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[54] **BOREHOLE CHARGING APPARATUS**

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[58] **Field of Search** .... 86/20 C, 21; 149/109; 102/23

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[57] **ABSTRACT**

A manually portable apparatus for the charging of small diameter boreholes with slurry explosive includes a slurry explosive storage compartment, a pneumatically operated reciprocal pump detachably connected to an outlet in the slurry storage compartment, delivery means attached to the pump for conveying slurry under pressure from the storage compartment into a borehold and control means for regulating the operating rate of the pump, the slurry delivery means being insertable to the bottom of the borehold and having attached to the forward end thereof means whereby the entrance of slurry under pressure into the borehole causes the delivery means to be withdrawn from the borehole.

7 Claims, 1 Drawing Figure

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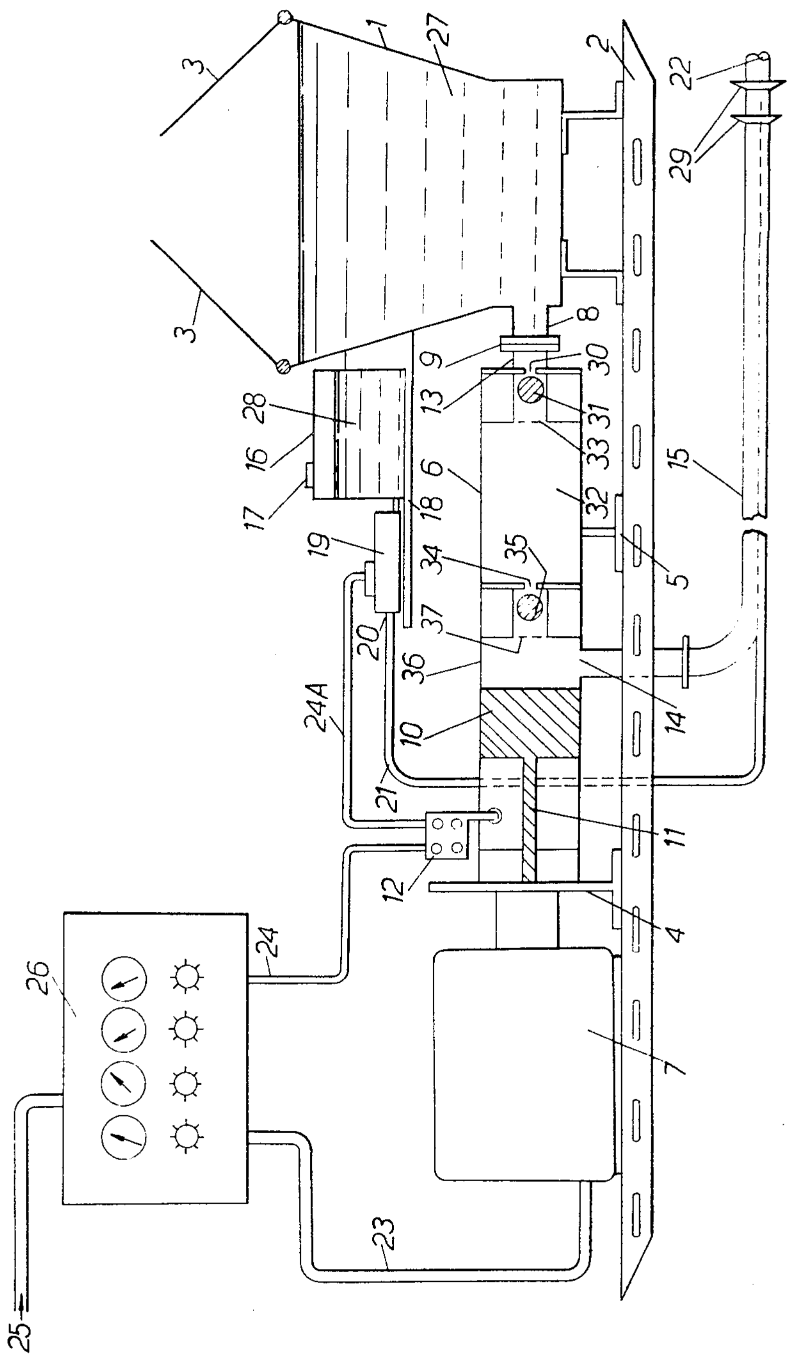

