sized to allow for easy installation of the fluid routing plug **116**. The second groove **406** has a diameter D**1**. A maximum diameter of the second beveled surface **384** has a diameter D**2**. A maximum diameter of the first beveled surface **380** has a diameter D**3**, and the first groove **400** has a diameter D**4**. The diameter D**4** is greater than the diameter D**3**. The diameter D**3** is greater than the diameter D**2**, and the diameter D**2** is greater than the diameter D**1**.

[0390] With reference to FIGS. **72-76** and **85-89**, the suction and discharge valves **292** and **294** are generally identical, with the exception that the discharge valve **294** may be larger in size than the suction valve **292**. As discussed above, the suction and discharge valves **292** and **294** each have a sealing element **346** and **360**. The sealing elements **346** and **360** each include a sealing surface **420** and **422** that tapers at an angle that matches the angle of the tapered wall **340** and **356** of the fluid routing plug **116**. Thus, the sealing surfaces **420** and **422** each taper at an angle of 30 or 45 degrees. Preferably, the tapered walls **340** and **356** and the sealing surfaces **420** and **422** both taper at an angle of 45 degrees.

[0391] Forming the mating tapered walls **340** and **356** and sealing surfaces **420** and **422** at 45 degrees provides more surface area for the valves **292** and **294** to seal against the fluid routing plug **116**. Providing more sealing surface area or a larger “strike face” helps distribute the forces applied to the valves **292** and **294** and the fluid routing plug **116**, thereby providing more evenly distributed sealing. Providing more evenly distributed sealing prevents certain areas from wearing faster than others, helping to increase the life of the parts.

[0392] Each valve **292** and **294** also has an outer sealing diameter A and an inner sealing diameter B, as shown in FIGS. **72** and **85**. The ratio of the outer sealing diameter A to the inner sealing diameter B is preferably 1.55 or greater. This ratio helps increase the life of the valves **292** and **294** and reduce any turbulent fluid flow during operation. The valves **292** and **294** and the fluid routing plug **116** are configured so that no portion of the valves **292** and **294** enters the first or second fluid passages **326** and **336** during operation. Additionally, no portion of the valve **292** enters the blind bore **328** during operation. Rather, the suction valve **292** is configured only to cover the entrance **342** of the blind bore **330** on the first surface **318**, and the discharge valve **294** is configured only to cover the openings **364** of the second fluid passages **336** on the second surface **320**.

[0393] Continuing with FIGS. **72-76**, the suction valve **292** is shown in more detail. The suction valve **292** comprises the sealing element **346** joined to a stem **424**. When the suction valve **292** is installed within the horizontal bore **106**, the stem **424** extends along an axis that is parallel to or aligned with central the longitudinal axis **114** of the housing **104**.

[0394] The sealing element **346** comprises opposed first and second surfaces **426** and **428** joined by the sealing surface **420**. A groove **430** is formed in the sealing surface **420** adjacent the first surface **426**, as shown in FIG. **76**. A seal **432** is installed within the groove **430**. The groove **430** is characterized by a first sidewall **434** joined to a second sidewall **436**. The sidewalls **434** and **436** may be joined by an inner groove **438**. The groove **430** is sized to correspond with the inward facing surface of the seal **432**. An outward facing surface of the seal **432** comprises a convex

surface **440** joined to a concave surface **442**. The seal **432** is preferably made of a polyurethane compound. In alternative embodiments, the seal may be made of a different elastomer material.
[0395] When the suction valve **296** seals against the first surface **318** of the fluid routing plug **116**, the seal **432** and a portion of the sealing surface **420** mate with the tapered wall **340**, as shown in FIG. **51**. The seal **432** is shaped so that the convex surface **440** displaces into, or toward, the concave surface **442** as the seal **432** engages the tapered wall **340**. This relative movement allows the shear forces to be dissipated, increasing the life of the seal **432** and the suction valve **292**. If the seal **432** becomes worn and no longer seals properly, the seal **342** may be removed and replaced with a new seal **432**. In alternative embodiments, the seal and groove may have various shapes and sizes, as desired. In further alternative embodiments, the sealing surface may not include a groove and corresponding seal.
[0396] Continuing with FIG. **76**, the second surface **428** of the sealing element **346** is sized to cover the entrance **342** of the blind bore **328**, as shown in FIG. **51**. A cutout **444** is formed within the second surface **428**. The cutout **444** creates a small cavity within the second surface **428**. The cavity provides space for fluid to collect and apply pressure to the suction valve **292**. Such pressure helps force the suction valve **292** to move axially to an open position.
[0397] Continuing with FIGS. **75** and **76**, the stem **424** projects from the first surface **426** of the sealing element **346**. An annular void **446** is formed in the first surface **426** and surrounds the stem **424**. The first surface **426** further includes a ring-shaped outer rim **448** that surrounds the annular void **446** and the stem **424**. The outer rim **448** joins the sealing surface **420**. The annular void **446** reduces weight within the suction valve **292** and helps orient the valve's center of gravity during operation.
[0398] An annular groove **450** is formed in the outer rim **448**. The groove **450** is configured for receiving a bottom portion of a spring **452**, as shown in FIG. **83**. As described below, a top portion of the spring **452** engages with the suction valve guide **296**, as shown in FIGS. **83** and **84**. The spring **452** biases the suction valve **292** in the closed position. Positioning the spring **452** on the outer rim **448** helps to stabilize the suction valve **292** during operation.
[0399] With reference to FIGS. **77-82**, the stem **424** is configured to move axially within the suction valve guide **296**. The suction valve guide **296** may also be referred to as a cage for the suction valve **292**. The suction valve guide **296** comprises a body **454** having opposed first and second surfaces **456** and **458**. A central passage **460** is formed within the body **454** and interconnects the first and second surfaces **456** and **458**. A plurality of legs **462** extend out from the body **454** adjacent its first surface **456** and project downward towards its second surface **458**. The suction valve guide **296** shown in FIGS. **77-82** has six evenly spaced legs **462** formed around its body **454**. In alternative embodiments, more or less than six legs may be formed on the body and may be non-uniformly spaced.
[0400] The legs **462** gradually decrease in thickness from the body **454** to a bottom surface **464** of each leg **462**. The bottom surface **464** of each leg **462** is extremely thin so that the legs **462** do not block or interfere with the openings **348** of the second fluid passages **336** on the first surface **318**, as shown in FIG. **50**.
[0401] Continuing with FIGS. **77-82**, an outer surface of each leg **462** includes a bevel **466**. The bevels **466** are configured to engage a corresponding bevel **468** formed in the walls of the housing **104**, as shown in FIGS. **50** and **51**. The suction valve guide **296** is inserted into the horizontal bore **106** until the bevels **466** and **468** engage, allowing the guide **296** to bottom out on the walls of the housing **104**. Once the bevels **466** and **468** are engaged, the suction valve guide **296** is held against the walls of the housing **104** by the spring **452** and fluid pressure.
[0402] When the suction valve guide **296** is in its installed position, the bottom surface **464** of each of the legs **462** hovers just above the first surface **318** of the fluid routing plug **116**, leaving a gap between the legs **462** and the plug **116**. The bottom surfaces **464** do not directly contact the fluid routing plug **116** in order to prevent the suction valve guide **296** from applying load to the plug **116**

