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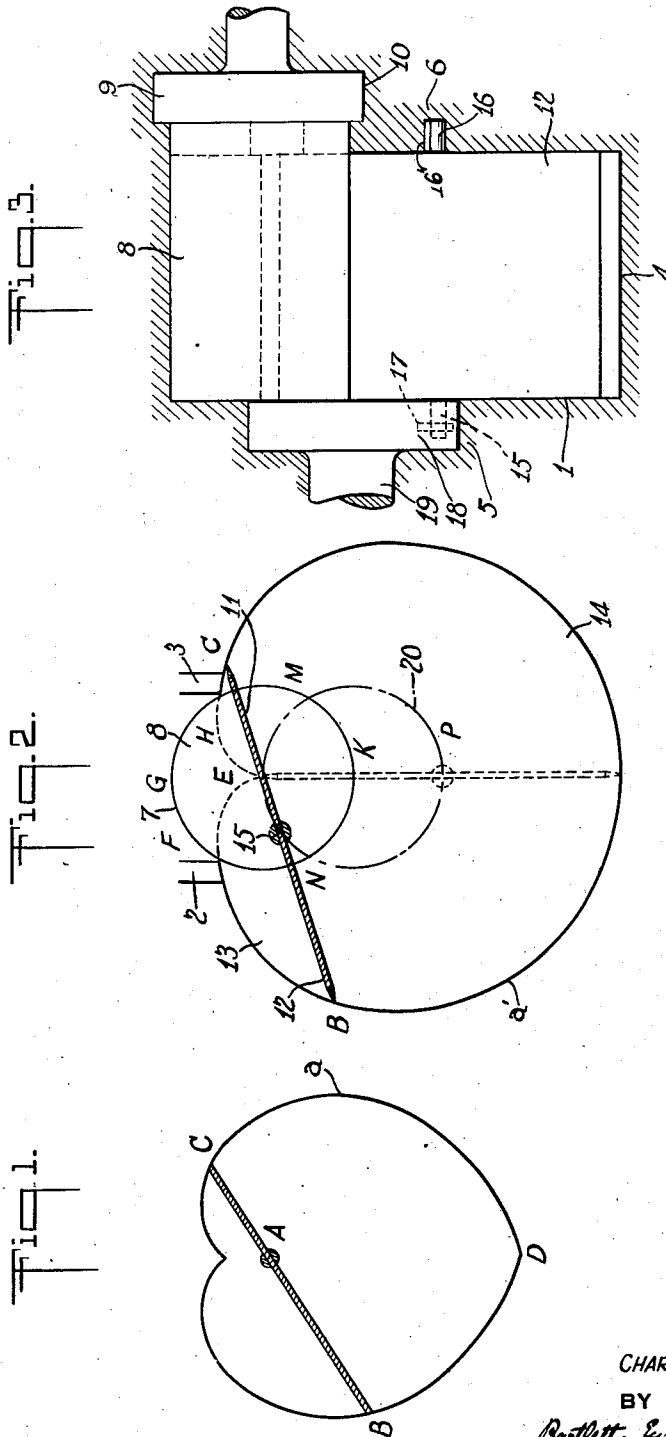
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2,373,656

