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(54) **HIGH PRESSURE FLUID SWIVEL**

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(52) **U.S. Cl.**

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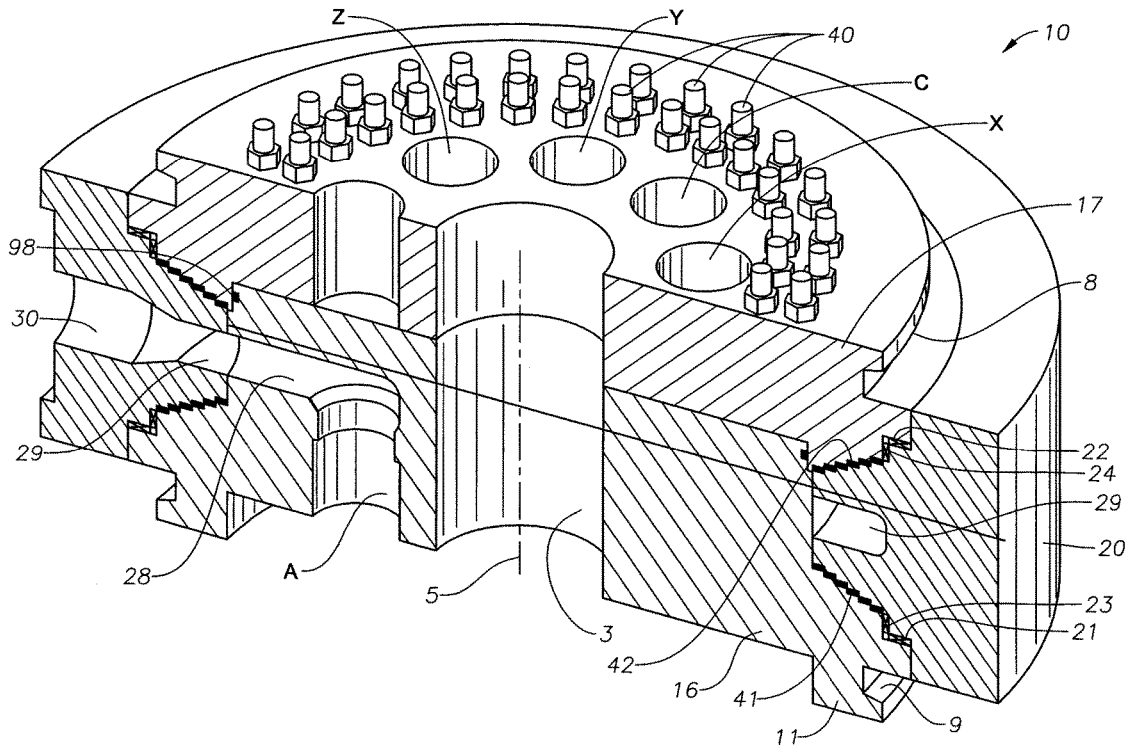
(57) **ABSTRACT**

A high pressure swivel is disclosed which includes swivel modules each having a stationary inner structure and a rotatable outer structure that can rotate about the inner structure. The inner structure of each module has the same number of vertical passages as the others. The inner structure of each module has a circumferential flange on the top and on a bottom lip so that each swivel unit can be secured to another swivel in its top or bottom with clamps around the flanges. The inner structures are rotatably positioned with respect to each other when assembled so that a vertical passage from a stationary base manifold to an outlet on the rotatable outer structure is formed. Various combinations of standard swivel modules can be assembled to accommodate specific swivel stack requirements for flow capacity and separate or commingled flow paths.



