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 [21] Appl. No. **750,728**
 [22] Filed **Aug. 6, 1968**
 Continuation-in-part of application Ser. No.
 612,945, Jan. 31, 1967, now Patent No.
 3,521,820
 [45] Patented **Nov. 10, 1970**
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FOREIGN PATENTS

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[54] **HYDRAULIC RAM JET DEVICE**
6 Claims, 2 Drawing Figs.

[52] **U.S. Cl.**..... **239/102,**
 239/601, 239/602; 175/67; 299/17

[51] **Int. Cl.**..... **B05b 3/14**

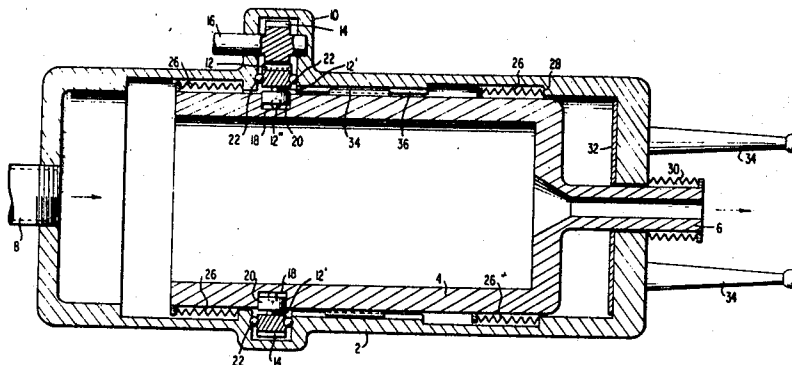
[50] **Field of Search**..... 239/101,
 102, 601, 602; 175/67; 299/17; 77/(NS)

[56] **References Cited**

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ABSTRACT: A system for producing repetitive pulsed jets of liquid employing a reciprocating hollow piston member having a nozzle at one end thereof and in which the piston member is cocked against the pressure of a liquid supply to a housing within which the piston reciprocates and in which the piston is allowed to be propelled under the pressure of the liquid supply to impact the forward face of the housing wherein a shock wave is generated within the liquid contained in the piston and is caused to eject from the nozzle in the form of a high velocity pulsed jet. For each impact of the piston against the housing wall, a pulsed jet is ejected from the system.



