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White

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(54) **PRELOADED DROP HAMMER FOR DRIVING PILES**

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This patent is subject to a terminal disclaimer.

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(60) Provisional application No. 60/411,683, filed on Sep. 17, 2002.

(51) **Int. Cl.**
B25D 9/00 (2006.01)

(52) **U.S. Cl.**
USPC **173/1**; 173/89; 173/132; 173/212

(58) **Field of Classification Search**
USPC 173/1, 89, 132, 133, 135–137, 206, 173/208, 209, 212; 405/232
See application file for complete search history.

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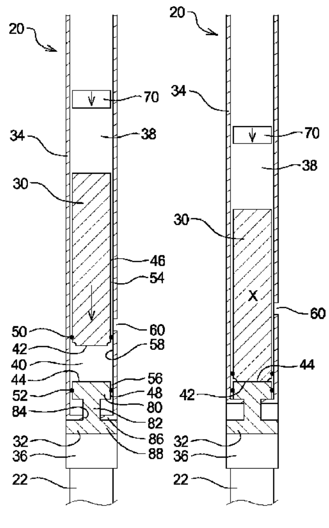
(57) **ABSTRACT**

A drop hammer for driving a pile comprising a ram member supported within a housing chamber for movement relative to the housing member between the lower position and the upper position and a lifting system for moving the ram member from the lower position to the upper position. When the lifting system raises the ram member above a preload position, ambient air substantially freely flows into and out of the housing chamber through a vent port. When the ram member falls below the preload position, fluid is prevented from flowing through the vent port such that ambient air within a preload chamber portion of the housing chamber compresses to create a preload force that is transmitted to the pile. When the ram member moves into the lower position, an impact force generated by the ram member is transmitted to the pile.

13 Claims, 4 Drawing Sheets



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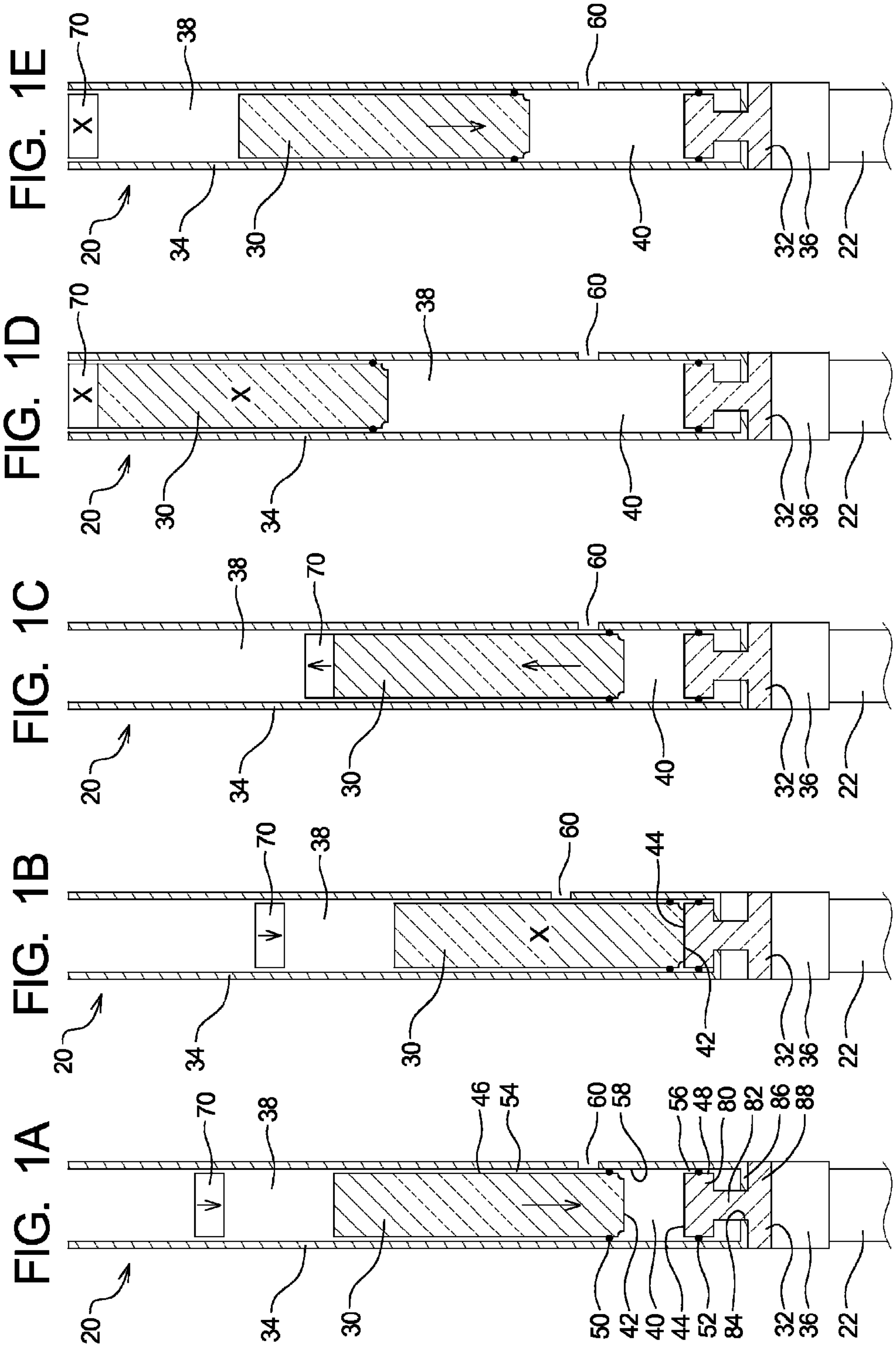


