Nov. 25, 1969 L. GYONGYOSI 3,480,091

FEED APPARATUS FOR ROCK DRILLS

Filed March 18, 1968 2 Sheets-Sheet 1

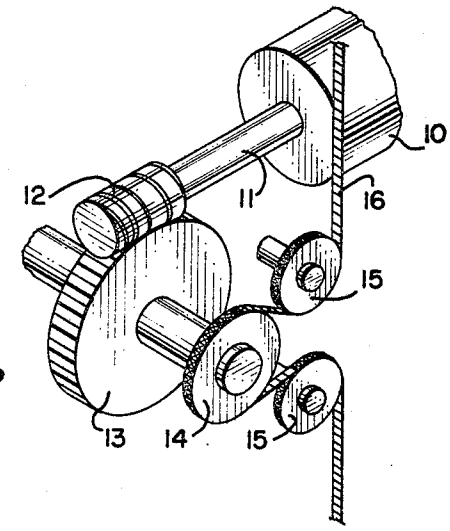


FIG. 2

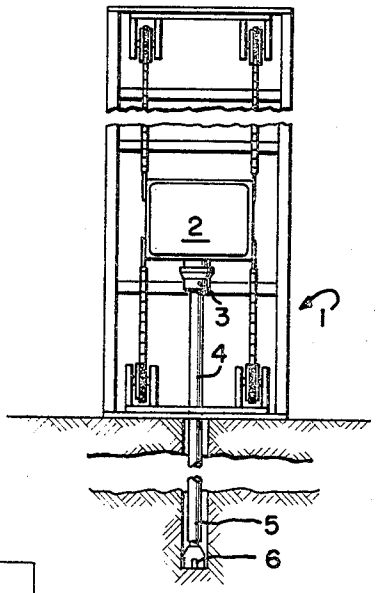


FIG. 1

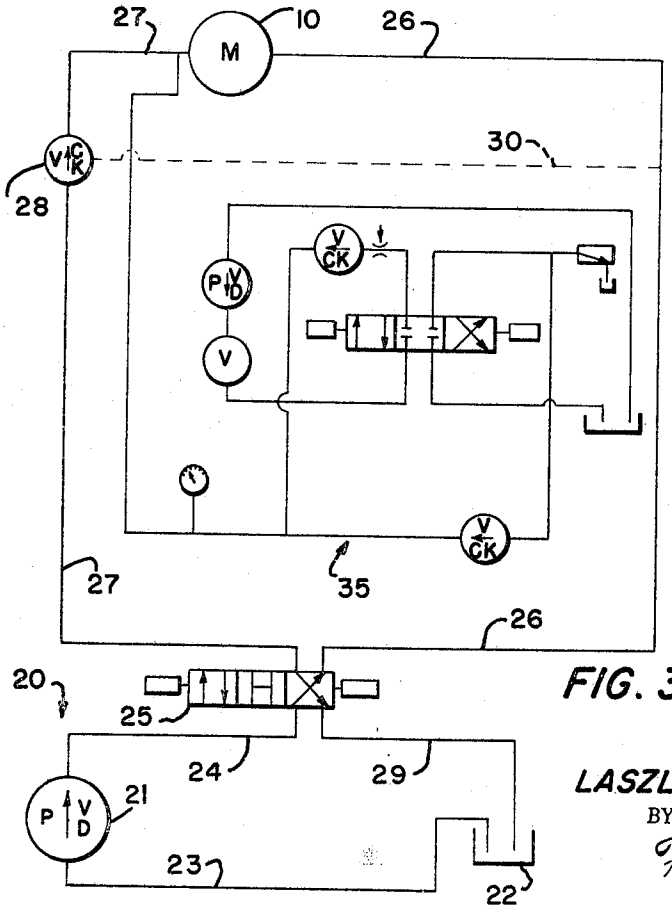


FIG. 3

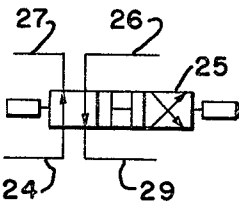


FIG. 4

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FEED APPARATUS FOR ROCK DRILLS

