United States Patent [19]

Bourke

[11] **3,771,906**

[45] **Nov. 13, 1973**

[54] **TEMPERATURE CONTROL OF STATOR/ROTOR FIT IN HELICAL GEAR PUMPS**

[75] Inventor: **John David Bourke**, Springfield, Ohio

[73] Assignee: **Robbins & Myers, Inc.**, Springfield, Ohio

[22] Filed: **June 5, 1972**

[21] Appl. No.: **259,986**

[52] **U.S. Cl.** **418/48,** 418/108, 418/153

[51] **Int. Cl.** **F01c 1/10,** F03c 3/00, F04c 5/00

[58] **Field of Search** 418/16, 48, 107, 418/108, 152, 153, 270; 222/146

[56] **References Cited**

UNITED STATES PATENTS

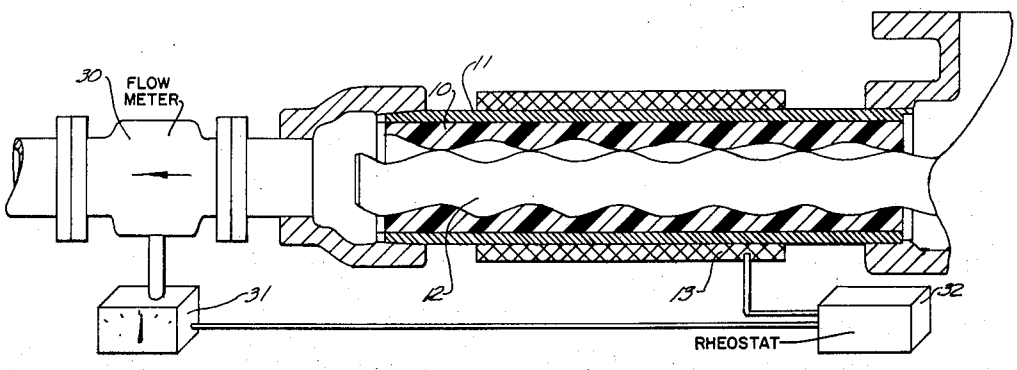
2,796,029 6/1957 Bourke 418/48

Primary Examiner—William L. Freeh
Assistant Examiner—Richard E. Gluck
Attorney—John W. Melville et al.

[57] **ABSTRACT**

Loss of capacity in a helical gear pump resulting from wear of parts is restored by raising the temperature of the stator, or by raising the temperature of the stator and also the temperature of the fluid being pumped. Regardless of the state of wear, the capacity of a helical gear pump operating against elevated discharge pressures is improved by raising the temperature or temperatures as above, whereby to produce a tighter fit between the elements. Various alternative means for raising the temperature or temperatures are disclosed.

