The present invention relates to positive displacement rotary piston engines of the helical screw rotor type designed for operation either to compress or expand an elastic fluid working medium and consequently embodying an inbuilt compression or expansion ratio for the working fluid independent of variations in the pressure of the fluid in the supply and discharge conduits leading to and from the machine. More specifically the invention relates to engines of the kind disclosed in U.S. Patent No. 2,543,874, granted to Alf Lysholm June 3, 1941, and generally characterized by casing structure providing a barrel portion having intersecting bores with coplanar axes in which are rotatably mounted male and female rotors having helical lands and grooves in an intersecting relation operative to form with the casing structure working chambers of chevron form each composed of cooperating portions of a male rotor groove and a female rotor groove. It is further characteristic of engines of the kind under consideration that the flanks of the major portions thereof lying outside the pitch circle of the rotor while the sides of the grooves of the female rotor are concavely curved with the major portions thereof lying inside the pitch circle of the rotor. In such engines the vane end of each of the working chambers is determined by a fixed transverse plane which in the case of engines provided with single helix rotors of the kind shown in the aforesaid patent and in the herein illustrated embodiments of the present invention is the plane of the high pressure end wall of the casing structure and the apex end of each of the working chambers is determined by the plane of intermesh of the rotors limiting the portions of the cooperating grooves forming the chamber, the latter place moving either toward or away from said transverse plane to decrease or increase the volumes of the individual chambers as the rotors are revolved either in the directions causing the engine to operate as a compressor or in the opposite directions causing it to operate as an expander. The present invention is not limited in its scope and utility to engines with single helix rotors and is equally applicable to engines having double helix or herringbone type rotors of the kind disclosed in U.S. Patent No. 2,289,371, granted to Alf Lysholm et al., July 14, 1942, in which type the bases of the working chambers are determined by the transverse plane located at the juncture of the helical land portions of different hand on each rotor. In all such engines, however, the bases of the working chambers are determined by an axially fixed plane while apices thereof move axially either toward or away from said plane as the rotors revolve. Still further it is characteristic of engines of the type to which this invention relates that the high pressure port with which the working chambers communicate is disposed with a major portion thereof located on one side of the longitudinal plane coincident with the coplanar axes of the casing bores while the low pressure port is disposed with a major portion thereof located on the opposite side of said plane.

In many applications of engines of the above described general type to practical industrial use, it is of paramount importance that either or both the inbuilt pressure ratio and the quantitative capacity of the engine be capable of being regulated, sometimes through ranges having widely separated limits, without substantial sacrifice of operating efficiency, and heretofore various expedients have been proposed for effecting such regulation. Such expedients as heretofore developed have not proved to be entirely satisfactory or effective and it is a principal object of this invention to provide new and improved regulating means for engines of the type under consideration which shall be effective to regulate either the inbuilt pressure ratio or the capacity, or both, which shall be capable, if desired, of regulating both in a predetermined relationship with respect to each other, which shall be simple and rugged in construction and comparatively inexpensive to manufacture and which will operate to provide part load capacity operation at the same or different pressure ratios while maintaining acceptable efficiency of operation.

To this end, the invention contemplates the provision of rotary regulating valve means associated with auxiliary port means providing controlled communication between the working chambers and either one of or both the high and low pressure passages with which the main high and low pressure ports respectively communicate. Preferably such auxiliary ports are axially spaced in the barrel portion of the casing structure and are in the form of oblique parallel sided slots separated by ligaments of casing structure with the oblique sides of the ports and ligaments at an angle approximately the same as the helix angle of the lands of the rotor which passes the ports, whereby quick opening and closing action of the individual ports is obtained and regulation effected in a step-by-step progression.

The rotary valve regulating means may be embodied in numerous different specific ways in order to obtain different specific functional effects and in the ensuing portion of this specification there will be described by way of example but without limitation, several embodiments of apparatus for carrying the invention into effect, such embodiments being described in conjunction with the accompanying drawings forming a part hereof, in which:

FIG. 1 is a longitudinal section through one embodiment along the line 1—1 of FIG. 2, FIG. 1a is a section taken on line 1a—1a in FIG. 2 and FIG. 2a is a section taken on line 2—2 in FIG. 1. FIG. 3 is a longitudinal section through another embodiment along the line 3—3 of FIG. 4 and FIG. 4a a section taken on line 4—4 in FIG. 3. FIGS. 5, 6, 7 and 8 are longitudinal sections through still further embodiments.

