United States Patent [19]

Green et al.

[11] **3,913,455**

[45] **Oct. 21, 1975**

[54] **RADIAL-PISTON ROTARY HYDROSTATIC MACHINES**

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[22] Filed: **Jan. 23, 1974**

[21] Appl. No.: **435,955**

[30] **Foreign Application Priority Data**

Apr. 9, 1973 United Kingdom............... 16895/73

[52] **U.S. Cl.**.................... **91/492;** 267/167; 267/156

[51] **Int. Cl.**[2]... **F01B 13/06**

[58] **Field of Search**...... 91/491, 492, 488; 267/155, 267/156, 167

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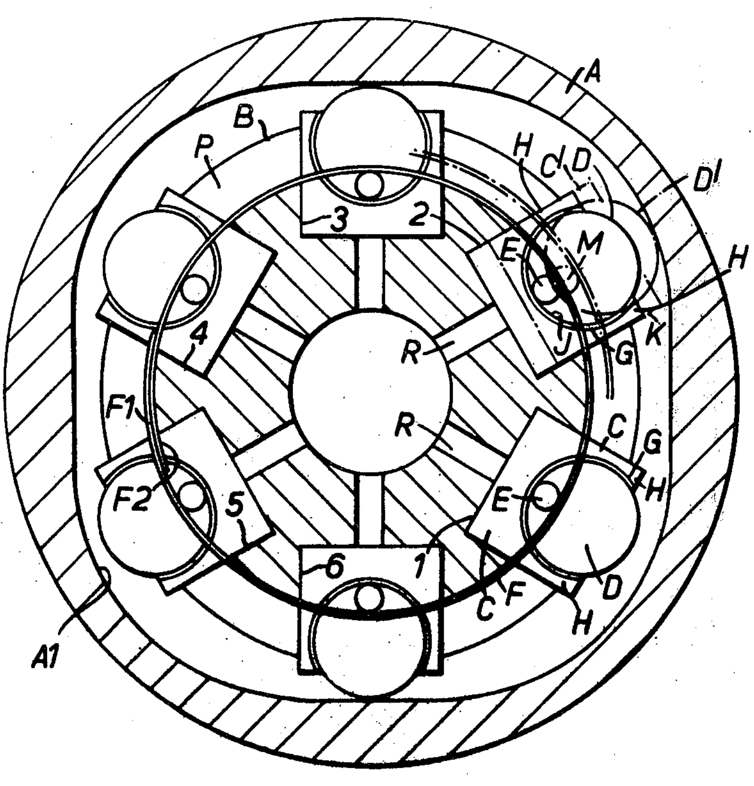
Attorney, Agent, or Firm—Cushman, Darby & Cushman

[57] **ABSTRACT**

A hydrostatic motor or pump which comprises a cylinder block with two banks of radial cylinders surrounded by a relatively rotatable cam ring affording cam tracks which coact with follower rollers carried by radially-reciprocable pistons in the cylinders. A circular leaf spring accommodated in a circumferential groove in the cylinder block marginally overlies the bodies of the pistons in the two banks being disposed between their follower rollers, and resiliently biasses the pistons radially inwardly to their innermost positions, the leaf spring acting on the pistons via interposed rollers or via radial pegs carried by the pistons. When the cylinders are unpressurised the leaf spring holds all the piston-and-roller assemblies withdrawn in their radially-inner positions clear of the cam tracks for freewheeling. When the cylinders are pressurised the pistons are moved radially outwardly, expanding the leaf spring, until their rollers engage the cam tracks.