13 Claims, 11 Drawing Figures



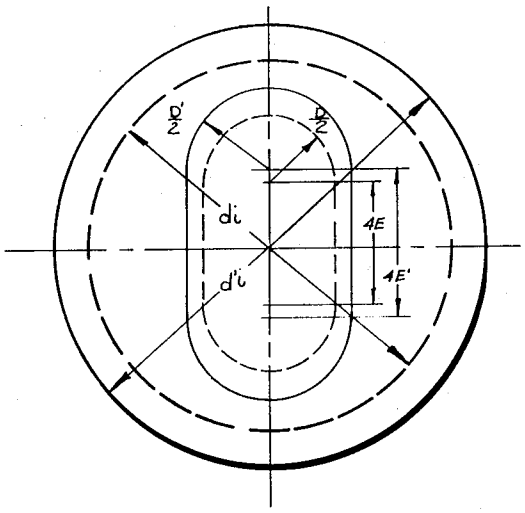


FIG 1

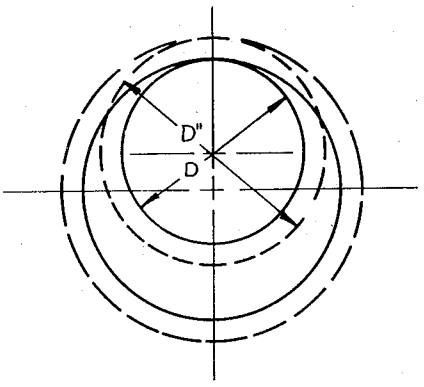


FIG 3

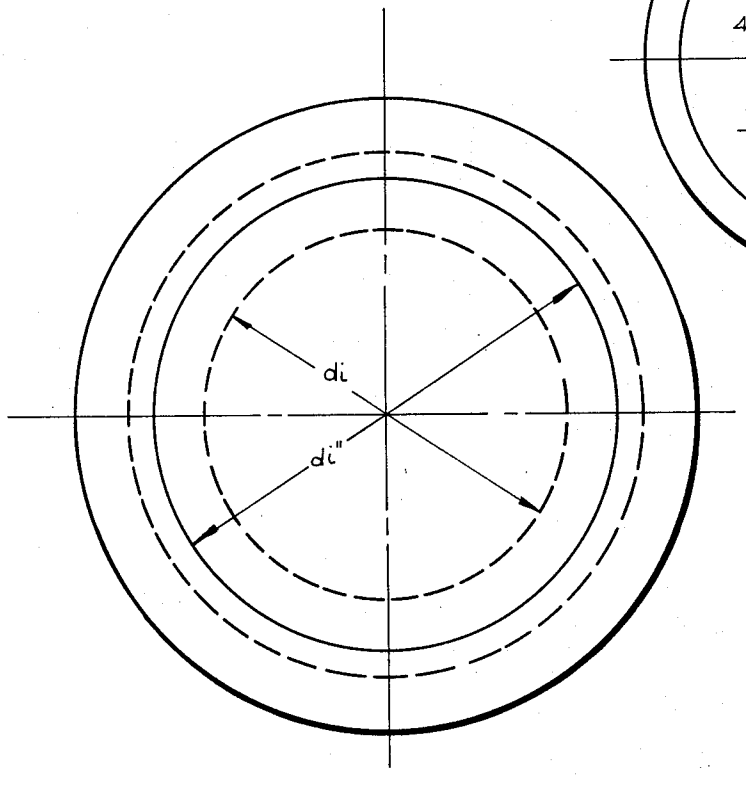


FIG 2

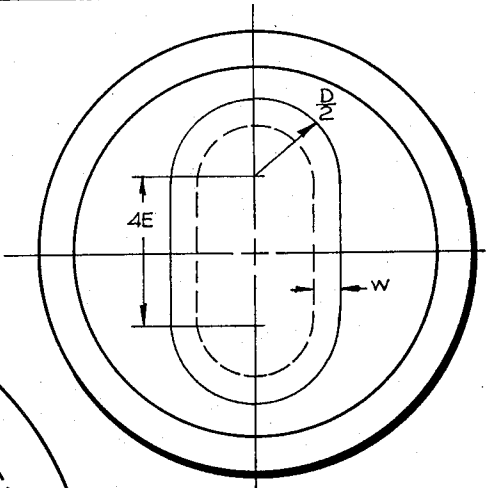


FIG 4

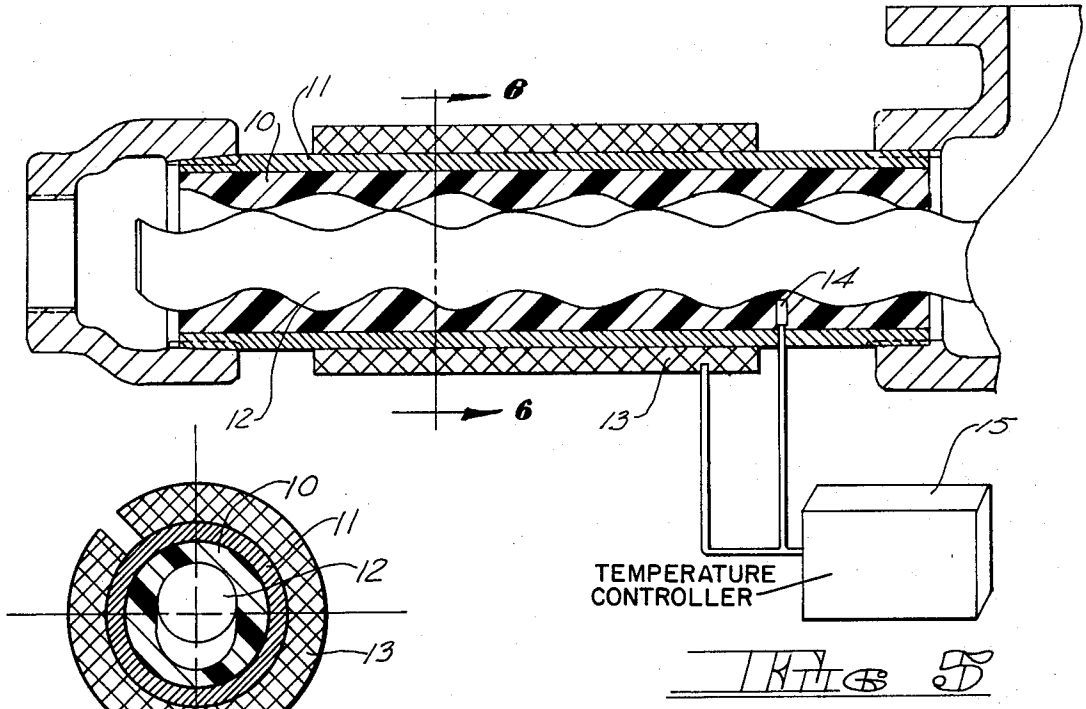


FIG 5

FIG 6

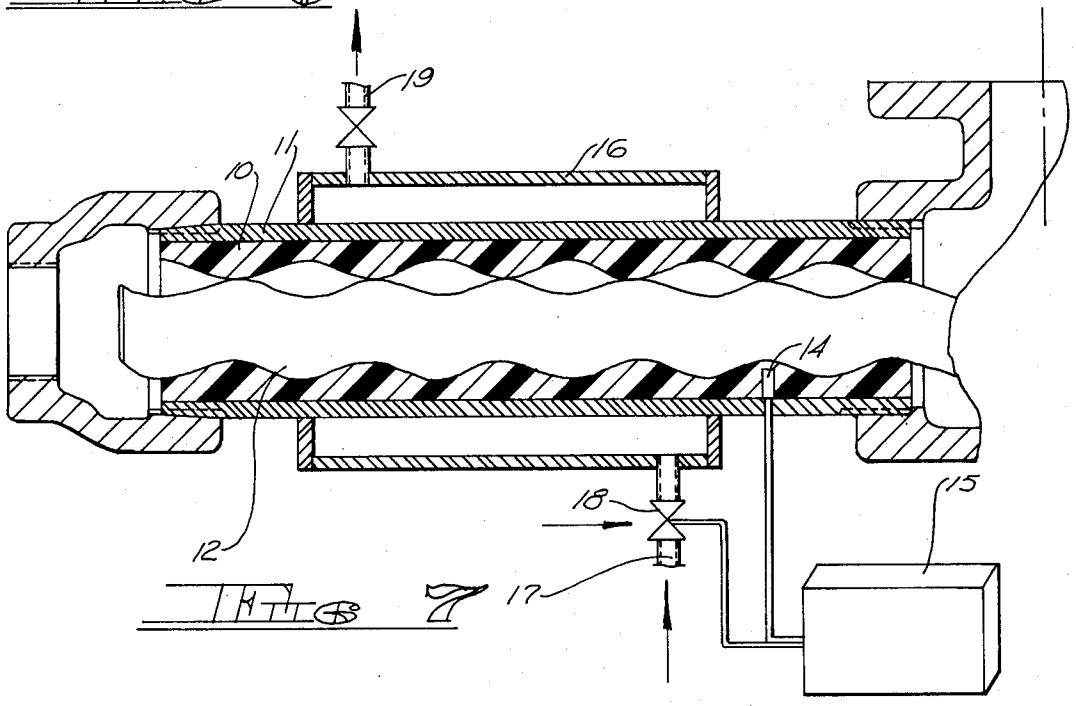


