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White

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(54) **DIESEL HAMMER SYSTEMS AND METHODS**

(75) Inventor: **John L. White**, Kent, WA (US)

(73) Assignee: **American Piledriving Equipment, Inc.**, Kent, WA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/124,201**

(22) Filed: **Apr. 16, 2002**

Related U.S. Application Data

(60) Provisional application No. 60/284,180, filed on Apr. 16, 2001.

(51) **Int. Cl.**^{7} **E02D 7/12**

(52) **U.S. Cl.** **173/135**; 173/136; 173/137; 173/206

(58) **Field of Search** 173/206, 135–137, 173/19–20

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Portions of Operations Manuals for Diesel Hammers Depicting the Basic Operation of Diesel Hammers and Fuel Pumps Used by Commercially Available Diesel Hammers (8 pages).

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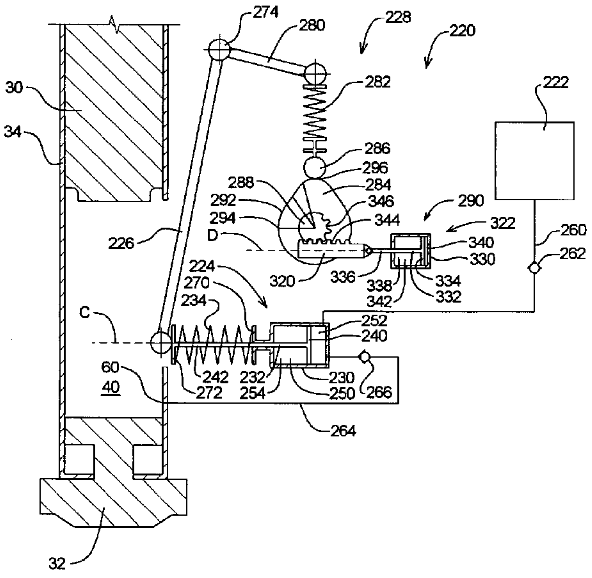
Primary Examiner—Rinaldi I. Rada
Assistant Examiner—Michelle Lopez
(74) *Attorney, Agent, or Firm*—Michael R. Schacht; Schacht Law Office, Inc.

(57) **ABSTRACT**

A diesel hammer system for driving piles. In one form of the invention, a control pinion is attached to a cam member employed to adjust the volume of a fuel portion of a pump chamber. A control rack is arranged to engage the control pinion such that linear movement of the control rack is translated into rotational movement of the control pinion. A hydraulic cylinder assembly is provided having a control housing and a control piston. The control piston is attached to the control rack such that linear movement of the control piston is transferred to the control rack. Hydraulic fluid is introduced into the control housing to cause linear movement of the control piston. Conventional hydraulic controls may be used at a remote location to introduce hydraulic fluid into the appropriate portions of the control housing chamber. In another form of the invention, indicia are formed on a housing of the variable fuel pump to allow an operator to see the setting of the fuel pump. In yet another form, the invention optionally comprises a pre-trigger system that allows the diesel hammer system to operate in a conventional mode or in a ram mode by preventing the fuel pump from injecting fuel into the combustion chamber when in the ram mode. Another optional form of the invention employs an extension sleeve that prevents dirt from entering the housing member of the diesel hammer system; the extension sleeve is preferably perforated to allow a user to see the movement of the ram member.