9 Claims, 5 Drawing Figures



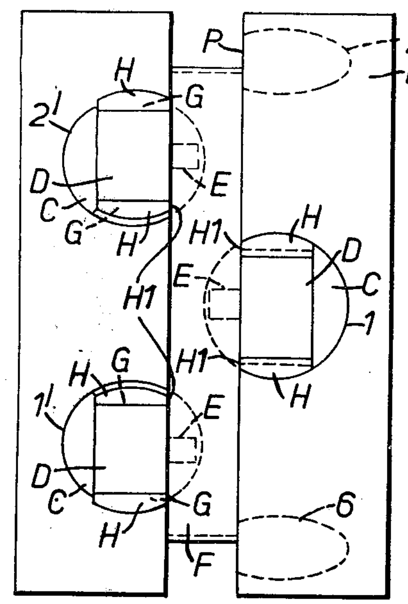

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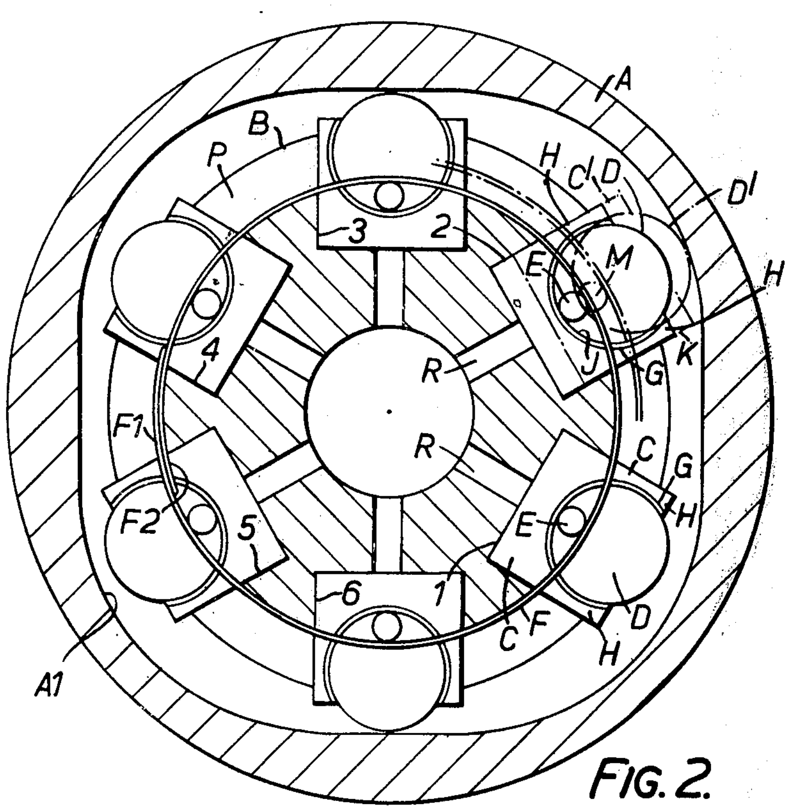
FIG. 1.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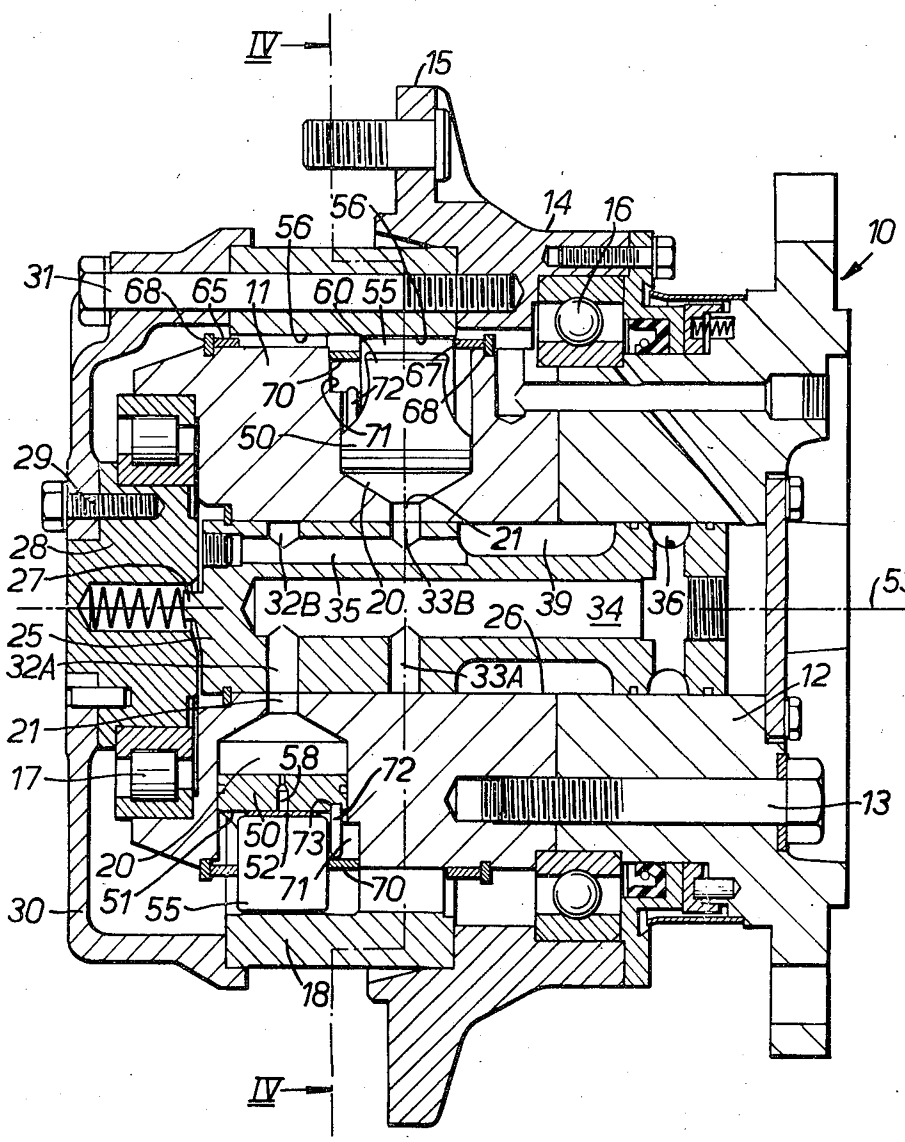
A1

