

[54] GEAR PUMP FOR VISCOUS
THERMOPLASTIC MELTS

[75] Inventor: **Heinz Schippers**, Remscheid,
Germany

[73] Assignee: **Barmag Barmer Maschinenfabrik
Aktiengesellschaft**, Wuppertal,
Germany

[22] Filed: **Aug. 6, 1970**

[21] Appl. No.: **61,643**

1,644,401 10/1927 Ross..... 418/206 X
2,831,435 4/1958 Hobbs et al..... 418/206

FOREIGN PATENTS OR APPLICATIONS

305,522 2/1955 Switzerland..... 418/206

Primary Examiner—Allan D. Herrmann

Attorney—Johnston, Root, O'Keeffe, Keil, Thompson
and Shurtleff

[30] Foreign Application Priority Data

Aug. 16, 1969 Germany..... P 19 41 673.0

[52] U.S. Cl..... 418/83, 418/206

[51] Int. Cl..... F04c 1/14, F04c 29/04

[58] Field of Search..... 418/83, 206

[56] References Cited

UNITED STATES PATENTS

3,553,777 1/1971 Fritsch..... 418/83 X
226,023 3/1880 Bocklet..... 418/206
280,220 6/1883 Nash..... 418/206 X

[57] ABSTRACT

A gear pump having two rotatable intermeshed gears mounted in a hollow cavity of the pump casing for transporting and discharging a viscous thermoplastic melt, the hollow cavity being enlarged at the inlet side of the pump casing to provide an elongated arcuate wedge-shaped filling chamber extending from the inlet outwardly around each gear to converge onto the gear periphery in the circumferential direction of the transported melt.

5 Claims, 2 Drawing Figures

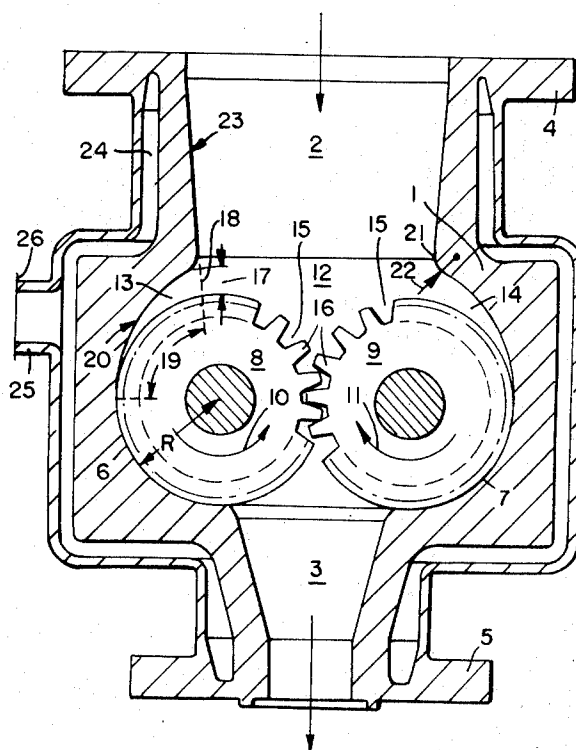


FIG. 1

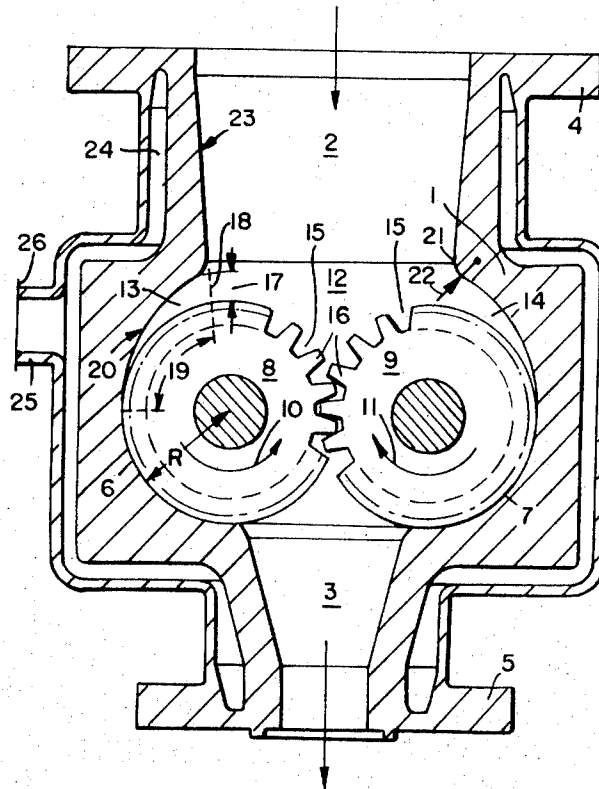
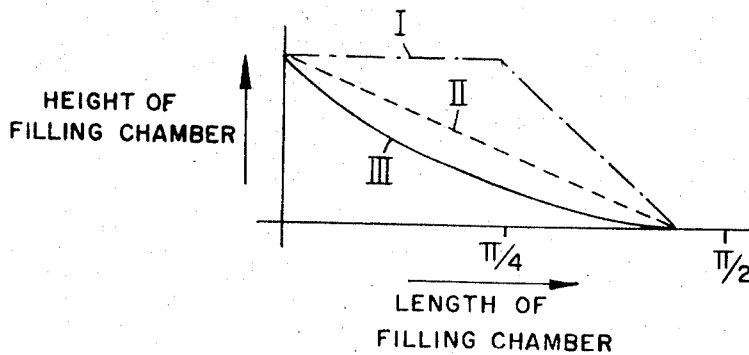


