DRILLING METHOD AND APPARATUS

Original Filed June 24, 1965 2 Sheets-Sheet 1

Fig. 1

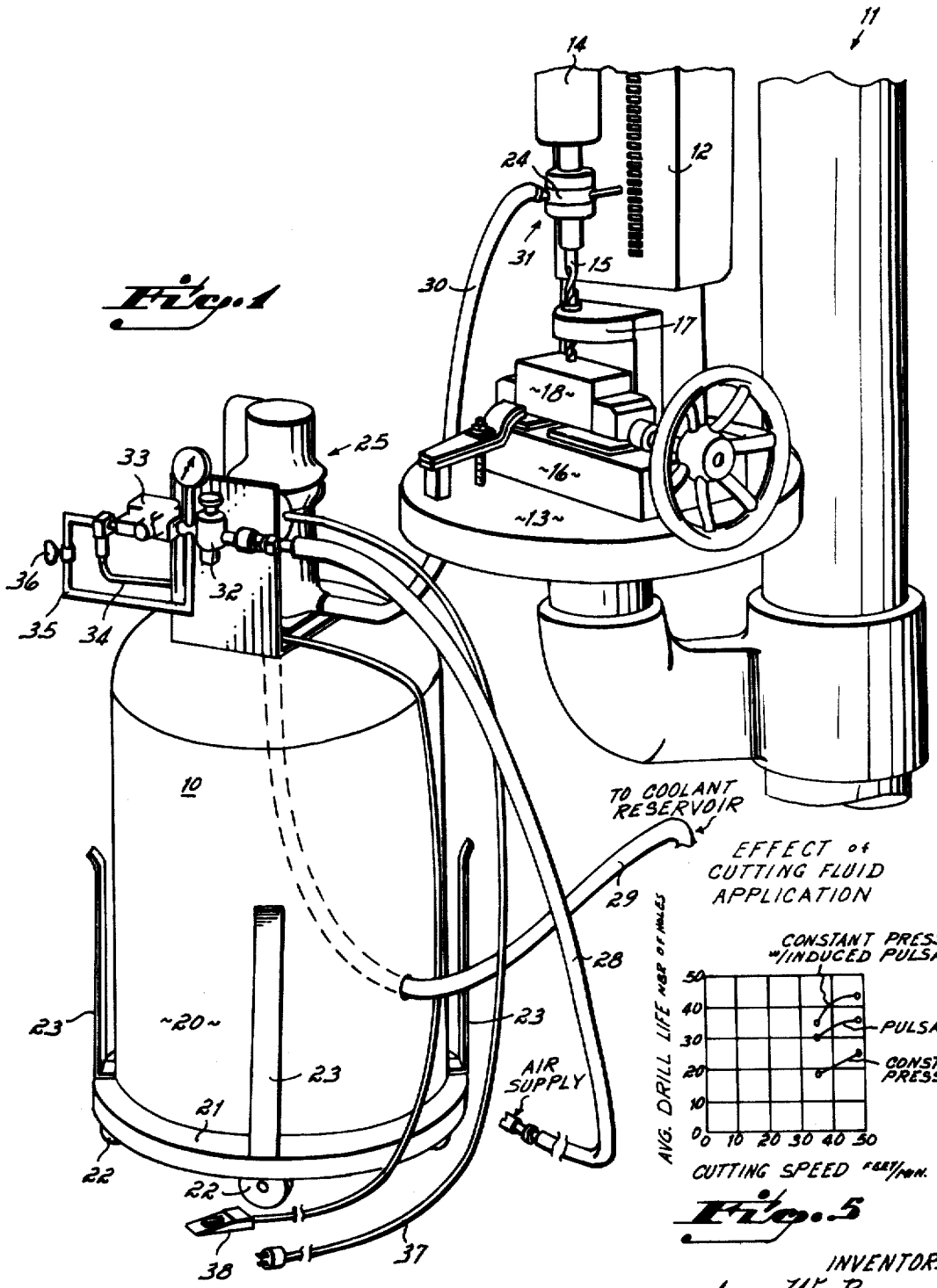


Fig. 5

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Oct. 27, 1970 J. W. BORMAN ET AL Re. 26,975

