United States Patent [19]
Ioannesian et al.

[11] 3,882,946
[45] May 13, 1975

[54] TURBODRILL

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[52] **U.S. Cl.** **175/107;** 173/73; 415/502
[51] **Int. Cl.** **E21b 3/12**
[58] **Field of Search** 175/107; 173/73; 415/502, 415/503

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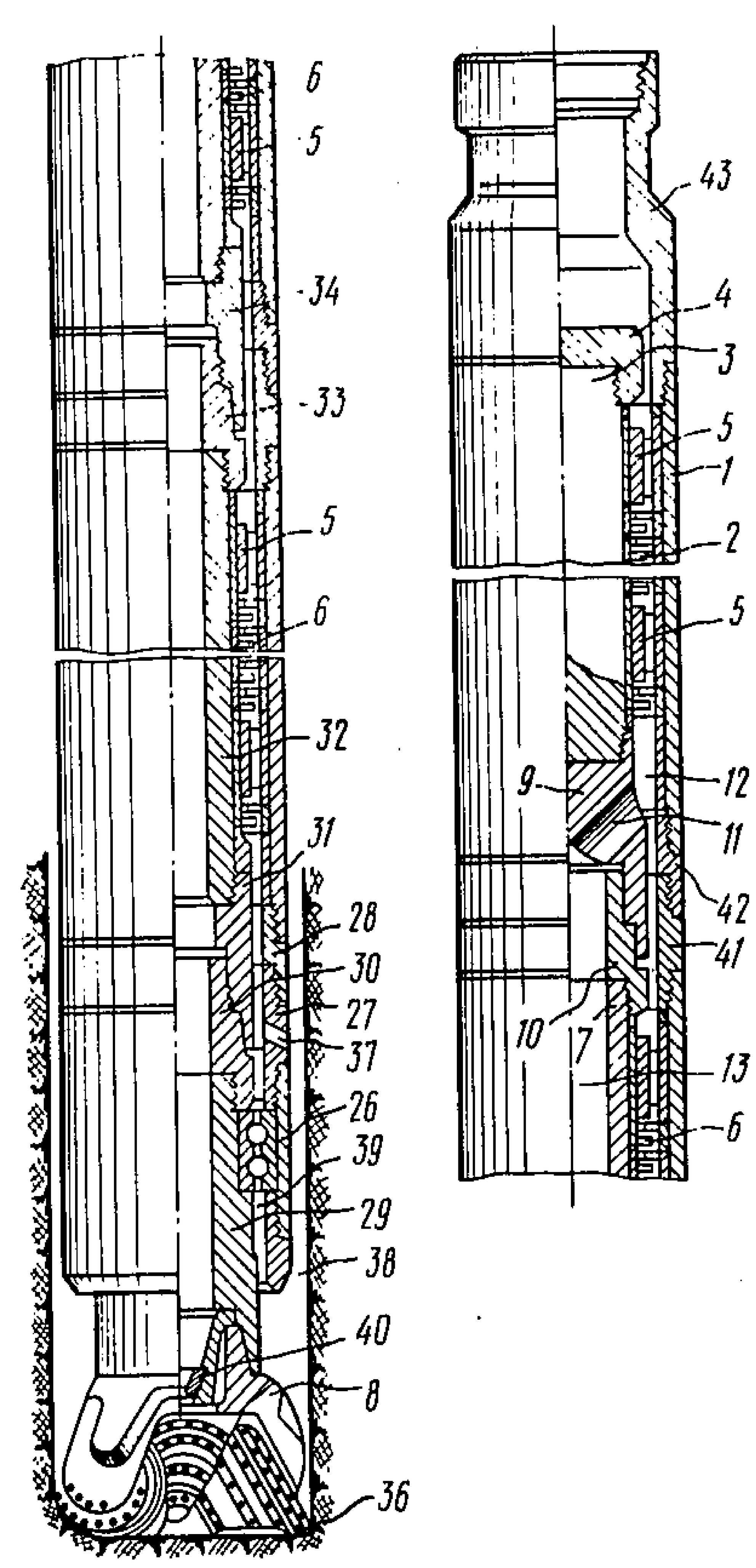
Attorney, Agent, or Firm—Holman & Stern

[57] **ABSTRACT**

A turbodrill provided with at least two multistage hydraulic turbines mounted one after another and operating in succession at different speeds. According to the invention, the first element along the path of the drilling fluid fed from the turbodrill is a low-speed turbine and/or hydrodynamic braking stages mounted on a solid shaft and capable of passing the total flow of the fluid. The second element along the path of the drilling fluid is a high-speed turbine capable of utilizing a high pressure drop and developing a high torque, with the turbine being mounted on a hollow shaft connected to a bit. Ahead of the high-speed turbine inlet, there is mounted a device dividing the fluid coming from the low-speed turbine into two flows, one being directed to the high-speed turbine and the other being directed to the bit through the hollow shaft of this turbine. The turbodrill allows a high pressure drop to be utilized in the bit without increasing the pressure in the delivery line of the mud pump and thereby providing for a hydraulic effect without using a packing gland at low speeds of the bit and high axial loads on the bottom hole.