FIG. 2



INVENTOR:
HEINZ SCHIPPERS

BY

Golding, Root, O'Keefe, Reif, Thompson & Shurtleff
ATT'YS

GEAR PUMP FOR VISCOUS THERMOPLASTIC MELTS

Gear pumps are generally known in which two intermeshed gears are rotatably positioned in axially parallel bores or circular openings and enclosed at both ends within the pump casing, one of the gears being driven from outside the casing. Such pump gears are used for transporting or conveying various liquids, for example oil (German Pat. No. 323,327), spinning solutions (German Pat. No. 1,230,314) and the like. They are most commonly adopted for use as metering pumps or so-called "dosing pumps" to provide an accurately measured continuous supply of a liquid. Depending on the chemical and physical properties of the liquid medium to be conveyed as well as their delivery or output capacity, gear pumps may be differently constructed with respect to size, certain dimensions and the precision of such dimensions and also with respect to the rotational speed of the gear wheels. As a rule, the pump casings are constructed of three plates joined to one another in sandwich fashion, i.e., face to face, the middle plate serving for the reception of the intermeshed gear wheels and the outer or end plates covering the pump space or cavity as well as the gear wheels at both facing ends. The pump cavity thus consists essentially of two overlapping bores or circular openings in the middle plate which follow closely around the circumference or outer periphery of each gear between an inlet on the feed side and an outlet on the discharge side of the pump casing. The gears are normally rotated so that the liquid is carried between the gear teeth and the facing walls of the circular openings in the middle plate in a direction from the inlet away from the point at which the gears intermesh with one another. It is often desirable to dimension the gear teeth so as to prevent any trapping of liquid within the intermeshed teeth while also preventing any leakage through the point of intermeshing. A backward flow of liquid around the gear teeth along the walls of the pump cavity can be tolerated, and is sometimes desirable, but the gear teeth are normally positioned quite close to the circular walls of the cavity between the inlet and outlet zones of the pump.

In known gear pumps which are used for metering a spinning material, e.g., in the formation of thermoplastic filaments, there exists the problem of exposing the spinning material, e.g., a melt of a thermoplastic fiber-forming polymer, in the course of the pumping operation to a continuously rising pressure so that gas bubbles which are present in the melt will go into solution as a consequence of the rising pressure. Such gas bubbles may consist, for example, of monomeric components which arise through decomposition caused by the heating of the thermoplastic polymer. In order to build up the required pressure, it is a known practice from German Pat. No. 1,230,314 to arrange in the plate forming the cylindrical bores or cavity of the pump casing, chambers which issue with their entry opening into the feed or inlet zone of the pump and which are tapered in wedge form in circumferential direction. In the turning of the toothed gears, the thermoplastic melt is engaged and drawn into the chambers. A gradually increasing pressure is thereby placed on the melt so as to dissolve the gas bubbles.

The gear pump as described in German Pat. No. 1,230,314 is intended to act as a metering pump for the

spinning material, and accordingly, the pump must have relatively small dimensions and a low conveyance or delivery capacity. The tapered or converging chambers are quite flat or shallow so that the requisite high pressures can be rapidly built up for dissolving gas bubbles.