DRILLING METHOD AND APPARATUS

Original Filed June 24, 1965 2 Sheets-Sheet 2

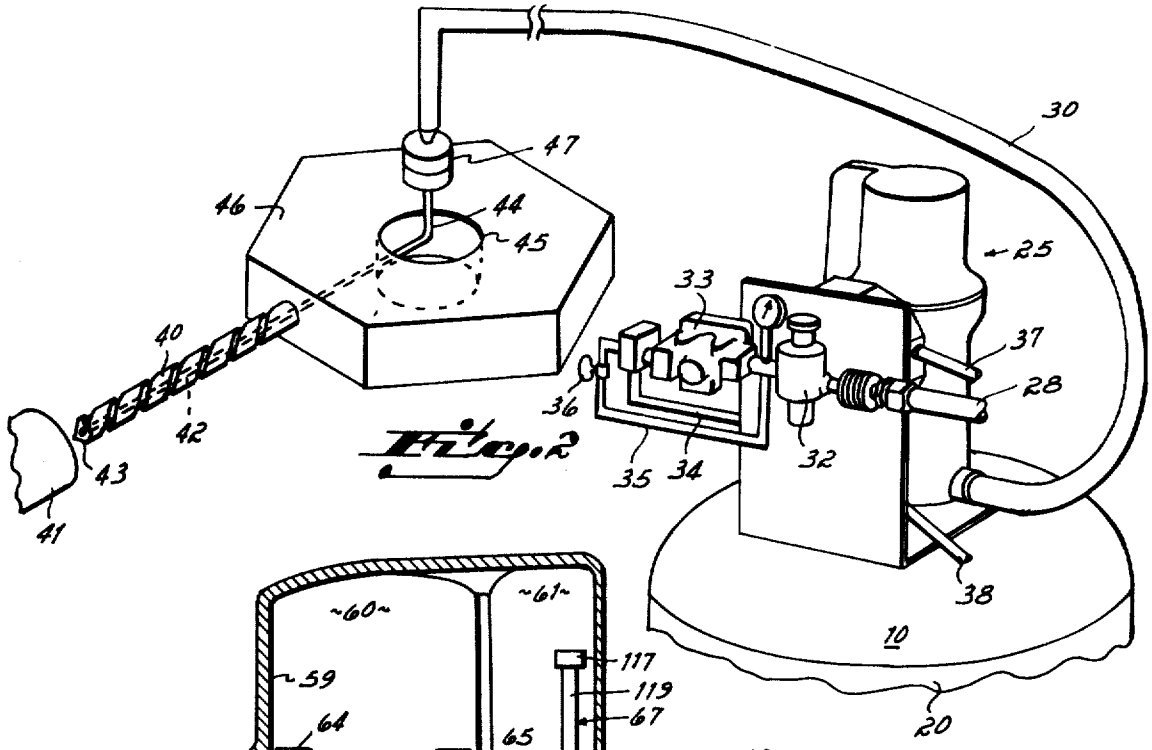


Fig. 2

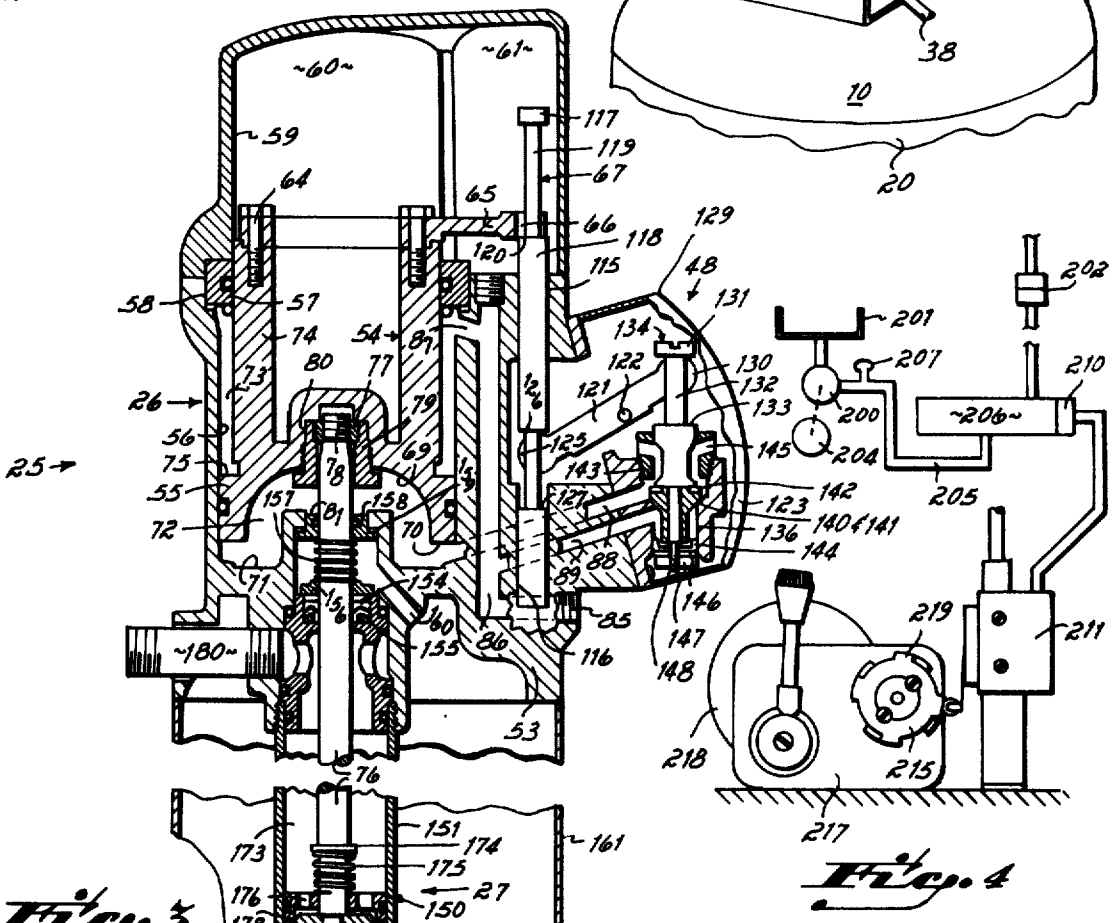


Fig. 4

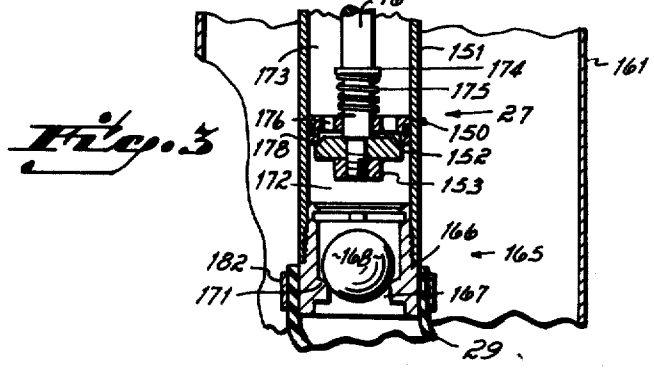


Fig. 3

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DRILLING METHOD AND APPARATUS

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Int. Cl. B35b *35/00, 51/06*

U.S. Cl. 77—5 13 Claims

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

ABSTRACT OF THE DISCLOSURE

A method and apparatus for supplying coolant to a tool for machining a hole in a workpiece by pulsating the flow of coolant through the tool so as to effect improved cutting efficiency and tool life.

This invention relates to a metal drilling method and apparatus and, more particularly, to a method and apparatus for cooling a drill and workpiece during a drilling operation.

One aspect of this invention is predicated upon the discovery that drilling efficiency and tool life of an oil hole drill or a drill in which cutting fluid is fed through the drill interior to the workpiece is substantially improved if the coolant pressure is regularly varied or pulsed during the drilling operation. It has therefore been an objective of this invention to increase tool life and cutting efficiency of a drill by improving both the method and apparatus for supplying coolant to the cutting edge of the drill.