during operation.
[0403] Continuing with FIG. **80**, a tubular insert **470** is installed within the central passage **460** of the body **454**. The insert **470** may be press-fit within the passage **460**. The insert **470** extends the length of the central passage **460** and is formed from a more wear resistant material than the suction valve guide **296**. For example, the insert **470** may be made of tungsten carbide, while the suction valve guide **296** may be made of high strength alloy steel. The stem **424** is installed within the insert **470** and reciprocates within the insert **470** during operation, as shown in FIGS. **50** and **51**. Any fluid contained within the insert **470** drains from the opening of the central passage **460** on the first surface **456** of the body **454**.
[0404] During operation, the stem **424** may wear against the insert **470** as it reciprocates. The insert **470** helps decrease the rate of wear and helps the stem to wear evenly against the insert. Forming only the insert **470** out of a wear resistant material helps reduce the cost of the other parts, which do not experience as much wear during operation.
[0405] Turning to FIGS. **83** and **84**, the spring **452** is interposed between the suction valve **292** and the suction valve guide **296**. The spring **452** is held between the outer rim **448** of the suction valve **292** and an inner surface **472** of the legs **462**. At least a portion of the spring **452** surrounds the body **454** of the suction valve guide **296**. As the suction valve **292** moves to an open position, the spring **452** compresses between the suction valve **292** and the suction valve guide **296**.
[0406] With reference to FIGS. **84**A-**84**F, another embodiment of a suction valve guide **451** is shown. The suction valve guide **451** is like the suction valve guide **296** but does not include the plurality of spaced apart legs **462**. Instead, the suction valve guide **451** comprises a thin-walled skirt **453** surrounding a plurality of support legs **455**. Three support legs **455** are shown in the figures. In alternative embodiments, the suction valve guide **451** may comprise more than three support legs or less than three support legs.
[0407] Continuing with FIGS. **84**A-**84**F, the suction valve guide **451** comprises a body **457** having opposed first and second surfaces **459** and **461**. A central passage **463** is formed within the body **457** and interconnects the first and second surfaces **459** and **461**. While not shown, the tubular insert **470**, shown in FIG. **80**, may be installed within the central passage **463**.
[0408] The plurality of support legs **455** extend out from the body **457** adjacent its first surface **459** and project downward towards its second surface **461**. The skirt **453** surrounds a lower portion of the support legs **455** and extends slightly past second surface **461** of the body **457**, as shown in FIG. **84**D. The skirt **453** comprises a tapered upper section **465** joined to a cylindrical lower section **467**. A plurality of large flow ports **469** are formed between adjacent support legs **455** and between the first surface **459** of the body **457** and the tapered upper section **465** of the skirt **453**, such that fluid may pass between the body **457** and the interior of the skirt **453**.
[0409] Turning back to FIG. **19**G, the suction valve guide **451** is shown installed within the housing **103**. When installed, the tapered section **465** of skirt **453** engages the beveled surface **468**. The cylindrical section **467** engages and covers the wall of the housing **103** between the fluid routing plug **116** and the beveled surface **468**. By covering the wall of the housing **103** in this area, the skirt **453** acts as a shield for the wall, helping to reduce any wear and erosion to this area of the housing **103**. All fluid flow is diverted through the flow ports **469** of the suction valve guide **451**, which can be easily replaced, if needed.
[0410] With reference to FIGS. **84**G-**84**L, another embodiment of a suction valve guide **471** is shown. The suction valve guide **471** is identical to the suction valve guide **451** but does not include any support legs **455**. Instead, the guide **471** comprises a skirt **473** joined to a body **479** by a plurality of support arms **481**. The arms **481** only extend between the body **479** and the skirt **473**. In contrast, the legs **455**, shown in FIG. **84**B, extend between the body **457** and the skirt **453** and down the interior of the skirt **453**. By removing the legs **455**, the open area within the interior of the skirt **453** is enlarged, providing more area for fluid flow.
[0411] Continuing with FIGS. **84**G-**84**L, the skirt **473** is identical to the skirt **453** and comprises a

tapered upper section **483** and a cylindrical lower section **485**. The suction valve guide **471** further comprises a plurality of flow ports **487**. The body **479** of the valve guide **471** and the flow ports **487** are identical to those used with the valve guide **451**.

[0412] With reference to FIGS. **84**M and **84**N, another embodiment of a suction valve guide **501** is shown. The suction valve guide **501** is identical to the suction valve guide **471** but a material **503** has been added to the interior cylindrical section **485** of the skirt **473**. The material **503** is configured to reduce wear and prevent erosion of the skirt **473** during operation. For example, the material **503** may comprise a hardened material, such as sprayed carbide, or other hardened materials known in the art. In alternative embodiments, the material **503** may comprise an elastomer configured to absorb fluid flow energy. In further alternative embodiments, the material **503** may comprise Teflon or other slick, smooth, slippery surface configured to reduce friction between fluid flow and the interior of the skirt **473**.

[0413] With reference to FIGS. **840** and **84**P, another embodiment of a suction valve guide **511** is shown. The suction valve guide **511** is identical to the suction valve guide **471** but a hardened wear ring **513** has been installed within the interior of the cylindrical section **485** of the skirt **473**. The wear ring **513** is preferably made of a harder material than that of the skirt **473**. During operation, the wear ring **513** prevents wear and erosion to the interior of the skirt **473**. In alternative embodiments, the wear ring **513** may be configured to cover more interior areas of the suction valve guide **511**.

[0414] The wear ring **513** may be press-fit into the interior of the skirt **473** or may be attached by other means known in the art, such as welding. The wear ring **513** may also be configured to be easily removed and replaced with a new wear ring **513**, if needed.

[0415] With reference to FIGS. **84**Q and **84**R, another embodiment of a suction valve guide **521** is shown. The suction valve guide **521** is identical to the suction valve guide **471** but comprises a skirt **523** having a cylindrical section **525** that is a separate piece from a tapered section **527** and the rest of the valve guide **521**. The cylindrical section **525** is separated from the tapered section **527** at a separation point **529**, as shown in FIG. **84**Q. When the suction valve guide **521** is installed within a housing, the cylindrical section **525** abuts the tapered section **527** of the skirt **523**.

[0416] The cylindrical section **525** is preferably formed from a different material than of the tapered section **527**. For example, the cylindrical section **525** may be formed of or sprayed with a hardened material, such as tungsten carbide, while the rest of the valve guide **521** may be formed of carbon steel.

[0417] In operation, the hardened cylindrical section **525** of the skirt **523** is resistant to erosion, extending the life of the skirt **523**. The cylindrical section **525**, being a separate piece from the rest of the suction valve guide **521**, may also be easily removed and replaced with a new cylindrical section **521**, if needed.

[0418] With reference to FIGS. **85-89**, the discharge valve **294** is shown in more detail. As discussed above, the discharge valve **294** is constructed identically to the suction valve **292**, with the exception that the discharge valve **294** may be larger in size. The discharge valve **294** shown in FIGS. **85-89**, for example, has a larger sealing surface **422** and a longer stem **474** than the suction valve **292**. When the discharge valve **294** is installed within the horizontal bore **106**, the stem **424** extends along an axis that is parallel to or aligned with the central longitudinal axis **114** of the housing **104**. A seal **475** is installed within a groove **477** formed in the sealing surface **422** and is configured to engage with the tapered wall **356** formed in the second surface **320** of the fluid routing plug **116**. A bottom surface **476** of the discharge valve **294** is sized to cover the central base **354**, as shown in FIG. **50**.

[0419] With reference to FIGS. **90-95**, the stem **474** formed on the discharge valve **294** is configured to move axially within the discharge valve guide **298**. The discharge valve guide **298** may also be referred to as a cage for the discharge valve **294**. The discharge valve guide **298** comprises a body **478** having opposed first and second surfaces **480** and **482** joined by an intermediate surface **484**. The intermediate surface **484** includes a front portion **486**, a medial portion **488**, and a rear portion **490**. The medial portion **488** has a larger diameter than both the front and rear portions **486** and **490**. The front portion **486** has a slightly larger diameter than the rear portion **490**.

[0420] Continuing with FIGS. **90-95**, a blind bore **492** is formed in the first surface **480** and extends into the front portion **486** of the body **478**. The blind bore **492** is configured to receive a tool used to grip the discharge valve guide **298**. The front portion **486** is sized to be received within the cutout **308** formed in the retainer **300**, as shown in FIGS. **50** and **51**. When the discharge valve guide **298** and the retainer **300** are engaged, the blind bore **492** opens into the central passage **310** formed in the retainer **300**.

[0421] A central passage **494** is formed in the body **478** and opens on the second surface **482**, as shown in FIGS. **93** and **94**. The central passage **494** opens in the body **478** into an axially blind counterbore **496**. A plurality of relief ports **498** are formed in the body **478**. Each relief port **498** interconnects the counterbore **496** and a base **500** of the medial portion **488**, as shown in FIG. **94**.

[0422] Continuing with FIGS. **93** and **94**, a tubular insert **502** is installed within the central passage **494**. The insert **502** is identical to the insert **470**, with the exception that the insert **502** may be larger than the insert **470**. During operation, the stem **474** moves axially within the insert **502** installed within the central passage **494**. Any fluid within the insert **502** drains from the body **478** through the counterbore **496** and the relief ports **498**.

[0423] Continuing with FIGS. **90-92**, a plurality of legs **504** project from the medial portion **488** and extend towards the second surface **482** of the body **478**. The discharge valve guide **298** shown in FIGS. **90-95** comprises five legs **504**. The legs **504** are positioned on the body **478** so as to leave a large space **506** between at least two adjacent legs **504**. Other than the space **506**, the legs **504** are equally spaced from one another. The space **506** is intended to align with the discharge bore **178**, thereby preventing any legs **504** from blocking the discharge bore **178** during operation. Providing the space **506** therefore allows fluid to flow freely between the discharge valve **294** and the discharge bore **178** without significant obstructions. The space **506** also helps minimize wear applied to the legs **504** by the flowing fluid over time. In alternative embodiments, the body may have more or less than five legs and be spaced, as desired, as long as the legs are positioned on the body so as to leave a large space between at least two of the legs.

[0424] With reference to FIG. **90**, each of the legs **504** has a thicker upper portion **508** and thinner lower portion **510**. The thicker upper portion **508** provides strength to the legs **504** while the lower portion **510** is thinned in order to provide more room for fluid flow around the legs **504**. The upper portion **508** also includes a tapered inner surface **512**. Tapering the inner surface **512** of the legs **504** provides strength and alleviates stress in the legs **504** during operation.

