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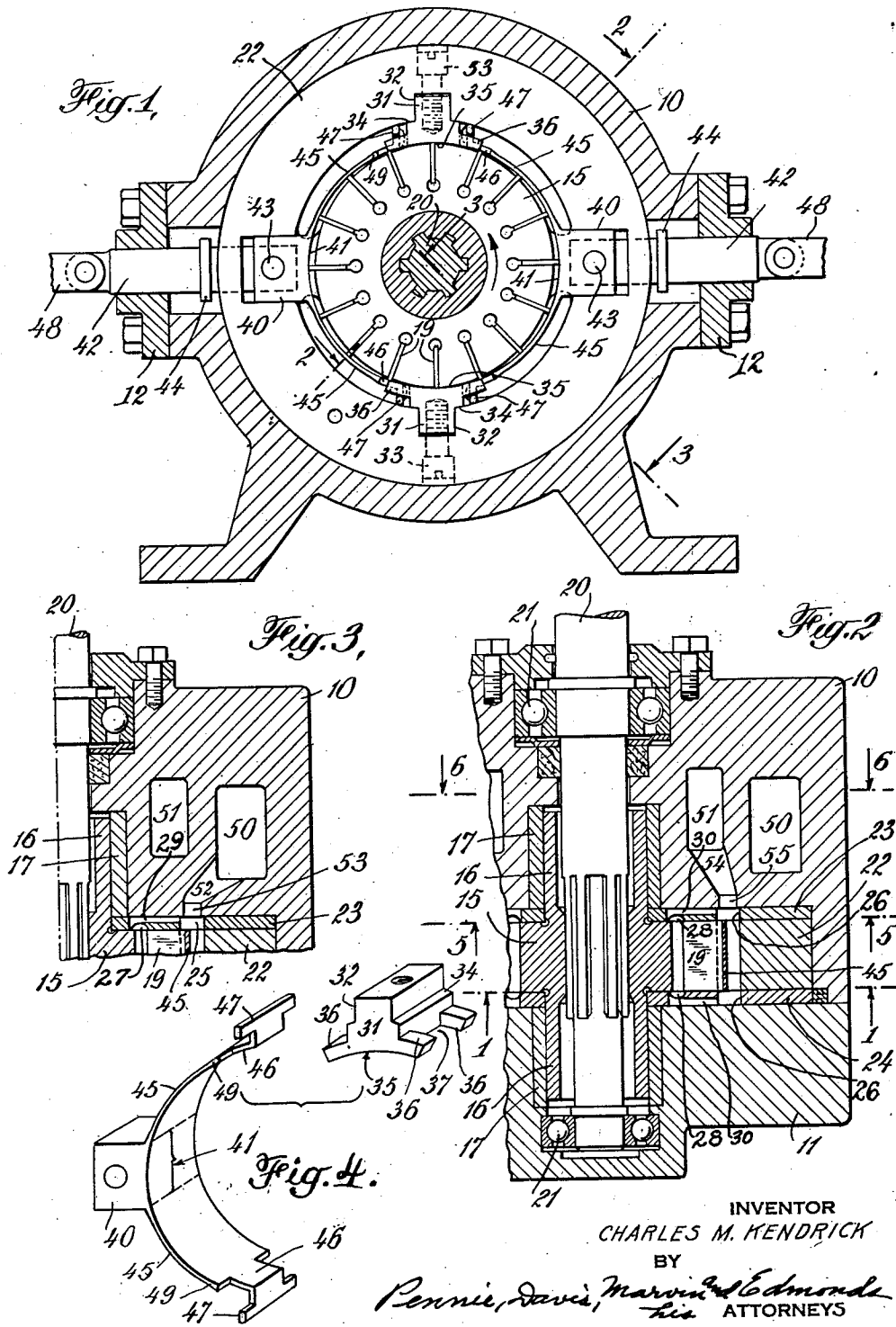
C. M. KENDRICK

