United States Patent [19]

Hayward

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[45] **Nov. 20, 1973**

[54] **MEANS FOR PUMPING LIQUIDS IN A PIPELINE**

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[52] **U.S. Cl.** **415/11,** 416/157, 290/52

[51] **Int. Cl.** **F04d 15/00,** F01d 15/10

[58] **Field of Search** 416/157, 158; 415/11; 290/52

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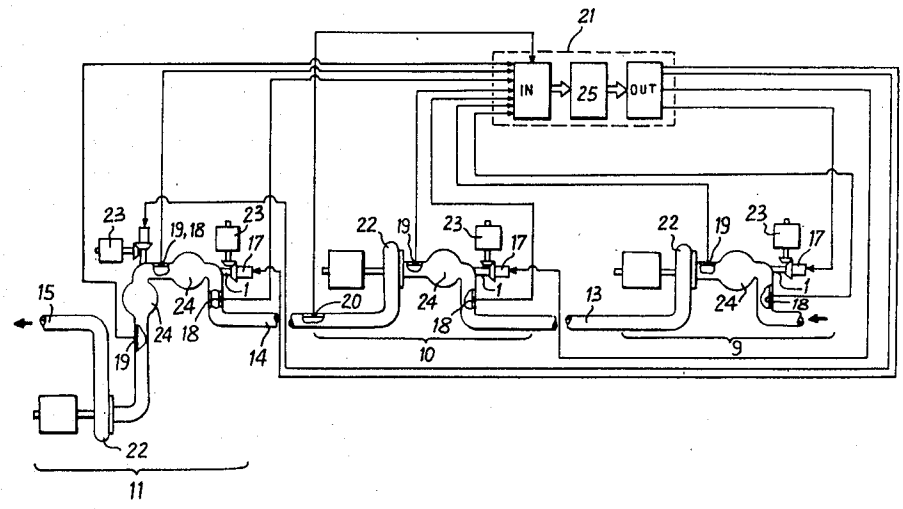
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[57] **ABSTRACT**

A pump for use in pumping liquids along a pipeline and having particular use in pumping hydrocarbons along extensive pipelines. The pump can be mono- or multi-stage with each stage having a rotor mounting pivotal paddles disposed on a cone of revolution whose axis is coincident with the axis of the rotor. Mechanical means such as gearing is provided to pivot the paddles, which gearing is operated by a servomotor. This servomotor is controlled by adjustment means which receive signals from measure devices or meters located in the pipe or pipeline and which measure the hydraulic parameters of flow in the pipeline.