ROTARY OPERATING MACHINE

Filed April 3, 1943

3 Sheets-Sheet 1



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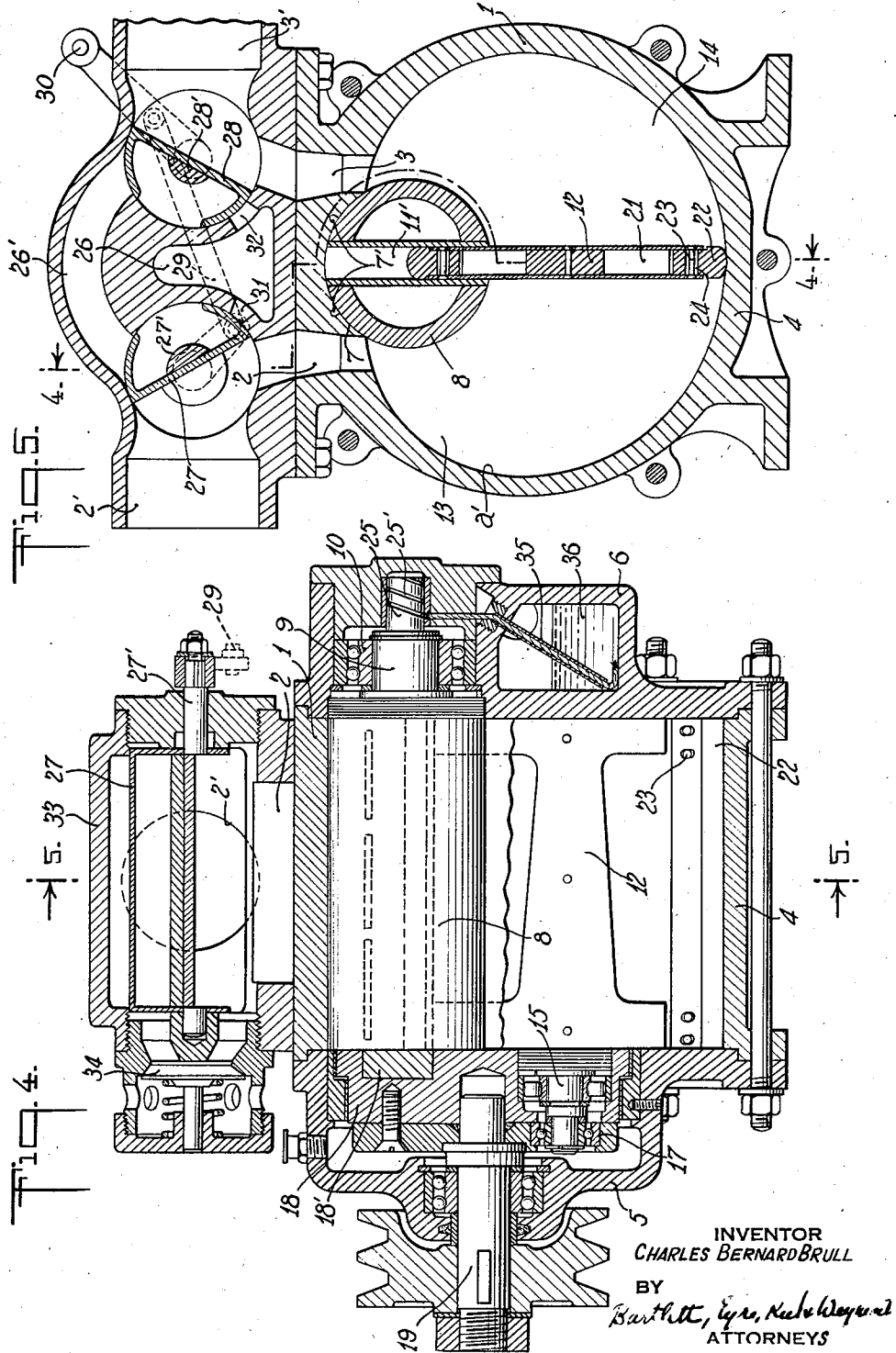
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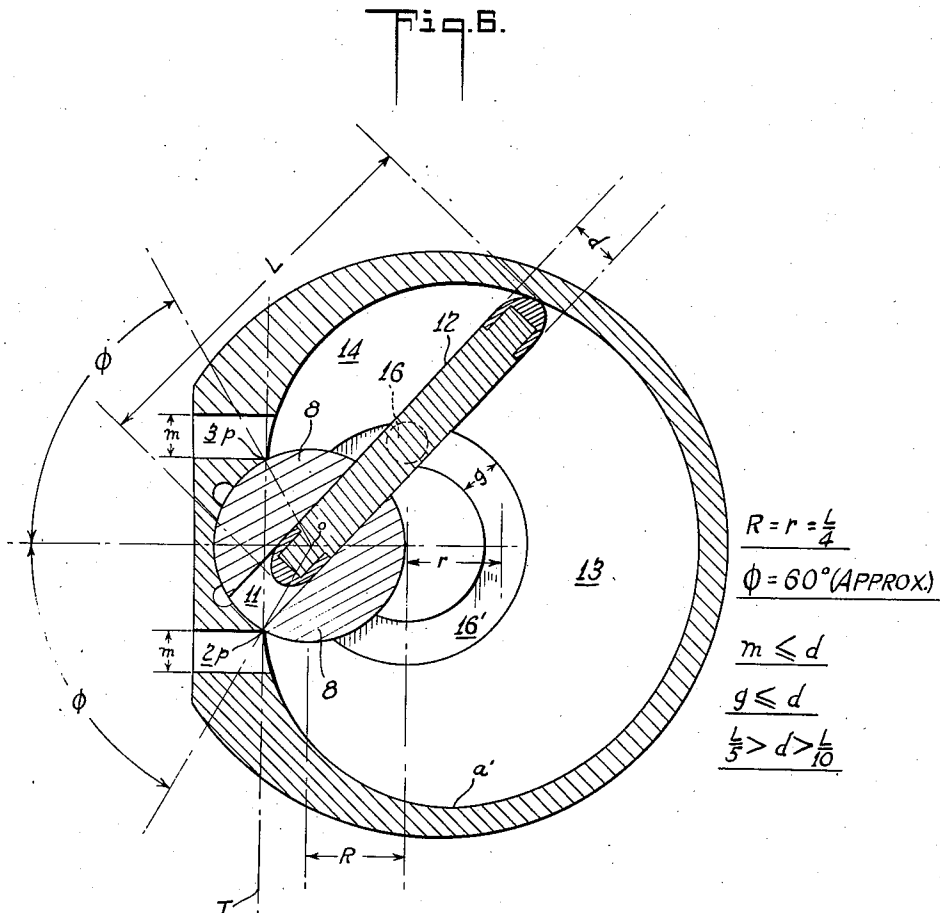
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UNITED STATES PATENT OFFICE