FIG. 1A
FIG. 1B
FIG. 1C
FIG. 1D
FIG. 1E

FIG. 2

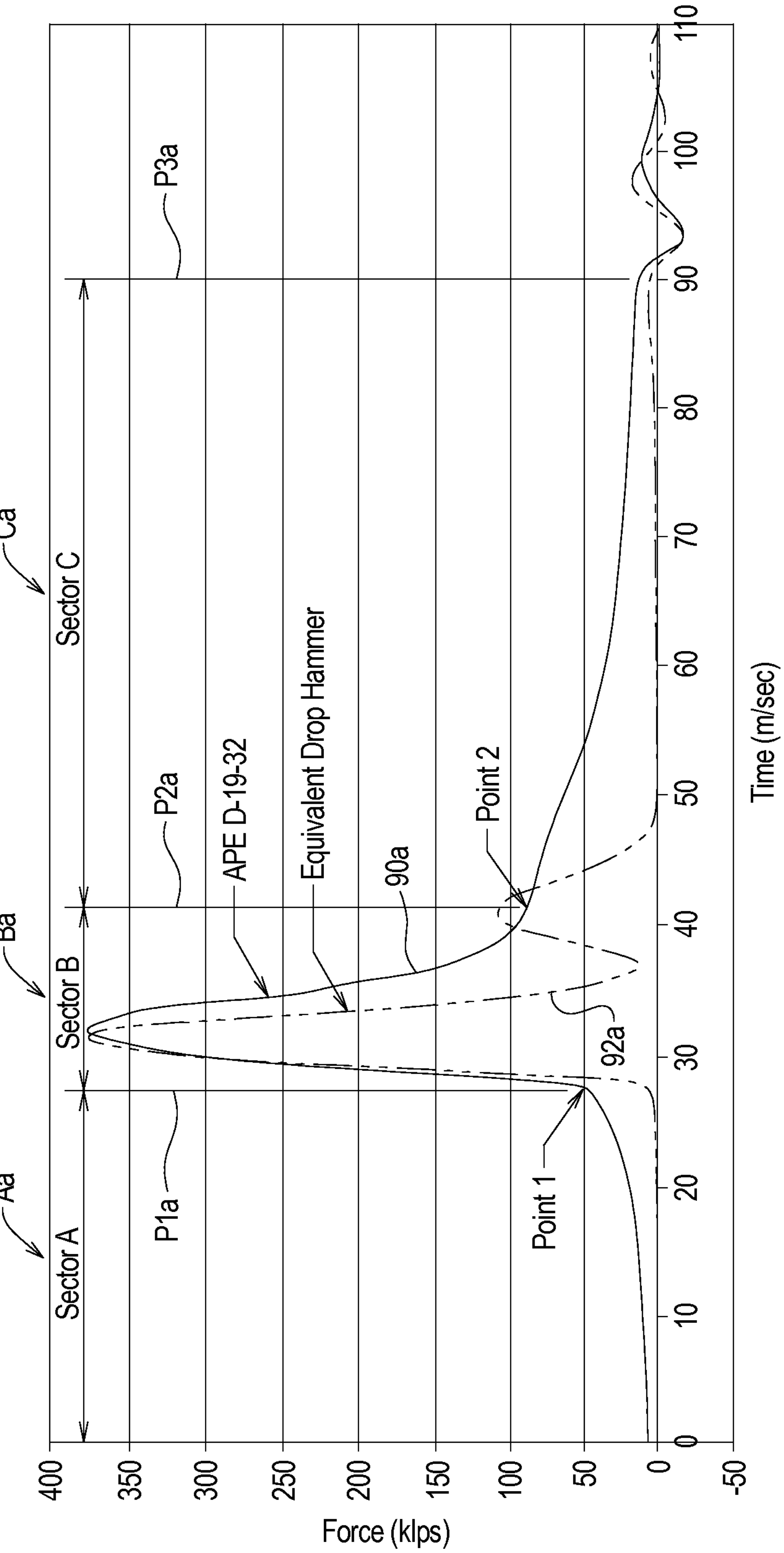

Aa
Ba
Ca
Sector A
Sector B
Sector C
P1a
P2a
P3a
APE D-19-32
Equivalent Drop Hammer
90a
92a
Point 1
Point 2
Force (klps)
Time (m/sec)
400
350
300
250
200
150
100
50
0
-50
0
10
20
30
40
50
60
70
80
90
100
110