5 Claims, 4 Drawing Figures



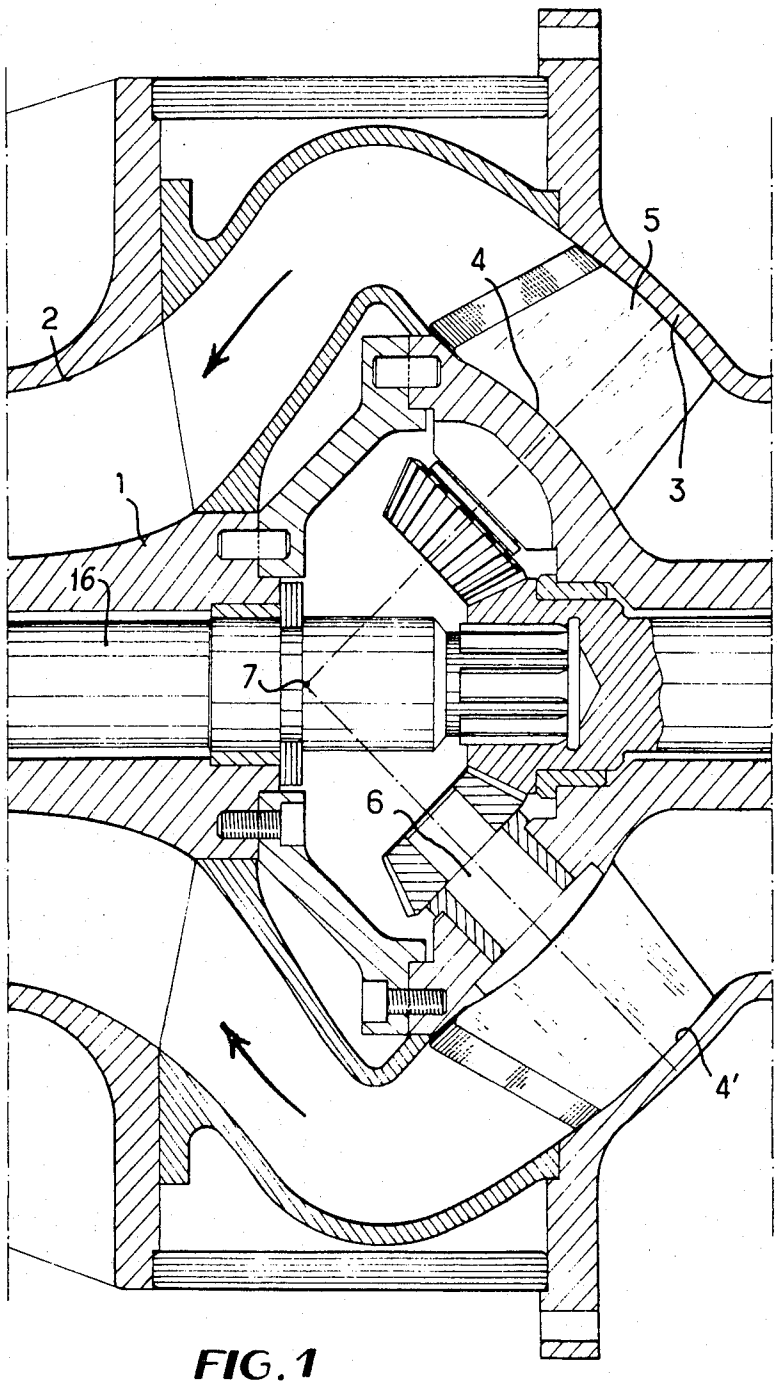
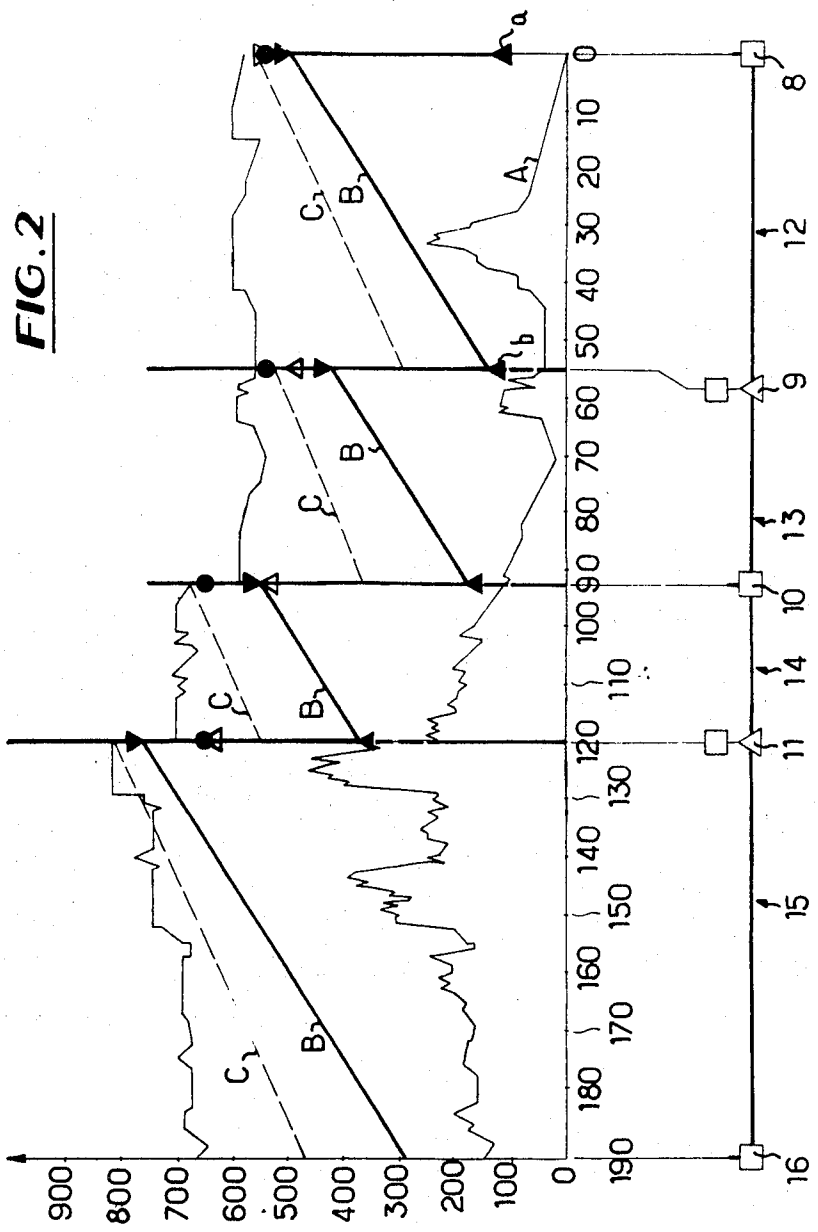


FIG. 1

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FIG. 2


900
800
700
600
500
400
300
200
100
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
8
12
9
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16
a
b
A1
B1
C1
B
C
B1
C
B1
C1