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ROTARY OPERATING MACHINE

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Application April 3, 1943, Serial No. 481,699
In France December 1, 1941

9 Claims. (Cl. 103—137)

The invention refers to rotary operating machines such as rotary pumps or compressors of the kind with single or multiple blades sliding in a shuttle.

These machines include a stator having a non-circular cylindrical inner surface and a rotor comprising at least one partition, generally called a blade, the plane of which is parallel to the generatrices of the stator. This partition subdivides the inner space of the stator into two independent and non-communicating chambers of volumes which vary during rotation due to the permanent contact of the longitudinal edges of the blade with the inner face of the stator; the said movable and variable chambers assuring the suction and discharge, and at the same time the transfer of, the fluid in closed circuit, which condition is very favorable for the preservation of tightness during the continuous angular displacement of the blade in the same direction. The blade is held and guided, during its alternating transverse motion which is necessary to assure its permanent contact with the non-circular wall of the stator, in a slot provided in a rotary cylindrical support generally called a shuttle. The rotor, therefore, consists of the blade-shuttle assembly.

The purpose of the invention is primarily to design these machines in such a manner that they can be manufactured by a simple machining means, that their volumetric efficiency is improved, that the sealing between the suction and the discharge is assured under the best conditions and that the friction between the moving parts and at the joints is reduced to a minimum, especially by a practically complete elimination of the effects due to centrifugal force. It also results from the arrangements described below that there are no complementary accelerations, thus avoiding any parasitic motions of the blade.

In accordance with the invention the inner surface of the stator of the new machine is in the form of a conchoid having one retrogression point, namely, a cardioid of a circle. The shuttle comprises a cylinder partially embedded in a cylindrical mortise arranged in the lateral wall of the stator in the region of the retrogression point of the cardioid. The blade, which reciprocates in a guiding diametric slot in the shuttle, is directly driven and itself drives the shuttle.

An important feature of the machine of the invention is the particular location of the suction and discharge ports of the machine and their width relative to the thickness of the blade which insures maximum volumetric efficiency.

Other important features of the invention include the ratio of shuttle diameter to blade length and the ratio of blade thickness to blade length which ratios are such as to insure mechanical stability and maximum efficiency.

A further feature of the invention is the means for insuring tightness along the longitudinal edges of the blade which comprises light gaskets in the form of scrapers capable of sliding transversely with limited amplitude.