2,368,223

FLUID PRESSURE DEVICE

Filed Nov. 23, 1940

3 Sheets-Sheet 1

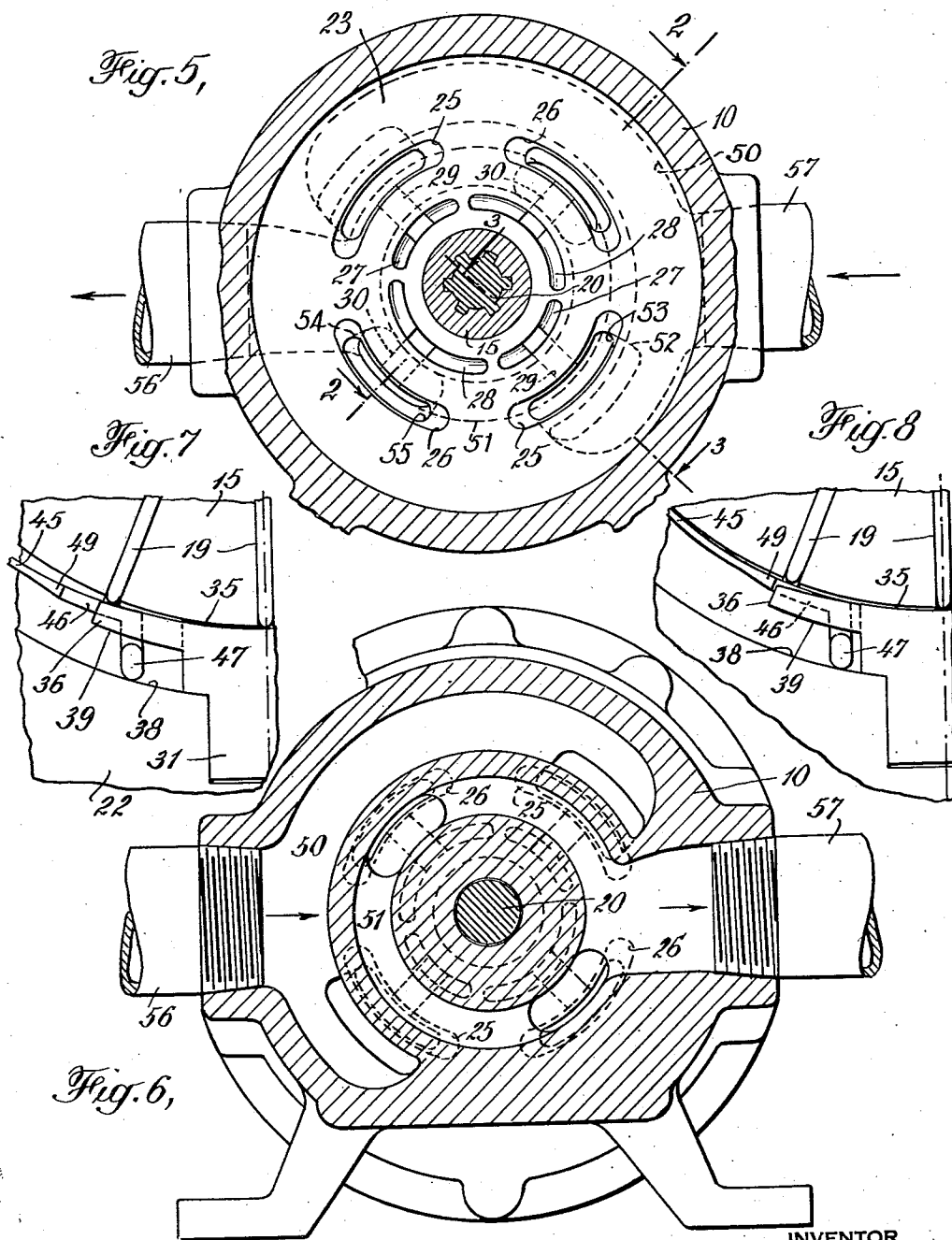


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3 Sheets-Sheet 2



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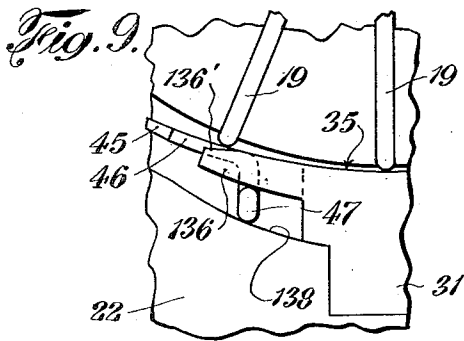
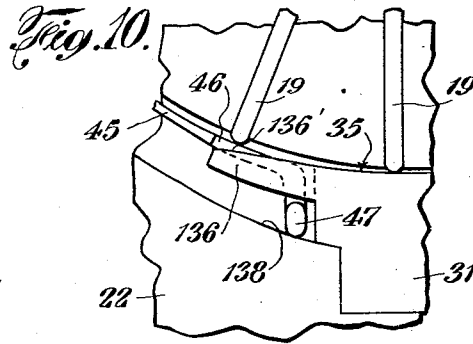
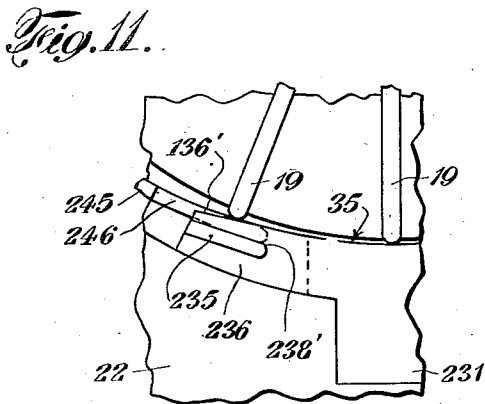
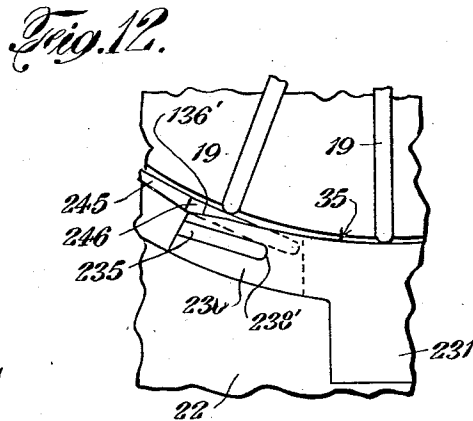
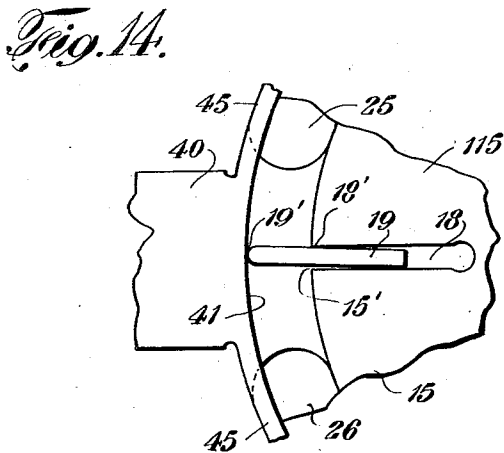
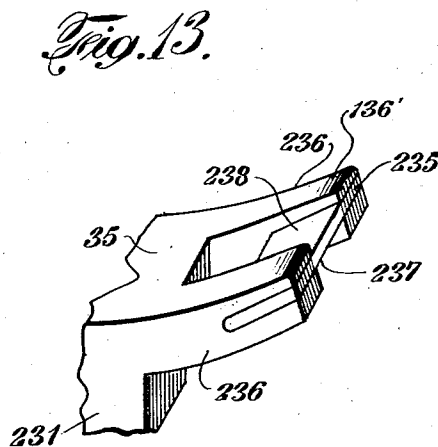
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FLUID PRESSURE DEVICE

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3 Sheets-Sheet 3



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2,368,223

FLUID PRESSURE DEVICE

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Application November 23, 1940, Serial No. 366,931

20 Claims. (Cl. 103—120)

This invention relates to vane type rotary fluid pressure devices, such, for example, as pumps or fluid motors, the volumetric capacity or output per revolution of which can be regulated or varied, and it relates more particularly to improvements in that portion of the fluid pressure device by means of which such variation of capacity or output is obtained. The present application is a continuation in part of my prior application filed December 24, 1938, Serial Number 247,586.

The widest present use for pumps and motors of this general class is as hydraulic devices, that is, devices for handling or whose motive fluid is a liquid, such, for example, as oil, and the device of the present invention will be described in connection with such use. It will be understood, however, that some features of the invention are applicable to fluid pressure devices operating with elastic fluids, although particularly intended for use in fluid pressure devices, such, for example, as pumps and motors, employed as hydraulic devices.

Fluid pressure devices of the type under consideration include a rotor provided with vanes which are movable inward and outward in a general radial direction and arranged to rotate within a chamber having side walls which closely fit the sides of the rotor and the side edges of the vanes. A trackway, which surrounds the radially outer ends of the vanes and controls their inward and outward movement, comprises one or more pairs of abutments and interconnecting flexible track elements. One abutment of each pair is preferably arranged in fixed position adjacent the circumferential surface of the rotor and the other abutment of the pair is adapted to be radially adjusted with respect to said circumferential rotor surface. With this preferred arrangement the work of the fluid pressure device is done while the vanes move across an arc on the movable abutment, termed the "working" or "pumping" arc, the working fluid being received at one end of this arc and discharged on the other.

The regulation of the volumetric capacity or output per revolution of the fluid pressure device is effected by moving or adjusting the abutments of each pair upon which the "working" or "pumping" arc is located, that is to say, by moving or adjusting the position of the movable abutment. The flexible track elements have extensible connections with one abutment of each pair, thereby permitting adjustment of the

movable abutment without changing the position of the other abutment.

Fluid pressure devices of this general type are disclosed, for example, in U. S. Patents Nos. 2,141,170 and 2,141,171, assigned to the same assignee as the present application. While the constructions disclosed in these applications have been found to provide entirely satisfactory operation, the present invention concerns certain improvements and its general object is to provide an improved fluid pressure device capable of equally satisfactory operation but in which the construction is materially simplified, rendering the parts easier and less expensive to manufacture.

Another object is to provide an improved and simplified structure by which the ends of the flexible track elements are brought into proper relation with respect to the fixed abutments so that the vanes may pass smoothly and without interruption from one to the other of these members.

Other and more specific objects will appear from the description which follows.

The invention will be understood from consideration of the accompanying drawings which illustrate, by way of example, embodiments of the invention in a pump of variable capacity.

In the drawings:

Fig. 1 is a view in vertical transverse section taken along the line 1—1 of Fig. 2.

Fig. 2 is a partial longitudinal sectional view taken along the line 2—2 of Fig. 1.

Fig. 3 is a similar view along the line 3—3 of Fig. 1, showing certain details of the pump's fluid circuit.

Fig. 4 is a perspective view of one of the fixed abutments and of one of the movable abutments shown in Fig. 1 and having the flexible track elements integral with the movable abutment.

Fig. 5 is a transverse section, along the line 5—5 of Fig. 2 and looking in the direction of the arrows, showing the casing end plate in position in the cavity of the pump casing and also showing in dotted lines the fluid connections between the ports of this end plate and the inlet and outlet conduits.

Fig. 6 is a sectional view, also transverse the axis of the pump but looking in a direction opposite to that of the view of Fig. 5 as indicated by the arrows at the line 6—6 of Fig. 2, along which line Fig. 6 is taken.

Fig. 7 is an enlarged view somewhat exaggerated showing the position of the end of one

of the flexible track elements illustrated in Figs. 1 and 4, relative to its corresponding fixed abutment, when the movable abutment thereof is adjusted to its "full stroke" or maximum outward position.

Fig. 8 is a view similar to Fig. 7 showing the relative positions of the parts when the movable abutment is adjusted to its "zero stroke" or extreme inward position.

Figs. 9 and 10 are enlarged views corresponding generally to Figs. 7 and 8 but showing a modification;

Figs. 11 and 12 are also enlarged views corresponding generally to Figs. 7 and 8 but showing another modification;

Fig. 13 is a fragmentary perspective view of a fixed abutment also shown in Figs. 11 and 12; and

Fig. 14 is an enlarged fragmentary view illustrating in somewhat exaggerated manner the preferred relationship between the vanes and vane slots.

Referring now to the drawings, as shown in Fig. 2 the pump includes a casing 10 and a head or cover 11 which co-operate to form a cavity for the rotor 15 and associated parts. The rotor 15 is rotatably supported by its hubs 16 which extend into bushings 17 carried by the casing 10 and cover 11 respectively and the rotor is also provided with substantially radial vane slots 18 in each of which is a vane 19 adapted to be moved radially inward and outward therein. The outer ends of the vanes 19 are preferably given a rounded or arcuate contour as indicated at 19' in Fig. 14, in order to contribute to their smooth and uninterrupted passage across the extensible connections between the vane trackway elements to be hereinafter described.

The pump's driving shaft 20 is revolvably supported in bearings 21 carried by the casing 10 and cover 11 respectively, and shaft 20 passes through the central bore of the rotor 15 with which it has a slidable splined connection as clearly shown in Figs. 1, 2 and 5.

A substantially annular spacer block or ring 22 surrounds the rotor and vane assembly (Fig. 1) and separates a pair of disk-shaped end plates 23 and 24 which are provided with holes at their centers through which pass the hubs 16 of the rotor 15, as best shown in Fig. 2. The outer faces of the end plates 23 and 24 fit snugly against the adjacent wall surfaces of the casing 10 and cover 11 respectively and form substantially fluid tight fits with the several ports and passages to be presently described. The inner or opposing faces of the end plates 23 and 24 form fluid tight fits with the sides of the spacer ring 22 by which they are axially positioned with respect to the rotor 15 in such manner that the rotor is permitted to rotate freely while its sides and the side edges of the vanes form substantially fluid tight running fits with the adjacent faces of the end plates 23 and 24.

The space within the chamber formed between the end plates 23 and 24 and which surrounds the rotor 15 is divided into a plurality of pumping sections, preferably two, each consisting of a working or pumping chamber flanked by an inlet area and an outlet area. In this embodiment this space is divided into two pumping sections by a pair of diametrically positioned fixed abutments 31 (Fig. 1) which extend inward from the spacer ring 22 and are positioned above and below the rotor 15. Each fixed abutment 31 is formed with a reduced outer end portion

32 which is received within an appropriate slot or recess in the spacer ring 22 and is held in place by a screw 33, as shown by the dotted lines of Fig. 1, so that the shoulder 34 (Figs. 1 and 4)

on each fixed abutment forms a fluid tight seal with the spacer ring 22. This arrangement also serves to accurately locate the fixed abutments 31 with respect to the rotor 15 and other parts of the pump. Each fixed abutment 31 is of the same width or thickness as that of the spacer ring 22 and hence forms a fluid tight seal with the faces of the end plates 23 and 24. The interior surface of each fixed abutment 31 includes an arcuate surface 35, termed a "sealing arc," which is adapted to form a substantially fluid tight sliding or running fit with the ends of the vanes 19 and which has an angular length equal to or slightly greater than the distance between a pair of adjacent vanes 19. The fixed abutments 31 thus co-operate with the rotor 15 and the vanes 19 to form the division between the pump's two pumping sections. The sealing arcs 35 may be concentric with the rotor 15, as in the embodiment illustrated in Figs. 1, 4, 7 and 8, although not necessarily so.