6 Claims, 10 Drawing Sheets



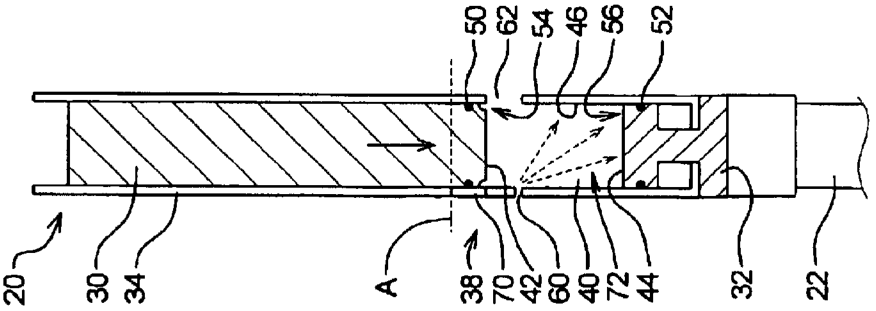


FIG. 1A

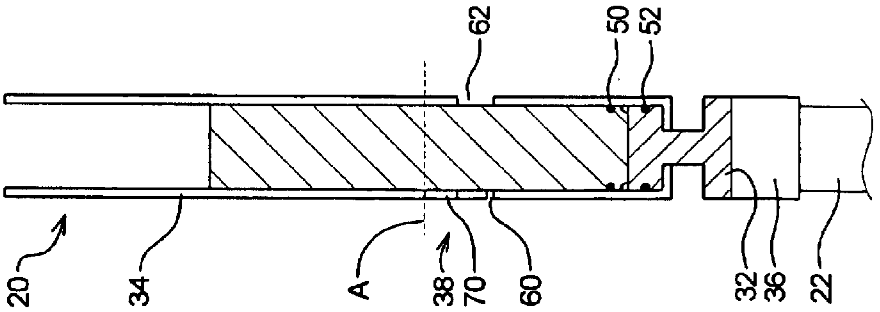


FIG. 1B

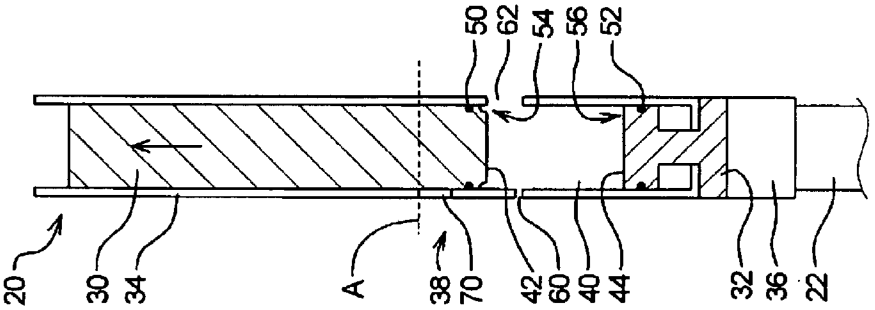


FIG. 1C

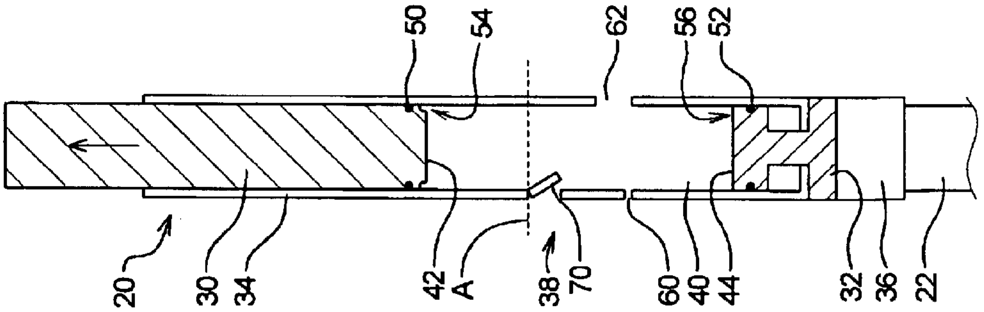


FIG. 1D

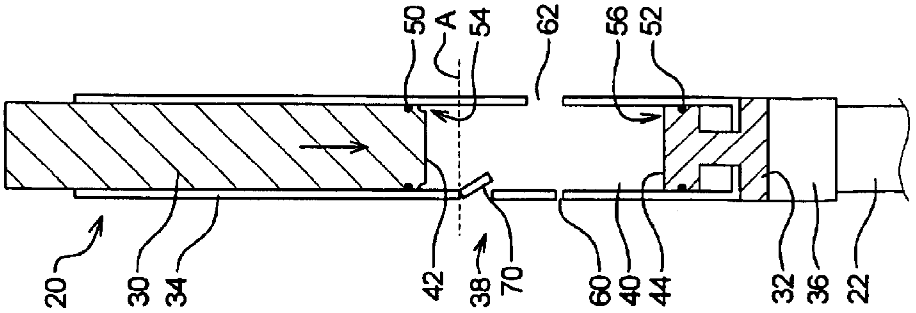


FIG. 1E

FIG. 2
PRIOR ART

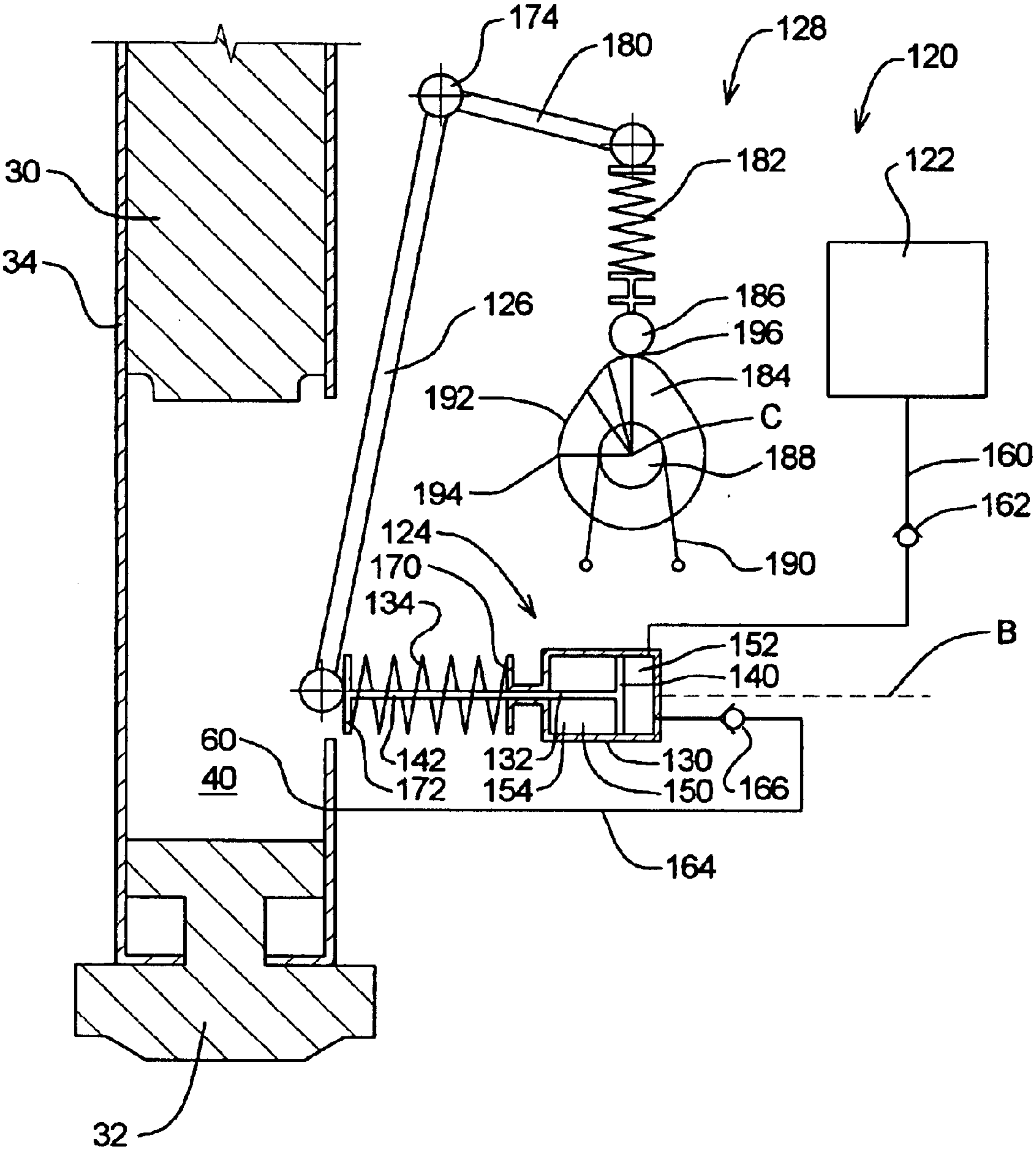


