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[54] **APPARATUS FOR PRODUCING A PULSE OF LIQUID FOR MACHINING OPERATIONS**

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[52] **U.S. Cl.** **239/101**, 83/53, 83/177, 239/331, 239/407, 239/569, 243/29

[51] **Int. Cl.** **B05b 1/08**

[58] **Field of Search** 239/101, 102, 569, 239/398, 407, 329, 331, 592; 137/268; 83/53, 177; 222/217, 218, 219, 373; 243/29, 30

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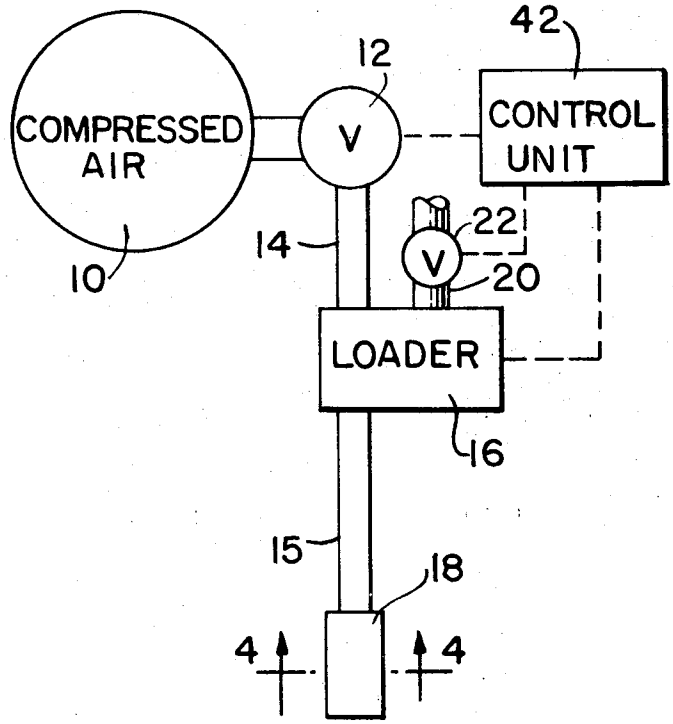
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[57] **ABSTRACT**

Apparatus for producing a high velocity jet pulse of liquid suitable for cutting or fracturing such materials as rock, metal, concrete and wood. A barrel is provided with a bore that intersects a rotatable valve which in a first position receives a liquid or gel charge and which in a second position is colinear with the barrel bore. Compressed gas expells the charge from the barrel through a nozzle to form a pulsed jet of liquid. Means can be provided for positioning the nozzle adjacent an extrusion as it issues from an extruder, permitting on-line cutting of the extrusion and for rotating the nozzle about a horizontal axis to permit operation at the optimum angle of cut.

13 Claims, 6 Drawing Figures



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3 Sheets-Sheet 1

FIG. 1.

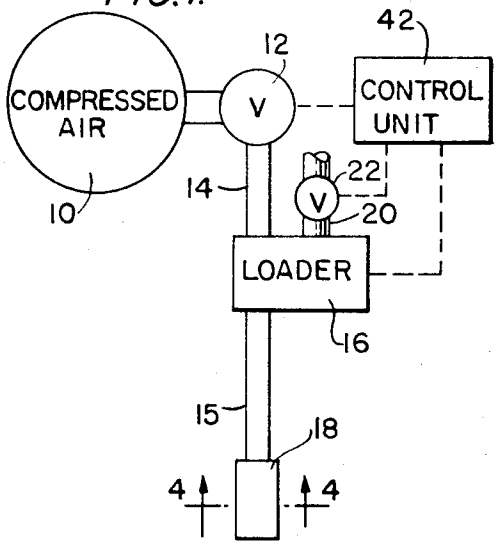


FIG. 3.