Another objective of this invention has been to improve the cutting efficiency and tool life of conventional oil hole drills or drills in which coolant is supplied to the drill tip through the interior of the drill. We have found that regularly varying the pressure or pulsing the coolant or cutting fluid supplied to the drill produces much longer tool life than supplying the coolant at a high but constant pressure. Heretofore the general theory was to supply as much fluid as possible or to flood the drill tip in order to increase the efficiency. We have found, however, that better results are achieved, and the tool life increased by approximately fifty percent, by regularly, as for example fifty times a minute, interrupting or decreasing the coolant pressure supplied to the drill so that a pulsing flow is supplied to the drill tip.

We have also found that tool speed and feed rates may be substantially increased if the coolant to an oil hole drill is pulsed or supplied at regularly varying pressures.

The explanation for this increased efficiency and tool life is apparently very complex and involves both metal cutting and heat treating principles. One feasible explanation which is at least partially empirically provable, is that the interrupted coolant flow allows the chips to heat up so that when suddenly cooled, they fracture into smaller chips than would otherwise occur and are easily flushed through the flutes of the drill.

Another objective of this invention has been to provide an inexpensive, portable unit useable with any machine tool which is capable of drilling a hole to enable that machine to be used to drill holes with a drill of the type in which coolant or cutting fluid is supplied to the drill tip or cutting edge through the interior of the drill.

An oil hole drill requires coolant to be supplied to the tool under much higher pressures than those available from conventional machine tool coolant pumps. Therefore an inexpensive portable pump unit for use with an oil hole drill mounted in a conventional machine fitted with a low pressure coolant pump is a highly desirable unit which substantially broadens the cutting capabilities spectrum of a conventional machine tool.

Another objective of this invention has been to provide a portable high pressure coolant unit including a pneumatic motor driven hydraulic pump for supplying coolant to an oil hole drill. The primary advantage of a pneumatic motor driven unit is that it is inexpensive to operate and less subject to break down under adverse operating conditions than more conventional electric motor driven units. The inexpensive operation derives primarily from the fact that most machine shops have air pressure available and unused in the form of a ninety p.s.i. pressure line running throughout the shop for purposes of driving small pneumatic motors of portable hand tools or for blowing chips and dust away to clean machines and workpieces. By utilizing this untapped capacity, the unit is much less expensive to operate than electrically driven units.

Another objective of this invention has been to provide an improved portable coolant supply unit for converting a conventional low pressure coolant supply machine tool into one capable of use with oil hole drills. To increase the portability of such a unit, the pump is supported upon a roller mounted hollow base which serves the dual function of acting as a hose reel when the unit is in storage or in transit between machines.

These and other objects and advantages of the invention of this application will be more readily apparent from the following description of the drawings in which:

FIGURE 1 is a perspective view of the coolant pump unit of this invention applied to a drill press,

FIGURE 2 is a perspective view, partially in diagrammatic form, of the pumping unit of this invention applied to a turret lathe,

FIGURE 3 is a cross-sectional view of the pump and motor unit of FIGURE 1,

FIGURE 4 is a diagrammatic illustration of a second embodiment of the inventive coolant pumping unit of this application, and

FIGURE 5 is a graph of tool life plotted against feed rate to illustrate the differential in tool life achieved from different coolant delivery methods.

Referring first to FIGURE 1, and the preferred embodiment of the invention, a coolant pumping unit **10** is shown as applied to a conventional drill press **11**. The drill press **11** includes the conventional vertical slideway **12** for supporting the vetrically moveable tool head (not shown) having a rotatable spindle **14** for supporting a drill bit **15**. The drill press **11** also includes a work support table **13** upon which is mounted a jig **16** having a guide bushing **17** for supporting the drill against lateral deflection as it is moved into a workpiece **18** clamped in the jig **16**. The drill press **11** and jig **16** form no part of this invention and are only illustrated to show the operative environment of use of the invention of this application.

The coolant pumping unit**10** is a portable unit which may easily be removed from one machine and attached to another whenever an oil hole drilling operation is programmed for a machine. It consists of a cylindrical, hollow, sheet metal base **20** having a lower flange **21** mounted upon a plurality of rollers or casters **22**. Hose retainer brackets **23** are welded or otherwise secured to the flange **21** so as to extend vertically parallel but spaced from the peripheral wall of the base **20**. These brackets **23** permit the pump hoses and electrical lines to be wound upon the base **20** in the fashion of a hose reel with the lower portion of the base **20** serving as a reel and the brackets **23** serving as hose retainers.

In the preferred embodiment, the pump **27** and the motor **26** for driving the pump, are a unitary assembly **25** mounted on the top of the hollow base **20**. The pump assembly **25** could, however, be mounted within the hollow base **20** if so desired.

The motor **26** is of the pneumatic type in which air under pressure is supplied to the motor **26** via an air supply line **28**, through a regulator **32** and solenoid controlled valve **33**, to a pump inlet line **34**. A by-pass line **35** including a flow control or needle valve **36** is provided around the solenoid **33** between the regulator **32** and the pump inlet line **34** so as to pass a limited volume of air to the pump motor when the solenoid **33** is in the valve closed position. When the needle valve **36** is partially open and the solenoid is in the closed position, air through the by-pass **35** is operative to drive the motor **26** at a slow rate so as to pump a small volume of cutting fluid or coolant to the drill **15** at a low pressure. This low pressure cutting oil or coolant is useful to start a drilling operation before the drill enters the workpiece so as to limit the splashing. After the drill enters the workpiece, the solenoid may be energized and high pressure coolant supplied without excessive splashing. Alternatively, the needle valve **36** may be closed completely, in which event, only high pressure coolant will be supplied to the drill and that only when the solenoid **33** is energized.

Solenoid valve **33** is a conventional electrically actuated valve to which power is supplied from a conventional 110 volt A.C. source via ilne **37** through a foot pedal **38** control switch. As an alternative, the switch may be controlled automatically by tool feed displacement. Additionally, rather than being electrically controled, the vave may be pneumaticaly controlled from an air operated microswitch.

The source of this air under pressure is one of the common lines of the plant or factory where the coolant unit is to be used. Most factories have such air supply lines running throughout the plant for cleaning parts or machines so that this is a convenient source of motive power.

