# United States Patent [19]

**Zimmern**

[11] **3,752,606**

[45] **Aug. 14, 1973**


[54] **LIQUID INJECTION SYSTEM FOR GLOBOID-WORM COMPRESSOR**


[76] Inventor: **Bernard Zimmern,** 27, rue Delabordere, Neuilly-sur-Seine, France



[22] Filed: **Dec. 14, 1971**

[21] Appl. No.: **207,804**

[52] **U.S. Cl.** ..... **418/97,** 418/195
[51] **Int. Cl.** ..... **F01c 1/08,** F04c 17/04, F04c 27/02
[58] **Field of Search** ..... 418/97–99, 195, 196



[56] **References Cited**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 3,181,296 | 5/1965 | Zimmern | 418/195 |
| 2,603,412 | 7/1952 | Chilton | 418/195 |
| 3,133,695 | 5/1964 | Zimmern | 418/98 |



*Primary Examiner*—Carlton R. Croyle
*Assistant Examiner*—John J. Vrablik
*Attorney*—Irvin S. Thompson et al.



[57] **ABSTRACT**

The invention relates to a system for injecting a liquid to ensure cooling, lubrication and leak-tightness in a globoid-worm compressor. In known systems the liquid is injected substantially parallel to the axis of the worm on the low pressure side of the compressor and in the vicinity of the pinions which cooperate with the worm. According to the invention, the liquid injection system comprises ducts formed in the casing of the compressor and opening in the vicinity of the pinions in the zone where the width of the crests of the worm threads is a minimum. Preferably the duct is oriented transversely to the plane of the pinions.