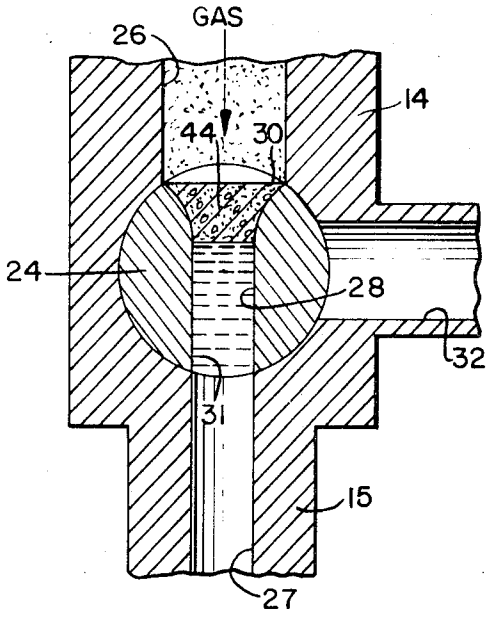
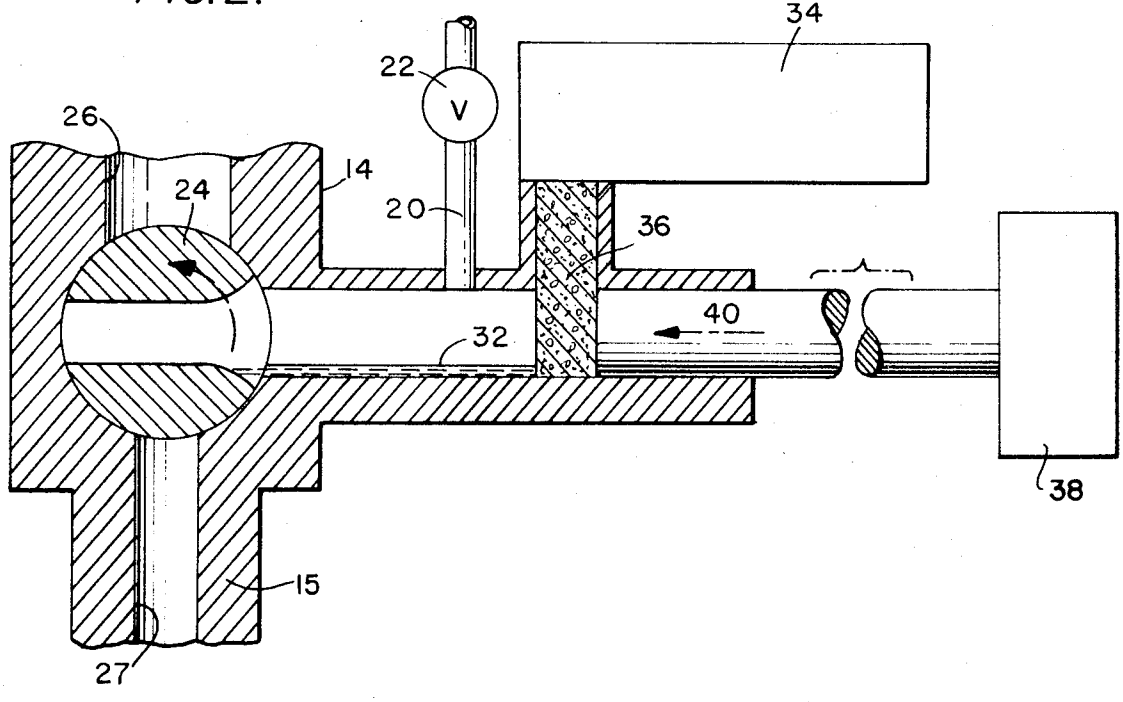


FIG. 2.



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FIG. 5.

