

PATENT SPECIFICATION

(11) 1260 630

DRAWINGS ATTACHED

- (21) Application No. 50440/70 (22) Filed 23 Oct. 1970
 (31) Convention Application No. 85078 (32) Filed 24 Oct. 1969
 (31) Convention Application No. 85079 (32) Filed 24 Oct. 1969
 (31) Convention Application No. 85080 (32) Filed 24 Oct. 1969 in
 (33) Japan (JA)
 (45) Complete Specification published 19 Jan. 1972
 (51) International Classification B 21 j 7/26 7/06//F 16 k 31/46
 F 02 m 59/10



- (52) Index at acceptance

B3H 21
 F1A 1A5 1C6B 2B 3F1B1 4S4
 F1B 1D8 2J11B 2J15A2 2J15B2 2J2
 F2V D9B1 M1C3

(54) DIESEL HAMMER

(71) We, ISHIKAWAJIMA - HARIMA JUKOGYO KABUSHIKI KAISHA, a Company organised and existing under the laws of Japan, residing at No. 2-1, 2-chome, Otemachi Chiyoda-ku, Tokyo-to, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a diesel hammer.

Conventional diesel hammers are known of the type in which the fuel is atomized by the impact of a ram on an anvil and also of the type in which the fuel is injected into the combustion chamber under high pressure, thereby atomizing the fuel.

Diesel hammers of these two types will be further illustrated with reference to Figures 1-3 of the accompanying drawings, in which:—

Figure 1 is a sectional view of a diesel hammer of the first type referred to,

Figure 2 is a sectional view of a diesel hammer of the second type referred to, and

Figure 3 is a detailed view, in section, of the invention apparatus of the second type.

Referring to Figure 1, an anvil 103 forms a part of the lower end of a cylinder 101 and a ram 102 is slidably arranged in the upper portion of the cylinder 101. A fuel tank 104 is fitted around the cylinder 101 and a lever 105 is disposed outwardly of the cylinder 101. A fuel pump 106 is attached to outer wall of the cylinder 101 and includes an oil chamber 107, a fuel port 108, a valve 109, and a connecting rod 110.

When the ram 102 drops, the lever 105 is pushed outwards thus forcing the connecting rod 110 downwards and actuating a plunger, so that the port 108 is closed and

the valve, 109 is opened whereby the fuel in the oil chamber 107 is ejected through a fuel injection port 111 formed through the wall of the cylinder 101 into a concave recess 115 in the anvil 103. The fuel pump 106 communicates with the fuel tank 104 through a fuel pipe 112. An opening 113 through which the lever 105 extends inwardly of the cylinder 101 and a suction-exhaust port 114 and also formed through the cylinder 101. The suction-exhaust port 114 is then closed by the ram 102 after the fuel has been dropped into the recess 115. As the ram 102 drops, the air in the cylinder 101 is compressed and when the ram 102 strikes the anvil 103, the mixture is compressed and ignited in a space defined by the concave surface 115 of the anvil 103 and the convex surface 116 of the ram 102. In consequence, the ram 102 is lifted to a predetermined height, thereby completing one cycle of pile driving. This cycle may be repeated automatically.

In this type of the diesel hammer, when the ram 102 strikes the anvil 103 combustion of the mixture takes place as soon as the diesel hammer starts to operate so that the temperature of the structural parts is low. But when the temperature of the structural parts, and especially that of the concave surface 115, is raised, part of the fuel may be vaporized so that combustion starts before the ram 102 strikes the anvil 103. The air pressure in the cylinder 101 thus becomes greater than that attained by adiabatic compression of the air, so that the downward movement of the ram 102 is considerably retarded or braked. Therefore, the striking velocity of the ram 102 on the anvil 103, and hence the pile driving efficiency of the diesel hammer is considerably reduced. When a diesel hammer of this type is used continuously, the

pile driving efficiency is reduced more and more, and this reduction in efficiency cannot be prevented. Furthermore, a suitable clearance must be provided between the inner wall of the cylinder 101 and the ram 102 so that the latter may slide in the former. In consequence, the convex surface 116 at the lower end of the ram 102 does not completely mate with the concave surface 115 of the anvil 103 when the ram 102 strikes the anvil 103. Therefore, the injected fuel concentrates in some portions of the combustion chamber, and the desired atomization of the fuel cannot be attained, thus reducing the efficiency even further.