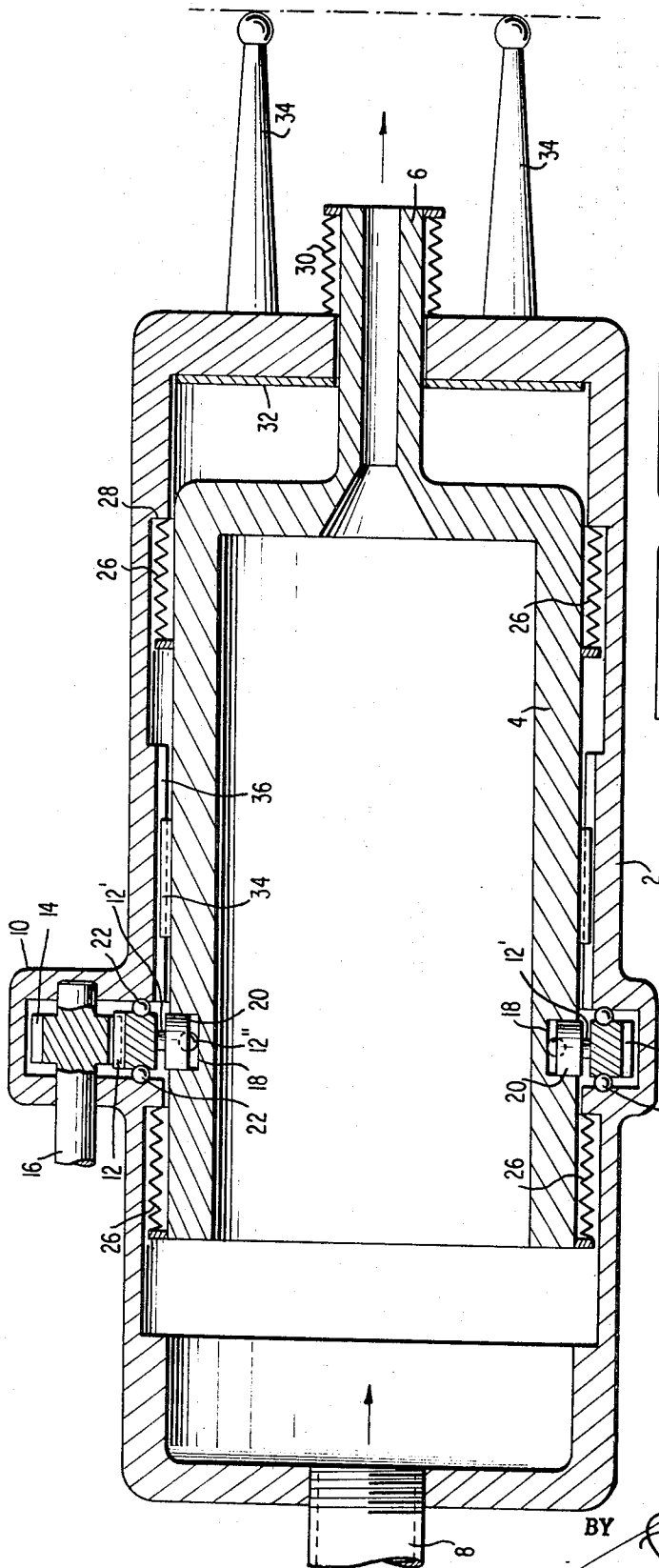


FIG. 1

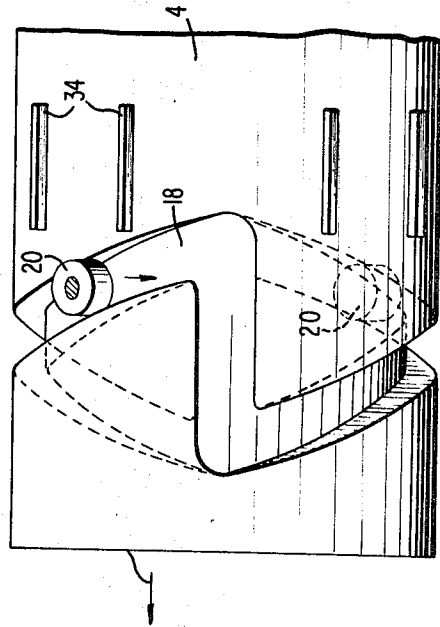


FIG. 2

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HYDRAULIC RAM JET DEVICE

This is a continuation-in-part application of Ser. No. 612,945, filed Jan. 31, 1967, now U.S. Pat. No. 3,521,820, entitled "Hydraulic Pulse Jet Device".

This invention relates to devices for producing pulsed jets of liquid from a nozzle under extremely high pressures in the order of 50,000 to 200,000 p.s.i. or higher which is particularly useful for rock breaking, rock tunneling, mining, breaking of concrete and a wide variety of other applications.

In the past systems for producing pulsed jets of liquid have utilized such methods as piston expulsion or cumulation or shaped charge principle. The piston expulsion theory utilized in fuel injection techniques offers difficulties with piston sealing and leakage of pressures greater than 3,000 atms. The cumulation principle, that is, the theory of explosive shaped charges, has been used for production of metallic jets but has not as yet been extensively applied for the production of liquid jets because of the complexity, expense and hazards in using explosive materials.

Accordingly, it is an object of this invention to provide a mechanically powered hydraulic pulsed jet device for producing repetitive pulsed jets of liquid with stagnation pressures greater than 100,000 p.s.i.

Another object of this invention is to provide a jet pulsing device employing a reciprocating piston having a high pressure liquid extrusion nozzle.

Still another object of this invention is to provide a jet pulsing device in which a reciprocating hollow piston member cooperates with a high pressure liquid cylindrical housing for ejecting pulsed liquid jets from the piston member and utilizing the supply of liquid under pressure to the housing for controlling the reciprocating action of the piston member.

It is a further object of this invention to provide a jet pulsing device which is designed for automatic continuous operation independent of the ambient environmental conditions such as water or drilling mud and which does not require the ejection of gases or liquid from the device to such ambient environment other than the pulsed jet itself.

It is a further object of this invention to provide a jet pulsing device employing a minimum of parts and which is constructed in a simple and economical manner for producing a reliable and continuous operation.

According to one embodiment employing the principles of this invention, there is provided a cylindrical housing with a reciprocating hollow piston member therein having a nozzle extending through an aperture provided in the housing. At one end of the housing is an input for supplying liquid under high pressure to the cylindrical housing and to the interior of the hollow piston. A mechanical drive connected to the hollow piston forces the piston rearwardly within the cylindrical housing against the liquid supply pressure to a point where the mechanical drive is tripped and the piston is propelled forwardly by the high pressure liquid supply, impacting against a front face of the cylindrical housing and generating a shock wave within the liquid contained in the piston. This shock wave moves rearwardly reducing the in-flow velocity of the liquid supply and increasing the pressure within the piston member supplying at the nozzle end of the piston a pressurized liquid in a range between 50,000 and 200,000 p.s.i. or higher and consequently ejecting a pulsed jet of liquid through the nozzle for each stroke of the piston.