BOREHOLE CHARGING APPARATUS

This invention relates to an apparatus for the charging of boreholes with bulk slurry explosives. In particular, the apparatus of the invention is suitably employed in underground mining in confined work areas.

Slurry explosives, which comprise a mixture of oxidizer and fuel ingredients dispersed in a fluid matrix, have found wide application in the mining and construction industries where they are customarily employed in boreholes of 3 to 6 inches in diameter or larger. In open pit mining and in quarrying in particular, slurry explosives have proven especially useful since it is possible to place the slurry in bulk (unpackaged) form directly into the boreholes from a vehicle-mounted delivery tank or mixer. In this fashion, large economics have been provided through improved blasting effectiveness and lower production cost as compared to the use of conventional dynamite types of explosives.

More recently, it has been proposed to take these convenient, economic and safe slurry explosives underground for use in boreholes of small diameter, that is, boreholes of a diameter of 2 inches or less. To this end improved slurry formulations of increased sensitivity have been developed which permit the slurry to be detonated in these small diameters by means of a blasting cap, which slurries will propagate the detonation along the full length of long reduced-diameter boreholes. For these underground uses, sensitive slurry mixtures have been packaged in fluid-retaining cartridges in the explosive factory and brought to the underground workings where they are used in much the same manner as the dynamite cartridges which they are designed to replace. These packaged slurries, while they possess the advantage of safety and lack of toxicity compared with dynamite types, are not without drawbacks. Packaging is difficult and sometimes costly because of the fluid nature of the slurry and the resultant soft cartridges are often awkward to hand load into boreholes. It would, therefore, be advantageous if slurry explosives could be bulk loaded into boreholes in underground workings in much the same manner as slurries are bulk loaded in surface mining operations. However, some difficulties become immediately obvious. In surface mining, boreholes are always vertical or nearly so and hence gravity loading of the holes or pressure loading through delivery hoses is relatively easy. In underground mining, however, boreholes may be located horizontally in the working face or even vertically overhead in a roof with the result that gravity can not be utilized to retain the slurry in the borehole. Similarly, the delivery of the bulk slurry to up-holes and horizontal holes cannot be accomplished utilizing the types of apparatus presently used to pump or otherwise deliver slurry into vertical surface holes. Additionally the restricted working areas underground preclude the use in these areas of the sometimes cumbersome equipment used in surface blasting.

It is the principal object of this invention to provide an apparatus for the charging of boreholes in underground workings with slurry explosives in bulk form. Other objects will become obvious from the further description herein.

According to this invention there is provided a portable apparatus adapted for the bulk slurry charging of boreholes which comprises, in combination, a slurry explosive storage compartment, a pneumatically operated reciprocal pump means detachably connected to an outlet in said slurry storage compartment, delivery means attached to said pump means and adapted to convey said slurry under pressure from said storage compartment into a borehole, and control means whereby the operating rate of said pneumatically operated pump means may be regulated, the said slurry delivery means being also adapted for insertion to the bottom of a borehole and having attached to the forward end thereof means whereby it can be retracted from the borehole as said slurry is pumped under pressure therein.

The invention also optionally provides a means whereby a chemical viscosity-increasing agent may be delivered from a storage compartment to and admixed with said slurry explosive close to or at the point of exit of said slurry from said delivery means.

By "portable apparatus" is meant that the apparatus is of suitable size and weight that it may be manually transported to a restricted underground working area as a single unit.