In the diesel hammer of the type illustrated in Figures 2 and 3 an anvil 103 forms a part of the lower end of a cylinder 101 and a ram 102 having piston rings 118 and 118' around its circumference is fitted into the upper portion of the cylinder 101. The upper end of the cylinder 101 is closed by a cover 119 so that an air chamber 120 is defined between the ram 102 and the cover 119. A fuel pump 106 is attached to the outer wall of the cylinder 101 and comprises a spring 121; a member 122 for supporting and guiding the spring 121; a plunger 123; a cylinder 124; a discharge valve 125; a discharge valve spring 126; a fuel port 127 and a connecting or actuating rod 128 extending below the upper end of the fuel pump 106. When the rod 128 is forced downwards by a lever 105 the plunger 123 moves downwardly against the spring 121, thereby discharging the fuel contained in the chamber 107. A nozzle 129 includes a fuel injection orifice 130 formed through the leading end of the main body of the nozzle, a nozzle tip 132 having a fuel oil chamber 131; a valve 133; a spring 134 for supporting the valve 133; and fuel ports 135 and 135'. The fuel is therefore injected into the cylinder 101 through the port 130 when the valve 133 is opened. Thus, the fuel in the fuel pump 106 may be injected through a fuel passage 136 and nozzle 129 into the combustion chamber 117.

The lever 105 for actuating the fuel pump 106 mechanically is rotatably fixed to the cylinder 101 above the fuel pump 106. The lever 105 is actuated by the downward movement of the ram 102 so that the rod 128, the plunger 123, and the member 122 move downwardly. The fuel below the plunger 123 is forced downwardly while the plunger 123 closes the port 127 and the fuel is forced into the passage 136 and then into the oil chamber 131 via the ports 135 and 135'. The valve 133 is opened against the spring 134 and the fuel is injected and atomized through the orifice 130 into the combustion chamber 117 above the anvil 103.

In a diesel hammer of the second type, the fuel injection pressure is produced when the

ram 102 engages with the lever 105 so that all the fuel is injected into the combustion chamber 117 during the downward stroke of the ram 102, so that combustion tends to start before the ram 102 strikes the anvil 103. Therefore, the downward momentum of the ram 102 is braked or retarded as in the case of the diesel hammer described with reference to Figure 1 and the efficiency is consequently decreased.

The present invention consists in a diesel hammer comprising a housing within which a ram is arranged to fall upon an anvil a combustion chamber being defined by the ram, the anvil, and the wall of the housing, and means for delivering fuel to the combustion chamber, said means being arranged to be actuated by the pressure of the air compressed within the combustion chamber when the ram falls towards the anvil.

The invention will be further described, by way of example only, with reference to Figures 4-15 of the accompanying drawings in which:—

Figure 4 is a side view partly in section of a diesel hammer in accordance with the present invention;

Figure 5 is a fragmentary sectional view thereof illustrating the ram striking the anvil;

Figure 6 is a horizontal sectional view illustrating the direction of the fuel spray from the nozzle;

Figure 7 is a further horizontal sectional view illustrating the direction of the fuel spray from the nozzles;

Figure 8 is a fragmentary sectional view illustrating the direction of the air flows;

Figure 9 is a horizontal view illustrating the direction of the air flows;

Figure 10 and 11 are horizontal sectional views illustrating the flow of the sprayed fuel;

Figure 12 is a detailed view of a fuel pump and a nozzle;

Figure 13 is a vertical sectional view of a diesel hammer provided with a device for stopping the operation thereof;

Figure 14 is a detailed view of one embodiment of a device for stopping the operation of the diesel hammer; and

Figure 15 is a view illustrating another embodiment of the device for stopping the operation.

Referring to Figure 4, an anvil 3 forms a part of the lower end of a cylinder 1, and a ram 2 having piston rings 4 fitted around its circumference and a portion reduced in diameter at its lower end (to be referred to hereinafter as "the reduced portion") is slidably fitted into the upper portion of the cylinder 1. When the ram is in contact with the anvil a combustion chamber 5 is defined by the cylinder 1, the anvil 3, and the ram 2, as shown in Figure 5. A fuel tank 6 is fitted around the outer periphery of the

