CAPACITY CONTROL VALUE FOR SCREW COMPRESSOR

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References Cited
UNITED STATES PATENTS
3,314,597 4/1967 Schibbye ................. 418/159

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ABSTRACT
A capacity control valve for a liquid injected helical screw gas compressor comprising an axially slidable wall portion of the compressor casing. The control valve body is integrally formed with a piston for a hydraulically actuated valve positioning cylinder, and is arranged in the compressor housing to respond to compressor discharge gas acting thereon to tend to move to a minimum capacity or open position. The capacity control valve is guided in the rotor housing by a cylindrical guide pin having passages for conducting compressor injection liquid to the compressor working chamber. The guide pin is interchangeable to provide for alternate locations for injecting liquid into the working chamber. The capacity control valve is operable to be positively locked in a predetermined axial position by a locking lever controlled from the exterior of the compressor.

13 Claims, 9 Drawing Figures
CAPACITY CONTROL VALUE FOR SCREW COMPRESSOR

BACKGROUND OF THE INVENTION

This invention relates to helical screw gas compressors of the liquid injected type generally characterized by a housing having a working chamber formed by a pair of parallel intersecting bores in which are located respective interfitting male and female screw rotors. The general type of compressor of the present invention is also characterized by the provision of means for injecting liquid into the compressor working chamber to cool the gas being compressed and to seal the spaces formed between the rotors and the walls of the housing defining the working chamber.

It has been suggested in the art of liquid injected helical screw gas compressors to provide capacity control means in the form of a movable wall portion of the compressor housing which is axially slidable with respect to the longitudinal axis of the screw rotors to form a bleed port of varying size. This bleed port has the effect of reducing the swept volume of the working chambers formed by the interfitting male and female rotors and the cooperating wall portions of the rotor housing.

Various arrangements of sliding capacity control valves are known in the prior art. In U.S. Pat. Nos. 3,314,597 and 3,432,089 to L.B. Schibbye it has been suggested, respectively, to provide a rotatable screw and ball nut assembly and a pressure fluid cylinder and piston device for axial positioning of the sliding valve member. In the disclosures of Schibbye the injection liquid is conducted to the working chamber through passages located in the sliding valve member. To this end somewhat complex arrangements of telescoping tubes have been provided for conducting liquid to the valve body regardless of the position of the valve. This arrangement requires precision locating of the fluid conducting tubes and also requires seals between the relative moving parts.

Prior art slide valves for screw compressors are also characterized by the provision of a guiding device for determining the angular position of the valve about its longitudinal axis so that the part of the valve body forming the wall portion of the compressor working chamber will be aligned with the corresponding wall portions of the rotor housing. Prior art guiding devices are permanently locked upon assembly of the compressor and are not well suited to provide for interchanging slide valves which is required for altering the built-in volume ratio of the compressor. A further problem associated with axial sliding capacity control valves for screw compressors pertains to positioning of the valve during compressor startup or in the event of a failure in the valve positioning mechanism. In U.S. Pat No. 3,432,089 it is suggested to position the valve in the maximum bleed port size or, accordingly, the minimum compressor capacity or load position by applying pressure fluid to the valve actuating cylinder during startup. This arrangement is not inherently failsafe as the compressor is dependent on the proper operation of a separate pressure fluid system. Moreover, in screw compressors in which the compressor lubricating and cooling liquid is used to position a capacity control valve through a pressure fluid actuating means it is desirable that the capacity control valve moves to a minimum load or maximum bleed port position in the event of a loss of liquid pressure.

SUMMARY OF THE INVENTION

The present invention provides for a liquid injected helical screw gas compressor including an improved sliding capacity control valve forming a movable wall portion of the compressor rotor housing. The capacity control valve of the compressor of the present invention includes improved guiding means comprising a piston for a pressure fluid control valve actuator, the piston being integrally formed with the capacity control valve body. The improved control valve guiding means also includes a cylindrical guide pin for guiding the valve body and having passages formed in the pin for conducting injection liquid to the compressor working chamber. The guiding pin is also interchangeable to provide for alternate locations for injecting liquid into the compressor working chamber. The capacity control valve and guide pin of the compressor of the present invention also provides for a simplified flow path for conducting compressor injection liquid to desired points of injection in the compressor.