Other objects and advantages will become apparent from the following detailed study of the specification and drawings, in which:

FIG. 1 is a side elevational view partly in cross section of the system utilizing the principles of this invention; and

FIG. 2 is an elevational view of the piston member with its cam track structure.

Referring now to FIG. 1, there is shown a generally elongated hollow cylindrical housing 2. Mounted for reciprocable movement within the housing 2 is a hollow piston member 4 which may be slidably mounted by suitable means, such as splines, keys or the like. The forward end of the piston 4 forms a nozzle portion 6 which extends through an axial opening in

the front face of the housing 2. The rear end of the piston 4 has an open face opposing a liquid supply inlet port 8 mounted on the rear face of the housing 2.

A mechanical drive for cocking the piston 4 is provided by way of example but not limited thereto in the camming device shown.

Extending circumferentially around the housing 2 is an annular channel member 10 in which is located a ring gear 12 driven by a pinion 14 which has a drive shaft 16 extending through the channel portion 10 and which is driven externally by a suitable motor drive either electrically, pneumatically or hydraulically. The ring gear 12 is provided with a pair of diametrically opposed and radially inwardly extending projections 12'. Each of the projections 12' terminates in a socket for supporting a roller ball member 12'' for engaging the bottom surface of a cam track 18 extending circumferentially along the outside surface of the piston member 4 as best shown in FIG. 1. Each of the projections 12' has journaled thereon a roller cam 20 which cams against the side walls of the cam track 18. The ring gear 12 is maintained in a median position within the channel 10 by means of a pair of ball bearing race members 22 occupying in each case the space between the side walls of the ring gear 12 and the side walls of the channel 10, as shown. The ball bearing race members 22 act as thrust bearings for the ring gear 12, to be more fully explained below. The space between the ring gear and the side walls of the channel 10 is filled with a suitable oil. To prevent leakage of the oil to the interior of the housing 2, annular bellows 26 are connected to the outside surface of the piston member 4 as well as to respective annular abutment edges 28 along the inside surface wall of the housing 2. The bellows 26, therefore, allow the piston member 4 to reciprocate past the channel 10 while at the same time acting as a seal for the oil contained therein. An annular bellows 30 arrangement is also provided at the front face of the nozzle 6 of the piston 4 for the purpose of preventing leakage of fluid from the interior of the housing 2, as well as for maintaining the vacuum in the space between the front face of the piston member 4 and the front face of the housing member 2, to be more fully explained below. A shock pad 32 of suitable shock absorbing material is positioned against the inside surface of the front wall face of the housing 2, as shown. Extending from the outside surface of the front wall face of the housing 2 are two or more leg members 34. These members extend a sufficient amount beyond the nozzle 6 to maintain a working space between the extended position of the nozzle 6 and the workpiece upon which the device is acting.

As shown in FIG. 2, the piston 4 has its cam track 18 substantially L-shaped along one-half of its circumference. The other half of the circumference is similarly shaped such that any point along the track 18 will have its corresponding point diametrically opposed. Adjacent the track 18 is an annular arrangement of splines 34 extending in the axial direction. The splines 34 engage one or more parallel grooved portions 36 provided on the interior surface of the housing 2. From a study of FIG. 2, it will be seen that as the rollers 20 move in a plane containing the ring gear 12, it will force the piston in a rearward direction as it travels along the track 18 until it reaches the trip point defined by a change in the direction of the track to an axial direction, at which time the piston 4 is free to move in the axial direction. The rollers 20 will continue their travel, again imparting a rearward motion to the piston as they engage the side walls of the track 18 and at the trip point where the rollers 20 reach the diametrically opposed axially directed portions of the track 18, the piston 4 will be free to move in the axial direction and will do so under the pressure of the liquid being supplied through the inlet port 8.

The operation of the system is as follows. Liquid, for example, water, at a pressure of 3,000 to 30,000 p.s.i. is supplied from an external source to the inlet port 8. For this purpose a length of rigid pipe may be connected to the inlet port. With the liquid entering the interior of the housing 2, and hence the interior of the piston 4, a flow through the nozzle 6 will be