FIG 7

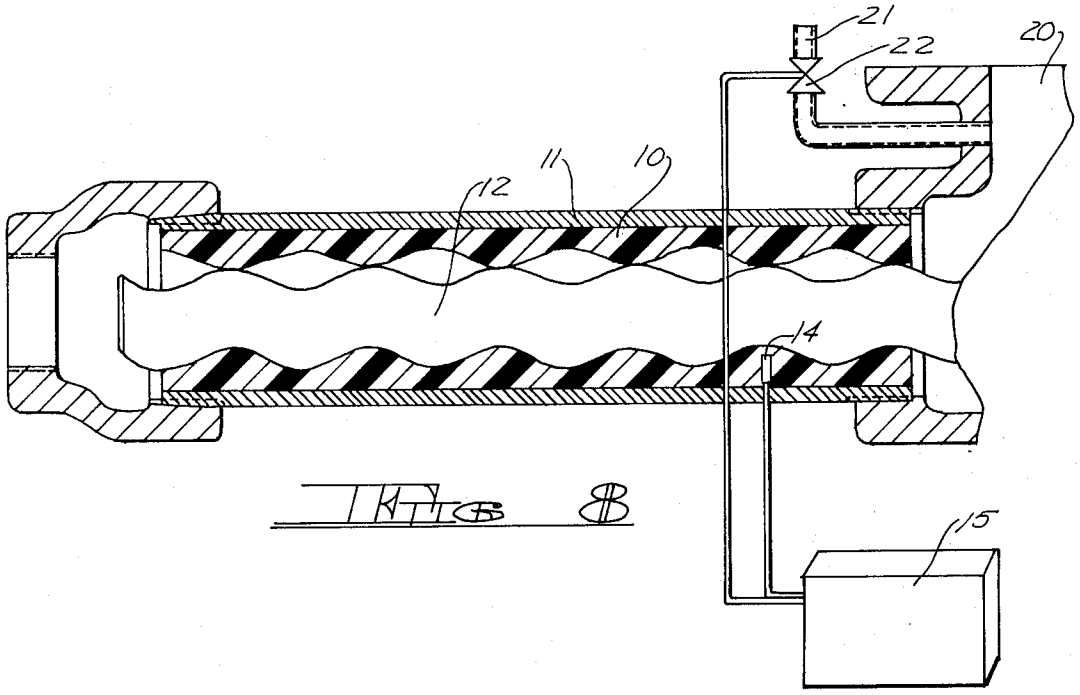


FIG. 8

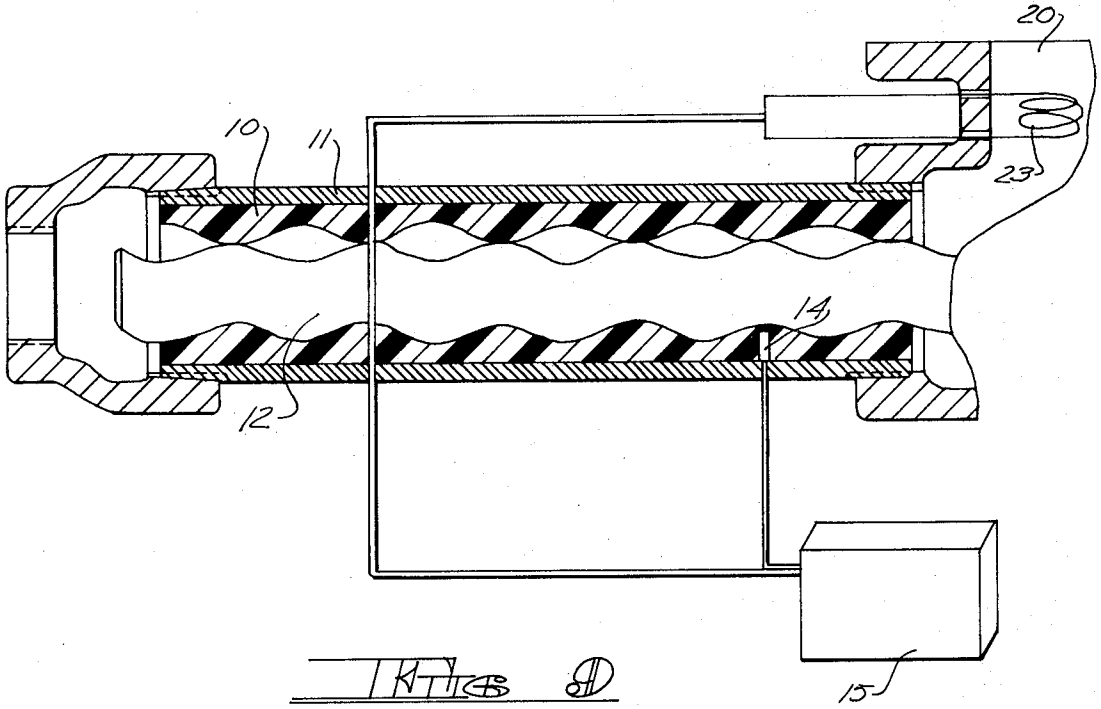
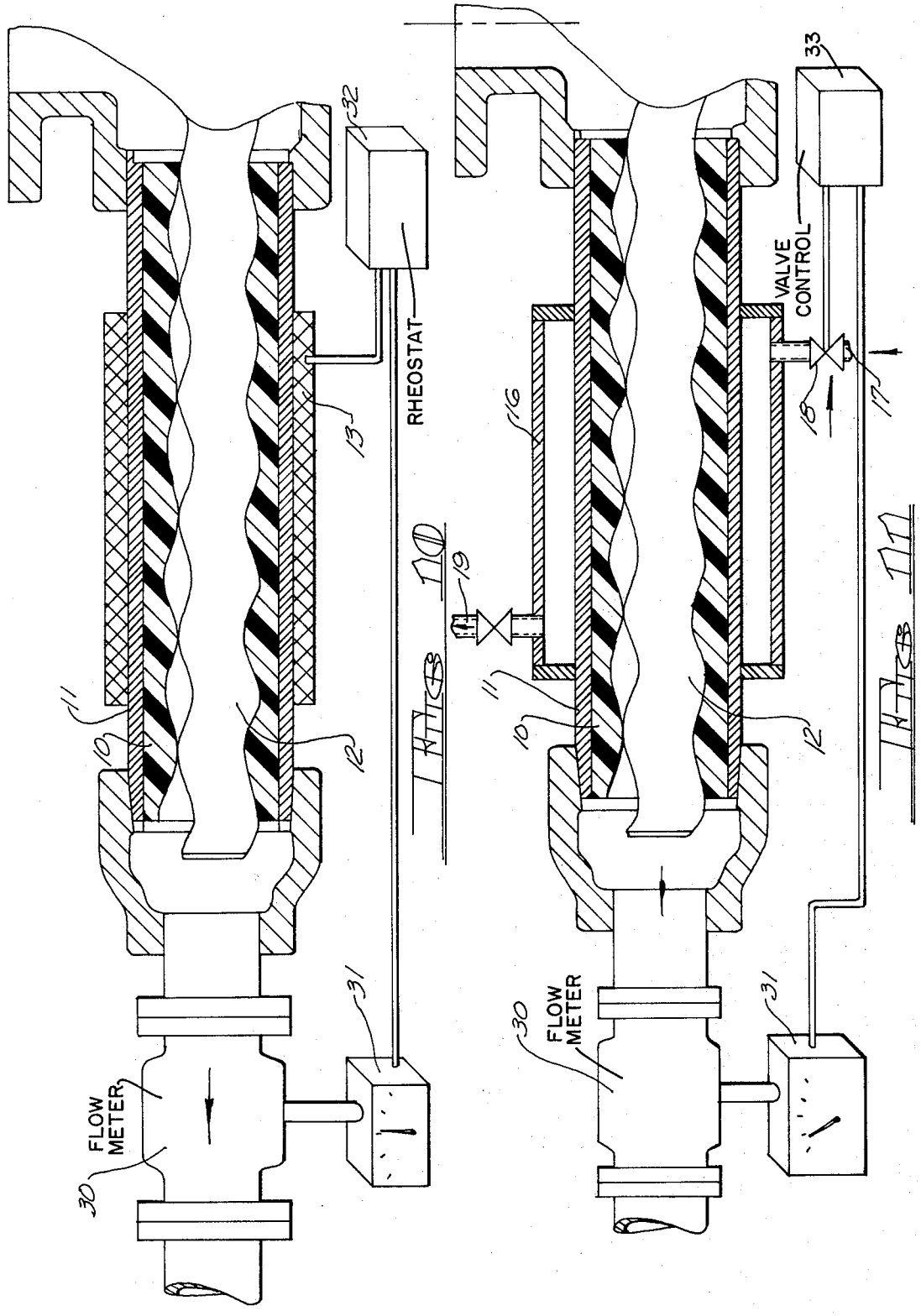


FIG. 9


RHEOSTAT
VALVE CONTROL
FLOW METER
FLOW METER
FIG 10
FIG 11

TEMPERATURE CONTROL OF STATOR/ROTOR FIT IN HELICAL GEAR PUMPS

BRIEF SUMMARY OF THE INVENTION

1. BACKGROUND

Helical gear pumps usually comprise a metallic rotor and a stator which is made of a flexible or resilient material such as rubber. The rubber stator of course is subject to wear, particularly if abrasive materials are being pumped. As the stator wears, the rotor/stator fit becomes loose so that the capacity of the pump decreases.