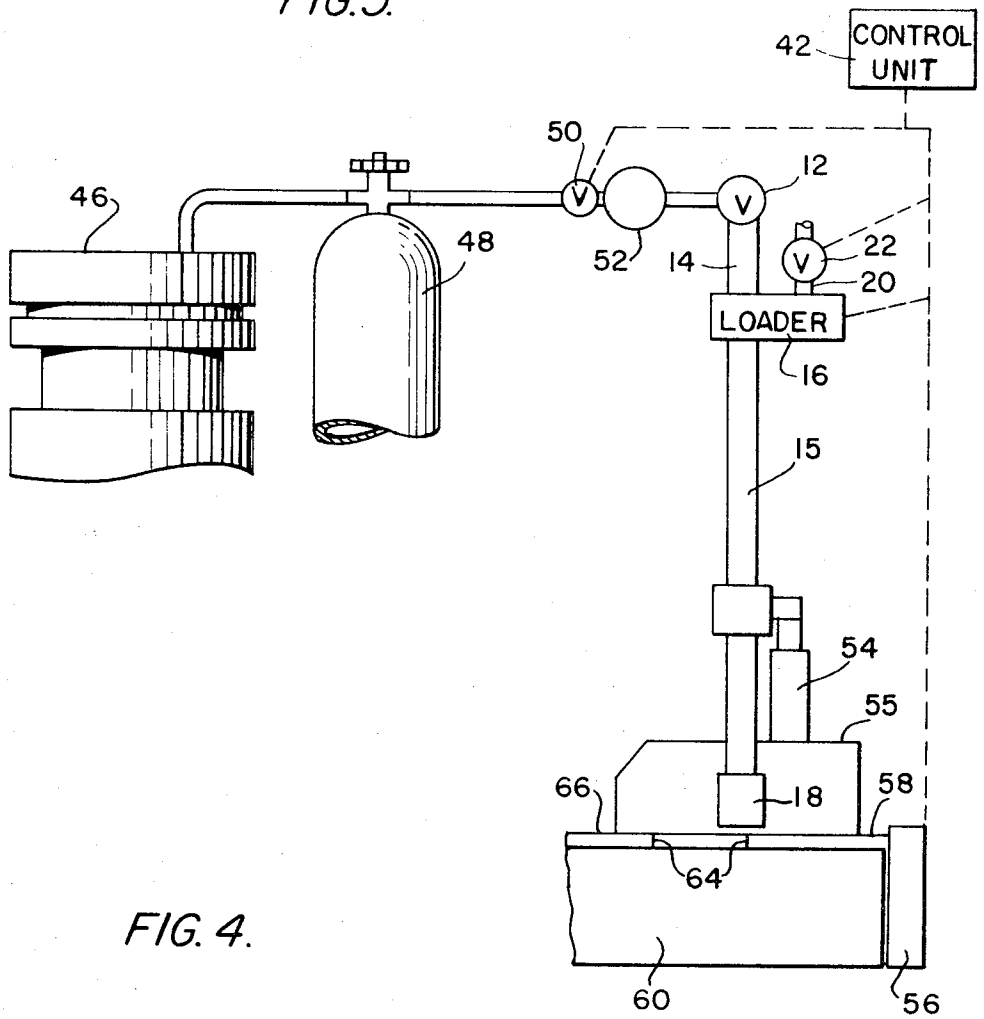
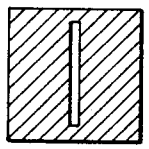


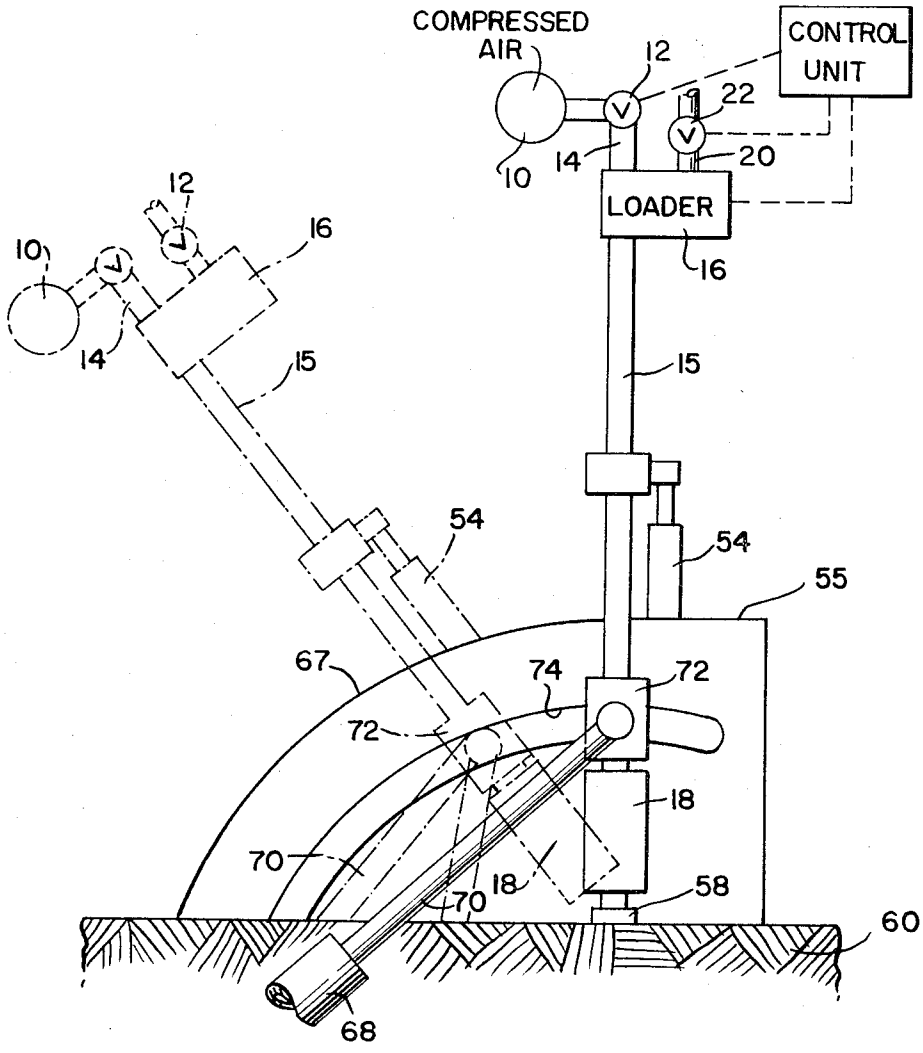
FIG. 4.