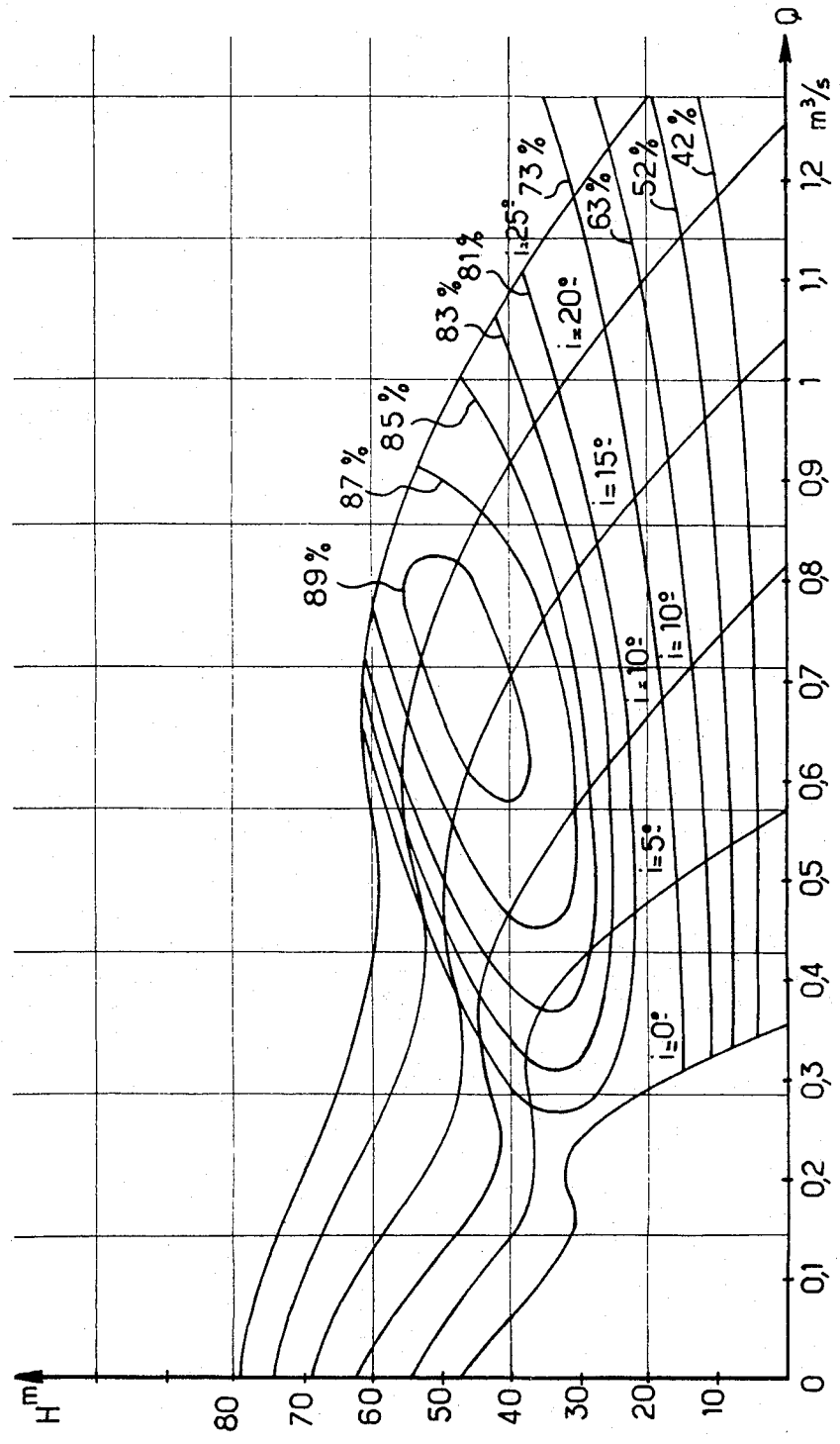

Q
m³/s
0
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8
0,9
1
1,1
1,2
H
m
10
20
30
40
50
60
70
80
89%
87%
85%
83%
81%
i=25°
73%
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42%
i=20°
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i=10°
i=10°
i=5°
i=0°