3
cylinder 1, and a fuel pump 7 actuable under
the pressure of the air inside the cylinder 1
is disposed below the fuel tank 6. A joint
9 for branching the fuel lines is disposed at a
suitable position below the fuel tank 6 a pair
of injection of fuel injection nozzles 8 and 8'
are disposed in diametrically opposed rela-
tionship so as to inject the fuel into the
combustion chamber 5. A suction-exhaust
port 15 is formed through the cylinder wall
and an air port 14 is also formed through
the cylinder wall substantially at the center
of the combustion chamber 5 so as to de-
liver the air pressure inside the cylinder 1 to
the fuel pump 7. A fuel line 10 intercom-
municates between the fuel tank 6 and the
fuel pump 7, which in turn communicates
with the joint 9 through a fuel line 11. The
joint 9 communicates with the nozzles 8 and
8' through fuel lines 12 and 13 respectively.
The air in the cylinder 1 is compressed when
the ram 2 closes the suction-exhaust port 15
and drops down towards the anvil 3 and is de-
livered to the fuel pump 7 so as to actuate
it in a manner which will be described in
detail below thereby delivering the fuel re-
ceived from the fuel tank 6 to the nozzles
8 and 8' through the joint 9.

As described hereinabove, the nozzles 8
and 8' are diametrically opposed in the com-
bustion chamber 5 and their orifices are
directed towards the center of the chamber
5. The injection orifice of each of the nozzles
8 and 8' may be so designed that the fuel is
injected into the combustion chamber over an
angle α that is, the fuel may be sprayed on
both sides on imaginary line α connecting the
orifices of the nozzles 8 and 8' as shown in
Figure 6. Alternatively, the fuel may be
sprayed at an angle α in one direction only
relative to the line α as shown in Figure 7.
The fuel pump 7 is fixed to the cylinder 1 by
bolts 16. Figure 12 is a detailed view of the
fuel pump 7. The pump 7 includes a cylinder
23 actuatable by the air (to be referred to
hereinafter as "the pneumatic cylinder") and
fixed to the cylinder 1 by bolts (not shown),
a piston 26 movable vertically within the
cylinder 23, a stop 22 fitted into the top
of the pneumatic cylinder 23 for limiting the
upper end of the stroke or movement of the
piston 26, and a push rod 27 arranged to
pass through the stop 22. The pump 7
further includes a fuel pump body 21
arranged above the stop 22, an air passage 24
formed in the lower portion of the pneumatic
cylinder 23 and communicating with the air
port 14. The pneumatic piston 26 is U-
shaped in cross-section and is provided with
piston rings 25.

When the piston 26 is forced upwards by
the air under pressure delivered from the
combustion chamber 5 through the port 14
and the passage 24, the push rod 27 is also
moved upwards through the stop 22 which

serves as a guide. An oil chamber 28 is
formed in the pump body 21 into which is
fitted a pump cylinder 30 having a lateral
fuel passage 29. A pump plunger 31 is
vertically slidable within the pump cylinder
30 and further oil chamber 32 is formed
above the pump plunger 31. A pump spring
guide 33 is vertically slidable within the
pump body 21 in such a manner that the
pump body 21 may support the lower end of the
plunger 31 and may be caused to move
vertically by the upper end of the push rod
27. A pump spring 34 is arranged within the
guide 33 and within the inner wall of the
pump body 21. The fuel in the fuel tank is
delivered into the oil chamber 32 through the
fuel line 10, the oil chamber 28 and the
fuel passage 29. A plug screwed into the
upper end of the pump body 21 has a fuel
passage 37 and a valve 35 which is closed
by a valve spring 36.

When the plunger 31 is raised by the push
rod 27 to close the fuel passage 29 and rise
further, the fuel in the oil chamber 32 is
compressed so that the valve 35 is opened,
thereby forcing the fuel into the fuel lines
11, 12 and 13.

Figure 12 also shows in detail the fuel
injection nozzles 8 and 8'. A nozzle tip 42
having an injection orifice 39 and oil cham-
bers 40 and 41 is fixed to the leading end of
a nozzle holder 38. A needle 43 is slidably
fitted into the nozzle tip 42 and is normally
pressed against a valve seat 45 by a valve
spring 44 so as to isolate the oil chambers
40 and 41 from each other. The spring 44
may have a constant force or its force may
be adjustable by a screw or the like. The
spring 44 is disposed within the nozzle holder
38 as shown in Figure 12. The fuel pass-
ages 46, 47 and 48 deliver the fuel from
the fuel lines 11, 12 and 13 to the oil cham-
ber 40. When the fuel is delivered into the
oil chamber 40, the needle valve 43 is
opened by the fuel pressure against the spring
44 so that the fuel may be ejected through
the orifice 39 from the oil chamber 41.