In gear pumps having a theoretically similar design but larger dimensions, for example are used for discharging or transporting large quantities of molten thermoplastic materials, the problem solved in the case of German Pat. No. 1,230,314 does not exist. Pumps of this type are thus used for discharging a freshly produced polymer from a polymerization or polycondensation reactor. Here there exists the desire to utilize the delivery or output capacity of the pump as much as possible in order to be able to discharge the polymerized composition as rapidly as possible from the reactor, the capacity of which frequently amounts to several tons. The emptying of the reactor as rapidly as possible is necessary so that the individual proportions of each polymer batch will have been exposed to approximately equal residence times and thereby also exhibit equal or uniform properties. When endeavoring to increase the delivery capacity of the discharge pump by increasing the rotational velocity of the gear wheels, narrow limits are set as a consequence of the high viscosity of many thermoplastic melts. On the other hand, the viscosity cannot directly be reduced by raising the melt temperature, since decomposition of the polymer tends to increase rapidly with such a temperature rise.

These difficulties are even more severe when it is necessary to convey the thermoplastic melt out of a reactor operated under a reduced pressure as compared to the outside pressure. In this case the flow speed of the viscous melt is still lower, so that a longer time is required for the complete filling of the gaps between pairs of adjacent teeth on each gear.

One object of the present invention is to provide an improved gear pump for the transport or discharge viscous thermoplastic melts at a relatively high output capacity, even when working with highly viscous melts and/or pumping from a reactor or other vessel operated under a reduced pressure. Another object of the invention is to provide a high capacity gear pump which tends to ensure a uniformly constant flow or discharge of a viscous thermoplastic melt and to permit a retention of uniform properties of the melt. Other objects and advantages will become more apparent upon consideration of the following detailed specification.

It has now been found, in accordance with the invention, that the operation of a gear pump in transporting or discharging viscous thermoplastic melts can be substantially improved by a careful and critical modification of the pump cavity or overlapping openings which contain the intermeshed gears within the pump casing. Thus the gear pump of the invention generally includes a conventional pump casing or housing which contains two intermeshed toothed gears mounted for rotation on parallel axes and situated in a hollow cavity or pair of bored openings centrally within the casing and which is adapted to transport the melt from an inlet or feed opening on one side of the pump outwardly around each gear, i.e., in the gaps between adjacent teeth of the gear, to an outlet or discharge opening on the other side of the pump. The improvement in combination with this conventional form of the gear pump comprises an elongated arcuate wedge-shaped filling cham-

ber located along a circumferential portion of each gear and extending from said inlet while converging in the circumferential direction onto the outer toothed periphery of the gear, the height of said wedge-shaped filling chamber at said inlet being equal to at least one times the height of a gear tooth as measured from the periphery of the gear radially outwardly to the facing wall of the cavity and the length of said wedge-shaped filling chamber being equal to about 5 to 10 and preferably about 6 to 8 times the height of a gear tooth as measured from said inlet circumferentially to the point of convergence on the gear periphery.

The gear pump of the invention is thus essentially characterized by providing an entry opening of the wedge-shaped filling chamber which is equal to at least about once the height of a gear tooth while also providing an arcuate length of the chamber which is equal to about 5 to 10 times, preferably 6 to 8 times, the height of a gear tooth (with the obvious understanding that all of the gear teeth have the same height measured radially of the gear from the root or base of a tooth to its outermost radial projection on the outer periphery of the gear). Through this specific dimensioning of the chamber height and circumferential length, it is made certain that the viscous melt will enter each filling chamber without trouble, where it is then engaged by the turning teeth of each gear wheel and transported to the pump outlet. The width of the filling chamber naturally corresponds to the axial length of the gears, and this same width is also preferably exhibited by the inlet or feed zone in fluid connection with both of the wedge-shaped filling chambers.

The invention is explained in greater detail in connection with the accompanying drawing in which:

FIG. 1 is a partly schematic longitudinal section through one embodiment of the gear pump according to the invention; and

FIG. 2 is a graphical representation of different embodiments of the invention, illustrating the rate at which the filling chamber converges over a circumferential angle of the gear wheel, i.e., over the arcuate length of the filling chamber.

In FIG. 1, there is illustrated a longitudinal section through the middle plate of a gear pump according to the invention, this middle plate being enclosed at the front and back by outer plates of the pump casing in a conventional manner. The middle plate 1 has a feed section or zone 2 at the inlet side of the pump as well as an outlet section or zone 3 for the discharge of the molten thermoplastic material. The feed and discharge sections are equipped with flanges 4 and 5 for connecting the pump to correspondingly flanged pipes, conduits or the like.