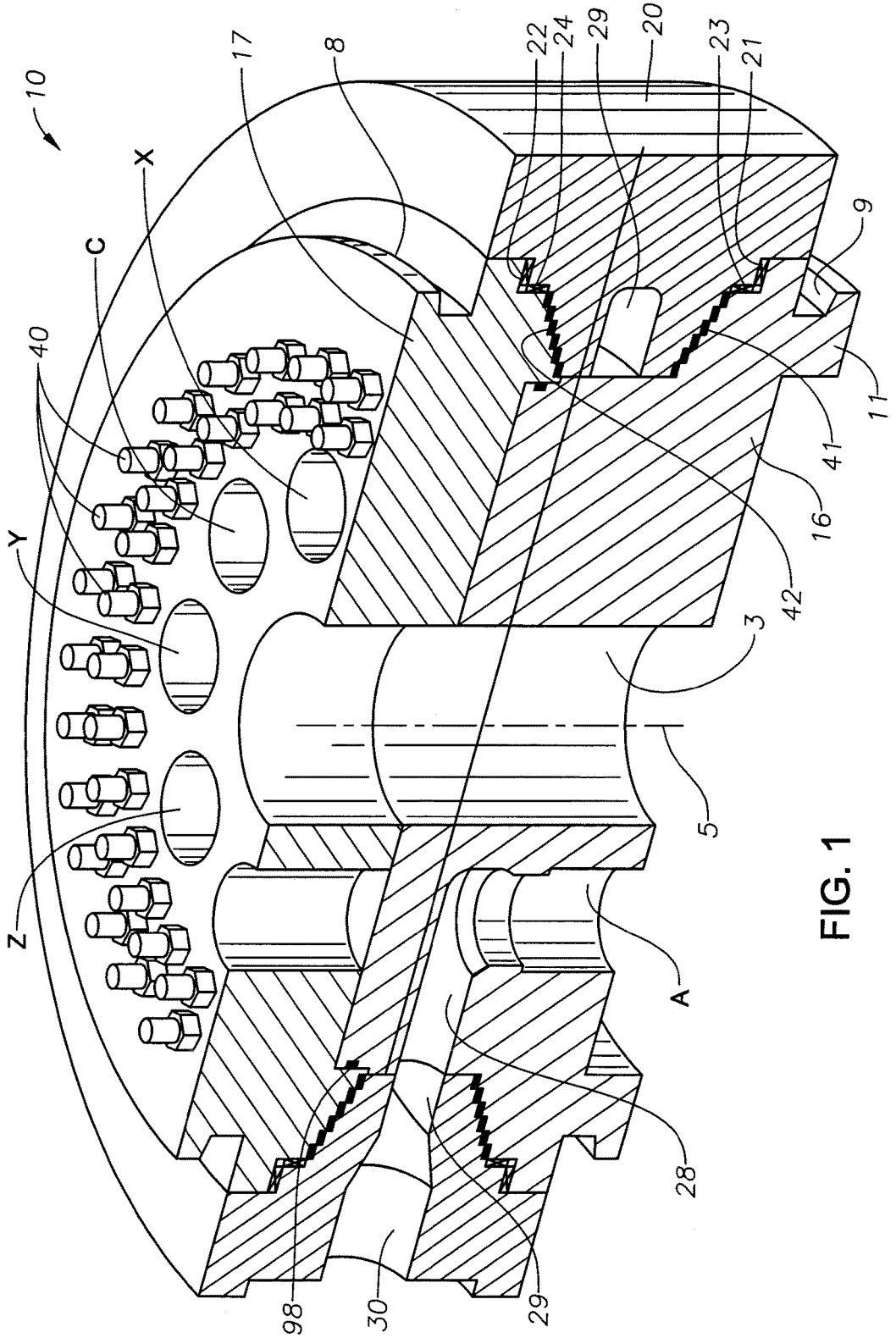


FIG. 1

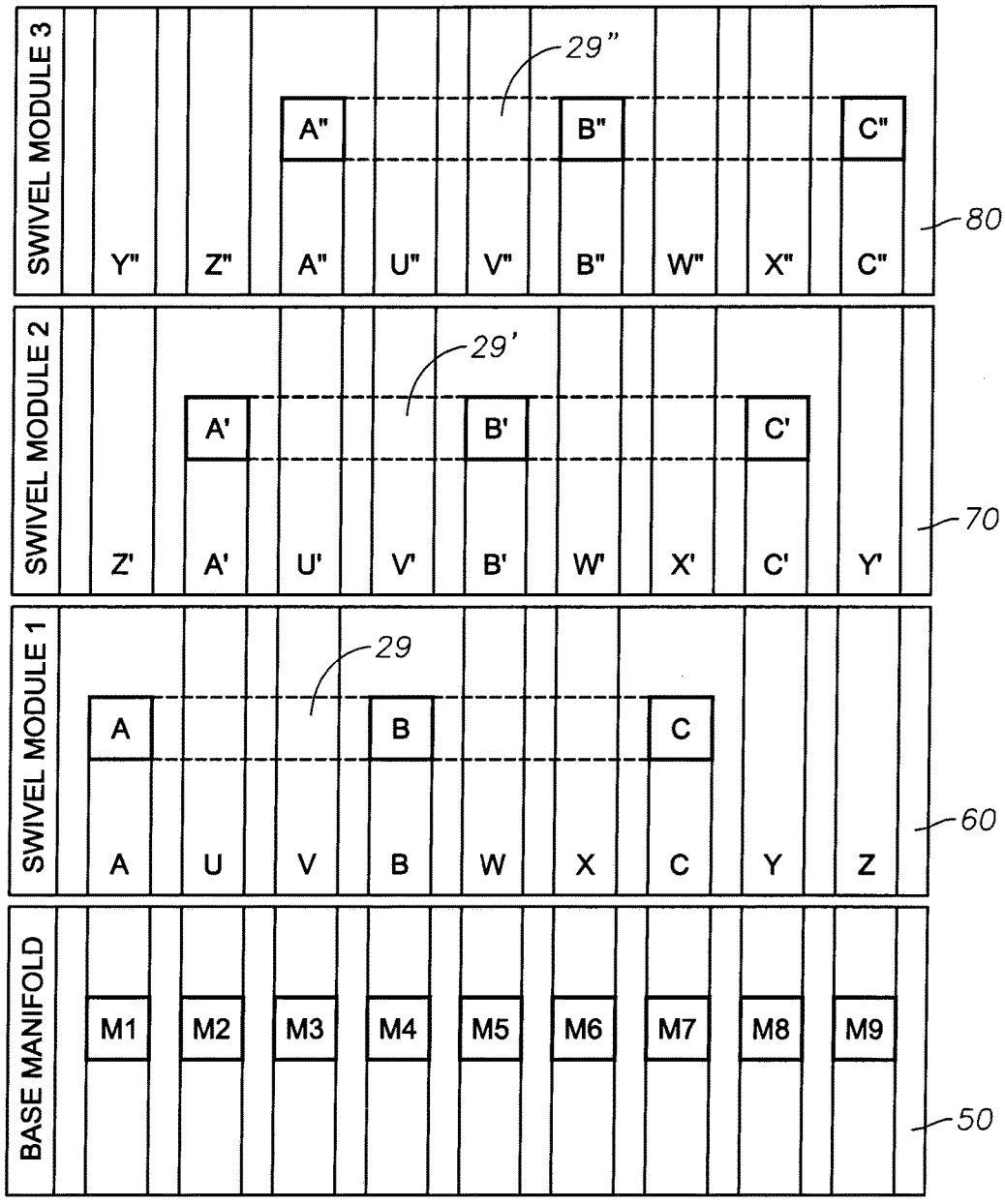

SWIVEL MODULE 3
29"
A"
B"
C"
Y"
Z"
A"
U"
V"
B"
W"
X"
C"
80
SWIVEL MODULE 2
29'
A'
B'
C'
Z'
A'
U'
V'
B'
W'
X'
C'
Y'
70
SWIVEL MODULE 1
29
A
B
C
A
U
V
B
W
X
C
Y
Z
60
BASE MANIFOLD
M1
M2
M3
M4
M5
M6
M7
M8
M9
50

FIG. 2A

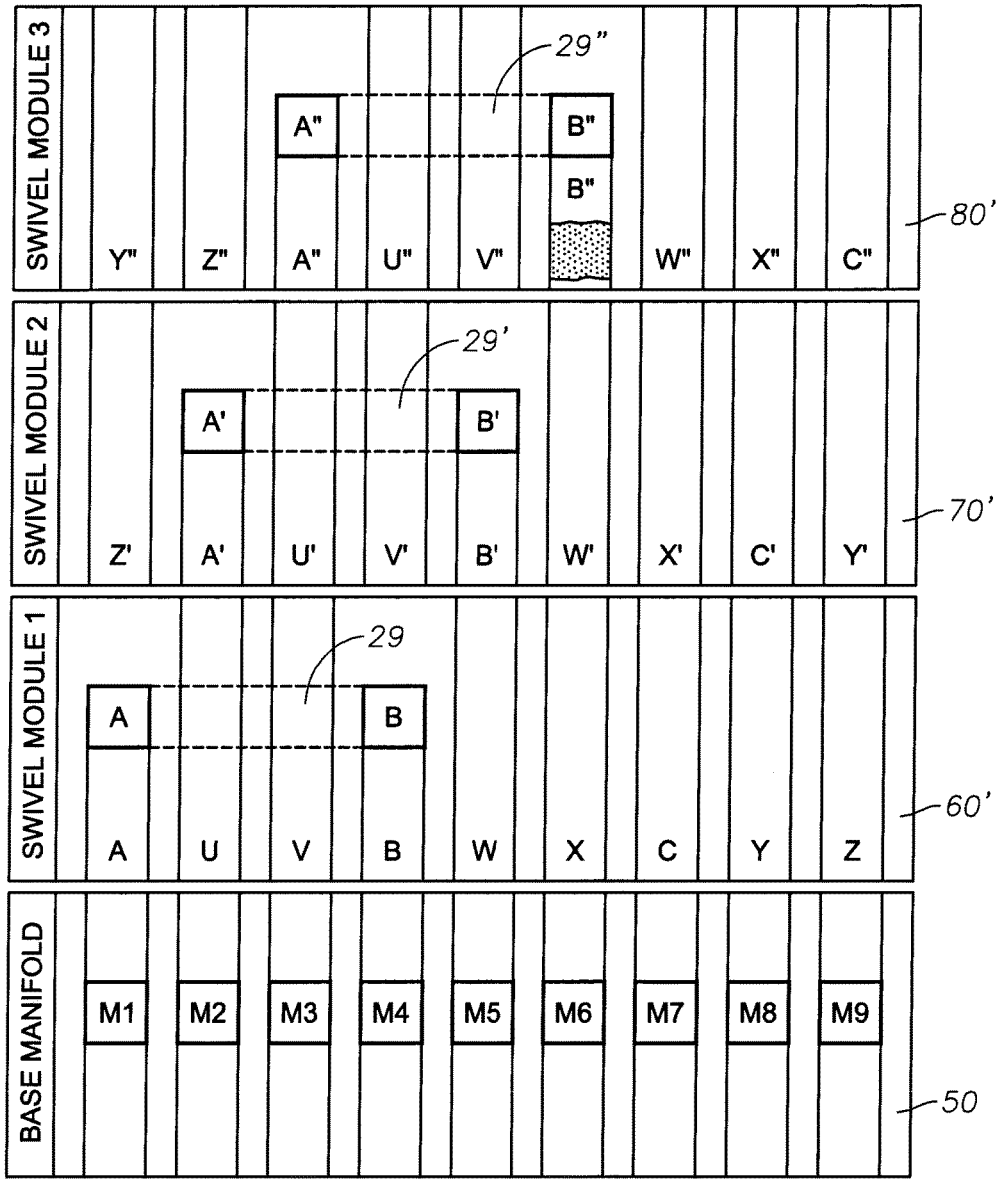

SWIVEL MODULE 3
Y"
Z"
A"
U"
V"
W"
X"
C"
A"
B"
B"
29"
80'
SWIVEL MODULE 2
Z'
A'
U'
V'
B'
W'
X'
C'
Y'
A'
B'
29'
70'
SWIVEL MODULE 1
A
U
V
B
W
X
C
Y
Z
A
B
29
60'
BASE MANIFOLD
M1
M2
M3
M4
M5
M6
M7
M8
M9
50