Other features of the invention will become apparent as the description proceeds.

Of the accompanying drawings,

Figs. 1 and 2 are diagrams used to facilitate the understanding of the general principle of operation of the rotary machine which is the subject-matter of the invention.

Fig. 3 is a view representing diagrammatically in elevation (partly in section), a pump or a compressor embodying the principles of the invention explained by the diagrams of Figs. 1 and 2.

Fig. 4 is a longitudinal sectional view taken along the line 4—4 of Fig. 5 of a compressor made in accordance with the invention.

Fig. 5 is a transverse sectional view taken along the line 5—5 of Fig. 4; and

Fig. 6 is a diagram illustrating to scale the optimum relative dimensions and geometrical relations of the various parts of a machine corresponding in general to the machine of Figs. 4 and 5, but including one feature of the invention shown in the structure of Fig. 3 but absent from that of Figs. 4 and 5.

In accordance with the invention, and more especially in accordance with that of its methods of application and those of the methods of realization of its various parts to which it appears that preference should be given, when it is intended to build a rotary operating machine such as a pump or a compressor, one proceeds as follows:

It is known that some closed geometrical curves, among which one may mention as discontinuous curves those constituted by judiciously assembled arcs of an Archimedes spiral, and, as continuous curves, those constituted by some circular conchoids, possess the peculiarity that the sum of the aligned radius vectors starting from a given point located in the plane of the closed curve and inside of same, is constant irrespective of the direction of these vectors.

Among circular conchoids, those with retrogression point (Figs. 1 and 2) have, of course, the above mentioned peculiarity, namely that the sum of the radius vectors AB and AC or EB and EC starting from the point A (Fig. 1), or from

the point E (Fig. 2) and limited by the curve a or a' , remains constant irrespective of the direction of the straight line BC with respect to a fixed reference axis.

In order to facilitate the machining, it is, however, necessary to set aside discontinuous curves formed by arcs of an Archimedes spiral giving rise to an angular point D (Fig. 1) and to retain only continuous curves without double point, such as circular cardioids (Fig. 2). These curves furthermore have the advantage that when they are used as directrices of a cylindrical surface which forms the inner face of a container, the volumes of the suction and discharge phases, according to the arrangements described below, are very large for a given occupied space.

In accordance with the invention, the directrix of the cylindrical surface which is to constitute the inner face of the stator of the rotary operating machine (pump, compressor or the like) to be constructed, is given the shape of a cardioid a' such as shown in Fig. 2.

At the place of the zone in the neighborhood of the retrogression point E (Fig. 2) and in a symmetrical manner with respect to the geometrical axis of the cardioid, there is arranged in the wall of the stator a cylindrical mortise 7 along the arc FGH which therefore removes the entire material which forms the lunule FEHG.

On each side of the said mortise, there is arranged, in the wall of the stator, a symmetrical group of one or more ports, such as 2 and 3 which are to serve for the suction and the discharge respectively of the fluid (liquid or gaseous) which fluid is intended to be drawn in or expelled by the machine.

As shown in Fig. 3, the stator is completed by a base 4 and by lateral covers 5 and 6 suitable to be mounted in a removable manner on the body 1 of the stator.

In the cylindrical mortise 7 the radius and position of which are such that the volumes of the suction and discharge phases remain as large as possible, there is placed a cylindrical member 8 of the same diameter, and which, thus partly engaged in the said mortise, assures a complete contact with the same over the entire surface of this mortise. This imbedding of the shuttle in its mortise has the further advantage of reducing the dead volume due to the shuttle.

The shuttle 8 is terminated by a bearing surface 9 which enables it to rest against a bearing 10 of any suitable shape arranged inside of the cover 6 of the stator.