The compressor of the present invention also provides for an improved sliding capacity control valve which is arranged in relationship to the compressor discharge gas flow path such that a resultant gas pressure force acting on the control valve body operates to move the control valve to the minimum capacity or maximum bleed port position to thereby reduce compressor work during startup and in the event of a failure of the valve positioning control system.

The compressor of the present invention further includes a capacity control valve which includes means for positively locking the valve in a predetermined axial position, the valve locking means being operable from the exterior of the compressor.

The present invention provides for a helical screw gas compressor including an improved axially slidable capacity control valve which is easily interchanged, which is simple in construction and economical to manufacture, and which enjoys advantages over prior art capacity control valves as will be appreciated from the disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a longitudinal section view of the helical screw compressor of the present invention taken substantially along the line 1—1 of FIG. 3;
FIG. 2 is a detail section view of the embodiment of the valve guide pin shown in FIG. 1;
FIG. 3 is a transverse section view taken along the line 3—3 of FIG. 1;
FIG. 4 is a transverse section view taken along the line 4—4 of FIG. 5;
FIG. 5 is a detail section view taken along the same line as FIG. 1—1 and showing an alternate embodiment of the control valve guide pin;
FIG. 6 is a section view taken along the line 6—6 of FIG. 1;
FIG. 7 is a view taken along the line 7—7 of FIG. 1;
FIG. 8 is a detail view of the locking lever for the capacity control valve locking means;
FIG. 9 is a detailed section view of the locking means for the capacity control valve taken along the line 1—1.
DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIGS. 1 and 3, a liquid injected screw compressor according to the present invention is illustrated and generally designated by the numeral 10. The compressor 10 is of a type generally well known in which a pair of cooperating rotors, a male rotor 12, and a female rotor 14, are rotatably housed in a rotor housing 16. The male rotor 12 has four helical lobes 22 and intervening grooves 24 and the female rotor 14 has six helical lobes 26 and intervening grooves 28. Various rotor lobe profiles and lobe wrap angles as well as combinations of numbers of lobes on the respective rotors are known and used in the art of screw compressors. However, for high pressure ratio liquid injected screw compressors a male-female lobe combination of four and six, respectively, with respective wrap angles of 300° and 200° have been found desirable. The rotors 12 and 14 are drivably interengaged to operate without synchronizing gears.

The rotor housing 16 is removably bolted to housing means comprising an intermediate housing 30 having a first transverse face 32 which forms the high pressure end wall of the compression or working chamber comprising the bores 18 and 20. The opposite end of the rotor housing 16 is partially closed by a bearing housing 34 removably bolted thereto and including a low pressure or inlet port 36 which opens through the end wall 37 into the working chamber. The inlet port 36 is primarily axial in accordance with known design practice for helical screw compressors.

The male rotor 12 is suitably supported in radial sleeve type journal bearings 38 and 40 located respectively in the bearing housing 34 and intermediate housing 30. The male rotor 12 also includes a rolling element thrust bearing 42 and a fluid actuated thrust piston 44 mounted on the rotor and located in a housing 46 fastened to a second transverse face 48 of the intermediate housing 30. The opposite end of the male rotor 12 includes an extension shaft portion 50 for drivingly connecting the compressor 10 to a prime mover, not shown. The female rotor 14 is similarly supported in suitable bearings, not shown, in a known manner.

The intermediate housing 30 includes an opening 52 in the transverse face 32 which is in communication with an area 54 and which comprises a discharge port for conducting high pressure gas from the compressor working chamber. The discharge gas from the compressor working chamber flows through the area 54 into the interior space 56 through suitable openings, not shown, in the transverse face 48. The interior space 56 is formed by a high pressure casing 58 which is bolted to the intermediate housing 30 and includes a discharge opening 60.