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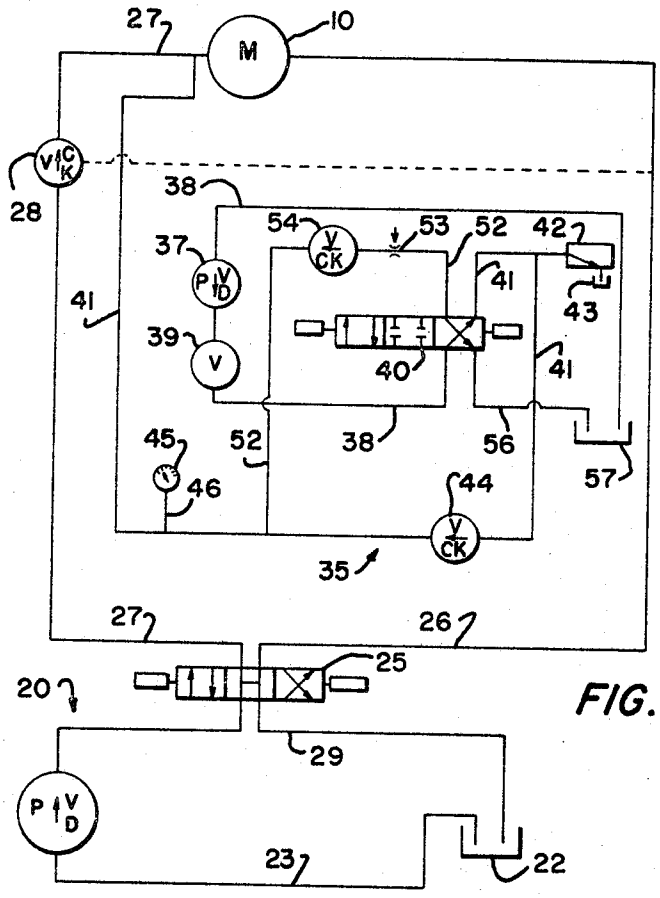


FIG. 5

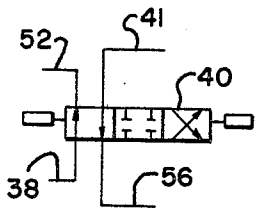


FIG. 6

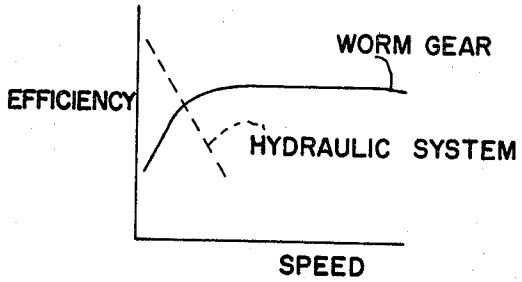


FIG. 7

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FEED APPARATUS FOR ROCK DRILLS

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Int. Cl. E21c 5/08; E21b 1/02, 3/02
U.S. Cl. 173—160 11 Claims

ABSTRACT OF THE DISCLOSURE

A feed control for rock drilling equipment capable of both high and low speed feed employing a worm gear drive unit powered by a hydraulic motor and a pair of variable delivery pumps. The high speed system is used for adding or removing drill rods to the drill string and for pulling the tool out of the hole. The low speed system is used during the drilling operation. The control is readily adaptable to both rotary and down-the-hole drilling.

BACKGROUND OF THE INVENTION

This invention relates to rock drilling and more particularly a feed system for a rock drilling apparatus which is used for drilling holes of a depth which requires a plurality of drill rods such as in water well drilling.

In rock drilling, the drill rod and drill string must be fed down the hole at a speed comparable to the speed at which the hole is being drilled. In most instances, this speed is quite slow. In deep hole drilling, the drill string is made up of a plurality of drill rods. As the hole is deepened, additional drill rods must be added to the drill string.

The apparatus which feeds the drill string down the hole during drilling operations is normally the same apparatus used to add drill rods to the string. During the addition of drill rods or the removal of the tool from the hole, the feed apparatus is operated at high speeds, often on the order of 80 feet per minute. During the actual drilling operation, the feed speed is slow, normally in the range of 20 to 200 feet per hour. It is therefore desirable to employ a feed system which operates efficiently at both high and low speeds. Such a system is difficult to achieve because the load on the system is the same, regardless of the direction or rate of feed.