Referring now to the drawings and more particularly to FIGS. 1, 2, and 2a, the embodiment illustrated is of the single helix rotor type having a casing structure comprising a barrel portion providing two intersecting bores 22 and 24 having coplanar axes and enclosing within the bores and between the low and high pressure ends walls 26 and 28, respectively, forming a part of the casing structure, the male rotor 12 and the female rotor 16. These rotors are of conventional form for this type of apparatus, the male rotor having helical lands 14 with convoluted curved flanks lying substantially outside the pitch circle of the rotor and the female rotor having lands 18 to provide intervening grooves with concavely curved sides lying substantially within the pitch circle of the rotors. As will be observed from the drawings the profile of the male rotor lands is symmetrical and generally circular, as disclosed in U.S. Patent No. 2,622,787, granted Dec. 23, 1952, to Hans Nilsson. The casing structure further provides a passage 36 for high pressure working fluid, terminating in a main high pressure port...
32 communicating with the bores 22, 24 and located generally on one side (which may be considered the high pressure side) of the longitudinal plane coincident with the axis of the bores said ports also being located to include the fixed transverse plane which defines the base ends of the working chambers, which in this form of engine also is the plane of the face of the casing end wall confronting the high pressure ends of the rotors. The casing structure also provides the passage 34 for low pressure working fluid, terminating in a main low pressure port 30 located on the side (which may be considered the low pressure side) of the plane through the axes of the bores opposite that in which the high pressure port is located.

Rotors 12 and 16 are mounted in bearings 38 and 40 and may be provided with synchronizing gears, one of which is shown at 42, for maintaining proper phase relation between the rotors. Preferably male rotor 12 is provided with a power shaft 44 for transmitting power absorbed by or generated by the machine.

In accordance with the basic principles of the invention, regulation of either or both the built-in compression ratio and the capacity of the machine is effected by controlling the area for flow of working fluid to or from the high and/or low pressure passages, through the medium of a plurality of auxiliary ports that may be sequentially opened or closed by turning movement of a rotary regulating valve coacting with the auxiliary ports.

In the embodiment shown in FIG. 1, and related figures, control of the high pressure port area is effected through the action of regulating means provided by a valve chamber 45 in which is located the rotary valve member 46. Valve 46 is comprised of a circular annular plate or obturator portion 46e, from which extends the circular skirt portion 46b provided with a helical control edge 46c. In the preferred embodiment shown the valve chamber and valve skirt are cylindrical, but other circular shapes may be employed.

In the present embodiment the valve casing and valve are located symmetrically with respect to the bores 22 and 24, and are arranged to coat with two sets or series of auxiliary high pressure passages, one set comprising passages 48 connecting the valve chamber with the bore 22 and the second set comprising passages 56 connecting the valve chamber with the bore 24. The passages 48, at the place of juncture with bore 22, terminate in auxiliary high pressure ports 56c and the passages 56, at their place of juncture with bore 24, terminate in auxiliary high pressure ports 56a. At their opposite ends, the passages 48 and 56 terminate in valve ports 56b and 56a, respectively. As will be seen more particularly from FIG. 1a, the auxiliary passages 48 and 56 are in the form of oblique slots separated by parallel sided webs or ligaments 20a formed in the barrel portion of the casing 20. As will further be noted from this figure, the angle at which slots 48 are disposed is substantially the same as the helix angle of the lands of the male rotor passing these passages. Further, this angle is also substantially the same as the helix angle of the control edge 46c of the valve. Inasmuch as the passages 56 open into bore 24 in which the female rotor is located and which has lands and grooves of opposite hand than those of the male rotor, passages 56 are oblique and of opposite hand than passages 48, to correspond with the helix angle of the grooves of the female rotor. Likewise for controlling the ports of passages 56 it is desirable to have a valve control edge of the same hand and helix angle as those of these ports, and accordingly there is provided angularly triangular auxiliary valve skirt member 50, non-rotatably mounted to move axially, in guides 52 and 54 in the casing structure, together with the valve 46 as the latter is turned. Member 50 is provided with a control edge 50c functioning the same with respect to passages 56 as edge 46c does with respect to passages 48.