Coolant is supplied to the pump assembly **25** from the machine coolant reservoir (not shown) via conduit **29**. Since nearly all machines are equipped with coolant reservoirs, there is no need for the coolant unit **10** to be equipped with its own coolant source. Pulsating coolant or coolant in which the pressure of the coolant regularly varies at a predetermined frequency, is supplied from the pump to drill **15** via conduit **30** and rotary union or arbor **31**. The rotary union or arbor **31** is a conventional coupling having a non-rotating collar **24** within which a drill supporting rotatable shaft is mounted and through which coolant is supplied to the drill **15**.

While the coolant pumping unit **10** is usually used in connection with a drill press, it is equally adaptable to use in a turret lathe as illustrated in FIGURE 2. Lathes are often used to support a non-rotating drill **40** fed axially relative to a rotating workpiece **41**. When drilling deep holes, it is preferable to use an oil hole drill in which coolant is supplied through the interior of the drill via a passage **42** to the cutting tip **43**.

An oil holed rill may only be used in a turret lathe if provision is made for supplying coolant at high pressure to the drill. In the embodiment of FIGURE 2, this provision consists of a coolant supply tube **44** mounted in the turret **46** so as to interconnect the drill oil hole passage **42** with a central aperture **45** of the turret **46**. The tube **44** is bent so that its free end extends vertically and is co-axial with the axis of rotation of the indexable turret **46**. Connecting the upper end of the tube **44** to the output of the coolant pump unit **10** is a snap-fit rotary union **47** and the flexible supply conduit **30**.

Referring now to FIGURE 3 and the preferred embodiment of the pump unit **10**, as stated above the unit comprises the reciprocal pneumatic motor **26** for operating the reciprocating fluid pump **27**. Reciprocating of the pneumatic motor **26** is controlled by a valve assembly **48**. This pump, motor, and valve assembly, per se, form no part of the invention of this application and therefore will only be described in general terms.

Considering first the motor **26**, it will be seen that it includes a motor cylinder body **53** in the form of a ported casting within which a piston **54** is receiprocable. The piston **54** has an enlarged flange or head **55** at its lower end which is in sliding engagement with the inner wall **56** of the cylinder body **53**. Guiding the upper end of the piston **54** is a retainer ring **57** secured in a seat **58** defined between the upper edge of the cylinder body **53** and the lower edge of a piston guide cap or head **59**. The inner wall **60** of this head **59** is configurated so as to provide a partially cylindrical bore for guiding support of the motor piston **54** as well as a recess **61** for recepition of a portion of the motor valve reciprocating mechanism. Attached to the upper end of the piston **54** by means of bolts **64** is a laterally extending arm **65** having a recess **66** at its outer end for reception of a tripper rod **67** of the valve assembly **48**.

The lower end or bottom of the piston **54** is defined by a generally semi-spherical recess **69** and flat bottom surface **70** of the piston head **55**. The semi-spherical surface **69**, the bottom surface **70**, together with the cylinder side wall **56** and bottom surface **71** of the cylinder define the lower motor chamber **72**. The upper chamber **73** of the motor **26** is defined between the bottom of retainer **57**, the top of piston head **55**, the cylindrical upper section **74** of piston **54** and the cylindrical wall **56** of the cylinder. The effective area against which the pressure supplied to the upper chamber **73** acts to force the piston **54** downwardly as viewed in FIGURE 3 is the upper surface **75** of the piston head **55**. This surface is much smaller in area than the total area of the lower piston surfaces **69**, **70** so that when equal pressure are applied to both sides, the total force applied to the bottom of the piston is much greater than that applied to the top with the result that the piston is moved upwardly.

Depending from the bottom of motor piston **54** is a piston rod **76**. This rod is attached to piston **54** by means of a nut **77** threaded on to the upper end **78** of the rod. The nut **78** is in turn clamped by means of a clamp nut **79** within a recess **80** in the bottom of the piston **54**. The piston rod **76** extends through an aperture **81** of the motor cylinder body **53** and supports the pump piston as is explained hereinafter.

The porting through the motor cylinder body **53** to the upper chamber **73** or the air motor consists of a pressure port **85** connected via a vertical conduit **86** to an inlet port **87** of the upper chamber **74**. The lower chamber **72** is connected via a conduit **88** to the reciprocating valve assembly **48**. This valve assembly **48** is in turn connected to the pressure conduit **86** via a conduit **89**. In operation, the pressure port **85** is connected to an air pressure line of approximately fifty to ninety p.s.i. depending upon the size drill and other variables such as splash, hole depth, etc.

The valve assembly **48** is controlled by the tripper rod **67**. This rod **67** is reciprocable within a pair of aligned apertures **115**, **116** of the motor cylinder body **53**. Reciprocation of the rod is controlled by the arm **65** attached to the top of the motor piston **54**. For this purpose, it is provided with an enlarged head **117** connected to the body **118** of the rod by a thin stem **119**. At the upper end of its stroke, the arm **65** engages the bottom of the head **117** causing the tripper rod **67** to be moved upwardly. At the lower end of its stroke and in the position illustrated in FIGURE 3, the arm **65** engages a shoulder **120** of the rod **67** and forces the rod downwardly from the position illustrated in this figure. By these movements, the rod **67** controls a toggle **121** which in turn controls a spool valve of the reciprocating valve assembly **42**.

The toggle **121** is the connecting link between the pneumatic motor **26** and valve **48**. It is pivotally mounted upon a pivot pin **122** which is in turn supported by the valve

casing **123**. One end **125** of the toggle **121** is engageable with a pair of spaced shoulders **126**, **127** of the tripper rod **47**. Upon downward movement of the rod **67**, shoulder **126** engages the top of the toggle **121** and pushes it downwardly while on upward movement of the rod, the shoulder **127** engages the bottom of the toggle **121** and pushes it upwardly.

The valve **48** consists of a two piece body or casing **123** secured to the motor body **53** and within which a two piece spool **134** is movable. To keep dust and dirt out of the valve, a cap **129** is secured over it.

The end **130** of the toggle opposite end **125** is engageable in one position with a head **131** attached to stem **132** of spool **134**. In the other position to which the toggle is movable, it engages a shoulder **133** of the spool **134** to force the spool **134** downwardly from the position illustrated in FIGURE 3.

