

von Casimir

[54] PULSEFREE PERISTALTIC PUMP

[76] Inventor: **Wolf von Casimir**, Am Blumengarten 8, Munich, Germany.

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3,437,050 4/1969 Hrdina417/476

Primary Examiner—William L. Freeh
Assistant Examiner—Richard E. Gluck
Attorney—Karl F. Ross

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[58] **Field of Search**.....417/474, 475, 476,
417/477

[56] **References Cited**

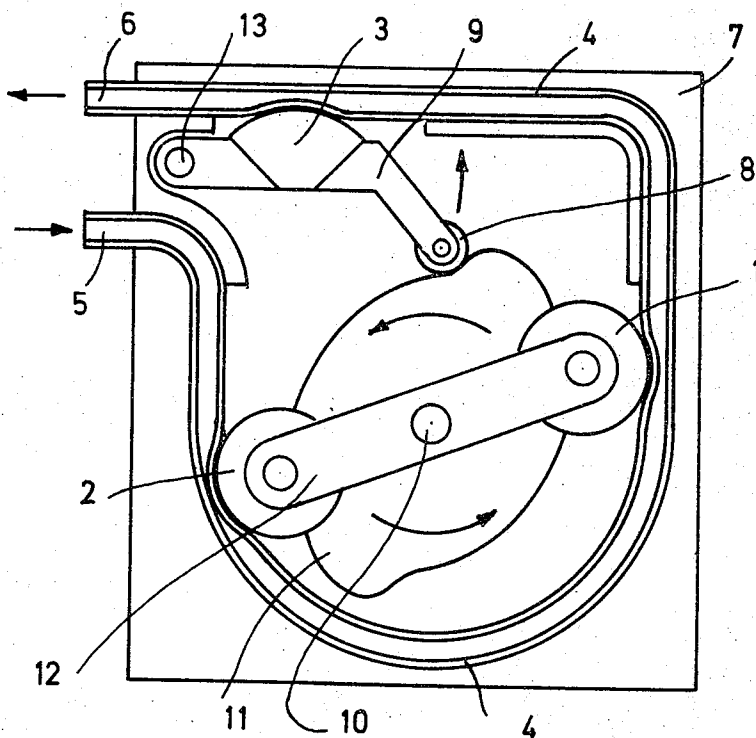
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[57] ABSTRACT

To smooth the pulsations in the flow rate of a fluid conveyed by a peristaltic pump, a cam-controlled pusher is synchronized with the driving elements (rollers or plungers) acting upon the wall of a flexible tube to constrict that wall, at a location downstream of the driving elements, when these elements advance the fluid toward the tube outlet and to allow its expansion at the beginning of every new operating cycle when a new pressure wave is initiated at a location remote from that outlet.