FIG. 3

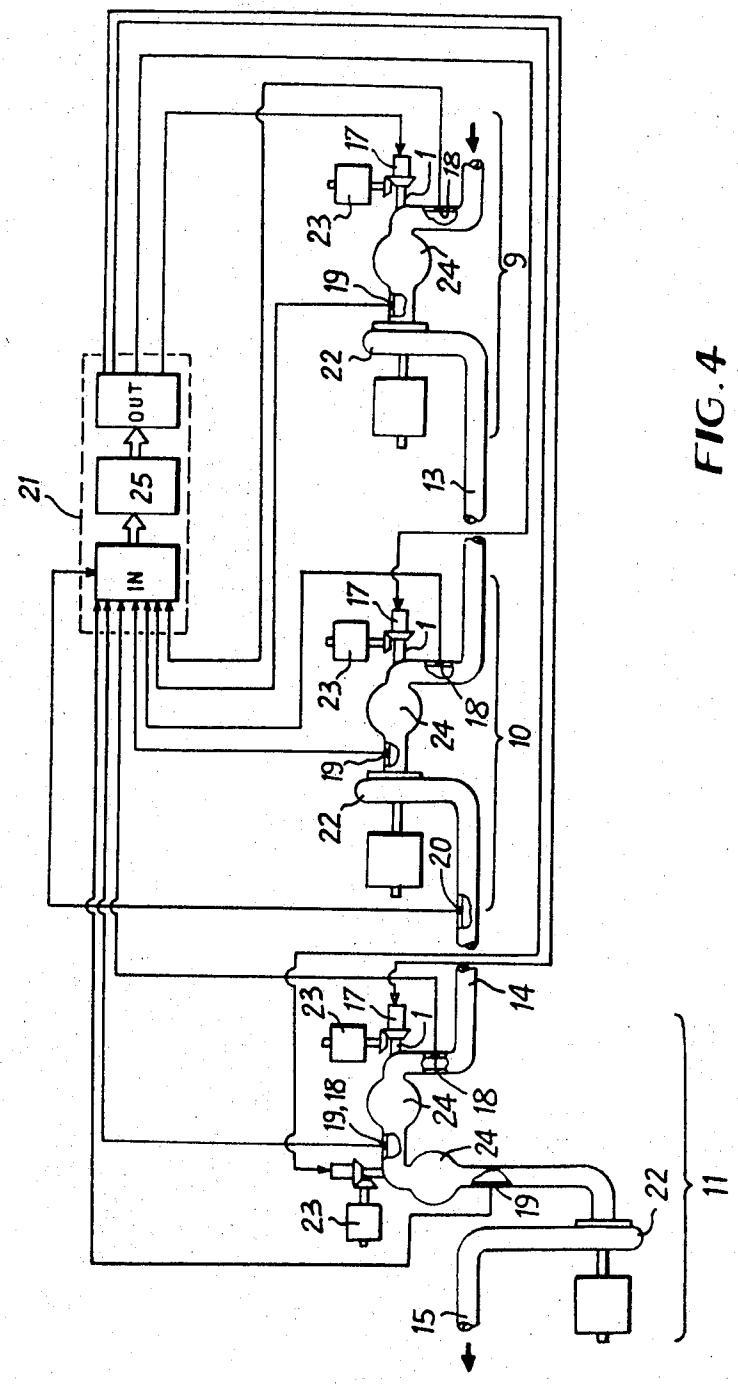


FIG. 4

MEANS FOR PUMPING LIQUIDS IN A PIPELINE

This invention relates to a device for pumping liquids along a pipe and relates in particular to the pumping of liquids, such for example as hydrocarbons, through piplines or to the pumping of solid material in suspension in a liquid.

It is known that a considerable amount of the cost of the transportation of liquids, and in particular hydrocarbons, through pipes of considerable length such for example as pipelines, is taken up by the cost of the energy necessary for pumping, this energy often being electrical energy. It is thus important that the pumping device ensuring the conveyance of the liquids has as high an output as possible. In addition, it is desirable that the pumping device has considerable operating flexibility in order to be able to adapt to the variable conditions in which the conveyance of different liquids through the pipeline takes place with as reliable operation as possible in order to avoid inopportune stoppages or slowing down of the liquid column, for safety reasons and for economic reasons.

Until now, conveyance through pipelines took place by means of pumping groups disposed in stations spread along the pipelines, the pumps being of the centrifugal type.

It is known that the operation of pipelines is conditioned by the situation in that section of pipeline where flow occurs in the most unfavorable manner, which section may, moreover, vary in the same pipeline according to the characteristics and particularly the viscosity of the different liquids which pass sequentially through the pipeline. The result is that the pressures and the flow assured by the pumping groups must vary frequently. These variations are at present caused either by the creation of additional pressure-losses or by variation of the flow speeds, for example, by means of regulators. In both cases, there is a considerable waste of energy, all the more since the different pumps operate with outputs imposed by the head and the assured flow and which are often far from the maximum outputs of the pumps. By considerable variations of flow, the pumping groups are started (or stopped) in parallel or in series. The starting or the stoppage of these pumping groups is abrupt, and this is translated by a loss of energy under temporary operating conditions, causing, moreover, mixture of the liquids on either side of the original interface.

Due to this lack of flexibility, it is difficult to take effective meansures against incidents such as water-hammering. Generally, when water-hammering occurs, it is ncessary to stop different pumping groups, which is translated upstream by cumulative effect in the region of each station which can cause damage to the pipeline.

In order to obviate or mitigate these different disadvantages, the present invention proposes the provision of a device for pumping liquids through a pipe, in particular along pipelines, which device has an economic cost price, facilitates constant operation with a high output and ensures operation of the pipeline with a maximum flexibility while reacting instantaneously to different situations which may occur.