In the shuttle, there is arranged a diametral slot 11 in which there engages with a loose fit a perfectly flat part 12 which constitutes the blade and the dimensions of which are such that its longitudinal edges, corresponding to the points B and C of Fig. 2, are directly or not, in contact with the inner face of the stator, thus dividing the inner space of the latter into two non-communicating chambers 13 and 14. It is known that this contact continues when the blade 12 is displaced angularly around a suitably selected point (E on Fig. 2). Inasmuch as the portion FEH of the cardioid is eliminated and has been replaced by the shuttle 8, the end of the blade, engaged in the shuttle, ceases to be in contact on the FGH side with the wall of the stator when the blade is directed in the neighborhood of the axis of symmetry of the cardioid, that is to say, all along the angle FEH (Fig. 2). However, this has no drawback because for these positions of the blade the tightness between chambers 13 and 14 continues

to be assured in the zone FGH by the shuttle 8 (the tightness thus obtained between the suction and the discharge makes it possible, in general, to eliminate the suction and discharge valves and springs on the corresponding ports). For the other directions of the blade, for example for that shown in Fig. 2, the tightness between the chambers 13 and 14 is assured by the permanent contact of the longitudinal edges of the shuttle with the inner face of the lateral wall of the stator without any prejudice to the tightness, obtained by suitable devices, between the transverse edges of the shuttle and the covers 5 and 6 of the stator. Continuous angular displacements of the blade 12 around the axis of rotation projected at E, Fig. 2, of shuttle 8 are obtained by having the torque act directly upon the longitudinal axis of symmetry of the blade 12, the shuttle carried along by the blade then rotating freely in the mortise 7, following the motions of the blade. It results from this that the section of the shuttle can be reduced to a minimum, which further reduces the volume lost due to the shuttle. It can be understood that by driving the blade 12 in this manner by its center (point 15, Fig. 2), there is obtained a balancing of the stresses which act upon same and therefore there is eliminated, on the blade, the effects of centrifugal force which with any other manner of drive would manifest themselves by considerable asymmetric friction between the blade 12 and the inner wall of the stator and between the blade 12 and the edges of the slot 11 of the shuttle 8. This is particularly what would occur if the driving of the blade were effected by direct application of the torque on the shuttle.

As indicated in Fig. 3 it is possible to prolong the axis of symmetry of the blade 12 by means of two round tenons 15 and 16, the tenon 15 being embedded so as to be able to rotate in a bearing 17 eccentrically carried in the drive plate 18 which is integral with the drive shaft 19, in such a manner that the path of this tenon is a circle indicated by the dot and dash line 20 (Fig. 2), the center K of which is also the center of the circle which is the generator of the cardioid.

The tenon 16 engages in a fixed annular mortise 16', concentric with the circular path traversed by the tenon 15, and corresponding to the arc MPN of circle 20, arranged in the wall of the cover 6 of the stator. The annular mortise 16' is limited by the housing of the shuttle but the slot 11 of the latter is sufficiently extended on the side where the tenon 16 is located so that the latter may slide in the same without any play and thus travel the remaining portion of its circular trajectory corresponding to the arc NEM of circle 20. The blade 12 is, therefore, guided in all positions by the shuttle 8, by the lateral walls or covers 5 and 6 of the stator, by the tenon 15 which is practically embedded in the plate 18, and by the tenon 16 which rests against the edges of the mortise 16' in the wall 6, when it moves along the part of its circular trajectory corresponding to the arc MPN, and against the edges of the slot 11 of the shuttle, when it moves along the remaining part of its circular trajectory. The shuttle 8 turns freely around its axis in a continuous motion and with constant speed, if the speed of the drive-shaft 19 is constant, thus cancelling complementary accelerations. The shuttle rests against the wall of the mortise 7, the bearing 10 and the adjacent face of the driving plate 18.

In the special case shown in Figs. 4 and 5, the tenon 16 is omitted and only the tenon 15

is used. This tenon 15 is carried in the bearing 17 of the driving plate 18. In this case the blade, all along its lateral face on the side of the cover 6, is in contact with the inner face of this cover 6, taking into consideration a predetermined clearance which depends, among other things, on the use of the apparatus. A counterweight 18' is provided for counter-balancing the bearing 17 in the plate 18.