FIG. 2B

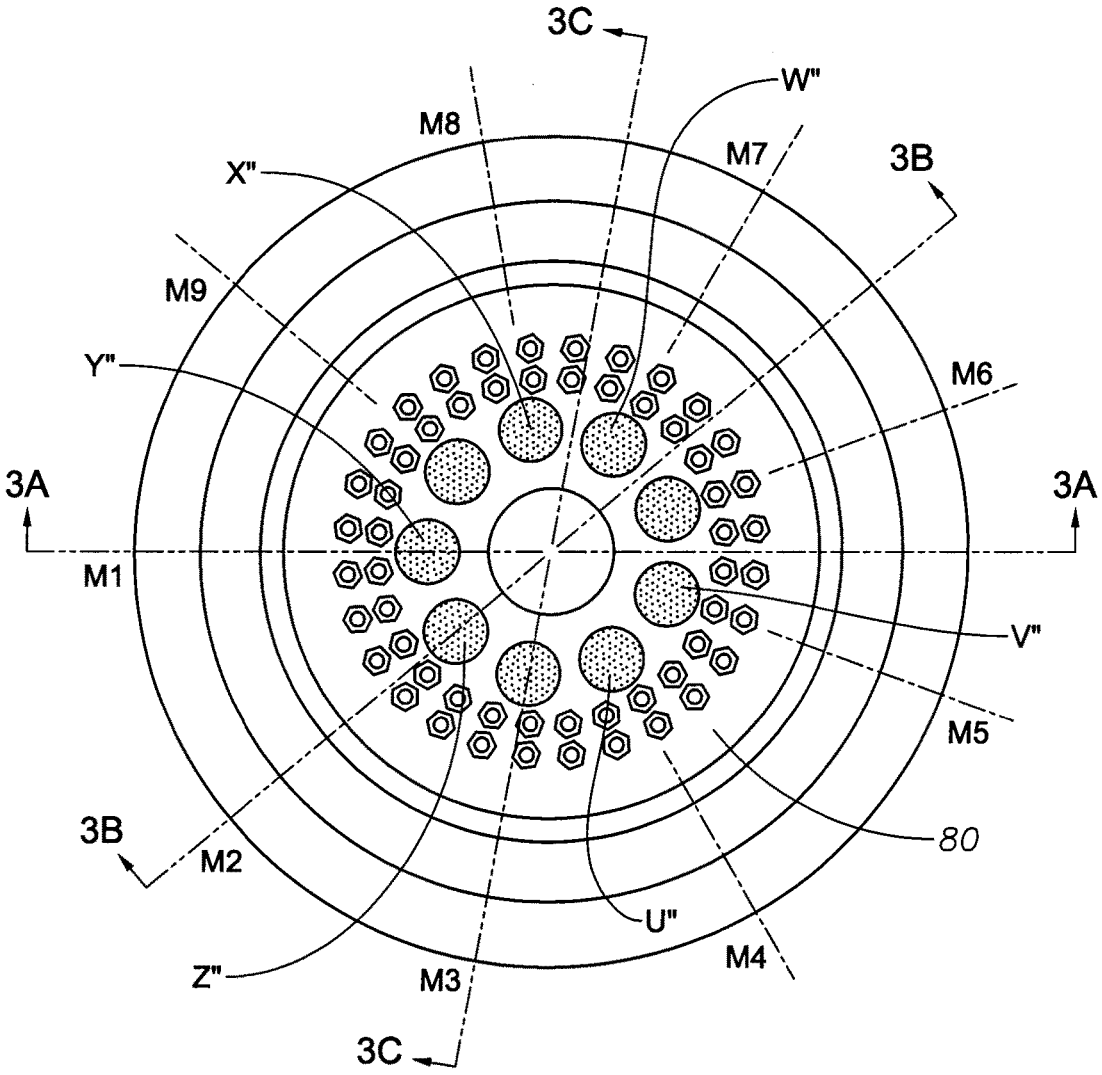


FIG. 3

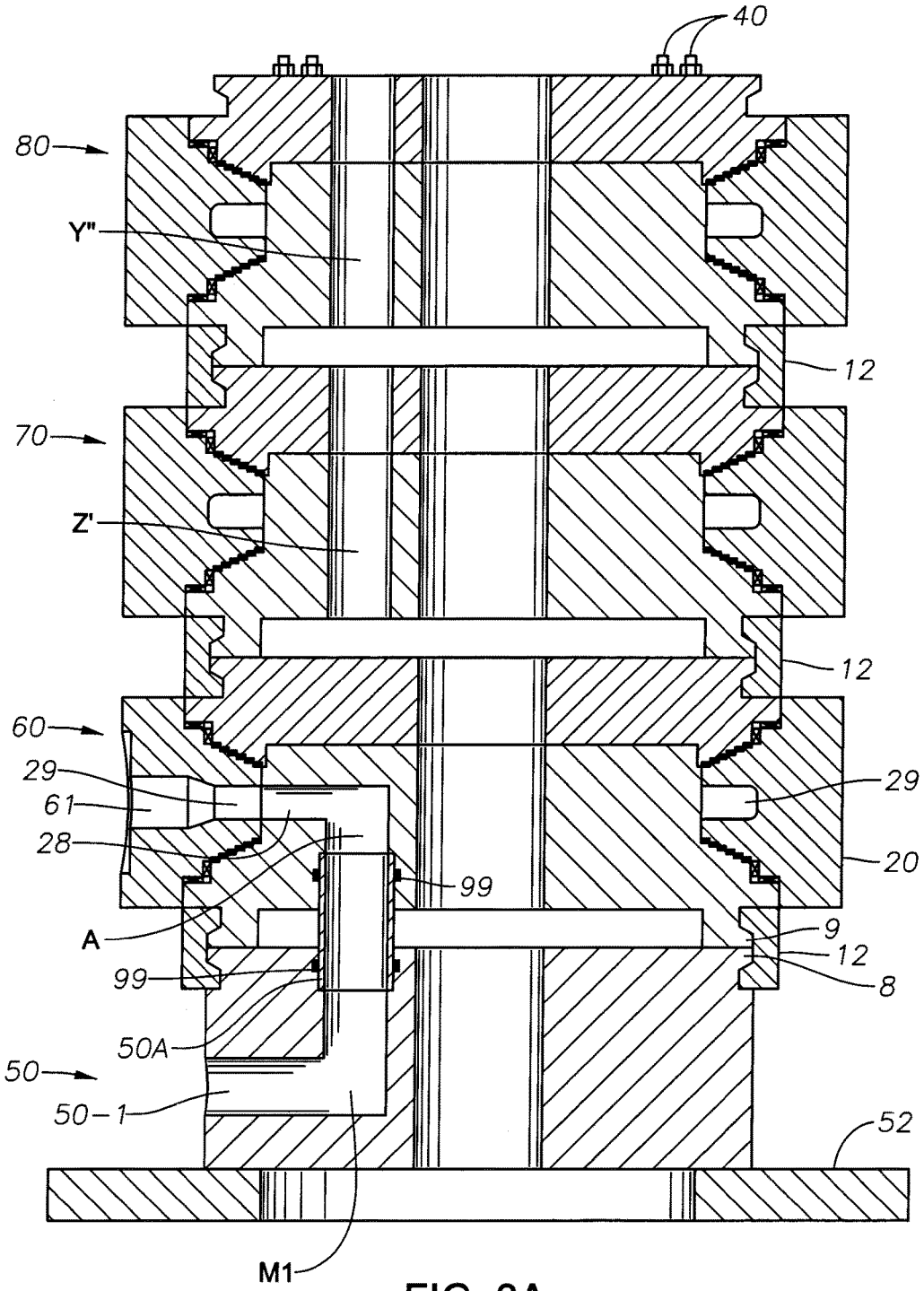


FIG. 3A

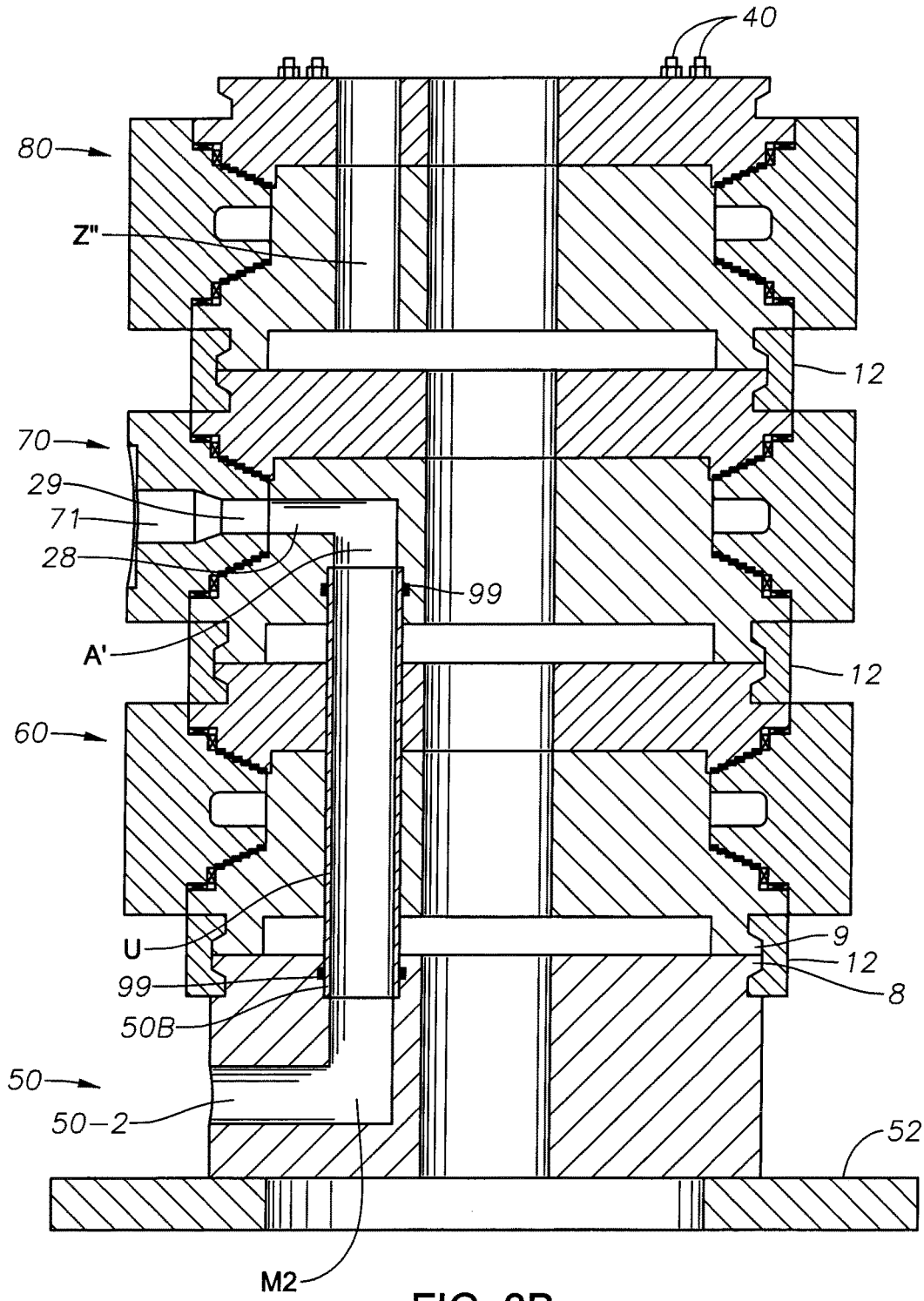


FIG. 3B

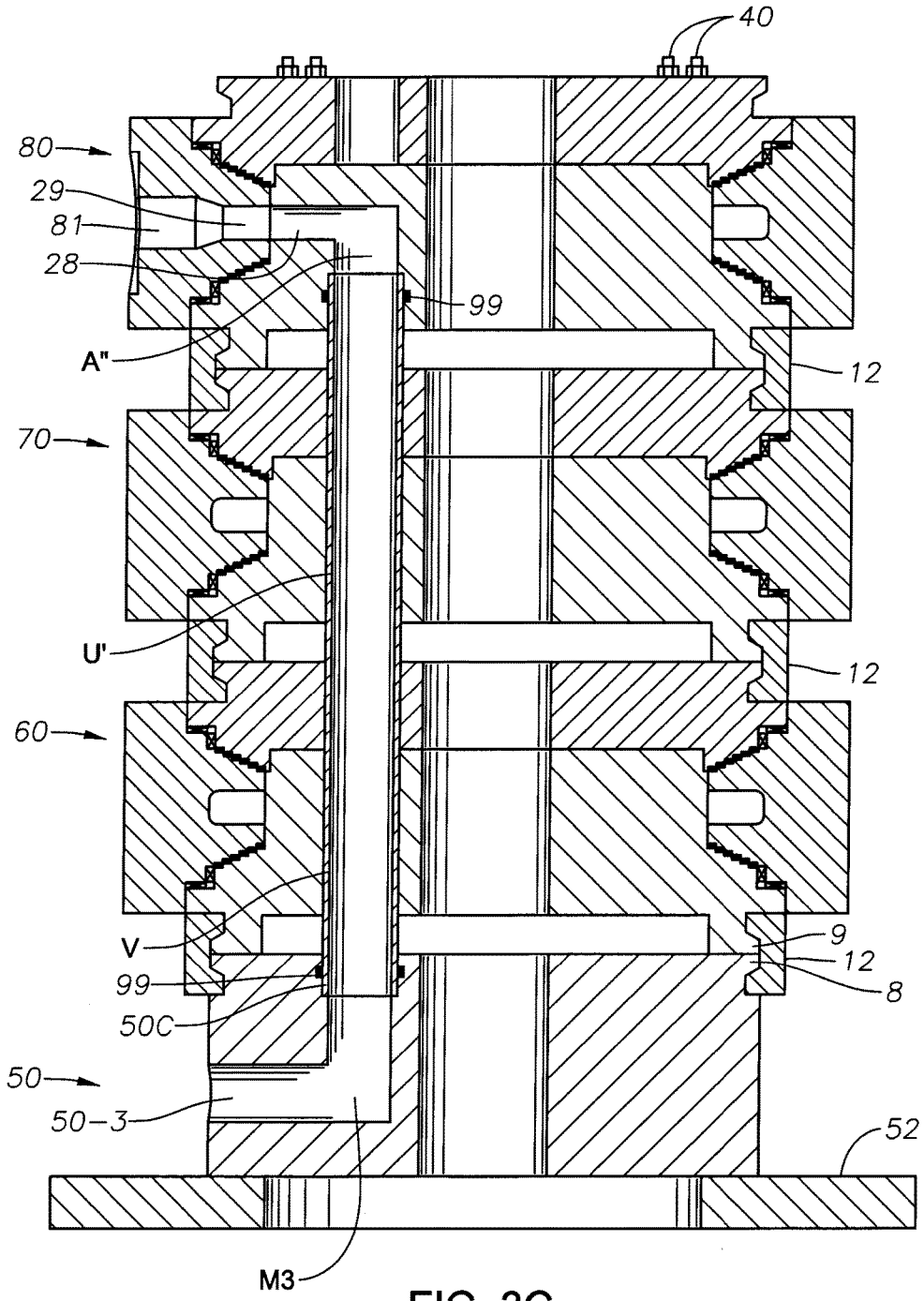


FIG. 3C

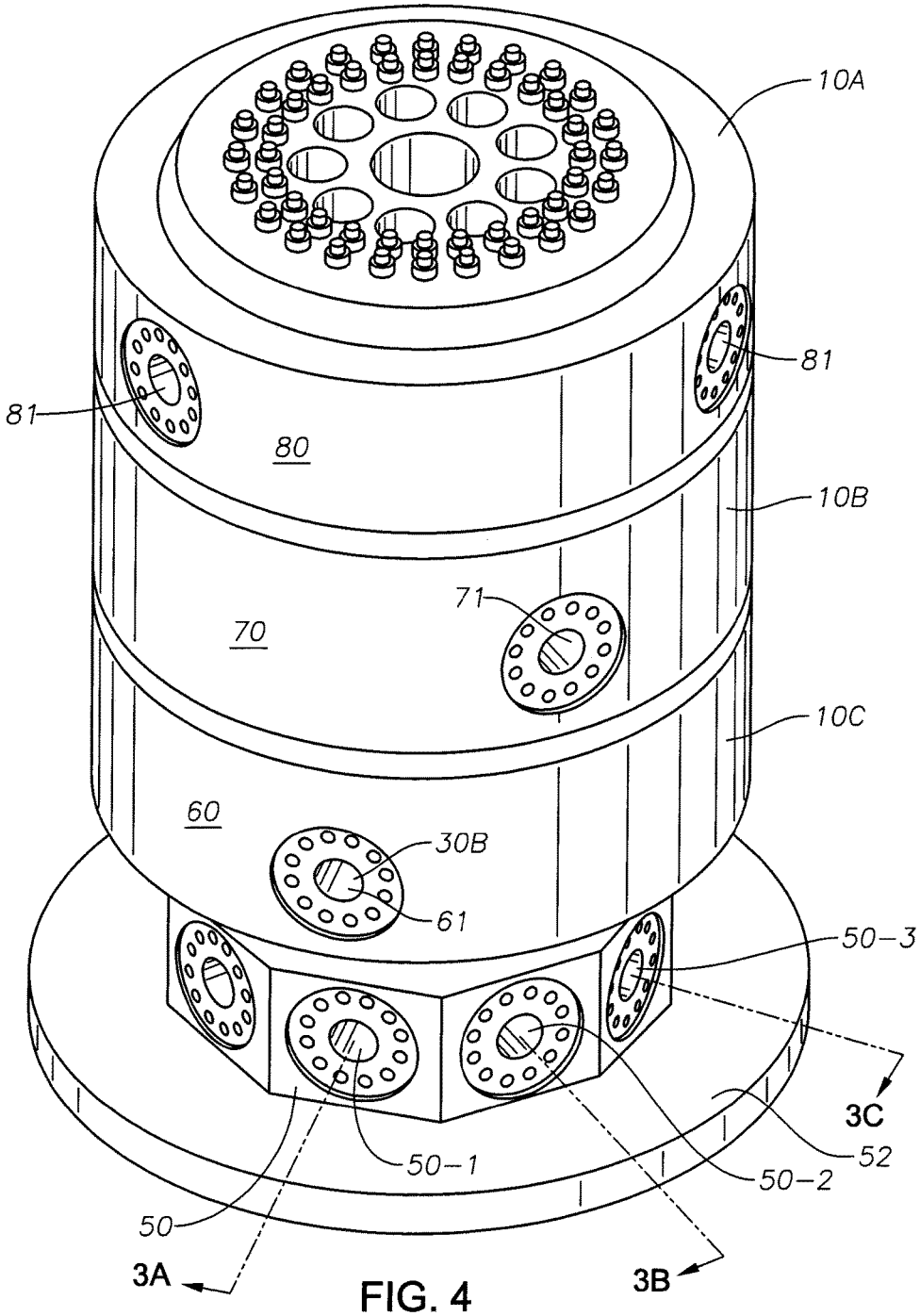


FIG. 4

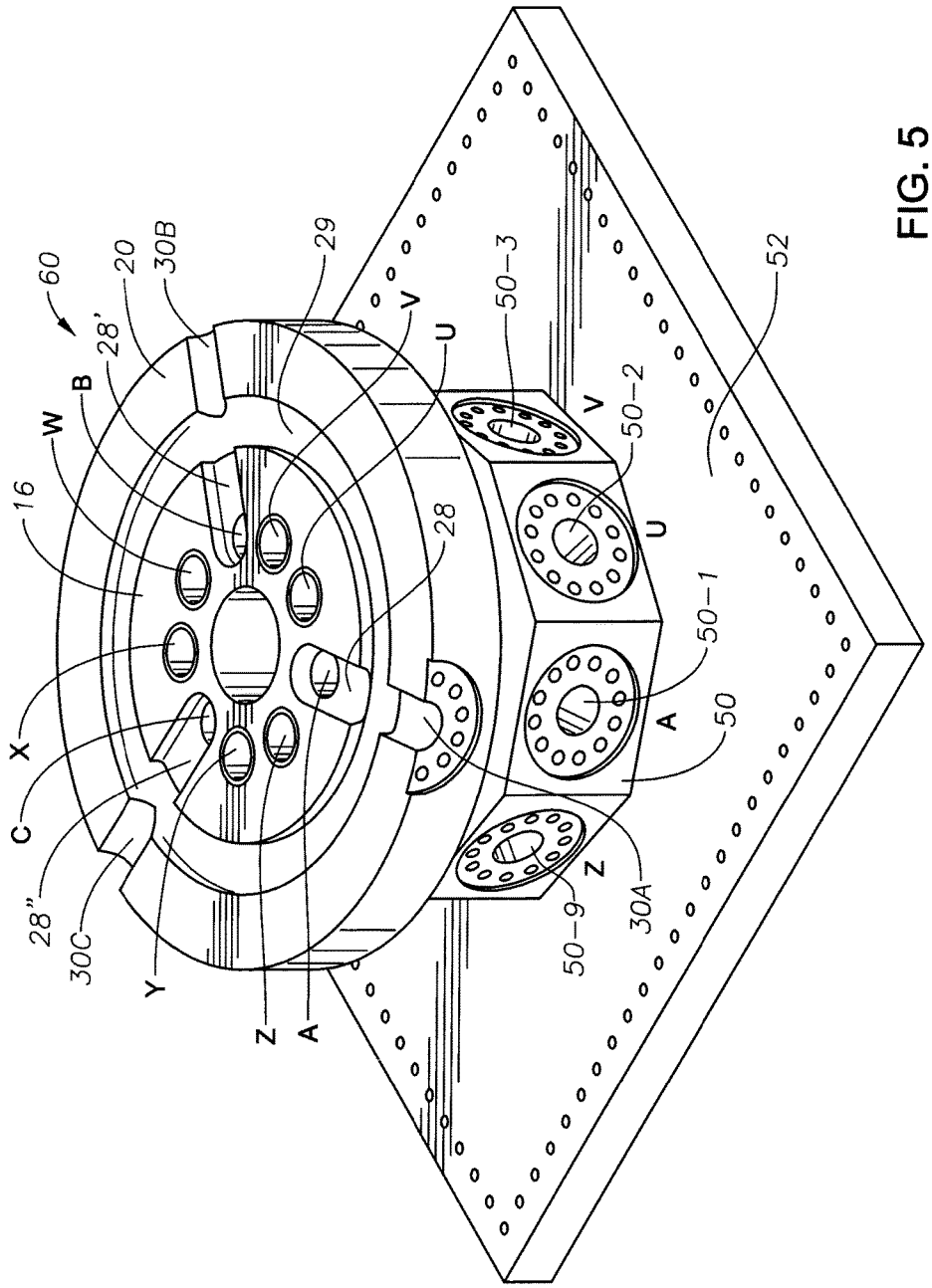

60
20
30B
29
28'
V
U
50-3
52
B
W
50-2
16
28
X
50-1
C
A
50
28"
30C
Y
Z
A
50-9
Z
30A

FIG. 5

HIGH PRESSURE FLUID SWIVEL

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] This invention relates in general to swivel equipment for transferring fluids. In particular, the invention relates to a fluid swivel joint for a swivel stack assembly adapted for transferring fluids between tankers, storage vessels and the like and one or more conduits beneath the ocean surface. The fluid of the swivel may be product such as hydrocarbons to be transferred from the seabed to a vessel or may be water or gas to be transferred from the vessel to the seabed for well stimulation.

[0003] Still more particularly, the invention relates to a novel fluid joint which can be stacked with one or more other fluid joints of like design so that a swivel stack can be assembled in a short time from an inventory of the fluid joints.

[0004] 2. Description of the Prior Art

[0005] The offshore search for oil and gas has greatly expanded in recent years and progressed into deep rough waters such as the North Sea. To facilitate production of oil and gas from remotely located offshore fields, complex mooring systems for offshore loading terminals, which serve as centralized production sites for the entire field, have been developed. Flexible fluid lines, called risers, extend from a subsea location to the mooring site to permit the transfer of fluids between a moored vessel and a subsea location. For example, certain fluid lines may be used to convey oil and gas into the floating vessel while other fluid lines may be used to inject liquids or gases back from the vessel into subsea wells for purpose of control, well stimulation, or storage.

[0006] Floating vessels can be moored to a single point mooring system, which permits the vessel to weathervane and rotate 360° about a single mooring point. To permit the vessel to rotate and move freely without causing twisting or entanglement of the various risers to which the vessel is attached, it is necessary to provide a fluid swivel assembly to connect the fluid lines to the mooring site. Furthermore, since a plurality of risers are involved, it is necessary that two or more swivel modules be stacked in order to have the capability of accommodating multiple fluid lines or risers.