According to the present invention, there is provided a device for pumping liquids along or through a pipe, the device comprising in combination, a plurality of mono- or multi-stage pumps whereof each pump rotor has paddles pivotable simultaneously about shafts located on a cone of revolution whose axis merges with the axis of the rotor, the pumps comprising devices which permit to pivoting of the said paddles, servomotors associated with the pumps for controlling the rotation of paddles about their shafts, drive means for driving the pumps, devices or meters located in a pipe associated with the pumps in the vicinity of the pumps for measuring the hydraulic parameters of flow of the pipe, and adjustment means receiving the measurements coming from the measuring devices or meters and controlling the servomotors for orientation of the paddles.

In a preferred embodiment of the invention, particularly applicable to pipelines, the pumps, provided with their servomotors and drive motors, are located at pumping stations provided along the pipeline according to the geographical configuration of the latter, each pumping station comprising a flow meter, meters for the suction and delivery pressure and optionally a meter for density and viscosity. The adjustment means acting on the servomotors for pivoting the paddles of the pumps are provided with electrical or other controls which enable them to receive the measurements of the devices or meters, these adjustments means comprising, moreover, devices which make it possible to compare the data received from the measuring devices or meters with data recorded externally, for example, the prescribed flows and/or pressures.

An embodiment of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

FIG. 1 is a diagrammatic view of a device for pumping according to the present invention;

FIG. 2 shows schematically the layout of a pipeline and the pressures established in the various sections of the pipeline by pumps for a given flow of a given liquid; and

FIG. 3 is a graph showing, for a given speed of rotation, the characteristics and the output curve of a pumping device according to the present invention.

FIG. 4 is a diagrammatic view of a pumping system incorporating principles of the present invention.

Referring to FIG. 1 there is shown one stage of a pumping device according to the invention, which stage comprises a rotor **1**, driven from the outside of a pipe by drive means (not shown), for example, electrical or diesel motors. The rotor **1** rotates within a front diffuser **2** and a rear diffuser **3** and comprises an annular section **4** preferably, but not exclusively, of spherical or even toric shape. This section **4** is provided with a number of paddles **5**. The pipe section **4'** located oppsite the rotor section **4** preferably also has a spherical shape. The paddles **5** are pivotable about shafts **6** which penetrate the rotor section **4**, the geometric extension of the shafts **6** all passing through the same point **7** on the rotor shaft so as to be all located on a cone of revolution, whose axis merges with the axis of the rotor. An appropriate mechanism **16**, for example, pinions or helical ramps, provided inside the rotor, makes it possible to pivot all the paddles **5** simultaneously about their respective shafts **6** through the same angle. According to the invention, the drive of the paddles **5**, through the intermediary of this mechanism **16**, takes place by means of a servomotor **17** which can be located either inside the rotor or even outside the pipe. It will be seen that by pivoting the paddles **5**, it is possible, if desired, practically to block the flow passage in the pump, so

that the paddles 5 have the effect of a gate on condition they are appropriately shaped. It will be readily understood that for a given speed of rotation, it is possible, by altering the inclination of the blades 5, to adapt the pumps so as to ensure flow and pressure with maximum efficiency. Indeed, in these pumps the output depends on the flow and the inclination of the paddles, as can be seen in FIG. 3. In this figure, the X-axis, Q, represents the flow in cubic meters per second and the Y-axis, H, the head in meters of water.

The curves $i = 0°$ to $i = 25°$ represent the characteristics for the different values of the angle of inclination i of the paddles. The curves 42 to 89 percent represent the curves of constant output.

Referring now to FIG. 2, a pipeline is illustrated in this figure which comprises a first station 8 and three intermediate stations 9, 10 and 11, defining four sections of pipeline 12, 13, 14 and 15, the section 15 ending at a delivery terminal 16 from which distribution of the liquids can be made to various users. There can be seen from the curve A, for which the X-axis is in kilometers and the Y-axis in meters, the outline in altitude of the pipeline.

Each of the stations 8, 9, 10 and 11 is provided with pumps of as hereinbefore described each with several stages.

By means of an appropriate device fluid entering the station 8 by suction is at a pressure corresponding to a head (*a*) of approximately 100 meters, the pumps of the station 8 raising this pressure head to 500 meters, a pressure at which the liquid, for example, a hydrocarbon, is sent into the pipeline. Due to the pressure losses the head decreases as the liquid moves forward in the section 12 and this decrease can be seen on the curve B which represents the pressure of the head of liquid, depending on the distance covered.

The liquid comes under the suction of the station 9 with a head of approximately 150 meters, at a point (*b*). At this point (*b*) the liquid is taken up again by the pumps of the station 9 which raise the pressure to a head of a little more than 400 meters. A new increase is produced in station 10, then in station 11 and the liquid or fluid finally arrives at the terminal 16 with a head of a little less than 300 meters.

Assuming that the flow and other conditions remain constant the curve D will remain constant in time. It is supposed that under these conditions the pumps of the various stations rotate at their maximum efficiency, characterized by the angles of inclination of their paddles 5, the angles generally differing from one station to the other.

