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[54] **ROTARY FLUID-POWERED APPARATUS**

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[52] **U.S. Cl.** **415/64,** 415/60, 415/122

[51] **Int. Cl.**..**F01d 1/24**

[58] **Field of Search**............................415/122, 60, 64

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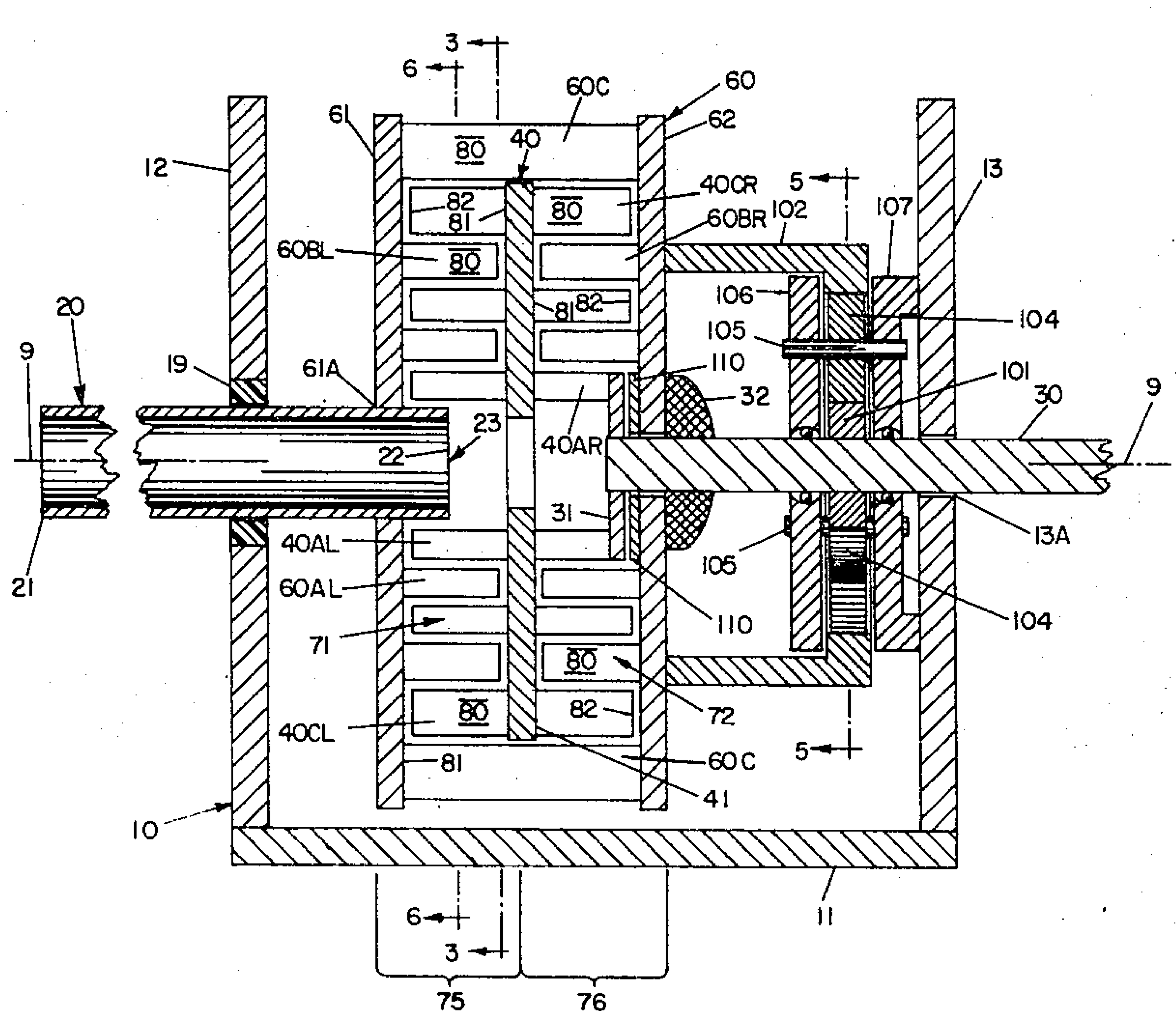
[57] **ABSTRACT**

There is disclosed herein rotary apparatus powerably motivatable with a pressurized fluid, such as air, steam, water, etc. Preferred embodiments of the rotary vaned apparatus comprise: a stationary frame member; a pair of vaned counter-rotatable motors, each revolvably associated with respect to the frame member and including an output-shaft extending longitudinally along a central-axis and directly corevolvable with one of said rotors; means for directing pressurized fluid radially outwardly from the central-axis and across the rotors' vanes, and to the appreciable exclusion of coincidental longitudinal fluid flow, thereby causing counter-rotation of the respective rotors; and planetary gear means operatively extending from the output-shaft to the oppositely rotating rotor to make the mechanical energy of the counter-rotating rotors available for use in a single angular direction about the central-axis. Other noteworthy specific features might include: vane means securely removably attached in concentric annular arrangements on the respective rotors together with a plurality of intra-annulus vane-like blades of regular cross-sectional size and shape, means to prevent or to minimize longitudinal stresses on the counter-rotating rotors; and means for making efficient use of the apparatus parts and the radial motive fluid.