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FIG. 6.



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APPARATUS FOR PRODUCING A PULSE OF LIQUID FOR MACHINING OPERATIONS

The present invention pertains to apparatus for producing a high velocity jet pulse of liquid suitable for cutting or fracturing such materials as rock, metal, concrete, and wood and to an apparatus for on-line cutting of extrusions as they issue from an extruder.

Pulsed jets of liquid have been obtained in the past by various means such as piston expulsion, cumulation techniques, and shaped charged techniques, often powered by a gun powder charge. While these means have provided such pulsed jets suitable for many applications, other applications make higher jet velocities and stagnation pressures desirable. Apparatus used in the past to provide pulsed jets of liquid have generally been of a type in which liquid is caused to flow continuously into the bore of a casing and a piston is used to propel accumulated liquid from the casing in the form of a pulsed jet. Since the liquid continually flows into the casing, the bore is always wet. It has been found that greater efficiency, higher velocity, and higher stagnation pressures can be obtained if the bore is kept dry between pulses.

So as to insure a smooth cut, metal extrusions issuing from an extruder are generally cut by apparatus which requires that the extrusion process stop during the cutting or by apparatus which moves with the issuing extrusion. Stopping the extrusion process is obviously costly in terms of production time and manpower. A cutter moving with the extrusion is complex since the cutter must be accelerated to the extrusion speed, maintained at that speed during the cutting, stopped, and returned to its initial position for the next cutting. All of this must be accomplished with the necessary repetition rate to make cuts at the desired intervals.

The present invention is an apparatus for providing pulsed jets of liquid at a high velocity and having a high stagnation pressure and an apparatus suitable for cutting metal extrusions as they issue from an extruder. In accordance with the present invention, apparatus is provided comprising a main casing or barrel having within it a longitudinal bore and including a rotating valve member which has a bore therethrough. In a first position of the valve, the valve bore is transverse to the barrel bore to permit the loading of a liquid or gel charge, and in a second position of the valve, the valve bore is aligned with the bore of the barrel for expulsion of the charge. With the rotating valve in its first position, a measured quantity of liquid or gel charge is passed into the valve and sealed by means of, for example, a "button" of wax. The valve is then rotated to its second position and a compressed gas is applied to expel the charge and the wax button. The charge and the button then pass through the barrel and out a nozzle. The apparatus of the present invention is capable of providing pulsed jets utilizing either a liquid charge material or a solid gel charge material, and so, although for the sake of simplicity in the following description the charge is generally referred to as a liquid, it is to be understood that a solid gel charge could likewise be utilized. By means of this apparatus it has been found possible to obtain liquid velocities upwards of 6,000 feet per second, providing a jet stagnation pressure in the order of 250,000 pounds per square inch. This apparatus has been found to provide a pulsed jet of liquid capable at room temperature of on-line cutting of an aluminum extrusion three inches wide with an average cross-sectional area of one square inch as it issues from an extruder at a speed in the order of ten feet per second, making cuts at a rate in the order of one every ten seconds. In view of the high velocity of the jet, the relative extrusion velocity of the aluminum is zero. Consequently, the jet need not travel with the extrusion.