A tight seal between chambers 13 and 14, along the longitudinal edges of the blade, can be assured by arranging, in the said edges, grooves 21 in each one of which there engages a scraper 22 made of a material which is both resistant and sufficiently plastic as to be deformable, as for instance hard rubber (ebonite) or similar material. Each scraper can slide freely in the corresponding groove, being guided by the edges of the same and is prevented from becoming displaced beyond a certain elongation by holding members such as pins 23 fastened to the blade and passing through mortises 24 of a suitable shape, arranged in the scraper. The scraper, when pulled toward the outside by centrifugal force, cannot therefore escape beyond its housing when the corresponding end of the blade moves into the slot 11 of the shuttle and ceases to be in contact with the wall of the stator.

These scraper devices are substantially the only parts of the machine subject to important friction. They may be cheaply constructed and are simple to replace. Being somewhat plastic, their shape will conform to the surface over which they travel. That is, after a certain period of operation their shape will automatically become exactly what it should be to insure a tight seal between the chambers, at all positions of the blade. Thus their initial shape does not have to be formed with any great care.

The tightness between the shuttle 8 and the mortise 7 of the stator is assured by the extent of their contact surface (arc FGH of Fig. 2) and also by a suitable number of fixed grooves 7', of suitable form and section, arranged in the wall of the mortise 7 and extending between the covers 5 and 6.

The tightness along the edges of the blade 12 which are in contact with the lateral walls or covers 5 and 6 of the stator may be assured by strips of greased felt engaged in grooves arranged in the said edges or by grooves of suitable sections and positions.

Where the tenon 16 is employed, as in the machine of Fig. 3, no permanent leakage can occur at the place where the fixed mortise 16' is hollowed into the wall 6 for the passage of the tenon 16, which fits exactly into the mortise, inasmuch as the diameter of this tenon remains smaller than or equal to the thickness of the blade.

In connection with certain applications, especially in the case of simplified low-vacuum or low-pressure suction or blower machines or of machines intended for the displacement of fluids loaded with dust (gas generators) it is possible to eliminate the scrapers and/or the strips of felt and be satisfied with a fitting with slight play of the moving parts with respect to the stationary parts.

In order to automatically assure a controlled lubrication the bearing surface 9 of the shuttle 8 can be prolonged by a stub shaft 25 in which there is arranged one or several helical grooves 25' fed with lubricant delivered through a wick 35 from a small tank or reservoir such as 36 ar-

ranged in the cover 6 or any other means. The oil placed under pressure by the movement of the grooves 25' is thereupon delivered through conduits (not shown in the drawings) to the places of the movable parts to be lubricated (shuttle 8, blade 12 and driving plate 18). In this manner the flow of the lubricant is proportional to the speed of rotation of the rotary parts. If one wishes to be able to place the machine out of circuit whenever necessary without its rotor ceasing to be driven, one may add to the said machine a distributor by means of which the suction ports 2 and the discharge ports 3, may be, for normal operation, placed in communication with the suction connection 2' and the discharge connection 3' respectively, or may, when it is desired to disconnect the machine, be isolated from the said connections.

The operation of this distributor must be such that when the communication between the corresponding ports and connections is interrupted (operation out of circuit) the apparatus draws in and directly discharges into the atmosphere—which contributes to its rapid cooling—while the circulation of the fluid from inlet to discharge continues to be freely assured, without the intervention of the said apparatus, by a special bypass channel.

One of the simple means of obtaining these results consists in arranging, between the suction port 2 and the suction connection 2', a rotary slide valve 27 and another similar rotary valve 28 between the discharge port 3 and the discharge connection 3', the shafts 27' and 28' of the said slide valves being connected with each other by means of a connecting rod 29, which can be operated by a joint drive 30.

Naturally one could use any other suitable combination for suitably combining the respective motions of the cylindrical slide valves such as 27 and 28.

When the slide valves 27 and 28 occupy the positions shown in Figs. 4 and 5, the operation as compressor or pump is normal, the slide valves closing the orifices 31 and 32 through which the suction port 2 and the discharge port 3 can be respectively placed in communication with the open air through the cavity 26.

On the other hand, when the driving member 30 is brought to its other characteristic position, the slide valves release the orifices 31 and 32, thus assuring the direct communication of the suction and of the discharge with the atmosphere, interrupt the communication between 2 and 2' on the one hand and 3 and 3' on the other hand, and furthermore permit the fluid to circulate independently of the machine through the bypass 26'.