FIG. 3

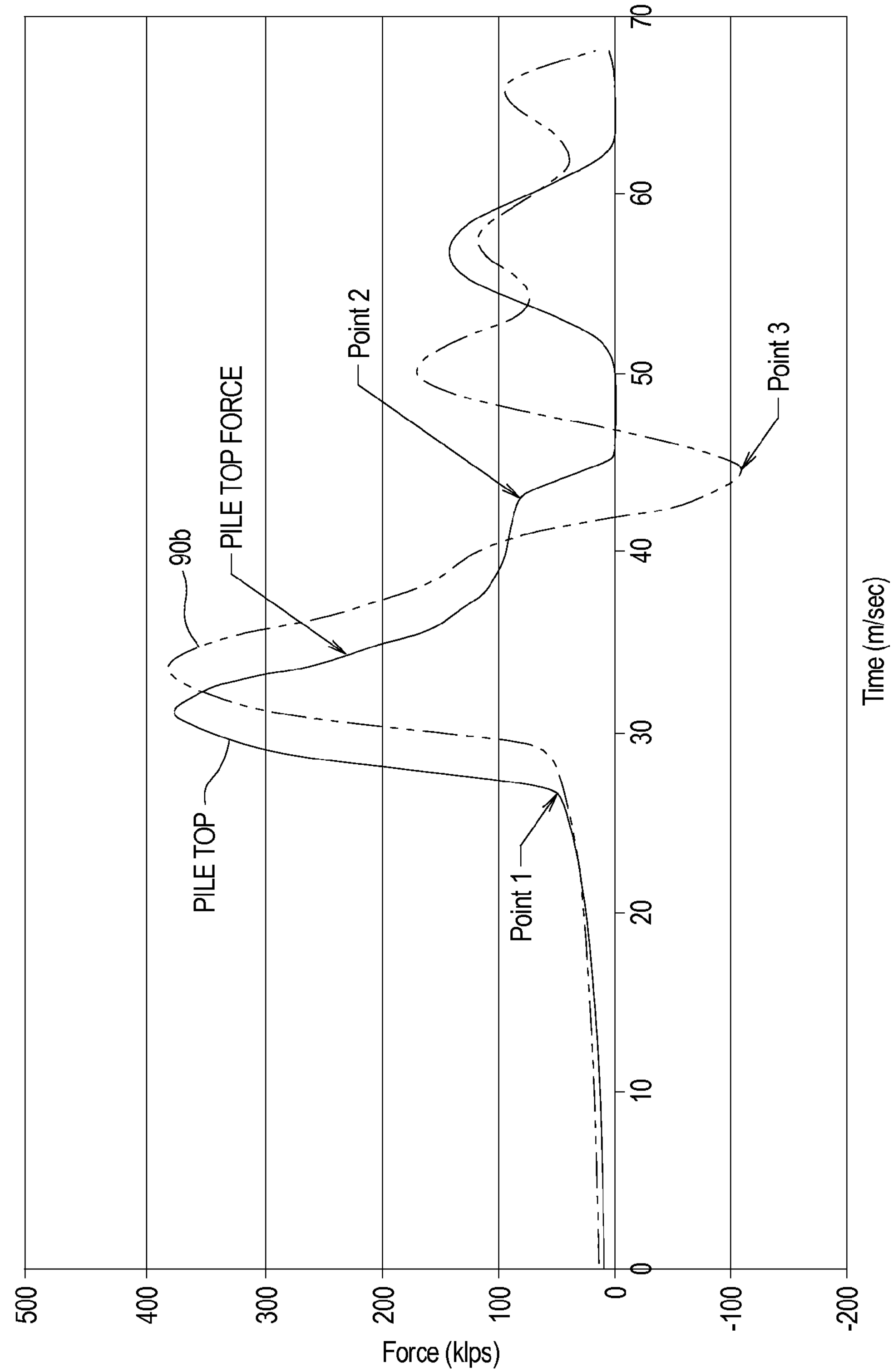