Spool **134** is slidable within a bore **136** of the valve housing **123**. This housing is ported so as to cooperate with the ports **88**, **89** of the air motor cylinder body **53** to control the connection of the motor lower chamber **72** with either exhaust or high pressure.

As shown in FIGURE 3, the conduit **88** in the cylinder body **53** is connected to exhaust or atmospheric pressure through valve ports **145**. High pressure in conduit **89** is at this time precluded from entering conduit **88** by a tapered seat **140** of the valve **134** engaging a correspondingly tapered seat **141** of the housing **123**.

When the spool **134** is moved upwardly from the position shown in FIGURE 3 by the toggle **121**, a rubber seat **142** of the spool engages a shoulder **143** of the housing **123** and is so doing, blocks the passage of air through the conduit **88** to exhaust via passage **145** in the valve housing **123**. Simultaneously, the upward displacement of the spool **134** results in the opening of the tapered seat **140**, **141** between the spool and the housing so that high pressure air may pass from the inlet port **85**, through the conduit **89**, past the seat **140**, **141** and into the conduit **88** to the lower chamber **72** of the air motor.

In order to preclude the escape of high pressure air in conduit **89** through the lower portions of the bore **136** in the housing **123**, a leather gasket **144** is attached to the bottom of the spool **134** by a washer **146** and nut **147** threaded onto the threaded lower end **148** of the spool.

The pump **27** consists of a piston **150** movable within a pump cylinder **151**. This cylinder is threaded into and depends from the motor body **53**. Vertical movement of a piston **150** within the cylinder **151** is controlled by the piston rod **76** of motor **26**. This piston **150** acts as a valve in cooperation with a valve plate **152** attached to the bottom of piston rod **76** by means of a nut **153** threaded onto the lower end of the piston rod **76**.

A conventional packing ring **154** is secured between the piston rod **76** and the sleeve **151** to prevent leakage of fluid from the pump into the motor. The packing ring **154** is secured within a recess **155** in the top of the cylinder **151** by a cap or washer **156**. The washer **156** is secured against the top of cylinder **151** by a spring **157** compressed between washer **157** and a washer **158** seated in a recess **159** of the motor body **53**. Any fluid which does inadvertently pass the packing ring or gland **156** is exhausted from the motor body **53** through an exhaust conduit **160** which is connected to atmospheric pressure within a pump casing **161**.

Attached to the lower end of the pump cylinder **151** is a one-way ball valve **165**. This valve consists of a valve body **166** having a restricted passage **167** which supports a ball **162**.

Normally the ball **168** rests upon the restricted passage defining section **171** of the valve body **166** so as to close the restricted passage **167**. Thus, fluid entrapped within the lower chamber **172** of the pump cannot flow out through the restricted passage **167**. However, if the pressure above the ball **168** is less than the pressure beneath the ball **168**, the ball **168** will be lifted from its seat so that fluid may flow into the chamber **172**. This occurs when the piston **150** is moved upwardly upon an upward stroke of the motor piston **54**.

The pump piston **150** is slidably mounted upon the motor piston rod **76**. Its sliding movement is however limited or restricted by valve plate **152** a ndby a compression spring **175** mounted over the rod **76** between a rod flange **174** and the upper side of the piston **150**. This spring normally biases the piston **150** downwardly into engagement with the valve plate **152**.

To permit the flow of fluid through the piston **150**, the plate **152** has a plurality of apertures **176** through which fluid may pass from the lower pump chamber **172** into the upper chamber **173**.

Upon a downstroke of the motor piston **54** and piston rod **76**, fluid trapped in the lower chamber **172** of the pump by the one-way check valve **165**, acts upon the exposed lower surface **178** of the piston **150** to force the piston **150** upwardly relative to the valve plate **152** and thus creates a passage for fluid entrapped in the lower chamber **172** to move into the upper chamber **173** through the apertures **176** in the piston **150**. On the upstroke, the piston **150** remains seated against the valve plate **152** so that fluid is forced out of the pump via an exit tube **180** which communicates with the upper pump chamber **173**. In the preferred embodiment, the pressure of the fluid exiting through the tube **180** is four times as great as the pressure of the air entering through port **85** to drive the pump motor. However, a seven to one ratio pump, in which the fluid pressure is seven times as great as the entering air pressure, has also been found satisfactory for this use.

In operation, air pressure is supplied to the pump unit by connecting a line **34** to the inlet port **85**. This air pressure is usually in the neighborhood of 50 to 90 pounds per square inch. The lower end of the pump cylinder **151** is connected to a source of coolant by the hose **29** and hose clamp **182**. The end of the hose **29** opposite the end attached to pump **27** is fitted with a 30 mesh (per lineal inch) screen filter (not shown) which rest swithin the coolant pump or tank (not shown) of the machine with which the unit is being used. The outlet tube **180** of the pump **27** is connected via the conduit **30** to the rotary union or arbor **32** or **47**.

With the pump unit in the position illustrated in FIGURE 3, high pressure air is supplied from the port **85** through conduits **86** and **87** to the upper chamber **73** of the motor. Simultaneously, the lower chamber **72** of the motor is connected via conduit **88** and valve ports **145** of the valve assembly to exhaust or atmospheric pressure. In this position of the valve, the motor piston **54** continues to move downwardly until the arm **65** engages the shoulder **120** of the tripper rod **67**, causing the rod to move downwardly from the position illustrated in FIGURE 3 and to pivot the toggle **121** about the pivot pin **122**. This results in upward movement of the spool **134** until the rubber gasket **142** of the spool seats and seals against the shoulder **143** of the valve housing **123** so that the lower motor chamber **72** is no longer connected to atmospheric pressure. This spool movement results in the lower chamber **72** being connected to the high pressure port **85** via the conduits **86**, **89** and **88** so that the same high pressure exists in the lower chamber **72** as in the upper chamber **73**. However, because the piston area in the lower chamber **72** is much greater than the piston area in the upper chamber **73**, the piston **54** is caused to move upwardly until the arm **65** engages the head **117** of the tripper rod **67** and moves the rod into its upper position. This results in the shoulder **127** engaging the lower side of the toggle **121**, causing the toggle to pivot in a clockwise direction as viewed in FIGURE 3 until the bottom of the toggle engages the shoulder **133** of the spool **134** and forces the spool downwardly back into the position shown in FIGURE 3.