[0425] Continuing with FIGS. **90-95**, when the discharge valve guide **298** is installed within the horizontal bore **106**, a bottom surface **514** of each leg **504** engages the outer rim **352** of the second surface **320** of the fluid routing plug **116**, as shown in FIGS. **50** and **51**. The discharge valve guide **298** is held against the fluid routing plug **116** by the retainer **300**. Such engagement helps keep the second bevel **382** of the fluid routing plug **116** seated against the second beveled surface **384**, as shown in FIGS. **65** and **68**.

[0426] Continuing with FIGS. **93** and **95**, a dowel pin **516** is installed within a blind bore **517** formed in the medial portion **488** of the body **478**. The dowel pin **516** is configured to be received within a dowel pin hole or groove **518** formed in the walls of the housing **104** surrounding the horizontal bore **106**, as shown in FIGS. **96** and **97**. The discharge valve guide **298** is installed within the horizontal bore **106** such that the dowel pin **516** is positioned within the dowel pin hole **518**. Such positioning ensures that the space **506** between the pair of legs **504** aligns with the discharge bore **178**, thus preventing any legs **504** from blocking the discharge bore **178** during operation.

[0427] Continuing with FIGS. **96** and **97**, a seal **520** is interposed between the intermediate surface

484 of the body **478** and the walls of the housing **104**. The seal **520** may be identical to the second seal **376** shown in FIGS. **65** and **70**. In alternative embodiments, the seal may be identical to the first seal **374** shown in FIGS. **65** and **71**. The seal **520** is installed within a groove **522** formed in the housing **104**. The groove **522** is characterized by two sidewalls **524** joined to a base **526**. The sidewalls **524** may join the base **526** via radius corner or at a 90 degree angle. During operation, the seal **520** wears against the outer intermediate surface **484** of the discharge valve guide **298**. If the intermediate surface **484** begins to erode, allowing fluid to leak around the seal **520**, the discharge valve guide **298** may be removed and replaced with a new discharge valve guide **298**.

[0428] With reference to FIGS. **98** and **99**, a spring **528** is installed between the discharge valve **294** and the discharge valve guide **298**. A bottom portion of the spring **528** sits in a groove **530**, shown in FIG. **89**, formed in an outer rim **532** of the discharge valve **294**. A top portion of the spring **528** engages a ledge **534** formed in the base **500** of the medial portion **488** of the discharge valve guide **298**. During operation, the spring **528** compresses against the ledge **534** of the medial portion **488**.

[0429] With reference to FIGS. **99**A-**99**F, another embodiment of a discharge valve guide **531** is shown. The discharge valve guide **531** is generally identical to the discharge valve guide **298** but only includes a pair of legs **533** instead of the five legs **504**, shown in FIG. **91**. Each leg **533** is wider than the individual legs **504** such that each leg **533** spans about a quarter of the circumference of a body **535** of the valve guide **531**. Each leg **533** is positioned opposite the other leg **533**. A large space **537** exists between each leg **533**, as shown in FIGS. **99**B and **99**E.

[0430] A plurality of relief ports **539** are formed in the body **535** between each leg **533**. The relief ports **539** are generally identical to the relief ports **498**, shown in FIG. **94**, but have wider openings. The remaining features of the discharge valve guide **531** are identical to those on the discharge valve guide **298**.

[0431] With reference to FIGS. **19**G and **19**H, the discharge valve guide **531** is shown installed within the housing **103**. The guide **531** is installed such that each space **537** aligns within each of the discharge bores **105** and **107**, providing a clear pathway for fluid flow.

[0432] Turning to FIG. **100**, the components installed within the housing **104** are installed through the first surface **108**, starting with the suction valve guide **296**. The diameter of the installed components slightly increases from the second surface **320** to the first surface **318**. For example, the suction valve guide **296** has smaller outer diameters than the fluid routing plug **116**, and the fluid routing plug **116** has smaller outer diameters than the discharge valve guide **298**. The discharge valve guide **298** has smaller outer diameters than the retainer **300**.

[0433] Likewise, the diameters of the walls surrounding the horizontal bore **106** generally increase from the second surface **110** to the first surface **108**. As shown in FIG. **100**, a diameter D**4** of the horizontal bore **106** is greater than a diameter D**3** of the horizontal bore **106**. The diameter D**3** of the horizontal bore **106** is greater than a diameter D**2** of the horizontal bore **106**. The diameter D**2** of the horizontal bore **106** is greater than a diameter D**1** of the horizontal bore **106**. Such construction allows the components to be installed without engaging the walls of the housing **104** until the component is at its intended installed position. The seals **374**, **376**, and **520** may be installed within the housing **104** prior to installing the other components described above.

[0434] Turning to FIGS. **100**A-**100**E, another embodiment of a fluid routing plug **550** is shown. The fluid routing plug **550** may be installed within the housing **104** in place of the fluid routing plug **116**. The fluid routing plug **550** is identical to the fluid routing plug **116**, with a few exceptions. The fluid routing plug **550** comprises a body **552** having a first outer surface **554** joined to a second outer surface **556** by an intermediate outer surface **558**. The second surface **556** of the fluid routing plug **550** is generally identical to the second surface **320** of the fluid routing plug **116**, but a central base **560** formed in the second surface **556** is spaced from an edge **562** of a tapered wall **564** formed in the second surface **556**. The central base **560** is spaced from the tapered wall **564** such that a throat **566** is formed between the central base **560** and the tapered wall **564**.

[0435] Continuing with FIGS. **100**A-**100**D, a blind hole **568** is formed in the central base **560** and a plurality of openings **570** corresponding to a plurality of second fluid passages **572** open on the central base **560** and surround the blind hole **568**. In operation, fluid exiting the openings **570** flows into the throat **566** before pushing against the discharge valve **294** engaged with the second surface **556**. Allowing fluid to gather in the throat **566** before contacting the discharge valve **294** helps the fluid to contact more surface area of the discharge valve **294**, instead of having a plurality of single points of contact from each second fluid passage opening. Allowing the fluid to contact more surface area of the discharge valve **294** helps reduce wear to the valve over time.
[0436] Continuing with FIGS. **100**E and **100**F, the intermediate surface **558** of the fluid routing plug **550** is identical to the intermediate surface **322** formed on the fluid routing plug **116**. However, the intermediate surface **558** may include a cutout **576** adjacent the second surface **556**. The cutout **576** provides space for fluid or proppant to collect during operation, as shown in FIG. **100**F. The cutout **576** also helps reduce friction during installation of the fluid routing plug **550** within the housing **104**. A small gap **578** may also exist between the walls of the housing **104** and the intermediate surface **558** between a second sealing surface **580** and the cutout **576**, as shown in FIG. **100**F. The gap **578** helps the seal **376** breath during operation.
[0437] Continuing with FIG. **100**B, the first surface **554** of the fluid routing plug **550** is identical to the first surface **318** of the fluid routing plug **116**, with the exception of its outer rim **582**. The outer rim **582** is flat and wider than the outer rim **338**, shown in FIG. **55**. Because the outer rim **582** is wider, a plurality of openings **584** for the second fluid passages **572** may have a slightly larger diameter than the openings **348**, shown in FIG. **56**. Likewise, the openings **570** may also have a slightly larger diameter than the openings **364** shown in FIG. **54**. Providing a slightly larger diameter for the second fluid passages **572** helps reduce fluid velocity through the fluid routing plug **550** during operation. Reducing fluid velocity within the fluid routing plug **550** helps reduce wear to the fluid routing plug **550** over time.
[0438] Turning to FIGS. **101**-**109**, another embodiment of a fluid routing plug **600** is shown. The fluid routing plug **600** may be installed within the housing **104** in place of the fluid routing plug **116**. The fluid routing plug **600** is identical to the fluid routing plug **116**, with a few exceptions. The fluid routing plug **600** comprises a body **602** having a first outer surface **604** joined to a second outer surface **606** by an intermediate outer surface **608**. In contrast to the fluid routing plug **116**, the first and second surfaces **604** and **606** of the fluid routing plug **600** are configured so that each surface **604** and **606** has identically sized tapered walls **610** and **612**, as shown in FIG. **103**. Because the tapered walls **610** and **612** are the same size, a suction valve **614** and a discharge valve **616** used with the fluid routing plug **600** may be identical in size, as shown in FIGS. **108** and **109**.
[0439] Using the same size suction and discharge valves **614** and **616** helps equalize the forces applied to the fluid routing plug **600** and the valves **614** and **616** during operation, helping to reduce any wear to the parts over time. Making the suction and discharge valves **614** and **616** identical also makes replacing the valves **614** and **616** during operation easier.
[0440] Continuing with FIGS. **103**, **105**, and **106**, the tapered wall **612** formed in the second surface **606** extends between an outer rim **618** and an annular groove **620** formed in the center of the second surface **606**. The annular groove **620** may be considered a central base formed in the second surface **606**. The groove **620** surrounds a blind bore **622** formed in the center of the second surface **606**. The blind bore **622** is identical to the blind bore **362** formed in the fluid routing plug **116**, as shown in FIG. **55**.
[0441] The groove **620** is characterized by two parallel sidewalls **624** joined by a base **626**. The sidewalls **624** each extend at a non-zero angle relative to a central longitudinal axis **628** of the body **602**. Because the sidewalls **624** of the groove **620** extend at an angle, the base **626** of the groove **620** extends at a non-zero angle relative to the central longitudinal axis **628** of the body **602**. Preferably, the base **626** extends at approximately the same angle as the tapered wall **612** so that the base **626** and the tapered wall **612** are in a generally parallel relationship. The tapered wall **612**

shown in FIG. **103** extends at a 45 degree angle relative to the central longitudinal axis **628**.