These and other aspects and advantages of the present invention are apparent in the following detailed description and claims particularly when considered in conjunction with the accompanying drawings in which like parts bear like reference numerals. In the drawings:

FIG. 1 is a schematic representation of apparatus in accordance with the present invention capable of producing pulsed jets of liquid;

FIG. 2 is an illustration, partially a fragmentary sectional view and partially in schematic form, illustrating a rotating valve suitable for use in the apparatus of FIG. 1 in a first position in which the valve is ready to receive a charge;

FIG. 3 is a fragmentary sectional view depicting the rotating valve of FIG. 2 in its second position ready to expel the charge;

FIG. 4 is a view taken along line 4—4 of FIG. 1;

FIG. 5 is a schematic representation of apparatus for the on-line cutting of an extrusion during a continuous extrusion operation and incorporating the apparatus of FIG. 1; and

FIG. 6 is a schematic representation of a modified embodiment of apparatus in accordance with the present invention.

As depicted in FIG. 1, gas under pressure such as compressed air, is applied from a source 10 through valve 12 to one end of barrel 14 of the pulsed liquid jet forming apparatus. Charge loader 16 intersects barrel 14 to provide a liquid charge for the apparatus. Barrel 15 exits from charge loader 16 co-linear with barrel 14 and terminates in nozzle 18. Inlet pipe 20, including valve 22, provides liquid or gel charge to charge loader 16 from a suitable source.

FIG. 2 depicts in detail charge loader 16. Rotating valve 24 intersects bore 26 of barrel 14 and bore 27 of barrel 15. Preferably, bore 26 has a greater diameter than does bore 27, and valve 24 includes a bore 28 which is tapered or flared so that, as depicted in FIG. 3, the inlet 30 of bore 28 mates with bore 26 while the outlet 31 of bore 28 mates with bore 27.

Charge inlet pipe 20 communicates with chamber 32 within loader 16 to provide a liquid or gel charge thereto. Wax supply container 34 is provided with an outlet communicating with chamber 32 on the side of charge inlet pipe 20 opposite rotating valve 24 to provide wax 36 thereto. Ram 38 includes rod 40 which enters chamber 32 to act against wax 36.

When it is desired to generate a pulsed jet of liquid, control unit 42 opens valve 22 to permit a suitable quantity of charge material to enter chamber 32. Ram 38 then causes rod 40 to extend into chamber 32 to remove a "button" 44 of wax from wax 36. As button 44 moves within chamber 32 under the urging of ram 40, the button pushes the liquid or gel charge material within chamber 32 into bore 28 of rotating valve 24. Wax button 44 seals the inlet end 30 of bore 28. Control unit 42 then causes rotating valve 24 to rotate so that bore 28 is aligned with bore 26 and bore 27, as depicted in FIG. 3. Control unit 42 then opens valve 12, permitting compressed gas from source 10 to enter

bore 26 at a pressure in the range of from about 2,000 pounds per square inch to about 6,000 pounds per square inch, and preferably at a pressure in the order of 5,000 pounds per square inch. Under the urging of the compressed gas, the liquid or gel charge and wax button 44 are expelled out of nozzle 18 as a high velocity liquid jet. If desired, the opening of valve 12 can be initiated by a contact closure when valve 24 has rotated. The rapid opening of valve 12 results in the compressed gas acting upon the charge before the charge has had time to drop any significant distance within bore 27. The smaller diameter of bore 27 with respect to bore 26 compensates for any pressure drop as the compressed gas flows through the valves. Bore 28 of valve 24 is designed to result in the charge being a liquid piston with a diameter in the order of one-half inch and a length in the order of two inches as the charges moves within barrel 15. Acceleration barrel 15 is essentially a precision tube capable of sustaining the compressed air pressures and sufficiently long to allow the piston or charge material to achieve a velocity of approximately 2,000 feet per second. A barrel with an inside diameter in the order of one-half inch and a barrel length in the order of six feet is suitable. Since the pressure required to accelerate the piston or charge is in the order of 2,000 to 6,000 psi, barrel 15 is not a highly stressed component. Since the piston or charge is a fluid and the bore 27 of barrel 15 is smooth, there is little wear on the barrel bore 27. The connection of barrel 15 to nozzle 18 can be a simple pinning arrangement with good alignment concentricity between the two bores.