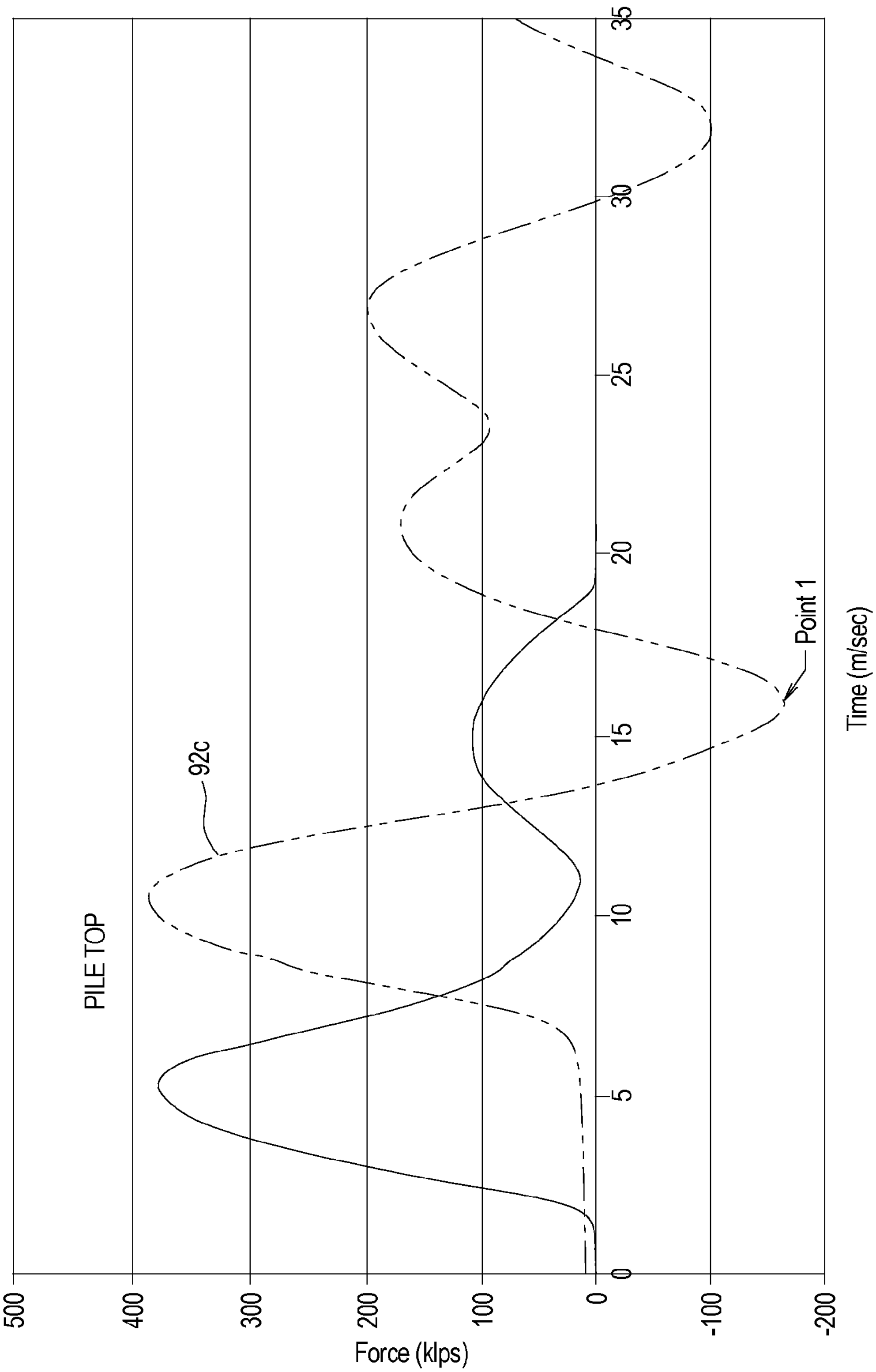