FIG. 2.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15
56
14
16
10
31
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65
11
56
60
55
70
72
67
68
50
71
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21
28
27
32B
35
20
33B
39
34
36
53
25
26
32A
33A
12
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17
58
72
13
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50
73
52
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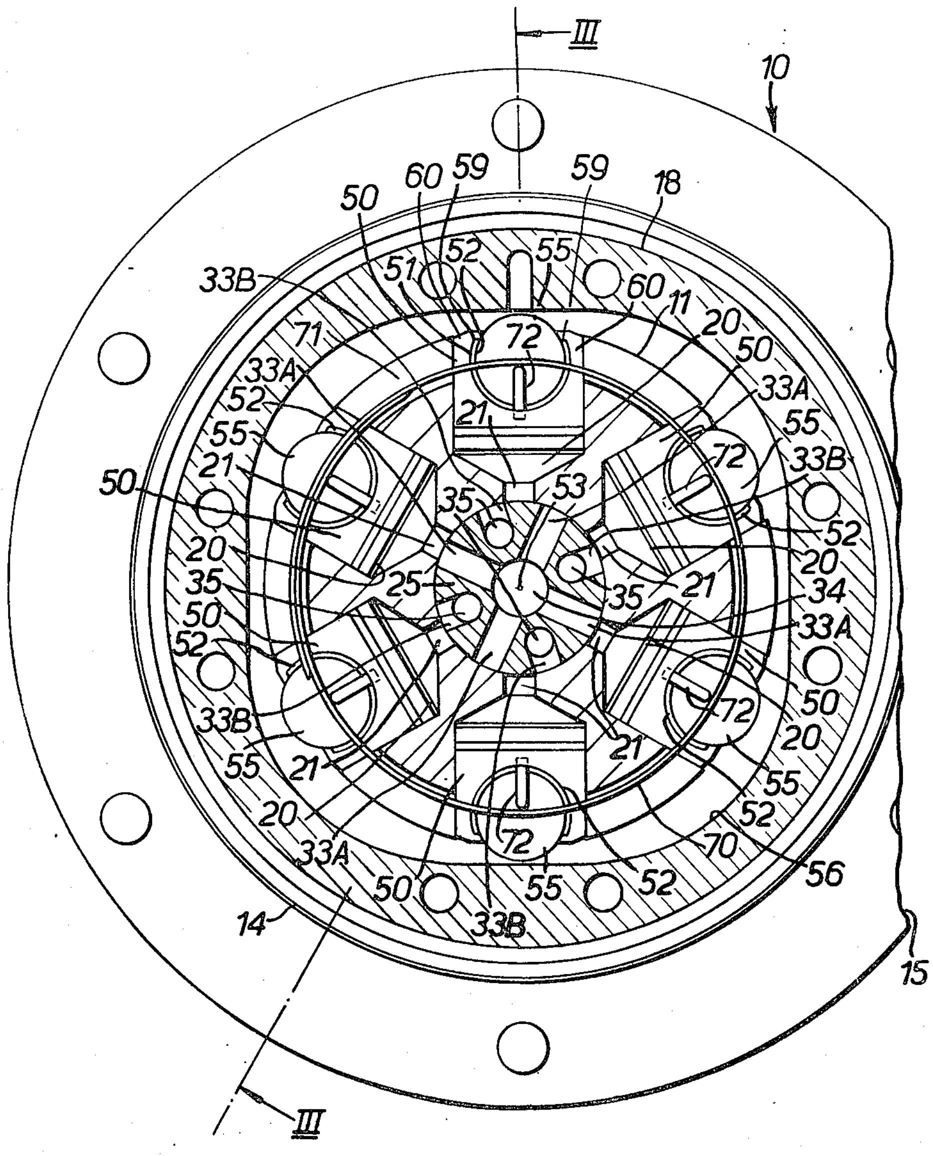
18
IV

FIG. 3.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50
60
59
59
18
33B
51
52
55
60
11
20
71
72
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33A
33A
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55
21
72
55
33B
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21
53
35
52
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20
25
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21
35
34
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33A
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72
33B
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33B
15
III

FIG. 4.

