A two-stage screw rotor compressor in which each stage is provided with an adjustable slide valve for varying the volumetric capacity of the stage which makes it possible to vary the capacity of the compressor within wide limits while maintaining a higher efficiency within the whole operating range than in hitherto known compressors of this type. Preferably the two valves are interconnected to move in unison.
TWO STAGE SCREW ROTOR MACHINES

The invention relates to screw rotor machines having at least two stages for compressing or expanding an elastic working fluid and being of the type in which each stage includes a pair of intermeshing screw rotors.

In for instance a two-stage compressor the first or low pressure stage determines the volumetric capacity of the compressor. Normally the compressor is designed and the built-in pressure ratios of the two stages are chosen such that at full load the compressor delivers a desired gas quantity at a desired final pressure and at a satisfactory efficiency. In almost all ranges of application the capacity of the compressor must be variable. One way to obtain a reduction of the capacity is to reduce the speed of the compressor. However, at lower speeds the unfavourable effect of the internal leakage of the stages upon the volumetric efficiency is resulting in a reduction of the overall efficiency of the compressor. In addition, if the compressor is driven by an induction motor a change speed gearing must be incorporated in the plant involving increased costs and space demands. Therefore, capacity control by speed variation is in most cases not recommendable.

U.S. Pat. No. 3,314,597 discloses a screw rotor compressor of the single stage type the capacity of which is variable by means of an axially movable slide valve member. In this compressor the built-in pressure ratio can be kept at a suitable high level also at partial capacity and the compressor can be adjusted down to very low capacities with a fairly high efficiency.

In a screw rotor machine there is always an internal leakage which is substantially proportional to the built-in pressure ratio or counter-pressure. Therefore, when a single stage compressor included in a compressed air system and being of the type disclosed in the above-mentioned patent is adjusted towards low capacity it will reach a condition in which its capacity corresponds to the leakage. In other words, when the grooves open towards the inlet port they are already filled with air of inlet pressure due to the internal leakage and therefore no fresh air can be sucked in into the grooves. Thus, the effective volumetric capacity of the compressor is zero in spite of the fact that it operates at full speed and the compressor can be said to function as a valve preventing air from leaving the system.

Two-stage screw rotor compressors are for several reasons normally designed such that the built-in pressure ratios of the two stages are substantially equal. For instance, if the total pressure ratio is 9:1 each stage has a built-in pressure ratio of about 3:1 and, starting from atmospheric pressure, the intermediate pressure will amount to about 3 kp/cm² at full load. This involves that the second stage need only have a volumetric capacity of about one-third of the volumetric capacity of the first stage in order to be capable of absorbing the gas mass delivered by the first stage at a pressure of 3 kp/cm².

However, if a compressor of the type disclosed in U.S. Pat. No. 3,314,597 is used as the first stage in a two-stage compressor and its valve member is moved towards low capacity position the volumetric capacity of the second stage remains unchanged. The second stage will therefore reduce the intermediate pressure and in certain cases the intermediate pressure may even sink below the inlet pressure of the first stage so that this stage will act as an expander. Thus, gas will al-

ways pass through the first stage irrespective of the position of the valve member and therefore it is impossible to bring the compressor down to zero capacity.

One object of the invention is to provide a multistage screw rotor machine the capacity of which may be varied within wide limits and in which the efficiency within the whole operating range is higher than in hitherto known machines of this type. To obtain this object the machine according to the invention is characterized in that each stage is provided with adjustable valve means for varying the volumetric capacity of the stage. Preferably the movable valve members of the valve means are interconnected to move in unison.

SUMMARY OF THE INVENTION

In a two-stage compressor made according to the invention the volumetric capacities of the first and second stages can be reduced concurrently in such a manner that the intermediate pressure is maintained substantially constant. Therefore, in a certain position of the valve member of the first stage the capacity of this stage is substantially zero as explained above. In a corresponding manner the capacity of the second stage can also be brought down to substantially zero. The compressor will then run at full speed at zero capacity. This is highly desirable for instance in refrigerating plants and compressed air systems in which the gas consumption may vary from zero to a maximum value.