In some cases, regardless of the state of wear of a pump, it is desirable to increase the capacity of the pump at higher discharge pressures and to provide a pump where the maximum efficiency would occur at higher pressures.

Various means have been devised in the past for accomplishing these objects. Reference may be had to Bourke U.S. Pat. No. 2,796,029, dated June 18, 1957; Bourke U.S. Pat. No. 2,874,643 dated Feb. 24, 1959; and Bourke U.S. Pat. No. 3,084,631 dated Apr. 9, 1963. These devices have involved mechanical and hydraulic or pneumatic methods of adjusting the rotor/-stator fit.

2. SUMMARY

The present invention recognizes that rubber expands cubically approximately 10 times the rate of steel or iron and that therefore the stator/rotor fit can be improved by causing the stator to expand either by heating the stator itself or by heating the fluid being pumped whereby the stator is heated. Since the molded rubber stator is contained within a metal housing, the expansion of the rubber stator is inward toward the rotor.

This application discloses the rationale of such temperature control and discloses a number of specific arrangements for accomplishing the desired results.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

FIG. 1 is a diagrammatic cross sectional view of a typical helical gear pump stator.

FIG. 2 is a diagrammatic cross sectional view of a typical pipe casing for the stator of FIG. 1.

FIG. 3 is a diagrammatic cross sectional view of a typical helical gear pump rotor.

FIG. 4 is a diagrammatic cross sectional view of a typical helical gear pump stator.

FIG. 5 is a somewhat diagrammatic cross sectional view through a typical helical gear pump showing one embodiment, wherein the stator is heated.

FIG. 6 is a cross sectional view taken on the line 6—6 of FIG. 5.

FIG. 7 is a view similar to FIG. 5 showing another embodiment.

FIG. 8 is a view similar to FIGS. 5 and 7 showing an embodiment wherein the fluid being pumped is heated.

FIG. 9 is a view similar to FIG. 8 showing another embodiment.

FIG. 10 is a view similar to FIG. 5, showing an arrangement for obtaining automatic control of the stator/rotor fit.

FIG. 11 is a view similar to FIG. 7, again showing an arrangement for automatic control of stator/rotor fit.

It may be pointed out that FIGS. 1 to 4 inclusive are diagrams intended to assist in understanding the mathematical computations involved.

DETAILED DESCRIPTION

The principle of adjustable stator compression by means of heat is based on the thermal expansion coefficient difference between rubber and metal. The thermal expansion coefficient of rubber is 63×10^{-6} inches/inch/°F and the thermal expansion coefficient of steel is 6×10^{-6} inches/inch/°F. Thus, since the stator of a helical gear pump is normally molded or clamped inside a steel housing, any expansion of the rubber stator caused by an increase either in the ambient temperature or an increase in the fluid temperature is much greater than the space left by the expansion of the steel housing. Therefore the expanded rubber must expand in the direction of the bore of the stator or toward the rotor. Thereby the compression of the stator/rotor fit is increased so as to compensate for stator wear.

For an understanding of the invention and to assist in an understanding of the formulas here involved and the derivation thereof, reference is made to FIGS. 1 to 4. The stator of a helical gear pump is generally molded or clamped in a casing or housing which may be considered as a piece of steel pipe. This steel pipe expands under the influence of heat and its coefficient of expansion is 6×10^{-6} inches/inch/°F. Thus, in FIG. 2 the dimension d_i represents the inside diameter of the steel pipe before heating and the dimension d_i'' represents the inside diameter of the steel casing after heating.

FIG. 1 shows a cross section through a typical rubber stator which is bonded inside the pipe of FIG. 2 and again d_i represents the inside diameter of the casing and of course the outside diameter of the stator. d_i' represents the outside diameter of the rubber liner after heating (free expansion is assumed). The coefficient of expansion of the rubber is 63×10^{-6} inches/inch/°F, which is 10 times as gteat as that of steel. The expansion of the rubber which is in excess of the expansion of the steel goes to the inside of the stator to increase the compression of the stator/rotor fit to compensate for stator wear.

SYMBOLS

T = normal pump operation temperature, °F.
t = temperature increment °F.
T' = temperature after heating, i.e. $T' = T + t$ ° F.
L = unit length in longitudinal direction, inches.
d_i = inside diameter of steel pipe and also outside diameter of rubber liner in inches.
d_i' = outside diameter of rubber liner after heating, inches.
d_i'' = inside diameter of steel pipe after heating, inches.
D = diameter rotor, inches, and minor diameter of stator, inches.
D'' = diameter rotor after heating, inches.
E = eccentricity of rotor, inches.
L' = unit length of rubber liner after heating, inches.
L'' = unit length of steel pipe after heating, also unit length of rotor after heating, inches.

