Nov. 10, 1970 E. A. BENDER 3,538,777

AIR CUSHION COUNTERBALANCE FOR LONG-STROKE WELL PUMPING APPARATUS

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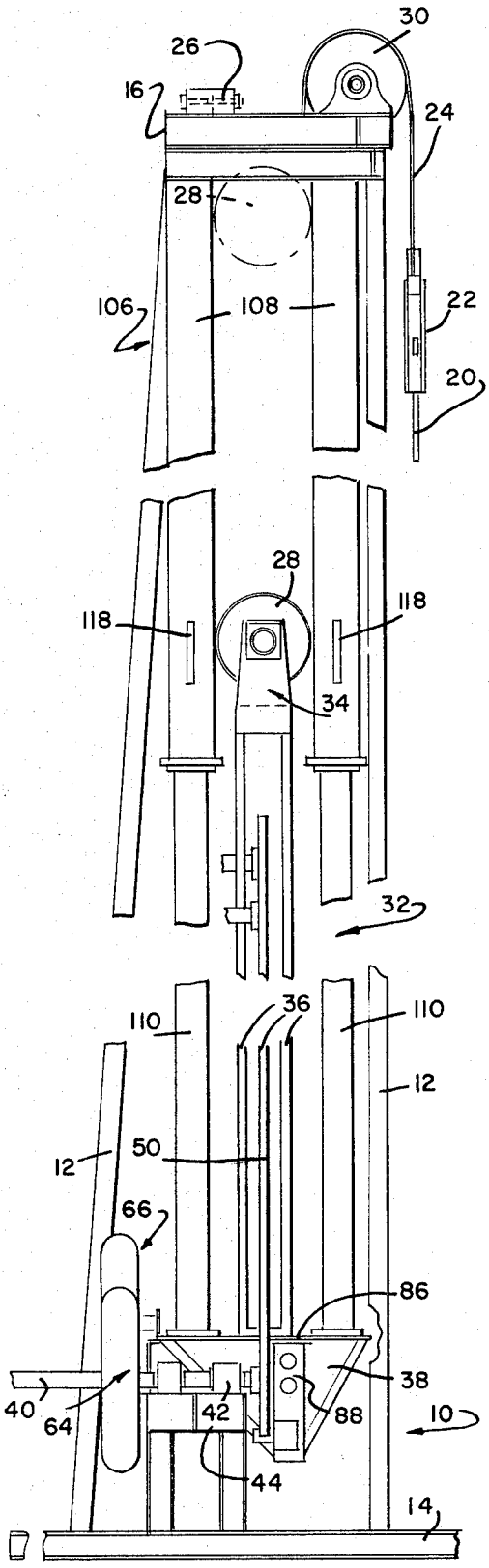