4 Claims, 9 Drawing Figures



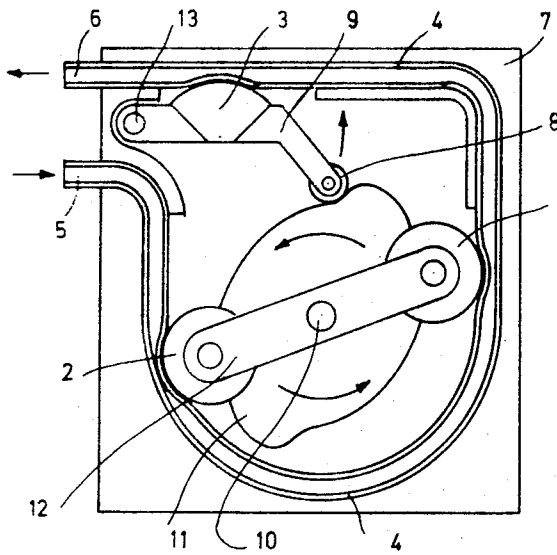


FIG. 1

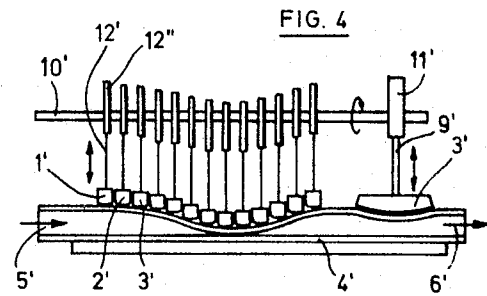


FIG. 4

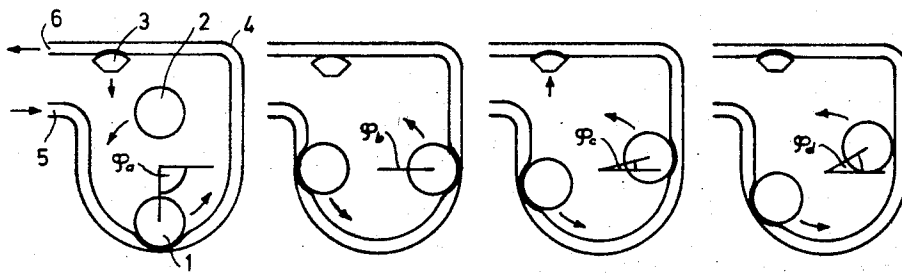


FIG. 2a

FIG. 2b

FIG. 2c

FIG. 2d

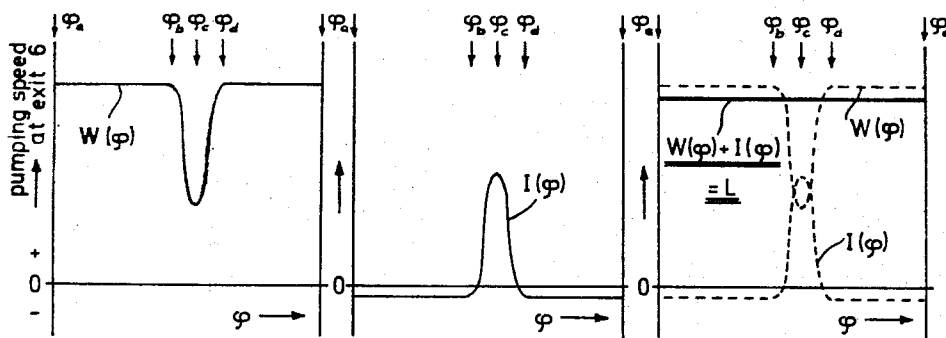


FIG. 3a

FIG. 3b

FIG. 3c

PULSEFREE PERISTALTIC PUMP

My present invention relates generally to the art of pumping liquids or gases with peristaltic pumps.

Conventional peristaltic pumps exhibit a disadvantageous retardation or even interruption of the flow at the exit each time one roller rolls off the tube and the next roller takes over the pumping action. Peristaltic pumps having several pushers which compress the tube in a caterpillar-like motion have the same shortcoming of pulsations. This is caused by the necessity of filling the reexpanding tube when the pumping component loses contact with the hitherto compressed tube.

According to the invention this drawback of the prior art is overcome by introducing a simple device, preferably a cam-operated pusher, which exerts an external pressure on the tube downstream from the pump proper, so that an appropriate compensatory pumping motion can be superimposed on the fluctuating forward motion of the pumped fluid. In the course of an operating cycle this device does not really pump but merely regulates, thus preventing undesired pulsations.

In the accompanying drawing:

FIG. 1 shows a peristaltic pump equipped with a cam-actuated pusher according to the invention;

FIGS. 2a to 2d show diagrammatically the movements of the essential components of the pump;

FIGS. 3a 3c help to explain the cooperation of the rollers and the pusher by showing the different pumping speeds as a function of the angular position of the rollers and of the position of the plunger; and

FIG. 4 shows schematically another embodiment of my invention.

As shown in FIG. 1, a pump embodying my invention comprises a case 7 with a groove for a flexible tube 4. On a shaft 10 there are mounted a cam 11 and a rotating arm 12 bearing two rollers 1 and 2 which roll along the tube 4 along a semicircular section of the groove. A little roller 8 transmits its motion, governed by the contour of the cam 11, to a pusher 3 by means of a lever 9 which is pivoted on a pin 13. A removable cover which is not shown and which is put on the front of the case 7 serves for keeping the tube 4 in its position in the groove.

