United States Patent [19]

Edstrom

[11] **3,738,780**

[45] **June 12, 1973**

[54] **CAPACITY CONTROL VALUE FOR SCREW COMPRESSOR**

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[73] Assignee: **Gardner-Denver Company**, Quincy, Ill.

[22] Filed: **Nov. 5, 1971**

[21] Appl. No.: **196,056**

[52] **U.S. Cl.** **417/281,** 417/310, 418/97, 418/159, 418/201

[51] **Int. Cl.**..... **F04b 49/02,** F04b 49/08, F01c 1/16

[58] **Field of Search**.......................... 417/310, 281; 418/159, 201, 97; 60/39.45

[56] **References Cited**

UNITED STATES PATENTS

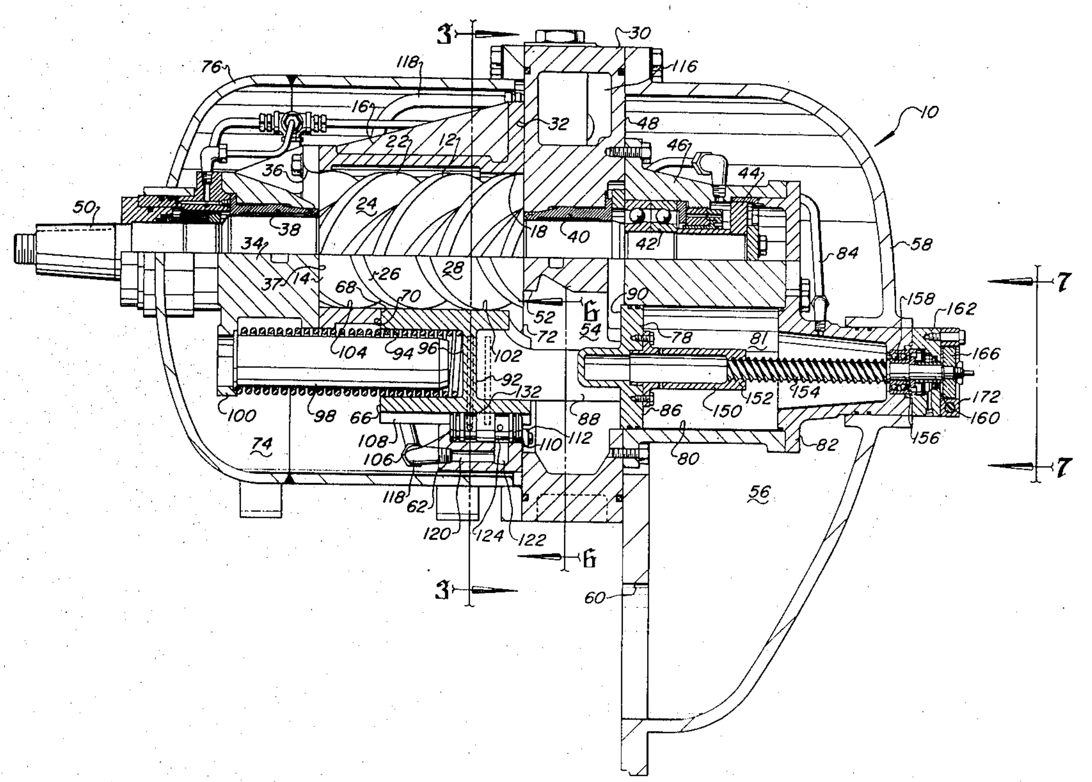
3,314,597	4/1967	Schibbye	418/159
3,432,089	3/1969	Schibbye	418/201 X

Primary Examiner—Carlton R. Croyle
Assistant Examiner—R. J. Sher
Attorney—Michael E. Martin