Assuming the engine to be operated as a compressor, the grooves are filled with working fluid admitted through the low pressure port in the usual fashion, and compression commences when the lands are being closed to the intermeshing relation at the inlet or low pressure end of the line of intersection of the two bores on the high pressure side of the compressor. At this time a chevron shaped substantially closed working chamber is formed by the portions of two grooves, one in each rotor extending from the apex formed at the place of internmesh to the base formed by the ends of the grooves closed at the plane of the high pressure end wall. As the rotors continue to rotate, the place of internmesh forming the apex of the chamber, moves progressively down the line of intersection toward the high pressure end, this progressively decreasing the volume of the chamber and compressing the trapped fluid. This action continues until the crests of the leading edges of the grooves forming the chamber pass the edge of a high pressure port, which in a compressor embodying the present invention may be any one of the auxiliary ports 48, 56 or the main port 32, depending upon the angular position of the control valve 46 and the corresponding axial position of member 50. With the valve in the position shown in FIG. 1, substantially no compression takes place, the machine acting substantially as a positive displacement blower. When an auxiliary passage is opened from the left of FIG. 1, auxiliary passages 48 and 56 are progressively closed until the minimum high pressure port area represented by the main high pressure port is all that is open, to thereby provide the maximum built-in compression ratio for which the machine is designed.

If the auxiliary passages 48, 56 are filled with elastic working fluid enters through the high pressure passage 36. From said passage it is conducted through the high pressure port 32 into one or more working chambers, entirely filling the portions of the grooves of the rotors facing the high pressure port 32. The rotors 12, 16 are forced to rotate so that the point of internmesh between the lands 14, 18 is moved towards the low pressure end wall 26 and so that the expansion chambers composed of the communicating portions of two grooves are enlarged. During the rotation of the rotors 12, 16 the lands 14, 18 and the edges of the high pressure ports 56a, 56b so that said expansion chambers are entirely closed and shut off from the high pressure passage. The working fluid is then expanded until the lands 14, 18 pass the edges of the low pressure port 30 and their point of internmesh reaches the low pressure end wall 26. By angular adjustment of the valve 46 one or several others of the slots may be uncovered. In this case the shut off of the expansion chambers from the high pressure passage 36 will occur at another point of internmesh between the lands 14, 18, i.e. at larger volume of the expansion chambers. In this way the quantity of working fluid passing through the machine is increased so that there is an adjustment of the power delivered from the machine. At the same time the built-in pressure ratio of the machine is changed. From the foregoing it will be seen that in this embodiment of the apparatus, when operating as a compressor only the built-in compression ratio is regulated, the regulation not operating on the quantity of fluid compressed, while when operating as a compressor both the built-in expansion ratio and the quantity of fluid expanded are affected by the regulation, the quantity increasing as more and more auxiliary ports are opened, and the built-in expansion ratio decreasing.

In the above described embodiment is shown as regulating two sets of ports one in each bore, which in certain cases is desirable in order to provide maximum free flow area through the auxiliary passages. Likewise the shaping of the auxiliary ports and the valve ports, and the valve control edges, to conform with the helices of the rotors lands, gives desirable quick opening.
of the machine can be adjusted for coincidence with the real pressure ratio outwardly of the machine.

In FIG. 7 an embodiment is shown provided with two separate angular adjustable valves 76, 78 on the same side of the plane through the axis of the rotors 12, 16 as the high pressure port 32. One 76 of said valves cooperates with slots 80 in the wall between the bore enclosing the male rotor 12 and the high pressure passage 36 and the other 78 of said valves cooperates with slots 82 in the wall between the bore enclosing the male rotor 12 and the low pressure passage 34. This embodiment can be regarded as a combination of the embodiments shown in FIGS. 1 and 2 and in FIG. 6.

In FIG. 8 an embodiment is shown provided with two separate, angularly adjustable valves 84, 86 one of which is located on either side of the plane through the axes of the rotors 12, 16. The valve 84 located on the same side of said plane as the high pressure passage 32 co-operates with slots 88 in the wall between the bore enclosing the male rotor 12 and the high pressure passage 36. The other valve 86 located on the same side of said plane as the low pressure passage 30 cooperates with slots 90 in the wall between the bore enclosing the male rotor 12 and the low pressure passage 34. This embodiment can be regarded as a combination of the embodiments shown in FIGS. 1 and 2 and in FIGS. 3 and 4.

Of course the invention is not limited to the embodiments shown in the drawings but comprises as well all other embodiments of machines lying within the scope of the following claims.