CALCULATIONS

$$d_i' = di\ (1 + 63 \times 10^{-6} \times t)$$
$$d_i'' = di\ (1 + 6 \times 10^{-6} \times t)$$
$$D'' = D\ (1 + 6 \times 10^{-6} \times t)$$

$L'' = L\ (1 + 6 \times 10^{-6} \times t)$

$L' = L\ (1 + 63 \times 10^{-6} \times t)$

The cross-sectional area of rubber liner

$$A = (\pi d_1^2/4) - (\pi D^2/4) - 4DE$$

The dimensions D and E of rubber liner become D' and E' at T' °F.

$$D' = D\ (1 + 63 \times 10^{-6} \times t)$$

$$E' = E\ (1 + 63 \times 10^{-6} \times t)$$

The cross sectional area of rubber (not restrained) becomes

$A' = (\pi d_i'^2/4) - (\pi D'^2/4) - 4\ D'E'$

$= (\pi d_i^2/4)\ (1 + 63 \times 10^{-6} \times t)^2 - (\pi D^2/4)\ (1 + 63 \times 10^{-6} \times t)^2 - 4\ DE\ (1 + 63 \times 10^{-6} \times t)^2$

$= A\ (1 + 63 \times 10^{-6} \times t)^2$

The volumetric increment of rubber liner

$\Delta V = A'L' - AL$

$= [A\ (1 + 63 \times 10^{-6} \times t)^2 \times L\ (1 + 63 \times 10^{-6} \times t) - AL]$

$= AL\ [(1 + 63 \times 10^{-6} \times t)^3 - 1]$

neglecting all t^2, t^3 terms (because these will be 10^{-12} and 10^{-18} which are insignificant)

$$\Delta V = AL\ (189 \times 10^{-6} \times t)$$

Since in the longitudinal direction, the rubber liner is bonded by the steel pipe outside, it may be assumed that the thermal expansions of rubber liner, steel pipe and steel rotor in the longitudinal direction are all the same as L''. Then the increment of cross sectional area of rubber is

$S_1 = \Delta V/L'' = AL\ (189 \times 10^{-6} \times t)/L\ (1 + 6 \times 10^{-6} \times t)$

$= A\ (189 \times 10^{-6} \times t)/(1 + 6 \times 10^{-6} \times t)$

The increment of the cross sectional area inside the steel pipe is

$S_2 = (\pi d_i''^2/4) - (\pi d_i^2/4) = (\pi d_i^2/4)\ (1 + 6 \times 10^{-6} \times t)^2 - (\pi d_i^2/4)$

$= (\pi d_i^2/4)\ [(1 + 6 \times 10^{-6} \times t)^2 - 1]$

Neglecting t^2 term (10^{-12})

$$S_2 = \pi d_i^2/4\ (12 \times 10^{-6} \times t)$$

The decrease of the cross sectional area of the oval-shaped hole as a result of the thermal expansion of rubber, less the increase caused by expansion of the pipe is:

$$S = S_1 - S_2 = \frac{\left(\frac{\pi d_i^2}{4} - \frac{\pi D^2}{4} - 4DE\right)(189 \times 10^{-6} \times t)}{(1 + 6 \times 10^{-6} \times t)} - \frac{\pi d_i^2}{4}\ (12 \times 10^{-6} \times t)$$

$$= \frac{(148.44 d_i^2 - 148.44 D^2 - 756 DE) \times 10^{-6} \times t}{1 + 6 \times 10^{-6} \times t} - 9.425 d_i^2 \times 10^{-6} \times t$$

$$= \frac{(148.44 d_i^2 - 148.44 D^2 - 756 DE) \times 10^{-6} \times t - 9.425 d_i^2 \times 10^{-6} \ldots}{1 + 6 \times 10^{-6} \times t}$$

$$\frac{\ldots \times t - 6 \times 9.425 d_i^2 \times 10^{-12} \times t^2}{1 + 6 \times 10^{-6} \times t}$$

Neglecting t^2 term (10^{-12})

$$S = [(139.\ d_i^2 - 148.44\ D^2 - 756DE) \times 10^{-6} \times t]/1 + 6 \times 10^{-6} \times t \qquad (1).$$

The increment of cross sectional area of rotor after heating is:

$$H = (\pi D''^2/4) - (\pi D^2/4) = (\pi D^2/4)\ (1 + 6 \times 10^{-6} \times t)^2 \quad (\pi D^2/4)$$

Neglecting t^2 term (10^{-12})

$H = \pi D^2/4\ (12 \times 10^{-6} \times t)$

$= 9.425\ D^2 \times 10^{-6} \times t$

If the rotor is also heated up to the same temperature as the stator, the decrease in area of the oval shaped hole due to the thermal expansion of both the rotor and stator is:

$$F = S_1 - S_2 + H$$

$$F = \frac{\begin{array}{r}(148.44 d_i^2 - 148.44 D^2 - 756 DE) \\ \times 10^{-6} \times t - 9.425 d_i^2 \times 10^{-6} \\ \times t(1 + 6 \times 10^{-6} \times t) + 9.425 D^2 \\ \times 10^{-6} \times t(1 + 6 \times 10^{-6} \times t)\end{array}}{1 + 6 \times 10^{-6} \times t}$$

Neglecting t^2 terms (10^{-12})

$$F = (139\ d_i^2 - 139\ D^2 - 756DE) \times 10^{-6} \times t/(1 + 6 \times 10^{-6} \times t) \qquad (2).$$

To calculate the temperature increment required to compensate for a wear of W inches (see FIG. 4)