[57] **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



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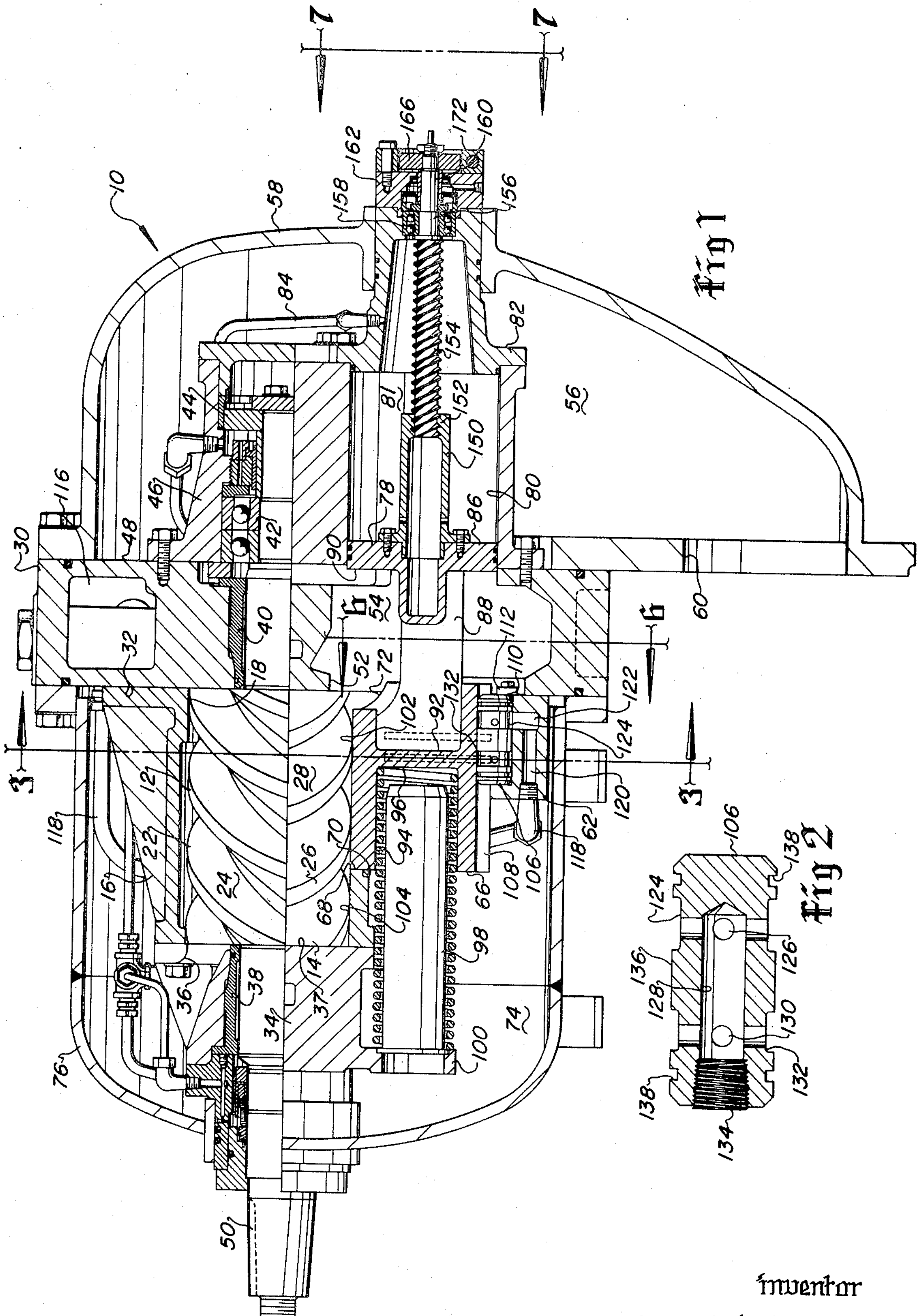

Fig 1

Fig 2

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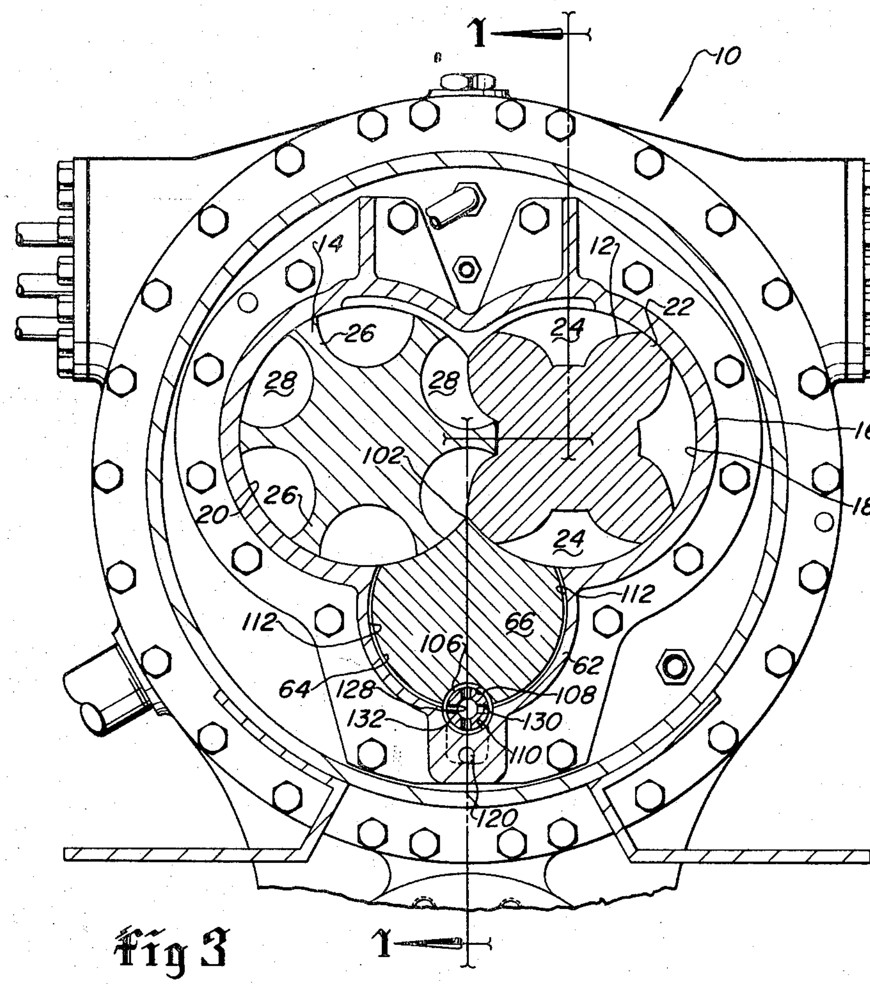
agent