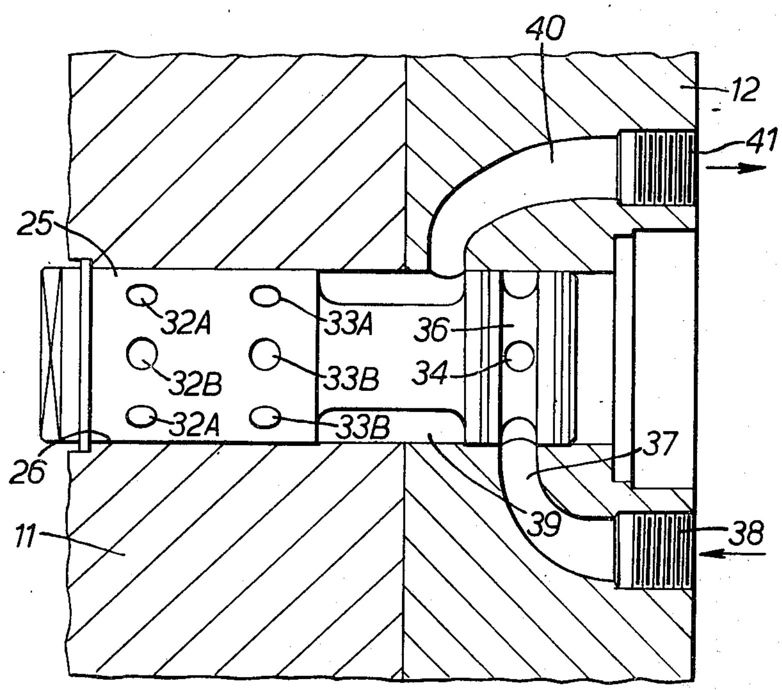

FIG. 5.

RADIAL-PISTON ROTARY HYDROSTATIC MACHINES

This invention relates to positive-displacement cam-controlled rotary hydrostatic machines of the radially-reciprocating piston and cam ring type. A machine of this type, which may be operated either as a hydrostatic motor or as a positive-displacement pump, has a cylinder block formed with one or more banks of radial cylinders in which piston assemblies reciprocate radially, the piston assemblies having cam followers, e.g. balls or rollers, which co-act with a circumferential cam profile formed on a cam ring which is co-axial with and rotatable relatively to the cylinder block. The cam ring may surround the cylinder block or vice versa, and either the cylinder block may be fixed and the cam ring rotatable about the axis of the cylinder block, or vice versa. For use as a hydrostatic motor, the inner ends of the cylinders are connected in the required sequence to a supply of pressurised hydraulic fluid and to a hydraulic return line, the resultant radial reciprocation of the pistons producing the required relative rotary drive between the cylinder block and the cam ring.

When a rotary hydrostatic machine of the type specified is rotating whilst its cylinders are unpressurised, so that there is insufficient radial bias on the pistons to keep their cam followers in rolling contact with the associated cam profile, the cam followers will intermittently hit the surface of the cam profile during such free rotation, causing noise and possibly damage. For example, in the case of a hydrostatic motor which normally provides the propulsion for a ground vehicle, this hitting of the cam surface by the piston-and-follower assemblies may occur when the vehicle is being towed whilst the motor is unpressurised.

An object of the present invention is to provide a hydrostatic motor of the type referred to above with a simple means for preventing the cam followers of the piston assemblies from hitting their associated cam surface under such conditions.

Another object of the present invention, is to provide a rotary hydrostatic machine of the kind specified, with a radially-resilient circular spring, e.g. a leaf spring formed by a flat spring strip curled lengthwise into circular form with its two end portions overlapping one another, which co-acts with the piston-and-follower assemblies of either one bank or two adjacent banks of the cylinders, and acts radially on each piston thereof to hold the piston resiliently in a radially-withdrawn position in which its follower is clear of the whole of the associated relatively-rotating cam profile.

For example in the case of a machine in which the cylinder block is surrounded by the cam ring, the or each circular spring may be a leaf spring located in a circumferential groove formed in the exterior of the cylinder block and intersecting all the cylinders of at least one bank on one side of the cylinders.

With such an arrangement one edge of the or each circular leaf spring will overlie a part of the circular body of each piston outside one end face of the cylindrical follower roller carried by the piston, so as to engage the piston radially with respect to the cylinder block, either directly or through the intermediary of a small roller or a radial peg or some other interposed member.