Force (klps)
500
400
300
200
100
0
-100
-200
Time (m/sec)
0
10
20
30
40
50
60
70
PILE TOP
90b
PILE TOP FORCE
Point 1
Point 2
Point 3

FIG. 4


PILE TOP
92c
Point 1
Force (klps)
500
400
300
200
100
0
-100
-200
Time (m/sec)
0
5
10
15
20
25
30
35

PRELOADED DROP HAMMER FOR DRIVING PILES

RELATED APPLICATIONS

This application U.S. application Ser. No. 13/477,925, is a continuation of U.S. application Ser. No. 12/758,723, filed Apr. 12, 2010.

U.S. application Ser. No. 12/758,723 is a continuation of U.S. application Ser. No. 10/667,176, filed Sep. 17, 2003, now U.S. Pat. No. 7,694,747, which issued on Apr. 13, 2010.

U.S. application Ser. No. 10/667,176 claims priority of U.S. Provisional application Ser. No. 60/411,683 filed on Sep. 17, 2002.

The contents of all related applications listed above are incorporated herein by reference.

TECHNICAL FIELD

The present invention relates to methods and apparatus for inserting elongate members into the earth and, more particularly, to drop hammers that create pile driving forces by lifting and dropping a hammer to apply a driving force to the top of a pile.

BACKGROUND

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 a helmet 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 helmet member in opposite directions. The helmet member further drives the pile, while the ram member begins a new combustion cycle. Another such system is a drop hammer that repeatedly lifts and drops a hammer onto an upper end of the pile to drive the pile into the earth.

Diesel hammers seem to exhibit fewer problems with tension cracking in concrete piles than similarly configured external combustion hammers. The Applicants have recognized that the combustion chambers of diesel hammers preload the system before the hammer impact and that this preloading may explain the reduction of tension cracking in concrete piles associated with diesel hammers.

The need thus exists for improved drop hammers that induce stresses in the pile driven that are similar to the stresses induced by diesel hammers.

SUMMARY

The present invention may be embodied as a drop hammer for driving a pile comprising a ram member and a lifting system. The ram member is supported within a housing chamber for movement relative to the housing member between the lower position and the upper position. The lifting system moves the ram member from the lower position to the upper position. When the lifting system raises the ram member above a preload position, ambient air substantially freely flows into and out of the housing chamber through a vent port. When the ram member falls below the preload position, fluid is prevented from flowing through the vent port such that ambient air within a preload chamber portion of the housing chamber compresses to create a preload force that is transmitted to the pile. When the ram member moves into the lower position, an impact force generated by the ram member is transmitted to the pile.

The present invention may also be embodied as a method of driving a pile comprising the following steps. A ram member is supported within a housing chamber for movement between an upper position and a lower position. The ram member is raised into the upper position and then allowed to fall from the upper position to the lower position such that the ram member transmits an impact force to the pile. While the ram member is above a preload position, ambient air is allowed to flow substantially freely into and out of the housing chamber through a vent port. While the ram member is below the preload position, fluid from is substantially prevented from flowing through the vent port such that ambient air within a preload chamber portion is compressed to transmit a preload force to the pile prior to transmission of the impact force to the pile.

The present invention may also be embodied as a drop hammer for driving a pile comprising a ram member, a helmet member, and a lifting system. The ram member is supported within a housing chamber for movement between the upper position and the lower position. The helmet member is supported for movement between a first position and a second position. The lifting system raises the ram member from the lower position to the upper position. As the ram member moves between the upper position and a preload position defined by a vent port, ambient air substantially freely flows into and out of the housing chamber through the vent port. When the ram member falls below the preload position and before the ram member contacts the helmet member, fluid is prevented from flowing through the vent port such that ambient air within a preload chamber portion of the housing chamber below the vent port compresses to transmit a preload force to the pile through the helmet member. When the ram member moves into the lower position, the ram member contacts the helmet member such that an impact is transmitted to the pile through the helmet member.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1**A-**1**E are somewhat schematic sectional views of a drop hammer of the present invention depicting the drive cycle thereof; and

FIGS. **2**-**4** represent computer simulations of force records comparing a conventional drop hammer with a conventional diesel hammer under various conditions.