11 Claims, 5 Drawing Figures



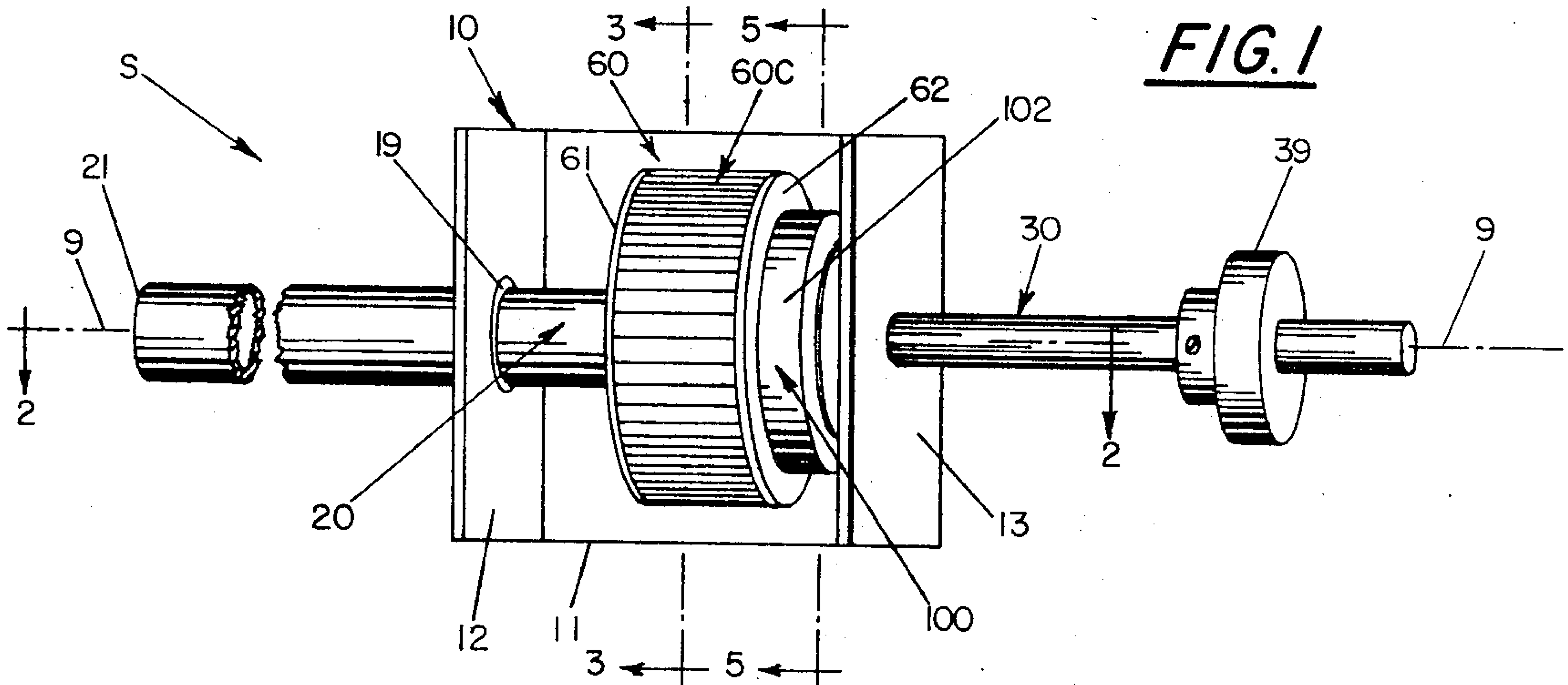


FIG. 1

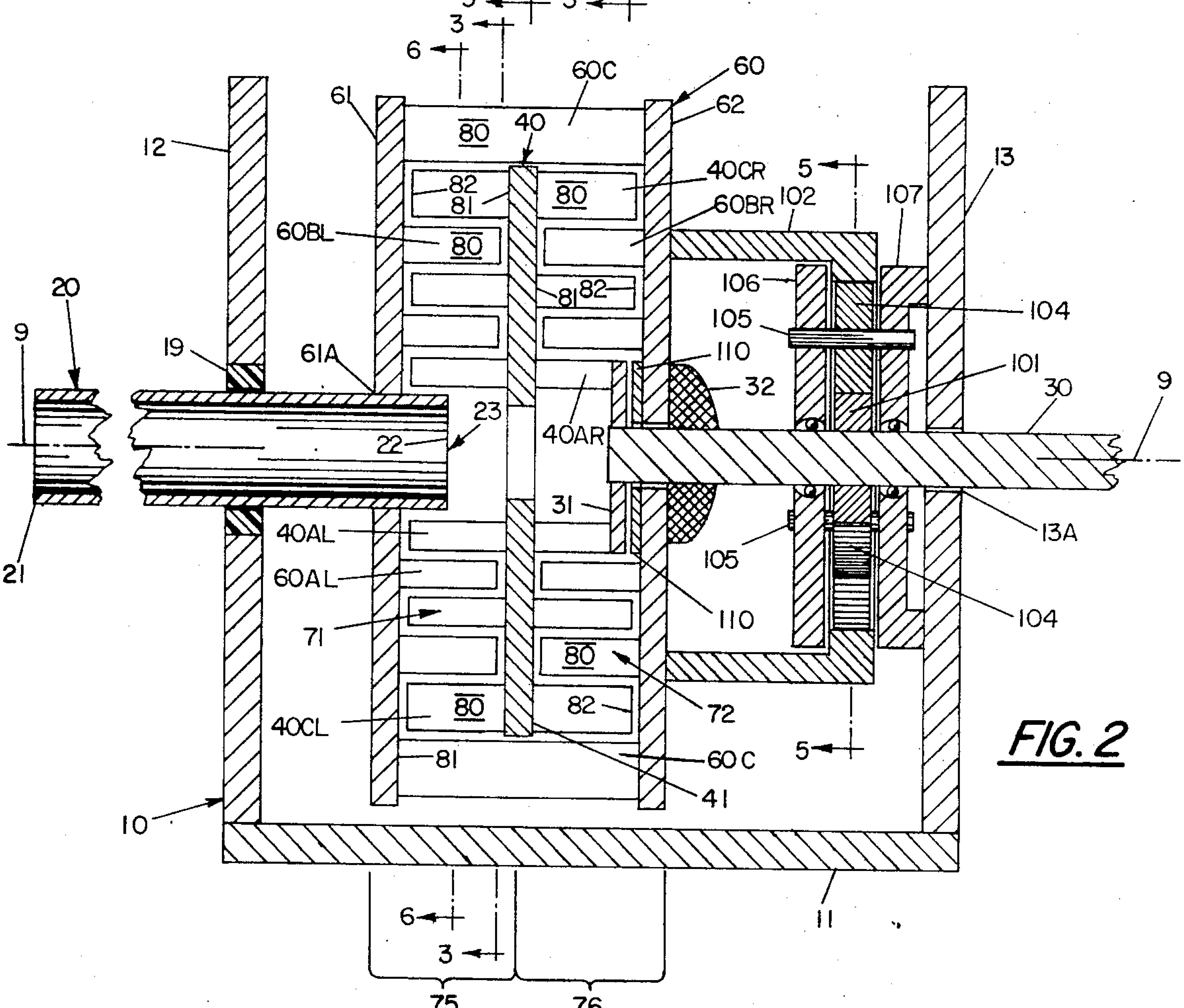