The invention may be carried into practice in various ways, but for the better understanding of the invention

two specific embodiments of the invention will now be described by way of example only, and with reference to the accompanying drawings, in which:

FIG. **1** is a diagrammatic side view of the cylinder block of a hydrostatic motor of the type specified;

FIG. **2** is a diagrammatic view of the cylinder block and surrounding cam ring of the motor, in section through the groove P in the cylinder block but showing only two cylinders of the block;

FIG. **3** is a view in axial section of a second embodiment of hydrostatic motor, the section line being indicated at III—III in FIG. **4**;

FIG. **4** is a cross-section on the line IV—IV of FIG. **3**, showing the machine with its pistons retracted; and

FIG. **5** is a fragmentary view showing the rotatable central pintle and porting arrangements of the motor.

In the first illustrated embodiment, FIGS. **1** and **2** shows schematically a hydrostatic motor which comprises a cam ring A formed with an internal endless circumferential cam profile A1 and surrounding co-axially a cylinder block B formed with two banks each of six radial cylinders, **1** to **6** and **1'**, **2'**, etc. The cam ring profile A1 is shown purely diagrammatically in FIG. **2**, no attempt having been made to illustrate its exact configuration. The cylinder block B is formed with a circumferential groove P in which is located a circular leaf spring F, whose two ends F1 and F2 overlap one another to allow the resilient radial expansion and contraction of the spring. The groove P intersects the cylinders of the two adjacent banks on their adjacent sides as shown, to a radial depth insufficient to open into the inner ends of the cylinders when their pistons are at their radially-outermost positions at the ends of their outward strokes. The piston C themselves carry cylindrical follower rollers D, each roller D being journalled in a part-cylindrical bearing shell G whose end portions, backed by opposed skirt portions H of the piston, extend around somewhat more than **180°** of the circumference of the respective roller D so that the roller is trapped in its journal shell and cannot escape radially from the piston. This feature is the subject of our co-pending U.S. Pat. Application Ser. No. **388622.**

As shown in FIG. **1**, the skirt of each piston C is cut away at H1 on either side up to the corresponding end face of its roller D, and each shell G is correspondingly cut away, to accommodate the overlapping edge portion of the circular leaf spring F, and a small roller E is trapped between the margin of the leaf spring F and the margin of the concave surface of the bearing shell G at the base of the cut-away side of the piston, so that the spring F can act radially inwardly on each piston C via the roller E to bias the piston radially inwardly and to tend to hold the piston resiliently in its innermost radial position, in which the follower roller D is clear of the path of the peaks of the cam profile A1 as the latter rotates relatively to the cylinder block.

Conventional rotary valve arrangements are provided for connecting the inner ends of the cylinders cyclically, via passages R, to the fluid pressure inlet and return ports (not shown) of the motor.

Thus so long as the cylinders remain unpressurised, the leaf spring F acting radially-inwardly on all the pistons C via their trapped rollers E will retain the piston-and-follower assemblies in their radially-withdrawn positions, as shown in firm lines for all the cylinders **1** to **6** in FIG. **2**, so that the cam ring A can be freely rotated relatively to the cylinder block B without the rollers D hitting the rotating cam profile A1.

When the cylinders are pressurised however, the leaf spring F will yield resiliently to allow the pistons to be moved radially-outwardly by the fluid pressure acting on them, to positions in which their rollers D engage and drive the cam, as shown at C', D' in the case of the cylinder 2 in FIG. 2. The spring yields by radial expansion, its overlapped end portions sliding circumferentially relatively to one another. When the pressure in the cylinders falls back to zero, the leaf spring F contracts radially to withdraw all the piston-and-follower assemblies once more to their innermost positions clear of the path of the relatively-rotating cam.

As seen in FIG. 1, the leaf spring co-operates with the pistons of two adjacent banks of cylinders, opposite edges of the spring acting resiliently on all the cylinders in the respective banks.

The spring F need not act on each piston via a small trapped or journalled roller, but might bear directly against a surface of the body of the piston itself.

It will be clear that in the case of a motor having an external cylinder block surrounding an internal cam ring with an outwardly-facing cam surface, the leaf spring would be arranged in an internal groove in the cylinder block to bear resiliently outwardly on the piston-and-follower assemblies, so as to retract them radially-outwardly away from the cam when the cylinders were not pressurised.