The working or pumping chambers of the two pumping sections are formed by means of the two diametrically positioned movable abutments 40, shown in side elevation in Fig. 1 and one of which is shown in perspective in Fig. 4. Each working or pumping chamber extends in a circumferential direction for a distance at least equal to the space between two adjacent vanes 19 which at any given instant are moving in contact with the corresponding arc 41 (Fig. 4) on the inner end of the corresponding movable abutment 40; the arcs 41 will be referred to as the "pumping arcs." The center line of each pumping arc 41 is preferably in line with the horizontal center line of its corresponding movable abutment 40 and the two pumping arcs or pumping chambers are thus diametrically opposite one another. The size of the pumping chambers, and hence the volume of fluid delivered per revolution of the rotor 15, is determined by the distance of the pumping arcs 41 from the circumferential surface of the rotor 15. The radial distance through which the vanes move in passing from the sealing arc 35 to the pumping arc 41 is termed the "stroke" of the pump and varies in length conformably with change in position of the movable abutments 40.

The movable abutments 40 are arranged to be adjusted in a substantially radial direction to permit regulation or variation in the size of the pumping chambers and hence in the output of the pump. The movable abutments 40 are accordingly supported by and form substantially fluid tight fits with a pair of slideways formed in the spacer ring 22, as shown in Fig. 1. The width of the movable abutments 40 is substantially the same as that of the spacer ring 22 and the arrangement is such that said movable abutments 40 likewise form substantially fluid tight sliding fits with the adjacent faces of the end plates 23 and 24. In this manner the movable abutments 40, in co-operation with the rotor 15 and the vanes 19, separate the inlet area of each pumping section from the outlet area thereof while permitting adjustment or variation in the size of the pumping chambers.

The movable abutments 40 are adapted to be moved or adjusted inward and outward, to regulate the output of the pump, by means of a pair of adjusting rods 42 (Fig. 1), the inner ends of

which are received within suitable holes drilled in the movable abutments 40 as indicated by the dotted lines of Fig. 1, and the parts are fastened together by pins 43. The adjusting rods extend through suitable holes in the spacer ring 22 and in the side covers 12 which close the horizontal adjusting rod bores formed in the casing 10. Movement or adjustment of the adjusting rods 42 and movable abutments 40 may be effected by any suitable means, not shown, which may be conveniently connected with the links 48 on the outer ends of the adjusting rods. Maximum outward adjustment of the movable abutments 40 is limited by the ends of the parallel slideways of the spacer ring 22 by which said movable abutments are supported and their maximum inward adjustment is limited by stops 44 formed on the adjusting rods 42 and having a diameter greater than that of the holes in the spacer ring 22 through which the adjusting rods pass.

Fluid is admitted to the spaces between the outer ends of the vanes as they approach each pumping chamber and fluid is discharged in like manner as the vanes recede therefrom. This admission and discharge is accomplished through a pair of diametrically opposite arcuate inlet ports 25 and a similar pair of outlet ports 26 formed in the casing end plate 23 as shown in the full lines of Fig. 5 and the dotted lines of Fig. 6; one of the inlet ports 25 is shown in the sectional view of Fig. 3 and one of the outlet ports 26 is similarly shown in Fig. 2. The end plate 24 is likewise provided with similar ports which serve as "balance ports" to contain fluid under the same pressure as that in the corresponding ports in the end plate 23 in order to substantially balance the hydraulic forces acting on the sides or axial ends of the vanes to prevent binding thereof. Fluid is also admitted and discharged, however, through the ports of the end plate 24 as the fluid is free to pass to or from said ports through the clearance space intermediate the flexible track elements 45, to be later described, and the spacer ring 22. This clearance space is open for the passage of fluid, particularly adjacent the fixed abutments 31, at all outputs of the pump and at all positions of adjustment of the flexible elements 45. With this arrangement fluid passes to and from the outer ends of the vanes at both axial sides of the rotor, thus reducing fluid speed which is particularly advantageous as the vanes move through the inlet or suction areas. This arrangement also provides substantial balance of the hydraulic forces acting on the flexible track elements in a radial direction and the ports 25 and 26 provide fluid connection for the outer ends of the vanes during substantially the portion of their rotary movement from one abutment to the other.

Each of the end plates 23 and 24 is also provided, on its face adjacent the rotor, with two pairs of arcuate vane slot ports 27 and 28 respectively which are positioned to register successively with the inner ends of the vane slots as the rotor revolves. The vane slot ports 27 are connected with the inlet ports 25 by radial passages or grooves 29 on the outer faces of the end plates 23 and 24, and similarly the vane slot ports 28 are connected with the outlet ports 26 by the passages or grooves 30. Fig. 5 shows the vane slot ports in full line and the passages 29 and 30 in dotted lines, and Fig. 6 shows both the vane slot ports and the passages 29 and 30 in dotted lines; the vane slot ports and their connecting passages may also be seen in the sectional views of Figs. 2 and 3. The arrangement is such that

the inner ends of the vane slots are connected with fluid under the same pressure as the fluid acting upon the outer ends of their corresponding vanes 19 while said vanes are passing from one abutment to another and hence the vanes 19 are substantially in hydraulic balance when they are moving radially and while they are passing along the flexible track elements 45. The vane slot ports 28 are preferably made of such length that they also connect with the inner ends of those vane slots whose vanes 19 are in contact with the arcs 35 on the fixed abutments 31 and the pumping arcs 41, so that fluid from the outlet ports 26 is supplied to the inner ends of such vanes to assist in holding their ends firmly in contact with the vane track surfaces as they move across the fixed and movable abutments.

The fluid circuit further includes a branched inlet conduit 50 formed in the casing 10 and an annular outlet conduit 51, also formed in said casing, as best shown in Figs. 2 and 5. The inlet conduit 50 is connected by slanted passages 52 with arcuate ports 53 formed in the side wall of the casing 10, as best shown in Fig. 3, the ports 53 registering with the inlet ports 25 of the casing end plate 23. The outlet conduit 51 is similarly connected with the outlet ports 26 of the casing end plate 23, this connection being through slanted passages 54 and arcuate ports 55 in the side wall of the casing 10 as best shown in Fig. 2. Fluid is supplied to the pump from a suitable reservoir, not shown, through the inlet pipe 56 and pressure fluid is discharged by the pump into the outlet pipe 57 which may be connected with any suitable hydraulic device that is to be operated thereby.

When the rotor 15 revolves in a counter-clockwise direction, as viewed in Fig. 1, fluid enters through the inlet ports 25 and passes into the inlet area of each of the two pumping sections of the pump. Pumping is accomplished by the vanes 19 as they move across the pumping arcs 41 and the vanes 19 thus force fluid into the outlet area of each of the two pumping sections from which it passes out through the outlet ports 26 and into the outlet conduit 51. As already stated the size of the pumping chambers and the volume of fluid delivered by the pump are determined by the distance of the pumping arcs 41 from the rotor 15; as this distance may be varied in infinitely small increments from minimum to maximum, the size of the pumping chambers and hence the volume of fluid delivered by the pump may likewise be varied from minimum to maximum. Each vane performs a pumping stroke as it passes through each pumping section so that each pumping section is in effect a complete pump and the two pumping sections combine to form a "double pump."

The pump of the present invention differs importantly from past constructions in respect to the flexible track elements and the other parts cooperatively associated therewith, which will now be described. The flexible track elements 45 are preferably carried by and are shown as made integrally with the movable abutments 40, that is to say, a pair of flexible track elements 45 project from the circumferential ends of the pumping arc 41 of each movable abutment and extend in a general circumferential direction toward the fixed abutments 31 with which they are adapted to connect, the arcuate length of each flexible element thus being less than 90°. Each flexible track element 45 includes a flexible arm or projection and terminates in a short rel-

actively rigid end portion 49 adjacent the fixed abutment 31.

The end portion 49 of each flexible track element is reduced in width to form a tongue 46 (Fig. 4) which extends into one of the spaces 37 between pairs of arms or prongs 36 projecting from each side or circumferential end of the fixed abutment 31, as will be evident from the perspective view of Fig. 4 and the enlarged views of Figs. 7 and 8. The thickness of each tongue 46 is preferably such, however, as to make said tongue substantially rigid so that substantially no flexing thereof takes place as the flexible element 45 is moved with the movable abutment 40; among other advantages, this construction assists in providing satisfactory vane-transferring relation between the vane-contacting surfaces on said tongue and its mating prongs, to be more fully explained presently, and also assists in providing satisfactory curvature or contour of the flexible track element 45 at all pump outputs. The arrangement is such that the vane-contacting surface on the tongue 46 overlaps the vane-contacting surface on the corresponding prongs 36 in all positions of the flexible track element 45 incident to adjustment of its corresponding movable abutment 40. The tongue 46 may have a sliding fit with the opposing side faces of the prongs 36 but it is preferable that these parts be loosely fitted to prevent binding thereof when the tongue 46 is moved relative to the prongs 36; the use of a loose fit also facilitates assembly and manufacture, and hence reduces cost.