FIG. 2

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FIG. 3

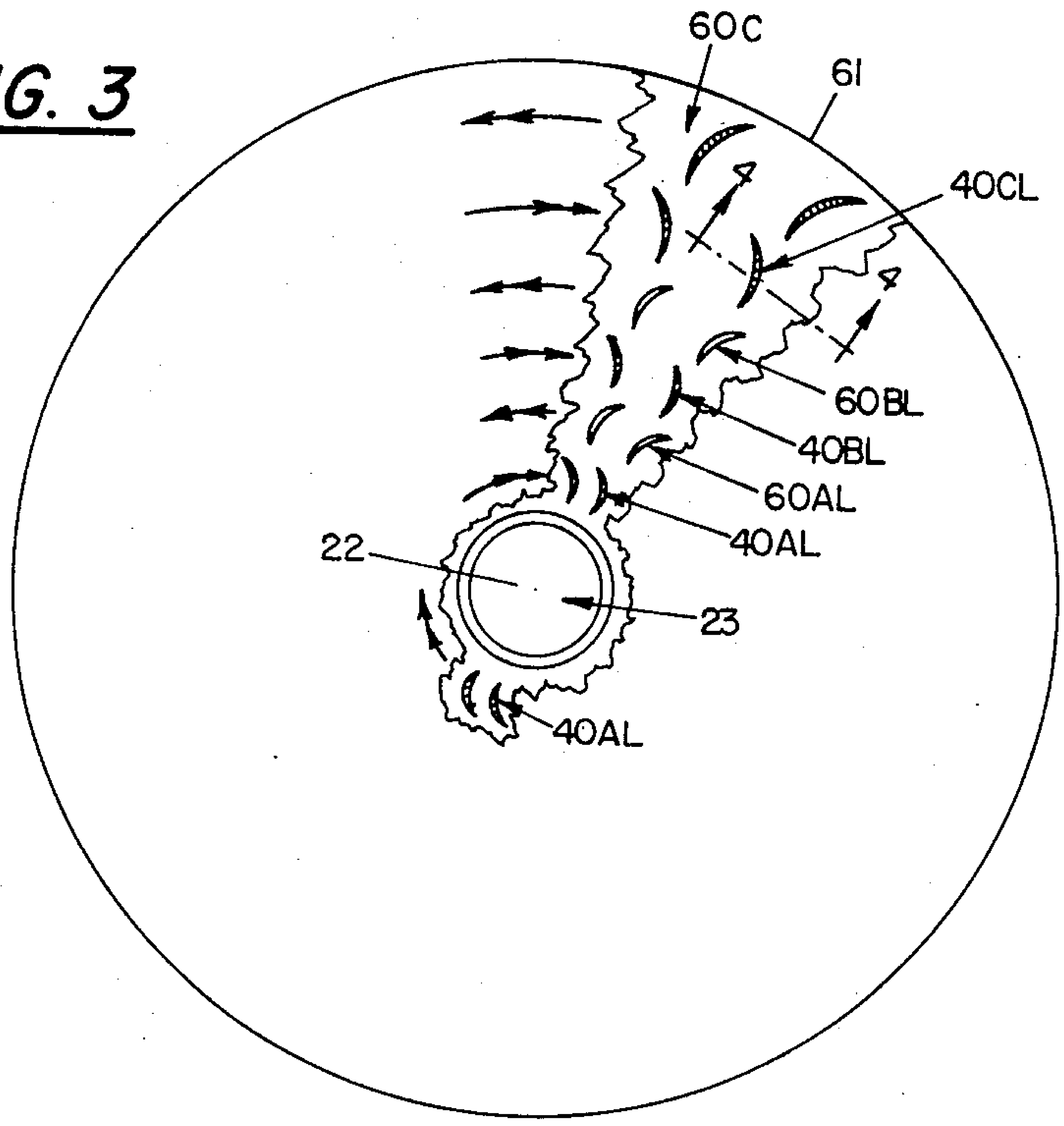