If the pump is driven in the rotary direction indicated by the arrows in FIG. 1 and in FIGS. 2a to 2d, the i.e. counterclockwise, the fluid to be pumped is sucked in at an inlet 5. Then it is propelled over the semicircular section of the tube 4 toward the spot where the pusher 3 partially compresses the tube 4. After passing this spot the medium leaves the pump via an exit 6.

The respective motions of the essential components, i.e. of the rollers 1 and 2 and of the pusher 3, during an operating cycle are shown in FIGS. 2a to 3d.

If the pusher 3 does not operate the roller 1 produces a pumping speed or delivery rate $W(\phi)$ as a function of its angular position ϕ as shown in FIG. 3a. The dip indicates the retardation of the flow at the exit 6 of the pump. This retardation is caused by the necessity of filling the reexpanding section of the tube 4 when the roller 1 moves off as it turns from position ϕ_b via ϕ_c to ϕ_d . After the roller 1 has lost contact with the tube 4, i.e. after passing through position ϕ_d , the pumping speed rate $W(\phi)$ is again at its normal level produced by the rollers 1 and 2 when rolling along the semicircular section of the tube 4.

The pusher 3 has to compensate the retardations of the flow. This is effected by forming the contour of the

cam 11 in such a way that a supplemental pumping rate $I(\phi)$ results, which is shown in FIG. 3b and which is measured at the exit 6 if the rollers 1 or 2 do not operate.

From FIG. 3b it will be seen that the pumping rate $I(\phi)$ assumes both negative and positive values. The volume of fluid admitted to the reexpanding constriction of the tube 4, following the downward motion of the pusher 3, is exactly equal to the positively displaced volume due to the upward motion of the pusher 3 coinciding with the angular motion of the roller 1 from ϕ_b via ϕ_c to ϕ_d . In the course of a cycle the pusher 3 in fact, does not pump but merely regulates. This cooperation of the rollers 1 and 2 with the pusher 3 may be compared with the behavior of a pressure accumulator: the pusher 3 holds back some of the fluid while the rollers 1 and 2 are working with full pumping speed, and restores it to the mainstream when the roller-pumped supply is reduced to its minimum volume.

More particularly, the shape of the cam 11 illustrated in FIG. 1 is such that, as shown, its radius has a minimum value at the two points engaged by the follower 8 at the instants when the rollers 1 and 2 restart the operating cycle every 180° of rotation by initiating a new pressure wave at a location remote from outlet 6, i.e. at the point of contact between tube 4 and roller 2 in the depicted position. With the cam rotating counterclockwise, follower 8 rides up one of its two diametrically opposite humps to a point of maximum radius; its radius then decreases progressively for almost half a circle, thereby generating the negative pressure which gives rise to the negative velocity component shown in FIG. 3b. Thus, the tube outlet 6 is partially blocked by the pusher 3, located downstream of the zone of engagement of the tube wall with driving elements 1, 2, at the very instant when roller 2 goes into action to generate additional pressure in the direction of flow; gradually, thereafter, this outlet is unblocked so that the excess fluid stored at the moment of blocking in the downstream tube portion can flow out at a controlled rate.

As will be seen from FIG. 3c, the superposition of the pumping speed $W(\phi)$ of the rollers 1 and 2 and the compensatory pumping rate $I(\phi)$ of the pusher 3 establishes a pulsation-free pumping rate L which does not the angle ϕ but merely on the rotary velocity $d\phi/dt$ of the pump.