In order for the pump to operate quietly and satisfactorily it is necessary that the vane-contacting surface on each tongue 46 be positioned in satisfactory vane-transferring relation with the vane-contacting surface on the corresponding or mating prongs 36 at all outputs of the pump and hence at all positions of the flexible elements 45 and at all lengths of the vane trackway.

According to the present invention satisfactory vane-transfer from the rigid element to the flexible element, or vice versa, is accomplished by greatly simplified structure in which movement of the track elements to alter the output of the pump and the length of the vane trackway not only changes the extent to which the track surface on the end of the flexible element overlaps the track surface on the contiguous rigid element at the extensible joint or connection therebetween but also otherwise changes the positional relation of part or all of the track surfaces on the mating parts and in such manner that satisfactory vane-transfer is at all times provided between said flexible and rigid elements. For example, and with particular reference to the structure illustrated herein, the arrangement may be such that substantially the entire overlapping portion of the track surface of the tongue 46 is aligned or even with the overlapped portion of the track surface on the mating prongs 36 (Fig. 7), with neither of these surfaces concentric with the rotor, when the flexible element is in its extreme outer position corresponding to maximum output of the pump and maximum length of the vane trackway; whereas the positional relation or extent and degree of alignment between the track surfaces of the tongue 46 and prongs 36 changes as the track parts are moved to decrease the output of the pump and the length of the vane trackway so that at other positions of the flexible element (corresponding to outputs of the pump and lengths of the vane trackway less than maximum) only a part of the overlapping sur-

faces may be even or in alignment with each other (Fig. 8) or the track surface on the tongue 46 may bear an "angular" or "intersecting" relation (i. e. without perfect alignment at any part of the overlapping surfaces) to the track surface on the mating prongs 36 (Fig. 10). This permissible variation in extent and degree of alignment is important because it can be obtained by simple, inexpensive structure, does not require costly precision and because with the arrangement of the present invention small variations in dimensions, etc., particularly of the flexible element, sufficient to somewhat change the aligning relation, do not adversely affect operation of the pump as has been proved in practice covering hundreds of hours of operation at pressures of 1,000 pounds per square inch or more. The improved and simplified structure of the present invention therefore provides an important cost advantage over previous arrangements as well as materially greater ease of adjustment of the track parts to alter pump capacity or output, as will be hereinafter more specifically pointed out. As used herein, the terms "smooth vane transfer," "satisfactory vane transfer" and other forms of these general expressions, are defined as transfer of the vane from the rigid track element to the flexible track element or vice versa, at the extensible joint or connection therebetween, which provides smooth, quiet and satisfactory operation of the pump without materially increased wear of the vanes or of the track parts at the extensible connection between them. The term "overlap" and other forms of the same general term used herein are intended to describe the general type of extensible joint arrangement illustrated herein, in which the joining flexible and rigid track elements and the track surfaces thereon have an interconnecting relationship with each other, such, for example, as the mating tongue-and-prong arrangement illustrated, so that the track surfaces on both track elements extend through a common circumferential portion of the trackway at the extensible joint or connection between them, in which common circumferential portion of the trackway part or all of the track surfaces on both track elements may be, but need not necessarily be, aligned or even with one another.

Referring now to the embodiment illustrated in Figs. 1, 4, 7 and 8, the end of each flexible track element 45 is positioned, relative to the vane-contacting surface on the prongs 36 of its corresponding fixed abutment 31, by a guide bar 47 which is connected with the tongue 46 at the end thereof by a portion having the same width as that of said tongue, thus producing a somewhat T-shaped end formation, as shown in Fig. 4. The guide bar 47 is adapted to be positioned by and bear against a suitable guide element or surface and as here shown (Figs. 7 and 8) its ends extend into substantially arcuate guide spaces formed by portions 38 of the inner circumferential surface of spacer ring 22 and the radially outer surfaces 39 of prongs 36, so that the end of the flexible track element 45 cannot be materially displaced from its proper location. Guide bars 47 may be arranged to bear against the radially outer surfaces 39 of prongs 36, or against the inner circumferential surface 38 of the spacer ring 22, or they may bear against both of these surfaces, but it is preferable that said guide bars bear against only one of said surfaces. In the preferred embodiment each guide bar 47 bears against only the circumferential surface 38 of spacer ring 22 and the arrange-

ment is such that the flexible track elements 45 act to continuously bias the guide bars 47 outward against said spacer ring surface in all positions of adjustment of said flexible track elements. The portions 38 of the inner circumferential surface of the spacer ring 22 against which the guide bars 47 bear thus serve as the guide surfaces in the present embodiment and will be so termed hereinafter, and the guide bars 47 serve as guided means for the ends of the flexible track elements 45. This continuously outward bias is readily obtained by forming the flexible track elements 45 and their attached guide bars 47 so that there is a slight inward compression of the flexible arms when the guide bars are in their extreme inward position toward the fixed abutments 31. The arrangement is thus also such that the compression of the flexible elements progressively increases as they are moved outward, i. e. in a direction away from their extreme inward positions, and the curvature of said flexible elements is simultaneously decreased; this assists in maintaining the track parts in stable operation positions and contributes toward providing a satisfactory vane track outline or curvature of the portion of the trackway on the flexible elements at all pump outputs. With this arrangement the guide bars 47 merely engage the guide surfaces 38 and the ends of the flexible track elements adjacent the fixed abutments 31 are thus free from other constraints in their movement relative to said fixed abutments as the output of the pump is altered by movement of the movable abutments 40.

This preferred arrangement has several advantages, one of which is that it does not require a close or accurate fit of the guide bar between the surfaces 38 and 39 of the spacer ring 22 and prongs 36 which form the guide space, thus making for easy manufacture and low cost. Another advantage of this preferred arrangement is that the force exerted by the vanes upon the flexible track elements 45, which acts in a radially outward direction, supplements (and does not oppose) the outward bias of the flexible track elements and assists in holding the guide bars against their guide surfaces. A still further advantage is that resistance to movement at the extensible joint between the tongues 46 and prongs 36 is reduced to a negligible amount which contributes to the ease with which the movable abutments 40 may be adjusted.

It is also necessary to provide suitable contours of the vane-contacting surfaces on the tongues 46 and prongs 36 in order that the vanes may pass without interruption from one to another of these members. In the embodiment now under consideration and as best shown in the enlarged views of Figs. 7 and 8, the vane-contacting surfaces of the prongs 36 are given a curvature which slightly but gradually recedes from the periphery of the rotor so that the vanes 19 begin to move radially outward immediately upon leaving the arcs 35, and vice versa. This curvature of the prongs 36 is made such that contact between their vane-contacting surfaces and the ends of the vanes 19 can be maintained by centrifugal force alone as the rotor revolves and the vanes move from the arcs 35 and across the prongs 36 which extend into the inlet area of each pumping section. The vane-contacting surface on the end of each tongue 46 is made of such contour that its overlapping portion merges smoothly and is substantially even with

the vane-contacting surfaces on the corresponding prongs 36 when the flexible track element 45 and its corresponding movable abutment 40 are in their "full stroke" or extreme outward position of adjustment. The vane-contacting surface on each tongue 46 smoothly joins the contiguous vane-contacting surface on the flexible arm or projection and the latter extends to and smoothly joins the pumping arc 41.

The vane-contacting surface on the flexible arm or projection preferably approximates a segment of a parabola when its corresponding movable abutment 40 is in its "half stroke" position, that is when said abutment 40 is midway between its extreme inward and outward positions; and is accomplished by forming said flexible arms or projections with a non-uniform or non-circular curvature when said arms or projections are free from bending forces. With this arrangement there is substantially constant deceleration and acceleration of the vanes 19 in their radially inward and outward movement when the abutment 40 is in its "half stroke" position.

The relative rigidity of end portion 49 including tongues 46 prevents flexing thereof as the position of the flexible track element is altered conformably with inward and outward adjustment of its movable abutment 40; the remainder of the flexible track element (i. e. the portion thereof previously referred to as the flexible arm or projection) is relatively flexible and may be conveniently although not necessarily of substantially uniform thickness up to a point close to the movable abutment 40, as illustrated. With this arrangement flexing is not localized but is distributed over a large part of the flexible element 45. Only a relatively small amount of flexing is required incident to adjustment of the movable abutment from one extreme position to another and the arrangement just described distributes this small amount over a relatively long spring member, so that for this reason there is relatively little distortion of the parabolic shape as the movable abutments 40 are adjusted outward from their "half stroke" positions, and little effort is required to flex the members.

The vane-contacting surfaces of tongues 46 merge and are substantially continuous with the vane-contacting surfaces on the prongs 36 when the parts are in their positions corresponding to the "full stroke" or maximum outward position of the movable abutments 40; this is illustrated in the enlarged view, Fig. 7. Hence transfer of the vanes takes place substantially as the vanes leave the tips of prongs 36. At other positions of adjustment of the movable abutments 40 transfer takes place at or near the end of each tongue 46, that is, at a point substantially in line with the corresponding guide bar 47, and only this portion of each tongue 46 is maintained even with the vane-contacting surface of the prongs 36 throughout the entire range of adjustment, although the flexible track element 45 may bend to align a greater portion of the vane-contacting surface of the tongue 46 with the vane-contacting surface on the prongs 36. The transfer point therefore moves toward the corresponding arc 35 as the movable abutment is adjusted inward from its "full stroke" position, and the circumferential length of the vane track is thus decreased accordingly. This will be understood from the enlarged view, Fig. 8, which shows the position of a tongue 46, rela-

tive to its corresponding fixed abutment 31, when its movable abutment 40 is adjusted to its extreme inward position, which may be "zero stroke" position at which there is no output.