DETAILED DESCRIPTION

Turning to the drawing, depicted at **20** in FIGS. **1**A-**1**E is a drop hammer system constructed in accordance with, and embodying, the principles of the present invention. The drop hammer system **20** is designed to insert a pile **22** into the ground. The drop 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 drop hammer system **20** comprises a ram member **30**, a helmet member **32**, a housing member **34**, and a clamp assembly **36**. The housing member defines a housing chamber **38**. The ram member **30** is guided by the housing member **34** for movement within the housing chamber **38** between a lower position (FIG. **1**B) and an upper position (FIG. **1**D). The helmet 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 helmet member **32** is rigidly connected to the clamp assembly **36**. The clamp assembly **36** is detachably fixed relative to the pile **22**.

A preload chamber portion **40** is formed within the housing chamber **38** of the housing member **34** between a lower surface **42** of the ram member **30** and an upper surface **44** of the helmet member **32**. The ram member **30** further defines an outer surface **46**, while the helmet member **32** defines an outer surface **48**. First and second seals **50** and **52** are arranged in first and second gaps **54** and **56** between an inner surface **46** of the housing member **34** and the outer surface **46** of the ram member **30** and outer surface **48** of the helmet member **32**, respectively. When the seals **50** and **52** function properly, fluid is substantially prevented from flowing out of the preload chamber portion **40** through the gaps **54** and **56** under certain conditions.

In particular, a vent port **60** is formed in the housing member **34**. The vent port **60** is arranged to allow exhaust gasses to be expelled from the preload chamber portion **40** under certain conditions and to allow air to be drawn into the chamber **40** under other conditions. The vent port **60** thus defines a preload position above which fluid can flow into and out of the preload chamber portion **40** and below which the preload chamber portion **40** is substantially sealed.

FIG. **1** illustrates a latch assembly **70** that moved up and down as will generally be described below. The latch assembly **70** represents an external lifting system that lifts the ram member **30** from the lower position to the upper position. The latch assembly **70** mechanically latches onto the ram member **30** during lifting and releases from the ram member **30** when the ram member reaches its upper position. The latch assembly **70** and external lifting system are well-known in the art and will not be described herein in detail.

The drop hammer system **20** operates in a drive 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 preload state. In the preload state, the ram member **30** has dropped past the vent port **60** such that the first seal **50** prevents fluid from flowing out of the preload chamber portion **40**. The second seal **52** seals the opposite end of the preload chamber portion **40** as generally described above. Accordingly, at this point the preload chamber portion **40** is effectively sealed, and continued dropping of the ram member **30** compresses the fluid within the preload chamber portion **40**. During this preload state, the helmet **32**, the clamp assembly **36**, and the pile **22** are gradually forced together by the compressed fluid in the preload chamber portion **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 helmet member **32**. In the impact state, the ram member **30** drives the helmet 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 helmet member **32** thus drives the pile **22** downward through the clamp assembly **36**. In addition, the housing member **34** will immediately fall onto the helmet member **32**, thereby applying additional driving forces onto the pile member **22**.

After impact, the helmet member **32** is raised to an upper position as shown in FIG. **1**C. As the helmet member **32** moves into the upper position, the lower end of the ram member **30** passes the vent port **60**. As the ram member continues on to its upper position, ambient air is drawn into the preload chamber portion **40** through the vent port **60**, thereby reducing resistance to continued upward movement of the helmet member **32**. As generally described above, the ram member **32** is raised by the latch assembly **70**, which is in turn driven by an external combustion source in a manner similar to that of a conventional drop hammer. In addition or instead, a hydraulic actuator may be used to raise the latch assembly **70** and ram member **32**.

After the ram member **30** reaches the upper position as shown in FIG. **1**D, the latch assembly **70** releases and the ram member **30** is allowed to drop again. The system **20** then enters a free-fall state as shown in FIG. **1**E. In the free-fall state, the preload chamber portion **40** is not sealed, and air is allowed to escape through the vent port **60**, again reducing resistance to downward movement of the ram member **32**. As the ram member **30** continues to drop, the first seal **50** on the ram member **32** again passes the vent port **60**, which seals preload chamber portion **40**. Again, the system **20** enters the preload state as described with reference to FIG. **1**A. At this point, and the drive cycle begins again.