If necessary one can also provide at the end of the case 33 in which the slide valves 27 and 28 are placed and at right angle to one of these slide valves or to both, a safety valve 34 communicating with the discharge connection 3' of the compressor in order to protect the inner member thereof against sudden excess pressure or back-firing in case the said compressor should be connected with a gas generator, for example, or with any other member likely to create these sudden counter pressures.

In order to obtain an operable and efficient machine of the character described in connection with Figs. 1 to 5, I have found that it is essential that certain ratios exist between the dimensions of the various elements, or at least that such ratios are closely approximated. Also, as hereto-

fore indicated, the position and width of the parts is of prime importance in insuring volumetric efficiency and in preventing communication between the chambers. These various necessary or preferred relations can best be understood with reference to Fig. 6 to which reference may now be had.

As indicated in Fig. 6, the radius R of the shuttle 8 is equal to the radius r of the generating circle for the cardioid defining the inner surface of the stator and is equal to one-fourth the length of the blade 12. With a shuttle of smaller diameter, when the blade 12 lies along the axis of symmetry, the length thereof within the slot 11 would be insufficient to insure smooth operation of the device and proper rotation of the shuttle by the blade. Furthermore, if a shuttle of smaller diameter were employed, some of the reentrant portion of the cardioid would remain and it would be impossible for the edge of a blade of finite width to follow such reentrant surface portion of the stator. On the other hand, with a shuttle of larger diameter, there would necessarily be a reduction in the volumes of chambers 13 and 14 and consequently a reduction in the capacity of the machine.

As shown in Fig. 6, the ports 2 and 3 are so positioned in the wall of the stator adjacent the shuttle 8 that lines drawn from o , the retrogression point of the cardioid and the axis of the shuttle, to points p , corresponding to points on the cardioid surface at the edge of the ports, make equal angles ϕ with the axis of symmetry of the cardioid. I have found that maximum volumetric efficiency is obtained when the ports are so located that the points p lie on the common tangent, indicated at T , of the cardioid. With such location of the edges of the ports, each angle ϕ is very nearly equal to 60° . The volumetric efficiency deteriorates rapidly as the angle ϕ varies from this optimum value. This position of the ports 2 and 3 results purely from theoretical considerations and hence is not dependent upon the relative dimensions of the shuttle. It will be apparent from Fig. 6, however, that with the optimum relative dimensions heretofore given for the blade, shuttle and generating circle, the optimum position of the ports 2 and 3 occurs adjacent the entry of the shuttle into the mortise cutting away the retrogression point and reentrant portion of the cardioid.

The width m of the ports 2 and 3, as indicated in Fig. 6 should be equal to, or less than, the thickness d of the blade. Preferably the width m should be equal to the thickness d and the same is true of the width g of the annular mortise 16' for reception of the tenon 16 of the blade. The thickness d of the blade 12 should be between one-fifth and one-tenth the length L of the blade. In the particular embodiment of the invention illustrated in Fig. 6, the thickness d is one-eighth the length L , which is approximately the preferred ratio.

A machine constructed according to the invention and having its elements proportioned as specified in Fig. 6 will, for a given output and at a given pressure, have the highest volumetric efficiency, with the result that the velocity of the moving parts can be reduced to a minimum. Accordingly the machine, as compared to machines heretofore proposed, will have less frictional losses, will be decidedly less noisy, and the parts will be less subject to wear and will require less lubrication. In the machine the blade works at one-half the speed of the driving member, with-

out the interposition of gears, and is completely dynamically balanced. When supported by tenons at both sides it is likewise mechanically balanced and hence not subject to stresses.

5 An important feature of the machine as above described is that during operation no pressure surges occur, with the result that the machine can be efficiently employed as a pump for colloidal liquids, such as milk, wine or the like where foaming must be avoided. When the machine is used for such liquids or for crude oil or for gases carrying dusts or powdered mineral matter, as for example when coupled with a gas producer, the scrapers may be omitted and a slight clearance provided between the moving parts.