It is also a requirement of the feed system that the proper amount of force is applied to the drill bit in order to drill at a satisfactory rate of speed. In rotary drilling, a high force is applied to the drill bit through the drill string while the drill bit is rotated. This force plus the rotation accomplishes the drilling function. In downhole drilling, a downhole drill is connected to the end of the drill string and the drill bit is mounted on the downhole drill and is adapted to be hammered by the downhole drill while the drill string, downhole drill, and bit are rotated. During downhole drilling, the force applied to the drill bit through the drill string must be relatively small or the downhole drill will not function properly. In both downhole and rotary drilling, the feed must be steady in order to provide a stable and properly functioning machine.

Prior to this invention, it has been common to use one or more hydraulic cylinders as a feed motor to accomplish the dual speed function. One advantage of such a system is that a constant force output is assured at any feed speed. One disadvantage of this system is that it tends to result in an unstable operation during drilling. The starting force is less than the running force so that there is a jerk each time the drill bit is stopped and then begins to move again. In addition, the cost of such a feed system is high for a long feed travel. The system is difficult to install and access to internal parts is limited. The carrying capacity of such a system is unequal in the two directions of travel.

A worm type gear feed motor system would provide the advantage that it is compact; access to internal parts is easy thereby permitting periodic inspection; there are a minimum number of components; its load carrying capacity is essentially equal in both directions; and the efficiency is high in the upper speed range. The primary disadvantage of a worm gear type feed motor is that it is inefficient in the lower 20% speed range. In this range, as speed is decreased, the efficiency of the worm gear type feed motor rapidly decreases. Since most drilling is done in the very low speed range, prior to this invention, use of a worm gear drive has been unacceptable. Since as the speed decreases, the torque decreases, the system becomes self stalling.

In many instances, it would be desirable to have a drilling machine capable of drilling by both the rotary and the downhole methods. Because of the great difference in feed pressures required by rotary and downhole drilling, a practical drilling machine capable of efficiently performing both drilling methods for sustained periods of time has not been available.

SUMMARY

It is therefore the principal object of this invention to provide a feed system for a rock drilling apparatus which is efficient at both high and low speed operation.

It is a further object of this invention to provide a feed apparatus for a rock drilling machine which permits the machine to be used for both rotary drilling and downhole drilling.

It is still a further object of this invention to provide a feed control system which is compact, easy to install and operate and contains a minimum number of components.

In general, these and other objects will be carried out by providing in combination with drilling apparatus having a drill string and a drill bit operatively connected to one end of the drill string, a system for feeding the drill bit and drill string down a hole being drilled comprising: a drive unit including hydraulic motor means and a worm gear drive driven by the hydraulic motor means operatively connected to a drill string for raising and lowering the drill string; a source of hydraulic fluid, and means for supplying hydraulic fluid under pressure to said motor means; said supplying means being coordinated with the drive unit to provide a substantially straight line relationship between efficiency and speed when said drive unit is operating at low speed.

BRIEF DESCRIPTION OF THE DRAWINGS

This invention will be described in connection with the annexed drawings wherein:

FIG. 1 is a diagrammatic view of a drilling apparatus employing the control of this invention;

FIG. 2 is a perspective view of a portion of the drive unit;

FIG. 3 is a schematic view of the hydraulic fluid supply system of this invention and the control valves positioned for high speed reverse feed;

FIG. 4 is a fragmentary view of a portion of FIG. 3 showing a control valve of this invention in a position for high speed forward feed;

FIG. 5 is a view similar to FIG. 3 with the control valves positioned for slow speed forward feed for downhole drilling;

FIG. 6 is a fragmentary view of a portion of FIG. 5 showing the control valves positioned for slow speed forward feed for rotary drilling; and

FIG. 7 is a graph comparing efficiency to speed for a worm gear drive and the hydraulic supply system of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, there is shown a drilling apparatus which includes a drill tower generally indicated at **1** with a universal feed and rotary mounting **2** having a rotary output **3**. The universal feed and rotary unit which includes both feed and rotary motors is described in detail in the U.S. patent application of Samuel Leven, Ser. No. 649,585, filed June 28, 1967, and assigned to the assignee of the present invention. A drill string **4** is connected to the rotary output **3**. A downhole drill **5**, well known in the art, is connected to the lower end of the drill string and a drill bit **6** is operatively connected to the drill **5** in the usual manner. During rotary drilling, the downhole drill may be removed and a drill bit connected directly to the drill string **4**.