The compressor 10 is further characterized by an integral portion 62 of the rotor housing 16 having a substantially cylindrical bore 64 spaced from and parallel to the bores 18 and 20 for supporting an axially slidable member 66 comprising a capacity control valve. Viewing FIG. 1, the capacity control valve member 66 forms a movable wall portion of the working chamber formed by the bores 18 and 20 which is axially slidable in the bore 64 from the position shown to a position to the right to open a bleed port formed between the edge 68 of the rotor housing 16 and a mating edge 70 of the valve member. The valve member 66 also includes an edge 72 forming a portion of the discharge port 52 of the compressor working chamber. The capacity control valve member 66 operates in a known way to reduce the volume of gas trapped into the grooves 24 and 28 formed by the rotors 12 and 14 to thereby reduce the compressed gas throughput of the compressor 10. Gas is vented from the compressor working chamber through the bleed port into the interior space 74 formed between a low pressure casing 76 and the rotor housing 16. The low pressure casing 76 is sealingly fastened to the intermediate housing 30 and includes an inlet opening, not shown, in communication with the interior space 74. Gas vented through the bleed port formed by the control valve member 66 is recirculated back to the inlet port 36.

The capacity control valve member 66 is further characterized by an integrally formed cylindrical piston 78 which is axially slidable in a bore 80 formed in the housing 46. The bore 80 together with an end cover member 82 comprises a chamber 81 for receiving pressure liquid through a suitable conduit 84 to act on the face 86 of the piston to axially move the valve member 66 toward the closed position. The integral piston 78 is joined to the valve member 66 by longitudinally extending spaced apart web portions 88, as shown in FIGS. 1 and 6. As shown in FIG. 1, the piston 78 includes a transverse pressure surface 90 exposed to the area 54 through which discharge gas flows from the compressor working chamber. The valve member 66 is so proportioned that the axially projected area of the surface 90 with regard to the longitudinal axis of the compressor 10 is at least ten percent greater than the opposed axially projected area of a surface 92 on the valve member 66. In this way there results a sufficient force acting on the valve member 66 due to the pressure of discharge gas flowing through the area 54 which biases the valve member to open the aforementioned bleed port. Therefore, the compressor capacity control valve 66 always moves to the minimum compressor capacity position in the absence of adequate fluid pressure in the actuator chamber 81, a condition usually present during compressor startup and in the event of a malfunction in the pressure liquid system which would cause a reduction in liquid pressure. The compressor 10 utilizes pressure liquid from a combined lubrication and working chamber injection system and, accordingly, a loss of pressure due to pump failure or line breakage will allow the control valve member to move to a position which places a minimum load on the compressor.

The valve member 66 is also biased toward the bleed port open position by a coil spring 94 extending into a recess 96 in the valve member and supported by a cylindrical tube 98. The tube 98 is suitably mounted at one end in a boss 100 forming part of the bearing housing 34. Although the valve member 66 is substantially supported by the bearing formed by the bore 64 of the housing portion, the piston 78 also operates to guide and support the valve member particularly when the valve member is moved to open the bleed port.

The valve member 66 is also provided for alignment of the crest edge 102 formed by the intersecting bores 18 and 20 with a corresponding crest edge 104 in the rotor housing. The valve member 66 is guided by means comprising a cylindrical pin 106 re-
movably interfitted in cooperating grooves 108 and 110 formed respectively in the valve member 66 and the housing portion 62. The guide pin 106 is retained in the bore formed by the grooves 108 and 110 by means of a removable retaining plate 112, FIG. 6. The guide pin 106, in addition to forming means for guiding the valve member 66, is also interchangeable with alternate embodiments to provide for alternate locations for injecting liquid into the working chamber formed by the bores 18 and 20.