FIG. 3
PRIOR ART

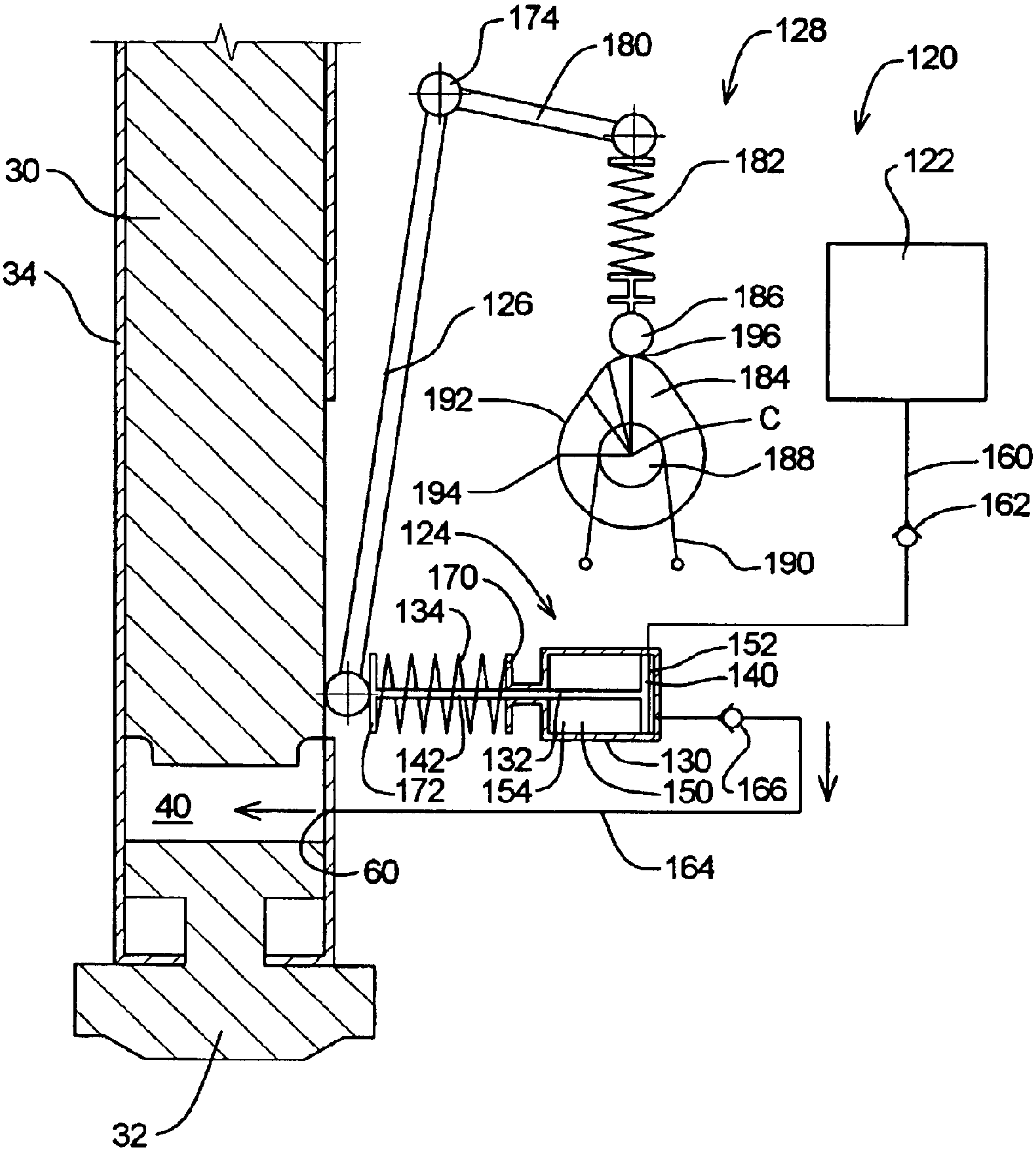


FIG. 4
PRIOR ART

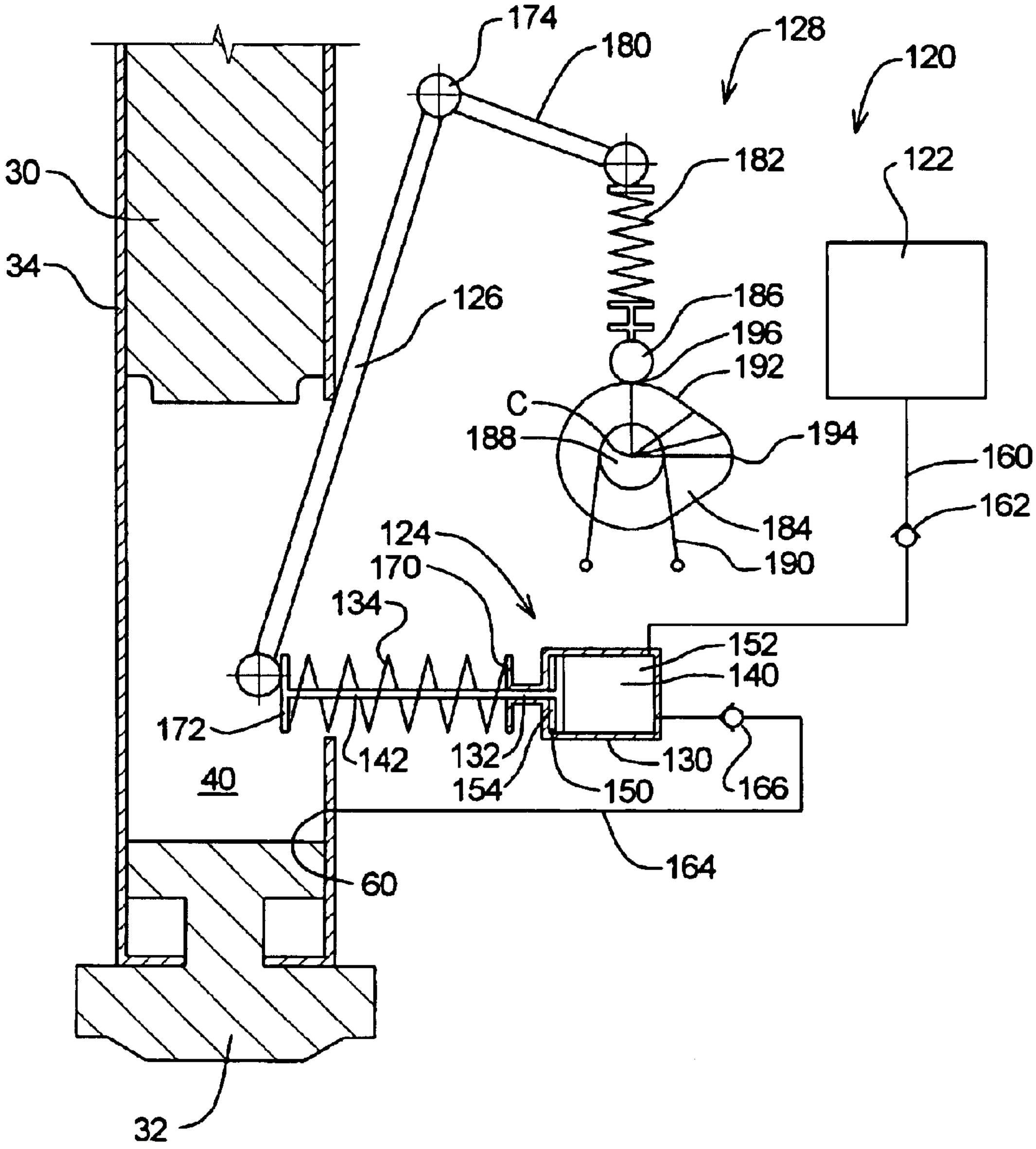


FIG. 5

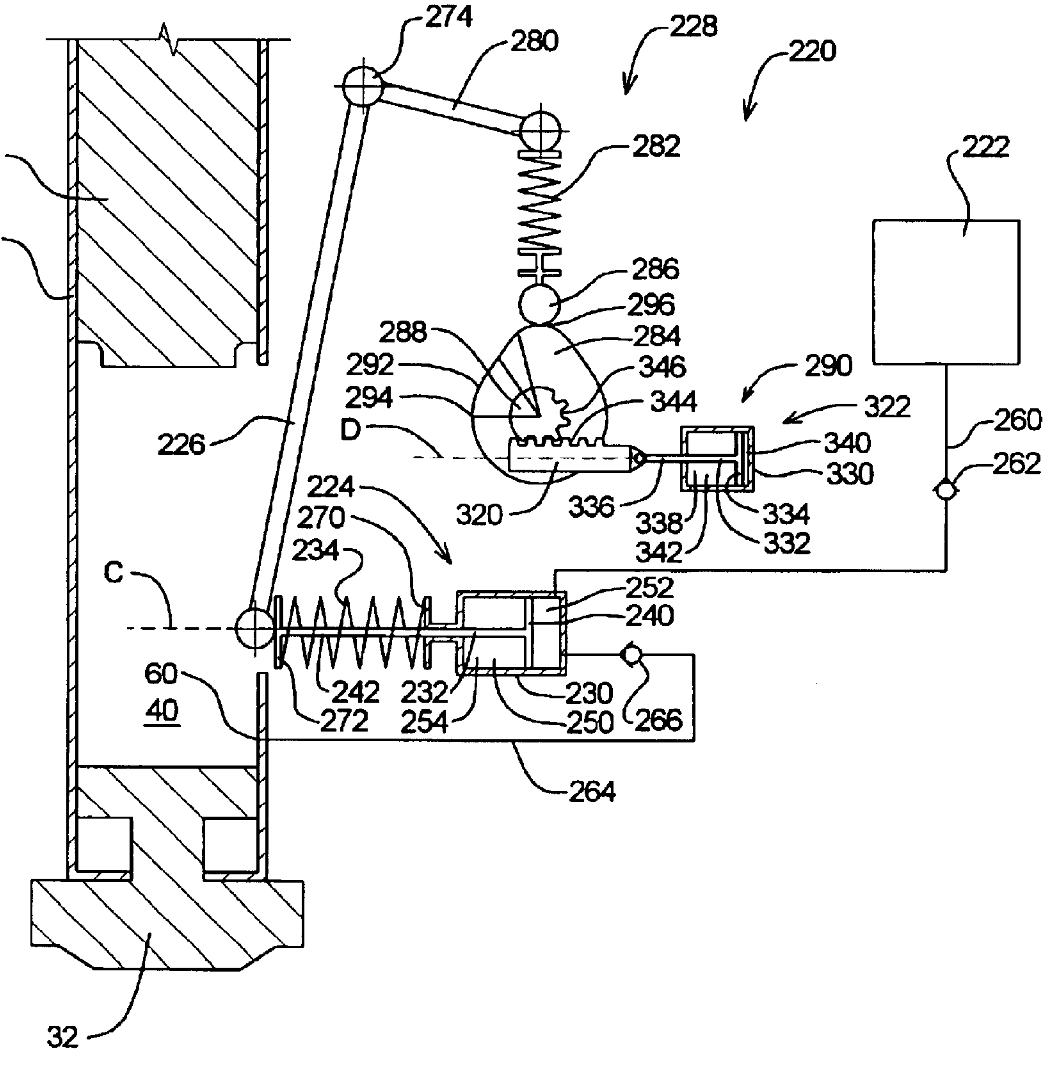

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FIG. 6

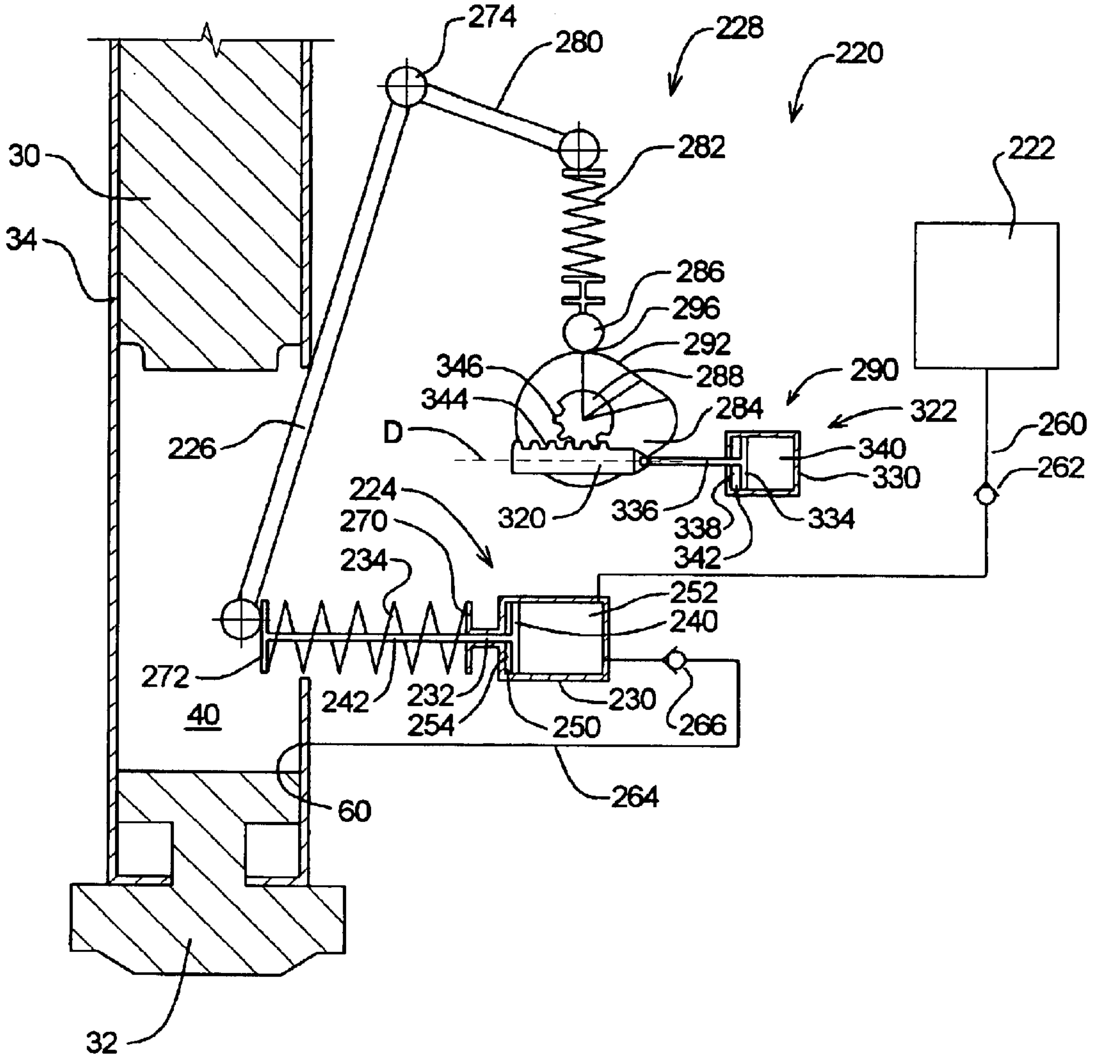
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FIG. 7