As the motor piston **54** and pistron rod **76** move upwardly, valve plate **152** and piston **150** move up forcing any fluid entrapped in the upper chamber **173** out through the outlet pipe **180** of the pump. Simultaneously, it draws a vacuum on the lower chamber **172** between the ball **168** and the valve plate **152**, causing the ball **168** to lift so that fluid is pulled into the lower chamber **172** from the coolant sump. When thereafter, the motor piston **54** moves downwardly, that fluid trapped in the lower chamber **172** between valve plate **152** and ball **168** must move from the lower chamber **172** into the upper chamber **173**. It does so by forcing the piston **150** upwardly relative to the valve plate **152** by compressing spring **175** so that fluid passes between valve plate **152** and piston **150** through ports **176** into the upper chamber **173** as the piston rod **76** moves downwardly. Thereafter, on the upstroke, that fluid which has just passed into the upper chamber **173** upon the downstroke of the piston rod **76**, is forced out of the upper chamber **173** and exits through the outlet tube **180**. The pressure at which this fluid exits through the outlet tube **180** in the preferred embodiment is approximately four times as great as the air pressure entering through the inlet port **85**. It is, of course, a pulsating pressure which varies from maximum pressure to zero during each pump cycle because of the reciprocal nature of the pump and because there is no accumulator to even out the pressure.

As an alternative pumping unit for supplying pulsating coolant to a tool, a second embodiment is illustrated in FIGURE 4. In this embodiment, a constant pressure pump **200** such as a rotary vane pump is used to supply coolant from a sump or tank **201** to a rotary union **202** and subsequently to a tool. The rotary union may be the same union **47** illustrated in FIGURE 2 or the union **32** illustrated in FIGURE 1.

The pump **200** is driven by a conventional electric motor **204**. Inserted into the pump outlet line **205** between the pump **200** and the rotary union **202** is a conventional solenoid valve **206** which, when the solenoid **210** is energized, blocks the flow of fluid to the rotary union **202** and tool. In order to handle the back pressure in line **205** when the valve **206** is closed, a conventional fluid pressure accumulator **207** is inserted in line **205** between the pump **200** and valve **206**.

In this embodiment, the solenoid **210** of solenoid valve **206** is controlled by a switch **211**. When the switch **211** is closed, the solenoid **210** is energized and the valve **206** blocks the flow of fluid to the union **202** and thus to the tool (not shown); but when de-energized, the valve **206** routes the fluid from conduit **205** to the rotary union and subsequently to the tool.

Controlling the energization of switch **211** is a rotary cam **215** mounted on the output shaft of a gear reduction unit **217**. The gear reduction unit is driven from an electric motor **218** at any selected speed within a limited range. The preferred speed of the cam plate **215** was found to be about 12 or 13 revolutions per minute so that the four lobes **219** of the cam closed the switch **211** at a rate of approximately 50 times per minute. This resulted in a pulsating pump pressure being supplied to the rotary union **202** and thus to the oil hole drill (not shown) under pressure which pulsed at a rate of approximately 50 pulses per minute. With this arrangement the pressure varied or pulsed between approximately 70 p.s.i. and 120 p.s.i. While the systems disclosed in FIGURES 1 and 2 are considered to be preferable to that illustrated in FIGURE 4, this latter system was satisfactory and did establish that a pulsating pressure of even this frequency and of this pressure differential was satisfactory to prolong the life of the tool and to increase the maximum tool feed rate.

Test results utilizing the setup of FIGURE 1 (indicated as "Pulsating" line on graph) and FIGURE 4 (indicated on graph as "Constant Pressure w/Induced Pulsation") as well as a conventional constant pressure pump ("Constant Pressure") for supplying the tool with coolant under pressure are shown graphically in FIGURE 5. To obtain these results, half-inch diameter holes were drilled in 4340 steel of 300 to 325 Brinnel hardness. In each case the drill was a half-inch diameter, high-speed steel, oil hole tapered web drill with a point angle of 118 degrees and a clearance of 17 degrees. The drill was fed into the workpiece at a feed rate of .005 inch per revolution and the cutting flux was a soluble oil. Tool life end points were established whenever a wearland of .015 inch was observed on the lip of the drill. The results of these tests were as follows:

TOOL LIFE
[No. of holes drilled]

Cutting speed ft./minute	Constant pressure (3.0 gal./min. 200 p.s.i.)	FIGURE 4 Constant Pressure, Induced pulsation (2.5 gal./min.) (70 to 120 p.s.i.)	FIGURE 1 Pulsating (2.0 gal./min.) (0 to 200 p.s.i.)
35	19	36	36, 24
48	24, 26	53, 43, 34	34, 40, 49

Graphically, the results are shown in FIGURE 5.

These tests clearly establish that pulsating the coolant supplied to an oil hole drill results in a tool life approximately 60 percent greater than that achieved using a constant pressure coolant source. And this was true even though the quantity of coolant supplied to the drill with the constant pressure source was as much as 50 percent greater than the quantity of coolant supplied with a pulsating source.

It was also found during the test of the oil hole drill pulsating coolant supply versus constant pressure coolant source, that the pulsating coolant was much more efficient than the constant pressure. In fact, the pulsating enabled the drill penetration maximum rate (drill feed multiplied by drill speed) to be increased substantially over that possible with constant pressure coolant.

This invention not only contributes to the tool life and feed rate of oil hole drills but also provides a convenient portable accessory unit which may be used with conventional jig borers or drill presses or even lathes to adapt these machines for use with oil hole drills even though they have no coolant source or a coolant source of insufficient pressure to enable the machine to be used for this purpose.

While only two embodiments of the invention have been disclosed and described herein, those skilled in the art to which this invention pertains will readily appreciate numerous changes and modifications which may be made in the invention without departing from the spirit thereof. Therefore we do not intend to be limited except b" the scope of the appended claims.