It will be appreciated by workers skilled in the art that a slurry explosive composition capable of self-retention in a horizontal or an upward slooping borehole must possess considerable viscosity if it is to remain in the borehole without slumping. Generally, such a slurry will be required to have substantially more resistance to flow than a slurry adapted for use in vertical down-holes in surface mining. The use of such an extra-viscous slurry in underground bulk slurry operations introduces problems associated with borehole filling not encountered on the surface. For example, the pumps known to be safe and useful for moving slurry explosives through large diameter hoses in surface mining are quite impractical for use in pumping high viscosity slurries through small diameter hoses. Additionally, it is known that the shearing forces at work within known slurry pumps tend to decrease the detonation sensitivity of high viscosity explosive slurries, which decrease cannot be tolerated if the slurry is to be successfully detonated in small diameter charges. Accordingly, it is an important aspect of this invention to provide a pump delivery means for a high viscosity explosive slurry which will transport the slurry through long lengths of small diameter hose into the boreholes without any appreciable reduction in the detonation sensitivity of the slurry.

An understanding of the preferred form of this invention may be obtained from a consideration of the following detailed description with reference to the accompanying drawing which shows, partly in section, a partly diagrammatic elevational view of the apparatus.

Referring to the drawing in detail, a bulk slurry explosive storage compartment or hopper **1** is shown mounted on sled **2.** Hopper **1** has a hinged cover or lid **3.** Also mounted on sled **2** by means of supports **4** and **5** is double-acting piston pump **6** and air powered motor **7.** Inlet **13** of piston pump **6** is attached to the bottom outlet **8** of hopper **1** by means of coupler **9** which is preferably a quick-connect coupler. Reciprocal piston **10** of pump **6** is attached to air powered motor **7** by means of shaft **11.** An actuator of air switch **12** is mounted so as to be operable by the movement of piston **10.** Outlet **14** of pump **6** has attached thereto slurry delivery hose **15.** Mounted on the outside of hopper **1** is shown chemical additive storage tank **16** which has a vented filling port 17 and bottom outlet 18. Attached to outlet 18 is air-operated additive pump 19. Outlet 20 of additive pump 19 has attached thereto tube 21 which tube penetrates hose 15 and terminates inside and near the exit end 22 of hose 15. Tube 21 is sufficiently strong to resist collapse from the pressure of the slurry within hose 15. Pressurized air for the operation of air powered motor 7 and air operated delivery pump 19 is delivered respectively by air lines 23 and 24. Air line 24 passes into acutator 12. Main air supply shown by arrow 25 is received from the compressed air source provided in underground workings for the operation of drills and the like. Air supply 25 may be appropriately reduced in pressure and volume, designated by panel 26, before passing to motor 7 and pump 19. A typical viscous slurry explosive 27 is shown in hopper 1 and a typical chemical additive, for example, a chromate cross-linking solution 28, is shown in tank 16.