**8 Claims, 10 Drawing Figures**

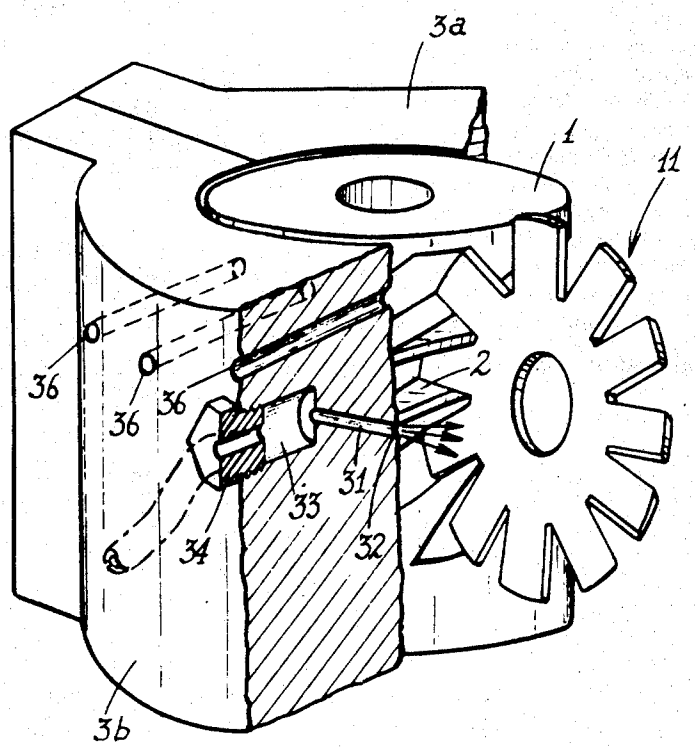


Fig.1

PRIOR ART

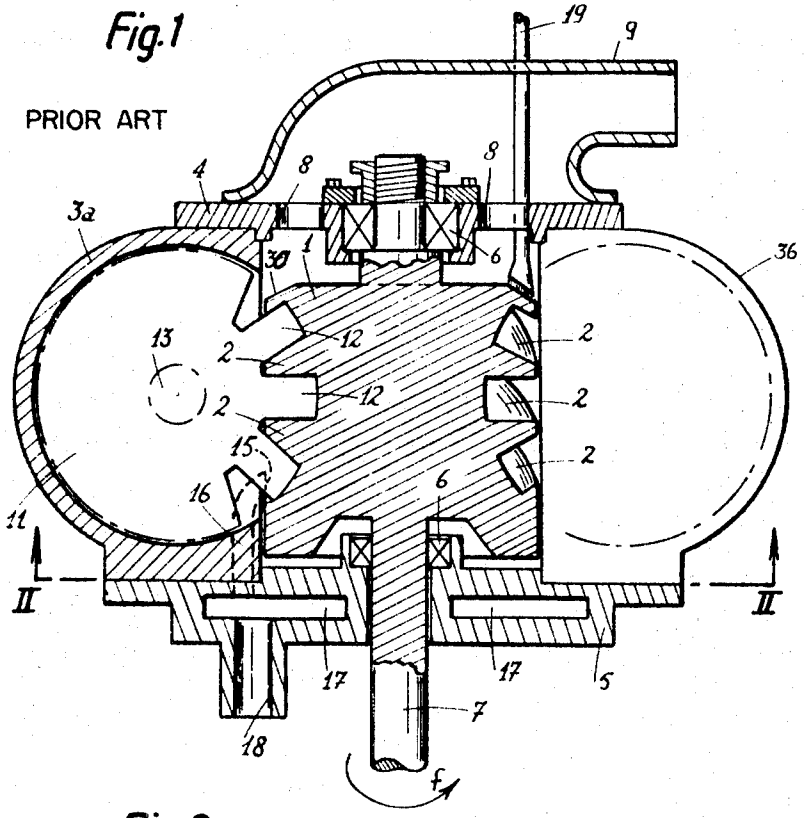
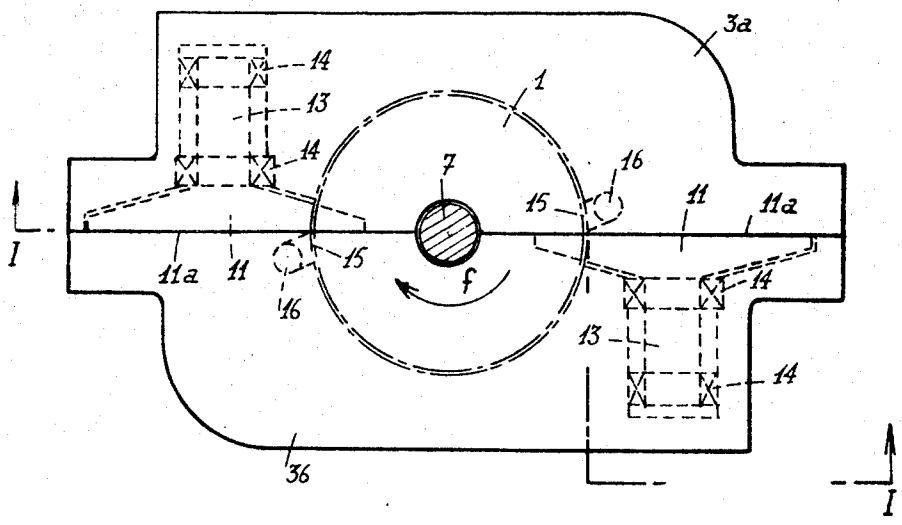