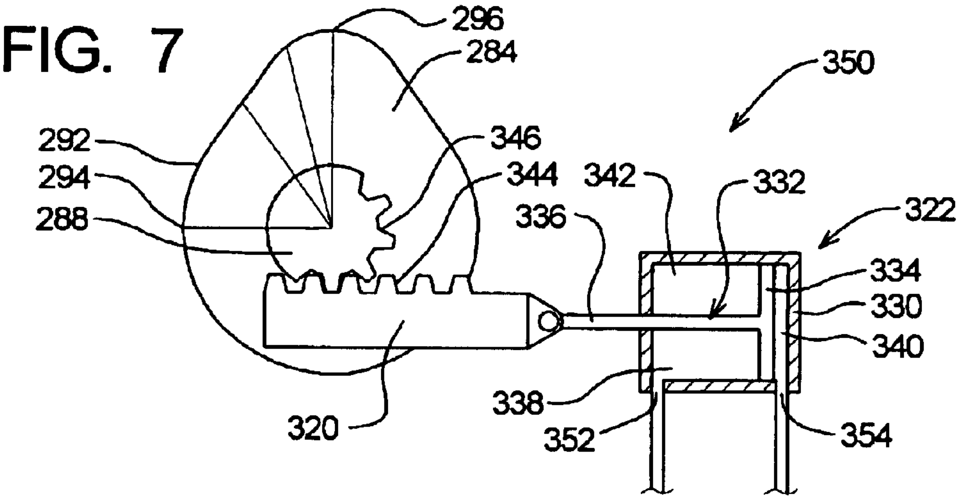


FIG. 8

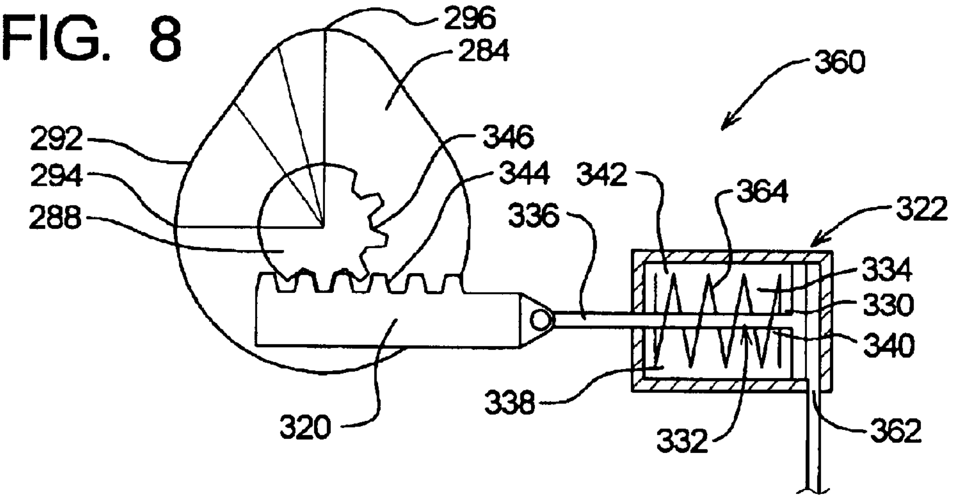


FIG. 9

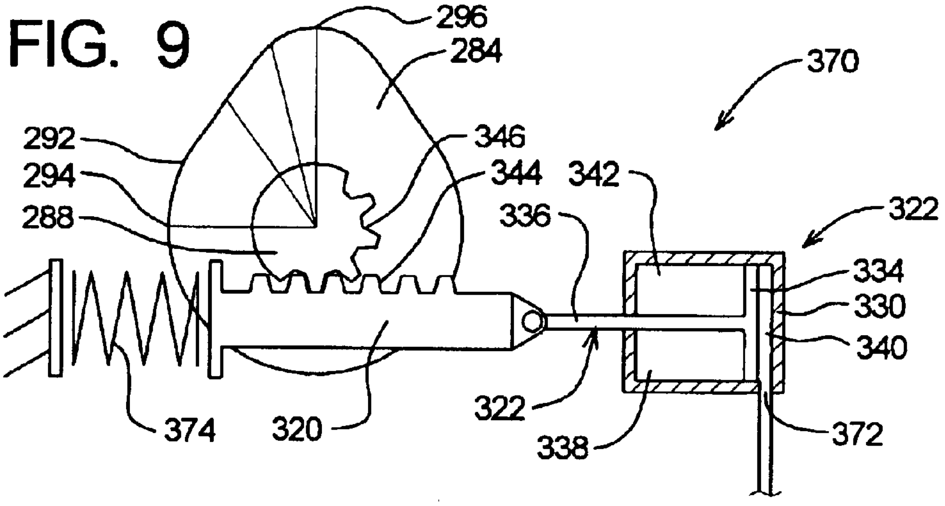


FIG. 10
PRIOR ART

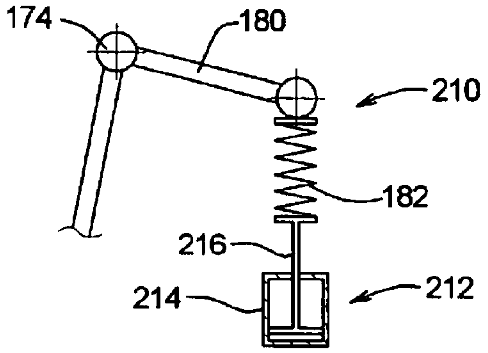


FIG. 11
PRIOR ART

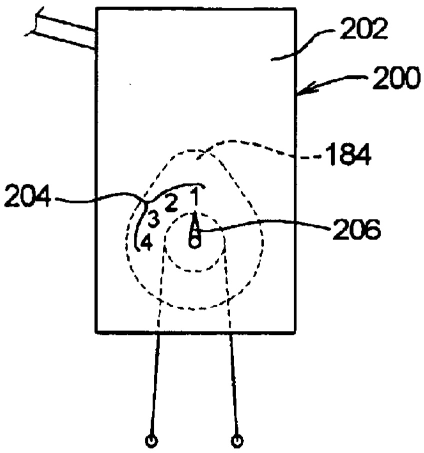


FIG. 12

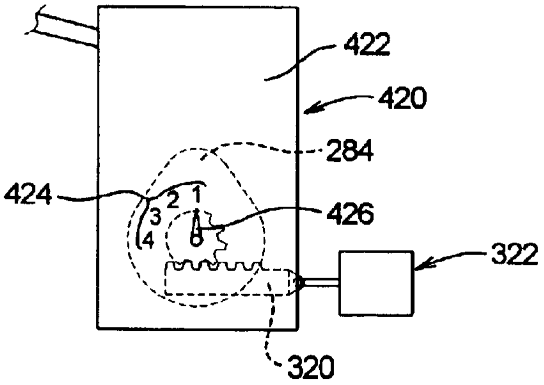


FIG. 14

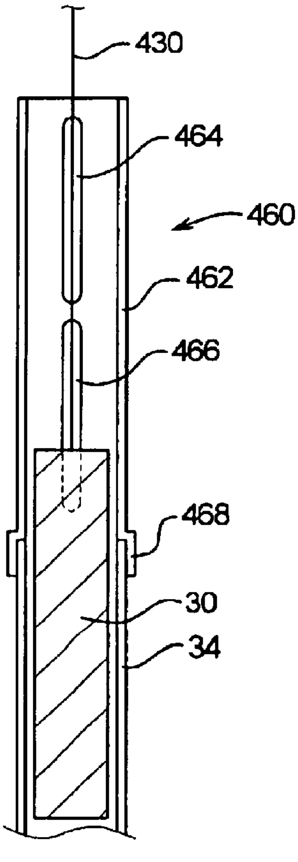


FIG. 13A

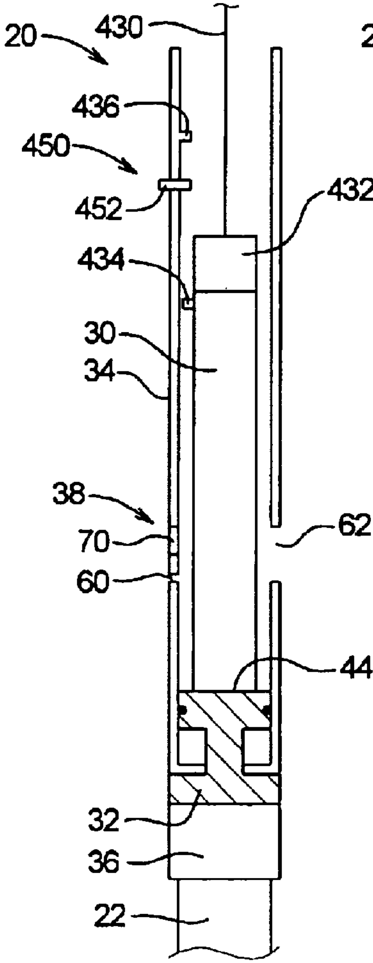


FIG. 13B

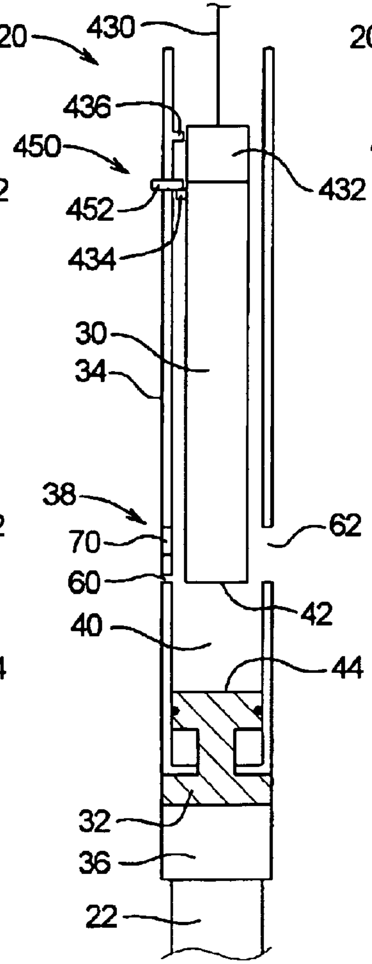


FIG. 13C

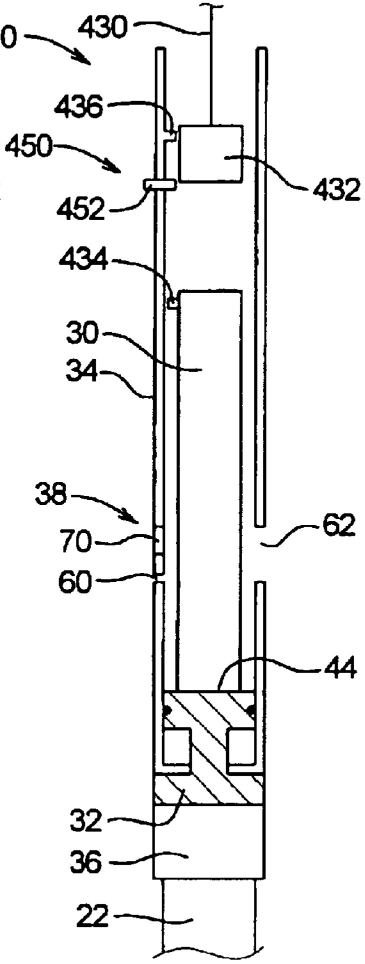


FIG. 13D

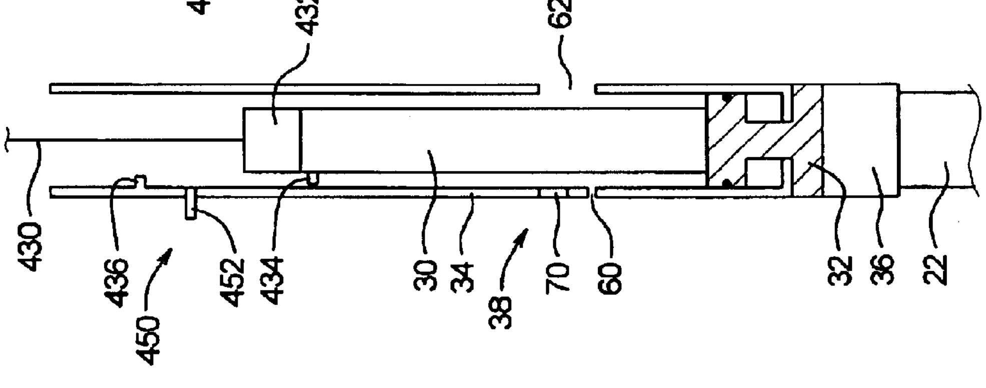


FIG. 13E

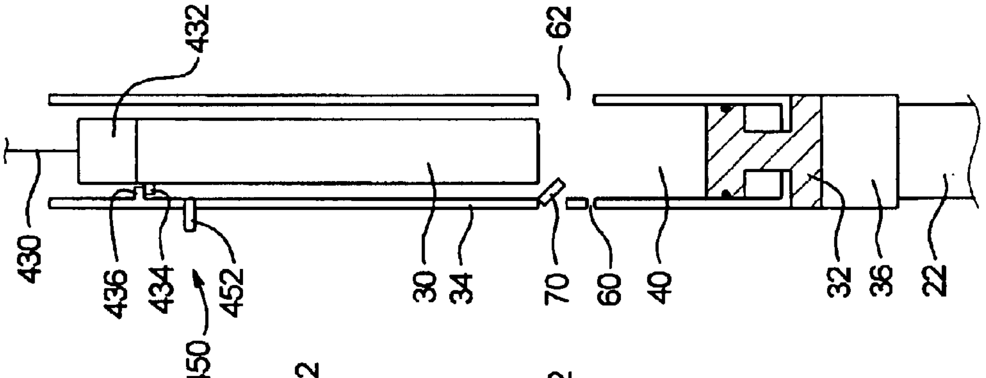
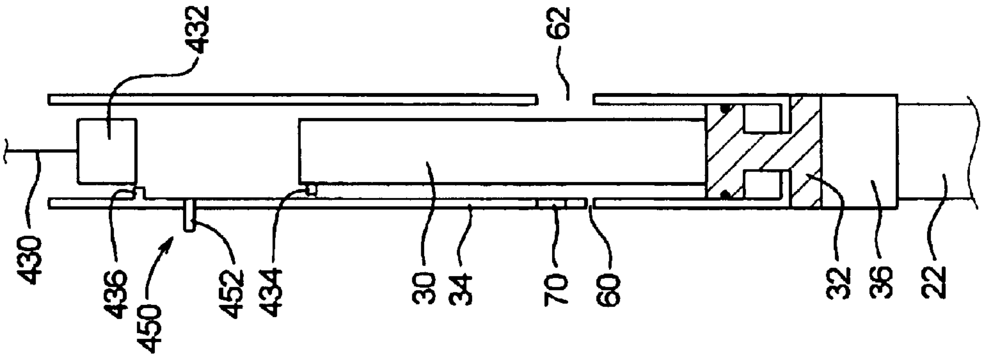


FIG. 13F



DIESEL HAMMER SYSTEMS AND METHODS

RELATED APPLICATIONS

This application claims priority U.S. Provisional Patent Application Serial No. 60/284,180, which was filed on Apr. 16, 2001.

TECHNICAL FIELD

The present invention relates to methods and apparatus for inserting elongate members into the earth and, more particularly, to diesel hammers that create pile driving forces by combusting diesel fuel.

BACKGROUND OF THE INVENTION

For certain construction projects, elongate members such as piles, anchor members, caissons, and mandrels for inserting wick drain material must be placed into the earth. It is well-known that such rigid members may often be driven into the earth without prior excavation. The term "piles" will be used herein to refer to the elongate rigid members typically driven into the earth.

One system for driving piles is conventionally referred to as a diesel hammer. A diesel hammer employs a floating ram member that acts both as a ram for driving the pile and as a piston for compressing diesel fuel. Diesel fuel is injected into a combustion chamber below the ram member as the ram member drops. The dropping ram member engages an anvil member that transfers the load of the ram member to the pile to drive the pile. At the same time, the diesel fuel ignites, forcing the ram member and the anvil member in opposite directions. The anvil member further drives the pile, while the ram member begins a new combustion cycle.

An important factor in the operation of a diesel hammer is the quantity of diesel fuel injected into the combustion chamber because the ignition of the diesel fuel directly determines the driving forces applied to the pile. In particular, the quantity of diesel fuel determines both the forces on the anvil member both at the point of ignition and, because it affects how high the ram member goes, when the ram member impacts the anvil member on the compression stroke prior to ignition.

Conventional diesel hammers employ a variable fuel pump having a fuel chamber, a control pulley, and a control rope. The fuel chamber stores the fuel to be delivered to the combustion chamber. The angular orientation of the control pulley determines the effective volume of the fuel chamber. The control rope extends partly around the control pulley such that pulling on either end of the control rope causes the control pulley to rotate and change its angular orientation. Conventional variable fuel pumps require an operator to stand on the ground adjacent to the diesel hammer and pull the control rope to adjust the effective volume of the fuel chamber. The process of adjusting the amount of fuel delivered to the combustion chamber is thus cumbersome and conventional variable fuel pumps are typically placed in one setting and left there during the driving process.

The need thus exists for improved variable fuel pumps for diesel hammers that make it easier for the operator to adjust the amount of fuel delivered to the combustion chamber as appropriate for a given situation.

RELATED ART

Submitted herewith are portions of operations manuals for diesel hammers depicting the basic operation of diesel

hammers and the fuel pumps used by commercially available diesel hammers. These references employ a control rope and control pulley to change the amount of fuel delivered to the combustion chamber as generally described in the BACKGROUND section of this application.

SUMMARY OF THE INVENTION

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1A–1E** are somewhat schematic sectional views of a diesel hammer depicting the basic combustion/drive cycle thereof;