FIGS. 3 to 5 show in greater detail another construction of hydrostatic motor embodying the present invention, the motor being suitable for the direct drive of a vehicle road or land wheel, and comprising a non-rotatable cylinder block **11** bolted to a back plate **12**, by means of bolts **13**, and a rotatable hub assembly **14** providing a wheel flange **15** to which a wheel can be bolted, the hub assembly **14** being rotatably mounted in bearings **16, 17** on the back plate **12** and cylinder block **11** and including a motor housing **18** which encloses the fixed cylinder block **11**. The cylinder block **11** is formed with twelve radial cylinders **20**, arranged in two axially-spaced banks each of six cylinders at **60°** spacings, the cylinders **20** being open at their radially-outer ends and each being provided with an inlet and discharge port **21** at its inner end which co-operates with a ring of ports formed in a pintle **25** rotatable with the hub assembly **14** in a coaxial central bore **26** in the cylinder block **11**, whereby the cyclic admission and discharge of hydraulic fluid to and from the cylinders is controlled in known manner as the hub assembly rotates. The pintle **25** is a close fit in the bore **26** in which it rotates, the pintle being keyed at **27** to a central spigot block **28** bolted by bolts **29** to a dished end cover plate **30** of the hub assembly **14**. The cover plate **30** is bolted by bolts **31** to the rotary motor housing **18** of the hub assembly, and its spigot block **28** is journalled by means of the bearing **17** in one end of the fixed cylinder block **11**. The pintle **25** thus rotates with the hub assembly **14** and in the bore **26** in the cylinder block. The pintle **25** is formed with two axially-spaced rings of ports, **32A, 32B** and **33A, 33B** which respectively co-operate with the ports **21** of the two banks of cylinders **20**. The ports **32A** and **32B** alternate in their ring and are respectively connected to an inlet gallery **34** and to associated discharge galleries **35**, all formed longitudinally in the pintle **25**. The ports **33A** and **33B** also alternate in their ring and are respectively connected to the galleries **34** and **35**, as shown. The central inlet gallery **34** leads into a circumferential groove **36** in the pintle surface, the groove **36** being in communication with a passage **37** formed in the back plate **12** and leading from an inlet port **38** for connection to a hydraulic pressure supply line, as shown in FIG. **5**. The four discharge galleries **35** all lead into a common circumferential groove **39** formed in the pintle surface, the groove **39** being in communication with a discharge passage **40** formed in the back plate **12** and leading to a discharge port **41** for connection to a hydraulic fluid return line. Thus as the hub assembly **14** and the pintle **25** rotate relatively to the back plate **12** and cylinder block **11**, the cylinder ports **21** are successively brought into alignment with the ports **32A, 32B**, or **33A, 33C** in the pintle and are thereby successively connected to the hydrostatic supply pressure and to the return pressure.

Slidable in each cylinder **20** is a cylindrical piston **50** formed in its outer end face with a concave recess **51** lined by a part-cylindrical bearing shell **52** whose axis extends parallel to the axis of rotation **53** of the hub. Journalled in the bearing **52** in each piston **50** is a cylindrical roller **55**, part of whose cylindrical surface protrudes outwardly from the piston bearing shell **52** and co-acts with a circumferential cam track **56** formed internally in the motor housing **18** for rotation with the hub assembly **14**, and surrounding the cylinder block **11**. There are two such cam tracks **56**, spaced apart axially and co-acting with the rollers **55** of the pistons **50** of the respective two banks of cylinders. Each bearing shell **52** has a small lubrication port in its base which communicates via a passage **58** (FIG. 3) through the recessed piston crown with the interior of the associated cylinder **20**, whereby pressure fluid from the cylinder **20** is fed to the bearing **52** to lubricate its bearing surface.

The pistons **50** are biassed radially inwardly in the associated cylinders **20** by a circular leaf spring **70** which lies in a circumferential groove **71** formed in the cylinder block **11**, and in addition fluid at low hydraulic pressure fills the interior of the housing **18** and acts on the pistons **50** to bias them radially inwardly. The rollers **55** are positively retained in their bearings **52** and prevented from separating radially from the pistons by the shape of the bearings themselves. Thus each bearing shell **52** subtends an angle of about **245°** at the axis of the roller **55**, so that the opposite side portions of the bearing shell **52** extend partially around the outer semi-cylindrical surface of the roller **55**, as shown in the drawings. The spacing between the longitudinal edges **59** of the bearing shell **52** is thus less than the diameter of the roller **55** which is therefore trapped against leaving the shell in the radially-outward direction. The skirts **60** of the piston **50** are similarly formed to extend beyond the level of the axis of the roller, in the outward direction of piston reciprocation, and are inwardly-curved at their outwardly-extending portions to back up and support the bearing shell **52** where this wraps around the roller **55**.

In this manner the follower rollers **55** are positively retained radially in their bearings and are prevented from leaving the pistons **50** during free-wheeling of the motor.