FIG. 1

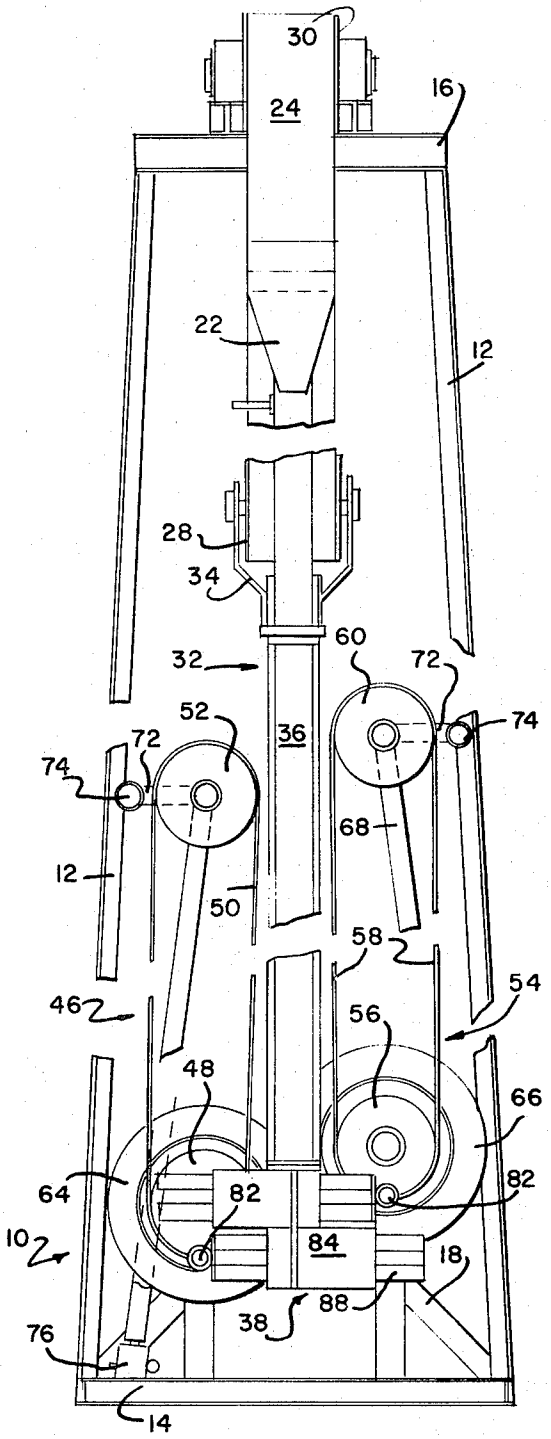


FIG. 2

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AIR CUSHION COUNTERBALANCE FOR LONG-STROKE WELL PUMPING APPARATUS

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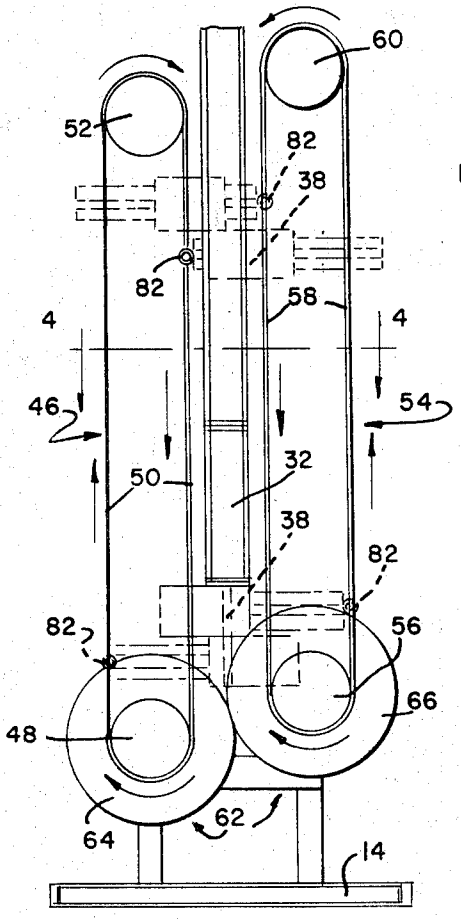