[0442] An annular inner edge **638** of the tapered wall **612** is joined to the outer sidewall **624** of the groove **620** at a right angle. The diameter of the inner edge **638** of the tapered wall **612** is the same size as a diameter of an entrance **630** of an axially blind bore **632** formed in the first surface **604**, as shown in FIG. **103**. In alternative embodiments, the groove formed in the second surface and the inner edge of the tapered wall may not have an annular shape.

[0443] Continuing with FIGS. **103**, **105**, and **106**, a plurality of second fluid passages **634** are formed in the body **602**. The second fluid passages **634** are identical to the second fluid passages **336** formed in the fluid routing plug **116**, shown in FIGS. **52-64**, with the exception of the positioning of their openings **636** on the second surface **606**. Each second fluid passage **634** opens on the base **626** of the groove **620** formed in the second surface **606**. Thus, the openings **636** are axially spaced from the inner edge **638** of the tapered wall **612**. Because the sidewalls **624** of the groove **620** are formed at an angle, the inner edge **638** of the tapered wall **612** slightly overlaps the openings **636**, as shown in FIG. **106**. By positioning the openings **636** in an axially spaced relationship with the inner edge **638** of the tapered wall **612**, the size of the tapered wall **612** can be decreased without decreasing the size of the openings **636**. The annular groove **620** also functions as a throat, similar to the throat **566** formed in the fluid routing plug **550**.

[0444] Because the tapered wall **612** is decreased in size from the tapered wall **356** shown in FIG. **55**, the outer rim **618** on the second surface **606** is wider than the outer rim **352**. The outer rim **618** also tapers between the intermediate surface **608** and the tapered wall **612**, as shown in FIGS. **103** and **104**. Such taper increases the length of the tapered wall **612** without increasing the length of the intermediate surface **608**.

[0445] Continuing with FIGS. **101-107**, the first surface **604** is identical to the first surface **318** shown in FIGS. **53**, **55**, and **56**, with the exception of its outer rim **640**. Instead of tapering like the outer rim **338**, shown in FIG. **55**, the outer rim **640** is flat. The outer rim **640** is flat in order to slightly decrease the size of the tapered wall **610** to match the size of the tapered wall **612**. The intermediate surface **608** of the fluid routing plug **600** is identical to that of the fluid routing plug **116**, shown in FIG. **64**. A plurality of first fluid passages **642** formed in the body **602** are identical to the first fluid passages **326**, shown in FIGS. **55**, **57**, and **59**. The second fluid passages **634** open on the outer rim **640** of the first surface **604**, as shown by the openings **644**. The openings **644** are positioned in groups **645**, in the same manner as the second fluid passages **336** formed in the fluid routing plug **116**, as shown in FIG. **56**. The openings **636** on the second surface **606** may remain spaced in groups **645**, as shown in FIG. **106**.

[0446] With reference to FIGS. **108** and **109**, the fluid routing plug **600** routes fluid throughout the housing **104** in the same manner as the fluid routing plug **116**. The suction valve guide **296** is shown engaged with suction valve **614**. Another embodiment of a discharge valve guide **647** is shown engaged with the discharge valve **616**.

[0447] The discharge valve guide **647** is identical to the discharge valve guide **298**, shown in FIGS. **90-95**, with a few exceptions. A counterbore **649** formed in the guide **647** is larger than the counterbore **496**. The counterbore **649** is larger in order to accommodate the shorter stem **646** of the discharge valve **616**. An insert **651** installed within the discharge valve guide **647** is the same size as the insert **470** installed within the suction valve guide **296**.

[0448] With reference to FIGS. **110-114**, as discussed above, in contrast to the valves **292** and **294**, the valves **614** and **616** are identical in size and shape. The valves **614** and **616** are generally identical to the valves **292** and **294**, with a few exceptions. Each valve **614** and **616** comprises a sealing element **652** joined to a stem **646**. The stem **646** projects from a first surface **650** of the sealing element **652**.

[0449] An annular cutout **648** is formed within a medial portion of the stem **646**. The cutout **648** provides space for fluid or proppants to collect during operation. Providing such space prevents the fluid and proppants from rubbing against the inserts **470** and **502**. The suction and discharge valves

292 and **294** may be configured to include an annular cutout within their stems **424** and **474**.

[0450] Continuing with FIGS. **110-114**, the sealing element **652** further includes a second surface **668** joined to the first surface **650** by a sealing surface **658**. A groove **656** is formed in the sealing surface **658** for housing a seal **654**. The groove **656** is identical to the groove **430**, shown in FIG. **76**. An outward facing surface of the seal **654** comprises a sidewall **660** joined to a tapered base **662**. In operation, the tapered base **662** engages the tapered walls **610** and **612** of the fluid routing plug **600**. The sidewall **660** may compress creating a tight seal.

[0451] The first surface **650** of the sealing element **652** includes an outer rim **664**. An outer ledge **666** surrounds the outer rim **664**. A bottom portion of a spring engages the outer rim **664** and is held in place by the outer ledge **666**. While not shown, a cutout may be formed in the second surface **668** of the sealing element **652**, like the cutout **444**, shown in FIG. **76**.

[0452] One or more kits may be useful in assembling the fluid end section **102**. A kit may comprise a plurality of housings **104** and a plurality of the corresponding fluid routing plugs **116**, **550**, or **600**. The kit may also comprise a plurality of suction valves **292** or **614**, discharge valves **294** or **616**, suction valve guides **296**, discharge valve guides **298** or **657**, springs **452** and **528**, retainer **300**, stuffing box **140**, retainer **232**, plunger packing **224**, packing nut **276**, fastening system **234**, discharge conduit **174**, and the various seals described herein. The kit may also comprise the intake manifolds **166** and **168**, pipe system **176**, connect plate **118**, fastening system **146** and stay rods **120**. The kit may also comprise other various features described herein for use with the fluid end **100**. Unless specifically described herein, the various components of the fluid end **100** may be made of high strength alloy steel, such as carbon steel or stainless steel.

[0453] With reference to FIGS. **115-117**, an alternative embodiment of a fluid routing plug **700** is shown. The fluid routing plug **700** may be installed within the housing **104** in place of the fluid routing plug **116**. The fluid routing plug **700** is identical to the fluid routing plug **116**, with the exception of the shape of its first and second bevels **702** and **704**. When the fluid routing plug **700** is first installed within the horizontal bore **106**, the second bevel **704** only partially engages a second beveled surface **706**, as shown in FIG. **116**. The bevels **704** and **706** mate at a second bevel mating surface **708** and a second beveled surface mating surface **710**. Below the mating surfaces **708** and **710**, the second bevel **704** and the second beveled surface **706** have mating angles that are not equal, causing a gap **712** to exist between the bevels **704** and **706**. Specifically, the second bevel **704** may have a slightly convex shape so that portions of the second bevel **704** don't match the flat shape of the second beveled surface **706**.

[0454] The width of the gap **712** gradually increases between the mating surfaces **708** and **710** and a bottom portion **714** of the second bevel **704** and a bottom portion **716** of the second beveled surface **706**. Thus, the width B of the gap **712** is wider than the width A of the gap **712**. Because the second bevel **704** has a slightly convex shape, the angle between the mating surfaces **708** and **710** is different from the angle between the bottom portions **714** and **716**.

[0455] Turning to FIG. **117**, the first bevel **702** and the first beveled surface **718** are shown in more detail. Like the second bevel **704**, the first bevel **702** may only partially engage a first beveled surface **718**. The bevels **702** and **718** mate at a first bevel mating surface **720** and a first beveled surface mating surface **722**. Below the mating surfaces **720** and **722**, the first bevel **702** and the first beveled surface **718** have mating angles that are not equal, causing a gap **724** to exist between the bevels **702** and **718**. Specifically, the first bevel **702** may have a slightly convex shape so that portions of the first bevel **702** do not match the flat shape of the first beveled surface **718**.

[0456] The width of the gap **724** gradually increases between the mating surfaces **720** and **722** and a bottom portion **726** of the first bevel **702** and a bottom portion **728** of the first beveled surface **718**. Thus, the width B of the gap **724** is wider than the width A of the gap **724**. Because the first bevel **702** has a slightly convex shape, the angle between the mating surfaces **720** and **722** is different from the angle between the bottom portions **726** and **728**.

[0457] The width of the gaps **712** and **724** has been exaggerated in FIGS. **116** and **117** for illustration purposes. In reality, portions of the gaps **712** and **724** may be approximately 0.002 inches in width, for example. However, the gaps **712** and **724** may be wider or smaller depending on the materials and forces used.