Given the foregoing general discussion of the invention, certain aspects of the exemplary hammer system **20** will now be described in further detail. The helmet member **32** comprises an inner portion **80** that lies within the preload chamber portion **40**, a connecting portion **82** that extends through a helmet opening **84** formed in a bottom wall **86** of the housing member **34**, and an outer portion **88** that is connected to the clamp assembly **36**. The length of the connecting portion **82** (i.e., the distance between the inner portion **80** and outer portion **88**) defines the range of movement of the helmet member **32** between the rest position and the impact position. The second seal **52** is formed on the inner portion **80** of the helmet member **32**.

The theoretical benefits of preloading the system by compressing fluid prior to impact will now be described with reference to FIGS. **2**-**4**. FIGS. **2**, **3**, and **4** plots computer generated models illustrating force versus time for various diesel and drop hammer configurations.

FIG. **2** illustrates the difference between a diesel hammer and a conventional drop hammer. The plot of FIG. **2** assumes the following conditions: 12" square concrete pile 400' in length with a three-inch thick plywood pile cushion; the pile was embedded 20 feet with a total soil resistance of 100 kips. The 400' pile length is not realistic but illustrates wave compression at the upper end of the pile without the effects of reflected waves. Trace **90***a* corresponds to the force record of an American Piledriving Equipment D-19-32 diesel hammer, while trace **92***a* corresponds to a conventional drop hammer of similar geometry and weight under the same conditions.

The trace **90***a* illustrates that the force during the time corresponding to a first time second Aa in FIG. **2** is the pile top force caused by the diesel hammer pre-compression force. In the first time sector Aa, the ram has moved past the exhaust ports and is compressing the air in the combustion chamber and thereby exerting a force on the pile. Impact occurs at first time point P**1***a* at the end of the first time sector Aa. The impact exerts an impact force during a second time sector Ba between the first point P**1***a* and a second time point P**2***a*. This second sector Ba represents the force at the top of the pile from the time of impact to the time of ram separation. During this second time sector Ba, pile penetration is induced by the large force arising from ram impact. Somewhere around the second time point P**2**a, the ram has separated from the impact block. A third time sector Ca begins at the second time point P**2**a; the third time period corresponds to the period from ram separation to the arrival of the reflection of the impact wave back from the toe of the pile. The force during this time comes from the combustion chamber pressure.

The force associated with the conventional drop hammer is shown by the trace **92**a. The trace **92**a illustrates that the stroke is set such that the same peak impact force was obtained. The double humped force record in sector Ba associated with impact is likely due to the dynamic interaction of the ram, pile cushion, and helmet. While a similar effect is associated with trace **90**a in sector Ba, the effects of the dynamic interaction of the ram, pile cushion, and helmet are likely smoothed by the combustion chamber pressure. After the impact as shown at P**1**a, the drop hammer force stays near zero during the third time sector Ca.

The relatively slow decay of the induced force after the impact event associated with the diesel hammer trace **90**a provides a compression force that acts to reduce the magnitude of any reflected tension stresses. The downward traveling compression wave associated with the trace **90**a reduces the reflected tension wave from the pile toe.

FIG. **3** illustrates a more realistic example using a conventional diesel hammer system to drive a pile having a length of **100**; all other conditions are also the same. As shown by trace **90**b, the element with the largest tension stress was located about 30 feet from the top of the pile. The maximum tension force at point **3** in FIG. **3** was 106 kips or 736 psi.

FIG. **4** contains a trace **92**c of a conventional drop hammer. Illustrated at point **1** on the trace **92**c in FIG. **4** is element with the largest tension stress. This element is about 30 feet from the bottom of the pile and represents a maximum tension force of approximately 166 kips or 1,140 psi. The tension force associated with the trace **92**c is thus significantly larger than that represented by the trace **90**b.

Given the foregoing, the Applicants have concluded that the operation of conventional drop hammer systems can be improved by establishing a pre-load state prior to impact that is generally similar to the compression state of a diesel hammer. The Applicants believe that the preload state will stretch out the compression force in the stress wave and thereby substantially reduce the possibility of tension cracking and damage in concrete piles.