Measuring devices or meters 18, 19, 20 make it possible to measure constantly, at the different stations 8, 9, 10, 11 and also possibly at the terminal 16, the suction pressure and the delivery pressure of the pumps, the density of the liquid in the various stations, the temperature and possibly the viscosity in the various stations.

The information from these measuring devices or meters 18,19,20 is transmitted to adjustment means 21 which can, example, be centralized at 21 for the whole pipeline. It is also possible, in a preferred embodiment, to provide autonomous control means at each station, these means being simply connected to a central command station 21 issuing the operating instructions.

When permanent operating conditions have thus been established, characterized by the flow and the suction and delivery pressure in the different stations, these operating conditions can change suddenly and this is generally the case in pipelines. Assuming for example, that a liquid of different density and viscosity, for example, greater viscosity, is now introduced through the first station 8, the pressure conditions will change rapidly through the whole pipeline, taking into account the fact that the delivery head, and likewise the pressure-loss, vary in section 12. The new conditions which are established in the pipeline are immediately detected by the measuring devices or meters which transmit this new data to the control means in which are effected calculations which make it possible to determine the new conditions to be established at the various points of the pipeline, in order to maintain constant flow and head for example. When these conditions have been determined, the control means define the angles which the paddles of the various pumps at the stations will have to adopt. Thus, the control means send the various servomotors of the pumps the appropriate instructions and these servomotors determine the orientation of the paddles of the pumps. Thus, the measuring devices or meters detect the new conditions which are established. In a case where these new conditions are different from the conditions provided, a new control would be effected in the same manner. If necessary, it is possible to vary the speed of the pumps while adjusting the orientation of the paddles of their stages in order to maintain an optimum output. As has been stated above, the control means preferably comprise autonomous control devices provided in the vicinity of each station thereby facilitating the automatic control of the station.

During the operation of a pumping station according to the invention, the pressure limits between which the station is allowed to operate are determined by pressure regulators, whose control parameters are preregulated and dependent of the mechanical possibilities of the pipeline. The flow in the station is prescribed by the stations upstream. The delivery head of the station is prescribed by the pressure-loss caused in the downstream section. All these parameters are determined by the measuring devices or meters 18, 19, 20 located at the stations and these parameters are transmitted to the automatic control device of the station, whose function is to set in action the required number of pumps 24 and adjust the angle of the paddles in order to obtain the maximum overall output. The automatic control device 25 can comprise, for this purpose, a cam surface corresponding to the output curves of the stations (these curves are obtained from the curves of FIG. 3 taking into account the number and the arrangement in series and/or parallel of the pumps), the cam surface cooperating with a roller or a follower positioned by positioning means controlled by the value of the parameters received by the measuring device or meter. The position in altitude of the roller or the follower on the cam surface determines the sending of a signal corresponding to this position to the servomotors of the pumps of the pumping station in order to determine the angle of inclination of the paddles of the pumps.

In such an automatic control device, it is also possible to replace the cam surface by a mathematical model of the characteristic surfaces of the pumps, such surfaces being comparable with surfaces of the second degree. In this case the control device can comprise a logic analog or numerical calculator connected to the various measuring devices or meters of the station, the calcula-

tor sending to the servomotors of the pumps of the station, instructions for bringing the angles of inclination of the paddles to the value corresponding to the point on the characteristic surface of the pumping group and the X-axis and Y-axis of which are determined by the values coming from the flow and pressure measuring devices or meters.

The mathematical model of the characteristic curves preferably comprises the calculation of the derived function in order to be able to calculate the maximum outputs instead of finding them step by step. One thus avoids the so-called "pumping" phenomenon which constituted a frequent disadvantage of standard regulators. The control means comprise, in addition to the local automatic control devices of the pumping groups, a central command device **21** connected to the various stations and sending to the various stations instructions (angle of inclination of the paddles, starting or stopping of the additional pumps, operating of shutters) depending on a mathematical model at **25** which determines the optimum pumping conditions in the pipeline according to the various parameters which are known in advance (volume and nature of the (cargo) product conveyed, requirement of the users, technical and economic conditions for the use of the pipeline). The mathematical model at **25** which is thus determined in known manner allows the central command device **21,** which can, for example, comprise a computer operating in proper time, the conditions which it would be most appropriate to have at each station, either terminal or singular. It is in dependence on the established conditions that the automatic control devices of the pumping stations act to adjust and maintain the operation of the pumps with as high an output as possible. The device according to the invention thus enables the various automatic control devices which it comprises to carry out a continuous and optimum control of the pumps as regards their number and the angle of their paddles and this over the whole extent of the possible range of permissible parameters. If certain instructions can no longer be respected the mathematical model informed by the measuring devices or meters and the transmission means will be able to determine new instructions which will also be made optimum by the said automatic control devices.