[0007] Separate swivel units or modules are stacked on top of each other with a swivel stack base fixed to a stationary frame which is anchored to the sea floor.

[0008] Prior high pressure product swivels have provided an inner housing and an outer housing which is rotatively supported on the inner housing by a bearing so that the outer housing is free to rotate about the inner housing. A toroidally shaped conduit chamber is formed between the two housings when the two housings are placed in registration with each other. An inlet from the inner housing communicates with the chamber, and an outlet in the outer housing communicates with the chamber. Upper and lower dynamic seals in the form of face seals or radial seals are placed in grooves or gaps between axially opposed or radially opposed surfaces of the inner and outer housings to prevent fluid from leaking past the two facing surfaces while the high pressure fluid is present in the chamber.

[0009] Prior swivel assemblies have required swivel units to be stacked on top of each other with each unit having its inner housing bolted to the inner housing of a unit stacked above or below. Furthermore, the entire stack of swivel units have been bolted to a base housing. Such an assembly functions properly as a swivel stack unit, but construction of the units and assembly requires that each stack be engineered for each requirement of an offshore application. Such prior assemblies have been costly to design, engineer, and build and have required a long lead time from contract signing to construction and delivery of the swivel stack.

[0010] 3. Identification of Objects of the Invention

[0011] A primary object of the invention is to provide a high pressure fluid swivel arrangement constructed from swivel units or modules that can be stacked and secured to each other without securing the swivel units together with long bolts through their inner housing.

[0012] Another object of the invention is to provide a pre-designed fluid swivel unit or module having vertical passages such that fluid swivel units can be pre-constructed and then stacked on top of each other and to a base housing so that fluid passages can be aligned from the base housing to desired outlets of the stacked fluid swivel units.

SUMMARY OF THE INVENTION

[0013] The objects identified above, as well as other advantages and features of the invention are incorporated in a rotatable fluid swivel unit and an assembly of such units into a swivel stack onto a base housing. Each swivel unit has inner and outer housings with one or more fluid pressure carrying radial annular groove cavities in the annular outer housing. Each annular groove cavity has one or more outlets from the outer housing. Each swivel unit has at least one vertical passage in the inner housing that terminates at a radial groove, but has other swivel vertical passages spaced equally from each other around a circle of a horizontal cross section through the inner housing.