FIGS. **2–4** are part sectional/part schematic views depicting the operation of prior art variable fuel pumps employed by conventional diesel hammers;

FIGS. **5** and **6** are part sectional/part schematic views depicting the operation of a variable fuel pump constructed in accordance with the principles of the present invention; and

FIGS. **7–9** are part sectional/part schematic views depicting the operation of exemplary control systems used by the variable fuel pump of FIGS. **5** and **6**;

FIG. **10** is a part sectional/part schematic view depicting yet another prior art variable fuel pump system;

FIG. **11** is a somewhat schematic front elevation view of the prior art fuel pump of FIGS. **2–4**;

FIG. **12** is a somewhat schematic front elevation view of an exemplary housing that may be used with a fuel pump of the present invention;

FIGS. **13**A–F are somewhat schematic section views of yet another exemplary diesel hammer of the present invention; and

FIG. **14** is a somewhat schematic section view of still another exemplary diesel hammer of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The first section of the following discussion will describe the basic construction and operation of diesel hammer pile driving systems. The next section will contain will be a more detailed discussion of prior art variable fuel pumps. The following section will contain a discussion of the variable fuel pump of the present invention.

I. Construction and Operation of Conventional Diesel Hammer

Turning to the drawing, depicted at **20** in FIGS. **1A–1E** is a diesel hammer system that may use a variable fuel pump constructed in accordance with, and embodying, the principles of the present invention. The diesel hammer system **20** is designed to insert a pile **22** into the ground. The diesel hammer system **20** will include a spotter, crane, or other equipment as necessary to hold the hammer system **20** in a desired orientation with respect to the ground. Such structural components of the hammer system **20** are conventional and will not be described herein.

The diesel hammer system **20** comprises a ram member **30**, an anvil member **32**, a housing member **34**, a clamp assembly **36**, and a fuel pump system **38**. The ram member **30** is guided by the housing member **34** for movement between a lower position (FIG. **1**B) and an upper position (FIG. **1**D). The anvil member **32** is guided by the housing member **34** for movement between a rest position (FIG. **1**A) and an impact position (FIG. **1**B). The anvil member **32** is rigidly connected to the clamp assembly **36**. The clamp assembly **36** is detachably fixed relative to the pile **22**.

A combustion chamber **40** is formed within the housing member **34** between a lower surface **42** of the ram member **30** and an upper surface **44** of the anvil member **32**. Seals **50** and **52** are arranged in gaps **54** and **56** between an inner surface **46** of the housing member **34** and the ram and anvil members **30** and **32**, respectively. When the seals **50** and **52** function properly, fluid is substantially prevented from flowing out of the combustion chamber **40** through these gaps **54** and **56**.

A fuel port **60** and an exhaust port **62** are formed in the housing member **34**. The fuel port **60** is arranged to allow the fuel pump system **38** to inject fuel into the combustion chamber **40**. The exhaust port **62** is arranged to allow exhaust gasses to be expelled from the combustion chamber **40** and to allow air to be drawn into the chamber **40**.

The fuel pump system **38** comprises a pump lever **70**. The pump lever **70** is biased into a ready position in which at least a portion of the pump lever **70** is within the housing member **34** (FIGS. **1**D and **1**E). When the ram member **30** drops below a trigger point A, the ram member **30** engages the pump lever **70** and moves the pump lever **70** from the ready position into a pump position (FIGS. **1**A–**1**C). Forcing the pump lever **70** from the ready position into the pump position causes diesel fuel to be injected into the combustion chamber **40** through the fuel port **60**.