FIG. 2 shows a portion of the universal drive unit **2** and includes a feed motor **10** which is a hydraulically powered, reversible motor. This motor is of the fixed displacement type but speed may be varied by varying the amount of hydraulic fluid supplied to it. The motor **10** has an output shaft **11** on which is mounted a worm **12**. The worm **12** drives a wheel **13** which, through a suitable shaft, drives a feed sprocket **14**. The feed sprocket **14** drives a feed chain **16** which feeds the unit **2**, drill rod **4**, downhole drill **5** and drill bit **6** in either the up or retract direction or the down or forward feed direction. A pair of pivot sprockets **15** provide balance as more fully explained in the aforementioned application of Samuel Leven.

For an efficient drilling machine, it is desirable to provide a feed system which may be driven at high speed in either direction for adding drill rods and pulling the tool out of the hole and at low speed feed for drilling. Prior to this invention, a worm gear arrangement was not acceptable for this dual speed function because of its inefficiency at low speeds. The efficiency of a worm gear drive can best be described by reference to FIG. 7 which shows a graph comparing efficiency to speed. The solid line represents the efficiency of a worm gear arrangement. It can readily be seen that in the upper speed range, there is essentially a straight line relationship between efficiency and speed. Thus, it is apparent that for high speed feed, such as is to be used for adding drill rods, a worm gear feed system is desirable. In the low speed range, however, it can be seen that as speed is decreased, efficiency rapidly decreases. Since high and constant feed force at low speeds is essential for proper drilling, the worm gear drive is undesirable.

By this invention I have introduced a hydraulic system for supplying motive fluid during slow speed feed which has an efficiency speed relationship, the reverse of that of the worm gear drive in the drilling speed range. In FIG. 7, the efficiency of the hydraulic system has been illustrated by a broken line. The hydraulic system or motive fluid supply means has been designed so that in the drilling speed range, as feed speed increases, efficiency decreases. The hydraulic system which feeds fluid to the motor for slow speed feed is coordinated with the worm gear drive unit so that when the two are considered together, in the low speed range, a substantially constant efficiency is provided. The slow speed fluid feed system is tailored to the worm gear drive by the use of long, relatively small inside diameter lines and orifices. Since the fluid feed lines are small in comparison to those of the high speed supply system, as the amount of fluid in the line increases in order to increase speed, pressure losses increase thereby reducing the efficiency of the system. The two, when combined, will have a low output force, but it will be substantially constant in the low speed range. In order to increase the output force in the low speed range to or slightly above that of the high speed, the slow feed system pressure limit is set higher than the established pressure limit for the fast feed system. The use of a tailored hydraulic system is possible because of the narrow speed range used for drilling. A suitable check valve arrangement insures that the two hydraulic systems are separated.

The arrangement of the feed control system of this invention is best shown in FIGS. 3 and 5 with FIG. 3 showing the system with the valving positioned for high speed feed in the retract direction. FIG. 4 is a fragmentary view showing a control valve positioned for high speed feed in the forward direction. The high speed system is generally indicated at **20** and includes a large variable delivery pump **21**. The pump **21** draws fluid from a sump or reservoir **22** through a supply conduit **23**. From the pump **21**, fluid flows through a conduit **24** to a four-way valve **25**, which includes a built in relief valve, and a conduit **26** which leads to the feed motor **10**. Exhaust from the motor passes into a conduit **27**. A check valve **28** is positioned in the line **27** and normally prohibits flow toward the lower set relief valve **25**. However, in the retract direction, high pressure fluid in line **26** passes through a pilot line **30** to open the check valve **28** and permit flow through line **27** back to the four-way valve **25**. From the four-way valve **25** the exhaust fluid flows through a conduit **29** to the sump **22**.

Should it be desired to operate the motor **10** in the high speed forward direction, the four-way valve **25** is repositioned to the position shown in FIG. 4. The pump **21** now pumps fluid through conduit **24** to conduit **27** through the check valve **28** to the motor **10** driving it in forward direction. Exhaust from the motor **10** flows through conduit **26** to the four-way valve **25** into conduit **29** back to the sump **22**. A suitable control (not shown) may be provided to adjust fluid flow through the pump **21** to vary speed. The low speed feed system is blocked by placing the valve **40** in a neutral position as shown in FIG. 3.