In operation the air compressed in the
cylinder 1 acts upon the piston 26 through
the port 14 and the passage 24, thereby
raising the piston 26, the push rod 27, the
guide 33 and the plunger 31. The valve 35
is opened so that the fuel is forced into
the fuel lines 11, 12 and 13, and is de-
livered through the passages 46, 47 and 48
into the oil chamber 40 so that the needle
valve 43 is opened against the spring 44.
Thus, the fuel is delivered into the oil cham-
ber 41 from which it is injected through the
orifice 39 into the combustion chamber 5.

Since the temperature of the air in the
combustion chamber 5 is elevated because of
the compression, the fuel is immediately
ignited.

The combustion product gas pressure then

acts upon the piston 26 so that the plunger 31 is raised. Therefore more fuel is caused to be injected into the combustion chamber 5 through the nozzle 8 and 8' so that the combustion may be continued. The pressure of the expanding gases acts upon the lower end of the ram 2, thereby lifting it to its initial position. When the ram 2 moves upwardly, it opens the suction-exhaust port 15, thereby exhausting the gases into the surrounding atmosphere, whereupon the piston 26, the push rod 27, the guide 33 and the plunger 31 are all returned to their respective initial positions by the spring 34. Fresh air is introduced into the cylinder 1 through the suction-exhaust port 15 when the ram 2 is raised to a predetermined height. The above-described operation may be cycled.

In the diesel hammer having the construction described hereinabove, where the ram 2 drops, it closes the suction-exhaust port 15 of the cylinder 1 and then compresses the air in the cylinder adiabatically. Finally, the ram 2 strikes the anvil 3 so that a pile (not shown) is driven into the soil. The compressed air in the cylinder 1 is delivered to the fuel pump 7 through the air port 14, thereby actuating the pump 7 as described hereinbefore. The fuel supplied from the fuel tank 6 is therefore forced into the fuel line 11 by the fuel pump 7 and is branched at the joint 9 so as to be delivered to the nozzle 8 through the fuel line 12 and to the nozzle 8' through the fuel line 13. The fuel delivered to the nozzles 8 and 8' is sprayed at an angle α relative to the line α and mixed with the air in the combustion chamber 5. Since the temperature of the air in the combustion chamber is raised due to being compressed, the sprayed fuel is burnt the combustion gas pressure forces the ram 2 up to its initial position. Thus, one cycle of operation is accomplished. This operation may be continued as often as described until the pile is driven into a desired setting depth.

From the foregoing, it will be readily seen that fuel pump 7 is actuated by the air compressed when the ram 2 drops in the cylinder 1 and then the fuel is injected into the combustion chamber 5 through the nozzles 8 and 8'. This means that the injection period may be arranged to coincide with the moment the ram 2 strikes the anvil 3. That is, only a small portion of the fuel is injected immediately prior to the ram 2 striking the anvil 3, while the substantial portion of the fuel is injected immediately after the ram 2 strikes the anvil 3. In other words, no combustion occurs as the ram 2 drops in the cylinder 1, so that the pressure in the cylinder 1 is low whereby the downward movement of the ram 2 will not be retarded at all.

As described hereinabove, only a small portion of the fuel is injected immediately prior

to the ram 2 striking the anvil 3 while the substantial portion is injected immediately after the ram 2 strikes the anvil 3, so that the ram 2 is raised from the position indicated by the chain lines in Figure 8 to the position indicated by the solid lines during the fuel injection. In consequence the volume of the combustion chamber 5 may be varied during the fuel injection but since the combustion chamber 5 is circular in cross section then the air in the cylinder 1 flows from the peripheral portion of the chamber 5 into the center thereof at a very high velocity when the ram 2 is raised during the fuel injection, as shown in Figures 8 and 9. Thus the fuel sprayed by the nozzle 8 and 8' is redirected toward the center of the combustion chamber 5. When the fuel is sprayed as shown in Figure 6, it is redirected as shown in Figure 10 and when the fuel is sprayed as shown in Figure 7 it is redirected toward the center as shown in Figure 11.

Even when the volume of the combustion chamber 5 varies because of the upward movement of the ram 2, the fuel is mixed with the air in an efficient manner, whereby the best combustion may be accomplished.