FIG. 3

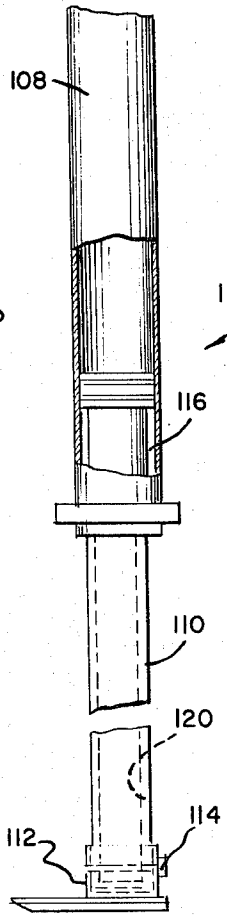


FIG. 6

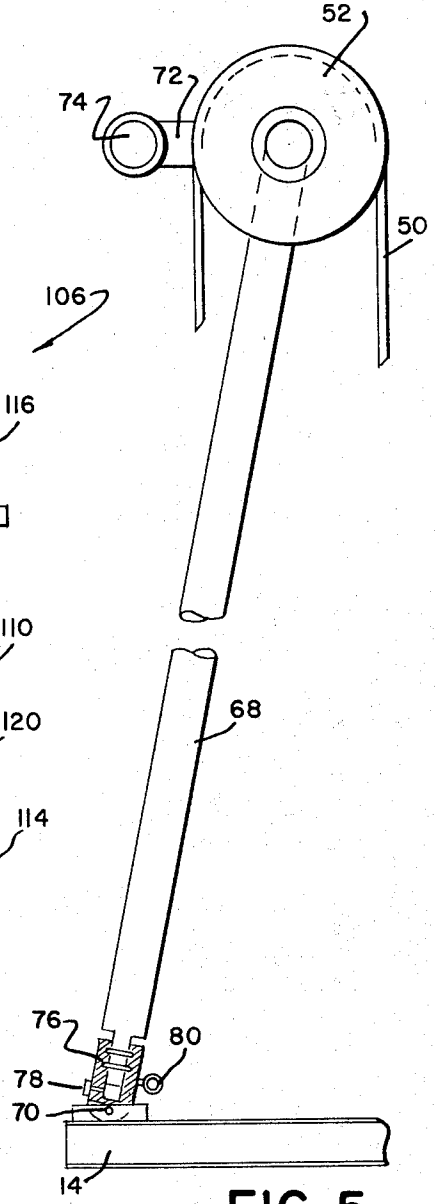


FIG. 5

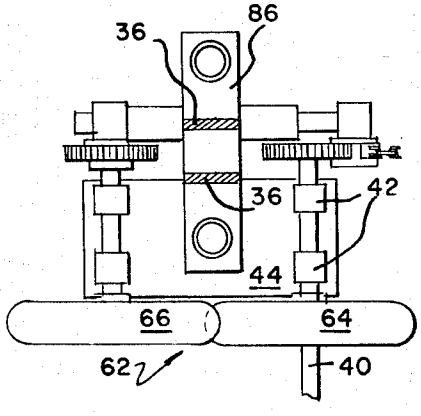


FIG. 4

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AIR CUSHION COUNTERBALANCE FOR LONG-STROKE WELL PUMPING APPARATUS
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FIG.8

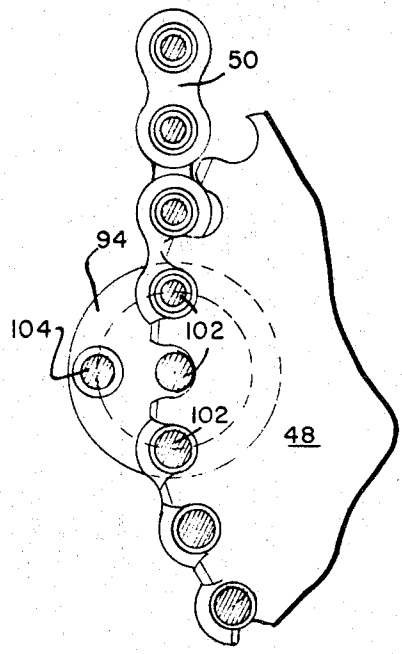


FIG.9

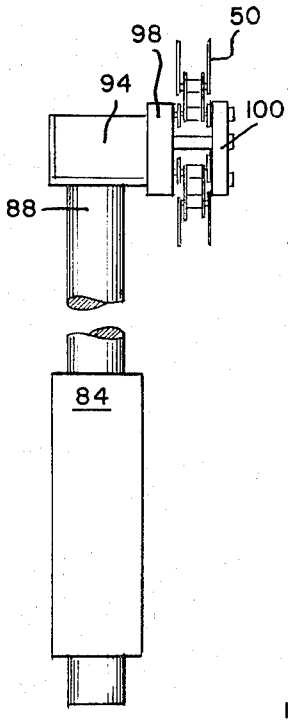
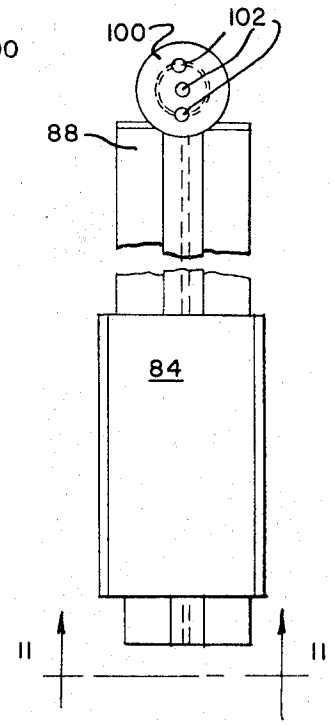


FIG.10



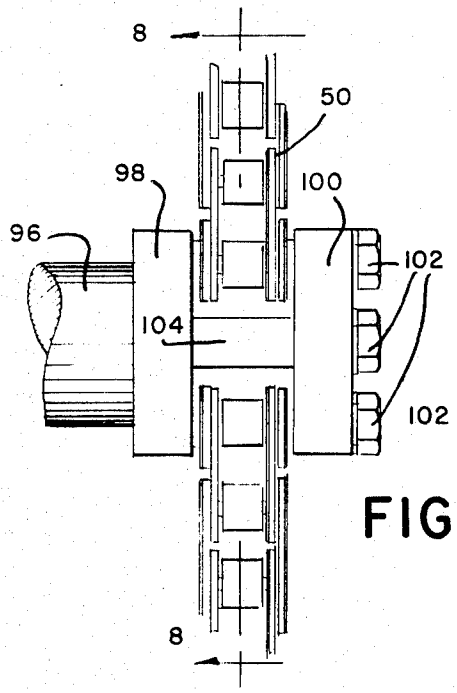
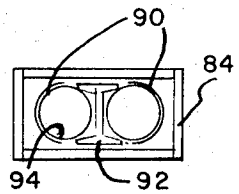