19 Claims, 10 Drawing Figures



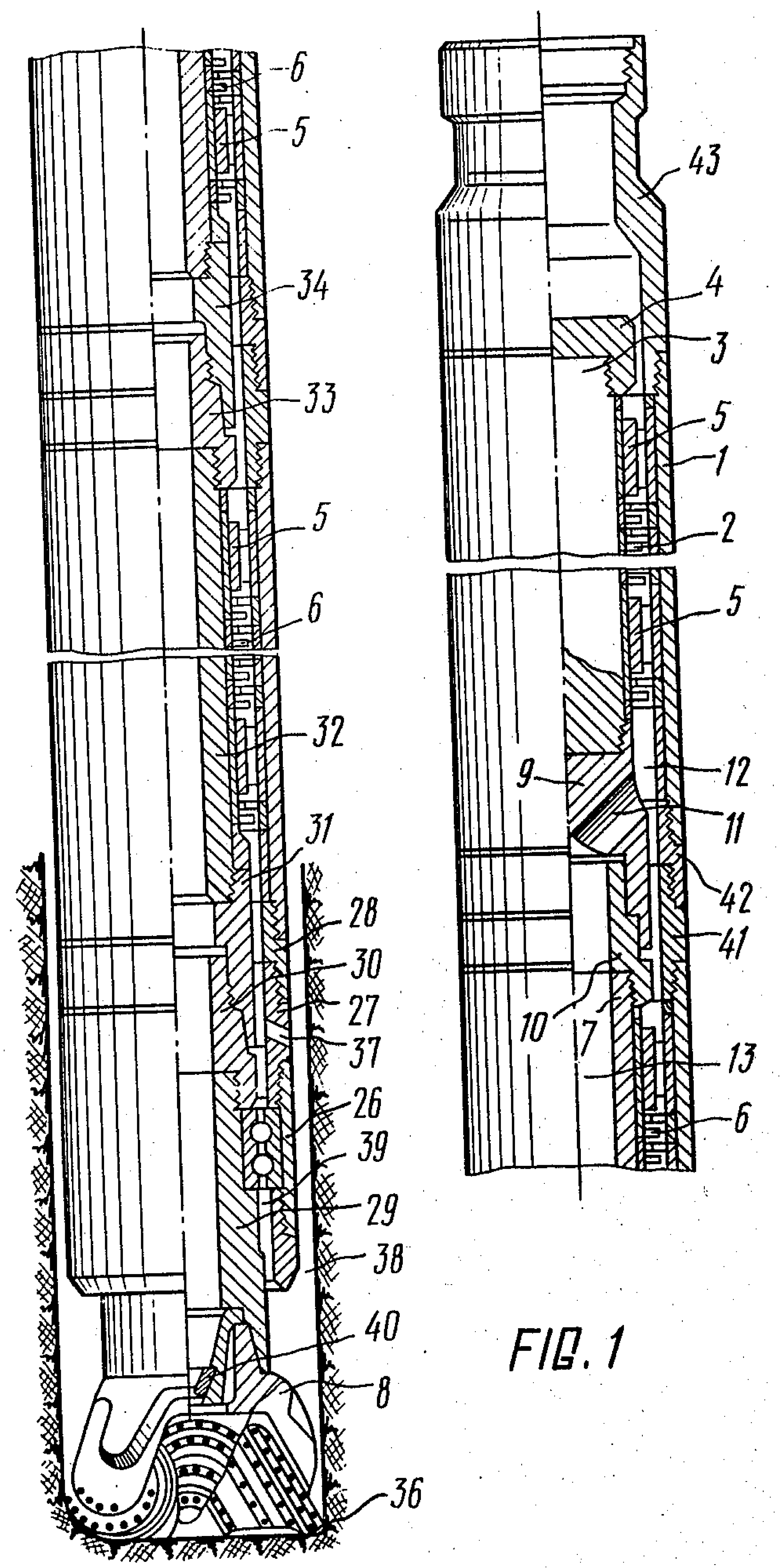

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FIG. 1

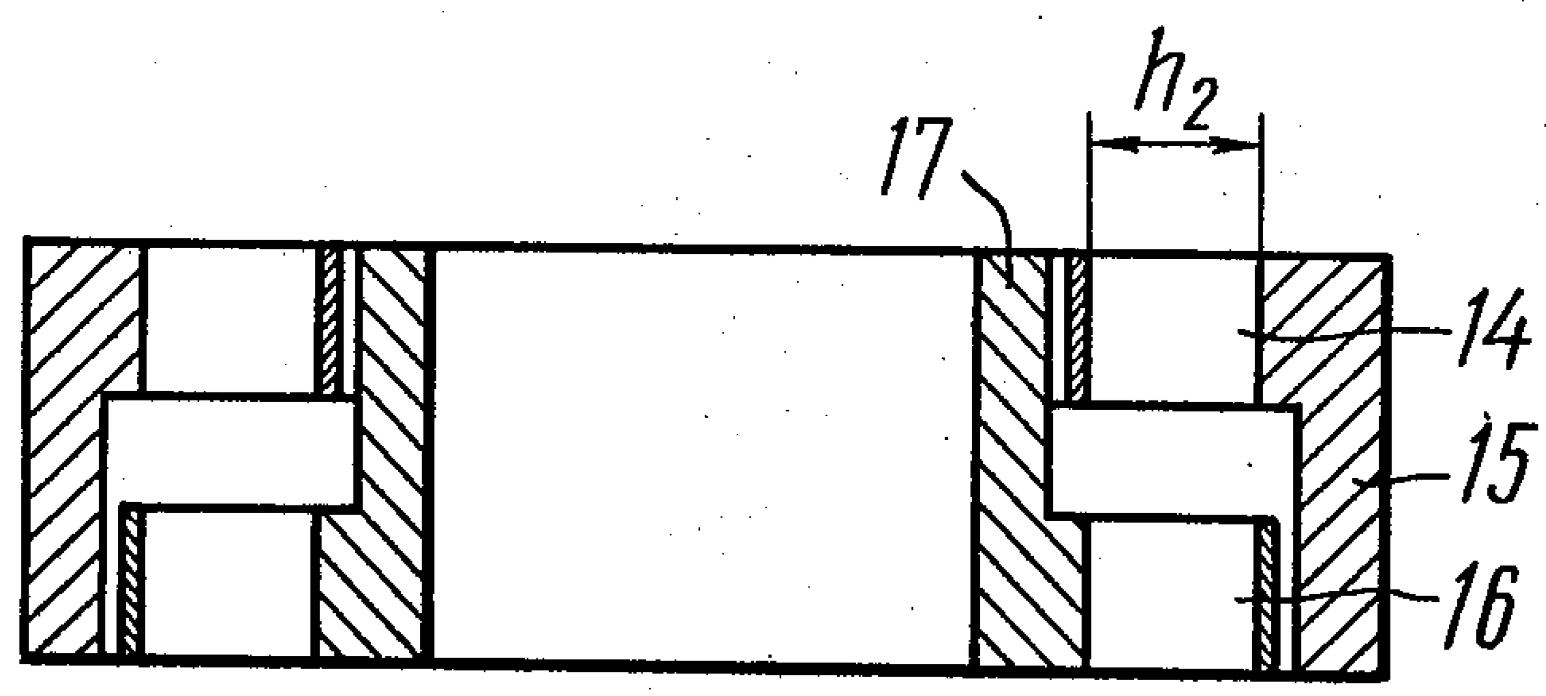

FIG. 2

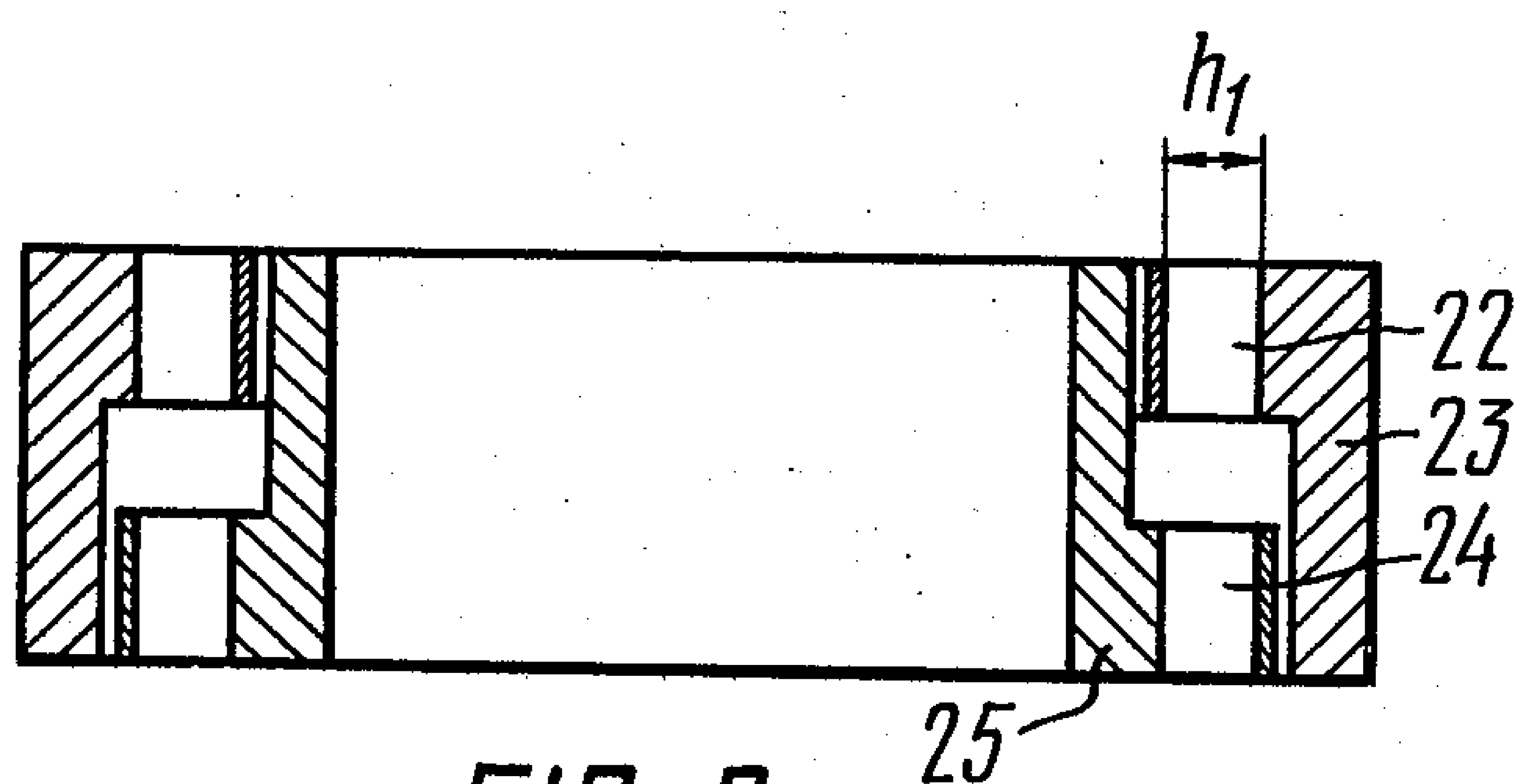

FIG. 8

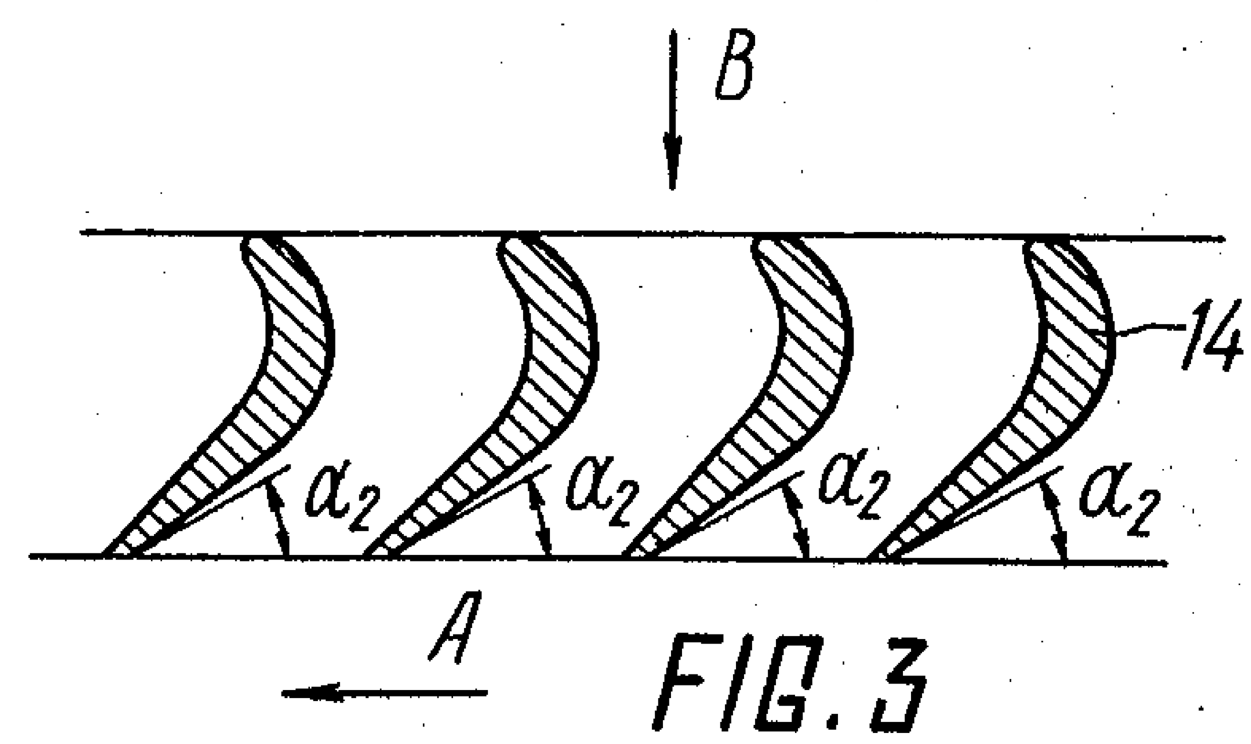

FIG. 3

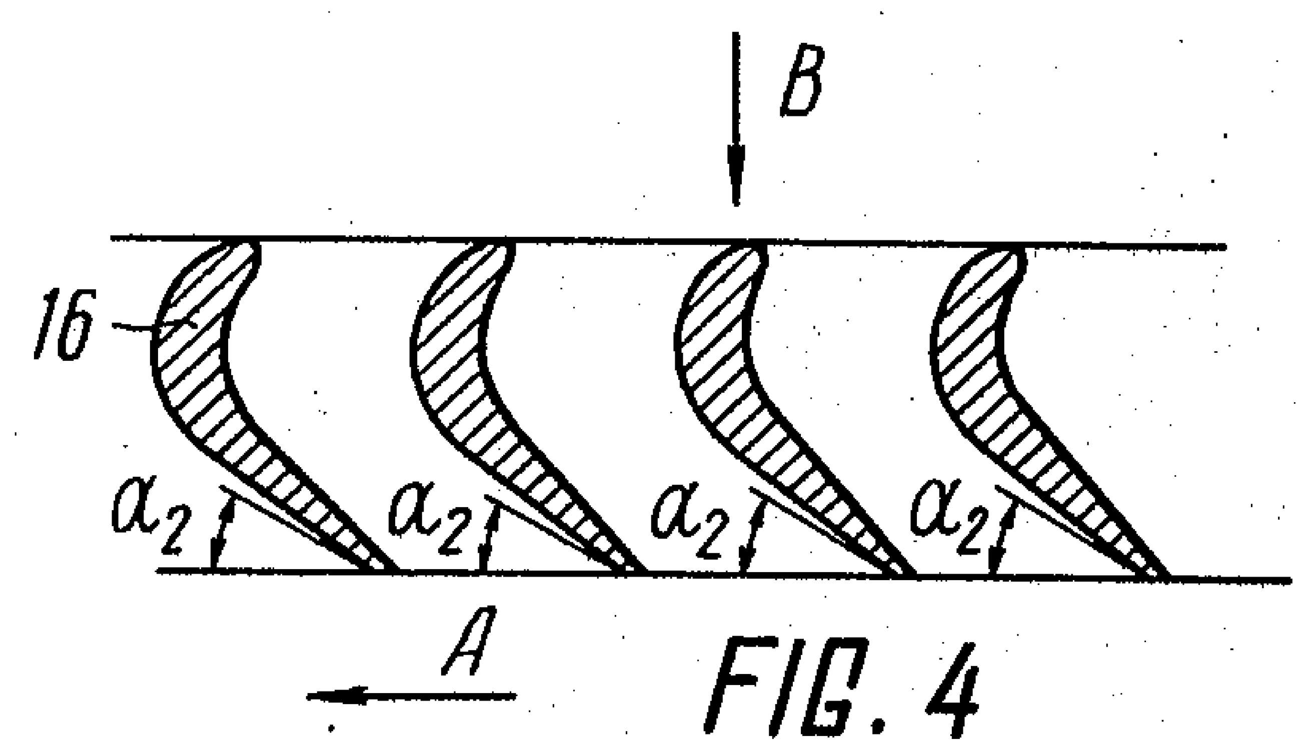

FIG. 4

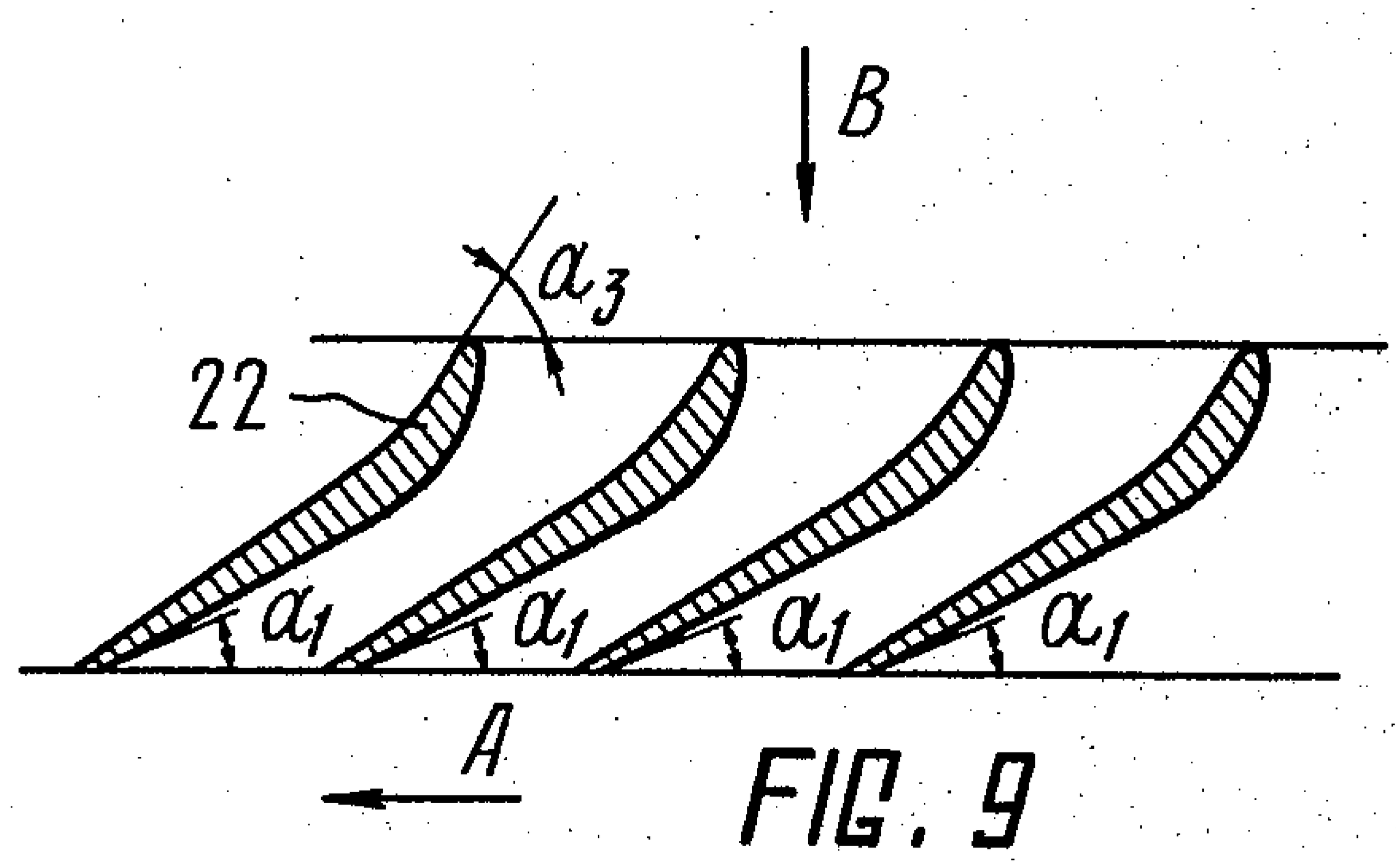

FIG. 9

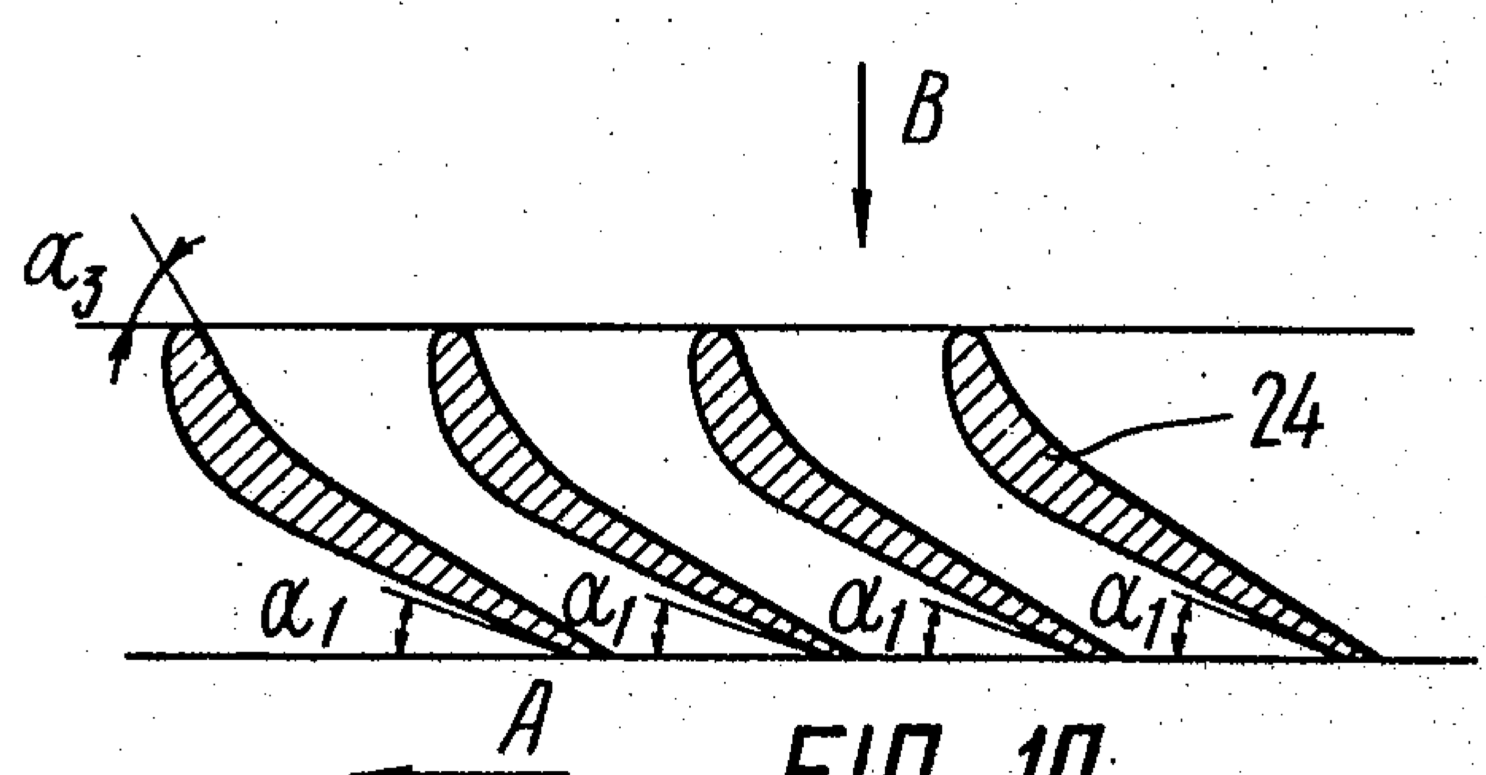

FIG. 10

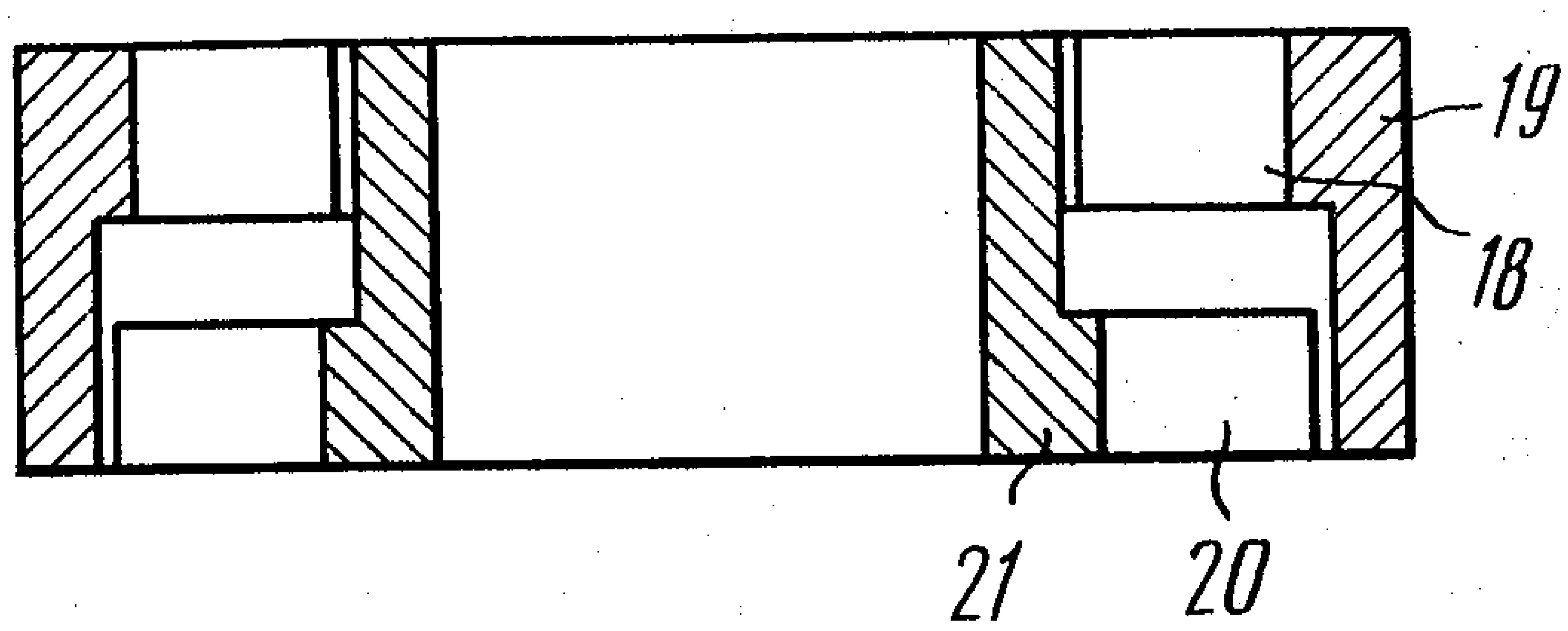

FIG. 5

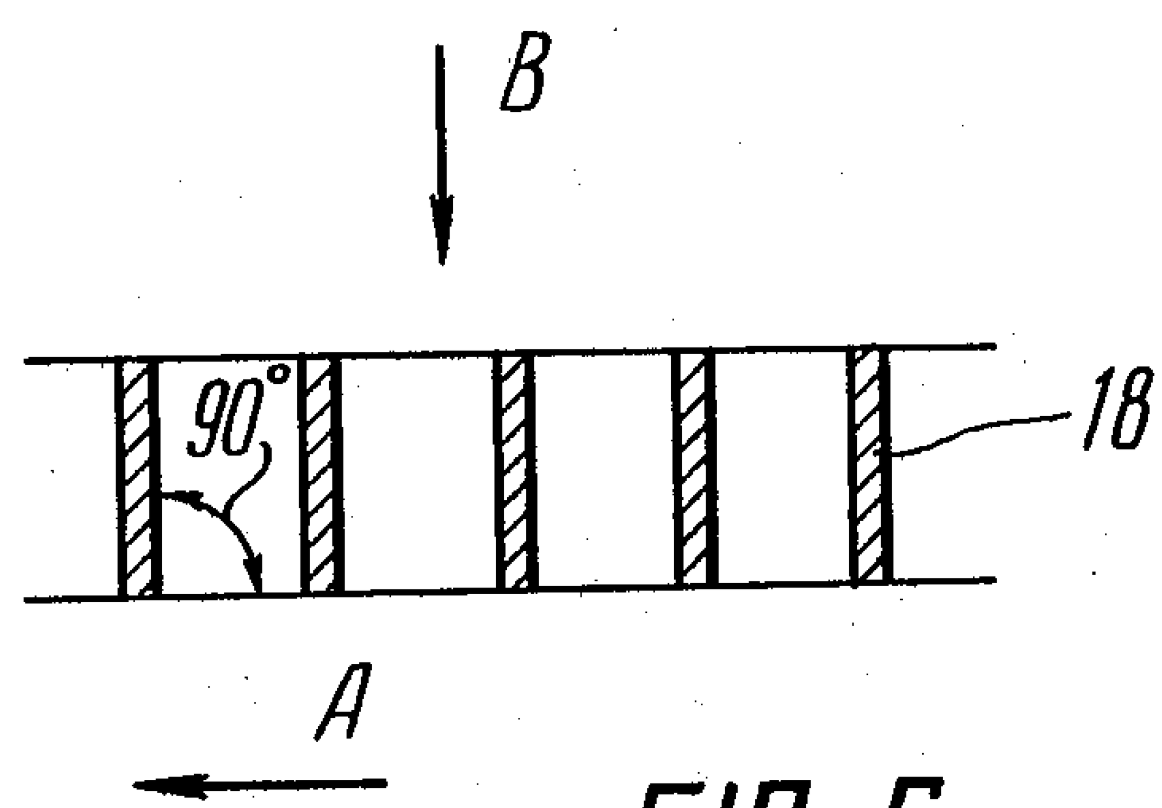

FIG. 6

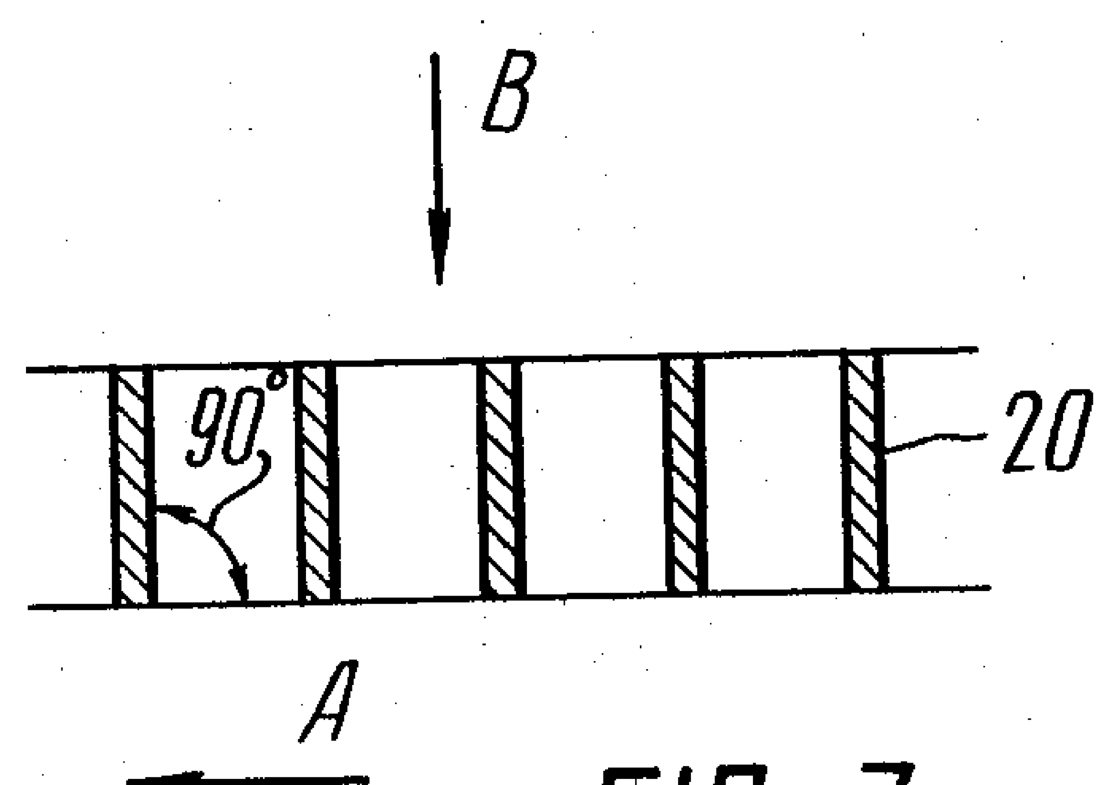

FIG. 7

TURBODRILL

BACKGROUND OF THE INVENTION

The present invention relates to drilling machines and, more particularly, to turbodrills used for drilling oil and gas wells.

The present machine can be used both for drilling the wells by a rock bit characterized by a high pressure drop, i.e., jet bits, and for drilling the wells by bits characterized by low pressure drops.

PRIOR ART

The turbodrills known in the drilling practice are not suitable for drilling with jet bits, since so far there is packing gland that could be reliable at high pressure drops.

A turbodrill with a rotary housing having three multistage hydraulic turbines mounted in succession and rotating a bit is known in the art. The turbines operate with different speeds. The high-speed turbine is located as a first element along the path of the drilling fluid fed from the drill pipes, a moderate-speed turbine is located as a next element, and the last element is a low-speed turbine, with all these turbines operating with the same fluid flow rate.

Since the known turbodrill has a rotary housing, the packing gland is located in its upper portion above the inlet of the fluid into the high-speed turbine.