The design of nozzle 18 permits full advantage to be taken of the unsteady shock hydrodynamics in order to accelerate the incoming fluid piston or charge from a velocity in the order of 2,000 feet per second to a velocity in the order of 5,500 feet per second. At this exit velocity, the jet has a stagnation pressure in the order of 250,000 pounds per square inch which is quite adequate for cutting aluminum. Nozzle 15 can be manufactured in two identical halves which are then bolted together using a series of high strength bolts torqued to pre-stress the nozzle. The entrance to nozzle 15 is a round bore one-half inch in diameter and aligned with the bore 27 of barrel 15. As depicted in FIG. 4, the nozzle exit is preferably an elongated slot 45, for example a slot with a length in the order of three inches and a width in the order of one-tenth inch.

FIG. 5 depicts an embodiment of apparatus in accordance with the present invention suitable for cutting an extrusion as it issues from an extruder. Compressor 46 provides gas at a high pressure to accumulator 48 from which the gas flows through valve 50 to single-shot accumulator 52. From there the gas passes through valve 12 to barrel 14. Loader 16 is positioned between barrel 14 and barrel 15, just as in the embodiment of FIG. 1. means such as a pneumatic piston 54 connected to surface 55 and to barrel 15 are provided for controlling the vertical adjustment of nozzle 18. Extruder 56 issues a continuous extrusion 58 which is supported on surface 60. Extrusion 58 passes beneath nozzle 18, the outlet of which is preferably an elongated opening 45, as depicted in FIG. 4. Control unit 42 senses the rate at which extrusion 58 issues from extruder 56 and at the desired intervals actuates the apparatus to cause a pulsed jet of liquid to be emitted from nozzle 18 to sever extrusion 58 at locations 64, forming lengths 66. Apparatus in accordance with this invention is capable of satisfactorily shearing an aluminum extrusion three inches wide with an average cross-sectional area of one square inch as it issues from an extruder at a rage in the order of ten feet per second, making cuts at a rate in the order of one every ten seconds.

FIG. 6 depicts an embodiment of the present invention suitable for cutting an extrusion as it issues from an extruder and capable of rotating the apparatus about a horizontal axis to permit operation at the optimum cutting angle. Compressed air from a source 10, which can include compressor 46, accumulator 48, valve 50 and single-shot accumulator 52 if desired, passes through valve 12 and barrel 14 to loader 16, the outlet of which is coupled by barrel 15 to nozzle 18, just as in the embodiments of FIGS. 1 and 5. Surface 55, which cooperates with piston 54 to control the vertical adjustment of nozzle 18, includes a smooth curve 67 about a horizontal axis parallel with the longitudinal axis of extrusion 58. Means are provided to rotate the apparatus about that same horizontal axis. Thus, as illustratively depicted in FIG. 6, pneumatic piston 68 is connected by arm 70 to coupling 72 which is attached to barrel 15 and which rides within smoothly curved slot 74, parallel with the curved surface 67. Under the urging of piston 68, the apparatus can be rotated from the full-line position of FIG. 6 through the broken line position, and to a position in which barrel 15 is substantially horizontal, and so, although generally it is preferred to make cuts by operating the apparatus with nozzle 18 directed vertically downward, the nozzle can be rotated should another orientation provide better results.

Although the present invention has been described with reference to preferred embodiments, numerous modifications and rearrangements could be made, and still the result would come within the scope of the invention.

What is claimed is:

1. Apparatus for forming a high velocity pulsed charge of liquid comprising:

a source of charge material;

a pressurized fluid source having an outlet;

first valve means connected to said pressurized fluid source outlet for controlling passage of fluid therefrom;

expulsion barrel means having a bore with an inlet communicatively coupled with said first valve means for receipt of fluid under pressure therefrom and with an outlet and including second valve means intermediate the bore inlet and the bore outlet and capable alternatively of assuming a first condition in which said second valve means is communicatively coupled with said source of charge material for receipt of charge material therefrom and of assuming a second condition in which said second valve means is communicatively coupled with said expulsion barrel means bore to permit passage of charge material therethrough; and

an automatic control unit which sequentially:

a. causes said second valve means to assume the first condition;

b. actuates said source of charge material to pass charge material from said source of charge material to said second valve means;

c. causes said second valve means to assume the second condition; and

d. actuates said first valve means to pass a pulse of fluid under pressure from said pressurized fluid source through said first valve means, said expulsion barrel means bore inlet, said second valve means, and said expulsion barrel means bore outlet to expel charge material therefrom.