Fig.2

PRIOR ART



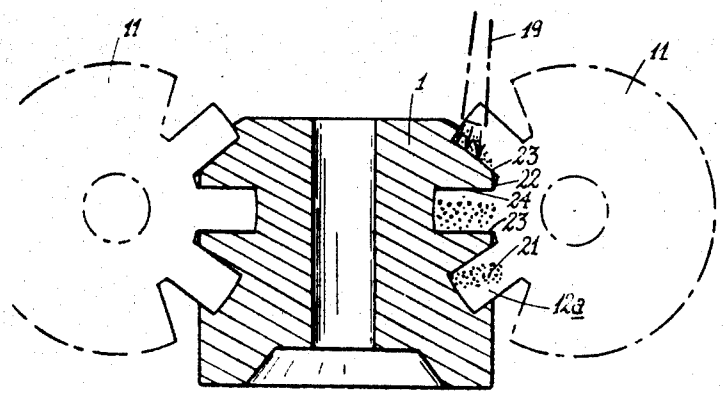



Fig.3

PRIOR ART

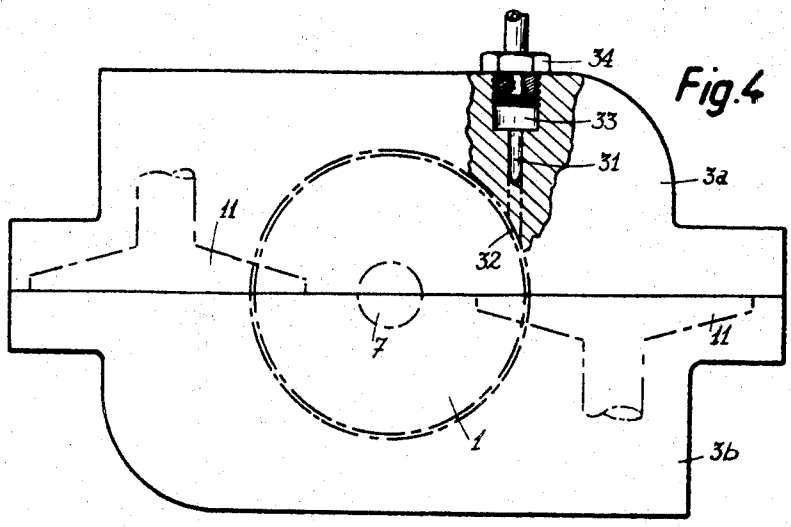



Fig.4

Fig.5

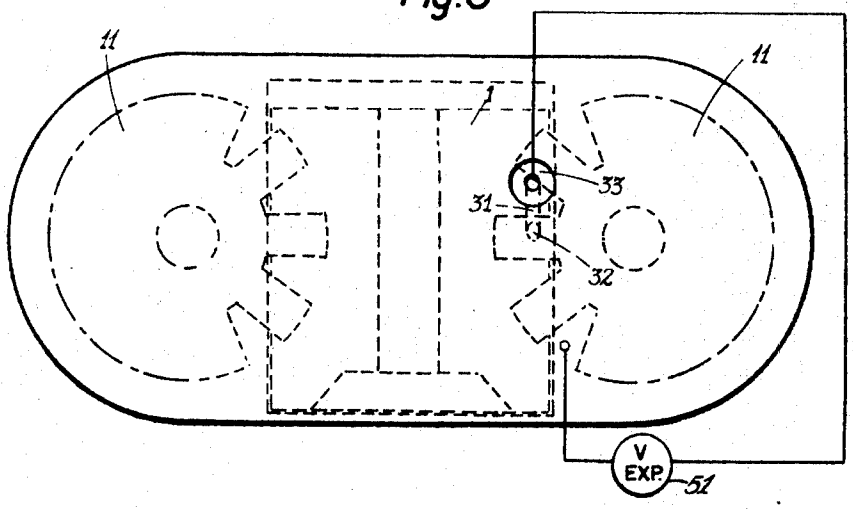


Fig.6

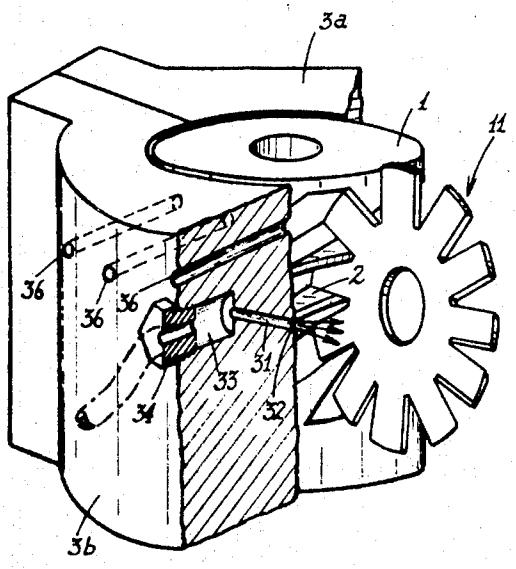



Fig.7

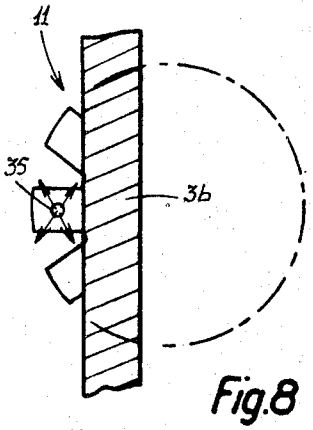



Fig.8

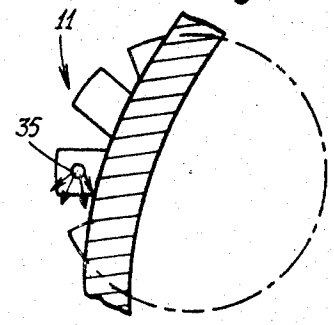



Fig.10

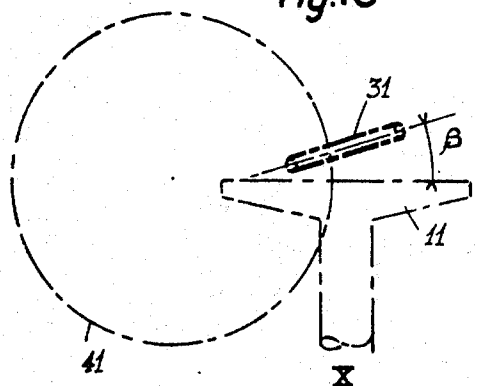
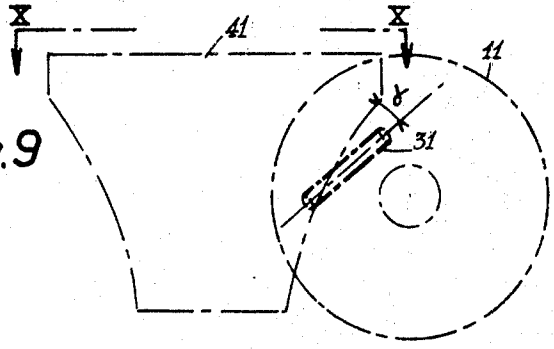



Fig.9



# LIQUID INJECTION SYSTEM FOR GLOBOID-WORM COMPRESSOR

This invention relates to a liquid injection system which is primarily intended to ensure leak-tightness, cooling and lubrication in a globoid-worm compressor.

It is known that a compressor of this type comprises a globoid worm having a plurality of threads designed to engage with at least one transverse pinion and to co-operate with a casing which is applied against at least part of the external surface of the worm. There are also provided an inlet port for the admission of a fluid to be compressed and at least one outlet port through which said fluid is discharged and which is located in the immediate vicinity of the pinion.

As has been disclosed in particular in French Pat. Nos. 1 268 586 and 1 331 998, it is a known practice in a compressor of the type referred-to above to ensure leak-tightness between worm, pinion and casing as well as to effect cooling and lubrication by injecting a liquid by means of injectors having axes which are substantially parallel to the axis of the worm, said injectors being located in the immediate vicinity of the pinion on that side of said pinion which is subjected to the pressure of the compressed fluid. Preferably, the rate of injection of the liquid, or injection velocity, is substantially equal to the peripheral velocity of the pinion.