Such an arrangement of the packing gland is disadvantageous, since it operates at a pressure drop equal to the sum of the turbine and bit pressures. It is known, however, that even when drilling by conventional rock bits operating at low pressure drops, the packing gland of the turbodrill becomes inoperative within a short period of time. For this reason, the jet bits operating at very high pressure drops can not be practically used with such turbodrill.

Furthermore, with the known turbodrill, the mud pump, besides the deleterious resistances in the drill string and annular space, has not overcome the pressure drop of the turbine and the bit and this increases the pressure in the delivery line of the pumps.

It should further be noted that the presence of turbines operating with different speed but at the same flow rate does not improve the power characteristics of the turbodrill and does not provide for drilling with a high pressure drop in the bit.

Attempts were made to develop a turbodrill in which the flow is divided for obtaining a hydraulic effect in the bit without an additional increase in the pressure in the delivery line of the mud pump. This device, however, has a number of disadvantages which do not allow the required effect to be obtained.

In this turbodrill, a part of the flow enters the turbine, while another part of the flow bypassing the turbine enters the bit through a hollow shaft. The part of the flow having been used in the turbine, is also supplied to the bit and with this object in view a packing gland is provided in the bottom portion of the turbodrill.

Thus, the high-pressure and low-pressure flows are mixed in the bit and this, first, reduces the hydraulic effect and, second, requires special bits with passages for the high-pressure and low-pressure streams. Furthermore, the supply of only a part of the flow to the turbine results in the following undesirable phenomena. When using a low-speed turbine, limited torques are developed on the shaft of such a turbodrill. Therefore, the drilling operation is effected with low bit weights, and this makes a rock bit very inefficient. When there is employed a high-speed turbine developing a high torque on the shaft, it results in a high speed of the machine and this is not good for a rock bit.

OBJECT AND SUMMARY OF THE INVENTION

The main object of the present invention is to provide a turbodrill which would allow to realize a high pressure drop in the bit without a considerable additional increase in the pressure in the delivery time of the mud pump.

Another object of the invention is to provide a turbodrill which would enable the drilling operation to be performed at a low speed of the bit and high axial load on the bottom hole.

Still another object of the invention is to provide a turbodrill which would operate with a hydraulic effect without using a packing gland.

These and other objects are attained by providing a turbodrill comprising at least two multistage hydraulic turbines mounted one after another and operating in succession with different speeds, said turbines rotating a bit, according to the invention, a low-speed and/or hydrodynamic braking stages, through which passes the total flow of a drilling fluid, are mounted on a solid shaft as a first element along the path of said drilling fluid supplied from the drilling pipes, with the next element along the path of the drilling fluid being a high-speed turbine mounted on a hollow shaft and made with a possibility of utilization of a high pressure drop and development of a high torque on the shaft; mounted ahead of said high-speed turbine inlet is a device dividing the flow of fluid coming from the low-speed turbine into two flows, one of which is directed to the high-speed turbine, while the other is directed to the bit through the hollow shaft of this turbine.