The fuel injection timing may be determined by the diameter (D_1 cm) of the piston 26, the Diameter (D_2 cm) of the plunger 31, the force constant (F_1 kg) of the spring 34, the diameter (D_3 cm) of the needle valve 43, the diameter (D_4 cm) of the valve seat 45, the force constant (F_2 kg) of the spring 44 and the pressure of the air inside the cylinder 1, in accordance with the formula:—

$$P = \left(\frac{D_2^2 \times F_2 + F_1}{D_3^2 - D_4^2} \right) \frac{1}{4} \pi D_1^2 \quad (1)$$

wherein P kg/cm² is the static pressure of the air inside the cylinder 1 when the fuel is injected through the nozzles 8 and 8'. The force of the spring 34 is not taken into consideration.

The fuel injection period is determined by the above described factors and the diameter (D_5 cm) of the orifice of the nozzle 39. The total mass of the movable parts such as the piston 26, the plunger 31, the push rod 27, the guide 33, the valve 35 the nozzle-needle valve 43, etc., the compression pressure and the pressure of the gases resulting from the combustion. However it has been empirically proved that when the mass of the movable parts is reduced to a minimum and the above defined factors are so selected as to satisfy the relation (2) below a required quantity of

fuel may be injected into the cylinder 1 during a required fuel injection period.

$$\left. \begin{aligned} (D_1/D_2)^2 &= 8 \text{ to } 16 \\ (D_2/D_5)^2 &= 300 \text{ to } 500 \end{aligned} \right\} (2)$$

The moment at which fuel injection begins may be arranged to coincide almost exactly with the moment at which the ram 2 strikes the anvil 3, so that only a small portion of the quantum of fuel is injected immediately prior to the ram 2 striking the anvil 3 while a substantial portion is injected immediately after the ram 2 strikes the anvil 3. Therefore we overcome one of the main disadvantages of the prior art i.e. that combustion occurs before the ram strikes the anvil, whereby the downward movement of the ram is retarded and its impact upon anvil is reduced.

For this purpose, the pressure P (kg/cm²) (at which the fuel injection into the cylinder 1 is started and which is obtained from Equation (1)) is selected so as to be of the order of $1/3$ to $1/2$ of the maximum air compression pressure, the diameters are selected so as to satisfy the relations (2). The fuel injection method according to the invention is not affected by the temperature of the diesel hammer, etc.

The fuel is sprayed continuously, not instantaneously, so that the combustion may continue gradually so that the initial pressure of the expanding gases resulting from the combustion is low and the stresses due to this initial pressure of the cylinder 1, etc., may be reduced.

In the embodiment described, the fuel injection system has been described and shown as comprising one fuel pump 7 and two nozzles 8 and 8'. However, it will be understood that the present invention embraces a fuel injection system comprising one fuel pump and one nozzle, or plurality of fuel pumps and a plurality of nozzles.

There are various methods for interrupting the delivery of the fuel from the fuel pump to the injection nozzle, thereby interrupting the operation of the diesel hammer. For example, the following methods may be used:

(a) interrupting the delivery of the fuel between the fuel pump and the fuel tank;

(b) providing a bypass valve at the outlet of the fuel pump so as to bypass the fuel to the inlet of the fuel pump;

(c) mechanically stopping the fuel pump; and

(d) interrupting the air passage between the cylinder and the fuel pump, thereby deactivating the fuel pump.

In methods (a) and (b), the resistance on

the discharge side of the fuel pump is made almost zero so that the movable parts such as plunger, etc. are excessively accelerated, thus resulting in damage to the apparatus. In methods (c) and (d), the design machining assembly etc. are very difficult.

These problems may be overcome by the interrupting device shown in Figures 13—15 which comprises a stop valve 51 having a port 55 in communication with the fuel pump 7 and a port 56 in communication with the nozzle 8, an L-shaped lever 52 for closing the passage between the ports 55 and 56 and an arm 53 adapted to lock the lever 52 during operation as shown in Figure 13. The fuel pump 7 communicates with the port 55 of the stop valve 51 through the fuel line 11. The nozzle 8 communicates with the port 56 of the stop valve 51 through the fuel line 54.