FIG.7

FIG.11



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AIR CUSHION COUNTERBALANCE FOR LONG-STROKE WELL PUMPING APPARATUS

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Int. Cl. F16h 19/06
U.S. Cl. 74—37 20 Claims

ABSTRACT OF THE DISCLOSURE

The invention disclosed is a continuously driven long-stroke oil well pumping unit which is counterbalanced by an air cushion cylinder and piston rod assembly so that the energy required of the power source for the pumping unit tends to equalize whether the pump is on a power stroke or a return stroke. The pump comprises a vertically reciprocating rod string having a stroke of about 32 feet and designed to reciprocate up to about 5 strokes per minute, a tower for mounting the pump, reciprocative motive means for the rod string including a reciprocating member connected to the rod string and a power source for the reciprocating member, air cushion means comprising a dual-cylinder and piston assembly connected to the reciprocating member, and connective means from the reciprocating member to the rod string including a first pulley mounted on the reciprocating member, a second pulley mounted on top of the tower, and a flexible belt trained under the first pulley and over the second pulley with one end secured to the tower and the other secured to the upper end of the rod string so that a simple pulley and line arrangement is provided whereby the reciprocating member moves one-half the distance of the rod string during a pumping stroke. A drive train is provided between the power source and the reciprocating member including a pair of endless drive chains each having a universal coupling attached to the reciprocating member, which is formed as a pair of cross-head blocks having horizontally sliding connective members therein, one for each universal coupling. A pneumatic tire transmission provides drive power to the two endless chains, and a tensioning assembly is provided for each drive chain.

BACKGROUND OF THE INVENTION

The invention relates generally to deep well pumping, and more particularly to oil well pumps of the long-stroke type, since most deep wells produce oil.

The usual walking beam oil well pump provides a satisfactory oil well pump at relatively shallow depths of only a few thousand feet, but such a pump becomes progressively less efficient at greater depths on the order of 5,000 to 8,000 feet and beyond, such deep wells being in an important majority of those being pumped today. By its very nature, the walking beam oil well pump has a maximum stroke of only 7 to 10 feet. At a depth of 8,000 feet, rod string stretch is on the order of several feet or more, leaving an effective pumping stroke of only 0 to about 3 feet. Obviously, most of the work of such a pump is wasted at such tremendous depths. Additionally, such a short stroke pump operates on the order of 11 strokes per minute or more thus requiring more stroke reversals per unit of time causing probable rod stress and possible rod string fracture or failure. Maximum stress occurs at the initiation of a power, or lift stroke, when the entire weight of the rod string as well as the oil to be lifted is being raised. In an 8,000 foot well, this total load will be on the order of 20,000 to 25,000 pounds thereby imparting unusual stress to the rod string as well as strain on the power source of the pump.

The desired solution to this problem was to maintain

or even increase well output while reducing the number of reversals required in the pump. Such was accomplished by the inventions disclosed in my prior patents, No. 3,248,958 and No. 3,345,950, which disclose a pumping unit having a stroke on the order of about 32 feet as opposed to the 10-foot stroke of a walking beam pump. At 8,000 feet, the rod stretch of such a pump remains on the order of about 4 feet but with a 32-foot stroke, thus leaving 28 feet of effective lift per stroke. At the same time, the number of reversals was reduced to approximately 2 strokes per minute yet substantially more oil per day was produced than with the walking beam pump. In both of these prior patents, the rod string was counterbalanced by means of a counterweight or counterweights.

It has been found that the use of a long-stroke pump employing a counterweight still imparts tremendous strain on the working members of the pump during initiation of the power stroke in particular. At this point in the pumping cycle, the power source must be strained to its maximum output to lift both the long rod string and the oil being lifted. Even the hydraulic power source disclosed in my prior Pat. No. 3,345,950 will wear out in an unacceptably short period of time. The primary reason for such unusual wear is the change in power source requirement from a power stroke of the pump to a return stroke. Therefore, it would seem desirable to design a long-stroke pumping unit wherein the power source requirement is substantially equalized during the power and return strokes. Such is the essence of the instant invention.

Provision of an equalization system for a pump of the walking-beam type is not novel, such being disclosed by U.S. Pat. No. 2,808,735, issued to Richard B. Becker. The invention disclosed therein includes an air pressure cylinder and piston assembly with an electrical control system for bleeding excess air pressure from the cylinder so as to equalize the energy requirements from the power source during a power stroke and a return stroke. One attempt at equalizing power source requirements in a pump of the long stroke type is shown in German Pat. No. 814,832, issued to Eduard Albrecht. In this patent, a power source unidirectionally drives an endless chain having a coupling thereon including a first line directed over a pulley to the rod string and a second line directed to a counterweight through a system of pulleys. The first patent teaches an invention useful only with a walking beam pump, and the German patent will still impart an unusual strain to the power source upon initiation of the power stroke of the pump.