2. Apparatus as claimed in claim 1 in which said source of charge material comprises:

a charge reservoir;

charge supply means responsive to said control means for supplying charge material to said charge reservoir; and

ram means responsive to said control means for moving charge material within said reservoir into said second valve means.

3. Apparatus as claimed in claim 2 in which said source of charge material further comprises wax supply means for supplying wax to said charge reservoir intermediate said ram means and said charge supply means to cause wax to enter and seal said second valve means after the charge material.

4. Apparatus as claimed in claim 1 in which said second valve means comprises a rotatable valve having a bore therethrough and capable of rotating between a first position in which the valve bore is communicatively coupled with said source of charge material for receipt of charge material therefrom and a second position in which the valve bore is communicatively coupled with said expulsion barrel means bore.

5. Apparatus as claimed in claim 4 in which the expulsion barrel means bore is of a first diameter adjacent said pressurized fluid source and of a smaller diameter on the opposite side of said second valve means and in which the rotatable valve bore is tapered to provide a rotatable valve bore inlet end of the first diameter and a rotatable valve bore outlet end of the smaller diameter.

6. Apparatus as claimed in claim 1 further comprising a nozzle connected to said expulsion barrel means bore outlet.

7. Apparatus for cutting extrusions issuing from an extruder by means of a high velocity pulsed charge of liquid, said apparatus comprising:

a source of charge material;

a pressurized fluid source having an outlet;

first valve means connected to said pressurized fluid source outlet for controlling passage of fluid therefrom;

expulsion barrel means having a bore with an inlet communicatively coupled with said first valve means for receipt of fluid under pressure therefrom and with an outlet and including second valve means intermediate the bore inlet and the bore outlet and capable alternatively of assuming a first condition in which said second valve means is communicatively coupled with said source of charge material for receipt of charge material therefrom and of assuming a second condition in which said second valve means is communicatively coupled with said expulsion barrel means bore to permit passage of charge material therethrough;

adjustment means for adjusting the vertical position of the expulsion barrel means outlet; and

an automatic control unit which sequentially:

a. causes said second valve means to assume the first condition;

b. actuates said source of charge material to pass charge material from said source of charge material to said second valve means;

c. causes said second valve means to assume the second condition; and

d. actuates said first valve means to pass a pulse of fluid under pressure from said pressurized fluid source through said first valve means, said expulsion barrel means bore inlet, said second valve means, and said expulsion barrel means bore outlet to expel charge material therefrom.

8. Apparatus as claimed in claim 7 in which said source of charge material comprises:

a charge reservoir;

charge supply means responsive to said control means for supplying charge material to said charge reservoir; and

ram means responsive to said control means for moving charge material within said reservoir into said second valve means.

9. Apparatus as claimed in claim 8 in which said source of charge material further comprises wax supply means for supplying wax to said charge reservoir intermediate said ram means and said charge supply means to cause wax to enter and seal said second valve means after the charge material.

10. Apparatus as claimed in claim 7 in which said second valve means comprises a rotatable valve having a bore therethrough and capable of rotating between a first position in which the valve bore is communicatively coupled with said source of charge material for receipt of charge material therefrom and a second position in which the valve bore is communicatively coupled with said expulsion barrel means bore.

11. Apparatus as claimed in claim 10 in which the expulsion barrel means bore is of a first diameter adjacent said pressurized fluid source and of a smaller diameter on the opposite side of said second valve means and in which the rotatable valve bore is tapered to provide a rotatable valve bore inlet end of the fist diameter and a rotatable valve bore outlet end of the smaller diameter.

12. Apparatus as claimed in claim 7 further comprising a nozzle connected to said expulsion barrel means bore outlet.

13. Apparatus as claimed in claim 7 further comprising rotation means for rotating the expulsion barrel means outlet about a horizontal axis to cause adjustment of the angle at which extrusions are cut.

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