The diesel hammer system **20** operates in a combustion cycle that will now be described with reference to FIG. **1**. Referring initially to FIG. **1**A, the hammer system **20** is shown in a pump state in which the ram member **30** is dropping and has forced the pump lever **70** from the ready position (FIGS. **1**D and **1**F) into the pump position (FIGS. **1**A–**1**C). When the pump lever is forced from the ready position into the pump position, diesel fuel is injected as shown at **72** through the fuel port **60** into the combustion chamber **40** where it is mixed with air.

As the combustion cycle continues, the ram member **30** drops to a level where both the fuel port **60** and exhaust port **62** are covered by the ram member **30**. At this point, the combustion chamber **40** is effectively sealed, and continued dropping of the ram member **30** compresses the air/fuel mixture within the combustion chamber **40**.

Referring now to FIG. **1**B, the hammer system **20** is shown in an impact state in which the lower surface **42** of the ram member **30** contacts the upper surface **44** of the anvil member **32**. In the impact state, the ram member **30** drives the anvil member **32** towards the pile **22** relative to the housing member **34** as shown by a comparison of FIGS. **1**A and **1**B. The anvil member **32** thus drives the pile **22** downward through the clamp assembly **36**. In addition, the housing member **34** will immediately fall onto the anvil member **32**, thereby applying additional driving forces onto the pile member **22**.

When the system **20** is in the impact state, the diesel fuel within the combustion chamber **40** ignites in the highly compressed air. The explosion resulting from the ignition of the air/fuel mixture forces the ram member **30** up and the anvil member **32** down. This explosion thus further drives the pile member **22** into the ground.

After the ignition occurs, the anvil member **32** is raised to an upper position as shown in FIG. **1**C. As the anvil member **32** moves into the upper position, the lower end of the ram member **30** passes the fuel and exhaust ports **60** and **62**. Expanding exhaust gasses are thus forced out of the combustion chamber **40** through the exhaust port **62**.

As the ram member continues on to its upper position, fresh air is drawn into the combustion chamber **40** through the exhaust port **62**. In addition, the ram member **30** disengages from the pump lever **70**. As soon as the ram member **30** disengages from the pump lever, the bias on the pump lever **70** returns the pump lever **70** to the ready position from the pump position and the fuel system **38** readies another quantity of fuel for the next cycle.

After the ram member **30** reaches the upper position as shown in FIG. **1**D, the ram member **30** is allowed to drop again. The system **20** then enters a pre-injection state as shown in FIG. **1**E. In the pre-injection state, the combustion chamber **40** is filled with fresh air and the fuel pump system **38** is primed to deliver another quantity of fuel. As the ram member **30** continues to drop, the system **20** enters the pump state as described with reference to FIG. **1**A and the cycle begins again.

Referring now to FIGS. **2**–**4**, depicted at **120** therein is a prior art variable fuel pump system that may be used as the fuel pump system **38** described above. In particular, the fuel pump system **120** comprises a source **122** of fuel, a fuel pump cylinder assembly **124**, a fuel pump lever **126**, and a travel limiting assembly **128**. The pump lever **126** is used as the pump lever **70** described above.

The fuel pump cylinder assembly **124** comprises a fuel pump housing **130**, a piston **132**, and a pump spring **134**. The fuel pump housing **130** defines a longitudinal axis B. The piston **132** comprises a piston head **140** and a piston shaft **142**. The axis of the piston shaft **142** is aligned with the housing axis B such that the piston **132** moves along the housing axis B.

The fuel pump housing **130** defines a fuel pump chamber **150**, and the piston head **140** divides the fuel pump chamber **150** into a fuel portion **152** and a reserve portion **154**. A seal (not shown) prevents the flow of fluid between the fuel portion **152** and reserve portion **154**.

The fuel source **122** is connected through a first conduit **160** to the fuel portion **152** of the fuel pump chamber **150**. A first check valve **162** arranged in the first conduit **160** allows fluid to flow only from the source **122** to the fuel pump chamber **150**. The fuel portion **152** of the fuel pump chamber **150** is also connected by a second conduit **164** to the fuel port **60** in the housing member **34**. A second check valve **166** arranged in the second conduit **164** allows fluid to flow only from the fuel pump chamber **150** to the fuel port **60**.

A spring landing **170** is formed on the fuel pump housing **130**, and a spring retainer **172** is formed on the piston shaft **142**. The pump spring **134** is a compression spring arranged between the spring landing **170** and the spring retainer **172**. The pump spring **134** thus biases the spring retainer **172** away from the spring landing **170**.

The fuel pump lever **126** is pivotably connected at one end to a pivot point **174** on the housing member **34**. The pump lever **126** thus rotates between the ready (FIGS. **2** and **3**) and pump (FIG. **3**) positions relative to the housing member **34**. The other end of the fuel pump lever **126** held against the piston shaft **142** by the travel limiting assembly **128** as will be described in detail below.

Accordingly, rotational movement of the fuel pump lever **126** about the pivot point **174** is translated into displacement of the piston **132** along the housing axis B. In particular, clockwise rotation of the fuel pump lever **126** causes the pump head **140** to move within the pump chamber **150** to decrease the volume of the fuel portion **152** thereof, while counter-clockwise rotation of the fuel pump lever **126** allows the pump spring **134** to move the pump head **140** in the opposite direction, thereby increasing the volume of the fuel portion **152** of the pump chamber **150**. The pump spring **134** thus assists movement of the fuel pump lever **126** in the clockwise direction and opposes movement of the fuel pump lever **126** in the counter-clockwise direction.

A comparison of FIGS. **2** and **3** shows that the descending ram member **30** engages the pump lever **126** to rotate this lever in the counter-clockwise direction against the force of the pump spring **134**. As shown in FIG. **2**, the descending ram member **30** thus indirectly forces any fluid within the fuel portion **152** of the pump chamber **150** out of the pump chamber **150** and into the combustion chamber **40** through the fuel port **60**.

Further, as shown in FIG. **3**, when the ram member **30** moves above the pump lever **126**, the pump lever **126** returns to the ready position under the force of the pump spring **134**. The movement of the piston head **140** as the pump lever **134** returns to the ready position draws fuel from the fuel source **122** to refill the fuel portion **152** of the pump chamber **150**.

The amount of fuel delivered by the variable fuel pump system **120** is determined by the volume of the fuel portion **152** of the pump chamber **150**. The travel limiting assembly **128** is used to adjust the angular position of the pump lever **126** when the lever **126** is in the ready position. Because the pump lever **126** is connected to the piston **132** as described above, the travel limiting assembly **128** thus determines the volume of the fuel portion **152**.

The travel limiting assembly **128** comprises a link arm **180**, a link spring **182**, a cam member **184**, a cam roller **186**, a control pulley **188**, and a control rope **190**. The cam member **184** rotates about a cam axis C. The control pulley **188** is attached to the cam member **184** such that rotation of the pulley **188** causes rotation of the cam member **184** about the cam axis C. The control rope **190** engages the control pulley **188** such that pulling on either end of the control rope **190** causes the control pulley **188** to rotate, which in turn causes the cam member **184** to rotate about the cam axis C.

The cam member **184** is eccentric such that the distance between a cam surface **192** and the cam axis C varies from a first location **194** to a second location **196** on the cam surface **192**. The cam roller **186** rides on the cam surface **192** such that the distance between the cam roller **186** and the cam axis C varies with angular rotation of the cam member **184**. The cam axis C is fixed relative to the housing member **34**; therefor, rotation of the cam member **184** causes the cam roller **186** to move relative to the housing member **34**.

The link arm **180** is rigidly connected to the pump lever **126** such that the link arm **180** also rotates about the pivot point **174**. The link arm **180** is arranged to apply a force on the cam roller **186** that holds the cam roller **186** against the cam surface **192**, with the link spring **182** in compression between the link arm **180** and the cam roller **186**.

A comparison of FIGS. **2** and **4** shows that the angular orientation of the cam member **184** determines the angular location of the pump lever **126**. With the cam member **184** in a first angular orientation as shown in FIG. **2**, the cam roller **186** engages the first location **194** on the cam surface **192**. With the cam member **184** in a second angular orientation as shown in FIG. **4**, the cam roller **186** engages the second location **196** on the cam surface **192**.

The cam roller **186** in turn acts through the link spring **182** and link arm **180** to place the pump lever **126** in a first angular location (FIG. **2**) or a second angular location (FIG. **4**). As described above, the angular location of the pump lever **126** determines the location of the piston head **142** within the pump chamber **150** and thus the volume of the fuel portion **152** thereof.

The angular position of the cam member **184** thus determines the volume of the fuel portion **152** of the pump chamber **150** when the pump lever **126** is in the ready position; this relationship can be seen by comparing FIGS. **2** and **4**.

As described above, pulling the ends of the control rope **190** determines the angular position of the cam member **184**; the control rope **190** can thus be used to set the volume of the fuel portion **152** of the pump chamber **150**.

Referring now to FIG. **11**, depicted therein is a schematic view of a housing **200** of the conventional variable fuel pump system **120** described above. The housing **200** has a face **202** on which is formed indicia **204** corresponding to angular positions of the cam member **184**. An indicator **206** is rigidly fixed in a predetermined relationship to the cam member **184**. The indicator **206** is located outside of the housing **200**. As the cam member **184** rotates, the indicator **206** also rotates; the position of the indicator **206** can thus be compared with the indicia on the housing face **202** to determine the location of the cam member **184**. The operator can thus determine the location of the cam member **184**, and thus the amount of fuel to be injected by the fuel pump system **120**, by comparing the location of the indicator **206** with the indicia **204**.