It is known in the art of liquid injected helical screw compressor that it is generally desirable to inject liquid into the compressor working chamber in an area which is subject to high gas pressure. This is particularly true when very cold gas is being compressed such as in refrigeration systems. The location of this area in the compressor working chamber is also necessarily occupied by the slideable capacity control valve member 66. It is also known that the optimum location for liquid injection into the working chamber is dependent on the compressor built in volume ratio which can be changed in various ways but which is desirably altered by changing the shape and location of the edge 72 forming a portion of the discharge port. Accordingly, different built-in volume ratios for the compressor 10 may be obtained by interchanging the valve member 66.

Referring to FIG. 1 through 5, the compressor 10 is provided with passage means for injecting liquid into the working chamber comprising a pair of circumferential grooves 112 formed in the bore 64 as shown in FIG. 3. Referring to FIGS. 4 and 5 a second pair of grooves 114 spaced axially from the grooves 112 is also formed circumferentially in the bore 64 and opens into the compressor working chamber. Referring to FIGS. 1, 2, and 3, compressor injection liquid is conducted to the grooves 112 from a suitable source, not shown, by way of a manifold 116 formed in the intermediate housing 30, and through a conduit 118 which is in communication with passages 120 and 122 in the housing portion 62. The passage 122 opens into a space formed by a recessed portion 124 of the guide pin 106. The guide pin 106 includes interconnecting passages 126, 128 and 130 formed thereon, FIG. 2, for conducting liquid to the space formed by a second recessed portion 132 of the pin. The passage 128 is closed by a plug 134. The recessed portion 132 is aligned with the pair of grooves 112, and a portion 136 of the pin, closely fitted in the bore formed by the grooves 108 and 110, blocks the alternate set of grooves 114. Suitable sealing ring grooves 138 are also provided in the pin to prevent leakage of liquid from the ends thereof.

As shown in FIGS. 4 and 5 an alternate embodiment of the guide pin is shown positioned in the bore formed by the grooves 108 and 110 and is designated by the numeral 140. The guide pin 140 includes a portion 142 closely fitted in the bore formed by the grooves 108 and 110 and blocking the pair of grooves 112. The guide pin 140 also includes a recessed portion 144 forming a passage for conducting injection liquid from the passage 122 to the pair of grooves 114 in communication with the compressor working chamber. Thus it may be appreciated that alternate locations for injecting liquid into the compressor working chamber may be easily selected by interchanging the pins 106 and 140 both of which define, in part, passage means for injecting liquid into the working chamber. Alternatively, an embodiment of a guide pin similar to the pins 106 and 140 could be provided which would communicate injection liquid to both pairs of grooves 112 and 114 simultaneously. Moreover, the location of the pairs of grooves 112 and 114 in the bore 64 provide for injection liquid to be used to lubricate the bearing surface formed by the bore 64 for the valve member. Injection liquid supplied to the grooves 112 or 114 at a suitably high enough pressure provides a lubricant film on said bearing surface for supporting the valve member 66 thereby operating as a hydraulic bearing to facilitate easy movement of the valve member. In the embodiment of FIGS. 4 and 5 a sliding valve member 146 is shown which is similar to the valve member 66 except for an edge 148 which in a well known manner is located to provide a volume ratio different from that provided by the edge 72.

The capacity control valve of the compressor 10 also includes a member 150, FIG. 1, removably fastened to the face 86 of the piston 78. The member 150 includes an internally threaded portion 152 which is threadedly engaged with an elongated screw 154. The screw 154 includes a shaft portion 156 supported in a suitable bearing 158 located in the housing cover 82. The thread geometry is suitably chosen to provide for rotation of the screw member 154 in response to an axial force acting on the valve member 66 from the spring 94, the pressure force acting on the pressure surface 96 or from pressure fluid in the fluid actuator chamber 81 acting on piston face 86.