FIG. 4

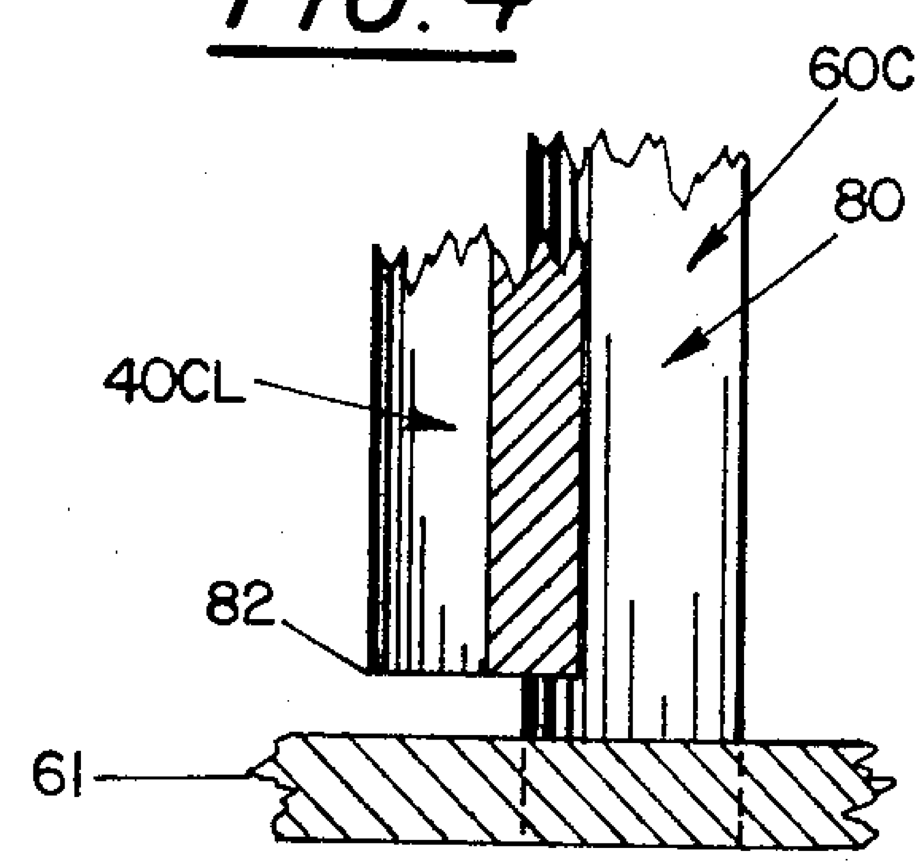
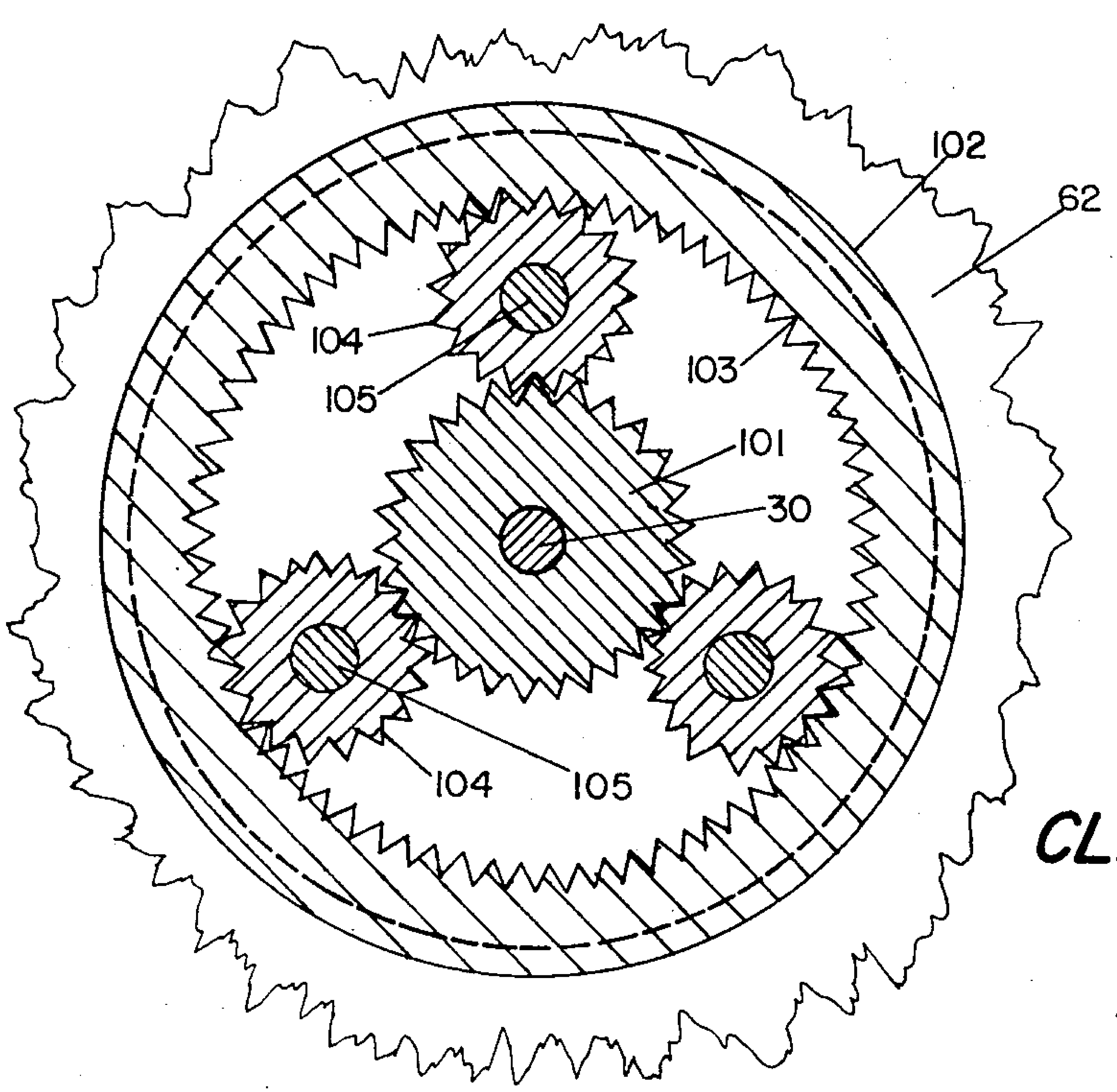