What is claimed is:

1. A drop hammer for driving a pile comprising:

a ram member supported within a housing chamber for movement relative to the housing member between the lower position and the upper position;

a lifting system for moving the ram member from the lower position to the upper position; and

a helmet member; whereby

when the lifting system raises the ram member above a preload position, ambient air substantially freely flows into the housing chamber through a vent port;

when the lifting system releases the ram member from the upper position,

the ram member moves from the upper position towards the preload position, and

the ram member forces a first portion of ambient air within the housing chamber out of the housing chamber through the vent port;

when the ram member falls below the preload position, the ram member compresses a second portion of the ambient air within a preload chamber portion of the housing chamber, where compression of the second portion of the ambient air within the preload chamber creates a preload force on the helmet member that is transmitted to the pile;

when the ram member falls into the lower position, the ram member strikes the helmet member to generate an impact force that is transmitted through the helmet member to the pile; and

seal system for sealing the preload chamber portion of the housing chamber when the ram member is below the preload position.

2. A drop hammer as recited in claim **1**, in which the helmet member is supported for movement between a first position and a second position, where the helmet member transmits the preload force and the impact force to the pile.

3. A drop hammer as recited in claim **2**, further comprising:

a housing member for defining the housing chamber, where the housing member supports the helmet member for movement relative to the housing member between the first position and the second position; wherein

the helmet member extends through a helmet opening formed in the housing member.

4. A drop hammer as recited in claim **3**, in which:

the ram member defines a ram side wall;

the housing member defines a housing interior wall;

fluid flow between the ram side wall and the housing interior wall is inhibited.

5. A drop hammer as recited in claim **1**, further comprising a clamp assembly for securing the helmet member to the pile.

6. A method of driving a pile comprising:

supporting a ram member within a housing chamber for movement between an upper position and a lower position;

supporting a helmet member relative to the ram member such that the ram member contacts the helmet member when in the lower position;

raising the ram member into the upper position;

allowing the ram member to fall from the upper position to a preload position such that the ram member forces a first portion of ambient air within the housing chamber out of the housing chamber through a vent port:

allowing the ram member to continue to fall from the preload position to the lower position such that the ram member compresses a second portion of the ambient air within a preload chamber portion of the housing chamber;

allowing the ram member to strike the helmet member to generate an impact force that is transmitted through the helmet member to the pile; and

inhibiting fluid flow between a side wall of the ram and an interior wall of the housing.

7. A method as recited in claim **6**, further comprising the steps of:

providing a housing member defining the housing chamber and the upper and lower positions; and

forming the vent port between in the housing member between the lower and upper positions, where the vent port defines the preload position.

8. A method as recited in claim **7**, further comprising the steps of:

supporting the helmet member for movement between a first position and a second position; and

transmitting the preload strength and the impact force to the pile through the helmet member by displacing the helmet member from the first position to the second position when the ram member strikes the helmet member.

9. A method as recited in claim **8**, further comprising a clamp assembly for securing the helmet member to the pile.

10. A method as recited in claim **6**, further comprising the step of sealing the preload chamber portion of the housing chamber when the ram member is below the preload position.

11. A drop hammer for driving a pile comprising:

a ram member supported within a housing chamber for movement between the upper position and the lower position;

a helmet member supported for movement between a first position and a second position; and

a lifting system for raising the ram member from the lower position to the upper position; whereby

as the ram member moves between the upper position and a preload position defined by a vent port, the ram member forces a first portion of ambient air within the housing chamber out of housing chamber through the vent port;

when the ram member falls below the preload position and before the ram member contacts the helmet member, the ram member compresses a second portion of the ambient air within a preload chamber portion of the housing chamber below the vent port, where compression of the second portion of the ambient air within the preload chamber creates a preload force that is transmitted to the pile through the helmet member;

when the ram member moves into the lower position, the ram member contacts the helmet member such that an impact is transmitted to the pile through the helmet member; and wherein

the ram member defines a ram side wall;

the housing member defines a housing interior wall;

a ram seal inhibits fluid flow between the ram side wall and the housing interior wall.

12. A drop hammer as recited in claim **11**, further comprising a housing member defining the housing chamber and the vent port, where the housing member supports the ram member and the helmet member.

13. A drop hammer as recited in claim **11**, further comprising a clamp assembly for securing the helmet member to the pile.

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