There is relatively little "rocking" of the tongue 46 when the flexible track element 45 moves conformably with adjustment of its corresponding movable abutment 40; in other words, if the guide bar 47 is substantially vertical in the "zero stroke position," it will be tilted only a slight amount when it moves to its position corresponding to "full stroke" position of its movable abutment. The vane transfer point at the end of tongue 46 may therefore be kept substantially even with the vane-contacting surface on the prongs 36 throughout the range of said tongue's movement by providing suitable curvature on the guide surface 38. If there was absolutely no rocking or tilting of the tongue 46 and guide bar 47, in order to produce perfect alignment of these track surfaces (at the point of vane transfer) the curvature on the guide surface should, theoretically, be identical with the curvature on the prongs 36 and the two surfaces should be spaced with respect to each other by a distance equal to the vertical dimension from the outer or guiding surface of the guide bar to the vane-contacting surface on the tongue 46. Such an arrangement is one method of providing non-parallel spaced relation (i. e. non-concentric in this instance) between the guide surface and the track surface on the fixed abutment adjacent the region of vane transfer.

Identical curvatures of the vane-contacting surface on the prongs 36 and of the guiding surfaces of the spacer ring have been successfully employed but it is not necessary that these surfaces have identical curvatures or identical contours; on the contrary and as will be presently explained in connection with a modification, there are frequently advantages in employing guide elements having surfaces that are not identical with the vane-contacting surfaces on the prongs 36. In the embodiment illustrated in Figs. 1, 4, 7 and 8, however, the already described curvature of the vane-contacting surface on each prong 36 approximates an arc having the same radius as that of the inner circumferential surface of the spacer ring 22 and substantially vertically spaced therefrom; that is to say, the shape of the track surface on each prong 36 approximates an arc having the same radius as that of the inner circumference of the spacer ring 22, the center of which approximated arc is positioned on the vertical center line of said spacer ring's inner circumferential surface and is vertically spaced from the center of said spacer ring 22. The approximation is sufficiently close for practical use and it is unnecessary, for purposes of aligning the track surfaces of these track elements, to provide on the guide surface regions 38 of the spacer ring 22 a special geometric curvature which would be expensive to make, but it is sufficient to leave the guide surfaces 38 arcuate in form and having substantially the same radius as the inner circumference of the spacer ring 22. Each guide surface 38 is thus positioned in non-parallel spaced relation with respect to the track surface on the corresponding prongs 36.

The very slight tilting of the guide bar 47 and the tongue 46 that takes place as the flexible element 45 is moved away from its corresponding fixed abutment 31 tends to compensate for variations in curvature of the track surface on

the prongs with respect to the curvature of the guiding surfaces 38 on the spacer ring. Referring to the drawings, particularly Figs. 7 and 8, as guide bar 47 slides along guide surface 38 from the position shown in Fig. 8 (zero output) to the position shown in Fig. 7 (full output), the guide bar tilts slightly to the left; that is to say, the upper end of this inverted T-shaped guide bar 47 where it joins the tongue 46 is slightly farther to the left than the bottom of the guide bar. This tilting results in a slightly outward movement of the tip end of the tongue 46 causing it to recede slightly from the surface of the rotor 15 and to either follow substantially the increasing curvature of the track surface on the prongs 36 or to move slightly radially outward with respect thereto. This arrangement therefore provides satisfactory transfer between the fixed abutments 31 and flexible track elements 45 at all positions of adjustment of the movable abutments 40. The use of generally similar but non-concentric arcs or curvatures (i. e., guide surfaces and vane track surfaces disposed in non-parallel spaced relation with one another at the regions of vane transfer) on the vane-contacting surfaces of the prongs 36 of the fixed abutments and on the guiding surfaces 38 for the ends of the flexible track elements according to this embodiment of the present invention also contributes to the advantages of simplicity and low cost.

Due to the substantial distribution of flexing throughout a large part of the length of the flexible portions of arms or projections 45 and to the fact that said flexible arms or projections are formed with a non-uniform curvature, said flexible arms do not assume true circular or arcuate shape as the movable abutments 40 are adjusted from their "half stroke" to their extreme inward or "zero stroke" positions and the diameter of the vane track at the arcs 35 is not its smallest diameter. This may be observed in Fig. 8 in which the portion of the flexible arm 45 just beyond end portion 49 is separated from the circumferential surface of the rotor 15 by a clearance that is less than the clearance between the rotor and the arc 35. The diameter of the rotor is thus determined by the diameter of the vane track at this point or region of radially inward protrusion of the flexible track elements 45 and the clearance between the rotor and the arcs 35 must be correspondingly greater than would otherwise be required. The operation of the pump is not adversely affected by this increased clearance or by the slight radial vane movement occasioned by the inward protrusion of the vane track since the vanes are substantially in hydraulic balance during this portion of their travel.

It is essential that the ends of the prongs do not at any time project radially inward beyond the track surface on the flexible track element radially in line therewith, as any such inward projection would interfere with the movement of the vanes in passing thereacross and would either produce noisy and unsatisfactory operation of the pump or prevent rotation of the rotor and vane assembly. Such inward projection of the prongs may occur when the flexible track elements are in or near their extreme outward positions corresponding to maximum or near maximum output of the pump and may be brought about by several causes, such, for example, as variation in desired or expected distribution or amount of the flexing in the flex-

ible track element due to variation in the thickness, etc. thereof. In practice it has been found that there is also a tendency for the flexible track element to move radially outward at or near the prongs, particularly in the high pressure or outlet areas, when the pump is operated at relatively high pressures so that the ends of the prongs tend to project radially inward beyond the track surface of the flexible track element. The latter tendency has been found to be present even when, as illustrated herein, there is substantial balance of the hydraulic forces acting in a radial direction on the flexible track element and on the vanes as they traverse said flexible track elements, that is to say, when the radially inner and outer surfaces of each flexible track element 45 are both connected with the corresponding port 25 or 26 and when the vane slot ports 27 and 28 are connected with the ports 25 and 26 respectively as already described. In some instances, for example, pumps generally similar to the already described embodiment have operated quietly and satisfactorily at relatively low pressures but have become noisy and otherwise unsatisfactory upon increase of the operating pressure to relatively high values such as 1,000 pounds per square inch or the like; upon removing the end head 11 and inspecting the track parts, the track surfaces on the flexible track elements 45 and prongs 36 have appeared to then be in proper relative positions to give quiet and satisfactory operation but the prongs 36 have shown evidence of having been struck by the vanes in a manner that could take place only if the prongs projected radially inward beyond the track surface on the flexible track elements; changes to prevent the possibility of such inward projection of the prongs when the flexible track elements are bent farther outward have corrected the trouble and given quiet and satisfactory operation of the pump at all discharge or operating pressures.

An arrangement embodying corrective changes of the character just mentioned is illustrated in Figs. 9 and 10. As best shown in Fig. 9, the vane-contacting surface adjacent the outer end of each modified prong 136 is tapered or given a contour having a rapidly increasing radius of curvature beginning at or near the position occupied by the portion of the track surface on the flexible track element 45 in line with the guide bar 47 when the flexible track element is in its normally maximum outward position corresponding to the maximum outward position of the movable abutment 40; this portion of the vane-contacting surface is designated by the reference numeral 136' in Figs. 9 and 10 and also in connection with a further modified prong 236 shown in Figs. 11, 12 and 13 and to be presently described. The arrangement is such that the portion of the vane-contacting surface 136' is positioned outward with respect to the corresponding portion of the flexible track element's track surface radially in line therewith when the parts are assembled and the movable abutment 40 is in its position corresponding to full output of the pump. With this arrangement, displacement of the flexible track element beyond its maximum normally or intended outward position has the effect of moving the point of vane transfer (from the flexible track element to the prongs, or vice versa) a short distance farther away from the tip end of the tongue 46, so that vane transfer takes place in the region of the surface 136' which serves as an auxiliary vane transfer

surface for the prong 136 and is accordingly so termed. This provides quiet and satisfactory operation of the pump at all operating pressures.

The guide bar 47 may move through its range of adjustment without tilting or may tilt slightly away from the fixed abutment 31 as it is moved toward its full stroke position, as explained in connection with the embodiment of Figs. 1, 4, 7 and 8. Any such tilting will cause the tip end of the tongue 46 to move outwardly or away from the rotor, due to the curvature on the outer end or surface of the guide bar 47. If such tilting takes place, however, and if the track surface at or near the tip end of the tongue 46 is made even with the track surface on the prongs 136 when the flexible track element 45 is in its position corresponding to full stroke of the pump and with the guide bar 47 so tilted, it is then possible that the tip end of the tongue 46 might project inward beyond the track surface on the prongs 136 when the flexible track element 45 is moved inward toward its position corresponding to zero stroke of the pump. The possibility of such inward projection of the ends of the tongues 46 may be avoided by use of guide surfaces that are non-identical in contour with the vane-contacting surfaces on the prongs, for example as illustrated in somewhat exaggerated manner in Figs. 9 and 10. According to this arrangement, the vertical distance between the modified guide surfaces 138 and the vane-contacting surfaces on the prongs 136 progressively increases toward the inner ends of the prongs, that is to say, the guide surface 138 is given a special contour such that the vertical distance between said guide surface 138 and the vane-contacting surface on the prongs 136 is greater at the position of the flexible track element 45 corresponding to small or zero pump outputs than, for example, at the position thereof corresponding to full output. This can be conveniently accomplished by forming the guide surface 138 with a radius of curvature less than that of the curvature at the vane-contacting surface on the prongs 136. The guide surfaces 138 are thus disposed in non-parallel spaced relation with respect to the track surfaces on the prongs 136.