1
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1

fig 3

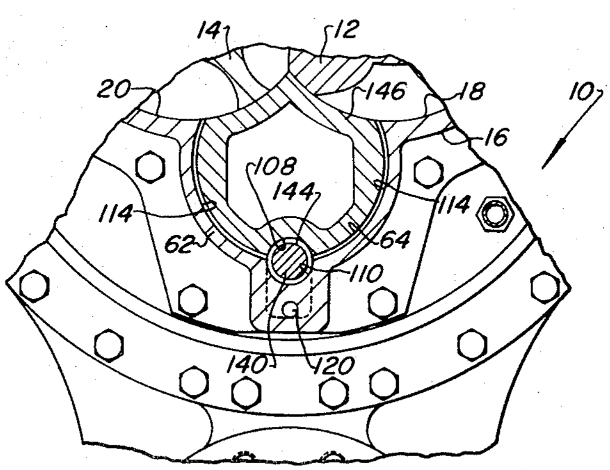
14
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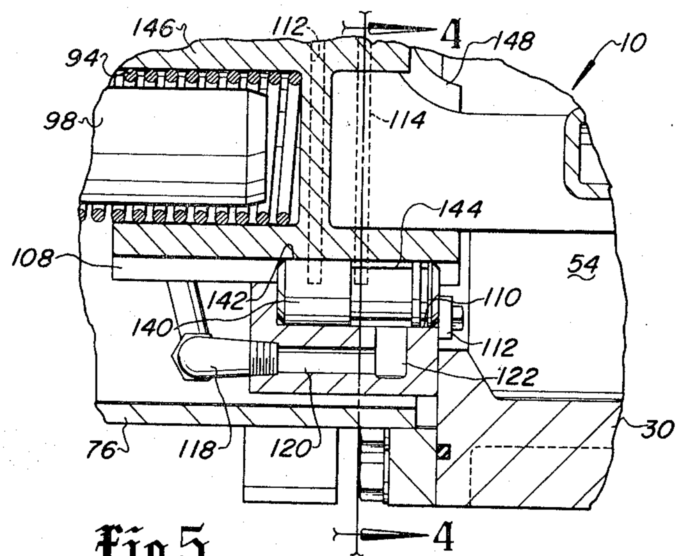
fig 4


146
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108
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142
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140
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122
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76
118
120
4

Fig 5

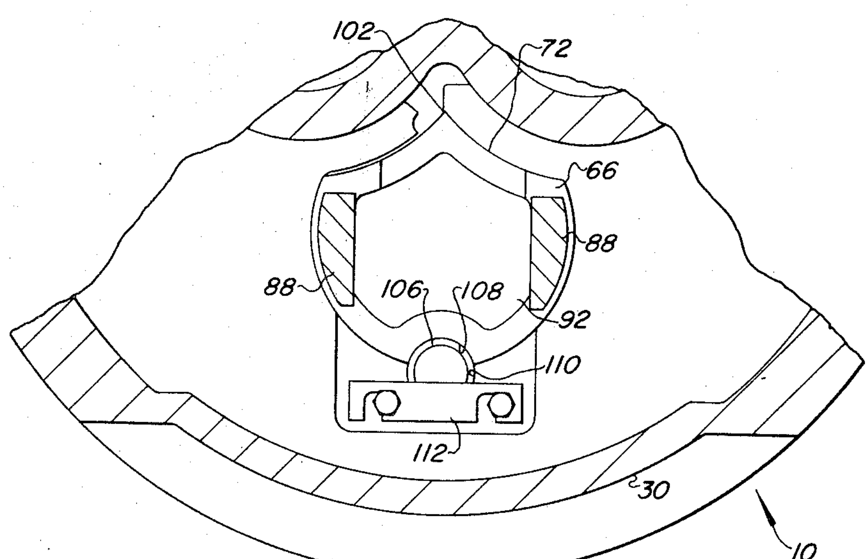
102
72
66
88
88
106
108
92
110
112
30
10