FIG. 5



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ROTARY FLUID-POWERED APPARATUS

There are in the prior art many rotary fluid-powered apparatus wherein a plurality of vaned rotors each revolvably surround a longitudinally extending central-axis and wherein a pressurized fluid is utilized to cause the rotors to revolve about the central-axis. Many such prior art rotary apparatus are necessarily awkward and inefficient in that the fluid flow is intermittent, rather than continuous, requiring cumbersome and complicated valves. Other prior art rotary fluid-powered apparatus require the combustion of hydrocarbon gases, thus introducing problems of inefficiency and objectionable combustion residues. Still other rotary apparatus require the motive fluid to be utilized in an annular path that surrounds and is removed from the central-axis, thus commonly necessitating cumbersome vanes and valves. In certain prior art rotary apparatus involving counter-rotating vaned rotors, the motive fluid flow is essentially parallel to the central-axis, thereby necessitating very elaborate and expensive vanes. In the so-called "turbine-type" rotary apparatus, where a continuous radially flowing motive fluid is employed for vaned rotors moving in the same angular direction about the central-axis, the fabrication, installation, and maintenance of the rotor vanes are exceedingly complicated and expensive. Moreover, the efficiency of such "turbine-type" apparatus is notoriously low.

It is accordingly the general object of the present invention to provide a rotary fluid-powered apparatus that overcomes the several disadvantages and deficiencies of prior art apparatus.

It is a further object to provide a rotary fluid-powered apparatus that is adaptable to efficiently utilize a variety of pressurized motive fluids, including liquids, inert gases, combustible gases, and the unusually efficient utilization of vaporizable liquids, such as steam, "Freon," etc.

It is another object to provide a fluid-powered rotary apparatus that is equally adaptable for use with continuous, variable, and intermittent motive fluid flow.

It is a specific object of the present invention to provide a fluid-powered rotary apparatus wherein the blade-like vanes employed in the revolvable rotors are of unusual simplicity for fabrication, for installation into and removal from the rotor, for rotor maintenance, and for exceedingly efficient utilization of the motive fluid.

It is a further object to provide rotary fluid-powered apparatus of the counter-rotating rotors type wherein longitudinal forces on the rotors can be minimized, or even essentially eliminated.

It is another object to provide a rotary fluid-powered apparatus of the generic turbine-type adaptable for use in unusually small, but efficient size, and at relatively high power output, adaptable for multi-staging assemblies and other economical embodiments, and having output power available in selectable angular directions and speed ratios.

With the above and other objects and advantages in view, which will become more apparent as this description proceeds, the rotary fluid-powered apparatus of the present invention generally comprises: a stationary frame member; a tubular inlet-shaft and an output-shaft, each shaft extending longitudinally along a central-axis and the output-shaft being revolvably associated with respect to the stationary frame member; a plurality of vaned counter-rotating rotors that are revolvably associated with respect to the stationary frame member and at least one rotor being directly corevolvable with the output-shaft; means for directing pressurized fluid radially outwardly from the central-axis toward a fluid exhaust means and while to the substantial exclusion of longitudinal fluid flow; and torque-addition means operatively extending from the output-shaft to the directionally oppositely revolvable fluid-actuatable rotor whereby the mechanical energy of the corotating fluid-actuatable rotors can be added together in the same angular direction about the central-axis.

In the drawing, wherein like characters refer to like parts in the several views, and in which:

FIG. **1** is a perspective view of a preferred embodiment of the rotary fluid-powered apparatus of the present invention.

FIG. **2** is a sectional elevational view taken along line 2—2 of FIG. 1.

FIG. **3** is a sectional elevational view taken along lines 3—3 of FIGS. 1 and 2.

FIG. **4** is a detail sectional elevational view taken along line 4—4 of FIG. 3.

FIG. **5** is a sectional elevational view taken along lines 5—5 of FIGS. 1 and 2.

Referring briefly initially to FIGS. **1-3**, the rotary fluid-powered apparatus embodiment "S" generally comprises: a stationary frame member **10**, seen in FIGS. **1** and **2** to be of U-shaped configuration; a tubular inlet-shaft **20** and an output-shaft **30**, shafts **20** and **30** extending longitudinally along central-axis **9** and at least the output-shaft **30** being revolvably associated with respect to the stationary frame member **10**; a pair of vaned counter-rotating rotors **40** and **60**, one of said rotors e.g.**40**, being directly co-revolvable with output-shaft **30**; means for causing pressurized motive fluid to flow between the counter-rotating rotors and to impinge upon the vanes thereof in radial fluid flow fashion, said means herein including the inlet-tube outlet-opening **23** together with the parallel plate-like fluid-impervious barriers **61** and **62** of rotor **60**; and planetary gear means **100** operatively extending from output-shaft **30** to the directionally oppositely revolving rotor **60** whereby the mechanical energy of the counter-rotating rotors **40** and **60** can be added together in the same angular direction about central-axis **9** and thereby collectively available to do singular work, as through pulley **39**.