In a liquid injection system of this type, it has become apparent from past experience that leaks develop and increase at the same time as the delivery pressure of the compressor. The actual displacement of compressed fluid is in that case lower than the theoretical displacement, this latter being equal to the volume of the compression chambers between adjacent threads which is swept by the teeth of the pinion. It is thus found that, if the delivery pressure is lower than a value of the order of two to three bars, the actual displacement is substantially equal to the theoretical displacement. However, if the delivery pressure exceeds the aforesaid value, the actual displacement decreases by one to three percent of the total displacement for each additional bar.

The primary object of the invention is to overcome this disadvantage and to permit the possibility, irrespective of the value of the delivery pressure, of obtaining a substantially constant actual displacement which is substantially equal to the theoretical displacement.

In accordance with the invention, the system for injecting liquid especially in order to ensure leak-tightness within a globoid-worm compressor of the type referred-to above is distinguished by the fact that the casing has at least one liquid-injection duct which opens in the vicinity of the pinion on that side of said pinion which is subjected to the pressure of the fluid to be compressed and in the vicinity of the zone corresponding to the minimum width of the crests of the worm threads.

In a preferred embodiment of the invention, the liquid-injection duct opens in the region located between that zone of the worm which corresponds to the minimum width of the thread crests and that end of said worm which is adjacent to the fluid discharge port. Said duct is directed transversely with respect to the plane of the pinion and towards that portion of the worm which is adjacent to the discharge port.

It has been proved in practice that the actual displacement obtained under the conditions just mentioned is substantially independent of the delivery pressure and very close in value to the theoretical displacement.