With this arrangement the vane-contacting surface at the end of the tongue 46 is even or aligned with the vane-contacting surface on the prongs 136 when the track members are adjusted for maximum pump output, in which they are shown in Fig. 9, but the end of the tongue 46 moves below or radially outward from the vane-contacting surface on the prongs 136 as the track members are adjusted to decrease the pump's output and the guide bar 47 is correspondingly moved toward the fixed abutment as will be seen in Fig. 10 which shows the relative positions of the parts at the extensible connection when the flexible track element 45 is in its position corresponding to minimum (zero) pump output. Movement of the end of the tongue 46 below or radially outward with respect to the vane-contacting surface on the prongs 136 results in a slight angular or intersecting relation between the overlapping portions of the track surfaces on these track members, without perfect alinement at any part thereof as shown in Fig. 10; this angularity is not sufficient, however, to interfere with vane action and smooth, satisfactory vane transfer has been obtained with an arrangement of this general character in pumps which have been operated with entire satisfaction at all pump outputs, at all pressures including 1000 pounds per square

inch and for hundreds of hours without material wear of the track surfaces or the vanes.

With the arrangement illustrated in and described in connection with Figs. 9 and 10, many of the dimensions of the track parts need not be held to the close limits necessary to provide theoretically perfect alinement of the vane-transferring surfaces at the extensible connections, with advantages both in manufacture and operation.

The vane track elements may be modified in other ways, such, for example, as the modified arrangement shown in Figs. 11, 12 and 13. In this modification the guide bars are omitted from the modified flexible track elements 245 and the outer surfaces of the tongues 246 serve as guided means which in the present instance are integral with the ends of the flexible track elements 245 and are adapted to bear directly on the guide elements or surfaces against which they are held by the continuously outward biasing force provided in the same general manner as already described. In this embodiment the guide elements or strips 235 are carried by the modified prongs 236, each guide element 235 being tightly fitted into or otherwise held in place in slots formed in the ends of the corresponding pair of prongs 236, each guide element 235 extending (in an axial direction relative to the rotor) across the space 237 (Fig. 13) between said pair of prongs. As here shown the guide elements 235 do not extend the full length of the prongs 236, thus leaving an opening between the inner end of each guide element 235 and the side wall of the modified fixed abutment 231 from which said prongs project.

The guide surfaces of the guide element 235 comprise its substantially flat or straight inner face or surfaces 238 (Fig. 13) and a portion of the surface 238' (Figs. 11 and 12) on or near the inner end of said guide element 235, the surface 238' being preferably given a tapered, or outwardly rounded contour as indicated in the drawings. The guide surface 238 is positioned in a general radially-outward direction relative to the vane-contacting surface on the prongs 236 by an amount approximately equal to the thickness of the tongue 246 as also indicated in the drawings. The vane-contacting surface on the prongs 236 is shown as substantially the same as that described in connection with the prongs 136 of the embodiment of Figs. 9 and 10. The guide surfaces 238 and 238' are thus disposed in non-parallel spaced relation with respect to the track surfaces on the prongs 236.

The arrangement in the embodiment shown is such that when the flexible track element 245 is in its extreme outward position corresponding to full pump output (Fig. 11) the greater part of the outer surface of the tongue 246 that extends onto the guide element 235 is in contact with the guide surface 238. The angular relation between the tongue 246 and guide surface 238 changes as the flexible track element is moved inward or toward the fixed abutment 231 and the end of the tongue 246 tends to recede into the opening intermediate the inner end of the guide element 235 and the side wall of the fixed abutment so that a portion of the outer surface of said tongue 246 contacts a portion of the guide surface 238', as indicated by the dotted line position of the tongue 246 in Fig. 12 which shows the flexible track element 245 in its extreme inward position corresponding to minimum or zero pump output. It will thus be observed that as the track element

245 approaches the position just mentioned the end of the tongue 246 extends beyond the end of the member 235 adjacent the fixed abutment 231, with the portion 238' serving as the guide element for said tongue, and substantially line contact existing therebetween as indicated by the dotted line position shown in Fig. 12. The outer surfaces of the tongues 246 merely engage the guide surfaces 238 or 238', as the case may be, and the ends of the flexible track elements 245 adjacent the fixed abutments 231 are not otherwise constrained in their movement relative to said fixed abutments. With this arrangement the relation between the vane-contacting surfaces of each tongue 246 and its mating prongs 236 at the extensible connection between them is substantially the same throughout the range of output variation as that described in connection with the embodiment of Figs. 9 and 10 and has provided smooth, satisfactory pump operation together with quiet and satisfactory pump operation at all outputs of the pump and at all operating pressures up to and including 1,000 lbs. per sq. in.

In fluid pressure devices employing vane tracks of the general character described it has been found advantageous to employ a relatively loose fit of the vanes 19 in the vane slots 18, as illustrated in exaggerated manner in Fig. 14. Loose fits of the vanes in the vane slots permit free movement of the vanes, without any binding thereof, and thus contributes toward quiet and satisfactory operation of the device, particularly when centrifugal force alone is utilized to move the vanes radially outward.

A pump embodying the present invention has many advantages, some of which have already been pointed out. The most practical and outstanding advantage is the simplicity of its parts and consequent low cost. This low cost is achieved, however, without sacrifice of desirable operating properties and a pump embodying the present invention has been operated with entire success at all outputs from zero to maximum and at all pressures including 1,000 lbs. per sq. in.; its performance shown to be fully on a par with that of pumps of other and more complicated and expensive constructions. Another important advantage is that only a very small amount of effort or force is required to adjust the movable abutments of the present pump from one extreme position to another; in fact, such adjustment may easily be made with one's fingers when the spacer ring is removed from the casing, whereas past constructions have required and adjusting force of approximately 100 lbs. or more under comparable circumstances. This ease of adjustment is very important, particularly where the output of the pump is to be frequently and automatically altered.

The vane track elements are also easy to assemble. For example, in the embodiment illustrated in Figs. 1, 4, 7 and 8 the movable abutments 40 are first put into place in the spacer ring 22 and the fixed abutments 31 are then inserted and fastened in position by the screws 33. The assembled spacer ring and vane tracks are then put into place in the cavity of the pump 10, the other parts of the pump being thereafter readily assembled.

While the present invention has been described as a pump it is also suitable for use as other types of fluid pressure device and, for example, will also function as a fluid motor if supplied with pressure fluid for its operation but the cycle of

operation will of course be reversed. When employed as a motor it is necessary to introduce means tending to hold the vanes radially outward, particularly if the motor is to be operated at low rotative speeds. The term "fluid pressure device" as used in the appended claims is therefore intended to include pumps and motors as well as all other forms of fluid pressure devices to which the invention is applicable. The expressions "non-parallel," "non-parallel spaced relation" or other forms of these expressions used in the claims in connection with the guide surfaces and the track surfaces on the ends of the fixed abutments are intended to include similar curvatures of these surfaces disposed in non-concentric relation with respect to one another, dissimilar curvatures of these surfaces, dissimilar contours thereof or any arrangement in which these surfaces are not parallel with one another.

It is to be understood that the foregoing are merely exemplifying disclosures and that changes, some of which have been indicated, may be made in the apparatus without departing from the invention which is defined in the appended claims.

I claim:

1. In a rotary fluid pressure device of variable output, a rotor, a plurality of vanes movable inwardly and outwardly of said rotor, a track for exerting guiding action on said vanes comprising a rigid element and a flexible element having an extensible connection therebetween including overlapping parts, means for moving one of said elements with respect to the other to vary the output of the device and to vary the length of said track, and means operative simultaneously with said moving means for maintaining said overlapping parts even with one another and for flexing said flexible element to produce a smooth guiding of the vanes at all outputs comprising a guide surface disposed outwardly of and concentric with the surface of the rotor, and guided means carried by said flexible element and biased against said surface continuously throughout the range of output variation.

2. In a rotary fluid pressure device of variable output, a rotor having a plurality of vanes movable inwardly and outwardly thereof, a trackway of variable circumferential length having a surface for guiding the ends of the vanes in their in and out movement comprising a rigid track element and a flexible track element having an extensible connection therebetween, means for moving one of said track elements with respect to the other to vary simultaneously the output of the device and the length of the trackway, the rigid track element having an end portion whose radius of curvature is greater than its central portion whereby at full stroke output the vanes moving away from the rigid track element commence their outward movement before contacting the flexible track element, the extensible connection including said end portion, and means for maintaining the track surfaces of the flexible element and said end portion in smooth vane-transferring relation with one another to produce a smooth guiding of the vanes at all outputs, said maintaining means including guided means carried by said flexible track element and a guiding surface for said guided means disposed outwardly of and non-concentric with said end portion, said guided means being biased into guiding engagement with said guiding surface at all circumferential lengths of the trackway, the end of said flexible track element at said extensible connection being free from other constraint in its

movement responsive to said guiding engagement as one of said track elements is moved with respect to the other.

3. In a rotary fluid pressure device of variable output, a rotor having a plurality of vanes movable inwardly and outwardly thereof, a trackway of variable circumferential length having a surface for guiding the ends of the vanes in their in and out movement comprising a rigid track element and a flexible track element having an extensible connection therebetween, means for moving one of said track elements with respect to the other to vary simultaneously the output of the device and the length of the trackway, the rigid track element having an end portion whose radius of curvature is greater than its central portion, the extensible connection including said end portion, and means for maintaining the track surfaces of the flexible element and said end portion in smooth vane-transferring relation with one another to produce a smooth guiding of the vanes at all outputs, said maintaining means including a guiding surface having a smaller radius of curvature than said end portion and disposed outwardly thereof, and a non-radial guide member fixed to the end of the flexible track element and biased against said guiding surface throughout all outputs of the device, said guide member being arranged to tilt as the output of the device is varied, the tilting when the output is increased occurring in a direction to compensate for the increase in radius of curvature of said end portion so as to prevent the end of the flexible track member from projecting above the track surface of said end portion at all outputs.