[0458] As discussed above, in operation, the fluid pressure applied to the fluid routing plug **700** will cause the plug **700** to compress and expand as the plunger **290** retracts from the housing **104**. As the fluid routing plug **700** starts to expand, the bottom portion **714** of the second bevel **704** will move to engage the bottom portion **714** of the second beveled surface **706**, causing the bottom portions **714** and **716** to mate. Likewise, the bottom portion **726** of the first bevel **702** will move to engage the bottom portion **728** of the first beveled surface **718**. Such movement of the fluid routing plug **700** distributes the load applied to the fluid routing plug **700** through the length of the first and second bevels **702** and **704**.

[0459] With reference to FIGS. **118-120**, an alternative embodiment of a fluid routing plug **800** is shown. The fluid routing plug **800** may be installed within the housing **104** in place of the fluid routing plug **116**. The fluid routing plug **800** is identical to the fluid routing plug **700**, with the exception of the shape of its first and second bevels **802** and **804**. Like the fluid routing plug **700**, the second bevel **804** is sized to leave a gap **806** between the second bevel **804** and a second beveled surface **808** when the fluid routing plug **800** is first installed within the housing **104**. In contrast to the gap **712**, an angle formed between the mating surfaces **810** and **812** and bottom portions **814** and **816** of the second bevel **804** and second beveled surface **808** remains the same. Thus, an area A of the gap **806** has the same angle as an area B of the gap **806**.

[0460] Likewise, the first bevel **802** is shaped so that an angle formed between the first bevel **802** and a first beveled surface **820** stays relatively the same between mating surfaces **822** and **824** and bottom portions **826** and **828**. Thus, the width A of the gap **818** has approximately the same angle as the width B of the gap **818**.

[0461] The width of the gaps **806** and **818** has been exaggerated in FIGS. **119** and **120** for illustration purposes. In reality, portions of the gaps **806** and **818**, for example, may be approximately 0.002 inches in width. However, the gaps **806** and **818** may be wider or smaller depending on the materials and forces used.

[0462] As discussed above, the first and second bevels **802** and **804** expand during operation. Such movement of the fluid routing plug **800** distributes the load applied to the fluid routing plug **800** through the length of the first and second bevels **802** and **804**.

[0463] In alternative embodiments, the first bevel may be configured to have a gap that increases in size, as shown in FIG. **117**, while the second bevel may be configured to have a gap that increases by a different amount, as shown in FIG. **119**, and vice versa. In further alternative embodiments, the width of the gap may be of various shapes and sizes depending on the materials used and forces involved. In even further alternative embodiments, the intermediate surface of the fluid routing plug may include any combination of the different bevel constructions described herein.

[0464] Turning to FIGS. **121-128**, another embodiment of a fluid routing plug **900** is shown. The fluid routing plug **900** may be installed within the housing **104** in place of the fluid routing plug **116**. The fluid routing plug **900** is identical to the fluid routing plug **116**, with a few exceptions. The fluid routing plug **900** comprises a body **902** having a first outer surface **904** joined to a second outer surface **906** by an intermediate outer surface **908**. A plurality of first fluid passages **910** are formed in the body **902** and interconnect the intermediate surface **908** and the first surface **904** by way of an axially blind bore **912**, as shown in FIG. **124**.

[0465] In contrast to the first fluid passages **326**, shown in FIGS. **55** and **58**, a longitudinal axis **914** of each first fluid passage **910** does not intersect a central longitudinal axis **916** of the body **902**, as shown in FIG. **125**. Rather, the first fluid passages **910** are formed such that the longitudinal axis **914** of each passage **910** is offset from the central longitudinal axis **916** of body **902**. The offset configuration of the first fluid passages **910** encourages a vortex type flow of fluid about the central longitudinal axis **916**, thereby reducing fluid turbulence during operation. In alternative embodiments, the longitudinal axis **914** of each first fluid passage **910** may intersect the longitudinal axis **916** of the body **902**.

[0466] A plurality of openings **918** formed on the intermediate surface **908** for the first fluid passages **910** are similar to the openings **334**, shown in FIGS. **57** and **59**, but have a more oblong shape, as shown in FIG. **121**. The oblong shape shown in FIG. **121** has opposed first and second ends **920** and **922**. The second end **922**, which is closer to the second surface **906**, is slightly wider than the first end **920**. The unequal size of the ends **920** and **922** helps direct fluid along the offset longitudinal axis **914** of the first fluid passages **910**. The unequal size of the ends **920** and **922** also helps increase the wall thickness in certain areas of the body **902** between the first fluid passages **910** and a plurality of second fluid passages **924**.

[0467] In alternative embodiments, the opposed ends of the openings may be identical in size or may be shaped identical to the openings **334**, shown in FIGS. **57** and **59**. The opening **918** of the first fluid passage **910** shown in FIG. **121** extends along an axis that is parallel to the longitudinal axis **916** of the body **902**. In alternative embodiments, the openings of the first fluid passages may extend at a non-zero angle relative to the longitudinal axis **916** of the body **902**, as shown for example by the openings **972** shown in FIG. **128**D. The angle at which the first fluid passages **910** are formed in the body **902** may vary, as desired, in order to increase the wall thickness within the body **902** and reduce stress in the body **902** during operation.

[0468] Continuing with FIGS. **122** and **126**, each of the second fluid passages **924** formed in the body **902** interconnects the first and second surfaces **904** and **906**. The second fluid passages **924** are identical to the second fluid passages **336**, shown in FIGS. **60-63**, but the second fluid passages **924** are slightly pivoted from the position of the second fluid passages **336**. Each second fluid passage **924** is pivoted so that it has a compound angle with respect to the central longitudinal axis **916**, as shown in FIGS. **122**, **123** **126**, and **127**. Meaning, each second fluid passage **924** extends such that it has two different angles relative to the central longitudinal axis **916**—up-and-down, and side-to-side. Like the first fluid passages **910**, forming the second fluid passages **924** at such angles encourages a vortex type flow of fluid about the central longitudinal axis **916**, thereby reducing fluid turbulence during operation.

[0469] Continuing with FIGS. **124**, **127**, and **128**, the first surface **904** of the fluid routing plug **900** may be identical to the first surface **318**, shown in FIGS. **53**, **55**, and **56**. However, an outer rim **926** of the first surface **904** may be flat rather than tapered. The second surface **906** of the fluid routing plug **900** is identical to the fluid routing plug **116**, but a central base **928** formed in the second surface **906** may be slightly set back within the body **902**, as compared to the central base **354**, shown in FIGS. **54** and **55**. An outer rim **930** on the second surface **906** may be slightly wider than the outer rim **352**, shown in FIGS. **54** and **55**. The intermediate surface **908** of the fluid routing plug **900** may be identical to the intermediate surface **322** of the fluid routing plug **116**. Alternatively, the intermediate surface may be identical to those formed on the fluid routing plug **700** or **800**.

[0470] In alternative embodiments, the first and second surfaces **904** and **906** of the fluid routing plug **900** may be configured so that its tapered walls **932** and **934** are the same size, like the fluid routing plug **600**. In further alternative embodiments, the first and second surfaces of the fluid routing plug **900** may be identical to the first and second surfaces of the fluid routing plug **116**.

[0471] Turning to FIGS. **128**A-**128**G, another embodiment of a fluid routing plug **950** is shown. The fluid routing plug **950** may be installed within the housing **104** in place of the fluid routing plug **116**. The fluid routing plug **950** is identical to the fluid routing plug **900**, with a few exceptions. The fluid routing plug **950** comprises a body **962** having a first outer surface **964** joined to a second outer surface **952** by an intermediate outer surface **966**. In contrast to the fluid routing plug **900**, the second surface **952** of the fluid routing plug **950** is formed identically to the second surface **856** of the fluid routing plug **850**, shown in FIGS. **100**A-**100**E. A central base **954** formed in the second surface **952** is spaced from an edge **956** of a tapered wall **958** such that a throat **960** is formed within the second surface **952**. The throat **960** serves the same purpose as the throat **566** formed in the fluid routing plug **550**.

[0472] Continuing with FIG. **128**A-**128**G, a plurality of first fluid passages **968**, shown in FIG. **128**G, and a plurality of second fluid passages **970**, shown in FIG. **128**A, are formed in the body **962**. The first and second fluid passages **968** and **970** are identical to the first and second passages **910** and **924** formed in the fluid routing plug **900**. However, as discussed above, an opening **972** of the first fluid passages **968** may extend along a non-zero angle relative to a central longitudinal axis **974** of the body **962**, as shown in FIG. **128**D. In alternative embodiments, the openings **972** may be identical to the openings **918**, shown in FIG. **121**. Like the fluid routing plug **900**, the angle at which the first fluid passages **968** are formed in the body **962** may vary, as desired, in order to increase the wall thickness within the body **962** and reduce stress in the body **962** during operation.