Further properties and advantages of the invention will become apparent from the detailed description which follows below.

A liquid injection system of known type and a number of embodiments of the injection system in accordance with the invention are illustrated in the accompanying drawings which are given by way of example without any limitation being implied, and in which :

FIG. 1 is a view in elevation and partial axial cross-section along line I—I of FIG. 2 and showing a compressor which comprises an injection system of known type ;

FIG. 2 is a view taken along line II—II of FIG. 1 ;

FIG. 3 is a diagrammatic axial sectional view of the compressor of FIG. 1 and shows the distribution of the liquid during operation ;

FIG. 4 is an end view which is partially broken away and shows a compressor which comprises an injection system in accordance with the invention ;

FIG. 5 is a view in elevation which corresponds to FIG. 4 ;

FIG. 6 is a view in perspective of the compressor which is illustrated in FIGS. 4 and 5 and in which the casing is partially broken away ;

FIG. 7 is a partial diagrammatic view of the compressor which is illustrated in FIGS. 4 to 6 and showing the arrival of the liquid on the pinion ;

FIG. 8 is a view which is similar to FIG. 7 and relates to the case of a globoid worm having a concave external profile;

FIG. 9 is a partial diagrammatic view in elevation showing a globoid-worm compressor having a concave external profile and provided with an injection system in accordance with the invention ;

FIG. 10 is a diagrammatic view taken along line X—X of FIG. 9.

The globoid-worm compressor which is illustrated in FIGS. 1 to 3 comprises a system of known type for injecting liquid in order to ensure leak-tightness, lubrication and cooling.

Said compressor comprises a globoid worm 1 having multiple threads 2, the crests of which are inscribed within a cylindrical surface. A casing made up of two elements 3*a* and 3*b* is applied against the greater part of the crests of the threads 2. Two end-caps 4, 5 which are centered in said casing are adapted to carry bearings 6 in which the shaft 7 of the worm 1 is rotatably mounted.

Two pinions 11 are mounted within recesses of the casing elements 3*a*, 3*b* and the teeth 12 of said pinions are disposed in meshing engagement with the threads 2 of the worm. The pinions 11 are disposed symmetrically with respect to the worm shaft 7 and their planes are substantially parallel to said shaft. The shafts 13 of said pinions 11 are carried by bearings 14.

The end-cap 4 which is located on the low-pressure side of the worm 1 is provided with inlet ports 8 for suction of the fluid to be compressed which is supplied through a duct 9. On the high-pressure side of the worm, the casing is provided with ports 15 located in the immediate vicinity of the pinions 11 for the discharge of compressed fluid. Said ports 15 communicate via passage-ways 16 with a chamber 17 which is formed

in the end-cap **5** and into which opens a high-pressure duct **18.**

The adjacent threads of the worm **1** define compression chambers with the casing elements **3***a*, **3***b*, the fluid which is to be compressed and which is supplied through the suction ports **8** being admitted into said chambers. When the worm **1** rotates in the direction of the arrows *f*, said chambers are successively sealed-off on the suction side by the teeth **12** of the pinions **11** which progressively compress the fluid contained in said chambers until the high-pressure end of these latter comes opposite to a discharge port **15.** One face **11***a* of each pinion **11** is therefore subjected to the pressure of the fluid.

In accordance with a known technique which is described in particular in French Pat. Nos. 1 268 586 and 1 331 586, the compressor which is illustrated in FIGS. **1** to **3** is provided with a liquid-injection system which is primarily intended to ensure leak-tightness between the worm, the casing and the pinion as well as to perform the functions of lubrication of the rotating parts and cooling of the compressed fluid.

To this end, the compressor is fitted with injectors such as **19** which are placed in the vicinity of each pinion **11** on the side which is exposed to the pressure of the fluid. Said injectors **19** are located on the low-pressure side of the worm **1** and oriented in a direction which is substantially parallel to the worm shaft **7.** In a preferred embodiment which is described in the patents cited above, the velocity of injection of the liquid is substantially equal to the peripheral velocity of the pinions **11.**

The intended function of said injection system is to form on that face of the pinion teeth which is subjected to the pressure of the fluid a film of liquid which, by reason of its inertia and its viscosity, prevents the compressed fluid from passing through the clearances formed between the pinions on the one hand and the worm and casing on the other hand.