Referring now to FIG. **10**, depicted at **210** therein is a modification to the variable fuel pump system **120** described above. The modification **210** eliminates the cam member **184**, cam roller **186**, control pulley **188**, and control rope **190** of the travel limiting assembly **128** described above. Instead, the modification **210** comprises an actuator assembly **212** that is connected to the link arm **180** through the link spring **182**. The actuator assembly **212** comprises a fixed housing **214** and a shaft member **216**. The actuator assembly **212** is operated to extend the shaft member **216** out of or retract the shaft member **216** into the housing **214**. Operation of the actuator assembly **212** thus can change the effective volume of fuel pump chamber **150**. However, the operator on the ground is provided with no visual feedback indicating the volume of the fuel pump chamber **150**. Accordingly, while some commercial diesel hammers incorporate the modification **210**, this modification **210** has thus not been generally adopted for use on variable fuel pump systems for diesel hammers.

II. Remote Controlled Variable Fuel Pump

Referring now to FIGS. **5–8**, depicted at **220** therein is a variable fuel pump system constructed in accordance with, and embodying, the principles of the present invention. The variable fuel pump system **220** may be used as the fuel pump system **38** described above.

The fuel pump system **220** comprises a source **222** of fuel, a fuel pump cylinder assembly **224**, a fuel pump lever **226**, and a travel limiting assembly **228**. The pump lever **126** is used as the pump lever **70** described above. The fuel pump cylinder assembly **224** comprises a fuel pump housing **230**, a piston **232**, and a pump spring **234**. The fuel pump housing **230** defines a longitudinal axis B. The piston **232** comprises a piston head **240** and a piston shaft **242**. The axis of the piston shaft **242** is aligned with the housing axis B such that the piston **232** moves along the housing axis B.

The fuel pump housing **230** defines a fuel pump chamber **250**, and the piston head **240** divides the fuel pump chamber **250** into a fuel portion **252** and a reserve portion **254**. A seal (not shown) prevents the flow of fluid between the fuel portion **252** and reserve portion **254**.

The fuel source **222** is connected through a first conduit **260** to the fuel portion **252** of the fuel pump chamber **250**. A first check valve **262** arranged in the first conduit **260** allows fluid to flow only from the source **222** to the fuel pump chamber **250**. The fuel portion **252** of the fuel pump chamber **250** is also connected by a second conduit **264** to the fuel port **60** in the housing member **34**. A second check valve **266** arranged in the second conduit **264** allows fluid to flow only from the fuel pump chamber **250** to the fuel port **60**.

A spring landing **270** is formed on the fuel pump housing **230**, and a spring retainer **272** is formed on the piston shaft **242**. The pump spring **234** is a compression spring arranged between the spring landing **270** and the spring retainer **272**. The pump spring **234** thus biases the spring retainer **272** away from the spring landing **270**.

The fuel pump lever **226** is pivotably connected at one end to a pivot point **274** on the housing member **34**. The pump lever **226** thus rotates between the ready (FIGS. **2** and **3**) and pump (FIG. **3**) positions relative to the housing member **34**. The other end of the fuel pump lever **226** held against the piston shaft **242** by the travel limiting assembly **228** as will be described in detail below.

Accordingly, rotational movement of the fuel pump lever **226** about the pivot point **274** is translated into displacement of the piston **232** along the housing axis B. In particular, clockwise rotation of the fuel pump lever **226** causes the pump head **240** to move within the pump chamber **250** to decrease the volume of the fuel portion **252** thereof, while counter-clockwise rotation of the fuel pump lever **226** allows the pump spring **234** to move the pump head **240** in the opposite direction, thereby increasing the volume of the fuel portion **252** of the pump chamber **250**. The pump spring **234** thus assists movement of the fuel pump lever **226** in the clockwise direction and opposes movement of the fuel pump lever **226** in the counter-clockwise direction.

A comparison of FIGS. **2** and **3** shows that the descending ram member **30** engages the pump lever **226** to rotate this lever in the counter-clockwise direction against the force of the pump spring **234**. As shown in FIG. **2**, the descending ram member **30** thus indirectly forces any fluid within the fuel portion **252** of the pump chamber **250** out of the pump chamber **250** and into the combustion chamber **40** through the fuel port **60**.

Further, as shown in FIG. **3**, when the ram member **30** moves above the pump lever **226**, the pump lever **226** returns to the ready position under the force of the pump spring **234**. The movement of the piston head **240** as the pump lever **234** returns to the ready position draws fuel from the fuel source **222** to refill the fuel portion **252** of the pump chamber **250**.

The amount of fuel delivered by the variable fuel pump system **220** is determined by the volume of the fuel portion **252** of the pump chamber **250**. The travel limiting assembly **228** is used to adjust the angular position of the pump lever **226** when the lever **226** is in the ready position. Because the pump lever **226** is connected to the piston **232** as described above, the travel limiting assembly **228** thus determines the volume of the fuel portion **252**.

The travel limiting assembly **228** comprises a link arm **280**, a link spring **282**, a cam member **284**, a cam roller **286**, a control pinion **288**, and a control rack assembly **290**. The cam member **284** rotates about a cam axis C. The control pinion **288** is attached to the cam member **284** such that rotation of the pulley **288** causes rotation of the cam member **284** about the cam axis C. The control rack assembly **290** engages the control pinion **288** to cause the control pinion **288** to rotate, which in turn causes the cam member **284** to rotate about the cam axis C.

The cam member **284** is eccentric such that the distance between a cam surface **292** and the cam axis C varies from a first location **294** to a second location **296** on the cam surface **292**. The cam roller **286** rides on the cam surface **292** such that the distance between the cam roller **286** and the cam axis C varies with angular rotation of the cam member **284**. The cam axis C is fixed relative to the housing member **34**; therefor, rotation of the cam member **284** causes the cam roller **286** to move relative to the housing member **34**.

The link arm **280** is rigidly connected to the pump lever **226** such that the link arm **280** also rotates about the pivot point **274**. The link arm **280** is arranged to apply a force on the cam roller **286** that holds the cam roller **286** against the cam surface **292**, with the link spring **282** in compression between the link arm **280** and the cam roller **286**.

A comparison of FIGS. **2** and **4** shows that the angular orientation of the cam member **284** determines the angular location of the pump lever **226**. With the cam member **284** in a first angular orientation as shown in FIG. **2**, the cam roller **286** engages the first location **294** on the cam surface **292**. With the cam member **284** in a second angular orientation as shown in FIG. **4**, the cam roller **286** engages the second location **296** on the cam surface **292**.

The cam roller **286** in turn acts through the link spring **282** and link arm **280** to place the pump lever **226** in a first angular location (FIG. **2**) or a second angular location (FIG. **4**). As described above, the angular location of the pump lever **226** determines the location of the piston head **242** within the pump chamber **250** and thus the volume of the fuel portion **252** thereof.

The angular position of the cam member **284** thus determines the volume of the fuel portion **252** of the pump chamber **250** when the pump lever **226** is in the ready position; this relationship can be seen by comparing FIGS. **2** and **4**.

The control rack assembly **290** comprises a control rack **320** and a control cylinder assembly **322**.

The control cylinder assembly **322** comprises a control cylinder housing **330** and a control piston **332** having a control piston head **334** and a control piston shaft **336**. The control piston head **334** is arranged within the cylinder housing **330** to divide a control chamber **338** defined by the housing **330** into first and second portions **340** and **342**. The application of hydraulic fluid to one or both of the control chamber portions **340** and **342** causes linear displacement of the control rack **320** along a path D.

The control rack **320** comprises a toothed surface portion **344**, and the control pinion **288** comprises a toothed surface portion **346**. The teeth on the surface portions **344** and **346** are designed to mate with each other. In addition, the control rack **320** is supported adjacent to the control pinion **288** such that these surfaces portions **340** and **342** engage each other. Accordingly, linear displacement of the control rack **320** along the path D causes rotation of the control pinion **288** about the cam axis C. Because the control pinion **288** is attached to the cam member **284**, the rotation of the control pinion **288** causes rotation of the cam member **284**.

Accordingly, the travel limiting assembly **228** allows the volume of the fuel portion **252** of the pump chamber **250** to be changed remotely by the appropriate application of hydraulic fluid to the cylinder assembly **322**. A comparison of FIGS. **5** and **6** illustrates that the location of the control piston **332** corresponds to different volumes of the pump chamber fuel portion **252**.

Referring now to FIG. **7**, depicted at **350** therein is a first embodiment of a control cylinder assembly that may be used as the control cylinder assembly **322** of the travel limiting assembly **228** of the present invention.

The control cylinder assembly **350** comprises first and second ports **352** and **354** that allow hydraulic fluid to be introduced into the first and second control chamber portions **340** and **342**, respectively. In particular, introducing fluid into the first control chamber portion **340** while allowing fluid to flow out of the second control chamber portion **342** causes the control piston **332** to move in a first direction along the axis D. Introducing fluid into the second control chamber portion **342** while allowing fluid to flow out of the first control chamber portion **340** causes the control piston **332** to move in a second (opposite) direction along the axis D. The conduits and hydraulic controls required to apply fluid to the first and second ports **352** and **354** are conventional and will not be described herein in detail.

Referring now to FIG. **8**, depicted at **360** therein is a second embodiment of a control cylinder assembly that may be used as the control cylinder assembly **322** of the travel limiting assembly **228** of the present invention.

The control cylinder assembly **360** comprises a port **362** that allows hydraulic fluid to be introduced into the first control chamber portion **340**. In addition, a return spring **364** is arranged in the second control chamber portion **342** to oppose movement of the control piston **332** in a first direction along the axis D. Hydraulic fluid is introduced into the first control chamber portion **340** to cause the control piston **332** to move in the first direction along the axis D to a desired position. As long as a predetermined level of hydraulic pressure is maintained in the first control chamber portion **340**, the control piston **332** will remain in the desired position. Releasing pressure within the first control chamber portion **340** allows the return spring **364** to move the control piston in a second (opposite) direction along the axis D. The conduits and hydraulic controls required to apply fluid to the first port **362** are conventional and will not be described herein in detail.

Referring now to FIG. **9**, depicted at **370** therein is a second embodiment of a control cylinder assembly that may be used as the control cylinder assembly **322** of the travel limiting assembly **228** of the present invention.