Two axially parallel bores or partly circular openings 6 and 7 are cut through the middle plate 1 to provide a central cavity in which there are installed the intermeshing gear wheels 8 and 9. These two gear wheels are rotatably mounted in the pump casing, preferably by means of bearing sleeves in a conventional manner (not shown). One of the gear wheels, for example 8, further includes a drive shaft which extends out from one side of the middle plate to pass through the adjacent cover plate, over which a drive torque is transmitted to the gear wheels. The two intermeshing gears 8 and 9 are turned during operation of the pump in the direction of the arrows 10 and 11. As described, one of the gears 8 can be referred to as the drive gear while

the other 9 is the driven gear. The gear teeth 16 are of conventional design, preferably so as to prevent any direct flow of the melt from the inlet 2 to the outlet 3 through the center or intermeshing point of the pump. These gear teeth can also be constructed in known manner to prevent the melt from being trapped between the intermeshed teeth or carried back toward the inlet.

The initial filling or supply zone 12 within the central cavity of the pump casing is widened in the circumferential direction of the gear wheels by the converging wedge-shaped filling chambers 13 and 14. These filling chambers have the function of giving to the more or less highly viscous melt flowing into the filling zone an opportunity to remain over a relatively long circumferential path in contact with the outer toothed surface of the gear wheels 8 and 9. With the rotational speed of the gears remaining constant, the time is thereby increased during which the melt has an opportunity to penetrate into the tooth gaps 15 located between adjacent teeth 16. In order to properly fulfill this function, it is essential to correctly dimension the arcuate wedge-shaped filling chambers 13 and 14, and this feature therefore represents the primary objective of the present invention.

The gear pump of the invention is thus characterized in that the height 17 of the entry opening 18 into each wedge-shaped chamber 13 or 14 is at least equal to about one times the height of a tooth 16, it being understood that these height measurements are taken radially of the gear. Also, the initial or entry height of the filling chambers 13 and 14 at the inlet, i.e., where these chambers adjoin the inlet section 2, is measured radially of the gear from its outer periphery to the facing wall 20 of the chamber. As a further condition of the invention, it is essential that the length of the individual filling chambers 13 and 14 is equal to about 5 to 10 times, preferably 6 to 8 times, the height of a tooth 16. This arcuate length can be measured along the outer circumference or periphery of the toothed gear, taken as the base of the wedge-shaped chamber, but is preferably identified as a radian measurement corresponding to the arc or angle 19.

For the exact geometric configuration of the filling chambers 13 and 14 there exists a number of different possibilities. The most practical and useful configurations are explained in FIG. 2 in graphical form.

In the graph of FIG. 2, the horizontal coordinate represents the length of the arcuate filling chamber, expressed as the radian measurement such as 19 in FIG. 1, taken with reference to the radius R of the gear wheel. On the vertical coordinate of this graph, there is plotted the height of the chambers 13 and 14, for example, in the form of the angle which a plane tangent to the outer periphery of the gear forms with a plane tangent to the roof or wall 20 of the chamber 13.

Curve I of FIG. 2 illustrates that case in which the chamber height first remains constant from the feed inlet or chamber entry opening 18 onward over a relatively large arc or length of the chamber and then falls off steeply toward the end of the chamber. Curve II illustrates a more advantageous embodiment in which the height of the chamber is reduced linearly from the entry opening to the end of the chamber, i.e., where the filling chamber height is an approximately linear function of the chamber length. Finally, Curve III illustrates an especially preferred embodiment of the filling cham-

ber, in which the height is reduced at first to a stronger degree and then to a weaker degree, i.e., so that the height of the chamber is a non-linear function of its length wherein a substantially greater degree of height reduction is followed by a substantially smaller degree of reduction as compared to a linear reduction.

All of the embodiment represented in FIG. 2 take into account the fact that during the progressive filling of the tooth gaps 15, the "free" melt volume remaining in the filling chamber 13 or 14 becomes less and less. The embodiment according to Curve III of FIG. 2 furthermore takes into account the fact that the flow resistance experienced by the melt in its progressive penetration into the tooth gaps 15 is increased directly with the progressive increase of the boundary surface between melt and tooth surfaces. Thus, it has been found to be especially advantageous to increase the flow resistance more rapidly at the beginning of the chamber so that the rate of its increase can be substantially decreased near the end of the chamber.