The instant invention represents a significant advance over the prior art by providing an air cushion system for a long stroke, deep well pump requiring a uniform energy output from the power source whether the pump is on a power stroke or a return stroke. Because of this uniform power output requirement, the efficiency of the pump is increased by better than 200%, since the number of strokes may be increased from about 2 up to about 5 strokes per minute without causing excessive wear on the power source.

SUMMARY OF THE INVENTION

The invention claimed includes a deep well pumping unit having cushioned means for applying a counterbalancing force to the pump comprising a closed fluid pressure ram system to drive the pump during a power stroke working against the pump during a return stroke so that the power source requirement is substantially equalized during each stroke. A fluid pressure expansion system is provided to accept excess air or fluid pressure during the return stroke of the pump and a simple pulley and line system is provided so that the effective stroke of the cushion ram system is only one half the stroke of the rod

string of the pump. The drive train for the pump includes a power source, a pneumatic tire transmission, a pair of drive chains driven from the transmission, a pair of universal couplings, one on each drive chain, and a reciprocating crosshead connected to the rod string, the crosshead including a pair of crosshead blocks, each having sliding members connected to the universal couplings. Adjusting means are provided to vary the tension in each drive chain as necessary.

BRIEF DESCRIPTION OF THE DRAWINGS

Details of construction and operation according to preferred embodiments of the invention will become readily apparent by reference to the following drawings wherein:

FIG. 1 is a fragmentary, side-elevational view of the invention;

FIG. 2 is a fragmentary, front-elevational view of the invention as depicted in FIG. 1;

FIG. 3 is a partial, diagrammatic elevational view of the drive chain train of the invention as shown in FIG. 2;

FIG. 4 is a sectional view taken along lines 4—4 of FIG. 3;

FIG. 5 is a partial, elevational view illustrating the drive chain tensioning means of the invention drawn to an enlarged scale;

FIG. 6 is a fragmentary, elevational view of a portion of the air cushion means of the invention, taken from the central portion of FIG. 2 drawn to an enlarged scale;

FIG. 7 is a detailed view of the universal coupling drive connection from one of the drives to one of the crosshead blocks and drawn to an enlarged scale;

FIG. 8 is a sectional view of the coupling taken along lines 8—8 of FIG. 7;

FIG. 9 is a partial, top-plan view of one of the crossheads and universal couplings, taken from the upper right hand corner of FIG. 4, and drawn to an enlarged scale;

FIG. 10 is a side elevation view of the crosshead block and universal coupling as shown in FIG. 9; and

FIG. 11 is an end view, taken along lines 11—11 of FIG. 10.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings by reference character, a tower **10** is shown having four tower legs **12** supported on skid platform **14**, and surmounted with a tower platform **16**. Structural rigidity in the tower is provided by a plurality of girts (not shown) and braces **18**. The components of the tower **10** are fabricated from appropriate steel sections suitably welded or bolted together according to the common practice in the art. For the sake of clarity, the tower is illustrated only diagrammatically, and the usual well-head is not shown in the drawings.

The terminal end of the rod string is indicated at **20**, being connected to a yoke **22**. In turn, the yoke **22** is connected to a flexible belt **24**, the distal end thereof being securely clamped to the tower at **26**. Belt **24** is trained under a first pulley **28** and over a second pulley **30** which is freely rotatably mounted at the top of the tower. As the first pulley moves through a full stroke, between the positions shown in solid line and in dot and dash line in FIG. 1, the rod string **20** will reciprocate vertically, thereby operating the oil pump. It should be noted that, because of this simple pulley and line assembly, movement of the first pulley **28**, as explained, will cause the rod string to move a vertical distance twice that of the first pulley **28**.

The remainder of the invention is concerned with means for moving the first pulley **28** to operate the oil well pump. This first pulley **28** is freely rotatably mounted upon a reciprocating member **32** which includes a yoke **34** for the pulley **28**, elongated vertical braces **36**, **36**, and a crosshead **38** beneath brace **36**. When the pump is operating, the entire reciprocating member **32** reciprocates vertically between limits of movement illustrated by the alternate positions of first pulley **28** illustrated in FIG. 1.

The prime mover or power source, which may be a gasoline, diesel, or hydraulic power source, is mounted on skid platform **14**, to the left of tower **10** as illustrated in FIG. 1. The power source is not illustrated. Rotational drive is transmitted from the power source by a pair of stages; the shaft **40** is shown as the connection to the power source. Chain-and-sprocket assemblies **46** and **54**, primary and secondary, are driven by first drive sprockets **48** and **56**, drive chains **50** and **58** and driven sprockets **52** and **60**. The axle **40** rests on bearing blocks **42**, **42** situated on a support platform **44**. The transmission train includes a pneumatic tire transmission pair **62** one tire of which is mounted on axle **40**. Pneumatic tire pairs used for power transmission are not new, per se, but are new as applied to this combination. Power distribution between drive assemblies **46**, **54** may be adjusted by control of the inflation of tires **64**, **66**.