[0014] An assembly of such swivel units is made from pre-constructed swivel units so as to achieve desired flow paths from the base housing to the radial outlets in the outer housings of the stacked modules.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] The objects, advantages, and features of the invention will become more apparent by reference to the drawings which are appended hereto, wherein like reference numbers indicate like parts, and wherein an illustrative embodiment of the invention is shown, of which:

[0016] FIG. **1** is a cross section view of a swivel module with a stationary inner annular structure and a rotatable outer housing with a plurality of vertical fluid passages spaced around a circle of the inner annular structure with one of the passages terminating at a fixed radial groove in the stationary inner structure, the groove communicating with a radial outlet of the rotatable outer housing;

[0017] FIG. **2**A in a flat layout illustration showing the stationary inner structure of three identical swivel units stacked on top of each other and onto a base housing with certain vertical passages terminating at a lower swivel unit and other vertical passages communicating with vertical passages of units stacked above;

[0018] FIG. **2**B is another flat layout illustration showing the stationary inner structure of three identical swivel units stacked on top of each other onto a base housing with a set of two vertical passages terminating at a lower swivel unit,

with one passage blocked off and other vertical passages communicating with vertical passages of units stacked above;

[0019] FIG. **3** is a top view of the swivel modules of FIG. **2**A showing section lines **3**A-**3**A, **3**B-**3**B, and **3**C-**3**C of a swivel assembly that is illustrated in FIGS. **3**A, **3**B, and **3**C;

[0020] FIGS. **3**A, **3**B and **3**C are three separate section views (as indicated in FIG. **3**) of a stack of three identical swivel units each having a stationary inner annular structure with nine vertical passages as shown in FIG. **2**A;

[0021] FIG. **4** in an elevation view of the swivel stack of FIGS. **3**A, **3**B, **3**C and with the vertical passages layout of FIG. **2**A; and

[0022] FIG. **5** is an elevation view of the stack of FIG. **4** showing the lower swivel unit with the other swivel units removed to illustrate the stationary inner housing with vertical passages and the rotatable outer housing, all mounted on a base manifold.