In certain applications of screw compressors of the type disclosed herein it is desirable to positively lock the slide valve members 66 or 146 in a predetermined position for extended operating periods. Referring to FIGS. 1, 7, 8 and 9 the elongated screw 154 also includes an integral shaft portion 160 which extends through a housing 162 which includes a face type seal assembly 164. The shaft portion 160 includes means for nonrotatably clamping the screw 154 comprising a circuit disk-like element 166 mounted on and nonrotatably secured to the shaft portion 160 by an interfitting key 168. The disk 166 is also secured on the shaft portion 160 by a nut 170 threaded over a complementary thread part of the shaft. The means for nonrotatably clamping the screw 154 also includes a member 172 characterized by a circular opening forming a surface 174 surrounding and closely adjacent to the circumference of the disk 166. The member 172 includes two jawlike portions 176 formed by the gap 178. The member 172 is suitably secured to the housing 162 by a fastener 180. The member 172 is operable to be actuated to nonrotatably clamp the disk 166 and the screw 154 by a manually actuated lever 182 which includes a shaft 184 extending through suitable holes in the jaws 176. The shaft includes a plurality of conical spring washers 186 fitted over one end and retained thereon by a nut 188. Suitable spring guide washers 190 are fitted on each side of the conical washers 186. The opposite end of the shaft 184 extends into a hollow spindle 192 of a lever handle 194, FIG. 8, and is pinned thereto at 196.

The lever handle 194 is rotatably supported in a boss 198 on the housing 162. The distal end of the spindle portion 192 includes a wedge-shaped cam surface 200 which fits into a complementary V-shaped notch 202 on the side of the member 172. In response to manually turning the lever handle 194 the apex of the wedge-shaped cam surface 200 is forced to ride up the sides of the notch 202 and forces the jaw portions 176 to
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gather to close the gap 178 and nonrotatably clamp the
disk 166 and, accordingly, the screw 154. The screw
154 being nonrotatably clamped thereby prevents axial
movement of the valve member 66. The member 172
is so proportioned and fabricated from a suitable elastic
material such as steel to have a stiffness in resistance to
clamping the disk 166 which is less than the stiffness of
the spring washers 186. The shaft portion 160 extend-
ing from the housing 162 may also be connected to a
suitable indicating device for indicating the axial posi-
tion of the valve member 66.
As may be appreciated from the foregoing, the pres-
et invention provides an axially slideable capacity con-

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7. The invention set forth in claim 3 wherein:
said pressure surface is formed on said piston.

8. The invention set forth in claim 7 wherein:
said piston is formed integral with said valve member.

9. In a screw compressor:
a rotor housing having two parallel intersecting bores
forming a working chamber;
an inlet port and a discharge port opening into said
working chamber;
a high pressure end wall at one end of said working
chamber and a low pressure end wall at the oppo-
site end of said working chamber;
interengaged male and female screw rotors located in
said bores and operable to entrap and compress gas
admitted to said working chamber through said
inlet port;
said rotor housing including a portion forming a bore
spaced from said intersecting bores forming said
working chamber;
a capacity control valve including a valve member
located in said bore and comprising a wall portion of
said working chamber, said valve member being
axially movable in said bore to open a bleed port
formed by said valve member and said rotor hous-
ing;
passage means in said rotor housing for conducting
injection liquid to said working chamber; and,
guide means comprising a member removably inter-
fitted between said rotor housing and said valve
member for guiding said valve member to provide for
substantial alignment of a crest edge on said
valve member with a corresponding crest edge
formed by said intersecting bores in said rotor
housing, said guide means defining, in part, said
passage means.

10. In a screw compressor:
a rotor housing having two parallel intersecting bores
forming a working chamber;
an inlet port and a discharge port opening into said
working chamber;
a high pressure end wall at one end of said working
chamber and a low pressure end wall at the oppo-
site end of said working chamber;
interengaged male and female screw rotors located in
said intersecting bores and operable to entrap and
compress gas admitted to said working chamber
through said inlet port;
said rotor housing including a portion forming a bore
spaced from said intersecting bores forming said
working chamber;
a capacity control valve including a valve member
located in said bore and comprising a wall portion of
said working chamber, said valve member being
axially movable in said bore to move said valve mem-
ber to close said bleed port.