As shown in FIG. 5, each driven sprocket **52**, **60** is mounted for vertical planar movement to adjust the tension in the respective drive chains **50**, **58**, respectively. As shown in FIG. 5, sprocket **60** is freely rotatably mounted on an elongate, angularly disposed support **68**, pivotally mounted to skid platform **14** at **70**. A connective arm **72** is pivotally mounted to supports **68** and sprocket **60**, and to a leg at **74**. Support **68** is movable along its length to vary the tension in drive chain **58** by means of a fluid cylinder and piston system **76**, at the base thereof. A nipple **78** is provided for introduction of fluid under pressure into the cylinder, and a gauge **80** may be employed to read the fluid pressure within the cylinder. Equalization of tension within chains **50** and **58** may be assured by reading the gauge **80**; equal tension in the drive chains assures uniform drive in both assemblies **46** and **54**.

Drive connection from drive chains **50**, **58** to crosshead **38** is provided by a pair of universal couplings **82**, **82**, one for each drive chain **50**, **58**, each of which is formed as an integral link in its appropriate drive chain (FIG. 7). Crosshead **38** includes a pair of crosshead blocks **84**, **84**, one mounted over the other and both beneath platform **86**, beneath vertical braces **36**, **36**. Each block **84** is bored centrally to receive a sliding, dual tube connective arm **88**, each slidable within block **84** on bearings **90**, which may be manufactured of "Teflon." The tubes of arm **88** are welded together at their meeting point to a structural T-beam **92**. The dual tubular arrangement prevents lateral twist in the connective arm when the pump is operative. A cylindrical journal **94**, which forms a part of coupling **82**, is formed on the outer, operative end of each sliding arm **88**. That portion of coupling **82** formed as a part of the drive chain **50** or **58**, includes a wristpin **96**, which fits within journal **94**, circular base **98** for wristpin **96**, plate **100**, on the other side of the drive chain from base **98**, and connective bolts **102**, securing base **98** to plate **100** and serving as rollers for two pitch-teeth of the drive chain. An additional bolt **104** (FIG. 8) may be provided to further assure structural integrity of the coupling **82**.

The operation of this terminal portion of the drive train is illustrated diagramatically in FIG. 3. Alternate positions of the crosshead **38** are shown in dot and dash line. Drive chains **50**, **58** rotate in the direction indicated by the arrows in the figure. When crosshead **38** is at the lower position illustrated, with couplings **82**, **82** on the outboard sides of drive chain **50**, **58**, the pump has just initiated a return stroke, and when the crosshead **38** is in the upper position illustrated, with couplings **82**, **82** on the inboard sides of drive chains **50**, **58**, the pump has just initiated a power, or pumping stroke.

Attention is now directed to FIGS. 1, 2, 3 and 6 for a disclosure of the air-cushioned cylinder and piston rod assembly **106** which replaces the usual weight counterbalance of a long-stroke oil well pumping rig. Assembly **106** includes a pair of air ram cylinders **108**, **108**, each having a piston **110** working therein, the outer end of which is secured to crosshead platform **86** by a cup **112** having a pivot pin **114** for connection. In the preferred

embodiment of the invention, continuous air pressure is employed, but alternatively, fluid under pressure may be provided by hydraulic liquid instead. Each cylinder **106** is hydraulically sealed at point **116**; an oil level gauge **118** may be provided to indicate the level of the hydraulic seal. The seals **116, 116** effectively prevent the escape of air pressure about the pistons **110, 110**. Since the cylinders **108, 108** are continually loaded with air pressure, the pistons **110, 110** assist the primary drive during a power stroke, as illustrated in FIG. 3, during the period of maximum stress in a stroke, when the entire weight of the rod string and oil to be pumped must be lifted. On the other hand, during a return stroke of the pump, by force of gravity, the rod string lowers itself, thereby requiring almost no energy from the prime mover of the pump. However, in the instant invention, the energy required of the prime mover is almost equal that required on a power stroke through the resistance of the air cushioned cylinder and piston assembly **106** which, being continually fed with air under pressure, resists the upward movement of crosshead **38** as the rod string **20** lowers. In this manner, the energy required from the power source is equalized during both return and power strokes of the oil pump.