In order to achieve optimum flow conditions for the melt at the chamber entry opening 18, it is further proposed in accordance with the invention that the upper boundary or intersecting edge 21 be rounded, i.e., the edge formed between the inlet section 2 and the arcuate cavity wall 20. The radius of this rounded edge should preferably be at least equal to the height of a gear tooth 16. With this dimension, it has been found that the flow conditions of the melt at the entry opening 18 of each filling chamber 13, 14 are greatly improved and permit an optimum filling rate.

The dimensions of the feed or inlet section 2 are less critical, but for purposes of discharging a thermoplastic melt from a reactor or similar feed source at a rapid rate of flow, it is advantageous to broaden this inlet 2 at its entry into the pump as much as possible and then permit it to taper slightly inwardly until it joins with the central cavity or bores 6 and 7 of the pump casing. The depth of the inlet 2 corresponds to the thickness of the middle plate 1 of the pump casing 23, i.e., corresponding to the axial length of the gears 8 and 9. With a narrower inlet 2, it is advisable to increase the height 17 of the connected entry opening 18, i.e., at the inlet into the filling chambers 13 and 14, maintaining of course a symmetrical relationship with reference to both gears. At the same time, the breadth of the inlet 2 (transverse to the flow direction) and its height (along the flow direction) tend to be limited since it is desirable to maintain the melt at a reasonably uniform temperature during its flow through the pump. Thus, to avoid excessive heating requirements or inadequate heating over the cross-section or length of the melt flow as it is fed into the pump, it will be recognized that practical maximum limits are placed on the inlet 2 as well as the overall size of the pump.

FIG. 1 makes it further evident that the pump casing 23 formed by the middle plate 1 and front and back cover plates is advantageously constructed as a double-walled or jacketed casing so that it is surrounded by a hollow space 24 which can be used in a known manner for heating the gear pump. The hollow space 24 can be connected with a fluid conduit 25 which is provided with a flange 26, thereby permitting the introduction of any suitable heating fluid in known manner, for example, using diphenyl as a fluid heat exchange medium. To be sure, other types of heating are also possible, for

example, by installing suitable electric resistance heating elements as is quite common in this art.

In the use of the gear pump of the invention, it is connected by means of the flange 4 to a supply source, for example to a reactor in which the melt has accumulated under reduced pressure. The pump is especially useful in conveying a thermoplastic polymer in the form of a highly viscous reaction product from the collecting zone or other interior space of the reactor. By means of the flange 5, the exit or discharge section 3 of the pump is connected to a pipe line or conduit which feeds the molten thermoplastic material to other processing apparatus, for example, a granulator. When the thermoplastic melt flowing into the primary filling zone 12 is relatively fluid and non-viscous, it becomes deposited more or less completely in the gear tooth gaps 15 of the gears 8 and 9 turning relatively slowly in the direction of the arrows 10 and 11. However, as the viscosity of the conveyed melt becomes higher and/or the gears are more rapidly rotated, the less complete becomes the filling of the tooth gaps 15. At a constant rotational speed of the gears and above a certain viscosity level, the staying or retention time of the individual tooth gaps in the region of the primary filling zone 12 is no longer sufficient to take up the melt completely. The teeth then move into the secondary filling zone of the arcuate wedge-shaped chambers 13 and 14 in which there occurs an after-filling of the tooth gaps. Thus, a decrease in the volume of the thermoplastic melt initially present in the tooth gaps 15 is compensated by a corresponding reduction in the interior space of the chambers 13 and 14, this reduction being achieved by the already described arcuate wedge-shaped design of the chambers as formed by the converging cavity wall section 20.

Practical experience and extensive testing with the gear pump according to the invention have shown that this type of pump will operate efficiently without difficulties even when transporting highly viscous thermoplastic melts in a viscosity range above about 20,000 poise. The performance of the new pump in this high viscosity range corresponds to the performances which previous gear pumps of equal size have shown only in a range of substantially lower viscosities.

By adhering to the specific dimensions of the arcuate wedge-shaped filling chambers or so-called secondary filling zones of the pump according to the invention, it is not a primary object to build up to the pressure on the melt as it is transported by the rotating gears. Instead, the extension of the filling zone into the converging wedge-shaped chambers assures that the melt has sufficient time to flow into the spaces or gaps between adjacent gear teeth and to completely fill these spaces. Thus, while it would be possible to increase the pressure by using similar chambers of relatively smaller dimensions, this would not inherently permit a proper filling around each gear, especially with highly viscous melts and/or at the maximum rotational speed of the gears.