established if the supplied pressure exceeds the nozzle exit pressure, which is normally the case. The drive means for the pinion 14 is actuated and thus rotate the ring gear 12 around the periphery of the piston 4 with the cam rollers 20 riding in the track 18 extending along the outside surface of the piston 4. As previously explained, engagement of the rollers 20 with the cam track will cause the piston 4 to translate rearwardly, that is, toward the inlet port 8. Energy is stored as a result of the piston motion against the supply pressure of the liquid from the inlet port 8, while at the same time a volume under vacuum is created between the piston's forward face and the front face of the housing 2. The potential energy stored in the system is equal to the product of the supply pressure and the volume of vacuum created by the piston displacement. When the cam rollers 20 pass the trip point in the track 18, as shown in FIG. 2, the piston is then free to accelerate toward the front face of the housing, thus storing kinetic energy in the liquid which rushes in under the supply pressure. When the piston impacts the shock pads 32 provided along the front face of the housing, a shock wave is generated in the liquid within the interior of the piston. This shock wave moves rearwardly through the system toward the inlet pipe 8 reducing the inflow velocity and at the same time increasing the pressure within the housing 2. During the time until the shock wave returns as a rarefaction wave from the inlet port 8, or from a flexible section of the supply piping further upstream, the nozzle 6 is supplied with pressurized liquid at the "water hammer" pressure P. This pressure P has an upper limit value:

where:

$$P = \rho CV.$$

ρ = Liquid density.

C = Velocity of sound in liquid.

V = Liquid velocity in the inlet port at the time when the piston comes to a stop and before the shock wave has reached the inlet port.

As a result, a pulsed jet of liquid is ejected from the nozzle 6 under the "water hammer" pressure P. The cam rollers 20 then act against the track 18 on the periphery of the piston causing the same to be cocked again, that is, moved rearwardly, to repeat the same operation and hence eject another pulsed jet of liquid. For a given supply pressure the energy available per pulse is proportional to the piston displacement volume. The required cam power for moving the piston rearwardly is proportional to the repetition rate which is determined by the number of cam track undulations per rotation of the ring gear 12 as well as the rotation rate of the ring gear. The example shown in FIG. 2 allows two cam undulations per 360° revolution of the ring gear. Thus, the piston 4 is moved rearwardly twice for each revolution of the ring gear 12 producing, therefore, two pulsed liquid jets for every revolution of the ring gear. The legs 34, all this while, will be abutting the workpiece or material upon which the liquid jet is acting, and as this material is broken away or cut through by the liquid jet, the legs 34 will move toward a fresh area of material always maintaining a working space between the nozzle 6 and the material. In this manner, the entire device, in effect, can burrow its way through the workpiece or material.

It will be seen that the device is independent of the ambient

environment, for example, water or drilling mud, because the liquid jet issues from the nozzle 6 under the "water hammer" pressure which can be large compared to ambient pressure. Also, the operation of the system according to this invention does not require ejection of gases or liquids to atmosphere, or to the ambient environment, other than the high pressure liquid jet itself.

I claim:

1. In a system for repetitively producing high velocity pulsed jets of liquid, the combination comprising, a hollow housing having an aperture and an inlet port for admitting a high pressure fluid, a hollow piston member movably mounted within said housing and having a nozzle aligned with said aperture, means for driving said piston member to a position adjacent said inlet port and means for releasing said piston, whereby said high pressure liquid drives said piston to impact a portion of said housing for generating a shock wave in said liquid and eject a high velocity pulsed jet of liquid through said nozzle.

2. In a system for repetitively producing high velocity pulsed jets of liquid, the combination comprising, a cylindrical housing having an aperture at one end thereof, an open-ended hollow piston member slidably mounted within the interior of said housing and having a nozzle member extending through said aperture, means supplying a high pressure liquid to the interior of said housing opposite said open-ended piston, means for driving said piston toward said liquid supply means and releasing said piston member, whereby said high pressure supply liquid drives said piston to impact the front end of said housing an generate a shock wave in the liquid within the interior of said piston for ejecting a high velocity pulsed jet through said nozzle.

3. In a system for repetitively producing high velocity pulsed jets of liquid, the combination comprising, a cylindrical housing having an axially aligned aperture at one end thereof, an open-ended hollow piston member slidably mounted within the interior of said housing along its axis, said piston having an axially aligned nozzle extension member extending through said aperture in said housing, an inlet port means positioned at the other end of said housing and facing the open end of said piston for supplying a high pressure liquid to the interior of said housing, means for driving said piston member toward said inlet port, and means for releasing said piston member from said drive means subsequent to the operation of said drive means, whereby said high pressure supply of liquid drives said piston to impact the front end of said housing for generating a shock wave in the liquid within the interior of said piston and ejecting a high velocity pulsed jet through said nozzle.

4. In a system according to claim 3, wherein a flexible sealing means is provided between said nozzle and said aperture of said housing.

5. In a device according to claim 3, wherein said drive means is positioned on said housing and extends within the interior of said housing to engage a portion of said piston.

6. In a system according to claim 5, wherein there is provided a flexible sealing means surrounding said driving means and extending between a portion of the interior wall surface of said housing and a portion of said piston.