Stationary frame member **10** herein is of generally U-shaped configuration and comprises three sturdy rectangular panels rigidly connected together (as by welding, etc.) including a horizontal base-panel **11** and a pair of opposed parallel side-panels **12** and **13** extending rigidly upwardly from base-panel **11**. The longitudinally separated side-panels **12** and **13** each transversely perpendicularly intersect the longitudinally extending central-axis **9**; first-side panel **12** has an opening therethrough at central-axis **9** for passage of inlet-tube **20**, and second side-panel **13** at central-axis **9** has an opening **13A** permitting passage therethrough of revolvable output-shaft **30**. In the preferred situation wherein tubular inlet-shaft **20** is revolvable about central-axis 9, and in the opposite angular direction of output-shaft 30 and its co-revolvable rotor (eg 40), first side-panel 12 carries a bearing 19 to journal the revolvable inlet-tube 20. Herein, inlet-shaft 20 has an inlet-end 21 and an outlet-end 22. The pressurized fluid utilized for revolvably motivating the rotors can be supplied longitudinally through inlet-tube 20 from a remote source; moreover, inlet-tube 20 can be provided with fluid outlet opening 23 adjacent to outlet-end 22 whereby the pressurized motive fluid is directable radially outwardly of central-axis 9 and of inlet-tube 20.

It is readily apparent that steam or other pressurized fluid, flowing in directions radially outwardly from central-axis 9, is adapted to simultaneously impinge upon the respective vanes of counter-rotatable rotors 40 and 60 actually causing them to revolve in opposite directions about central-axis 9. In this vein, the vane means portion of the respective revolvable rotors are of appropriate configuration to cause the rotors' counter-rotation about central-axis 9. For example, identical type curved blades, e.g. 80, might be employed as the fluid-responsive vane means for each rotor. As seen in FIG. 3, the said blades 80 have reverse curvatures on the respective rotors to cause uniplanar radial fluid flow to rotate the rotors in opposite angular directions. The multi-blades vane means of the two rotors extend toward each other and parallel to central-axis 9, and preferably longitudinally overlap (i.e. intersect a common reference-plane, such as 6—6) whereby substantially all the radially flowing fluid simultaneously motivates the respective rotors. After the radially flowing motive fluid has acted upon the radially incrementally spaced vane means of the respective rotors, the lower pressure motive fluid is exhausted from the rotors, herein radially outwardly of annulus 60C of rotor 60. As will be pointed out later in greater detail, there are means (such as fluid-impervious barriers 61 and 62) to ensure that the pressurized fluid will travel directionally radially outwardly from central-axis 9 past the rotors' vane means, and coincidentally to the substantial exclusion of fluid flow parallel to central-axis 9.

The vane means of the respective rotors is preferably arranged in annulli, each circularly concentric about central-axis 9. The radial distance of each vane means annulus on one rotor with respect to central-axis 9 differs from the annulli radial distances on the other rotor thereby ensuring that vane means annulli from both rotors will longitudinally overlap, e.g. intersect a common reference-plane such as 6—6 that is perpendicular to central-axis 9. For example, the vane means of rotor 40 are arranged in concentric circular annulli 40A, 40B, and 40C, the radial distance between said annulli on rotor 40 being sufficient to accommodate therebetween the concentric circular annulli 60A, 60B, and 60C of rotor 60. Each of said annulli 40A, 40B, 40C, 60A, 60B, and 60C, comprises a plurality of similar curved blades 80, as an integrally connected portion of the rotor. The several curved blades 80 are of regular cross-sectional shape (FIG. 3) along the longitudinally extending length 81–82 thereof, making possible economic fabrication of and maintenance for the bladed rotors. Moreover, a plurality of intra-annulus blades 80 are of regular cross-sectional dimensional size along the longitudinally extending length 81–82; however, the blades' dimensional size for inward annulli (such as 40A and 60A) are preferably smaller than for the outer annulli (40C, 60C, etc.) so as to permit more efficient utilization of the radially flowing pressurized fluid.

Preferably, one of the respective counter-rotating rotors includes vane means extending in both longitudinal directions toward the other rotor, thereby minimizing the possibility that the radially flowing fluid will produce severe thrust on one or more rotors in the longitudinal direction, i.e. parallel to central-axis 9. In this vein, as seen in FIG. 2, one rotor (60) might take a drum-like form having two longitudinally-separated fluid-impervious walls 61 and 62, with the other rotor (40) being as an inner-rotor located within the drum-like outer-rotor (60). Thus, two distinct longitudinally-separated annular fluid expansion chambers 71 and 72 exist between the inner-rotor 40 and the respective transverse walls 61 and 62 of the drum-like outer-rotor 60. In such structure, the outlet-opening 23 of inlet-shaft 20 communicates with both chambers 71 and 72 so that pressurized fluid can flow radially through both expansion chambers simultaneously. Herein, solid output-shaft 30 is loosely surrounded by outer-rotor wall 62, said output-shaft being tightly surrounded by a rigidly attached mounting-disc 31; mounting-disc 31 is rigidly attached to the free-ends 82 of the respective vane blades of annular row 40AR, whereby output-shaft 30 is directly co-revolvable with inner-rotor 40. It can be seen that the longitudinal length 81–82 of the several blades 80 are substantially equal, except for the shorter blade lengths in annular row 40AR and the "-double lengths" in annular row 60C. Assuming that the rotors pair 40 and 60 is substantially symmetrical (dimensionally and gravimetrically) about member 41 (two substantially identical halves 75 and 76), and that the rates of fluid flow into the expansion chambers 71 and 72 are substantially equal, then the radially moving fluid would develop no appreciable lateral thrust upon the respective rotors. However, for ensurance purposes, output-shaft 30 herein carries a longitudinally stationed and co-revolvable thrust bearing 110 adjacent outer-rotor wall 62. Thus, it is readily apparent that while one-half alone (e.g. 76) of the dual-rotors structure 40 and 60 might provide an otherwise efficaceous apparatus, the use of both halves 75 and 76 together greatly reduces longitudinal thrust problems and a balanced apparatus "S."