The interruption device will be described in more detail with reference to Figure 14. The stop valve 51 has a passage 57 arranged coaxially with the valve body 59. The ports 55 and 56 communicate with each other through an oil chamber 58. The valve body 59 is arranged within a valve housing 60, there being no gap therebetween. A spool 61 for interrupting the communication between the ports 55 and 56 is slidably arranged within the passage 57. A rod 62 having its lower end fixed to the upper end of the spool 61 extends upwardly of the valve housing 60. A nut 63 fits around the rod 62 and is screwed into the upper end of the valve housing 60. A spring 64 is arranged above the upper face of the nut 63 and around the head of the rod 62. The shorter arm of the L-shaped lever 52 is pivotally fixed to the cylinder 1 about a pivot 67 above the stop valve 51. A rope 68 is securely fixed to the free end of the longer arm 66 of the lever 52 and can be pulled down so that the lever 52 rotates about the pivot 67 towards the piston shown in broken lines. A projection 69 projects out of the paper (as shown in Figure 14) from the side wall of the lever 52. The arm 53, having a rope 68' affixed to the free end thereof, is pivotally fixed to the cylinder 1 above the lever 52 in such a manner that the arm 53 is normally arranged by a spring 70 to be positioned horizontally. When the rope 68 is pulled so that the lever 52 is inclined, a projection 71 formed at the bend of the lever 52 pushes the rod 62 and the spool 61 downwardly so that the passage between the ports 55 and 56 is interrupted by the spool. In consequence, the fuel delivery is stopped. When the lever 52 is thus rotated spring 70 makes arm 53 become horizontal, and the leading end of the arm 53 engages the projection 69, thereby preventing the return of the lever 52. In consequence, the diesel hammer remains deactivated. The spring 64 has a force stronger than that of the spring 70. A stop 72 serves

to determine the rest position of the lever and hence spool 61 during operation of the hammer.

When the lever 52 is in the position indicated by the solid lines, the port 55 communicates with the port 56 so that the diesel hammer operates. Therefore, when the ram 2 drops, the air in the cylinder 1 is compressed and this compressed air operates the fuel pump 7 as previously described. The fuel delivered from the tank 6 is delivered to the nozzle 8 through the ports 55 and 56 by the fuel pump 7 so that the diesel hammer is driven.

To stop the diesel hammer, an operator pulls the rope 68 causing the lever 52 to rotate about the pin 67 to the position indicated by the chain lines so that the projection 71 pushes down on the rod 62 which in turn acts on spool 61. Since the spool 61 fits exactly into the oil chamber 58 so that the gap therebetween is very small, the communication between the ports 55 and 56 is interrupted and the flow of fuel from the pump 7 to the nozzles 8 and 8' is cut off, whereby the operation of the diesel hammer is stopped.

Being released by the rotation of the lever 52, the arm 53 rotates under the force of the spring 70 until the arm 53 engages the projection 69 of the lever 52 and thereby prevents the lever 52 from returning to the operative position indicated by the solid lines under the force of the spring 64. To return the lever 52 from the operative position to the inoperative position, the operator pulls the rope 68' connected to the arm 53, thereby rotating it toward the position indicated by the solid lines, whereupon the lever 52, the rod 62 and the spool 61 return to their original positions under the action of the spring 64 whose force constant is greater than that of the spring 70. Simultaneously, the arm 53 returns to its initial position. The port 55 again communicates with the port 56 so that fuel may be delivered to the nozzles 8 and 8' whereby the diesel hammer is driven.

Figure 15 shows a further operation interruption device. An arm 53' is rotatably fixed to one side of the lever 52 and a spring 70 is so loaded as to rotate clockwise the arm 53' pivotably fixed to one side of the lever 52. A stop 73 is fixed to the cylinder 1 so as to prevent the arm 53' from moving past the horizontal position. When the rope 68 is pulled, the lever 52 is rotated so that the rod 62 is pushed downwardly and the arm 53' is rotated by spring 70 from its rest position (shown in full lines) until it engages stop 73, in which position it is substantially horizontal and its end engages the cylinder 1 so that the return of the lever 52 is prevented. When the rope 68' is pulled, the arm 53' is pivoted anticlockwise and disengaged

from the cylinder 1 so that the lever 52 can be returned to its initial position by spring 64.

If the port 56 communicated with the fuel pump 7, and port 55 with the nozzle 8 the operating pressure of the fuel pump 7 generally greater than that required to open the valve 43 of the nozzle 8, would act on the spool 61 so that the force required to rotate the lever 52 would be increased. Preferably therefore, as described the port 55 communicates with the fuel pump 7 while the port 56 communicates with the nozzle 8.

The position of lever 52 provides a visible indication of whether the hammer is in operative condition or not.