While each wedge-shaped chamber as essentially defined by its height at the inlet and its arcuate length can be shaped such that the initial height remains constant over a considerable portion of the chamber length, it is much more advantageous to permit a continuous reduction of this height from the inlet over the arcuate length, i.e., to provide a gradually converging or tapering dimension. This permits the melt to penetrate fur-

ther and further into the gaps between adjacent gear teeth as the melt advances around the outer periphery of the gears. The so-called "free space" of the melt in the wedge-shaped chambers, i.e., between the outer gear periphery and the facing wall of the gear-receiving cavity, is best shaped so as to be sharply reduced over its first or initial length and then much more gradually reduced as it approaches its converging end.

Taking into account the decreasing "free volume" of the melt, i.e., that volume which is not directly engaged by the gear teeth, a heating of the pump casing by any suitable means becomes especially significant because it improves the exact filling of the melt in the interior of the carefully dimensioned wedge-shaped chambers or pockets. Such heating thus contributes to the achievement of a maximum conveyance or delivery capacity in the pump performance without any significant danger of overheating the melt. The wedge-shaped chambers or pockets are still sufficiently small as to be very uniformly heated, but the retention time is also quite short as the melt passes through these chambers and then circumferentially in the small gaps between the gear teeth after the cavity wall has converged onto the gear periphery. Therefore, it becomes quite safe to raise the melt temperature to a maximum value, corresponding to the lowest possible viscosity of a given melt, exactly along those points where a maximum filling of the gears and the most rapid conveyance must be achieved.

It will be appreciated that only a limited number of embodiments of the gear pump according to the invention have been illustrated and described in detail hereinabove, and that a relatively large number of variations are permissible within the prescribed limitations. Also, while the gear pump of the invention is not limited to use with highly viscous thermoplastic melts, it is specifically designed to achieve maximum performance for this purpose, especially as a discharge pump for polymerization or polycondensation reactors. Thus, the gear pump of the invention will be found to be especially useful in conveying or discharging any highly viscous liquid, especially from an evacuated container or vessel, and assures a complete filling of the gear tooth gaps while also permitting a substantial increase in the rotational speed of the gears. Finally, it will be noted that the invention provides a gear pump having a gener-

ally conventional and economical design, requiring only moderate but significant changes in the central gear cavity.

I claim

1. A gear pump for transporting a viscous thermoplastic melt wherein the pump casing contains two intermeshed toothed gears mounted for rotation on parallel axes and situated in a hollow cavity of the casing for transport of the melt from an inlet outwardly around each gear to an outlet, the improvement which comprises an elongated arcuate wedge-shaped filling chamber located along a circumferential portion of each gear and extending from said inlet while converging in the circumferential direction onto the outer toothed periphery of the gear, the height of said wedge-shaped filling chamber at said inlet being equal to at least one times the height of a gear tooth as measured from the periphery of the gear radially outwardly to the facing wall of the cavity, the arcuate length of said wedge-shaped filling chamber being equal to about 5 to 10 times the height of a gear tooth as measured from said inlet circumferentially to the point of convergence on the gear periphery and said height of the wedge-shaped chamber being reduced gradually from said inlet to said point of convergence such that the angle formed by a plane tangent to the gear periphery with a plane tangent to the facing wall of the cavity is reduced as a function of the arcuate length of said chamber, which function is a linear to non-linear function with any non-linearity requiring a substantially greater degree of height reduction followed by a substantially smaller degree of height reduction over said arcuate length.

2. A gear pump as claimed in claim 1 wherein the length of said wedge-shaped filling chamber is about 6 to 8 times the height of a gear tooth.

3. A gear pump as claimed in claim 1 wherein the intersecting edge of the inlet wall with the cavity wall facing the gear periphery is rounded.

4. A gear pump as claimed in claim 3 wherein the radius of said rounded edge between the inlet wall and the cavity wall facing the gear periphery is equal to at least about one times the height of a gear tooth.

5. A gear pump as claimed in claim 1 wherein heating means are included in the walls of the pump casing.

* * * * *

50

55

60

65

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,746,481 Dated July 17, 1973

Inventor(s) Heinz Schippers

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

Column 1, line 20, "A a rule" should read -- As a rule --.

Column 3, line 18, "5 to 10 5 times" should read
-- 5 to 10 times --.

Column 5, line 7, "embodiment" should read -- embodiments --.

Column 8, line 5, claim 1, "A" should read -- In a --; line 21, claim 1, "as measures" should read -- as measured --.

Signed and sealed this 27th day of November 1973.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

RENE D. TEGTMEYER
Acting Commissioner of Patents