10 Although the shuttle, in the embodiments of the invention illustrated and above described is not independently driven, driving means may be provided therefor if desired. When the machine is operated at high pressures, driving means for the shuttle, as for example gearing between the drive shaft 19 and shaft 25 of the shuttle, if provided, would reduce the stress on the driving tenon 15.

15 This application is a continuation in part of my application Serial No. 467,347, filed November 30, 1942.

I claim:

1. A rotary apparatus comprising in combination a stator and a rotor, said stator comprising a generally cylindrical casing, the internal surface of said casing being so formed that a cross-section thereof is in the form of a circular cardioid except for the wall section adjacent the retrogressive point, said wall section being cut away the full distance between the points on the cardioid having a common tangent to provide a longitudinal arcuate recess, said rotor comprising a cylindrical shuttle and a blade, the shuttle being 30 rotatably mounted in said casing with a portion thereof extending into said recess, said shuttle being provided with a longitudinal diametric slot, the blade being positioned in said slot and transversely movable therein and being of such length that the edge thereof engages the inner surface of the casing during rotation of said shuttle, said casing being provided with ports each of a width substantially equal to the thickness of the blades, and at either side of said recess for ingress and egress of fluid, and means independent of said shuttle for driving said blade to cause an edge thereof to sweep over the internal surface of said casing.

2. The rotary apparatus according to claim 1, including end walls for said casing and wherein said last mentioned means include a plate rotatably mounted in one of said walls, a spindle on said blade rotatably mounted in said plate, and means for rotating said plate to cause said spindle to traverse a circle corresponding to the generator of the cardioid.

3. The rotary apparatus according to claim 1 including deformable means carried by said blade adjacent the longitudinal edge thereof for yieldingly engaging the walls of said casing.

4. The rotary apparatus according to claim 1 including end walls secured to said casing, one of said walls being provided with an annular groove, a plate rotatably mounted in the other of said walls, an axial extension on said blade extending into said groove, a second axial extension on said blade rotatably mounted in said plate and means for rotating said plate.

5. A rotary apparatus comprising in combination a stator and a rotor, said stator comprising a

generally cylindrical casing, the internal surface of said casing being so formed that a cross-section thereof is in the form of a cardioid except for the wall section adjacent the retrogression point, said wall section being cut away between the points on the cardioid having a common tangent to provide a longitudinal arcuate recess, said rotor comprising a cylindrical shuttle and a blade, the shuttle having a diametrical slot and being rotatably mounted in said casing with its axis passing through the retrogression point and with a portion of its surface engaging the walls of said recess, the diameter of said shuttle being equal to the diameter of the generating circle of the cardioid, said blade being positioned in said slot and transversely movable therein, the length of said blade being twice the diameter of the shuttle, said casing being provided with ports at either side of said recess for ingress and egress of fluid.

6. The rotary apparatus according to claim 5 including end walls for said casing, a plate rotatably mounted in one of said walls, a spindle on said blade rotatably mounted in said plate, and means for rotating said plate to cause said spindle to traverse a circle corresponding to the generator of the cardioid.

7. A rotary apparatus according to claim 5 wherein said ports are so located relative to the retrogression point that imaginary lines joining said point with the edges of said ports make an

angle of approximately 60 degrees with the axis of symmetry of the cardioid.

8. A rotary apparatus according to claim 5 wherein the thickness of said blade is between one-fifth and one-tenth the length thereof and wherein the width of each of said ports is equal to the thickness of said blade.

9. A rotary apparatus comprising in combination a stator and a rotor, said stator comprising a generally cylindrical casing, the internal surface of said casing being so formed that a cross-section thereof is in the form of a circular cardioid except for the wall section adjacent the retrogression point, said wall section being cut away the full distance between the points on the cardioid having a common tangent to provide a longitudinal arcuate recess and said casing being provided with ports adjacent said recess, said rotor comprising a cylindrical shuttle and a blade, said shuttle being rotatably mounted in said casing with a portion thereof extending into said recess and being provided with a diametric slot for reciprocation of said blade therein, and deformable scraper members carried on the longitudinal edges of said blade for engaging the inner surface of said casing during rotation of said rotor, said scrapers being mounted to permit of limited movement lengthwise of the blade.

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