When a returning or resetting mechanism of the arm 53 or 53' is not provided, the fuel pump is always operated. Therefore there is a danger when the ram is dropped for the purposes other than that of starting the diesel hammer. But the present invention provides the mechanism for returning the lever 52 to its operative position so that the operation of the diesel hammer may be well safeguarded and become simple.

Our diesel hammer is not driven through mechanical cam means so that the movements of the movable parts are very smooth and their wear may be prevented. When the fuel is sprayed at an angle relative to the center line connecting the opposing nozzles and the center of the combustion chamber, the fuel injection timing and the injection pressure may be adjusted by suitably adjusting the force of the nozzle valve spring 44.

The combustion after mixing of the fuel and air may be started at the best time which may be empirically determined. This condition will not vary, irrespective of the operation time, the temperature, etc. The air compressed in the combustion chamber may be smoothly delivered to the fuel pump. The air flows toward the center of the combustion chamber after the ram strikes the anvil so that the fuel sprayed at a predetermined angle through the nozzles may be concentrated toward the center, so that the direction of the fuel injection may be optimized irrespective of the variation in volume of the combustion chamber. The fuel will be well mixed with the air at the center of the cylinder so that the best combustion occurs, whereby the efficiency of the diesel hammer and the pile driving force or impact may be much improved.

The pressure of the expanding gases when the combustion is started is low, the stress acting upon the cylinder is therefore reduced.

WHAT WE CLAIM IS:—

1. A diesel hammer comprising a housing within which a ram is arranged to fall upon an anvil, a combustion chamber being defined by the ram, the anvil, and the wall of



to determine the rest position of the lever and hence spool 61 during operation of the hammer.

5 When the lever 52 is in the position indicated by the solid lines, the port 55 communicates with the port 56 so that the diesel hammer operates. Therefore, when the ram 2 drops, the air in the cylinder 1 is compressed and this compressed air operates the fuel pump 7 as previously described. The fuel delivered from the tank 6 is delivered to the nozzle 8 through the ports 55 and 56 by the fuel pump 7 so that the diesel hammer is driven.

15 To stop the diesel hammer, an operator pulls the rope 68 causing the lever 52 to rotate about the pin 67 to the position indicated by the chain lines so that the projection 71 pushes down on the rod 62 which in turn acts on spool 61. Since the spool 61 fits exactly into the oil chamber 58 so that the gap therebetween is very small, the communication between the ports 55 and 56 is interrupted and the flow of fuel from the pump 7 to the nozzles 8 and 8' is cut off, whereby the operation of the diesel hammer is stopped.

30 Being released by the rotation of the lever 52, the arm 53 rotates under the force of the spring 70 until the arm 53 engages the projection 69 of the lever 52 and thereby prevents the lever 52 from returning to the operative position indicated by the solid lines under the force of the spring 64. To return the lever 52 from the operative position to the inoperative position, the operator pulls the rope 68' connected to the arm 53, thereby rotating it toward the position indicated by the solid lines, whereupon the lever 52, the rod 62 and the spool 61 return to their original positions under the action of the spring 64 whose force constant is greater than that of the spring 70. Simultaneously, the arm 53 returns to its initial position. The port 55 again communicates with the port 56 so that fuel may be delivered to the nozzles 8 and 8' whereby the diesel hammer is driven.

50 Figure 15 shows a further operation interruption device. An arm 53' is rotatably fixed to one side of the lever 52 and a spring 70 is so loaded as to rotate clockwise the arm 53' pivotably fixed to one side of the lever 52. A stop 73 is fixed to the cylinder 1 so as to prevent the arm 53' from moving past the horizontal position. When the rope 68 is pulled, the lever 52 is rotated so that the rod 62 is pushed downwardly and the arm 53' is rotated by spring 70 from its rest position (shown in full lines) until it engages stop 73, in which position it is substantially horizontal and its end engages the cylinder 1 so that the return of the lever 52 is prevented. When the rope 68' is pulled, the arm 53' is pivoted anticlockwise and disengaged

from the cylinder 1 so that the lever 52 can be returned to its initial position by spring 64.

If the port 56 communicated with the fuel pump 7, and port 55 with the nozzle 8 the operating pressure of the fuel pump 7 generally greater than that required to open the valve 43 of the nozzle 8, would act on the spool 61 so that the force required to rotate the lever 52 would be increased. Preferably therefore, as described the port 55 communicates with the fuel pump 7 while the port 56 communicates with the nozzle 8.