By way of example, specific figures may be illustrated to amplify this discussion of the operation of the invention. First, assume an oil well pumping depth of 8,000 feet, the combined weight of the rod string and oil to be lifted being on the order of 25,000 pounds. The air cushion assembly **106** will therefore have to produce a force of about 50,000 pounds to lift the rod string and oil since the stroke of the pistons **110, 110** is but one-half that of the stroke of the rod string, due to the provision of the pulley and line arrangement provided by flexible belt **24** and pulleys **28** and **30**. Therefore, each cylinder will be loaded with an effective force of 25,000 pounds. Assuming a cylinder diameter of about 10½ inches and piston head diameter of about 8½ inches, a pressure load of about 400 pounds in each cylinder **108** will produce an effective drive force of about 50,000 pounds. On the other hand, during a return stroke, the weight of the rod string, being on the order of about 18,000 to 20,000 pounds will cause an effective lift on pulley **28** of about 35,000 to 40,000 pounds, the resistance of friction being considered, since the stroke of rod string **20** is twice that of pulley **28** and pistons **110, 110**. A load of about 350 pounds air pressure in each cylinder **108** will provide a resistance of about 40,000 pounds during the return stroke, thereby equalizing the energy requirements of the power source during the power and return strokes. The means for providing continuous air pressure to cylinders **108, 108** may be any of those common to the art, forming no part of the instant invention, and therefore, are not illustrated in the drawings. The change in pressure load from 400 pounds during a power stroke and 350 pounds during a return stroke may be compensated by forming a cavity in each piston **110** at **120** (FIG. 6) and/or by provision of common air pressure expansion tanks for each cylinder **108** (not shown).

Referring again to FIG. 3, it would appear from the foregoing discussion that the universal couplings **82** illustrated would be too fragile to handle the loads given above. However, during a power stroke, unidirectional force on each coupling **82** is provided by, first, drive force on chains **50, 58** from the power source and from the force provided by air cushioned assembly **106**. During a return stroke, unidirectional force is provided by the drive force on chains **50, 58** as well as by force of gravity on rod string **20** as it lowers into the well. In practice, according to the above examples, it has been found that the maximum tensile load in each coupling **82** has been no more than about 2,500 pounds, or 5,000 pounds, the figures for both chains being combined.

Obviously, the scope of the invention is significantly broader than outlined in the preferred embodiments above discussed, as is apparent from the following claims.

1. In a pumping apparatus for an oil well or the like, including a pump, comprising a vertically reciprocating rod string actuated by reciprocating motive means, the rod string being suspended from a tower having a height greater than the stroke of the reciprocating rod string, which includes a reciprocating member connected to the rod string and a power source for driving the reciprocating member, cushioned means for applying a counterbalancing force to the reciprocating member whereby the energy output required of the power source is substantially equalized during both the power stroke and return stroke of the pump, comprising:

(a) a closed fluid pressure ram system including at least one cylinder and at least one piston head extending therefrom said piston head secured to said reciprocating member, said system arranged to positively drive the reciprocating member during a power stroke of the pump, said system being continuously fed with sufficient fluid pressure to exceed the combined weight of the pipe string and oil to be lifted; and

(b) fluid expansion means closed against bleeding, for accepting excess fluid pressure during a return stroke of the pump, said system remaining loaded to work against the reciprocating member during the return stroke, whereby the energy output required of the power source remains substantially constant during both power and return strokes.

2. The invention as recited in claim **1** wherein the closed fluid pressure ram system comprises a pair of cylinders, each cylinder including a piston, the heads of the pistons secured to the reciprocating member, the reciprocating member being connected to the rod string by pulley and line means, whereby in a single stroke of the reciprocating member, the rod string moves twice the distance of travel of the reciprocating member, each cylinder being loaded with pressure sufficient to exceed the combined weight of the rod string and the oil to be lifted.

3. The invention as recited in claim **2** wherein the pulley and line means comprise:

(a) a first pulley mounted on the reciprocating member;

(b) a second pulley mounted on the top of the tower; and

(c) a flexible connective member, having one terminal end secured to the top of the tower, trained beneath the first pulley and over the second pulley, and having its free distal end secured to the rod string.

4. The invention as recited in claim **3** wherein the flexible member comprises an elongated belt of substantial width.

5. The invention as recited in claim **3** wherein each pulley is crowned at a central portion thereof, to retain the flexible member centrally on the pulley.

6. The invention as recited in claim **1** wherein the length of each piston exceeds the stroke distance of the reciprocating member, said expansion means comprising means defining an elongated cavity within the piston.

7. The invention as recited in claim **6** wherein the expansion system further includes fluid pressure expansion tank means, connected to said cylinders by fluid pressure line means.