11. The invention set forth in claim 1 wherein:
said housing means includes a transverse face form-
ing said high pressure end wall of said working
chamber and said discharge port opens through
said high pressure end wall into said interior area
of said housing means.

3. The invention set forth in claim 1 wherein:
said capacity control valve includes valve actuating
means comprising a piston disposed in a pressure
fluid chamber and connected to said valve mem-
ber, said piston being responsive to pressure fluid
admitted to said chamber to move said valve mem-
ber to close said bleed port.

4. The invention set forth in claim 3 wherein:
said compressor includes means for locking said
valve member in a predetermined axial position.

5. The invention set forth in claim 4 wherein:
said means for locking said valve member includes
an elongated screw rotatably mounted on said com-
pressor and engaged with means connected to said
valve member forming a nut threadedly engaged
with said screw, and said screw is rotatable in re-
sponse to a force applied to said valve member
which is sufficient to axially move said valve mem-
ber and said nut.

6. The invention set forth in claim 5 wherein:
said means for locking said valve member includes
means for nonrotatably clamping said elongated
screw comprising a member mounted on said screw
nonrotatably with respect to said screw and en-
geageable by a clamping member mounted on said
compressor for nonrotatably clamping said mem-
ber and said screw to lock said valve member in a
predetermined axial position.

What is claimed is:
1. In a screw compressor:
a rotor housing having two parallel intersecting bores
forming a working chamber;
an inlet port and a discharge port opening into said
working chamber;
a high pressure end wall at one end of said working
chamber and a low pressure end wall at the oppo-
site end of said working chamber;
interengaged male and female screw rotors located in
said bores and operable to entrap and compress gas
admitted to said working chamber through said
inlet port;
a capacity control valve including a valve member
comprising a wall portion of said working chamber
axially movable to open a bleed port formed by
said valve member and said rotor housing for vent-
ing gas from said working chamber, said valve
member including a pressure surface thereon; and,
housing means including an interior area in commu-
nication with said discharge port and forming a
flow path for pressure gas discharged from said
working chamber, and said pressure surface is in
communication with said interior area and is re-
sponsive to pressure gas discharged from said dis-
charge port acting on said pressure surface to bias
said valve member to open said bleed port.

2. The invention set forth in claim 1 wherein:
said housing means includes a transverse face form-
ing said high pressure end wall of said working
chamber and said discharge port opens through
said high pressure end wall into said interior area
of said housing means.

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axially movable in said bore to open a bleed port formed by said valve member and said rotor housing;
passage means in said rotor housing for conducting injection liquid to said working chamber; and,
guide means disposed in said rotor housing for guiding said valve member to provide for substantial alignment of a crest edge on said valve member with a corresponding crest edge formed by said intersecting bores in said rotor housing, said guide means defining in part said passage means, and said guide means comprising a cylindrical guide pin removably interfitted in cooperating grooves formed in said valve member and said rotor housing.

11. The invention set forth in claim 10 wherein:
said passage means for injecting liquid into said working chamber include grooves formed in said bore and in communication with said working chamber and said passage means defined by said guide pin.

12. The invention set forth in claim 11 wherein:
said grooves formed in said bore include a first pair of circumferential grooves and a second pair of circumferential grooves spaced axially in said bore from said first pair of circumferential grooves and said guide pin is characterized in that one of said pairs of circumferential grooves is blocked from receiving injection liquid through said passage means by said guide pin while the other of said pairs of circumferential grooves is in communication with said passage means defined by said guide pin.

13. The invention set forth in claim 11 wherein:
said bore and said pairs of circumferential grooves formed in said bore together with injection liquid supplied to said circumferential grooves form a hydrostatic bearing for supporting said valve member.

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