It has now become readily apparent that there need be means to ensure that the pressurized fluid flows radially outwardly of central-axis 9, and to the substantial exclusion of fluid flow parallel to central-axis 9, at least until the fluid is exhausted from the rotors, e.g. at multi-blades row 60C. In this vein, fluid-impervious barriers are employed; for example the transverse walls 61 and 62 of outer-rotor 60 might be of metallic plate-like configuration. If but a single halve (e.g. 76) of the dual-rotors structure be employed, then the transverse wall 41 of rotor 40 would need to be fluid-impervious. Herein, for purposes of greater simplicity and reliability, inlet-tube 20 passes through an opening 61A in wall 61 and is rigidly attached to wall 61 whereby inlet-tube 20 is directly co-revolvable with rotor 60. Frame first-side-panel 12 carries a stationary annular bearing 19 which journals revolvable inlet-rube 20.

As had already been alluded to, the several intraannulus curved blades **80** are of regular cross-sectional shape and size along the longitudinal length **81–82**, which unusually facilitates fabrication and maintenance of the rotors. Moreover, such regularly cross-sectioned blades **80** are exceedingly easy to securely (though removably) attach onto the rotor, thereby also facilitating replacement and repair of faulty blades. Herein, as indicated in FIG. **4**, each of the rotor plate-like transverse walls (**41**, **61**, and **62**) is provided with longitudinally extending depressions of a cross-sectional size and shape like that for the blades **80**, whereby the blades **80** actually intersect the rotors' transverse walls. For example, in inner-rotor **40**, each blade **80** within annuli **40A**, **40B**, and **40C** securely (though removably slidably) passes through a geometrically similar opening of wall **41**. Thus, within the respective common-radius annulli **40AL** and **40AR**, **40BL** and **40 BR**, and **40CL** and **40CR**, the same structurally continuous blades **80** pass through and extend on both sides of plate-like wall **41**. Within annulus **60C** on outer-rotor **60**, several such "double-length" blades **80** pass securely (though longitudinally slidably) through the walls **61** and **62**, the spaces between intra-annulus **60C** blades providing a type fluid exhaust means. Also, the removably connected blades of annulus **60C** provide a means for dis-assembly(longitudinally) of outer-rotor **60**. However, the "single-length" blades (which span at least 90 percent the longitudinal distance to inner-rotor wall **41** from the walls **61** and **62**) are employed within annulli **60AL**, **60BL**, **60AR**, and **60BR**.

There are torque-addition means operatively extending from output-shaft **30** to the directionally oppositely revolvable rotor (**60**) whereby the mechanical energy of the counter-rotating rotors **40** and **60** can be added together in the same angular direction about central-axis **9**. Thus, the total kinetic energy of counter-rotating rotors **40** and **60** can be transmitted to a single external work load, as through pulley **39** co-revolvable with output-shaft **30**. Preferred herein for the torque-addition means is a planetary gear train **100** comprising a pinion gear **101** positioned between the outer-rotor wall **62** and frame second side-panel **13**, said pinion gear **101** being attached to and directly co-revolvable with output-shaft **30**. There is an annular spur gear **102** rigidly attached (as by welding,etc.) to outer-rotor wall **62** whereby spur gear **102** is directly co-revolvable with outer-rotor **60**. The annular gear surface **103** of spur gear **102** is located in transverse alignment with pinion gear **101**. A plurality (herein three) idler-gears **104** extend radially from pinion gear **101** to gear surface **103**, each idler-gear **104** being revolvable about a longitudinally extending idler-shaft **105**. The idler-gears **104** are revolvably associated with respect to the respective idler-support plates **106** and **107**, plate **107** being integrally connected to second side-panel **13** whereby elements **104–107** are stationary i.e. are non-rotatable about central-axis **9**. However, output-shaft **30** is revolvably secured by the stationary plates **106–107**. Co-revolvably attached to output-shaft **30** herein is sealer-gasket **32**. Thrust-bearing **110** is integrally co-revolvably attached to wall **62** between said wall **62** and mounting-disc **31**, whereby elements **31** and **110** rotate in opposite angular directions. It is also possible to take the torque power from the revolvable inlet-tube **20** by placing a pulley (not shown) thereon, analagous to pulley **39**. In this way, the inlet-tube **20** travels at an angular velocity of less than one-half (and herein about one-fourth that of output-shaft **30**) thereby giving a selection of two disparate velocities for the harnessable output of apparatus "S".

In an alternate form of the rotary fluid-powered apparatus, the dual-rotors structure (**40** and **60**) is isolated from the planetary gears train **100** by an intervening-plate located between spur gear **102** and outer-rotor wall **62** and parallel to said wall **62** and side-panel **13**. A tubular-sleeve revolvably surrounding the output-shaft **30** passes unrestrictably through a said intervening-plate, the respective two ends of such tubular-sleeve being co-revolvably attached to outer-rotor wall **62** and to annular spur gear **102**. A sealer-gasket, analagous to **32**, can be employed at the revolvable juncture opening of said intervening-plate and the tubular-sleeve. Such alternate apparatus structure has several apparent advantages, including the provision for independent lubrication systems.

From the foregoing, the construction and operation of the rotary fluid-powered apparatus will be readily understood and further explanation is believed to be unnecessary. However, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction shown and described, and accordingly, all suitable modifications and equivalents may be resorted to, falling within the scope of the appended claims.