8. The invention as recited in claim **1** wherein the base of the cylinder adjacent the piston is oil filled, said base including gauge means indicating the oil level therein.

9. A pumping apparatus for an oil well or the like, including:

(a) a pump comprising a vertically reciprocating rod string;

(b) a tower for mounting the pump, having a height greater than the stroke of the reciprocating rod string;

(c) reciprocating motive means for the rod string, comprising:

(1) a reciprocating motive means for the rod string; and

(2) a power source for driving the reciprocating member;

(d) cushioned means for applying a counterbalancing force to the reciprocating member whereby the energy output required of the power source is substantially equalized during both the power and return strokes of the pump; and

(e) connective means from the reciprocating member to the upper, distal end of the rod string comprising pulley and line means whereby during a single stroke of the pump, the rod string moves a distance greater than the movement of the reciprocating member.

10. The invention as recited in claim **9** wherein the reciprocating motive means further include drive train means from the power source to the reciprocating member comprising:

(a) a drive line from the power source;

(b) at least one sprocket wheel driven from the drive line;

(c) a generally vertically arranged endless drive chain trained about said one sprocket wheel, and about an idler sprocket wheel; and

(d) a universal coupling, interconnecting said reciprocating member with a portion of the endless drive chain.

11. The invention as recited in claim **10** wherein said drive train means further comprise:

(a) a second generally vertically arranged drive chain;

(b) a second driving sprocket wheel driven from said drive line, and a second idler sprocket wheel, the second drive chain trained therearound; and

(c) a second universal coupling interconnecting said reciprocating member with a portion of the second drive chain.

12. The invention as recited in claim **11** wherein additional drive transmission means to the driven sprocket wheels is provided, comprising:

(a) a first pneumatic tire, rotationally driven from the drive line;

(b) a second pneumatic tire, driven by frictional engagement with the first pneumatic tire;

(c) a pair of drive axles, one connecting the one driven sprocket wheel and the first pneumatic tire, the other drive axle connecting the second driven sprocket wheel and the second pneumatic tire.

13. The invention as recited in claim **11** wherein the reciprocating member comprises:

(a) a pair of crosshead blocks;

(b) means defining a longitudinal bore in each crosshead block;

(c) a pair if sliding connective members, one mounted in each block;

said universal coupling connected to the free distal end of one of the sliding connective members, said second universal coupling connected to the free distal end of the other of the sliding connective members.

14. The invention as recited in claim **13** wherein each bore is lined with substantially frictionless material, and each sliding connective member comprises;

(a) a pair of elongated tubular members, one secured vertically over the other; and

(b) a connecting beam interfitted between the tubular members;

the bore for said sliding connective member being configured in cross-section to a cross-section taken through the sliding connective member.

15. The invention as recited in claim **11** wherein each universal coupling comprises:

(a) a wristpin mounted in the drive chain; and

(b) a generally cylindrical journal mounted on the reciprocating member, arranged to receive the wristpin.

16. The invention as recited in claim **11** wherein each drive chain includes chain tensioning means comprising:

(a) a support mounted on the base of the tower and having the idler sprocket mounted at its upper, free distal end;

(b) a connective arm; pivotally mounted to the junction of the idler sprocket and support, and to a side of the tower; and

(c) means mounted at the base of the support for extending the support in the direction of the idler sprocket to tighten the drive chain about the driven idler sprockets.

17. The invention as recited in claim **16** wherein the means mounted at the base of the support for extending the support comprise:

(a) a piston formed on the lower terminal end of the support;

(b) an adjusting cylinder secured to the tower base for receiving the support piston; and

(c) means for introducing fluid under pressure to said cylinder to move said piston.

18. The invention as recited in claim **9** wherein the cushioned means for applying a counterbalancing force to the reciprocating member comprise:

(a) a pair of cylinders each filled with fluid under pressure;

(b) a pair of pistons, one for each cylinder, the free piston head of each piston connected to the reciprocating member, the length of each piston exceeding the storage distance of the reciprocating member; and

(c) fluid expansion means closed against bleeding, for accepting excess fluid pressure during a return stroke of the pump.

said cylinders loaded with sufficient fluid under pressure to exceed the combined weight of the rod string and oil to be lifted.

19. The invention as recited in claim **9** wherein the pulley and line means comprise:

(a) a first pulley mounted on the reciprocating member;

(b) a second pulley mounted on top of the tower; and

(c) a flexible connective member, trained under the first pulley and over the second pulley, and having one terminal end secured to the top of the tower, and its free distal end connected to the rod string.

20. The invention as recited in claim **19** wherein each of the pulleys is centrally crowned, and the flexible connective member comprises an elongated belt having a width substantially equal the width of one of the pulleys.

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