In operation, a high viscosity slurry explosive 27, previously prepared at a surface location and transported underground in, for example, polyethylene bags, is placed in hopper 1 of the sled-mounted pumping unit located close to the face of the underground working. Hopper 1 may hold up to 400 pounds or more of slurry explosive. A member of the work crew inserts hose 15 into a borehole until the hose end 22 is felt to reach the toe or bottom of the hole. Flexible discs 29 of rubber or other resilient plastic material which are fixed to and circumscribe hose 15 near end 22, serve to center the hose end in the borehole and function to eject hose 15 out of the borehole when the slurry is pumped under pressure through end 22 against the bottom of a borehole. As shown in the drawing, discs 29 are slightly cup-shaped and have their concave side facing the forward end 22 of hose 15. With hose 15 suitably located in the borehole, air is supplied to air line 23 and if desired, to air line 24 to operate air motor 7 and delivery pump 19. Upon application of air to motor 7, piston 10 is set in motion which motion will be described, first, as a forward stroke in the direction away from hopper outlet 8 and second, as a reverese stroke in the direction towards hopper outlet 8. As piston 10 moves forward, slurry 27 is sucked through hopper outlet 8 and pump inlet 13 through pump orifice 30 displacing valve 31. The slurry then enters chamber 32, through opening 33, passes orifice 34 displacing valve ball 35 and enters outlet chamber 36 through opening 37. On completion of the forward stroke of piston 10, air motor 7 reverses to carry pistion 10 in a reverse stroke, which stroke forces balls 31 and 35 to close off orifices 30 and 34 respectively to prevent the slurry within the pump from returning to hopper 1 and instead causes the slurry to be forced through pump outlet 14 into hose 15. Successive reciprocal strokes of piston 10 cause a pulsating flow of slurry through hose 15 and into the borehole. The reciprocal movement of piston 10 operates actuator 12 and allows air to flow through line 24A to operate additive pump 19. Pump 19, attached to the outlet of additive tank 16 thus delivers proportioned quantities of an additive, such as a crosslinker solution, to the slurry close to the exit 22, of hose 15. Moderate mixing of the crosslinker and slurry occurs at the hose exit and, if additional or improved mixing is required, the hose may be equipped near its end with an inline interfacial surface mixer well known in the art. As mentioned heretofore, as the slurry is ejected from hose end 22 into and against the bottom end of the borehole, the slurry engages the flexible disc or discs 29 and, utilizing the pressure transmitted through the slurry, pushed hose 15 towards the collar or top end of the borehole. The borehole is thus completely filled as the delivery hose is withdrawn. To avoid spillage of the slurry from the hose end when moving between boreholes, the air supply to panel 26 is shut off. Any residual pressure in the pump and hose may cause some small ejection or oozing of slurry from the hose end which slurry can be collected in a catch receptacle. Alternatively, a bleed line or hose (not shown) may be attached to the pump or delivery hose in order to direct and return any excess slurry to hopper 1. At the end of an operating period, the hopper, pump and hose may be cleaned simply by passing water or similar solvent through the system.

The pump suitable for use in the apparatus is a modified version of the type of pump normally employed to pump very viscous materials such as grease, caulking compounds and the like. Such a pump may be described as a single-stroke double-acting piston pump which has been especially modified, for safety and other reasons, for the handling of explosive slurries. For obvious reasons, metal-to-metal contact of moving parts within the pump is to be avoided. Valve balls 31 and 35, for example, are made of an inert plastic material such as polytetrafluoroethylene as are the seats for these valves around orifices 30 and 34. Rubber or plastic packing is provided around shaft 11 and non-metallic piston rings are provided around piston 10. In order to increase the rate of flow of slurry through the pump it may be necessary to increase the usual size of orifices 30 and 34 and openings 33 and 37. The air motor 7 used to drive pump 6 is preferably a double-acting diaphragm motor containing a stroke adjustment feature which provides accurate control of the amount of slurry delivered on each stroke of the pump. Hopper 1 and tank 6 may be of any suitable material resistant to the corrosive effect of the oxidizing salts employed in slurry explosive mixtures. Stainless steel may be advantageously used.

The following examples illustrate the use of the apparatus of the invention in underground mine workings.