The follower rollers **55** are also provided with positive end location means to hold them centralised in their bearings with respect to the axes of their respective cylinder bores and square to the cam tracks **56.** This end location means comprises two outer guide rings **65** and **67** which coaxially surround the cylinder block **11,** and are located immediately adjacent to the outer ends of the rollers **55** of the respective cylinder banks, the leaf spring **70** being interposed between the cylinder banks as a spacer between the two sets of rollers **55.** The outer two guide rings **65** and **67** are axially retained by means of spring circlips **68** fitted outside them in shallow circumferential grooves in the cylinder block, to hold the guide rings **65** and **67** in positions slightly overlapping the open ends of the cylinders **20.** The guide rings **65** and **67** are a free running fit on the cylinder block **11,** so that they are freely rotatable to reduce rubbing losses between them and the rollers by reducing the relative speeds of sliding between the rollers and the guide rings when the rollers are rotating in their bearings **52.** It will be seen that the guide rings thus provide endwise location for the rollers without interfering significantly with the free reciprocation of the pistons and rollers as the latter co-act with the cam tracks.

It will be seen from FIG. **3** that the circuferential groove **71** formed in the cylinder block **11** intersects the cylinders **20,** the walls of the groove **71** being approximately coplanar with the respective inner side faces of the rollers **55** of the two banks of cylinders. The leaf spring **70** is a free fit in the groove **71** and thus overlaps the margins of the full-diameter cylindrical bodies of the pistons **50.** The intersection of the part-cylindrical transverse bore **51** in each piston which provides the recess for its follower roller **55** and bearing liner shell **52,** with the cylindrical outer surface of the body of the piston **50** produces a waisted profile of the two skirt portions **60** of the piston, as shown in elevation in FIG. **3,** whereby one longitudinal margin of the leaf spring can partially overlie the crown of each piston **50** as shown. As also clearly shown in FIG. **3** the axial length of each follower roller **55** is less than the full diameter of the piston **50** which carries it, and the leaf spring **70** which as mentioned is a free running fit in the groove **71** lies between the follower rollers **55** of the two banks of cylinders, with the opposite edges of the leaf spring lying in opposed relationship to the adjacent end faces of the rollers **55** of the respective banks of cylinders, so that the edges of the leaf spring constitute abutments to provide endwise location of the follower rollers of the respective banks in the axial direction towards one another. Endwise location of the follower rollers in each bank in the direction away from the other bank of cylinders is provided by the respective rotatable guide ring **65** or **67.** A peg **72** having a domed upper end is mounted in a small hole **73** formed in the body of each piston **50** at one outer end of the transverse bore **51** and at the radially-lowest part of that bore **51,** the peg **72** extending parallel to the axis of the piston **50** in the radially-outward direction with respect to the cylinder block, so that the domed outer end of each peg engages the inner side of the leaf spring **70.** The pegs **72** thus take the places of the small rollers E of the preceding embodiment, so that when there is no supply pressure in the inner ends of the cylinders the leaf spring **70** will act resiliently on the pistons **50** via their pegs **72** and will hold the pistons in their fully-withdrawn radially-innermost positions in the cylinders **11,** as shown in FIG. **4,** in which positions the rollers **55** are just clear of the cam tracks **56,** and the motor housing **18** together with the cam tracks **56** can free-wheel relatively to the cylinder block **11** without the rollers **55** hitting the cam tracks.

However, when the inner ends of the cylinders **11** are pressurised for driving the motor, the supply pressure will force the pistons **50** radially outwardly until their rollers **55** engage the cam tracks **56,** the leaf spring **70** yielding by expansion under the radial pressure applied to it by the pegs **72** carried by the pistons **50,** as shown in FIG. **3.** When the pressure in all the cylinders is again relieved for free-wheeling, the leaf spring **70** again contracts to withdraw all the pistons **50** and their follower rollers move once more to their innermost position just clear of the path of the relatively-rotating cam tracks.

It will be understood that whilst in the embodiments described and illustrated the cylindrical surfaces of the rollers and their bearing shells are generated by straight lines, it would also be possible for the rollers to be slightly barrel-shaped, i.e. generated by curved generators, and for the cam tracks and possibly also the bearing shells to be correspondingly curved. The terms "cylindrical" and "part-cylindrical" as used herein are to be interpreted accordingly.