I claim:

1. A rotary fluid-powered apparatus comprising a plurality of rotors each of which is revolvable about a longitudinally extending central-axis and is powerably revolvable by a pressurized fluid flowing radially outwardly from the central-axis, said rotary fluid-powred apparatus comprising:

A. A relatively stationary frame member;

B. An outer-rotor revolvably associated with said frame and revolvably surrounding said central-axis, said outer-rotor including a longitudinally-separated pair of fluid-impervious barriers attached in co-revolvable relationship and including vane means to cause the fluid actuatable outer-rotor to revolve in a first-angular direction about said central-axis in response to a said radially flowing pressurized fluid;

C. An inner-rotor located between the fluid-impervious barriers of said outer-rotor and associated with the said frame so as to revolvably surround the central-axis, said inner-rotor including vane means extending in both longitudinal directions toward the respective fluid-impervious barriers of the outer-rotor to provide two distinct longitudinally-separated fluid expansion chambers between the inner-rotor and the outer-rotor and whereby the inner-rotor is caused to revolve in a second-angular direction about the said central-axis in response to said radially flowing pressurized fluid;

D. A tubular inlet-shaft extending along the said central-axis through a fluid-impervious barrier of said outer rotor, said tubular inlet-shaft being provided with outlet-opening means situated between the outer-rotor fluid-impervious barriers to permit pressurized fluid from the inlet-shaft to flow at substantially like rates simultaneously into both fluid expansion chambers whereby longitudinally extending forces by the radially flowing pressurized fluid upon the two rotors is minimized;

E. An output-shaft rigidly attached to and directly co-revolvable with one of said fluid-actuatable revolvable rotors, said output-shaft extending along the said central-axis; and

F. Torque-addition means operatively extending from the said output-shaft to the directionally oppositely revolvable fluid-actuatable rotor whereby mechanical energy of the two oppositely revolvable rotors can be added together in the same angular direction about the said central-axis.

2. The rotary fluid-powered apparatus of claim **1** wherein the torque-addition means is a planetary gears assembly.

3. The rotary apparatus of claim **2** wherein the vane means of the respective rotors is of the multi-blades type, multi-blades vane means of the respective rotors actually intersecting a common reference-plane that is substantially perpendicular to the central-axis to ensure plural rotors utilization of pressurized fluid flowing radially substantially along said reference-plane.

4. The rotary apparatus of claim **3** wherein the vane means of two such respective rotors is arranged in concentric circular annulli, each annulus circularly surrounding the central-axis and comprising a plurality of blades, the radial distance of each multi-blades annulus of the first-rotor from the central-axis differing from the radial distance of each multi-blades annulus of the second-rotor to ensure that multi-blades annulli from both rotors will overlap and actually intersect a said reference-plane.

5. The rotary apparatus of claim **1** wherein the vane means of two such respective rotors are of the multi-blades type and arranged in concentric circular annulli, each annulus circularly surrounding the central-axis and comprising a plurality of said blades, intra-annulus blades being of regular cross-sectional size and shape along a longitudinally extending length thereof.

6. The rotary apparatus of claim **5** wherein there are fluid exhaust means located radially outwardly from a plurality of said multi-blades annulli, said fluid-impervious barriers extending radially to the fluid exhaust means whereby the radially moving fluid during its transvanes flow is prevented from moving longitudinally through a rotor.

7. The rotary apparatus of claim **6** wherein the tubular inlet-conduit is rigidly attached to and directly co-revolvable with one of said rotors and differing from the rotor to which the output-shaft is co-revolvably attached whereby the inlet-shaft and the output-shaft revolve in opposite angular directions about said central-axis; and wherein a plate-like said fluid-impervious barrier also provides a mounting means for the vane

blades, respective blades of said rotor having a free-end located longitudinally remote of the plate-like mounting means and having a root-end located immediately adjacent thereto, respective blades actually intersecting and passing into the said plate-like mounting means to provide efficient and secure mounting of the blades thereon.

8. The rotary apparatus of claim **1** wherein the vane means of the two respective rotors are arranged in concentric circular annulli, each annulus comprising a plurality of blades that extend from the respective rotors to the respective expansion chambers, annulli from each rotor and within the same expansion chamber longitudinally overlapping to intersect a common reference-plane of perpendicularity with the central-axis.

9. The rotary apparatus of claim **8** wherein intra-annulus blades are of regular cross-sectional size and shape along a longitudinally extending length thereof; wherein the tubular inlet-shaft is rigidly attached to the first-plate barrier means of the outer-rotor and directly co-revolvable with said outer-rotor; wherein the output-shaft passes through an opening of the outer-rotor second-plate barrier means and is rigidly attached to a radially-first multi-blades annulus of the inner-rotor and directly co-revolvable with the inner-rotor; wherein the respective blades of the outer-rotor's radially outward annular vane means extend from one plate-like barrier to the other to provide a removable connection between said barriers and also fluid exhaust means; and wherein the torque-addition means is a planetary gears assembly operatively extending from said output-shaft to the outer-rotor second-plate barrier means, said gearing being appropriate to cause the output-shaft to travel at an angular velocity at least twice that for the tubular inlet-shaft, the said planetary gearing including a plurality of idler-gears that are rigidly attached with respect to the frame and thus non-rotatable about said central-axis.

10. The rotary apparatus of claim **4** wherein there are fluid exhaust means located radially outwardly from a plurality of said multi-balades annulli; wherein the output-shaft is rigidly attached to and directly co-revolvable with the inner-rotor; and wherein the planetary gears assembly torque-addition means actuatably extends from a fluid-impervious barrier of the outer-rotor to said output-shaft.

11. The rotary apparatus of claim **10** wherein the tubular inlet-shaft is rigidly attached to and directly co-revolvable with the outer-rotor; and wherein the planetary gears assembly torque-addition means includes an annular spur gear attached to a said fluid-impervious barrier of the outer-rotor and surrounding the said output-shaft whereby the output-shaft and the co-revolvable inner-rotor travel at an angular velocity at least twice that for the outer-rotor.

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