It should be noted that the device according to the invention makes it possible to obtain notable progress relative to known pipelines. Indeed, in the latter, assuming for example, that for a given flow, all the pumps are rotating at the optimum output and that it is necessary to reduce the heads, it would thus be necessary to throttle the flow by creating artificial pressure losses and by losing on the total output or by varying the speed of the pumps, which thus causes losses of efficiency, or even by stopping one or more pumps. It should be noted that in pipelines generally the conditions vary constantly not only due to the different liquids but due to requirements at the inlet and the outlet as well as to the tariff variations of hourly periods of electricity. It should be noted that due to the invention, the adaptation to the various, desired new conditions takes place gradually due to the possibility of progressively varying the inclination of the paddles of the pumping devices.

Thus, when the same phenomenon occurs in a conventional pipeline, i.e., when a more viscous liquid is introduced into a pipeline traversed by a less viscous liquid, it will be necessary, in order to respect the safety conditions of the pipeline, to reduce the flow so as not to have too great a pressure loss and so as not to be obliged to apply too great a pressure at the inlet. Stations such as **9, 10, 11,** must thus modify their operation as well as the inlet station **8.** It is thus necessary either to create pressure losses, which incur sudden stoppages in the liquid column, or to vary the speed of the pumps, which causes a rapid drop in the flow, or even to stop certain pumps. Experience proves that it is not possible, in these conventional pipelines, and this independent of the fact that one loses a considerable quantity of energy, gradually to vary the conditions of time and space. Indeed, the conventional devices used necessarily incur sudden variations which are translated for example by overpressures running along the pipeline and the different devices which undergo this sudden variation which is propagated are not able to intervene in a flexible enough manner so as to reduce or suppress the effects of it.

On the other hand, due to the possibility of progressively varying the inclination of the paddles the various pumping devices according to the present invention can co-operate with each other progressively to absorb the sudden stoppages and maintain the flow in a state reducing the mixtures at the interfaces of the various liquids and reducing the energy losses.

This progression is also an advantage in the case of starting or stopping flow through the pipeline. In the case of starting, for example, it is a question of rotating the pumps with a zero paddle angle and then of progressively increasing this angle in order to set up inside the tube the desired pressures and to pipe the desired flow. Similarly, with stopping it is possible progressively to decrease the pressure whereas the abrupt suppression of one or more pumps in the conventional installations creates an extremely rapid fall in pressure which can be translated by disturbances in the pipeline.

Moreover, it is appropriate to note that by opening the paddles to 90°, the paddles of the pump, if they are shaped for this purpose, overlap each other and thus practically prevent the liquid from passing, thus forming a valve. Here too, this closure can be effected very gradually, which reduces the danger of water-hammering.

On the other hand, the smoothness of the operation of the pipeline makes it possible to reduce the turbulence in separation zones of the different liquids conveyed in the pipeline and thus to reduce considerably the tendency towards telescoping of a concertina effect of the different liquid columns. Due to this there is thus a considerable reduction in the interpenetration of the liquids in the regions of contact which normally cause serious problems, especially in very long pipelines.

Another advantage of the pumping device according to the invention is that it is possible to operate certain pumps as energy receivers, and this by a suitable orientation of their paddles. This possibility is particularly advantageous for the braking of the liquid column in the descending portions of the pipeline and it may even be possible to recover the energy produced by connecting to the pump **24** to a device for the recovery of energy, an electric generator, for example. There are thus rendered unnecessary the outflow reservoir and the valve which are normally used in such conditions.

It is also possible, by pivoting the paddles, to reverse the direction of operation of the pump in order to re-

verse the flow of the pipeline and thus to limit a loss of any product if there is a crack or hole in the pipeline. Pumps can thus be located preferably in the region of certain areas in order to prevent pollution, such as rivers, roads, built-up areas. The device according to the invention makes it possible to adapt the various stations rapidly and accurately to the new conditions of flow. Thus, in the case of water-hammering, caused for example by the sudden closing of a valve, it will be noted that an overpressure is caused which spreads very rapidly upstream and it is necessary to stop the pumps located there. In conventional pipelines, this stoppage of the pumps is necessarily abrupt. These abrupt stoppages create, in their turn overpressures which spread and join the overpressure caused by the water-hammering which causes a risk of damage to the pipeline.

In the device according to the invention the shock wave is detected by one of the measuring devices or meters **18, 19, 20** located along the pipeline and measuring, in known manner, the gradient of the front of waves so as to distinguish it by a simple rise in the static pressure. The measuring device or meter transmits the information by a telecommunication system to the stations upstream which thus receive the order to create a low pressure wave in order to absorb the overpressure wave. In the device according to the invention, the stoppage of the pumps can thus be assured very gradually and the water-hammering can thus be absorbed without disconnecting the pumps abruptly and without any danger of causing cumulative effects. In addition, the stoppage of the motors is not obligatory which facilitates the re-starting of the pumping as soon as the flow may be resumed and thus saves further starting of the motors which can always be damaged by the latter. Naturally, it is possible in certain cases to connect the device according to the invention to conventional pipeline pumping devices **22.** Thus, it is possible to place in series, in one or more conventional pumping stations of a pipeline, pumps **24** with inclined paddles which can be orientated and provided with their servomotor **17** and their adjustment and control means **21.** In this case, the device **24** according to the invention, connected to a conventional pipeline, would only intervene for effecting a regulation of the pipeline, the main pumping work being nevertheless assured by standard pumping units **22.**