Having described our invention we claim:

[1. The method of drilling a hole in a workpiece which comprises:

effecting relative rotational movement between a workpiece and a drill while said drill remains in engagement with said workpiece,

supplying coolant fluid through a passagway in said drill terminating adjacent to the tip thereof, said coolant fluid being supplied to said workpiece so as to cool said drill and workpiece and flush chips away from the tip of said drill, and

varying the pressure of the coolant flowing through said drill by at least 30 percent at a frequency of at least 30 times per minute so as to regularly pulse the fluid flow to said drill tip.]

2. The method of drilling a hole in a workpiece which comprises:

effecting relative rotational movement between a workpiece and a drill while said drill remains in engagement with said workpiece,

supplying coolant *liquid* to said drill tip through a passageway terminating adjacent said tip at a low pressure at the time said drill initially contacts and partially enters said workpiece,

thereafter supplying coolant [fluid] *liquid* through said passageway in said drill to said workpiece at a high pressure so as to cool said drill and workpiece and flush chips away from the tip of said drill, and

regularly varying the pressure of the coolant *liquid* flowing through said drill so as to pulse the fluid flow to said drill tip.

3. The method of drilling a hole in a workpiece which comprises:

effecting relative rotational movement between a workpiece and a drill while said drill remains in engagement with said workpiece,

supplying coolant *liquid* to said drill tip through a passageway terminating adjacent said tip at a low pressure at the time said drill initially contacts and partially enters said workpiece,

thereafter supplying coolant [fluid] *liquid* through said passageway in said drill to said workpiece at a high pressure so as to cool said drill and workpiece and flush chips away from the tip of said drill and

regularly varying the pressure of the coolant *liquid* flowing through said drill by at least 30 percent so as to pulse the fluid flow to said drill tip.

4. In a machine tool having a rotatable tool mounted in a rotatable member, said rotatable tool including an axial passageway terminating adjacent to the tip of said tool, the improvement which comprises a portable unit for supplying coolant through said axial passageway of said tool, said portable unit comprising:

a floor supported base,

a single acting reciprocal fluid pump mounted upon said base, said pump being operable to regularly vary the pressure of fluid being pumped through an outlet of said pump,

inlet conduit means having one end attached to the inlet of said pump and the other end adapted to be inserted into the coolant reservoir of the machine tool with which the unit is to be utilized,

outlet conduit means connected at one end to the outlet of said pump,

a rotary union attached to the other of said outlet conduit and adapted to be attached to said rotatable member of said machine tool,

pneumatic motor means mounted upon said base and operatively associated with said pump so as to control fluid flow from said pump to said rotary union, and

control means operable to control said pneumatic motor means.

5. In a machine tool apparatus having a rotatable tool mounted in a rotatable member of the machine tool, said rotatable tool including an axial passageway terminating adjacent to the tip of said tool, the improvement which comprises a portable unit for supplying coolant through said axial passageway to the tool, said portable unit comprising:

a lightweight, hollow, floor supported base,

a reciprocal fluid pump mounted upon said base, said pump being operable to regularly vary the pressure of fluid being pumped through an outlet of said pump so as to generate a pulsating flow,

inlet conduit means having one end attached to the inlet of said pump and the other end adapted to be inserted into the coolant reservoir of the machine tool with which the unit is to be utilized,

outlet conduit means connected at one end to the outlet of said pump,

a rotary union attached to the other end of said outlet conduit and adapted to be attached to said rotatable member of said machine tool,

pneumatic motor means supported upon said base and operable to drive said pump,

valve means supported upon said base and operatively associated with said motor means so as to control said motor and thus control fluid flow from said pump to said rotary union, and

switching means operable to control valve means.

6. In a drilling apparatus which includes a drill of the type having a longitudinal passageway including an outlet opening adjacent to the tip thereof, the improvement which comprises a coolant supply unit for supplying coolant through said passageway of said drill, said colant supply unit including:

a base,

a single piston, reciprocating pump supported by said base,

a first conduit for supplying coolant from a reservoir to said pump,

a second conduit for supplying coolant from said pump to said drill, and

means including said pump for supplying coolant through said drill passageway at regularly varying pressures whereby said coolant pulses in its flow through said drill.

7. In a drilling apparatus which includes a drill of the type having a longitudinal passageway including an outlet opening adjacent to the tip thereof, the improvement which comprises a coolant supply unit for supplying coolant through said passageway of said drill, said coolant supply unit including:

a base,

a reciprocal piston pump supported by said base,

a first conduit for supplying coolant from a reservoir to said pump,

a second conduit for supplying coolant from said pump to said drill, and

means including said pump for supplying coolant through said drill passageway at regularly varying pressures whereby said coolant pulses in its flow through said drill,

said means including a pneumatic motor for drving said pump from an air pressure source.

8. In a drilling apparatus which includes a drill of the type having a longitudinal passageway including an outlet opening adjacent to the tip thereof, the improvement which comprises a coolant supply unit for supplying coolant through said passageway of said drill, said coolant supply unit including:

a base,

a reciprocal piston pump supported by said base,

a first condiut for supplying coolant from a reservoir to said pump,

a second conduit for supplying coolant from said pump to said drill,

means including said pump for supplying coolant through said drill passageway at regularly varying pressures whereby said coolant pulses in its flow through said drill,

said means including a pneumatic motor for drving said pump,

a source of air pressure connected by an air conduit for operating said motor, and

valve means in said air conduit for controlling the operation of said motor.

9. In a drilling apparatus which includes a drill of the type having a longitudinal passageway including an outlet opening adjacent to the tip thereof, the improvement which comprises a coolant supply unit for supplying coolant through said passageway of said drill, said coolant supply unit including:

a base,

a reciprocal piston pump supported by said base,

a first conduit for supplying coolant from a reservoir to said pump,

a second conduit for supplying coolant from said pump to said drill,

means including said pump for supplying coolant through said drill passageway at regularly varying

pressures whereby said coolant pulses in its flow through said drill,

said means including a pneumatic motor for driving said pump,

a source of air pressure connected by an air conduit to said motor for operating said motor,

solenoid operated valve means in said air conduit for controlling the flow of air through said air conduit to said motor, and

an electrical switch for controlling said valve means.