The concept of a "low-speed" or "high-speed" turbine is defined by the peripheral speed of the rotor when running idle, with a flow rate of 1 dm^3/sec.

The mutual arrangement of the turbines, when the low-speed turbine is located first along the path of the fluid and the high-speed turbine is the last along the same, as well as the fact that the first turbine operates with a total flow rate and the second, developing high torques, operates with a part of this flow, make it possible to obtain a high torque and comparatively low speed of the turbodrill shaft suitable for rock bits.

The division of the incoming fluid into two flows, one of which is fed into the high-speed turbine from which it passes through the holes in the turbodrill housing directly into the space between the housing and the well wall, while the other flow passes directly to the bit, makes it possible to provide a turbodrill without packing glands and to obtain a hydraulic effect on the bit without any substantial increase in the pressure in the delivery line of the mud pump.

From the technological point of view, the device for division of the fluid into two flows is expedient to be made in the form of a coupling connecting the shafts of the low-speed turbine and/or hydrodynamic braking stages with the shaft of the high-speed turbine for summing up the turbine torques transmitted to the bit. For this purpose, a half-coupling mounted on the solid shaft has openings for admitting a portion of the fluid supplied from the low-speed turbine into the hollow shaft of the high-speed turbine.

Due to the face that the couplings between the shafts in the turbodrills are obligatory components, it is most expedient technologically, to use them for division of the flow, with these components being removable.

When the turbodrill is to be used for drilling a deep well, the low-speed turbine is preferably provided with hydrodynamic braking stages in which the stator and rotor blades have the equal inlet and outlet angles and are inclined at the same angle to the plane normal to the turbodrill axis.

When drilling very deep wells, all stators and rotors mounted on the solid shaft are preferably made with blades having equal inlet and outlet angles and inclined at the same angle to the plane normal to the turbodrill axis.

Use of such stators and rotors allows the speed of the turbodrill shaft to be controlled within a wide range and makes it possible to select the most expedient operating conditions for the bit depending on the depth of the well, the type of the bit, the character of the drilled rock, and the properties of the drilling fluid.

In the high-speed turbine stators and rotors, the outlet angles of blades must be less with respect to the plane normal to the turbodrill axis than the corresponding angles of the low-speed turbine. The blades' radial heights of the high-speed turbine are also expedient to have lower than those of the low-speed turbine. The expediency of such a construction is dictated, on the one hand, by the necessity of designing a hollow shaft of the largest possible diameter and, on the other hand, by the fact that with a low radical height of the turbine blades with specified outlet of angles of the rotors and stators, the turbine pressure drop is increased and this makes it possible to utilize the high pressure drops which are required for efficient operation of the jet bits.