On the other hand, in certain particular applications the device according to the invention, can comprise only a single pumping station for pipes not requiring the use of several relay stations such as, for example, on oil-tanker ships. During the operation of such a device, the adjustment means which are operated keep the pump with a zero paddle angle, so as to avoid too great a demand for energy in the motor which drives the pump, or generally too high a starting torque, as soon as the starting sequence of the motor is finished, the angle of the paddle increases and the pump operates.

The adjustment means record the flow and the suction and delivery pressures so as to determine the flow or the head at which a second pump or a second group of pumps should start in order to retain the optimum output. When the operating conditions are established, the adjustment means equalize the paddle angles of all the pumps. The adjustment means can be programmed in order to assure the successive operation of the various pumps of the pumping station, whether the latter are arranged in series or in parallel, when the output of the pumps previously started, which is kept at as high a value as possible by the adjustment means acting on the servomotors, decreases to a certain value predetermined in advance. Thus by starting the following pumps the output is again increased. Naturally, in a particular case, the device can comprise only a single pump **24** with one or more stages with the corresponding servomotor(s) **17** and adjustment means **21.**

The paddles **5** are mounted on the rotor view shafts **6** which are geared to a shaft means **16** rotatable with respect to the rotor to pivot the paddles. In FIG. **4,** a servomotor **17** is shown provided for rotating the shaft means **16** in response to measurements made by the suction pressure measuring device **18,** delivering pressure measuring device **19** and flow measuring device **20.** These measurements are communicated from the measuring devices to the servomotor by adjustment means **21,** shown constituted by a pipeline central command means for a plurality **24** of the FIG. **1** pumps, in series. The central command means includes a device **25** which makes it possible to compare observed data with externally received data to effect adjustments in accordance with such comparisons. The pumps of the invention can be used in conjunction with conventional pumps **22.**

I claim:

1. A device for pumping liquids through a pipe comprising:

at least one pump having at least one stage;

each pump including:

a casing;

a rotor;

means journalling the rotor for rotation about the longitudinal axis thereof in the casing;

means for rotating the rotor about said axis;

a plurality of paddles disposed between the rotor and the casing;

shaft means mounting each paddle on the rotor for pivotal movement about the longitudinal axis of the respective shaft means said shaft means, collectively, having the longitudinal axes thereof arranged on a cone of revolution coaxial with the rotor;

means associated with said rotor, including servomotor means, for pivoting said paddles with respect to the rotor about the longitudinal axes of said shaft means;

hydraulic flow parameter measuring means for disposition in said pipe;

and adjustable means connecting the measuring means to the servomotor means for effecting pivotal movements of the paddles in response to measurements made by said measuring means.

2. The device of claim **1** further including first complementary spherically curved surface means exteriorly on the rotor and on each paddle at the base thereof; and second complementary spherically curved surface means interovly on the casing and on each paddle distally of the base thereof, the first and second complementary spherically curved surface means being centered on the apex of said cone of revolution.

3. The device of claim **1** wherein the hydraulic flow parameter measuring means includes a suction pressure measuring device, a delivery pressure measuring device and at least one flow measuring device.

4. A device for pumping liquids comprising;
a pipeline;
a plurality of pumping stations spaced along the pipeline, each including at least one pump having at least one stage interposed in the pipeline;
each pump including:
a casing;
a rotor;
means journalling the rotor for rotation about the longitudinal axis thereof in the casing; means for rotating the rotor about said axis; a plurality of paddles disposed between the rotor and the casing;
shaft means mounting each paddle on the rotor; for pivotal movement about the longitudinal axis of the respective shaft means said shaft means, collectively, having the longitudinal axes thereof arranged on a cone of revolution coaxial with the rotor;
means associated with said rotor, including servomotor means, for pivoting said paddles with respect to the rotor about the longitudinal axes of said shaft means;
hydraulic flow parameter measuring means for disposition in said pipe;
and adjustment means connecting the measuring means to the servomotor means for effecting pivotal movements of the paddles in response to measurements made by said measuring means.

5. The device of claim 4 wherein a plurality of said at least one pump are interposed in series in said pipeline.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,773,429 Dated November 20, 1973

Inventor(s) Pierre P. Hayward

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

In the Heading:

Please add --Claims priority, application France 70 10585, March 24, 1970--.

Signed and sealed this 20th day of August 1974.

(SEAL)
Attest:

McCOY M. GIBSON, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

ORM PO-1050 (10-69)

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

UNITED STATES PATENT OFFICE

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