I claim:

1. A positive displacement, rotary regulating valve engine of the helical screw rotor type comprising casing structure providing a barrel portion having intersecting bores with co-planar axes, male and female rotors having helical lands and intervening grooves, a rotatable mountable in said bores, the lands of the male rotor having convexly curved flanks the major portions of which lie outside the pitch circle of the male rotor and the grooves of the female rotor having concavely curved sides the major portions of which lie inside the pitch circle of the female rotor, and said casing structure comprising a high pressure passage terminating in a main high pressure port communicating with said bores, a major portion of said port being located on one side of the plane of said axes at the place of said transverse plane and a low pressure passage terminating in a main low pressure port communicating with said bores, a major portion of said low pressure port being located on the side of the plane of said axes opposite that of said high pressure port, said casing structure further providing a circular valve chamber in direct communication with one of said passages and a plurality of auxiliary passages providing communication between said valve chamber and said working chambers, said auxiliary passages terminating at one end in a plurality of axially separated 64 auxiliary ports located in at least one of said bores and at their opposite end terminating in a plurality of axially separated valve ports in said valve chamber, rotary regulating valve means located in said valve chamber comprising an obturating portion providing a closure extending across said valve chamber and a circular skirt portion extending axially from said obturating portion and having an oblique control face, the flow of working fluid passing through the said obturating portion being regulated by said control face means for obtaining the desired working pressure within said working chamber.
2. An engine as defined in claim 1 in which said casing structure provides a high pressure valve chamber on one side of the plane of said axes in direct communication with said high pressure passage and a low pressure valve chamber on the other side of said plane in direct communication with said low pressure passage, there being auxiliary passages and ports providing communication between said bores and each of said valve chambers and there being separate rotary regulating valve means in each chamber, each of said valve means comprising an obturator portion and a skirt portion having an oblique control edge, the skirt portion of the valve means in the high pressure chamber being on the same side of the obturator portion as the transverse plane defining the base ends of said working chambers, whereby to control flow of working fluid through said high pressure valve chamber between said working chambers and said high pressure passage, and the skirt portion of the valve means in the low pressure chamber being on the side of the obturator portion opposite to that of said transverse plane defining the base ends of said working chambers, whereby to control flow of working fluid through said low pressure valve chamber between said working chambers and said low pressure chamber, and means for separately adjusting the angular positions of the valve means located in each of said chambers.

3. An engine as defined in claim 1 in which said auxiliary ports comprise a plurality of axially spaced elongated oblique openings in the wall of one of said bores.

4. An engine as defined in claim 3 in which the oblique edges of said auxiliary ports have substantially the same helix angle as that of the lands of the rotor located in the same bore.

5. An engine as defined in claim 4 in which said auxiliary passages are separated by ligaments of casing structure having parallel oblique sides connecting said auxiliary ports and said valve ports, whereby both ports have substantially the same helix angle as that of the lands of said rotor, and in which the control edge of said skirt portion of the valve means has substantially the same helix angle as that of said ports.

6. An engine as defined in claim 1 in which said auxiliary passages and associated auxiliary and valve ports comprise two separate sets, one in each of said bores adjacent to the line of intersection between the bores, said sets of passages and ports being oblique and opposite hand, respectively, and of substantially the same helix angles as those of the lands of the rotors located in the bores into which the respective sets of auxiliary ports open, and in which said valve means includes a non-rotatably mounted and axially movable auxiliary skirt portion having an oblique control edge of opposite hand than that of said rotary skirt portion, said auxiliary skirt portion moving axially in accordance with turning movement of said rotary skirt portion to control the ports of one of said sets as the ports of the other of said sets are controlled by said rotary skirt portion.

7. An engine as defined in claim 1 in which said valve chamber is located on the same side of the plane of said axes as that of said high pressure port.

8. An engine as defined in claim 7 in which said skirt portion of the rotary valve means is located on the same side of said obturator portion as said transverse plane defining the base ends of said working chambers, whereby to control flow of working fluid through certain of said auxiliary passages between said working chambers and said high pressure passage.

9. An engine as defined in claim 7 in which said skirt portion of the rotary valve means is located on the side of said obturator portion opposite to that of said transverse plane defining the base ends of said working chambers, whereby to control flow of working fluid through certain of said auxiliary passages between said working chambers and said low pressure passage.

10. An engine as defined in claim 7 in which said rotary regulating valve means is provided with two skirt portions extending oppositely from an intermediate obturator portion, whereby to control flow of working fluid by one skirt portion through certain of said auxiliary passages between said working chambers and said high pressure passage and to control flow of working fluid by the other skirt through certain other of said auxiliary passages between said working chambers and said low pressure passage.

11. An engine as defined in claim 10 in which said control edges of said skirt portions are disposed to decrease area of the ports communicating with the high pressure passage as the area of the ports communicating with the low pressure passage is increased.

12. An engine as defined in claim 10 in which said valve means comprises two separate rotary valve elements each comprising a skirt portion and an obturator portion and in which means is provided for separately adjusting the angular position of each of said valve elements.

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