1. For heating the stator only

$$S = (\pi D + 8\ E)\ W \qquad (3).$$

substituting (1) into (3)

$$\frac{(139 d_i^2 - 148.44 D^2 - 756 DE) \times 10^{-6} \times t}{1 + 6 \times 10^{-6} \times t} = (\pi D + 8E) W$$

$$(139 d_i^2 - 148.44 D^2 - 756 DE) \times 10^{-6} \times t = (\pi D + 8E) W + 6(\pi D + 8E) W \times 10^{-6} \times t$$

$$(139 di^2 - 148.44 D^2 - 756 DE - 6\pi DW - 48 EW) \times 10^{-6} \times t = (\pi D + 8E) W$$

$$t = \frac{(\pi D + 8E) W \times 10^{-6}}{139 d_i^2 - 148.44 D^2 - 756 DE - 18.5 DW - 48 EW} \qquad (4)$$

2. For heating stator and rotor both

$$F = (\pi D + 8E)\ W \qquad (5.)$$

substituting (2) into (5)

$$\frac{(139 d_i^2 - 139 D^2 - 756 DE) \times 10^{-6} \times t}{1 + 6 \times 10^{-6} \times t} = (\pi D + 8E) W$$

$$(139 d_i^2 - 139 D^2 - 756 DE) \times 10^{-6} \times t = (\pi D + 8E) W\ (1 + 6 \times 10^{-6} \times t)$$

$$(139 d_i^2 - 139 D^2 - 756 DE) \times 10^{-6} \times t = (\pi D + 8E) W + 6(\pi D + 8E) W \times 10^{-6} \times t$$

$$(139 d_i^2 - 139 D^2 - 756 DE - 6\pi DW - 48 EW) \times 10^{-6} \times t \quad (\pi D + 8E) W$$

$$t=\frac{(\pi D+8E)W\times 10^6}{139d_i^2-139D^2-756DE-18.5DW-48EW} \quad (6)$$

D, E, and d_i are design constants for the pump elements. If it is desired to know how much temperature change is required, it is only necessary to substitute the values of D, E, d_i and W (wear) into either equation (4) or equation (6). Substitution in equation (4) will give the temperature increment required for heating the stator only and equation (6) will give the temperature increment required for heating the fluid being pumped in order to heat the stator.

By way of example, in the case of a number 10 H Moyno Pump manufactured by Robbins & Myers, Inc. wherein $D = 2.958$ inches, $E = 0.3937$ inches, $d_i = 6.065$ inches, wherein the wear amounted to 0.0225 inches, t_1 is found to be 95.5° F. and t_2 is found to be 92.8° F.

For a number 8 Moyno Pump, wherein $D = 2.509$ inches, $E = 0.315$ inches, $d_i = 5.047$ inches, wherein the wear amounted to 0.005 inches, t_1 was found to be 25.9° F. and t_2 was found to be 25.1° F.

For a number 12 H Moyno Pump, wherein $D = 3.75$ inches, $E = 0.4724$ inches, $d_i = 7.981$ inches, and wherein the wear amounted to 0.03 inches, t_1 was found to be 86° F. and t_2 was found to be 84° F.

It is possible by following one or another of the embodiments to be described hereinafter to make a pump have better performance than an ordinary pump. For example, an ordinary pump without means for heating either the stator or the fluid being pumped, running at 400 r.p.m. at 100° F. stator temperature, will pump 110 gallons per minute against 0 p.s.i. discharge pressure. It will pump 107 gallons per minute against 50 p.s.i. discharge pressure and it will pump 97 gallons per minute against 100 p.s.i. discharge pressure, and 85 gallons per minute against 150 p.s.i. discharge pressure. Some actual capacity figures for different temperatures of the stator for the same series of discharge pressures are shown in the table below.

Stator Temp.	0 p.s.i. GPM	50 p.s.i. GPM	100 p.s.i. GPM	150 p.s.i. GPM
100° F.	110	107	97	85
110° F.	108	105	98	88
120° F.	107	104	99	92
140° F.	106	104	100	96

The figures above are for the same pump at the same speed and the improvement in capacity at 150 psi is substantial.

The improvement in efficency against high discharge pressures is also significant. The same pump described above without the present improvement had its maximum efficiency of 75 percent against a discharge pressure of 115 p.s.i. This pump dropped in efficiency to 66 percent at 190 p.s.i. and to 50 percent at 200 p.s.i. discharge pressure. A pump modified as described herein had its maximum efficiency of 80 percent at 130 p.s.i. discharge pressure and dropped only to 75 percent against 190 p.s.i. and only to 65 percent against 200 p.s.i. discharge pressure.

As pointed out heretofore, the stator temperature can either be raised by heating the stator externally or by heating the pump fluid in order to raise the stator temperature. Generally speaking, the arrangement is a combination of a temperature controller, a thermocouple and a heater. The thermocouple serves as the sensor of the temperature controller and controls the on-off switch of the heater in order to adjust the stator temperature. Several arrangements are shown in the Figures.