The control cylinder assembly **370** comprises a port **372** that allows hydraulic fluid to be introduced into the first control chamber portion **340**. In addition, a return spring **374** is arranged to engage the control rack **322** to oppose movement of the control piston **332** in a first direction along the axis D. Hydraulic fluid is introduced into the first control chamber portion **340** to cause the control piston **332** to move against the force of the spring **374** in the first direction along the axis D to a desired position. As long as a predetermined level of hydraulic pressure is maintained in the first control chamber portion **340**, the control piston **332** will remain in the desired position. Releasing pressure within the first control chamber portion **340** allows the return spring **374** to move the control piston in a second (opposite) direction along the axis D. The conduits and hydraulic controls required to apply fluid to the first port **372** are conventional and will not be described herein in detail.

In any of the control cylinder assemblies **350**, **360**, and **370**, the hydraulic fluid may be applied to the control ports from a location remote from the location of the hammer system **20**. For example, an operator of the crane or other equipment that supports the hammer system **20** may be provided with a lever or button that may be pulled or depressed to apply hydraulic fluid to these control ports as described above. The operator need not be physically adjacent to the hammer system **20** to vary the amount of fuel required, so the operator is more likely to adjust the fuel setting as required by a particular situation. Referring now to FIG. **12**, depicted therein is a schematic view of an exemplary housing **420** that may be used to enclose the variable fuel pump system **220** described above. The housing **420** comprises a face **422** on which is formed indicia **424** corresponding to angular positions of the cam member **284**.

In one form of the invention, an indicator **426** is rigidly fixed in a predetermined relationship to the cam member **284**. The indicator **426** is located outside of the housing **420**. As the cam member **284** rotates, the indicator **426** also rotates; the position of the indicator **426** can thus be compared with the indicia on the housing face **422** to determine the location of the cam member **284**. The operator can thus determine the location of the cam member **284**, and thus the amount of fuel to be injected by the fuel pump system **220**, by comparing the location of the indicator **426** with the indicia **424**.

Referring now to FIG. **11**, depicted therein is a schematic view of a housing **200** of the conventional variable fuel pump system **120** described above. The housing **200** has a face **202** on which are formed indicia **204** corresponding to angular positions of the cam member **184**. An indicator **206** is rigidly fixed in a predetermined relationship to the cam member **184**. The indicator **206** is located outside of the housing **200**. As the cam member **184** rotates, the indicator **206** also rotates; the position of the indicator **206** can thus be compared with the indicia on the housing face **202** to determine the location of the cam member **184**. The operator can thus determine the location of the cam member **184**, and thus the amount of fuel to be injected by the fuel pump system **120**, by comparing the location of the indicator **206** with the indicia **204**.

IV. Pre-trigger System

Referring now to FIGS. **13**A–F, these figures illustrate that the diesel hammer system **20** conventionally comprises a line **430** from which is suspended a coupling assembly **432**. The coupling assembly **432** is detachably attached to an upper end of the ram member **30**. Accordingly, lifting the line **430** lifts the ram member **30**. In addition, the coupling assembly **434** conventionally comprises a trigger member **434** that, when properly displaced, detaches the coupling assembly **432** from the ram member **30**. The coupling assembly **432** comprises a trigger projection **436** that extends from the housing member **34** to engage the trigger member **434** and release the ram member **30** from the coupling assembly **434**. The coupling assembly **432** is conventional and will not be described herein in detail.

Conventionally, the trigger projection **436** is located to engage the trigger member **434** and cause the coupling assembly **434** to release the ram member **30** after the ram member **30** has disengaged from the pump lever **70** and allowed the pump lever **70** to return to its ready position. In this case, the location of the trigger projection **436** ensures that fuel is injected into the fuel chamber **40** each time the line **430** is raised and the ram member **30** dropped.

In some situations, however, it is desirable to use the diesel hammer system **20** in a mode in which energy is applied to the pile **22** solely from the weight of the ram member **30** and not from the ignition of the fuel in the combustion chamber **40**.

As shown in FIGS. **13**A–F, the diesel hammer system **20** depicted therein comprises a pre-trigger system **450** that allows the diesel hammer system **20** to operate in a conventional ignition mode and in a ram mode. The pre-trigger system **450** comprises a pre-trigger member **452** mounted on the housing member **34**. The pre-trigger member **452** is movable relative to the housing member **34** between a retracted position (FIGS. **13**D–F) and an extended position (FIGS. **13**A–C).

When the pre-trigger member **452** is in the retracted position, the diesel hammer system **20** incorporating the pre-trigger system **450** operates in a conventional ignition mode. As shown in FIG. **13**D, the ram member **30** starts in the impact state; the ram member **30** is subsequently raised to an upper position as shown in FIG. **13**E in which the pump lever **70** is in the ready position. Then, as shown in FIG. **13**F, the trigger projection **436** engages the trigger member **434** to cause the coupling assembly **434** to release the ram member **30**, thereby allowing the ram member **30** to drop back into the impact position. Fuel is injected into the fuel chamber **40** when the ram member **30** engages the pump lever **70** as the ram member **30** moves towards into the impact position. In the ignition mode, both the impact of the ram member **30** and the ignition of the fuel drive the anvil member **32**.

When the pre-trigger member **452** is in the extended position as shown in FIGS. **13**A–C, the pre-trigger member **452** engages the trigger member **434** before the trigger member **434** reaches the trigger projection **436**. More specifically, the pre-trigger member **452** is arranged such that, as shown in FIG. **13**B, the pre-trigger member **452** engages the trigger member **434** to release ram member **30** before the pump lever **70** has a chance to move into the ready position. Because the pump lever **70** never reaches the ready position, no fuel is injected into the combustion chamber before the ram member **30** strikes the anvil member **32** as shown at FIG. **13**C. Accordingly, when the pre-trigger member **452** is in the extended position, the forces applied to the anvil member **32** are primarily due to the weight of the ram member **30** and not to the combustion of fuel within the combustion chamber **40**.

The pre-trigger member **452** may be hand operated or, more conveniently, may be remotely operated by a hydraulic, pneumatic, or electrical actuator.

A diesel hammer system incorporating the pre-trigger system **450** may thus operate as a diesel hammer and as a conventional drop hammer. The user of such a diesel hammer system thus has more options when driving the piles **22** than with either a conventional diesel hammer system or a conventional drop hammer system.

Referring now to FIG. **14**, depicted at **460** therein is a housing extension member that may be used in connection with the diesel hammer system **20** described above. The housing extension member **460** extends from the housing member **34** of the system **20**. The ram member **30** extends at least partly into the extension member **460** when the ram member **30** is in its upper position. The extension member **460** inhibits entry of dirt and other debris into the housing **34**. Preferably, one or more slots such as slots **464** and **466** are formed in the extension member **460** to allow the user on the ground to see the travel of the ram member **34** as it is raised and lowered.

From the foregoing, it should be clear that the present invention may be embodied in forms other than those described above. The above-described systems are therefore to be considered in all respects illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than the foregoing description. All changes that come within the meaning and scope of the claims are intended to be embraced therein.

I claim:

1. A diesel hammer system for driving a pile, comprising:

a housing;

an anvil member supported by the housing;

a clamp assembly adapted to connect the anvil member to the pile;

a ram member disposed within the housing;

a fuel pump system for injecting fuel into a combustion chamber defined by the housing, anvil member, and the ram member, the fuel pump system comprising

a pump housing defining a fuel chamber,

a pump piston disposed partly within the fuel chamber,

a pump lever that engages the pump piston,

a cam member, where an angular position of the cam member acts on the pump lever to determine a position of the pump piston within the fuel chamber and thus determine an effective volume of the fuel chamber; and

an actuator assembly arranged to change the angular position of the cam member, where the actuator assembly comprises

a control pinion operatively connected to the cam member such that rotation of the control pinion causes angular movement of the cam member,

a control rack operatively engaged with the control pinion such that axial displacement of the control rack causes rotation of the control pinion, and

a control assembly for causing axial displacement of the control rack; whereby

movement of the ram member from an upper position into an impact position causes the ram member to act on the pump piston through the pump lever to force fuel out of the fuel chamber and into the combustion chamber;

operation of the actuator assembly determines the volume of fuel forced out of the fuel chamber and into the combustion chamber based on an angular position of the cam member; and

operation of the control assembly determines the angular position of the cam member and thus the volume of fuel forced into the combustion chamber.

2. A diesel hammer system as recited in claim **1**, in which the fuel pump system further comprises:

a fuel pump housing on which indicia are formed; and

an indicator fixed relative to the cam member; wherein

the indicator extends out of the fuel pump housing adjacent to the indicia to indicate the effective volume of the fuel chamber.

3. A diesel hammer system as recited in claim **1**, in which the control assembly comprises a control cylinder assembly having first and second ports, where introduction of hydraulic fluid into the first port causes displacement of the control rack in a first direction and introduction of hydraulic fluid into the second port causes displacement of the control rack in a second direction.

4. A diesel hammer system as recited in claim **1**, in which the control assembly comprises a control cylinder assembly comprising:

a fluid port; and

a return spring; whereby

the return spring biases the control rack in a first direction; and

introduction of hydraulic fluid into the fluid port causes displacement of the control rack in a second direction.

5. A diesel hammer as recited in claim **4**, in which the control assembly comprises a control cylinder assembly comprising:

a control cylinder housing; and

a control piston head arranged within the control cylinder housing and operatively connected to the control rack; wherein

the return spring is located within the control cylinder housing and engages the control piston head.

6. A diesel hammer as recited in claim **4**, in which the control assembly comprises a control cylinder assembly comprising:

a control cylinder housing; and

a control piston head arranged within the control cylinder housing and operatively connected to the control rack; wherein

the return spring is located outside of the control cylinder housing and engages the control rack.

* * * * *