[0473] In alternative embodiments, the first and second surfaces **964** and **952** of the fluid routing plug **950** may be configured like the fluid routing plug **600**. In further alternative embodiments, the first and second surfaces of the fluid routing plug **950** may be identical to the first and second surfaces of the fluid routing plug **116**.

[0474] Turning to FIGS. **129-131**, another embodiment of a fluid routing plug **1000** is shown. The fluid routing plug **1000** may be installed within the housing **104** in place of the fluid routing plug **116**. The fluid routing plug **1000** is identical to the fluid routing plug **116** but includes a first and second annular recess **1002** and **1004** formed in its intermediate surface **1001**. The first annular recess **1002** is positioned between a first bevel **1006** and a first sealing surface **1008**. The second annular recess **1004** is positioned between a second sealing surface **1010** and a second bevel **1012**.

[0475] When the fluid routing plug **1000** is installed within the horizontal bore **106**, a small annular space exists between the wall of the housing **104** and each recess **1002** and **1004**. The space provides relief areas for excess fluid or proppant to collect during operation. The first and second recesses **1002** and **1004** may also be formed in the intermediate surfaces of the fluid routing plugs **550**, **600**, **700**, **800**, **900**, and **950**.

[0476] With reference to FIGS. **131**A-**131**K, another embodiment of a fluid routing plug **901** is shown. The fluid routing plug **901** is generally identical to the fluid routing plug **550**, shown in FIGS. **100**A-**100**E but includes modified first and second surfaces **903** and **905**. The first surface **903** comprises a recessed area **907** positioned between the opening of an axially blind bore **909** and a tapered surface **911**. The recessed area **907** is configured to receive a hardened insert **913**, shown in FIG. **131**I.

[0477] Similarly, the second surface **905** comprises a recessed area **915** positioned between openings **917** of the second fluid passages **919** and a tapered surface **921**. The recessed area **915** is configured to receive a hardened insert **923**. The inserts **913** and **923** are sized to form an extension of the tapered surfaces **911** and **921**, as well as not block fluid flow through the plug **901**. The hardened inserts **913** and **923** help reduce wear to the plug **901** over time due to repeated contact of the intake and discharge valves **292** and **294**.

[0478] With reference to FIGS. **131**L-**131**S, another embodiment of a fluid routing plug **931** is shown. The fluid routing plug **931** is generally identical to the fluid routing plug **550**, shown in FIGS. **100**A-**100**E but has an alternative embodiment of an intermediate surface **933**. First and second grooves **935** and **937** are formed in the intermediate surface **933** adjacent the corresponding first and second surfaces **939** and **941**. The grooves **935** and **937** are configured to receive a first and second seal **943** and **945**, as shown in FIGS. **131**Q and **131**R. The seals **943** and **945** may be generally identical to the seals **374** and **376**, shown in FIGS. **70** and **71**. However, the seals **943** and **945** may have a smaller diameter than the seals **374** and **376**.

[0479] Continuing with FIG. **131**S, the fluid routing plug **931** is used with an alternative embodiment of a housing **947**. The housing **947** does not include any grooves for housing seals that engage with the fluid routing plug **931**. Instead, the seals **943** and **945** installed within the fluid routing plug **931** engage the flat walls of the housing **947**. The area of the housing walls engaged with the seals **943** and **945** are characterized as first and second sealing surfaces **1150** and **1152**. In some embodiments, the sealing surfaces may be sprayed with a hardened material to help reduce wear and erosion. As shown in FIG. **131**S, the fluid routing plug **931** further engages the walls of the housing **947** at first and second fluid routing plug engaging surfaces **1154** and **1156**. The fluid routing plug engaging surfaces **1154** and **1156** may also be characterized as the first and second beveled surfaces **380** and **384** shown in FIGS. **65**, **58**, and **69**. As further shown in FIG. **131**S, the second sealing surface **1152** has a diameter, D**1**, the second fluid routing plug engaging surface **1156** has a diameter, D**2**, the first fluid routing plug engaging surface **1154** has a diameter, D**3**, and the first sealing surface **1150** has a diameter, D**4**. D**1** is greater than D**2**, D**2** is greater than D**3**, and D**3** is greater than D**4**.

[0480] In alternative embodiments, a first groove for housing a seal may be formed in the fluid routing plug and a second groove for housing a seal may be formed in the walls of the housing, and vice versa. In such embodiment, a first sealing surface is formed on the fluid routing plug and a second sealing surface is formed on a wall of the housing, or vice versa.

[0481] With reference to FIG. **131**T, another embodiment of a fluid routing plug **951** is shown. The fluid routing plug **951** is a combination of the new features added to the fluid routing plugs **901** and **931**. The fluid routing plug **951** comprises recessed areas **953** and **955** for hardened inserts **957** and **959**. The fluid routing plug **951** also comprises first and second grooves **961** and **963** for housing first and second seals **965** and **967**.

[0482] In alternative embodiments, the first and second surfaces of each of the fluid routing plugs **550**, **600**, **700**, **800**, **900**, **950**, **901**, **931**, and **951** may each be sized to engage with identically sized suction and discharge valves **292**, **294**, **614** or **616**, as discussed with regard to fluid routing plug **600**. In further alternative embodiments, the first and second surfaces of each of the fluid routing plugs **550**, **600**, **700**, **800**, **900**, **950**, **901**, **931**, and **951** may be sized to engage with differently sized suction and discharge valves **292**, **294**, **614** or **616**. In such embodiment, the valves **292**, **294**, **614** or **616** may be sized as desired, as long as the ratio of the outer sealing diameter A to the inner sealing diameter B of each valve is preferably 1.55 or greater, as discussed with regard to FIGS. **72** and **85**. The desired size of the valve may vary depending on the desired fluid velocity within the corresponding fluid routing plug.

[0483] With reference to FIGS. **132** and **133**, another embodiment of a fluid end section **1100** is shown. The fluid end section **1100** is similar to the fluid end section **102** but comprises another embodiment of a housing **1102**. The housing **1102** is similar to the housing **104**, with the exception of its first surface **1104**. Rather than having a retainer threaded into its first surface **1104**, like the housing **104**, a retainer **1106** is attached to the first surface **1104** of the housing **1102** using a fastening system **1108**.

[0484] With reference to FIGS. **134-137**, the retainer **1106** comprises a first surface **1110** joined to a second surface **1112** by an intermediate surface **1114**. A central passage **1116** is formed in the retainer **1106** and interconnects the first and second surfaces **1110** and **1112**. The walls surrounding the central passage **1116** are threaded. A plurality of passages **1118** are formed in the retainer **1106** and surround the central passage **1116**. Each passage **1118** interconnects the first and second surfaces **1110** and **1112** of the retainer **1106**.

[0485] With reference to FIG. **138**, a plurality of threaded openings **1120** are formed in the first surface **1104** of the housing **1102**. The openings **1120** surround an opening of a horizontal bore **1122** formed in the housing **1102**. The passages **1118** formed in the retainer **1106** are alignable with the openings **1120** in a one-to-one relationship. A dowel pin groove **1124** is also formed in the housing **1102** adjacent the opening of the horizontal bore **1122**, as shown in FIG. **139**. The dowel pin groove **1124** is configured to receive a dowel pin installed within the retainer **1106**. The dowel pin helps properly align the retainer **1106** on the first surface **1104** of the housing **1102**.

[0486] Turning back to FIGS. **132** and **133**, the fastening system **1108** comprises a plurality of studs **1126**, washers **1128**, and nuts **1130**. A first end **1132** of each stud **1126** mates with one of the openings **1120** formed in the housing **1102**, in a one-to-one relationship. The passages **1116** formed in the retainer **1106** subsequently receive the plural studs **1126** projecting from the first surface **1104** of the housing **1102**.

[0487] When the housing **1102** and the retainer **1106** are brought together, a second end **1134** of each stud **1126** projects from the first surface **1110** of the retainer **1106**. A washer **1128** and a nut **1130** are subsequently installed on the second end **1134** of each stud **1126**, in a one-to-one relationship. The nut **1130** is turned until it tightly engages the washer **1128** and the first surface **1110** of the retainer **1106**, thereby securing the housing **1102** and the retainer **1106** together. Rather than applying a single large torque to a single retainer, the fastening system **1108** contemplates distribution of smaller torques among a plurality of studs **1126** and nuts **1130**.

[0488] A retainer nut **1136** is threaded into the central passage **1116** formed in the retainer **1106**. The shape and construction of the retainer nut **1136** is identical to the shape and construction of retainer **300** shown in FIGS. **47-49**. Rather than remove all of the nuts **1130** and washers **1128**, the operator can simply remove the retainer nut **1136**. When the retainer nut **1136** is removed, the operator can access the interior of the housing **1102** through the central passage **1116** of the retainer **1106**. Should any fatigue failures occur between the retainer **1106** and the retainer nut **1136**, the retainer **1106** and/or retainer nut **1136** may be removed and replaced with a new retainer **1106** or retainer nut **1136**.