Fig 6

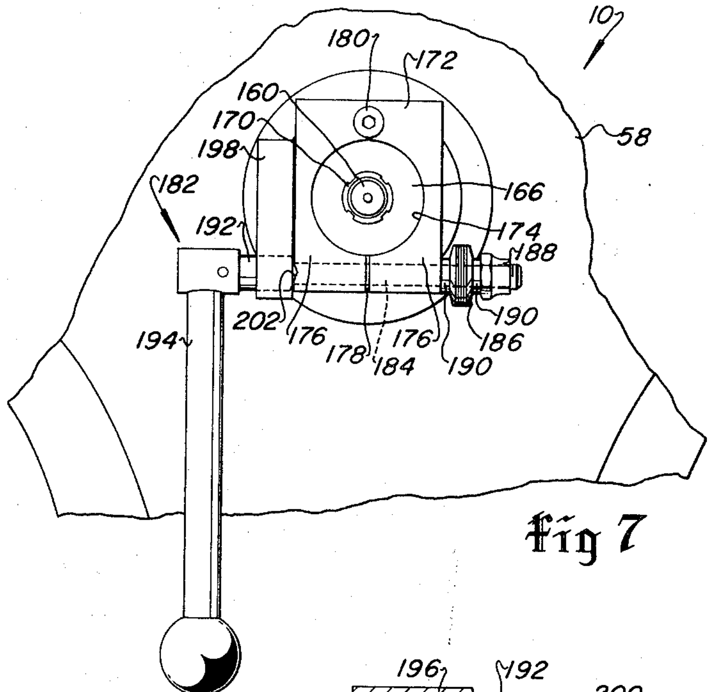

Fig 7

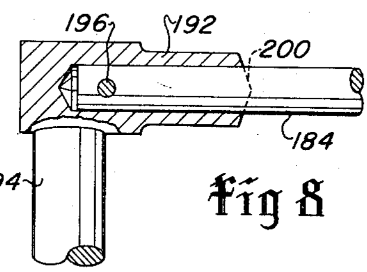

Fig 8

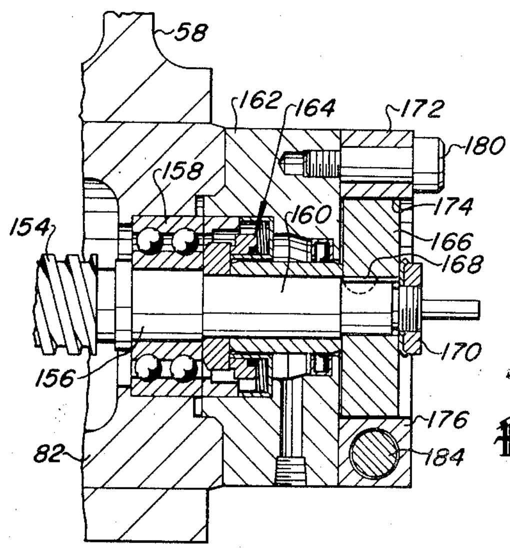

Fig 9

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 minumum 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; and,

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** having parallel intersecting bores **18** and **20** surrounding in close fitting relationship the respective rotors **12** and **14.** 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 guided to provide for alignment of the crest edge **102** formed by theintersecting 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** removably 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 slidable 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 FIGS. **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 hydrostatic 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 **90,** 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 disklike 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 threaded 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** together 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** extending from the housing **162** may also be connected to a suitable indicating device for indicating the axial position of the valve member **66**.

As may be appreciated from the foregoing, the present invention provides an axially slidable capacity control valve for screw compressors which is superior in performance and ease of manufacture and which includes an improved arrangement for liquid injection into the compressor working chamber. Moreover, the improved capacity control valve of the present invention also includes a novel locking device for locking the valve in a predetermined 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 opposite 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 venting gas from said working chamber, said valve member including a pressure surface thereon; and,
housing means including an interior area in communication 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 responsive to pressure gas discharged from said discharge 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 forming 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 member, said piston being responsive to pressure fluid admitted to said chamber to move said valve member 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 compressor and engaged with means connected to said valve member forming a nut threadedly engaged with said screw, and said screw is rotatable in response to a force applied to said valve member which is sufficient to axially move said valve member 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 engageable by a clamping member mounted on said compressor for nonrotatably clamping said member and said screw to lock said valve member in a predetermined axial position.

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 opposite 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 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 comprising a member removably interfitted 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 opposite 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 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.

* * * * *