10. In a drilling apparatus which includes a drill of the type having a longitudinal passageway including an outlet opening adjacent to the tip thereof, the improvement which comprises a coolant supply unit for supplying coolant through said passageway of said drill, said coolant supply unit including:

a base,

a reciprocal piston pump supported by said base,

a first conduit for supplying coolant from a reservoir to said pump,

a second conduit for supplying coolant from said pump to said drill,

means including said pump for supplying coolant through said drill passageway at regularly varying pressure whereby said coolant pulses in its flow through said drill,

said means including a pneumatic motor for driving said pump,

a source of air pressure connected by an air conduit to said motor for operating said motor,

valve means in said air conduit for controlling the flow of air through said air conduit to said motor,

control for opening said valve means, and

means including by-pass air conduit means around said valve means for operating said pneumatic motor at a slow speed until said valve opens whereby fluid at a relatively low pressure may be supplied to said drill until said drill enters said workpiece and thereafter fluid at a relatively high pressure may be supplied to said drill.

11. In a drilling apparatus which includes a drill of the type having a longitudinal passageway including an outlet opening adjacent to the tip thereof, the improvement which comprises a coolant supply unit for supplying *liquid* coolant through said passageway of said drill, said coolant supply unit including:

a pump,

a first conduit for supplying *liquid* coolant from a reservoir to said pump,

a second conduit for supplying *liquid* coolant from said pump to said drill,

means including said pump for supplying *liquid* coolant through said drill at regularly varying pressures whereby said *liquid* coolant pulses in its flow through said passageway of said drill,

said means including a valve in one of said conduits and means for operating said valve at a regular frequency.

12. In a drilling apparatus which includes a drill of the type having a longitudinal passageway including an outlet opening adjacent to the tip thereof, the improvement which comprises a coolant supply unit for supplying *liquid* coolant through said passageway of said drill, said coolant supply unit including:

a pump,

a motor for operating said pump,

a first conduit for supplying *liquid* coolant from a reservoir to said pump,

a second conduit for supplying *liquid* coolant from said pump to said drill,

means including said pump for supplying *liquid* coolant through said drill at regularly varying pressures whereby said *liquid* coolant pulses in its flow through said passageway of said drill,

said means including a valve and rotating cam means for operating said valve at a regular frequency.

13. In a drilling apparatus which includes a drill of the type having a longitudinal passageway including an outlet opening adjacent to the tip thereof, the improvement which comprises a coolant supply unit for supplying *liquid* coolant through said passageway of said drill, said coolant supply unit including:

a fluid pump,

an electric motor for operating said pump,

a first conduit for supplying *liquid* coolant from a reservoir to said pump,

a second conduit having a pressure accumulator therein for supplying *liquid* coolant from said pump to said drill,

a solenoid operated valve in said second conduit for controlling the flow of [fluid] *liquid* from said pump to said drill,

electrical switch means for controlling said solenoid valve,

a rotary cam operable to control said switch means, and

means for driving said cam so as to control the opening and closing of said switch means at a regular frequency whereby said valve operates to vary the pressure of [fluid] *liquid* supplied through said drill passageway by pulsing said [fluid] *liquid* flow.

[**14.** The method of drilling a hole in a workpiece which comprises:

effecting relative rotational movement between a workpiece and a drill while said drill remains in engagement with said workpiece,

supplying coolant fluid through a longitudinal passageway in said drill terminating near the tip thereof to said workpiece so as to cool said drill and said workpiece and to flush chips away from the cutting tip of said drill, and

regularly varying the pressure of the coolant flowing through said drill so as to pulse the fluid flow to said drill tip.]

[**15.** The method of drilling a hole in a workpiece which comprises:

effecting relative rotational movement between a workpiece and a drill while said drill remains in engagement with said workpiece,

supplying coolant fluid through a longitudinal passageway in said drill terminating near the tip thereof to said workpiece so as to cool said drill and workpiece and flush chips away from the tip of said drill, and varying the pressure of the coolant flowing through said drill at a frequency of at least 30 times per minute so as to regularly pulse the fluid flow to said drill tip.]

[**16.** The method of drilling a hole in a workpiece which comprises:

effecting relative rotational movement between a workpiece and a drill while said drill remains in engagement with said workpiece,

supplying coolant fluid through a longitudinal passageway in said drill terminating near the tip thereof to said workpiece so as to cool said drill and workpiece and flush chips away from the cutting tip of said drill, and

regularly varying the pressure of the coolant flowing through said drill by at least 30 percent so as to pulse the fluid flow to said drill tip.]

17. In a drilling apparatus which includes a drill of the type having a longitudinal passageway including an outlet opening adjacent to the tip thereof, the improvement which comprises a coolant supply unit for supplying *liquid* coolant through said passageway of said drill, said coolant supply unit including:

a pump,

a first conduit for supplying *liquid* coolant from a reservoir to said pump,

a second conduit for supplying *liquid* coolant from said pump to said drill, and

means including said pump for supplying *liquid* coolant through said drill passageway at regularly varying pressures whereby said liquid coolant pulses in its flow through said drill.

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FRANCIS S. HUSAR, Primary Examiner

U.S. Cl. X.R.

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(5/69)

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 26,975 (reissue) Dated October 27, 1970

Inventor(s) Jess R. Borman and John P. Schaefer

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the specification:

Col. 2, line 50: please change the word vetrically to read -- vertically --.
Col. 3, line 29: change the word ilne to read -- line --.
Col. 3, line 33: change the word vave to read -- valve --.
Col. 3, line 33: change the word pneumaticaly to read --pneumatically --.
Col. 3, line 74: change the word reciprocating to read -- reciprocation --.
Col. 4, line 15: change the word recepition to read -- reception --.
Col. 4, line 35: change the word pressure to read -- pressures --.
Col. 4, line 49: change the number 74 to read -- 73 --.

In the claims:

Claim 4, Col. 9, line 42: after the word other insert -- end --.
Claim 5, Col. 10, line 3: after the word control insert -- said --.
Claim 6, Col. 10, line 8: the word colant should read -- coolant --.
Claim 6, Col. 10, lines 8 and 9: "suppuly" should read -- supply --.
Claim 7, Col. 10, line 37: the word drving should be changed to read -- driving --.
Claim 10, Col. 11, line 25: change the word pressure to read -- pressures --.

SIGNED AND
SEALED
JAN 5 1971

(SEAL)
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