[0489] Continuing with FIG. **133**, another embodiment of a fluid routing plug **1138** is shown installed within the housing **1102**. The walls surrounding the horizontal bore **1122** formed in the housing **1102** are configured to mate with the fluid routing plug **1138**. Fluid is routed throughout the fluid routing plug **1138** and the housing **1102** in the same manner as the fluid routing plug **116** and the housing **104**, shown in FIGS. **50** and **51**. The fluid routing plug **1138** is described in more detail in U.S. patent application Ser. No. 16/951,605, authored by Thomas et al. and filed on Nov. 18, 2020, the entire contents of which are incorporated herein by reference.

[0490] In alternative embodiments, one of the other fluid routing plugs described herein or described in U.S. patent application Ser. No. 16/951,605, authored by Thomas et al. and filed on Nov. 18, 2020, may be installed within the housing **1102**. In such embodiments, the housing **1102** may be configured to receive the chosen fluid routing plug.

[0491] Continuing with FIGS. **132** and **133**, the stuffing box **140** and corresponding components are shown attached to a second surface **1140** of the housing **1102**. The connect plate **118** is also shown attached to the housing **1102** in FIG. **132**. A plurality of notches are not shown formed in the housing **1102** adjacent its second surface **1140**. In alternative embodiments, the housing **1102** may include a plurality of notches, like the notches **136** shown in FIG. **6**.

[0492] With reference to FIGS. **139**A-**139**D, another embodiment of a fluid end section **1500** is shown. The fluid end section **1500** is generally identical to the fluid end section **102**, shown in FIGS. **7**A and **7**B but its housing **1502** has an integrally formed connect plate **1504**. Thus, the connect plate **1504** forms an extension of the housing **1502**, such that it functions as a flange on the housing **1502**. A plurality of openings **1506** are formed in the connect plate **1504** for receiving the stay rods **120**, as shown in FIG. **139**D. The stay rods **120** are attached to the connect plate **1504** in the same manner as they are attached to the connect plate **118**, shown in FIG. **16**.

[0493] With reference to FIGS. **140** and **141**, another embodiment of a fluid end section **1200** is shown. The fluid end section **1200** comprises another embodiment of a housing **1202**. The housing **1202** is generally identical to the housing **1102** but comprises a first section **1204** joined to a second section **1206** by a fastening system **1208**. A discharge bore **1210** is formed in the first section **1204** and a pair of intake bores **1212** and **1214** are formed in the second section **1206**, as shown in FIG. **140**. The first section **1204** joins the second section **1206** between the discharge bore **1210** and the intake bores **1212** and **1214**.

[0494] With reference to FIGS. **142-148**, the first section **1204** comprises a first surface **1216** joined to a second surface **1218** by an intermediate surface **1220**. A horizontal bore **1222** extends through the first section **1204** and interconnects the first and second surfaces **1216** and **1218**. Internal threads **1217** are formed in the walls of the first section **1204** surrounding the horizontal bore **1222** adjacent the first surface **1216**, as shown in FIGS. **143** and **145**.

[0495] The intermediate surface **1220** of the first section **1204** includes a first portion **1224** joined to a second portion **1226**. The second portion **1226** has a reduced diameter from that of the first portion **1224** and is positioned adjacent the second surface **1218** of the first section **1204**. A plurality of passages **1223** are formed in the first section **1204** and surround the horizontal bore **1222**. Each passage **1223** interconnects the first surface **1216** and a base **1219** of the first portion **1224**.

[0496] With reference to FIGS. **149-152**, the second section **1206** comprises a first surface **1228** joined to a second surface **1230** by an intermediate surface **1232**. A horizontal bore **1234** extends through the second section **1206** and interconnects the first and second surfaces **1228** and **1230**. A counterbore **1235** is formed in the first surface **1228** of the second section **1206** that is sized to fittingly receive the second portion **1226** of the first section **1204**. A plurality of threaded openings **1233** are formed in the first surface **1228** of the second section **1206** and surround the horizontal bore **1234**. The openings **1233** are alignable with the passages **1223**, in a one-to-one-relationship.

[0497] Turning back to FIG. **140**, when the second portion **1226** is installed within the counterbore **1235**, the base **1219** of the first portion **1224** abuts the first surface **1228** of the second section **1206**. A seal **1238** is interposed between an outer surface of the second portion **1226** and the walls of the second section **1206** surrounding the counterbore **1235**. The seal **1238** is installed within a groove **1240** formed in the walls of the second section **1206** surrounding the counterbore **1235**, as shown in FIGS. **149** and **152**. The seal **1238** and groove **1240** may be identical to the seal **376** and the groove **406**, shown in FIG. **70**.

[0498] Continuing with FIG. **141**, the fastening system **1208** comprises a plurality of studs **1242**, nuts **1244**, and washers **1246**. The fastening system **1208** attaches the first section **1204** to the second section **1206** in the same fashion as the fastening system **1108** attaches the retainer **1106** to the housing **1102**, shown in FIG. **133**. A first end **1248** of each stud **1242** is configured to mate with the openings **1233** formed in the first surface **1228** of the second section **1206**, in a one-to-one relationship. The passages **1223** formed in the first section **1204** subsequently receive the plurality of studs **1242** projecting from the first surface **1228**. A nut **1244** and washer **1246** are subsequently installed on a second end **1250** of each stud **1242** and is turned until the first section **1204** and the second section **1206** are secured together.

[0499] In operation, the second section **1206** experiences higher fluid pressure and therefore more stress than the first section **1204**. Thus, the first section **1204** may be made of a lower strength and less costly material than the second section **1206**. If any failures occur in the first section **1204** during operation, the first section may be removed and replaced with a new first section **1204**. Likewise, if any failures occur in the second section **1206** during operation, the second section can be removed and replaced with a new second section **1206**.

[0500] Continuing with FIGS. **140** and **141**, the stuffing box **140** and corresponding components are shown attached to the second surface **1230** of the second section **1206**. The fluid routing plug **1138** is shown installed within both the first and second sections **1204** and **1206**. The walls surrounding the aligned horizontal bores **1222** and **1234** are configured to mate with the fluid routing plug **1138**. Fluid is routed throughout the fluid routing plug **1138** and the first and second sections **1204** and **1206** in the same manner as the fluid routing plug **116** and the housing **104**, shown in FIGS. **50** and **51**.

[0501] In alternative embodiments, one of the other fluid routing plugs described herein or described in U.S. patent application Ser. No. 16/951,605, authored by Thomas et al. and filed on Nov. 18, 2020, may be installed within the first and second sections **1204** and **1206**. In such embodiments, the first and second sections **1204** and **1206** may be configured to receive the chosen fluid routing plug.

[0502] With reference to FIG. **153**, another embodiment of a fluid end section **1300** is shown. The fluid end section **1300** comprises another embodiment of a housing **1302**. The housing **1302** comprises a first surface **1304** joined to a second surface **1306** by an intermediate surface **1308**. A horizontal bore **1305** is formed in the housing **1302** and interconnects the first and second surfaces **1304** and **1306**.
[0503] With reference to FIGS. **154-157**, the intermediate surface **1308** of the housing **1302** includes a first portion **1310** joined to a second portion **1312**. The second portion **1312** has a reduced diameter from that of the first portion **1310** and includes the second surface **1306** of the housing **1302**. The first portion **1310** includes varying diameter sections and has an asymmetrical cross-sectional shape, as shown in FIGS. **156** and **159**. The varying diameter sections and asymmetrical shape are due to portions of the first portion **1310** being removed. Portions of the first portion **1310** have been removed in order to remove excess weight from the housing **1302**, thereby making the housing **1302** easier to move during assembly.
[0504] With reference to FIGS. **160** and **161**, the second portion **1312** of the housing **1302** is sized to receive another embodiment of a stuffing box **1314**. A tapered wall **1316** is formed in the second portion **1312** that extends between the horizontal bore **1305** and the second surface **1306**.
[0505] With reference to FIGS. **162-165**, the stuffing box **1314** is identical to the stuffing box **140** but has a first portion **1318** joined to a second portion **1320** by a tapered portion **1322**. A plurality of passages **1324** are formed in the second portion **1312**. Each passage **1324** interconnects a second surface **1319** of the stuffing box **1314** and the tapered portion **1318**. The tapered portion **1318** conforms to the tapered wall **1316** formed in the second surface **1306** of the housing **1302**. The stuffing box **1314** is attached to the housing **1302** in the same manner as the stuffing box **140**, shown in FIGS. **20** and **21**.
[0506] Continuing with FIG. **160**, another embodiment of a connect plate **1326** is attached to the housing **1302**. A central bore **1328** formed in the connect plate **1326** is sized to receive the second portion **1312** of the housing **1302** and at least a portion of the stuffing box **1314**. The connect plate **1326** is attached to the housing **1302** in the same manner as the connect plate **118**, shown in FIG. **17**. The connect plate **1326** is shown and described in more detail in U.S. Provisional Patent Application Ser. No. 63/053,797, authored by Thomas et al. and filed on Jul. 20, 2020.
[0507] Turning back to FIG. **153**, a discharge bore **1329** formed in the housing **1302** interconnects a bottom surface **1330** of the intermediate surface **1308** and the horizontal bore **1305**. Likewise, a discharge conduit **1332** is shown attached to the bottom surface **1330** of the housing **1302**. In alternative embodiments, the discharge bore may interconnect a top surface of the housing and the horizontal bore, like the discharge bore **178** shown in FIG. **9**. In such embodiment, the discharge conduit is attached to the top surface of the housing, like the discharge conduit **174**, shown in FIG. **9**.
[0508] Continuing with FIG. **153**, another embodiment of a fluid routing plug **1334** is shown installed within the housing **1302**. The walls surrounding the horizontal bore **1305** formed in the housing **1302** are configured to mate with the fluid routing plug **1334**. Fluid is routed throughout the fluid routing plug **1334** and the housing **1302** in the same manner as the fluid routing plug **116** and the housing **104**, shown in FIGS. **50** and **51**. The fluid routing plug **1334** is described in more detail in U.S. patent application Ser. No. 16/951,605, authored by Thomas et al. and filed on Nov. 18, 2020.
[0509] In alternative embodiments, one of the other fluid routing plugs described herein or described in U.S. patent application Ser. No. 16/951,605, authored by Thomas et al. and filed on Nov. 18, 2020, may be installed within the housing **1302**. In such embodiment, the housing **1302** may be configured to receive the chosen fluid routing plug.
[0510] With reference to FIGS. **166** and **167**, another embodiment of a fluid end section **1400** is shown. The fluid end section **1400** comprises a housing **1402** having a first surface **1404** joined to a second surface **1406** by an intermediate surface **1408**. The housing **1402** further comprises an