DESCRIPTION OF THE INVENTION

[0023] The aspects, features, and advantages of the invention summarized above are described in more detail below by reference to the drawings where like reference numerals represent like elements. The following table provides a list of reference numbers used in this specification and the features that they represent:

Reference Numeral	Feature
3	central passage
5	central longitudinal axis
8	upper flange
9	lower flange
10	swivel module - see FIGS. 2A, 2B
11	lower lip
12	segmented clamp - see FIGS. 3A, 3B, 3C
13	imaginary circle for vertical passages (FIG. 1)
16	swivel inner housing
17	seal plate
20	rotatable outer housing
21	lower axial swivel bearing
22	upper axial swivel bearing
23	lower radial bearing
24	upper radial bearing
28	fixed radial passage in inner housing 16
29	circular groove in outer housing 20
30	out passage
40	bolts
41	lower face seal
42	upper face seal
50	base manifold
50-1-50-2, etc.	radial inlets
M1, M2 . . . , etc.	vertical passages in base manifold
A, U, V . . . , etc.	vertical passages in swivel unit
50-A, 50-B . . .	liner conduit
52	stationary frame
60	swivel unit (MODULE 1)
61	outlet in swivel unit (MODULE -1) (FIG. 4)
70	swivel unit (MODULE 2)
71	outlet (MOD-2)
80	swivel unit (MODULE 3)
81	outlet (MOD-3)
98	static seal
99	static seal for conduits 50

[0024] FIG. **1** is a cross section elevation view of a swivel unit **10** according to the invention where this section view shows the inner annular stationary structure **16**, **17** oriented about a central longitudinal axis **5** through a central passage **3**. The inner annular structure includes a swivel inner housing **16** and a seal plate **17** which are secured together by a plurality of bolts **40**. The rotatable outer housing **20** is rotatably mounted with respect to swivel inner housing **16** and seal plate **17** by axial lateral swivel bearings **21**, **22**. Radial bearings **23**, **24** provide radial support for outer housing **20** while rotating about stationary inner annular structure **16**, **17**.

[0025] The inner annular stationary structure **16**, **17** includes an upper flange **8** formed about the outer periphery of seal plate **17**, and inner housing **16** includes a lower flange **9** formed on an outer periphery of a circumferential lower lip **11** which extends a short distance below the bottom of inner housing **16**. As illustrated below in FIGS. **3**A, **3**B, **3**C, the flanges **8** and **9** are used to couple swivel units stacked on top of each other. A plurality of clamps **12** (see FIGS. **3**A, **3**B, **3**C) secure the flanges **8**, **9** to vertically stacked swivel units. Such clamping enables a swivel unit to be removed and replaced much more easily and rapidly than in prior swivel assemblies where bolts extend through all swivels in a stack.

[0026] The swivel unit **10** has plural vertical passages A, B . . . which have center points arranged on an imaginary circle **13** through the inner annular structure **16**, **17**. A total of nine passages are shown in the drawings, but fewer or more passages could be provided for certain applications. All of the passages are of the same diameter. FIG. **3** is a top view of a swivel unit like that of FIG. **1**. FIG. **3** shows, for an example configuration, that all seal plates **17** can be identical and have nine holes so they can be oriented in any angular position as needed for passage of liner conduits **50**. For the arrangement shown in FIG. **2**A, all passages below top seal plate **17** are used, and the holes in top seal plate **17** are unused. Usually in practice smaller utility swivels having small flow conduits passing through central passage **3** are attached on top of the stack of high pressure swivels. In this case the attachment covers the open holes in upper seal plate **17** and bolts **40** thereby protecting them from the elements. Swivel unit **10** of FIG. **1** shows passage A which terminates and communicates with radial groove **28**, but passage A does not extend up to the hole through seal plate **17**.

[0027] Outer housing **20** includes a circular groove **29** which communicates with radial passage **28** and has an outlet passage **30** which opens into groove **29**. This arrangement allows fluid flow through stationary housing **16** passage A to radial passage **28** into groove **29** and outlet **30** of rotatable housing **20**.

[0028] Upper and lower face seal arrangements **42**, **41** are described in a corresponding patent application by the same inventors of this application. Such application has Ser. No. 14/178,106 and was filed May 19, 2015. Such application is incorporated herein by reference into this specification. Such seal arrangements allow swivel operation at extremely high pressures. Static seals **98** provide static sealing between inner housing **16** and seal plate **17**.

[0029] FIG. **2**A illustrates inner housings of a stack of swivel units like that of FIG. **1**, where each unit **60**, **70**, **80** is like the others with each unit having nine vertical passages formed through the inner housing, with each passage starting in the bottom of the unit. The bottom unit **60** is illustrated as being stacked and clamped atop base manifold **50** which is secured on top of swivel stack support base **52** (see FIG. **4**). As illustrated in FIGS. **3**A, **3**B, **3**C . . . , base manifold **50** has nine radial inlets, **50-1**, **50-1**, **50-3**, **50-4**, **50-5**, **50-6**,

50-7, **50-8**, **50-9** equally angularly spaced from each other with each communicating with its assigned vertical passage, M**1**, M**2**, M**3**, M**4** . . . M**9**.

[0030] FIG. **2**A illustrates that for an example swivel unit **60**, its vertical passages A, U, V, B, W, X, C, Y, Z, are spaced equally about its bottom surface and are aligned respectively with vertical passages M**1**, M**2**, M**3** . . . M**9** of base manifold **50**. For the example of FIG. **2**A, and of FIGS. **3**, **3**A, **3**B, **3**C, each of the vertical passages in the swivel unit **60** and base manifold **50** are angularly spaced by 40 degrees (360°/9). FIG. **2**A shows (see also FIG. **5**) that vertical passages A, B and C terminate in their respective radial passage **28** and communicate with circumferential groove **29** in the outer housing **20**, (see FIGS. **1** and **5**) so fluids input into passages M**1**, M**4** and M**7** of base manifold **50**, when aligned with vertical passages A, B and C of swivel unit **60** terminate via passages **28** to groove **29** and flow out via outlets **61** in swivel unit **60**. (See FIG. **4**) The other passages in swivel unit **60**, U, V, W, X, Y and Z traverse the entire height of internal structure **16**, **17** of the swivel **60** as illustrated in FIG. **2**A. FIG. **1** shows that passages X, C, Y, and Z traverse the entire height of internal structure **16**, **17** and illustrates that several configurations of vertical path commingling are possible as illustrated in FIG. **2**A.

[0031] As shown in FIG. **2**A, stacked swivel units **70** and **80** have the same vertical flow passages configuration as does swivel unit **60**. Swivel unit **70** is rotated by 40° (360°/9) with respect to the orientation of swivel unit **60**, so that the vertical passage A' of unit **70** is aligned with through vertical passage U of unit **60**; vertical passage B' of unit **70** is aligned with through vertical passage W of unit **60**; and vertical passage C' of unit **70** is aligned with through passage Y of unit **60**. The fluid flow from vertical passages M**2**, M**5** and M**8** are commingled via radial passage **28'** to groove **29'** in unit **70**. Finally, for this example, the unit **80**, constructed like units **70**, **60**, but stacked on top of unit **70** and rotated by 40° with respect to unit **70**, has it's A" vertical passage aligned with through passages U' of unit **70** and B" aligned with W' and C" with Y' of unit **70** so that fluid can flow from passage M**3** of base manifold **50** to outlet A" of unit **80**. In the same way, fluid communication is established between outlet B" and passage M**6** via B" of unit **80**, W' of unit **70** and X of unit **60**. Fluid communication is established between outlet C" of unit **80** and M**9** of base manifold **50** via passages C" of unit **80**, Y' of unit **70** and Z of unit **60**.

[0032] FIG. **2**B illustrates another configuration of the swivel units of the invention. The inner housing of the swivel units **60'**, **70'**, **80'** have nine vertical passages starting at the bottom of each unit. FIG. **2**B illustrates that the vertical passages A, U, V, B, W, X, C, Y. Z of swivel unit **60'** are equally spaced about its bottom surface and each one is aligned respectively with one of the vertical passages M**1**, M**2**, M**3** . . . M**9** of base manifold **50**. Only two of the passages, A and B, terminate in a radial passage **28** and circular groove **29**. The swivel unit **70'** has its A' and B' passages aligned with M**2** and M**5** of base manifold **50** and have their circular grooves **29'** linked together. Swivel unit **80'** is similar, but has its vertical passage B" blocked so that aligned passage W' does not communicate with groove **29"**. Many other configurations are possible. FIG. **2**B shows that passages M**7** to W", M**8** to X", and M**9** to C" remain open and available for additional single and two-path swivel modules mounted above swivel module **3** for more flow paths.

[0033] FIGS. **3**, **3**A, **3**B and **3**C illustrate the swivel stack of three units as indicated above for the arrangement of FIG. **2**A and assembled atop of module **50**. FIG. **3** is a top view of the stack of FIG. **2**A with section lines **3**A-**3**A, **3**B-**3**B and **3**C-**3**C, each spaced 40° apart. The top view section **3**A-**3**A, FIG. **3**A, shows that the top of the unit **80** has a passage Y" and Z' that pierces the top of the unit, but other passages, such as Z", U", V", W" X" cannot be seen because of the way the section A is positioned. FIG. **3**A shows that a radial passage **50-1** from the exterior of manifold **50** communicates with vertical passage M**1** of base manifold **50**. Passage M**1** is aligned with vertical passage A of unit **60**. Passage A terminates and communicates with radial passage **28** of the swivel inner housing **16** which intersects with circular groove **29** and outlet **61** of rotatable outer housing **20**.

[0034] Clamps **12** secure respective flanges **8** and **9** which face each other of the swivel units **60**, **70** and **80**. FIG. **3**A shows that passages Z' and Y" of units **70** and **80** are aligned and pierce the top of the stack as illustrated in FIG. **3**. A liner conduit **50**A is placed in passages A and M**1** with static seals **99** to prevent leakage when fluid flows in those vertically aligned passages.