4. In a rotary fluid pressure device of variable capacity, a rotary assembly including a rotor and a plurality of vanes movable inwardly and outwardly thereof, a casing therefor including a first abutment coacting with a portion of the peripheral surface of the rotary assembly, a second abutment coacting with another portion of said surface, and a trackway of variable circumferential length for guiding the outer ends of the vanes in their in and out movement as they rotate from one abutment to another, means for adjusting one of said abutments radially to vary simultaneously the output of the device and the circumferential length of the trackway, said trackway comprising the faces of the abutments and a flexible interconnecting track member, one of the abutments having an end portion which has an increasing radius of curvature, the flexible track member having a sliding connection with said end portion and being fixed at its opposite end to the other abutment, and means for maintaining the track surfaces of the extensible connection in smooth vane-transferring relation to one another to produce a smooth guiding of the vanes at all outputs comprising a guiding surface which is substantially concentric with the rotor and disposed outwardly from the flexible track member, and a non-radial guide member fixed to the end of the flexible track member and engaging said guide surface, said guide member being biased against said guide surface at all circumferential lengths of the trackway, the guide member being arranged to tilt as the output of the device is varied, the tilting when the output is increased occurring in a direction to compensate for the increase in radius of curvature of said end portion so as to prevent the end of the flexible track member from projecting above the track surface of said end portion at all outputs.

5. In a rotary fluid pressure device of variable

capacity, a rotary assembly including a rotor and a plurality of vanes movable inwardly and outwardly thereof, a casing therefore including a stationary abutment projecting inward from said casing and arranged to coact with a portion of the peripheral surface of the rotary assembly, a movable abutment coacting with another portion of said surface, and a trackway for guiding the outer ends of the vanes in their in and out movement as they rotate from one abutment to the other, means for adjusting the movable abutment radially to vary simultaneously the output of the device and the circumferential length of the trackway, said trackway comprising the faces of the abutments and a flexible interconnecting track member fixed at one end to the movable abutment, the fixed abutment having an end portion comprising a pair of spaced prongs adapted to receive between them the opposite end of the flexible track member, a guide member projecting outwardly between the prongs from the end of the flexible track member, and a guiding surface coacting with the guide member to maintain the track surface of the flexible member and the prongs in smooth vane-transferring relation at all outputs of the device, said flexible track member biasing said guide member against said guiding surface continuously throughout the range of output variation.

6. In a rotary fluid pressure device of variable capacity, a rotary assembly including a rotor and a plurality of vanes movable inwardly and outwardly thereof, a casing therefore including a stationary abutment coacting with a portion of the peripheral surface of the rotary assembly, a movable abutment coacting with another portion of said surface, and a trackway for guiding the outer ends of the vanes in their in and out movement as they rotate from one abutment to the other, means for adjusting the movable abutment radially to vary simultaneously the output of the device and the circumferential length of the trackway, said trackway comprising the faces of the abutments and a flexible interconnecting track member fixed at one end to the movable abutment, the fixed abutment having an end portion comprising a pair of spaced prongs adapted to receive between them the opposite end of the flexible track member, a guide member projecting outwardly between the prongs from the end of the flexible track member, and a guiding surface coacting with the guide member to maintain the track surface of the flexible member and the prongs in smooth vane-transferring relation at all outputs of the device, the track surfaces of said prongs having an increasing radius of curvature, and the guide member being disposed in non-radial position and arranged to tilt as the output of the device is increased in such a direction as to compensate for the increase in radius of curvature of the track surface of the prongs thereby preventing the end of the flexible track member from projecting above those track surfaces at all outputs.

7. In a rotary fluid pressure device of variable output, a rotor having a plurality of vanes movable inwardly and outwardly thereof, a trackway of variable circumferential length having a surface for guiding the ends of the vanes in their in and out movement comprising a rigid track element and a flexible track element having an extensible connection therebetween, means for moving one of said track elements with respect to the other to vary simultaneously the output of the device and the length of the trackway, and means

for maintaining the track surfaces of the rigid and flexible track elements at the extensible connection in smooth vane-transferring relation with one another to produce a smooth guiding of the vanes at all outputs comprising a guide surface disposed outwardly of and concentric with the surface of the rotor and in non-parallel spaced relation with respect to the track surface of the rigid element at said extensible connection, and guided means carried by said flexible element and biased against said guide surface continuously throughout the range of output variation.

8. In a rotary fluid pressure device of variable volumetric capacity per revolution, a rotor having a plurality of vanes movable inwardly and outwardly thereof, a trackway of variable circumferential length having a track surface for guiding the ends of the vanes in their in and out movement and comprising a rigid track element and a flexible track element having an extensible connection therebetween, said extensible connection comprising a vane-transferring surface on said flexible track element adapted to overlap and inter-connect in smooth vane-transferring relation with a vane transferring surface on said rigid element, the extent to which the vane-transferring surface on said flexible track element overlaps the vane-transferring surface on said rigid element varying conformably with change in length of said trackway, means for moving one of said track elements with respect to the other to vary simultaneously the volumetric capacity of the device and the length of the trackway, and means for effecting smooth vane-transferring relation between said over-lapped and inter-connecting vane-transferring surfaces of the flexible and rigid track elements at all volumetric capacities of the device comprising guided means carried by said flexible track element and a guide surface for said guided means disposed in non-parallel spaced relation with the vane transferring surface on said rigid track element, said guided means being continuously biased against said guide surface throughout the range of relative movement between said flexible and rigid track elements incident to all variation of volumetric capacity.

9. In a rotary fluid pressure device of variable volumetric capacity per revolution, a rotor having a plurality of vanes movable inwardly and outwardly thereof, a trackway of variable circumferential length having a track surface for guiding the ends of the vanes in their in and out movement and comprising a rigid track element and a flexible track element having an extensible connection therebetween, said flexible track element extending in a generally circumferential direction for an arcuate distance less than 90°, said extensible connection comprising a vane-transferring surface on said flexible track element adapted to overlap and inter-connect in smooth vane-transferring relation with a vane-transferring surface on said rigid element, the extent to which the vane-transferring surfaces overlap one another varying conformably with change in length of said trackway, means for moving one of said track elements with respect to the other to vary simultaneously the volumetric capacity of the device and the length of the trackway, and means for effecting smooth vane-transferring relation between said over-lapped and inter-connecting vane-transferring surfaces of the flexible and rigid track elements at all volumetric capacities of the device comprising guided means carried by said flexible

track element and a guide element positioned outwardly in non-parallel spaced relation with respect to the vane-transferring surfaces of said flexible and rigid track elements and against which said guided means is continuously biased throughout the range of relative movement between said flexible and rigid track elements incident to all variation of volumetric capacity, said guide element engaging said guided means in guiding and positioning contact therewith at all outputs of the device, the end of said flexible track element adjacent said extensible connection being otherwise free from constraint in its position and movement responsive to said guiding and positioning engagement.

10. In a rotary fluid pressure device of variable volumetric capacity per revolution, a rotor having a plurality of vanes movable inwardly and outwardly thereof in a substantially radial direction, a casing therefor including a member surrounding the rotor and vane assembly, a trackway of variable circumferential length having a track surface for guiding the ends of said vanes in their in and out movement, said trackway including a movable abutment supported upon said surrounding member and movable to simultaneously vary the volumetric capacity of said device and the circumferential length of said trackway, said trackway also including a fixed abutment carried by and projecting inward from said surrounding member, said trackway further including a flexible track element carried by and movable with said movable abutment, said flexible track element having a vane-contacting surface formed with a non-uniform curvature and connecting the track surfaces of said movable and fixed abutments in all positions of said movable abutment, said flexible track element having a substantially rigid end adjacent the fixed abutment, said substantially rigid end having thereon a vane-transferring surface forming an interconnecting extensible joint with the track surface of said fixed abutment, and a guide element for said substantially rigid end of said flexible track element to position the vane-transferring surface thereon in vane-transferring relation with the track surface of said fixed abutment at all positions of the movable abutment and all lengths of said trackway, said substantially rigid end of said flexible track element being continuously biased into engagement with said guide element throughout its range of movement in unison with said movable abutment but being otherwise free to adjust its position relative to the track surface carried by said fixed abutment at the extensible joint therebetween.

11. In a multi-section rotary fluid pressure device of variable volumetric capacity per revolution, a trackway including pairs of oppositely positioned movable and fixed abutments, flexible track elements carried by the movable abutments and connecting the track surfaces of said movable and fixed abutments in all positions of the movable abutments, and guide surfaces for the ends of the flexible track elements disposed in non-parallel spaced relation with respect to the track surfaces of said fixed abutments at the regions of the connections between the track surfaces of said flexible track elements and said fixed abutments, the ends of said flexible track elements being continuously and uni-directionally biased outwardly into engagement with said guide surfaces throughout the range of movement of said movable abutments.