In point of fact, experience has shown that the liquid which is injected in accordance with this known technique performs its intended function only to a partial extent. It is found in particular that leaks develop and increase to a substantial extent as soon as the delivery pressure exceeds a given value. Thus, in the case of a compressor which is designed for a given compression ratio, it has been found that if the delivery pressure within the pipe **7** does not exceed a value of the order of two to three bars, the actual displacement of compressed fluid is practically equal to the theoretical displacement, that is to say to the compression-chamber volume which is swept by the teeth of the pinions **11.** On the other hand, as soon as the delivery pressure exceeds three to four bars, the actual displacement decreases by a value of the order of 1 to 3 percent of the total displacement for each additional bar.

This phenomenon is all the more surprising since the compressor has a compression ratio which is well defined by its structural design and since the fluid is in fact compressed as a consequence to the maximum pressure which is determined by said compression ratio irrespective of the delivery pressure. It may therefore be concluded that the sealing liquid permits residual leakage, especially during the fluid delivery stage.

Stroboscopic studies have revealed that, if a film of sealing liquid is in fact present over the entire surface of the teeth **12** in the low-pressure region of the compressor, the liquid tends to collect within the central zone **21** of the teeth towards the end of the compression stage (tooth **12***a* in FIG. **3**).

It has been found in practice that, if the rate of injection of liquid is varied, liquid may be present within the high-pressure region, on either of the two lateral edges of the teeth but not on both edges at the same time. The maximum displacement of fluid is obtained when the liquid collects in the central portion of the teeth as shown in FIG. **3.**

Under these conditions, leaks occur between the pinion teeth and the worm threads. Other leaks occur between the teeth and the casing since the clearances between these components are sealed-off by the liquid only in the central portion of the teeth. Leakage of the type last mentioned is the most dangerous since the fluid is at maximum pressure in this zone. It is in any case known that the clearances between the faces of the pinions **11** exposed to the pressure of the fluid and the casing are very critical, thereby entailing the need for machining tolerances which can be maintained only with very great difficulty in design solutions which do not call for the use of sealing liquid.

An explanation of the foregoing plenomenon will now be given although this does not in any way affect the scope of the invention.

The droplets of liquid which are projected at an initial velocity having a direction which is substantially parallel to the axis of the worm and a value equal to the injection velocity are practically not capable of acceleration since the action of gravity is negligible. Moreover, a point of contact such as **22** between a thread crest, a pinion **11** and the casing has an axial velocity component which is variable during rotation of the worm **1.** A simple calculation shows that this axial velocity of the point of contact **22** begins to decrease, passes through a minimum value and then increases. The droplets of liquid are therefore first retarded by the thread flank **23** which is located on the high-pressure side and then move away from said flank as the axial velocity of this latter increases. If the injection velocity of the liquid is increased, the droplets move progressively away from the other thread flank **24,** the axial velocity of which is insufficient.

The worm-type compressor which has an external cylindrical profile as shown in FIGS. **4** to **6** comprises a liquid injection system in accordance with the invention. In these figures, the same components as those shown in FIGS. **1** to **3** are designated by the same reference numerals.

Each half-casing **3***a*, **3***b* is provided with an injection duct **31** which terminates on the internal wall of the casing in an orifice **32** which is located in the vicinity of the pinion **11** on that side of said pinion which is subjected to the pressure of compressed fluid and in the vicinity of that zone in which the thread crests of the worm are of minimum width. Said orifice **32** is preferably located between that zone of the worm in which the thread crests have a minimum width and the high-pressure extremity of the worm which is adjacent to the fluid discharge port. The dimension of the orifice **32** as measured in a plane at right angles to the axis of the worm **1** is larger than the width of the thread crest in the region of said orifice **32** so that this latter is not completely sealed-off while a worm thread passes in front of said orifice.

The injection duct **31** is directed transversely with respect to the plane of the pinion **11** and is inclined at an angle which can attain **90** degrees with respect to said plane. In the case of an oblique arrangement with respect to the plane of the pinion, the duct **31** is directed towards the high-pressure end of the worm **1**. The angle of inclination with respect to the pinion plane is preferably of the order of 60°.

The duct **31** has its opening on the external side of the casing in a chamber **33** having an internally threaded portion into which is screwed the extremity **34** of a liquid supply pipe.