In a preferred embodiment of the machine two stages are arranged in side-by-side relationship, the rotor pairs being drivingly interconnected by transmission means at one end of the machine while actuating means for the valve members are provided at the other end thereof. If in this case the high pressure port of the low pressure stage and the low pressure port of the high pressure stage are located at the same end of the machine as the transmission means and are in communication with each other through a passage the valve members may be interconnected by means of an inextensible flexible member guided by idler pulleys and passing through said passage, one of the valve members being connected to said actuating means.

The invention will now be described more in detail with reference to the accompanying drawings in which:

FIG. 1 is a longitudinal sectional view of a two-stage compressor embodying the invention taken along line I—I in FIG. 2,

FIG. 2 is a section taken along line II—II in FIG. 1 and

FIG. 3 is a section taken along line III—III in FIG. 1.

The compressor illustrated in the drawings is of the same general type as the compressor described in U.S. Pat. application Ser. No. 158,176, filed June 30, 1971, and assigned to the same assignee as the present application, comprising a casing enclosing two working spaces disposed side-by-side and a pair of intermeshing screw rotors in each space. Each rotor pair consists of a male rotor and a female rotor.

In the drawings numeral 10 designates the intermediate or barrel member of the compressor casing which further includes end wall members 12 and 14. In the barrel member 10 there are provided a low pressure working space 16 and a high pressure working space 18 disposed side-by-side and each working space is in known manner composed of two intersecting bores with parallel axes.
The end wall member 12 (to the left in FIG. 1) encloses an inlet chamber 20 and an outlet chamber 22. The inlet chamber 20 communicates with the low pressure working space 16 through a low pressure port 24 while the outlet chamber communicates with the high pressure working space 18 through a high pressure port 26.

A transfer chamber 28 is provided in end wall member 14 and communicates with the low pressure working space 16 through an outlet port 30 and with the high pressure working space 18 through an inlet port 32. The outlet port 30 forms the high pressure port of the firsts low pressure stage of the compressor while the inlet port 32 forms the low pressure port of the second or high pressure stage thereof.

To the outside of the end wall member 14 is secured a transmission housing 34 enclosing a drive gear 36 and two driven gears 38 and 40 the pitch circles being indicated by chain-dotted lines in FIG. 3. The drive gear 36 is carried by a drive shaft 42 journalled in and projecting through the housing 34 and connectable to a drive motor. The driven gear 38 is secured to the shaft 44 of the male rotor of the first stage and the driven gear 40 is secured to the shaft 46 of the male rotor of the second stage of the compressor. For the sake of simplicity the rotors are omitted in the Figures.

The rotors of the low pressure stage are journalled in combined radial and thrust bearings in end wall member 14 and in radial bearings in end wall member 12. The rotors of the high pressure stage are journalled in combined radial and thrust bearings in end wall member 12 and in radial bearings in end wall member 14. Since the bearings are located above and below the plane of FIG. 1 they are not visible in this Fig.

Each stage is provided with an axially movable slide valve member of the type disclosed in U.S. Pat. No. 3,314,597. The function of such a valve member is described in detail in said specification. By moving the valve member from one end position to the other the volumetric capacity of each stage can be varied between a maximum and a minimum value.

In the following discussion, identical elements 52, 54, 56, 58, 60, 62 and 68 in FIG. 1, elements 54 and 60 in FIG. 2 and element 68 in FIG. 3 appear in two places — once in the high pressure stage and once in the low pressure stage. In the drawing, the suffix "A" is added to elements in the low pressure stage, but they are referred to herein without said suffix.

The valve member 48 of the high pressure stage is shown in its position for maximum capacity and located in an axially extending recess 50 in the wall of the working space 18. An insert 52 in the end wall member 12 forms an extension of the recess 50 so that the valve member can be moved out into the outlet chamber 22 to its end position for minimum capacity.