During actual drilling operations, the drill bit and drill string must be fed down the hole at a speed coordinated with the speed the hole is being drilled. In order to feed at a slow speed, a slow feed supply system **35** is provided. Referring to FIGS. 5 and 6, the large pump **21** is set to zero delivery and the four-way valve **25** is set in neutral position. The second pump **37** is connected to a sump **57** and supplies fluid under pressure through a conduit **38** and a pressure compenated flow control valve **39** to the valve **40** which permits selection between rotary and downhole drilling as well as neutral position for high speed feed. The pump **37** is preferably a pressure compensated pump which can be run continuously, even though the output is blocked without overheating.

The pressure compensated flow control valve **39** insures a constant volume regardless of the pressure conditions existing in the system and may be adjusted to control the volume of fluid supplied by the pump to the motor **10**. As known in the art, during downhole drilling, it is desirable to maintain minimum pressure on the bit since the drill bit must be free to be hammered by the piston of the downhole drill. If the pressure is too high, there will be no room for the drill bit to reciprocate or be hammered and the force of the downhole drill will be transmitted to the drilling machine rather than the drill bit. In order to insure a lower pressure on the bit, fluid flows from the conduit **38** through four-way valve **40** and into a small inside diameter conduit **41**. A pressure relief valve **42** which drains into a sump **43** and may be adjustable to permit variations in the amount of pressure used in downhole drilling is positioned in the conduit **41**. Fluid under pressure then flows through a check valve **44** to the line **27** and the motor **10**. Exhaust fluid from the motor flows through line **26** to four-way valve **25**, line **29** and back to the sump **22**.

During rotary drilling it is necessary to use high force on the bit. To achieve this high force a high pressure and greater volume of fluid must be supplied to the

feed motor **10** so that the increasing internal leakages under a higher pressure will be offset and there will be a greater pull down force on the bit by the feed motor. The higher pressures required by rotary drilling are accomplished by moving the valve **40** to the position shown in FIG. 6 so that the relief valve **42** is by-passed. In this position fluid flows through conduit **38** to conduit **52**, through a variable restriction **53**, and check valve **54** to the small inside diameter conduit **41**, and the motor **10** by way of conduit **27**. As is the case of downhole drilling, exhaust from the motor **10** is through conduit **26**, four-way valve **25**, conduit **29** to sump **22**.

A drain line **56** and reservoir **57** are preferably connected to the valve **40**. The sumps **22**, **43** and **57** are preferably interconnected with each other or may constitute one large reservoir. They have been shown separately in order to simplify the drawings.

During drilling, the valve **39** is set to allow a certain volume of fluid to flow to the motor **10**. This volume gives a certain pressure in the system, such pressure being indicated on a pressure gauge **45**, connected to line **41** by conduit **46**. The optimum drilling speed will be indicated by a certain pressure known to the operator. Should the hardness of rock decrease, the hole will be drilled faster than the motor **10** is feeding. Since this will cause a reduction in the amount of work which must be done by the motor **10**, there will be a drop in pressure in the system. This drop in pressure will be indicated by a lower pressure shown on the meter **45**. The operator may then adjust valve **39** to permit a greater volume of fluid to be supplied to the motor **10** until the speed of feed is returned to the optimum value as indicated by the pressure on the gauge **45**.

An increase in the hardness of the rock will result in the hole being drilled slower than the rate the motor **10** tries to feed the bit and drill string down the hole. This will result in a build up of back pressure at the motor **10** and in the supply lines. Such a build up in pressure will be indicated on the gauge **45**. The operator may then adjust valve **39** to reduce the volume of fluid supplied to the motor **10** which will reduce the speed of the feed to the proper rate.

The apparatus is self compensating to a certain extent. Inherently, the system will have a certain number of points at which internal leakage will occur. The amount of leakage will depend on the pressure of the fluid within the system. Should the pressure increase a slight amount due to slight increases in rock hardness, there will be an increased amount of leakage in the system. This increased amount of leakage reduces the volume of fluid which reaches the motor **10** and hence reduces the speed of feed a slight amount. Should a slightly lesser hardness rock be encountered for example, broken rock, the pressure in the system will be decreased. This decrease in pressure reduces the amount of inherent leakage and hence permits a greater volume of fluid to reach the motor **10** and speed is increased. The control through gauge **45** and valve **39** is effective for both rotary and downhole drilling.