Experience has shown that this injection system provides appreciable improvements over the known system which was described earlier. Thus, in the case of a compressor which has a theoretical displacement of **520** liters per minute and a delivery pressure of **7** bars, the actual displacement increases from 430 liters per minute in the case of the known system to approximately 490 liters per minute in the case of the injection system according to the invention.

The results obtained are surprising since it could reasonably be assumed that a jet of liquid whose initial velocity has a very small or zero axial component would not be capable of forming a suitably distributed liquid film on the pinion teeth. Moreover, in the case of an injection zone located at a distance from the low-pressure end of the worm, substantial leakage in the initial compression stage could be expected.

One explanation of the excellent results which have been confirmed in practice and which is given solely by way of indication without thereby implying any limitation in the scope of the invention is illustrated in FIG. **7**. Even if the liquid jet **35** is substantially perpendicular to the pinion **11**, the impact of said jet on the pinion produces velocity components in all directions parallel to the plane of the pinion which are sufficient to form a liquid seal which is not subject to the retarding action mentioned with reference to FIG. **3** by reason of the choice of the injection zone.

Moreover, it is highly likely that leakage in the low-pressure zone of the worm is negligible by reason of the low fluid pressure within this zone. In addition, liquid droplets which pass through the clearances between the pinion and the worm in the high-pressure zone are probably collected by the worm during the following suction phase and serve to limit leakage in the low-pressure zone.

It will be noted that the worm of FIGS. **4** to **6** does not have the frusto-conical inlet configuration **35** as is the case with the worm of FIGS. **1** to **3** but is of the type shown in FIGS. **2** to **4** of U.S. Pat. application Ser. No. 884 606, now U.S. Pat. No. 3,632,239, in the name of the present Applicant. The injection system in accordance with the invention makes it possible to employ this type of worm without a truncated portion which is not compatible with the known axial injection system and thus makes it possible to benefit by the advantage described in the Application cited in the foregoing. The fluid to be compressed is accordingly admitted through ducts **36** which are pierced around the periphery of the casing on the low-pressure side.

The velocity and pressure of injection of liquid in the system according to the invention are higher than in the known system of axial injection, at least in the case of high values of delivery pressure. The invention makes it possible to adjust the injection pressure to a value which is higher as the duct **31** is inclined at a larger angle with respect to the plane of the pinion **11**.

Thus, in a compressor consisting of a worm having six threads and pinions having eleven teeth and in which the liquid jet is inclined at an angle of 60° with respect to the plane of the pinion, it has been found that the injection velocity at high values of the delivery pressure must be substantially doubled whilst the injection pressure must be substantially quadrupled with respect to the velocity and pressure employed in an axial injection system.

This corresponds in the case of the liquid jet to a flow velocity of the same order as the peripheral velocity of the worm which is substantially double the peripheral velocity of the pinion in the case of the numbers of threads and pinion teeth mentioned above. Thus, at peripheral velocities of the worm and the pinion which are equal respectively to 35 and 20 meters per second, the optimum injection pressure is in the vicinity of 0.8 to 1.5 bar in the case of axial injectors and in the vicinity of 4 to 7 bars in the case of an injection duct which is inclined at an angle of 60° whilst the delivery pressure of the compressor is **7** bars.

In point of fact, many industrial air compressors deliver at a pressure of 6 to 9 bars and have peripheral worm velocities of the order of 30 to 40 meters per second. In the system according to the invention, it is accordingly only necessary to withdraw the liquid at the outlet of the compressor at the delivery pressure in order to re-inject said liquid directly without interposition of a pressure-reducing unit as is necessary in the known axial injection systems.

It has been found in practice that, when the delivery pressure is of a low order, the injection pressure can have distinctly lower values than those mentioned above without thereby affecting the displacement of the compressor. This makes it possible to withdraw the sealing liquid at the delivery pressure and to re-inject this latter directly into compressors which operate at widely variable delivery pressures such as the compressors employed in cooling installations. Apart from the economy which is achieved by dispensing with pressure reducers, this possibility has the advantage of reducing the flow rate of liquid which is injected at low delivery pressures and consequently of reducing the energy losses which result from agitation of the liquid by the worm.