[0035] FIG. **3**B shows the section view of the three swivel units **60**, **70**, **80** clamped together where the section view is drawn as in FIG. **3** with section lines **3**B-**3**B. FIG. **3** shows that passage Z" of module **80** is visible from the top of the stack. Liner conduit **50**B with upper and lower static seals **99** is provided in the aligned passages of M**2** of base manifold **50** and U of module **60**, A' of module **70** to insure leak-free passage of fluid from passage M**2** of base manifold **50** to the outlet **71** in module **70**.

[0036] FIG. **3**C shows the section view of the swivel units **60**, **70**, **80** clamped together where the section view is drawn as in FIG. **3** with section lines **3**C-**3**C. Liner conduit **50**C with static seals **99** is provided in the aligned passages of A" of module **80**, U' of module **70**, V of module **60** and M**3** of base manifold **50** to insure leak free passage of fluid from inlet **50-3** of base manifold **50** to the outlet **81** in module **80**.

[0037] FIG. **4** is an elevation view of the stack of three swivel modules **60**, **70**, **80** stacked and secured to each other as illustrated in FIGS. **2**A, **3**, **3**A, **3**B and **3**C. The swivel modules are stacked atop base manifold **50** which is secured to support base **52**. Outlets **61**, **71**, **81** can be in any angular rotation position since outer housings **20** rotate. The illustration happens to have them aligned for convenience.

[0038] FIG. **5** shows the swivel stack of FIG. **4**, but with modules **70** and **80** removed and with a horizontal section view through module **60** presented. Vertical passages A, U, V, B, W, X, C, Y, Z are seen opening through inner housing **16** of module **60**. The horizontal circular groove **29** in outer housing **20** communicates respectively with passages A, B, C via radial passage **28**, **28'** and **28"** which in turn communicate with outlets **30**A, **30**B and **30**C. The module **60** is illustrated as being secured to the top of base manifold **50**. Inlets **50**A, **50**U, **50**V communicate with vertical passages A, B, and C and with outlets **30**A, **30**B, **30**C.

[0039] The orientation of modules **60**, **70**, and **80** of FIGS. **2**, **3**, **3**A, **3**B, **3**C, **4**, **5** is by way of example as to how swivel modules as illustrated in FIG. **1** can be oriented.

[0040] Of course the swivel stack base **50** is to be positioned on a stationary frame **52** anchored to the sea floor. Risers from the sea floor are connected to the inlets **50-1**, **50-2**, . . . etc., of the manifold base **50**. Fluid lines to the vessel are connected to the outlets **61**, **71**, **81** . . . etc., and

rotate, with the vessel, with respect to the base manifold **50**. Although FIGS. **2**A, **2**B, through **5** illustrate coupling of multiple vertical passages, such as passages A, B and C coupled by groove **29** in module **60**, the swivel units can be configured so that one or more vertical passages can extend from the base module **50** to the top module of the module stack. Many different configurations can be formed while using identical components.

[0041] The swivel module **10** of FIG. **1**, with its modification as illustrated in FIG. **2-5** have advantages of,

[0042] (1) ease of assembly when stacking by connecting flanges of adjacent modules together rather than using bolts which extend the entire height of the stack;

[0043] (2) prefabrication of swivel units so that a stack can be assembled quickly when needed;

[0044] (3) relative ease of replacing a swivel unit in a stack if needed without disturbing swivel units below a unit which needs to be replaced. For example, when using a stack of three identical swivel modules, **10**A, **10**B, **10**C, an additional spare unit **10** can be stored on the vessel. If any module fails, the spare unit can be used as a replacement; and

[0045] (4) single swivel units can be independently assembled and tested at the factory for installation in any position in the stack. This advantage provides significant cost reduction and decreased delivery times.

What is claimed is:

1. A fluid swivel unit (**10**) comprising,

a stationary inner annular structure (**16**, **17**),

a rotatable outer housing (**20**) positioned coaxially about said inner annular structure (**16**, **17**) with said outer housing (**20**) arranged and designed to rotate relative to said inner annular structure (**16**, **17**) about a central longitudinal axis (**5**),

said stationary inner annular structure (**16**, **17**) including a first horizontal flange (**8**) about an outer circumference of an upper portion of said structure and a second horizontal flange (**9**) on a lower lip (**11**) about an outer circumference of a lower portion of said structure,

said first and second flanges (**8**), (**9**) arranged and designed for stacked connection of said fluid swivel unit (**10**) with other fluid swivel units.

2. The fluid swivel unit of claim **1**,

wherein said first flange (**8**) of said fluid swivel unit (**10**) is capable of being secured to a second flange (**9**) of a second fluid swivel unit by plural clamps (**12**), placed about the circumference of the first and second swivel units, thereby creating a stacked connection of fluid swivel units.

3. The fluid swivel unit (**10**) of claim **1** wherein,

a horizontal circular groove (**29**) is disposed in said outer housing (**20**),

said circular groove (**29**) is defined by a circle of a horizontal cross section through said outer housing (**20**), said groove (**29**) intersecting with a first fixed radial passage (**28**) in said inner annular structure (**16**, **17**) which intersects with a first vertical passage (A) that extends from the bottom of said inner annular structure (**16**, **17**) and terminates at said fixed radial passage (**28**) so that fluid communication can be established between said first circular groove (**29**) and said first vertical passage (A), and

a radial outlet (**30**) is disposed in said outer housing (**20**) that is positioned for fluid communication with said first radial horizontal groove (**29**) and said first vertical passage (A) via said fixed radial groove (**28**),

so that a fluid communication path is established between the rotatable outer housing (**20**) and the stationary inner structure (**16**, **17**) via the first vertical passage (A), the fixed radial passage (**28**), a portion of the circular groove (**29**) and the radial flow outlet (**30**).

4. The fluid swivel unit (**10**) of claim **1**,

wherein said inner annular structure (**16**, **17**) includes a swivel seal plate (**17**) secured to a swivel inner housing (**16**) by a plurality of bolts (**40**) spaced around said central longitudinal axis (**5**).

5. The fluid swivel unit (**10**) of claim **4** wherein,

said first longitudinal flange (**8**) is disposed on an outer periphery of said swivel seal plate (**17**), and

said second longitudinal flange (**9**) is disposed on an outer periphery of said swivel inner housing (**16**).

6. The fluid swivel unit (**10**) of claim **5** further comprising,

at least two additional radial passages (**28'**, **28"**) formed in said swivel inner housing (**16**) so that at least three radial passages (**28**, **28'**, **28"**) are formed in said inner housing (**16**), each equally angularly separated from each other, and each interconnecting with said first circular horizontal groove (**29**) of said swivel outer housing (**20**),

at least two additional vertical passages (B, C) that extend from the bottom of said inner housing (**16**), with each of said two additional vertical passages (B, C) terminating with one of said additional radial passages (**28'**, **28"**) so that fluid communication is established between said first circular groove (**29**) and said vertical passages (A, B, C), and

at least two additional radial outlets (**30'**, **30"**) disposed in said outer housing **20** that are positioned for fluid communication with said circular groove (**29**) so that three fluid communication paths are established between the rotatable outer housing (**20**) and the stationary inner structure (**16**, **17**) via the vertical passages (A, B, C), the fixed radial passages (**28**, **28'**, **28"**), portions of the circular groove (**29**) and the radial flow outlets (**30**, **30'**, **30"**).

7. The fluid swivel unit (**10**) of claim **6** wherein,

six additional vertical passages (U, V, W, X, Y, Z) extend from a flat bottom surface of said stationary inner structure (**16**, **17**) through said structure to a flat top surface of said stationary inner structure (**16**, **17**),

whereby a total of nine vertical passages (A, U, V, B, W, X, C, V, Z) are equally spaced in a circle of said stationary inner structure about said central longitudinal axis (**5**).

8. A fluid swivel assembly comprising,

a base manifold (**50**) disposed about a central longitudinal axis (**5**) and having a plurality of radial inlet passages (**50-1**, **50-2** . . .) equally angularly spaced around the circumference of said manifold and a plurality of vertical passages (M**1**, M**2**, . . .), each of said vertical passages (M**1**, M**2**, . . .) in fluid communication with a corresponding one of said inlet passages (**50-1**, **50-2** . . .),

a first fluid swivel unit (**60**) stacked on and secured to the top of said base manifold (**50**), said first fluid swivel unit (**60**) including,

a stationary inner annular structure (**16**, **17**),

a rotatable outer housing (**20**) positioned coaxially about said inner annular structure (**16**, **17**) with said outer housing (**20**) arranged and designed to rotate relative to said inner annular structure (**16**, **17**) about a central longitudinal axis (**5**),

a horizontal circular groove (**29**) disposed in said outer housing (**20**) of said first fluid swivel unit (**60**), said circular groove (**29**) defined by a circle of a horizontal cross section of said housing (**20**), said groove (**29**) intersecting with a first fixed radial passage (**28**) in said inner housing (**16**) which intersects with a first vertical passage (A) that extends from the bottom of said inner annular structure (**16**, **17**) and terminates at said fixed radial passage (**28**) so that fluid communication can be established between said first circular groove (**29**) and said first vertical passage (A),

a radial outlet (**61**) disposed in said outer rotatable housing (**20**) said radial outlet (**61**) positioned for fluid communication with said first radial horizontal groove (**29**) and said first vertical passage (A) via said fixed radial passage (**28**), so that a fluid communication path is established between the rotatable outer housing (**20**) and the stationary inner structure (**16**, **17**) via said first vertical passage (A), the fixed radial passage (**28**), a portion of the circular groove (**29**) and the radial flow outlet (**61**),

wherein said first vertical passage (A) of said first fluid swivel unit (**60**) is aligned with said vertical passage (M**1**) of said base manifold (**50**), and

with a conduit (**50**-A) placed in the first vertical passage (A) and in the base manifold vertical passage (M**1**) so as to achieve fluid communication through the first vertical passage (A) and the base manifold vertical passage (M**1**) of said first fluid swivel unit (**60**) and said base manifold (**50**).