In the bottom of the recess 50 there is a groove 54 which communicates with an oil supply opening 56. To the ends of the valve member 48 are secured plates 58 which sealingly engage the groove 54. The valve member is further provided with two transverse bores 60 in communication with the groove 56. Passages 62 at the bottom of each bore 60 form nozzle openings for injecting oil into the working space for cooling, sealing and lubricating purposes as known per se.

The valve member 64 of the low pressure stage is of the same design as valve member 48 and need not therefore be described.

The two valve members 48 and 64 are interconnected by an inextensible flexible member 66 such as a chain which is guided by two idler pulleys 68 and passes through the transfer chamber 28 in the end wall member 14. During operation the valve members are biased by the fluid pressure towards their maximum capacity positions shown in FIG. 1 and the length of the flexible member 66 is adjusted such that in this condition the flexible member is free from slackness.

To the high pressure end of the valve member 48 of the high pressure stage is secured the piston rod 70 of a servo motor 72 of the piston and cylinder type secured to the outside of the end wall member 12. A typical servo motor 72 is shown in U.S. Pat. No. 3,432,889 (especially FIG. 3), assigned to the same assignee as the present application. By means of this servo motor both valve members 48 and 64 can be moved simultaneously to any desired position independently of the fluid pressure acting upon the valve members the flexible member 66 being stretched by the low pressure valve member 64 so that the valve members move in unison.

A compression spring 74 is inserted between the valve member 48 of the high pressure stage and a bracket 78 provided in the transfer chamber 28 in the end wall member 14. When the compressor plant is stopped this spring moves the valve members 48 and 64 to their minimum capacity positions thereby reducing the torque and power required to re-start the plant.

The invention is not limited to the preferred embodiment shown and described but may be applied to all types of multistage screw rotor machines.

We claim:

1. In a two-stage screw rotor machine for an elastic working fluid in which each stage includes a pair of intermeshing screw rotors, the improvement wherein each stage comprises adjustable valve means for varying the volumetric capacity of the respective stage and means for concurrently operating said adjustable valve means of each stage.

2. A machine as defined in claim 1, in which the adjustable valve means include movable valve members which are interconnected to move in unison.

3. A machine as defined in claim 1, in which the adjustable valve means each include an axially slideable valve member which is biased towards its full capacity position by the fluid pressure at the high pressure end of the respective stage, and comprising actuating means to move the valve members to and keep them in partial capacity positions.

4. A machine as defined in claim 1, in which the two stages are arranged in side-by-side relationship and the adjustable valve means each include a movable valve member, and including transmission means drivingly interconnecting the rotor pairs at one end of the machine, and actuating means for the movable valve members provided at the other end of the machine.

5. A machine as defined in claim 4, in which the two stages are high and low pressure stages, each having respective ports, the high pressure port of the low pressure stage and the low pressure port of the high pressure stage being located at the same end of the machine as the transmission means and being in communication with each other through a passage, the movable valve members being interconnected by means of an inextensible flexible member guided by idler pulleys and pass-
5. A machine as defined in claim 5, in which the flexible member comprises a chain.

6. A machine as defined in claim 1, in which means are provided to move the movable valve members towards the low capacity position when the machine is stopped.

* * * *
CERTIFICATE OF CORRECTION

Patent No. 3,756,753 Dated September 4, 1973

Inventor(s) Walther PERSSON and Lauritz Benedictus SCHIBBYE

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

On initial page of patent after "[75] Inventors:
Walther Persson, Johanneshov;" change
"Lauritz Benedictus" to --Lauritz
Benedictus Schibbye--.

Signed and sealed this 18th day of December 1973.

(SEAL)

Attest:

EDWARD M. FLETCHER, JR. RENÉ D. TEGTMeyer
Attesting Officer Acting Commissioner of Patents