This clearly pre-supposes that the maximum delivery pressure is sufficient to impart to the jet of liquid a suitable initial velocity of the same order of magnitude as the peripheral velocity of the worm in the case of injection at an angle of 60°. Should this not be the case, the invention permits the advantageous possibility of reducing the angle of inclination of the injection duct with respect to the plane of the pinion as has been stated earlier.

On the contrary, if the maximum delivery pressure is too high when taking into account the peripheral velocity of the worm, it is naturally possible to reduce the injection pressure by providing an expansion valve **51** or any other equivalent system between the outlet of the compressor and the injection duct.

The injection system according to the invention is not limited to compressors of the cylindrical worm type which have been described thus far but also applies to worms having either a conical or flat external profile. The system makes it possible to employ not only worms

of the type in which the external profile has rectilineal generator-lines as described in French Pat. No. 1 331 998 cited in the foregoing but also worms of the type having a concave as well as a convex profile.

FIGS. **8** to **10** show diagrammatically the application of the injection system to a compressor in which the external profile of the worm is concave.

In the case of conical or flat worms, provision is made in accordance with the invention to orient the injection duct **31** in such a manner as to ensure that this latter forms an angle $\beta$ with the plane of the pinion **11** (as shown in FIG. **10**) and an angle $\gamma$ with the generator-line of the surface which is circumscribed about the threads of the worm **41** (as shown in FIG. **9**), both angles being of very small value. Spreading of the jet **35** as it reaches the pinion **11** (FIG. **8**) makes it possible to obtain an effective liquid seal between the pinion and the casing whereas the liquid would collect at the thread root if the angle $\gamma$ were too large.

As is readily understood, the invention is not limited to the embodiments which have been described and which permit many alternative forms of execution without thereby departing from the scope of this invention. Provision may accordingly be made for a number of injection ducts per pinion. The cross-section of the injection ducts need not be limited to a circular shape but may be oblong, for example, or said ducts may alternatively be designed in the form of slits.

What I claim is:

**1.** In a compressor comprising a worm which has a body shaped as an hour glass rotating about an axis of symmetry and a plurality of threads projecting from said body, at least one transverse pinion having teeth which mesh with the worm threads, a casing applied against at least part of the external surface of the worm, an inlet port which is located at one end of the worm for the admission of the fluid to be compressed into the casing and an outlet port which is located in the immediate vicinity of the pinion, near the opposite end of the worm and through which said fluid is discharged from the casing, said worm threads projecting from said body to an extent which varies from one end of the worm to the opposite end thereof, the crests of said threads having a width which first decreases, starting from one end of said worm, then passes through a minimum value in a central zone of the worm and lastly increases up to the opposite end of the worm; the improvement comprising means for injecting a liquid into the interior of the casing to ensure leaktightness between the worm threads and the casing and between the worm threads and the pinion teeth, said means comprising at least one injection duct which has an opening into the interior of the casing in the vicinity of the pinion, on that side of the pinion which is subjected to the pressure of the fluid to be compressed and in the vicinity of said central zone, and means to supply said liquid to said duct.

**2.** A compressor according to claim **10**, wherein the liquid-injection duct opens in the region of the casing located between said central zone and that end of said worm which is located on the same side as the outlet port for the discharge of fluid at high pressure.

**3.** A compressor according to claim **1**, wherein the opening of the liquid-injection duct in the internal wall of the casing has a dimension in the plane at right angles to the axis of the worm which is greater than the width of the worm-thread crest in the region in which said duct terminates.

**4.** A compressor according to claim **1** and means making the liquid-injection pressure proportional to the delivery pressure of the compressor.

**5.** A compressor according to claim **1**, wherein the liquid-injection duct is directed transversely with respect to the plane of the pinion.

**6.** A compressor according to claim **5**, wherein the liquid-injection duct is directed towards that portion of the worm which is adjacent to the outlet port.

**7.** A compressor according to claim **5**, wherein the angle of inclination of the liquid-injection duct with respect to the plane of the pinion is about 60°.

**8.** A compressor according to claim **5**, in the surface which is circumscribed about the thread crests is a plane or a cone of revolution, wherein the liquid-injection duct is inclined at a small angle both with respect to the plane of the pinion and with respect to the corresponding generator-line of the surface which is circumscribed about the worm threads.

* * * * *