In order to increase the pressure drop, which can be utilized in a jet bit with its speed being reduced, the inlet and outlet angles of the rotor and stator blades of the high-speed turbine are to be made substantially equal to each other. The pressure drop in the turbines having blades of such a shape increases with a decrease in the speed of the turbodrill shaft. In this case, a higher amount of drilling fluid will be supplied into the nozzles of the jet bit. The pressure drop in the bit will increase correspondingly and this increases the efficiency of the hydraulic jet.

Other objects and advantages of the present invention will be apparent from the following detailed description of one particular embodiment of the invention with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a general view of the turbodrill according to the invention, in longitudinal section; with the bottom components of the turbodrill being connected along the line I—I;

FIG. 2 is a longitudinal section of the stator and rotor of the low-speed turbine;

FIG. 3 is a shape of the stator blades of the low-speed turbine;

FIG. 4 is a shape of the rotor blades of the low-speed turbine;

FIG. 5 is a longitudinal section of the stator and rotor with the equal inlet and outlet angles of the blades and located at the same angle to the plane normal to the turbodrill axis;

FIG. 6 is a shape of the stator blades disposed at an angle of 90° to the plane normal to the turbodrill axis;

FIG. 7 is the same of the rotor blades;

FIG. 8 is a longitudinal section of the stator and rotor of the high-speed turbine;

FIG. 9 is a shape of the stator blades of the high-speed turbine and;

FIG. 10 is the same of the rotor;

DETAILED DESCRIPTION OF THE INVENTION

The present invention is a turbodrill for drilling oil and is gas wells and used as a component of a drilling unit which also comprises drill pipes through which the drilling fluid delivered by a mud pump passes to the turbodrill.

The turbodrill comprises two multistage hydraulic turbines operating in succession at different speeds and mounted one after another in a housing **1** (FIG. **1**).

According to the invention, a low-speed turbine **2** is mounted as a first element along the path of the drilling fluid coming from the drill pipes (not shown). This turbine is secured on a solid shaft **3** and is fixed thereto by means of a nut **4**. The shaft **3** is fixed with respect to the housing **1** by means of radial bearings **5**. The total flow of drilling fluid fed to the turbodrill passes through the low-speed turbine **2**.

A high-speed turbine **6** is mounted after the low-speed turbine along the path of the drilling fluid. A hollow sectional shaft **7** connected to bit **8** is used for mounting the turbine **6**.

Mounted before the inlet of the high-speed turbine **6** is a device for the division of the fluid coming from the low-speed turbine **2** into two flows.

The device dividing the fluid into two flows is a coupling consisting of two half-couplings **9** and **10** connecting the shafts **3** and **7** of the turbines **2** and **6**, respectively, for summing up the torques developed by the turbines and transmitted to the bit **8**.

The half-coupling **9** is secured on the solid shaft **3** and has openings providing communication between a space **12**, separating the turbines, and are space **13** of the shaft **7** of the high-speed turbine **6** and serving for by passing a portion of the fluid coming from the low-speed turbine **2** into the hollow shaft **7** of the high-speed turbine **6**.

Both half-couplings **9** and **10** form a coupling transmitting the torque from the solid shaft **3** to the hollow shaft **7**.

When drilling deep wells, it is necessary to run the turbodrill and, therefore the bit **8**, at low speeds. In this case, the low-speed turbine performs two functions: it not only develops a torque on the solid shaft **3** but also limits the speed of the high-speed turbine **6**, thus serving as a hydrodynamic brake.

Depending on a required speed of the bit **8**, the low-speed turbine **2** may have the blades of different shapes.

In order to obtain average revolutions, blades **14** of a stator **15** and blades **16** of rotor **17** of the low-speed turbine **2** should be made of the shapes shown in FIGS. **3** and **4**.

In order to obtain a lower speed of the bit **8**, the solid shaft **3** should be provided with a part of the stages with a shape of the blades **14** and **16** of the stators **15** and rotors **17** shown in FIGS. **3** and **4** and with another part of the stages with a shape of blades **18** of stators **19** and blades **20** of rotors **21** shown in FIGS. **6** and **7**.

In order to obtain the lowest speed, the solid shaft 3 must be equipped with stators 19 and rotors 21 with the blades 20 and 18 of the shapes shown in FIGS. 6 and 7. Shown in FIGS. 3 to 10 by an arrow A is a direction of rotation of the turbodrill shaft, while an arrow B shows the direction of the fluid flow.

The high-speed turbine 6 is capable of utilizing a high pressure drop and provides for a high torque on its shaft 7. For this purpose, the outlet angles α_1 of blades 22 of stators 23 and the outlet angles α_1 of blades 24 of rotors 25 of the turbine 6 are less than the similar angles α_2 of the blades 14 of the stators 15 and the angles α_2 of the blades 16 of the rotors 17 of the low-speed turbine 2.

What is more, the high-speed turbine 6 has blades 22 and 24 whose radial heights h_1 (FIG. 8) are lower than the radial heights h_2 (FIG. 2) of the blades 14 and 16 of the low-speed turbine 2.

The hollow shaft 7 of the multistage high-speed turbine 6 is made sectional. A part of the shaft 7 connected to the bit 8 is a spindle consisting of a body 26, secured to the housing 1 of the turbodrill by means of connecting subs 27 and 28, and a shaft 29. One end of the shaft 29 has a thread for connection with the bit 8, while the other end thereof is used for connection by means of half-couplings 30 and 31 with a shaft 32 serving as a next part of the shaft 7 of the turbine 6. The shaft 32 is connected to the shaft 7 by half-couplings 33 and 34.

Mounted in the spindle is a multistage bearing 35 taking the hydraulic load due to the pressure drop in the turbines 2 and 6 and transmitting the axial load to bottom hole 36.

The connecting sub 27 has openings 37 for admitting the drilling fluid, having been operated in the high-speed turbine 6, into the well 38.

The turbodrill can be made so that the drilling fluid used in the high-speed turbine 6 is fed into the well 38 through an annular space 39 provided between the body 26 of the turbodrill spindle and the sshaft 29 of the spindle.

When drilling with a jet bit, the flow of fluid fet into the hollow shaft 7 passes directly into the bit since the nozzles of the bit 8 are in communication with the space of the shaft 7 of the turbine 6. In this case, the passage cross sections of the jet bit nozzles are selected to that the cooperating pressure in the bit corresponds to the pressure drop in the high-speed turbine 6.

When drilling with a conventional bit, ahead of this bit, there is mounted a removable nozzle 40 from which the fluid is fed into the central hole of the bit.

The diameter of the nozzle 40 is selected taking into account the pressure equal to the pressure drop in the high-speed turbine 6.

In face, the diameters of the jet bit nozzles or the diameter of the removable nozzle 40 mounted ahead of the convention bit 8, define the portion of fluid which will be fed through the hollow shaft 7 to the bit 8 and the portion of fluid which will be fed to the high-speed turbine 6 bypassing the bit 8.

The inlet angles α_3 (FIG. 10) and the outlet angles α_1 of the blades 22 of the stators 23 (FIG. 8) of the high-speed turbine 6 are substantially equal to each other and the inlet angles α_3 (FIG. 10) and the outlet angles α_1 of the blades 24 of the rotors 25 (FIG. 8) of the same turbine are also equal to each other. In this case, the pressure drop in the turbine 6 increases with a reduction in its speed.

Therefore, in the process of turbodrilling, the speed of the bit 8 goes down with an increase in the load on the bottom hole 36 (FIG. 1) and therefore, the distribution of the total flow between the turbine 6 and the bit 8 will be varied. From this it follows that the higher the load on the bottom hole, i.e., the lower the bit speed, the higher amount of fluid is fed into the bit; and hence the higher the operating pressure in the jet bit.