elongate plunger housing **1410** joined to the second surface **1406** of the housing **1402**. A horizontal bore **1412** is formed in the housing that interconnects the first surface **1404** and terminal end **1414** of the plunger housing **1410**. Only one intake bore **1416** is shown in the housing **1402**. In alternative embodiments, the housing **1402** may include a second intake bore.

[0511] Continuing with FIG. **167**, the plunger housing **1410** is used in place of the stuffing box **140**, shown in FIGS. **20** and **21**. The plunger housing **1410** is sized to receive an elongate plunger **1418**. Fluid is routed throughout the housing **1402** in the same manner as the housing **104**, shown in FIGS. **50** and **51**, but the plunger **1418** has a much longer plunger stroke.

[0512] Continuing with FIG. **167**, another embodiment of a fluid routing plug **1420** is shown installed within the housing **1402**. The walls surrounding the horizontal bore **1412** formed in the housing **1402** are configured to mate with the fluid routing plug **1420**. Fluid is routed throughout the fluid routing plug **1420** and the housing **1402** in the same manner as the fluid routing plug **116** and the housing **104**, shown in FIGS. **50** and **51**. The fluid routing plug **1420** is described in more detail in U.S. patent application Ser. No. 16/951,605, authored by Thomas et al. and filed on Nov. 18, 2020.

[0513] In alternative embodiments, one of the other fluid routing plugs described herein or described in U.S. patent application Ser. No. 16/951,605, authored by Thomas et al. and filed on Nov. 18, 2020, may be installed within the housing **1402**. In such embodiment, the housing **1402** may be configured to receive the chosen fluid routing plug.

[0514] The housings described herein have various embodiments of suction valves, discharge valves, suction valve guides, and discharge valve guides. One of skill in the art will appreciate that these components may have various shapes and sizes depending on the construction of the housing and various components.

[0515] While not shown herein, in an alternative embodiment, the fluid end **100** described herein may be formed as a single housing having a plurality of horizontal bores formed therein and positioned in a side-by-side relationship. The housing may be attached to a single, large connect plate. In further alternative embodiments, the single housing described above may be broken up into one or more sections having two or more horizontal bores formed therein. Such housings may be attached to one or more connect plates.

[0516] One of skill in the art will further appreciate that various features of the fluid routing plugs, housings, and other components described herein may be modified or changed, as desired. While not specifically shown in a figure herein, various features from one or more of the fluid routing plugs described herein may be included in another one of the plugs. Likewise, various features from one or more of the different housings described herein may be included in another one of the housings.

[0517] The concept of a “kit” is described herein due to the fact that fluid ends are often shipped or provided unassembled by a manufacturer, with the expectation that a customer will use components of the kit to assemble a functional fluid end. Alternatively, some components are replaced during operation. Accordingly, certain embodiments within the present disclosure are described as “kits,” which are unassembled collections of components. The present disclosure also describes and claims assembled apparatuses and systems by way of reference to specified kits, along with a description of how the various kit components are actually coupled to one another to form the apparatus or system.

[0518] The term “means for routing fluid” refers to the various fluid routing plugs described herein and structural equivalents thereof. The term “means for regulating fluid flow” refers to the various suction and discharge valves and suction and discharge valve guides described herein and structural equivalents thereof. A “means for pressurizing fluid” refers to the fluid end and the various embodiments of housings and components installed within or attached to the various housings described herein and structural equivalents thereof.

[0519] As used herein, “modular” means an apparatus that is comprised of a plurality of components joined together to form a complete apparatus. Such components may be removable and replaceable with like components, if needed. For example, in some embodiments of the fluid end **100** described herein, the fluid end **100** comprises a plurality of fluid end sections **102** joined together to form the fluid end **100**. Each fluid end section **102** may be removed and replaced with a new fluid end section **102**, if needed.

[0520] The various features and alternative details of construction of the apparatuses described herein for the practice of the present technology will readily occur to the skilled artisan in view of the foregoing discussion, and it is to be understood that even though numerous characteristics and advantages of various embodiments of the present technology have been set forth in the foregoing description, together with details of the structure and function of various embodiments of the technology, this detailed description is illustrative only, and changes may be made in detail, especially in matters of structure and arrangements of parts within the principles of the present technology to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed. Changes may be made in the construction, operation and arrangement of the various parts, elements, steps and procedures described herein without departing from the spirit and scope of the invention as described in the following claims.

Claims

1. A fluid end section, comprising: a housing having a bore formed therein; a fluid routing plug situated within the bore, the fluid routing plug comprising a body having opposed first and second surfaces; a first valve configured to engage the first surface of the fluid routing plug; a second valve configured to engage the second surface of the fluid routing plug; a valve guide configured to prevent axial movement of the first valve, the valve guide comprising: a body having a central passage formed therein, the central passage configured to receive a portion of the first valve; and a cylindrical component situated in the bore and abutting the valve guide.

2. The fluid end section of claim 1, in which the valve guide is formed from a first material and the cylindrical component is formed from a second material.

3. The fluid end section of claim 2, in which the second material is harder than the first material.

4. The fluid end section of claim 1, further comprising an insert installed within the central passage and surrounding the portion of the first valve; in which the portion of the first valve is a valve stem.

5. A fluid end section, comprising: a housing having a bore formed therein; a valve pair situated within the bore, the valve pair comprising: a first valve; and a second valve; and a valve guide situated within the bore and configured to prevent axial movement of the first valve, the valve guide comprising: a first section; and a cylindrical section engaging the first section, in which the cylindrical section is separable from the first section at a separation point.

6. The fluid end section of claim 5, in which the cylindrical section is formed from a different material than a material used to form the first section.

7. The fluid end section of claim 6, in which the material used to form the cylindrical section is harder than the material used to form the first section.

8. The fluid end section of claim 5, further comprising a fluid routing plug installed within the bore.

9. The fluid end section of claim 8, in which the fluid routing plug is situated intermediate the first valve and the second valve.

10. The fluid end section of claim 8, in which the fluid routing plug comprises: a first surface configured to engage the first valve; and a second surface configured to engage the second valve.

11. A fluid end section, comprising: a housing having a longitudinal axis and a bore extending along the longitudinal axis; a first valve situated within the bore; a second valve situated within the bore; and a first valve guide configured to prevent axial movement of the first valve, the first valve guide comprising: a first section; and a second section separable from the first section.

12. The fluid end section of claim 11, in which the first section is formed from a first material and the second section is formed from a second material.

13. The fluid end section of claim 12, in which the second material is harder than the first material.

14. The fluid end section of claim 11, in which the first section abuts the second section at a separation point.

15. The fluid end section of claim 11, further comprising a fluid routing plug installed within the bore; in which the fluid routing plug is situated intermediate the first and second valves.

16. The fluid end section of claim 15, further comprising a reciprocating plunger situated at least partially within the bore; in which the first valve guide is situated intermediate the plunger and the first valve.

17. The fluid end section of claim 11, in which the first valve comprises a valve stem.

18. The fluid end section of claim 17, in which the first section comprises a central passage, the central passage configured to receive the valve stem.

19. The fluid end section of claim 18, further comprising an insert installed within the central passage, the insert surrounding and engaging the valve stem.

20. The fluid end section of claim 19, in which the insert is formed of tungsten carbide.

21. A method of manufacturing the fluid end section of claim 11, in which the second section is made from a first material and a separate second material, the method comprising: forming the first material into a cylindrical shape; and applying the second material to the cylindrical shape.