EXAMPLE 1

In an underground gold mine at a depth of 2,400 feet, a number of 2 inch diameter boreholes are drilled in a ring configuration in the roof, walls and floor of a drift. The angle of the holes varied from 89° above horizontal to 43° below horizontal and hole depth was from 28 feet to 69 feet. A slurry pumping apparatus of small capacity and similar to that shown in the drawing was located close to the work area where the hopper was filled with slurry explosives taken underground in polyethylene bags. The explosive slurry used consisted of a mixture of approximately 63 percent by weight of oxidizing salts, 10 percent by weight of particulate self explosive, 18 percent by weight of water, 5 percent by weight of aluminium powder, 2 percent by weight of glycol, the remainder being minor amounts of thickener, crosslinker and pH control agents. The slurry was pumped through 80 feet of one inch (inside) diameter rubber hose to within 6 feet to 14 feet of the collar of the boreholes. After pumping, there was no evidence of run-out of slurry from even the most vertical of the holes after an overnight period. The rate of filling of the 2 inches boreholes was about 4 feet per minute which slow rate was mainly attributed to the inexperience of the operators and the low capacity of the pump used. After filling, each hole was primed by means of a 1 ½ inch diameter dynamite cartridge which was inserted well into the slurry at the collar of the hole. Detonation of each primer was by means of an electric blasting cap. Inspection of the blast site 2 days after detonation indicated a successful blast.

EXAMPLE 2

In an underground working drift in a pyrite mine, two rings of 2 inch diameter boreholes were drilled into the rocks to depths ranging from 5 to 58 feet and at angles of from –62° to +90°. In all 815 linear feet of 2 inch diameter boreholes were prepared. A slurry explosive comprising approximately 15 percent by weight of water, 69 percent by weight of oxidizing salts, 7 percent by weight of carbonaceous material, 3 percent by weight of sulphur, 5 percent by weight of aluminium powder and the remainder thickening agent and cross-linker, was taken underground and placed in the hopper of an apparatus similar to that shown in the drawing. The slurry was pumped through 80 feet of 1 inch (inside) diameter rubber hose into each borehole at an average rate of 35 linear feet per minute to within 3 to 5 feet of the top of the holes. None of the above horizontal holes showed any evidence of any slumping of the slurry. All holes were primed with a 1 ½ inch diameter dynamite cartridge with an electric blasting cap in one end. The slurry was soft enough to permit burial therein of the primer. After detonation it was observed that an excellent blast had taken place.

It may be seen from the foregoing that the apparatus of the invention provides a safe and efficient means for charging underground boreholes with bulk slurry explosive compositions of high viscosity. The invention, however, is not to be limited to the embodiment described and a wide range of materials of construction, arrangement of components and modes of supplying product will be apparent. The portable apparatus may, for example, be mounted on a wheeled base or frame where this is practicable. The slurry may, for example, be delivered to the portable apparatus in tote bins adapted for transport by, for example, lift truck. Remote controls close to the filling hose may be provided for closely monitored operation. Other modifications are possible without departing from the scope of the invention.

What we claim is:

1. A manually portable apparatus for the charging of boreholes of 2 inches or less in diameter with slurry explosive comprising, in combination, a slurry explosive storage compartment, a pneumatically operated reciprocal pump means detachable connected to an outlet in said slurry storage compartment, delivery means attached to said pump means for conveying said slurry under pressure from said storage compartment into a borehole, and control means for regulating the operating rate of said pneumatically operated pump means, the said slurry delivery means being insertable to the bottom of a borehole and having attached to the forward end thereof means whereby the entrance of slurry under pressure into said borehole causes the said delivery means to be withdrawn from the said borehole.

2. An apparatus as claimed in claim **1** wherein the pump means is a single-stroke double-acting piston pump.

3. An apparatus as claimed in claim **1** wherein the pump is constructed of such materials that its moving parts present no metal-to-metal contact.

4. An apparatus as claimed in claim **1** wherein the pump is driven by an air motor.

5. An apparatus as claimed in claim **1** wherein the means attached to the forward end of the delivery means comprises at least one resilient cup-shaped disc having its concave side facing said forward end.

6. An apparatus as claimed in claim **1** comprising a storage compartment for a chemical viscosity-increasing agent and conveying means for conveying the said viscosity-increasing agent from the storage compartment to a position in proximity to the forward end of the slurry delivery means.

7. An apparatus as claimed in claim **6** comprising an actuator for operating the conveying means, said actuator being mounted so as to be operable by the movement of the reciprocal pump means.

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