What we claim as our invention and desire to secure by Letters Patent is:

1. A positive-displacement cam-controlled rotary hydrostatic pressure machine comprising a cylinder block having a bank of angularly-spaced radial cylinders, radially-reciprocable pistons in the cylinders, a cam ring mounted coaxially with the cylinder block for rotation relative thereto, an endless circumferential cam track on the cam ring, the pistons carrying cam followers which coact with the cam track to relate the cyclic radial reciprocation motion of the pistons to rotary motion of the cam ring relative to the cylinder block, valve means cyclically controlling the inlet and discharge of hydraulic fluid to and from the cylinders in synchronism with the rotary motion of the cam ring relative to the cylinder block, and a radially-resilient circular leaf spring comprising a spring strip curled lengthwise into circular form with its two ends overlapping one another, the spring acting resiliently and radially on the pistons in the bank to hold each piston resiliently in a radially-withdrawn position in which its follower is clear of the path of the cam track during rotation of the cam ring relative to the cylinder block with the cylinders unpressurized.

2. A motor as claimed in claim **1** in which the follower of each piston comprises a cylindrical roller rotatably mounted in a recess formed in the end of the piston nearest to the cam ring, the roller being prevented from separating radially from the piston, and in which the longitudinal edges of the leaf spring lie in opposed relationship to end faces of the rollers of the respective banks of cylinders, whereby the opposite edges of the leaf spring constitute abutments which provide endwise location for the follower rollers of the respective banks of cylinders.

3. A rotary machine as claimed in claim **1** in which there are two of the said banks of cylinders in the cylinder block, the cylinders in the respective banks being angularly-staggered in relation to one another, and in which the leaf spring is interposed between the two banks of cylinders with the opposite circumferential marginal portions of the leaf spring respectively overlapping the cylinders of the two banks and acting on the respective pistons therein.

4. A rotary machine as claimed in claim **3** in which the cam ring circumferentially surrounds the cylinder block and the leaf spring is located as a free fit in a circumferential groove in the outer circumference of the cylinder block, the groove intersecting the cylinders of both banks, and in which the follower of each piston comprises a cylindrical roller rotatably mounted in a recess in the end of the piston nearest to the cam ring, the roller being prevented from separating radially from the piston, and in which the longitudinal edges of the leaf lie in opposed relationship to end faces of the rollers of the respective banks of cylinders, whereby the opposite edges of the leaf spring constitute abutments which provide endwise location for the rollers of the respective banks of cylinders.

5. A rotary machine as claimed in claim **4** including spacer rollers freely interposed between the inner face of the leaf spring and each piston, the axes of the spacer rollers being parallel to the axis of the cam ring, and the resilient force of the leaf spring being transmitted radially to each piston through its associated spacer roller.

6. A rotary machine as claimed in claim **4** including a radial peg mounted on each piston to protrude radially outwardly towards the leaf spring, each peg having a domed outer end in contact with the inner face of the leaf spring whereby the resilient force of the leaf spring is transmitted to each piston through its associated peg.

7. A positive-displacement cam-controlled rotary hydrostatic motor comprising a cylinder block having two axially-spaced banks of angularly-spaced radial cylinders, the cylinders in the respective banks being axially-staggered in relation to one another, radially-reciprocal pistons in the cylinders, a cam ring coaxially surrounding the cylinder block and mounted for rotation relative thereto, an endless circumferential internal cam track on the cam ring facing the cylinder block, the pistons carrying followers which co-act with the cam track to convert cyclic radial reciprocating motion of the pistons in the cylinders into continuous rotary motion of the cam ring relative to the cylinder block, inlet and exhaust ports for high pressure fluid, valve means cyclically controlling the admission of pressurized hydraulic fluid from the inlet port to the cylinders and the discharge of the fluid from the cylinders to the exhaust port in synchronism with the rotary motion of the cam ring relatively to the cylinder block for driving the motor, and a circular leaf spring comprising a flat spring strip curled lengthwise into circular form with its two end portions overlapping one another, the leaf spring being housed in an external circumferential groove in the cylinder block, which groove is positioned between the two banks of cylinders and intersects the cylinders of both banks, and in which the leaf spring overlaps the cylinders of both banks and opposite circumferential marginal portions of the leaf spring respectively act resiliently and radially-inwardly on the pistons in the respective banks, so that the leaf spring holds each piston resiliently in a radially-withdrawn inner position in which its follower is clear of the path of the cam track during rotation of the cam ring relative to the cylinder block when the cylinders unpressurized.

8. A motor as claimed in claim **7** including spacer rollers freely interposed between the inner face of the leaf spring and each piston, the axes of the spacer rollers being parallel to the axis of the cam ring and the resilient force of the leaf spring being transmitted to each piston through its associated spacer roller.

9. A motor as claimed in claim **7** including a radial peg mounted on each piston to protrude radially outwardly towards the leaf spring, each peg having a domed outer end in contact with the inner face of the leaf spring whereby the resilient force of the leaf spring is transmitted to each piston through its associated peg.

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