Since the high-speed turbine 6 develops a high torque, it can be made of two sections whose bodies are connected by subs 41 and 42 so that even when a part of the fluid flow fed into the turbodrill passes through this turbine, a high torque required for drilling with the bit 8 is developed on the hollow shaft 7. At the same time, since this turbine is made with a possibility of utilization of a high pressure drop, it also performs the function of a packing gland limiting the amount of fluid fed into the well by-passing the bit 8.

The present turbodrill operates as follows; working drilling fluid delivered by the mud pumps through the drill pipes and the upper sub 43 of the turbodrill enters the low-speed turbine 2, which passes the total flow of the fluid. From the low-speed turbine 2, the fluid is fed into the space between the turbines, from which a portion of the fluid through the device dividing the fluid flow is supplied into the hollow shaft 7, while the other portion of the fluid is fed into the high-speed turbine 6. The fluid, having been run in the turbine, through the openings 37 is directed into the well 38, while the other flow through the hollow shaft 7 and the nozzle 40 of the bit 8 is directed onto the bottom hole 36 of the well 38 cooling the bit 8 and carrying out the cuttings to the surface.

From the above, it can be seen that the present turbodrill has a high torque at a limited shaft speed and provides for operation with high-pressure jet bits without substantial loading of the mud pump.

Furthermore, the present construction of the turbodrill allows it to be made without a high-pressure packing gland since its function is performed by the high speed turbine.

What is claimed is:

1. A turbodrill for drilling oil and gas wells in an assembly with a drilling unit comprising drill pipes, through which a drilling fluid is supplied into the turbodrill and a mud pump for delivering the drilling fluid into said drill pipes; said turbodrill, comprising, in combination, a housing, at least two multistage hydraulic turbines having different speeds, said turbines being mounted in said housing one after another and operating in succession; the low-speed turbine passing the total flow of the drilling fluid coming from said drill pipes being located as a first element along the path of said fluid; the next element along the path of said fluid being the high-speed turbine utilizing a high pressure drop and developing a high torque; a solid shaft on which said low-speed turbine is mounted; a hollow shaft on which said high-speed turbine is mounted and having one end connected to a bit; a device dividing the fluid coming from said low-speed turbine into two flows, one flow being directed to said high-speed turbine and the other flow being directed through said hollow shaft to said bit so that the turbodrill operates with a hydraulic effect defined by the pressure drop in both the turbines and utilized by the high-speed turbine

without applying any substantial additional load to said mud pump.

2. The turbodrill as claimed in claim 1, in which the device dividing the fluid into two flows is a coupling connecting the solid shaft with the hollow shaft for summing up the torques developed by the turbine and transmitted to the bit; the half-coupling secured on the solid shaft having openings for bypassing a portion of the fluid running from the low-speed turbine into the hollow shaft of the high-speed turbine.

3. The turbodrill as claimed in claim 1, in which the high-speed turbine is made so that the inlet and outlet angles of the rotor blades are substantially equal to each other and the inlet and outlet angles on the stator blades are substantially equal to each other.

4. The turbodrill as calimed in claim 1, in which the high-speed turbine has stator and rotor blades whose inlet and outlet angles are less than the similar angles of the low-speed turbine blades.

5. The turbodrill as claimed in claim 4, in which the high-speed turbine is made so that the inlet and outlet angles of its rotor blades are substantially eqial to each other and the inlet and outlet angles of the stator blades are substantially equal to each other.

6. The turbodrill as claimed in claim 1, in which the high-speed turbine has blades whose radial heights are lower than those of the low-speed turbine blades.

7. The turbodrill as claimed in claim 6, in which the high-speed turbine is made so that the inlet and outlet angles of its rotor blades are substantially equal to each other and the inlet and outlet angles of its stator blades are substantially equal to each other.

8. A turbodrill for drilling gas and oil wells in an assembly with a drill unit comprising drill pipes, through which a drill fluid is supplied into the turbodrill, and a mud pump for delivering the drilling fluid into said drill pipes; said turbodrill comprising, in combination, a housing, a low-speed turbine defining, hydrodynamic braking stages and a high-speed turbine located in said housing one after another and operating in succession; the hydrodynamic braking stages being arranged first along the path of the drilling fluid coming from said drill pipes and passing the total flow of said fluid; the next element along the path of said drilling fluid being the high-speed turbine capable of utilizing a high pressure drop and developing a high torque; a solid shaft mounting the hydrodynamic braking stages; a hollow shaft mounting said high-speed turbine and one end of which is connected to a bit; a device dividing the fluid coming from the low-speed turbine into two flows, one of which is directed to said high-speed turbine, while the other is directed through said hollow shaft to said bit so that the turbodrill operates with hydraulic effect.

9. The turbodrill as claiamed in claim 8, in which the device dividing the fluid into two flows is a coupling connecting the solid shaft to the hollow shaft for summing up the torques developed by the turbines and transmitted to the bit; the half-coupling secured on the solid shaft having openings for bypassing a portion of the fluid flow running from the low-speed turbine into the hollow shaft of the high-speed turbine.

10. The turbodrill as claimed in claim 8, in which the high-speed turbine has stator and rotor blades whose inlet and outlet angles are less than the similar angles of the low-speed turbine blades.

11. The turbodrill as claimed in claim 10, in which the high-speed turbine is made so that the inlet and outlet angles of the rotor blades are substantially equal to each other and the inlet and outlet angles of the stator blades are substantially equal to each other.

12. The turbodrill as claimed in claim 8, in which the high-speed turbine has blades whose radial heights are lower than those of the low-speed turbine blades.

13. The turbodrill as claimed in claim 12, in which the high-speed turbine is made so that the inlet and outlet angles of its rotor blades are substantially equal to each other and the inlet and outlet angles of its stator blades are substantially equal to each other.

14. A turbodrill for drilling gas an oil wells in an assembly with a drilling unit comprising drill pipes, through which a drilling fluid is supplied into the turbodrill, and a mud pump for delivering said drilling fluid into said drill pipes; said turbodrill comprising in combination, a housing, two multistage hydraulic turbines operating with different speeds and hydrodynamic braking stages arranged in said housing one after another and operating in succession; the first element along the path of the drilling fluid coming from said drill pipes being the low-speed turbine and the hydrodynamic braking stages which pass the total flow of said fluid; the next element along the path of said drilling fluid being a high-speed turbine capable of utilizing a high pressure drop and developing a high torque; a hollow shaft mounting said high-speed turbine and one end of which is connected to a bit; and a device dividing the fluid coming from said low-speed turbine and hydrodanymic braking stages into two flows, one of which is directed into said high-speed turbine and the other is directed through said hollow shaft to said bit so the turbodrill operates with a hydraulic effect.

15. The turbodrill as claimed in claim 14, in which the device dividing the fluid into two flows is a coupling connecting the solid shaft with the hollow shaft for summing up the turbine torques transmitted to the bit; the half-coupling secured on the solid shaft having openings for bypassing a portion of the fluid flow running from the low-speed turbine into the hollow shaft of the high-speed turbine.

16. The turbodrill as claimed in claim 14, in which the high-speed turbine has stator and rotor blades whose inlet and outlet angles are less than those of the low-speed turbine blades.

17. The turbodrill as claimed in claim 16, in which the high-speed turbine is made so that the inlet and outlet angles of its rotor blades are substantially equal to each other and the inlet and outlet angles of its stator blades are substantially equal to each other.

18. The turbodrill as claimed in claim 14, in which the high-speed turbine has blades whose radial heights are lower than those of the low-speed turbine blades.

19. The turbodrill as claimed in claim 18, in which the high-speed turbine is made so that the inlet and outlet angles of its rotor blades are substantially equal to each other and the inlet and outlet angles of its stator blades are substantially equal to each other.

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