The position of lever 52 provides a visible indication of whether the hammer is in operative condition or not.

When a returning or resetting mechanism of the arm 53 or 53' is not provided, the fuel pump is always operated. Therefore there is a danger when the ram is dropped for the purposes other than that of starting the diesel hammer. But the present invention provides the mechanism for returning the lever 52 to its operative position so that the operation of the diesel hammer may be well safeguarded and become simple.

Our diesel hammer is not driven through mechanical cam means so that the movements of the movable parts are very smooth and their wear may be prevented. When the fuel is sprayed at an angle relative to the center line connecting the opposing nozzles and the center of the combustion chamber, the fuel injection timing and the injection pressure may be adjusted by suitably adjusting the force of the nozzle valve spring 44.

The combustion after mixing of the fuel and air may be started at the best time which may be empirically determined. This condition will not vary, irrespective of the operation time, the temperature, etc. The air compressed in the combustion chamber may be smoothly delivered to the fuel pump. The air flows toward the center of the combustion chamber after the ram strikes the anvil so that the fuel sprayed at a predetermined angle through the nozzles may be concentrated toward the center, so that the direction of the fuel injection may be optimized irrespective of the variation in volume of the combustion chamber. The fuel will be well mixed with the air at the center of the cylinder so that the best combustion occurs, whereby the efficiency of the diesel hammer and the pile driving force or impact may be much improved.

The pressure of the expanding gases when the combustion is started is low, the stress acting upon the cylinder is therefore reduced.

WHAT WE CLAIM IS:—

1. A diesel hammer comprising a housing within which a ram is arranged to fall upon an anvil, a combustion chamber being defined by the ram, the anvil, and the wall of

the housing, and means for delivering fuel to the combustion chamber, said means being arranged to be actuated by the pressure of the air compressed within the combustion chamber when the ram falls towards the anvil.

2. A diesel hammer as claimed in claim 1, including a fuel tank mounted on the housing.

3. A diesel hammer as claimed in claim 1 or 2, in which said means for delivering the fuel to the combustion chamber comprises at least one fuel pump.

4. A diesel hammer as claimed in claim 3, in which the or each fuel pump includes a piston arranged to be actuated by the pressure of the compressed air, a push rod arranged to be actuated by said piston, a stopper arranged to restrict the movement of said piston, said stopper also serving as a guide for said push rod, and further apparatus arranged to be actuated by the movement of said push rod so as to deliver fuel to the combustion chamber.

5. A diesel hammer as claimed in any of claims 1 to 4, in which the striking face of the ram is partly cut away so that a combustion chamber is defined even when the ram is in striking contact with the anvil.

6. A diesel hammer as claimed in any of claims 1 to 5, in which the fuel is injected into the combustion chamber through at least one nozzle fitted into the wall of the housing.

7. A diesel hammer as claimed in claim 6, in which there are two nozzles arranged diametrically opposite from each other, so that fuel is injected into the combustion chamber from opposite sides.

8. A diesel hammer as claimed in claim 6 or 7, in which the nozzle is or nozzles are so arranged that fuel will be sprayed

from the or each nozzle over a predetermined angle.

9. A diesel hammer as claimed in any of claims 1 to 8, in which the fuel delivery means is arranged to inject fuel into the combustion chamber at the moment at which the ram strikes the anvil.

10. A diesel hammer as claimed in any of claims 1 to 9, in which means are provided by which the flow of fuel to the combustion chamber may be cut off, so as to stop the operation of the diesel hammer.

11. A diesel hammer as claimed in claim 10, in which said means comprises a stop valve arranged to interrupt the flow of fuel along the fuel delivery means, said stop valve being operated by a lever.

12. A diesel hammer as claimed in claim 11, in which means are provided which urge the lever from its operative to its non-operative position.

13. A diesel hammer as claimed in claim 12, in which said means is a compression spring.

14. A diesel hammer as claimed in any of claims 11 to 13, in which there is provided a second lever by means of which the first lever may be locked in its operative position.

15. A diesel hammer substantially as herein described with reference to, and as shown in, Figures 4 to 15 of the accompanying drawings.

MARKS & CLERK,
Chartered Patent Agents,
57 & 58 Lincoln's Inn Fields,
London, WC2A 3LS.
Agents for the Applicant(s).

Printed for Her Majesty's Stationery Office, by the Courier Press, Leamington Spa, 1972.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from
which copies may be obtained.