9. The fluid swivel assembly of claim **8** further comprising,

a second vertical passage (U), a third vertical passage (V), a fourth vertical passage (B), a fifth vertical passage (W), a sixth vertical passage (X), a seventh vertical passage (C), an eighth vertical passage (Y) and a ninth vertical passage (Z),

wherein each of said vertical passages are spaced at equal angular intervals about a circle through a horizontal section of said first fluid swivel unit (**60**).

10. The fluid swivel assembly of claim **9** wherein,

said fourth vertical passage (B) extends from the bottom of said inner housing (**16**) to said horizontal circular groove (**29**) of said first fluid swivel unit (**60**) with termination at a second fixed radial passage (**28**) and fluid communication to a second radial outlet (**30**B) that is disposed in said outer housing (**20**) and positioned for fluid communication with said fourth vertical passage (B),

wherein said fourth vertical passage (B) of said fluid swivel unit (**60**) is aligned with a fourth vertical passage (M**4**) of said base manifold (**50**), and

with a conduit (**50**-B) placed in the fourth vertical passage (B) and in the aligned base manifold fourth vertical passage (M**4**) so as to achieve fluid communication through said vertical passage (M**4**) of said base manifold (**50**) and vertical passage (B) of said first fluid swivel unit (**60**).

11. The fluid swivel assembly of claim **10** wherein,

said seventh vertical passage (C) extends from the bottom of said fixed inner housing (**16**) to said horizontal circular groove (**29**) of said first fluid swivel unit (**60**) with termination at a third fixed radial passage (**28**) and fluid communication to a third radial outlet (**30**C) that is disposed in said rotatable outer housing (**20**) that is positioned for fluid communication with said seventh vertical passage (C),

wherein said seventh vertical passage (C) of said first fluid swivel unit (**60**) is aligned with a seventh vertical passage (M**7**) of said base manifold (**50**), and

with a conduit (**50**-C) placed in the seventh vertical passage (C) and in the aligned base manifold seventh vertical passage (M**7**) so as to achieve fluid communication through the seventh vertical passage (M**7**) of said base housing (**50**) and said seventh vertical passage (C) of said first fluid swivel unit (**60**).

12. The fluid assembly of claim **8** wherein,

said stationary inner annular structure (**16**, **17**) includes a first horizontal flange (**8**) about an outer circumference of said structure and a second horizontal flange (**9**) about an outer circumference of a lower portion of said structure,

said first and second flanges (**8**), (**9**) arranged and designed for stacked connections of said first fluid swivel unit (**60**) with other fluid swivel units or said base manifold (**50**).

13. The fluid swivel assembly of claim **12** wherein,

said first fluid swivel unit (**60**) is secured to the top of said base manifold (**50**) with clamps (**12**) for clamping said second horizontal flange (**8**) of said first fluid swivel unit (**60**) to a horizontal flange (**9**) about an outer circumference of said base manifold (**50**).

14. The fluid swivel assembly of claim **8** further including a second swivel module (**70**) which includes,

a first vertical passage (Z'),

a second vertical passage (A'),

a third vertical passage (U'),

a fourth vertical passage (V'),

a fifth vertical passage (B'),

a sixth vertical passage (W'),

a seventh vertical passage (X'),

an eighth vertical passage (C') and

a ninth vertical passage (Y'),

wherein each of said vertical passages are spaced at equal angular intervals about a circle through a horizontal section of said second swivel module (**70**).

15. The fluid swivel assembly of claim **14** wherein,

said second fluid swivel module (**70**) is stacked and secured to the top of said first fluid swivel unit (**60**) and wherein,

said second fluid swivel module (**70**) includes,

a stationary inner annular structure (**16'**, **17'**)

a rotatable outer housing (**20'**) positioned coaxially about said inner annular structure (**16'**, **17'**) with said outer housing (**20'**) arranged and designed to rotate relative to said inner annular structure (**16'**, **17'**) about said central longitudinal axis (**5**),

a horizontal circular groove (**29'**) disposed in said outer housing (**20'**) of said second fluid swivel module (**70**), said circular groove (**29'**) defined by a circle of a horizontal cross-section of said housing (**20'**), said groove (**29'**) intersecting with a first fixed radial passage (**28'**) in said inner housing (**16'**) which

intersects with said second vertical passage (A') that extends from the bottom of said inner annular structure (**16'**, **17'**) and terminates at said fixed radial passage (**28'**) so that fluid communication can be established between said first circular groove (**29'**) and said second vertical passage (A') and

a radial outlet (**30'**) disposed in said rotatable outer housing (**20'**), said radial outlet (**30'**) positioned for fluid communication with said first radial horizontal groove (**29'**) and said second vertical passage (A') via said fixed radial passage (**28'**) so that a fluid communication path is established between the rotatable outer housing (**20'**) and the stationary inner structure (**16'**, **17'**) via the second vertical passage (A'), the fixed radial passage (**28'**), a portion of the circular groove (**29'**) and the radial flow outlet (**30'**),

wherein said second fluid swivel module (**70**) is rotatably aligned with said first fluid swivel unit (**60**) so that said second vertical passage (A') is aligned with said first vertical passage (U) of said first fluid swivel unit (**60**), and said first vertical passage (U) of said first fluid swivel unit (**60**) is aligned with said vertical passage (M**2**) of said base manifold (**50**).

16. The fluid swivel assembly of claim **15** wherein,

said fifth vertical passage (B') of said second fluid swivel module (**70**) is aligned with said fifth vertical passage (W) of said first fluid swivel unit (**60**), and

said fifth vertical passage (W) of said first fluid swivel unit (**60**) is aligned with said fifth vertical flow passage (M**5**) of said base manifold (**50**).

17. The fluid swivel assembly of claim **16**,

wherein said eighth vertical passage (C') of said second fluid swivel module (**70**) is aligned with said eighth vertical passage (Y) of said first fluid swivel unit (**60**), and

said eighth vertical passage (Y) of said first fluid swivel unit (**60**) is aligned with said eighth vertical flow passage (M**8**) of said base manifold (**50**).

18. A fluid swivel assembly comprising,

a first swivel module (**10**) having,

a stationary inner annular structure (**16**, **17**),

a rotatable outer housing (**20**) positioned coaxially about said inner annular structure (**16**, **17**) with said outer housing (**20**) arranged and designed to rotate relative to said inner annular structure (**16**, **17**) about a central longitudinal axis (**5**),

with vertical passages through said stationary inner annular structure (**16**, **17**), including

a number N of vertical passages (A, U, V, B, . . .) equally angularly spaced about a circle through a horizontal section of said inner annular structure (**16**, **17**), such that each vertical passage is angularly spaced from another by 360/N degrees,

a horizontal circular groove (**29**) disposed in said outer housing (**20**) of said fluid swivel unit (**10**), said circular groove (**29**) defined by a circle of a horizontal cross-section of said housing (**20**), said groove (**29**) intersecting with a first fixed radial passage (**28**) in said inner housing (**16**) which intersects with a first vertical passage (A) that extends from the bottom of said inner annular structure (**16**, **17**) and terminates at said fixed radial passage (**28**) so that fluid communication can be established between said first circular groove (**29**) and said first vertical passage (A), and

a radial outlet (**30**) is disposed in said outer rotatable housing (**20**), said radial outlet (**30**) positioned for fluid communication with said first radial horizontal groove (**29**) and said first vertical passage (A) via said fixed radial passage (**28**), so that a fluid communication path is established between the rotatable outer housing (**20**) and the stationary inner structure (**16**, **17**) via the first vertical passage (A), the fixed radial passage (**28**), a portion of the circular groove (**29**) and the radial flow outlet (**30**).

19. The fluid swivel assembly of claim **18** further comprising a second swivel module (**10**) configured like that of said first swivel module, where

said second swivel module (**10**) is stacked on top of said first swivel module (**10**) with an inner annular structure (**16**, **17**) of the second swivel module (**10**) rotated by 360/N degrees from the inner annular structure of the first swivel module (**10**), such that the first vertical passage (A') of the second swivel module (**10**) is aligned with the second vertical passage (U) of said first swivel module (**10**), and

the second vertical passage (U') of the second swivel module (**10**) is aligned with the third vertical passage (V) of said first swivel unit (**10**).

20. The fluid swivel assembly of claim **18** wherein the number N of vertical passages is nine, such that each vertical passage is angularly separated from an adjacent vertical passage by forty degrees.

21. The fluid swivel assembly of claim **18** further comprising,

a plurality of swivel modules (**10**) positioned in a stack, where each swivel module includes one vertical passage.

22. The fluid swivel of claim **21** wherein,

said plurality of swivel modules can be assembled to accommodate separate flow path requirements and volume flow rate capacity requirements.

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