Referring first to FIG. **5** and **6**, the stator **10** is bonded into a pipe **11** and the rotor **12** operates within the stator. The rotor is usually steel and the stator is usually rubber. An electric blanket **13** is shown wrapped around the outside of the stator tube and a thermocouple **14** is embedded and sealed into the rubber liner of the stator to sense the temperature thereof. A temperature controller is shown diagrammatically at **15** and in response to the sensor **14** controls the operation of the electric blanket **13.**

In the embodiment of FIG. **7**, again the stator **10** is heated directly but this time by means of a steam jacket **16.** Steam is supplied through a line **17** and controlled by a valve **18** which valve in turn is controlled by the temperature controller **15** on the basis of sensings of the thermocouple **14.** The steam outlet is shown at **19.**

In FIG. **8** there is shown an embodiment wherein the fluid being pumped is heated in order to heat the stator. The suction port of the pump is indicated at **20.** A steam line at **21** controlled by a valve **22** feeds steam into the suction port of the pump to heat the fluid therein and again the temperature is sensed by the thermocouple **14** and the temperature controller **15** controls the valve **22.**

Another embodiment is shown in FIG. **9** wherein the suction port of the pump at **20** has a heating coil **23** mounted therein and electric power supplied to the heating coil **23** under control of the controller **15** as dictated by sensings of the thermocouple **14.**

The principles of this invention can of course be used with a flow meter to control the heat input to the pump. Thus in FIG. **10** a flow meter is shown at **30**; and the flow meter, depending on its type, transmits either an electrical or a pneumatic signal through a recorder and transmitter indicated at **31** to a rheostat or the like at **32,** to raise or lower the stator temperature as needed to maintain flow. If the flow drops, a change in signal causes the stator to be heated until flow returns to normal.

In FIG. **11,** the signal from the transmitter **31** is transmitted to a valve controller **33** which operates the value **18** until normall flow is restored.

It will be clear that numerous modifications may be made without departing from the spirit of the invention. No limitation not specifically set forth in the claims should therefore be implied and no such limitation is intended.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A helical gear pump having a suction port and a discharge port, a working chamber formed by a metallic rotor and a rubber stator, said stator confined within a metallic casing, a temperature sensing element embedded in said rubber stator, means for heating said rubber stator in order to expand the stator and produce a tighter fit between said stator and said rotor, and control means for said heating means responsive to sensings of said sensing element.

2. A helical gear pump according to claim **1,** wherein said stator is heated by means of an electrical heating element surrounding said metallic casing.

3. A helical gear pump according to claim 1, wherein said metallic casing is provided with a jacket for a heat transfer fluid, and said stator is heated by said fluid.

4. A helical gear pump according to claim 1, wherein said stator is heated by heating the fluid being pumped.

5. A helical gear pump according to claim 4, wherein the fluid being pumped is heated by steam introduced into the suction port of a pump.

6. A helical gear pump according to claim 4, wherein the fluid being pumped is heated by an electric heating coil disposed in the suction port of a pump.

7. The method of compensating for stator wear in a helical gear pump having a working chamber formed by a metallic rotor eccentrically arranged in a rubber stator, said stator confined within a metallic casing, which includes the steps of heating said stator to cause expansion thereof to enhance the rotor/stator fit, and basing the temperature increment upon the amount of stator wear.

8. The method of claim 7, wherein said stator is heated by raising the ambient temperature adjacent said stator.

9. The method of claim 8, wherein the temperature increment is determined by the equation:

$$t_1 = W(3.1416D + 8E) \times 10^6/(139\ d_i^2 - 148.44D^2 - 756DE - 18.5DW - 48EW)$$

wherein

t_1 is the temperature increment in ° F.,

D is the diameter of the rotor in inches,

E is the eccentricity of the rotor in inches,

d_i is the inside diameter of the metallic casing in inches,

W is the wear in inches.

10. The method of claim 7 wherein said stator is heated by raising the temperature of the fluid being pumped.

11. The method of claim 10, wherein the temperature increment is determined by the equation:

$$t_2 = W(3.1416D + 8E) \times 10^6/(139\ d_i^2 - 139D^2 - 756DE - 18.5DW - 48\ EW)$$

wherein

t_2 is the temperature increment in ° F.,

D is the diameter of the rotor in inches,

E is the eccentricity of the rotor in inches,

d_i is the inside diameter of the metallic casing in inches,

W is the wear in inches.

12. A helical gear pump having a suction port and a discharge port, a working chamber formed by a metallic rotor and a rubber stator, said stator confined within a metallic casing, an electrical heating element surrounding said rubber stator to heat said rubber stator in order to expand the stator so as to produce a tighter fit between said stator and said rotor, flow meter means disposed at the discharge of the pump, means to change electrical current supplied to said heating element in response to a change in flow through said pump as determined by said flow meter.

13. A helical gear pump having a suction port and a discharge port, a working chamber formed by a metallic rotor and a rubber stator, said stator confined within a metallic casing, said casing provided with a jacket for a heat transfer fluid to heat said stator in order to expand the stator so as to produce a tight fit between said stator and said rotor, flow meter means disposed at the discharge of the pump, means to change flow of heat transfer fluid to said jacket in response to a change in flow through the pump as determined by said flow meter.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3771,906 Dated November 13,1973

Inventor(s) John David Bourke

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

COLUMN 4, LINE 38 and 39, the formula identified as (4)

should read:

$$t = \frac{(\pi D + 8E)\ W\ X\ 10^6}{139d_i^2 - 148.44D^2 - 756DE - 18.5DW - 48EW}$$

Signed and sealed this 24th day of September 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

USCOMM-DC 60376-P69
★ U.S. GOVERNMENT PRINTING OFFICE : 1969 O—366-334

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,771,906 Dated November 13, 1973

Inventor(s) John David Bourke

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

COLUMN 4, the last line should read --

$$x\ 10^{-6}\ x\ t = (\pi D + 8E)\ W$$

Signed and sealed this 2nd day of April 1974.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

USCOMM-DC 60376-P69
★ U.S. GOVERNMENT PRINTING OFFICE : 1969 O—366-334

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