As a hole being drilling deepens, additional drill rods must be added to the drill string. Each added drill rod adds weight to the drill string and hence additional pressure is applied to the drill bit. It is therefore necessary to reduce the volume of fluid supply after a number of drill rods have been added to the string in order to maintain proper pressure on the bit. The increased weight of the drill rods is not indicated by an increased pressure in the supply and therefore operator skill must be relied on. The gauge **45** is helpful, however. For example, if optimum drilling pressure as measured on the gauge **45** is 2000 p.s.i. and each drill rod adds 30 p.s.i. to the pressure on the bit, with the addition of each drill rod to the drill string, the operator may reduce the pressure applied to the bit through the feed system by adjusting valve **39**. The reduction in system pressure will be indicated on gauge **45**.

It is apparent from the foregoing that a system has been provided which permits both high speed and low speed feed and permits drilling by bath the downhole drill method and the rotary method. The system overcomes the inherent disadvantages of a worm gear type feed motor yet retains its advantages by the use of a supply system which is coordinated with the drive unit to produce high efficiency at low speeds.

It is intended that the foregoing description be merely that of a preferred embodiment and that this invention be limited solely by that which is within the scope of the appended claims.

I claim:

1. In combination with a drilling apparatus having a drill string and a drill bit operatively connected to one end of the drill string, a system for feeding the drill bit and drill string down a hole being drilled comprising:
- a drive unit including hydraulic motor means and a worm gear drive driven by the hydraulic motor means operatively connected to a drill string for raising and lowering the drill string;
- a source of hydraulic fluid;
- a conduit for conducting fluid from said source to said hydraulic motor means;
- an adjustable pressure compensated valve for regulating the volume of fluid supplied to said hydraulic motor means from said reservoir and for permitting a constant volume of fluid to be supplied to said hydraulic motor means regardless of variations in pressure;
- means for limiting the maximum pressure at which fluid is supplied to said motor means; and
- valve means for selectively directing fluid under pressure through said limiting means.

2. The apparatus of claim **1** wherein said regulating means is a pressure compensated valve.

3. The apparatus of claim **2** further comprising a relief valve for limiting the pressure of the fluid supplied to said motor by said second pump means and second valve means permitting said relief valve to be selectively bypassed.

4. The apparatus of claim **3** further comprising check valve means positioned between said second valve means and said relief valve.

5. The apparatus of claim **4** wherein said fluid is a hydraulic fluid.

6. A two direction feed control system comprising:
- a source of fluid;
- a fluid pressure operated reversible motor;
- first pump means for supplying fluid under pressure from said source to said motor for driving said motor at one speed;
- first valve means for controlling the direction said first pump drives said motor;
- second pump means for supplying fluid under pressure from said source to said motor for selectively driving said motor at a second speed; and
- means for selectively regulating the volume of fluid supplied to said motor from said second pump means.

7. Rock drilling apparatus comprising:
- a drill tower;
- a drill rod mounted on said tower;
- a drill bit operatively connected to said drill rod;
- means for rotating said drill rod and drill bit relative to said tower;
- motor means operatively connected to said drill rod for raising and lowering said drill rod relative to said tower;
- a source of fluid;
- first supply means for supplying fluid under pressure from said source to said motor means for raising and lowering said drill rod at one speed;
- second supply means for supplying fluid under pres-

sure from said source to said motor means for lowering said drill rod at a second speed;

said second supply means being coordinated with said motor means to provide optimum efficiency at low operating speeds.

8. The rock drilling apparatus of claim **7** wherein said motor means includes a worm gear drive for raising and lowering said drill rod and said first supply means includes pump means and first valve means for controlling the direction said motor means is operated.

9. The rock drilling apparatus of claim **8** wherein said second supply means includes pump means for selectively supplying fluid under pressure to said motor means.

10. The rock drilling apparatus of claim **9** wherein said second supply means further includes a pressure compensated valve positioned in a flow connection between said pump means and said motor means for controlling the volume of fluid supplied to said motor means by said second pump means.

11. The rock drilling apparatus of claim **10** wherein said second supply means further includes a relief valve for limiting the pressure of fluid supplied to said motor means and second valve means permitting said relief valve to be selectively by-passed.

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U.S. Cl. X.R.

60—52; 175—122