12. A rotary vane-type fluid pressure device of

variable output having a rotor, a plurality of vanes movable inwardly and outwardly thereof, a trackway of variable circumferential length having a track surface for guiding the ends of the vanes in their in and out movement, said trackway comprising a rigid track element and a flexible track element having an extensible connection therebetween, said flexible track element having its end portion reduced and mating with an end portion of said rigid track element to form said extensible connection, guide and supporting means disposed outwardly with respect to said flexible track element and means for moving one of said track elements with respect to the other to vary simultaneously the length of the trackway and the output of the device, said end portion of said flexible track element being continuously biased into engagement with said guide and supporting element at all circumferential lengths of said trackway and forming therewith the sole support for the corresponding end of said flexible track element, said guide and supporting element also forming the sole means adjacent said extensible connection active to maintain the track surfaces of said flexible and rigid track elements in vane-transferring relation with one another at said extensible connection throughout the range of relative movement between said track elements, said reduced end portion of said flexible track element being substantially rigid whereby the contour of the track surface thereon remains substantially unchanged at all outputs of the device.

13. In a rotary vane-type fluid pressure device of variable output having a rotor provided with a plurality of vanes movable inwardly and outwardly thereof, a trackway of variable circumferential length having a track surface for guiding the ends of said vanes in their in and out movement, said trackway comprising a rigid track element and a flexible track element having an extensible connection therebetween, guided means carried by said flexible element at the end thereof adjacent said extensible connection, a guide element for said guided means disposed outwardly with respect to said flexible track element and forming the sole support and guide for the end of said flexible track element adjacent said extensible connection, said guided means being continuously biased against said guide element at all circumferential lengths of said trackway, and means for moving the flexible track element relative to the rigid track element to vary simultaneously the length of the trackway and the output of the device, said rigid track element having at said extensible connection a vane-transferring surface gradually receding from the rotor in a direction toward said flexible track element and arranged to provide vane-transferring relation with the track surface on said flexible track element throughout all intended lengths of said trackway and throughout all intended positions of the portion of said flexible track element adjacent thereto including the maximum intended outward position thereof, and said rigid track element also having a surface merging with said vane-transferring surface and receding from the rotor gradually but more rapidly than said vane-transferring surface, said last named surface being arranged to contact the ends of the vanes to thereby form an auxiliary vane-transferring surface upon displacement of the portion of said flexible track element adjacent thereto beyond the maximum intended outward position thereof.

14. In a rotary fluid pressure device of variable output, a rotor having a plurality of vanes movable inwardly and outwardly thereof, a trackway of variable circumferential length having a track surface for guiding the ends of the vanes in their in and out movement comprising a stationary rigid track element and a flexible track element having an extensible connection between the track surfaces thereon, the end of said flexible track element at said extensible connection being movable in a generally circumferential direction relative to said rigid track element to alter the length of said trackway simultaneously with change in output of the device and also being movable in a generally radial direction relative to the rotor, and a guide surface for guiding the end of said flexible track element at said extensible connection to alter its position in said generally radial direction simultaneously and conformably with movement of said flexible track element in said generally circumferential direction, thereby providing vane-transferring relation between the track surface on said flexible and rigid track elements at said extensible connection throughout the range of variation of length of said trackway and of outputs of said device, said end of said flexible track element being continuously biased against said guide surface at all lengths of said trackway, said guide surface being disposed in non-parallel spaced relation with respect to the track surface on said rigid element at said extensible connection and said non-parallel spaced relation providing between said guide surface and said track surface on said rigid track element a spacing that increases in the direction in which said flexible track element is moved to decrease length of said trackway and output of the device.

15. In a rotary fluid pressure device of variable output, a rotor having a plurality of vanes movable inwardly and outwardly thereof, a trackway of variable circumferential length having a track surface for guiding the ends of the vanes in their in and out movement comprising a stationary rigid track element and a flexible track element having an extensible connection between the track surfaces thereon, the end of said flexible track element at said extensible connection being movable in a generally circumferential direction relative to said rigid track element to alter the length of said trackway simultaneously with change in output of the device and also being movable in a generally radial direction relative to the rotor, and a guide surface for guiding the end of said flexible track element adjacent said extensible connection to alter its position in said generally radial direction simultaneously and conformably with movement of said flexible track element in said generally circumferential direction, thereby providing vane-transferring relation between the track surface on said flexible and rigid track elements at said extensible connection throughout the range of variation of length of said trackway and of outputs of said device, said end of said flexible track element being continuously biased against said guide surface at all lengths of said trackway, at least a portion of said guide surface having a substantially straight contour disposed more distantly from the track surface of said rigid track element at the end thereof adjacent said rigid track element than at the end thereof adjacent said flexible track element.

16. In a rotary fluid pressure device of variable output, a rotor having a plurality of vanes

movable inwardly and outwardly thereof, a trackway of variable circumferential length having a track surface for guiding the ends of the vanes in their in and out movement comprising a stationary rigid track element and a flexible track element having an extensible connection between the track surfaces thereon, the end of said flexible track element at said extensible connection being movable in a generally circumferential direction relative to said rigid track element to alter the length of said trackway simultaneously with change in output of the device and also being movable in a generally radial direction relative to the rotor, and a guide surface for guiding the end of said flexible track element adjacent said extensible connection to alter its position in said generally radial direction simultaneously and conformably with movement of said flexible track element in said generally circumferential direction, thereby providing vane-transferring relation between the track surface on said flexible and rigid track elements at said extensible connection throughout the range of variation of length of said trackway and of outputs of said device, said end of said flexible track element being continuously biased against said guide surface at all lengths of said trackway, said guide surface comprising a substantially straight portion for guiding said end of said flexible track element at positions thereof corresponding to relatively large outputs of the device and a portion of arcuate contour for guiding said end of said flexible track element at positions thereof corresponding to relatively small outputs.

17. In a rotary fluid pressure device of variable output, a rotor having a plurality of vanes movable inwardly and outwardly thereof, a trackway of variable circumferential length having a track surface for guiding the ends of the vanes in their in and out movement comprising a stationary rigid track element and a flexible track element having an extensible connection between the track surfaces thereon, the end of said flexible track element at said extensible connection being movable in a generally circumferential direction relative to said rigid track element to alter the length of said trackway simultaneously with change in output of the device and also being movable in a generally radial direction relative to the rotor, and a guide element for guiding the end of said flexible track element at said extensible connection to alter its position in said generally radial direction simultaneously and conformably with movement of said flexible track element in said generally circumferential direction, thereby providing vane-transferring relation between the track surface on said flexible and rigid track elements at said extensible connection throughout the range of variation of length of said trackway and of outputs of said device, said end of said flexible track element being continuously biased against said guide element at all outputs of said device, said end portion of said flexible track element projecting in part circumferentially beyond said guide element toward said stationary rigid track element at least during the last portion of the movement of said flexible track element into the position occupied thereby at minimum circumferential length on said trackway.

18. A rotary vane-type fluid pressure device of variable output having a rotor, a plurality of vanes movable inwardly and outwardly thereof, a casing therefor, a trackway of variable circum-

ferential length having a track surface for guiding the ends of the vanes in their in and out movement, said trackway comprising a rigid track element and a flexible track element having an extensible connection therebetween, said rigid track element being an abutment projecting inwardly from the casing and having a vane transfer surface at said extensible connection gradually receding in one direction from the rotor, said rigid track element also having an auxiliary vane-transferring surface merging with said vane transfer surface and receding from the rotor gradually but more rapidly than said vane transfer surface, said auxiliary vane-transferring surface being arranged to provide vane-transferring relation with said flexible element upon displacement thereof beyond its maximum intended outward position, and means for moving one of said track elements with respect to the other to vary simultaneously the length of said trackway and the output of the device?

19. A rotary vane-type fluid pressure device of variable output having a rotor, a plurality of vanes movable inwardly and outwardly thereof, a casing therefor, a trackway of variable circumferential length having a track surface for guiding the ends of the vanes in their in and out movement, said trackway comprising a rigid track element and a flexible track element having an extensible connection therebetween, said rigid track element being an abutment projecting inwardly from the casing and having a vane transfer surface at said extensible connection gradually receding in one direction from the rotor, means for moving one of said track elements with respect to the other to vary simultaneously the length of the trackway and the output of the device and means for maintaining the track surface on the end of said flexible track element at said extensible connection in vane transferring relation with the vane transfer surface of said rigid element at all lengths of said trackway and all outputs of said device, said last named means including a guide surface for the end of said flexible track element at said exten-

sible connection, said guide surface being disposed in non-parallel spaced relation with respect to the vane transfer surface of said rigid element.

20. In a rotary fluid pressure device of variable output, a rotor having a plurality of vanes movable inwardly and outwardly thereof, a trackway of variable circumferential length having a track surface for guiding the ends of the vanes in their in and out movement comprising a stationary rigid track element and a flexible track element having an extensible connection between the track surfaces thereon, the end of said flexible track element at said extensible connection being movable in a generally circumferential direction relative to said rigid track element to alter the length of said trackway simultaneously with change in output of the device and also being movable in a generally radial direction relative to the rotor, and a guide element for guiding the end of said flexible track element at said extensible connection to alter its position in said generally radial direction simultaneously and conformably with movement of said flexible track element in said generally circumferential direction, thereby providing vane-transferring relation between the track surface on said flexible and rigid track elements at said extensible connection throughout the range of variation of length of said trackway and of outputs of said device, said end of said flexible track element being continuously biased against said guide element at all outputs of said device, said end of said flexible track element projecting in part circumferentially beyond said guide element toward said stationary rigid track element at least during the last portion of the movement of said flexible track element into the position occupied thereby at minimum circumferential length on said trackway, the projecting part thereof receding from the track surface on said stationary rigid track element in a generally radial direction.

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