The exact mathematical formulation of these relationships is as follows: to the time-dependent pumping speed $W(\phi)$ of the pump another pumping speed $I(\phi)$ is added which conforms, at every instant t during the time interval from t_1 to t_2 of an operating cycle, to the equations

$$\int_{t_1}^{t_2} I(t) dt = 0 \text{ and } I(t) = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} W(t) dt - W(t)$$

This enables everybody skilled in the art to find out the contour of the cam 11 by measuring the curve $W(t)$ or $W(\phi)$, then determining $I(\phi)$ preferably graphically, and reproducing step by step the position of the pusher 3 and the position of the cam-follower roller 8 which governs in this experiment the contour of the cam to be determined.

A peristaltic pump of another type is shown in FIG. 4. The flexible tube 4' is compressed in a caterpillar-like motion by several plungers 1', 2', 3', ...; plunger 1' for instance is actuated via a bar 12' by a cam 12'', the latter being mounted on a shaft 10' together with the cams of the other plungers. The shaft 10' also drives the cam 11' which effects the compensatory motion of the pusher 3'. Thus a steady pumping speed is attained, according to the invention, at the exit 6'.

Peristaltic pumps according to the invention may also be used as constant-rate suction pumps within the given limitations of the deformability of flexible tubes by suction. If steady pumping in either direction is desired, another pusher working on the other side of the pump proper has to be provided.

In all fields of medical, chemical and biochemical research or industries where constant-rate delivery and of sensitive or active fluids is desired, the aforescribed peristaltic pump as shown in FIG. 1 is advantageous because of its simple structure as well as of the easy way the tube can be fitted into the pump or the pump can be installed in or removed from a closed-flow system without disconnecting any tube involved. This is very important for instance where sterile conditions are to be maintained.

I claim:

1. A peristaltic pump comprising:

- a tube provided with a flexible wall having an inlet for a fluid to be conveyed, an outlet for said fluid and an operating zone between said inlet and outlet;
- driving means periodically engageable with said tube along said operating zone for deforming the wall thereof to advance said fluid toward said outlet in a series of recurrent operating cycles, said driving means comprising a set of driving elements and shaft means for intermittently moving each driving element into contact with said tube to obstruct same completely at a point advancing from said inlet toward said outlet in the course of an operating cycle;
- a pusher movable substantially at right angles to the wall of said tube at a location downstream of said

zone, said pusher being capable of only a partial blocking effect; and

cam means synchronized with said driving means for actuating said pusher to constrict said tube upstream of said outlet at a stage of each operating cycle in which the driving element closest to said pusher is substantially fully withdrawn from said wall for progressively allowing the tube to expand at said location during the remainder of an operating cycle, thereby smoothing the flow of said fluid through said outlet.

2. A pump as defined in claim 1 wherein said cam means is mounted on said shaft means.

3. A pump as defined in claim 2 wherein said driving elements are a plurality of rollers and a rotatable support therefor coaxially mounted with said cam means for moving each roller in contact with said tube along an arc centered on said shaft means.

4. A peristaltic pump comprising:
a tube provided with a flexible wall having an inlet for a fluid to be conveyed, an outlet for said fluid and an operating zone between said inlet and outlet, said operating zone being substantially semicircularly curved about an axis;

a support rotatable about said axis;
a pair of diametrically opposite driving rollers mounted on said support for alternate engagement with said tube along said operating zone for deforming the wall thereof to advance said fluid toward said outlet in a series of recurrent operating cycles by obstructing said tube completely at a point advancing from said inlet toward said outlet in the course of an operating cycle;

a pusher movable substantially at right angles to the wall of said tube at a location downstream of said zone with a partial blocking effect; and

cam means on said shaft for actuating said member to constrict said tube upstream of said outlet at the beginning of each operating cycle and for progressively allowing the tube to expand at said location during the remainder of an operating cycle, thereby smoothing the flow of said fluid through said outlet.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,726,613 Dated 10 April 1973

Inventor(s) Wolf von CASIMIR

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

between the lines "[21]" and "[52]" of the heading insert:

--[30] FOREIGN APPLICATION PRIORITY DATA

11 October 1969 Germany P 19 51 347.4--.

Column 4, line 5, for "operatic" read -- operating --.

Signed and sealed this 12th day of March 1974.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents