United States Patent

McArthur et al.

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[45] **May 2, 1972**

[54] HYDRAULIC INTENSIFIER

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[52] **U.S. Cl.**.....**417/397**, 417/567, 92/169

[51] **Int. Cl.**.....**F04b 17/00**, F04b 35/00, F04b 21/02, F04b 39/10, F01b 11/02

[58] **Field of Search**.....417/397, 404, 540, 542, 567, 417/225, 543; 91/282; 92/169

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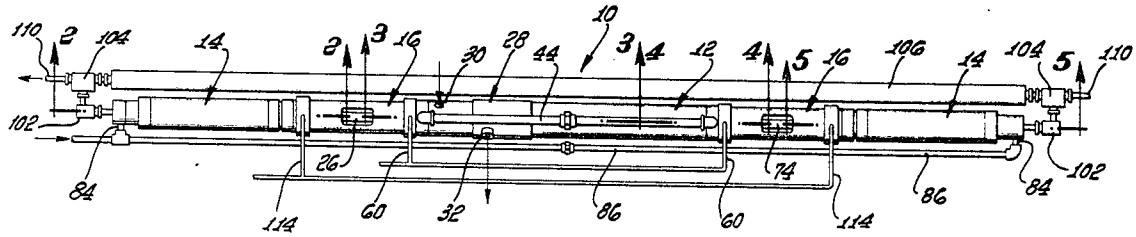
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[57] **ABSTRACT**

A hydraulic intensifier operable by a fluid, such as oil, at relatively low pressures to deliver a fluid, such as water, at very high pressures for any desired purpose. The intensifier includes a fluid operated, double acting, reciprocating engine and two single acting, reciprocating pumps respectively located at opposite ends of and in alignment with the engine and connected to the engine for actuation thereby, the displacement of the pumps being small as compared to that of the engine so as to produce a discharge pressure many times the operating fluid pressure.

The intensifier is capable of producing discharge pressures of the order of 30,000 to 70,000 psi, or higher, with operating fluid pressures of the order of 2,000 to 5,000 psi. Further, the intensifier is capable of transmitting power of the order of 50 horsepower, or more, in a relatively lightweight unit which is portable and relatively maneuverable.

13 Claims, 7 Drawing Figures



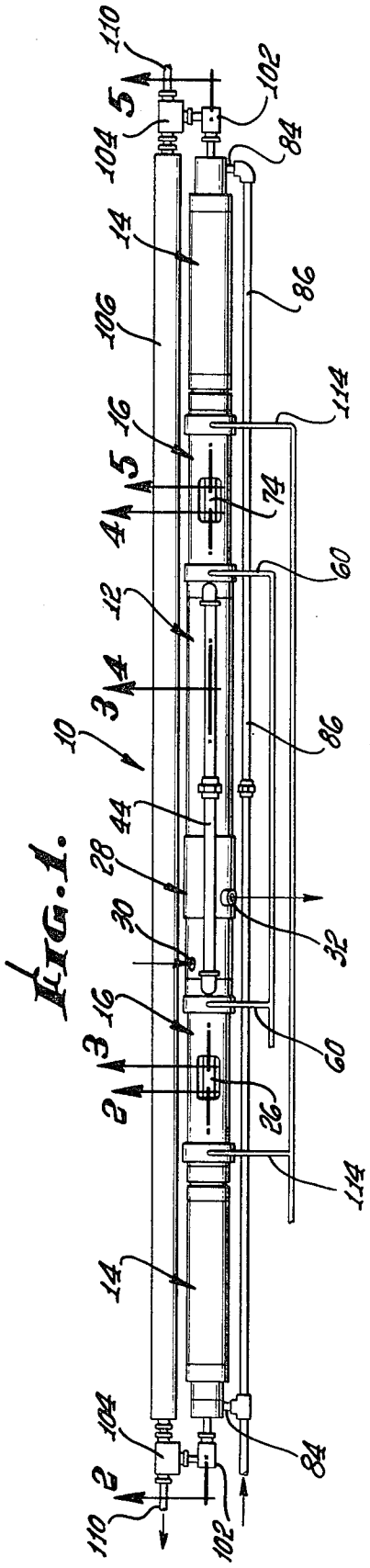


FIG. 1.

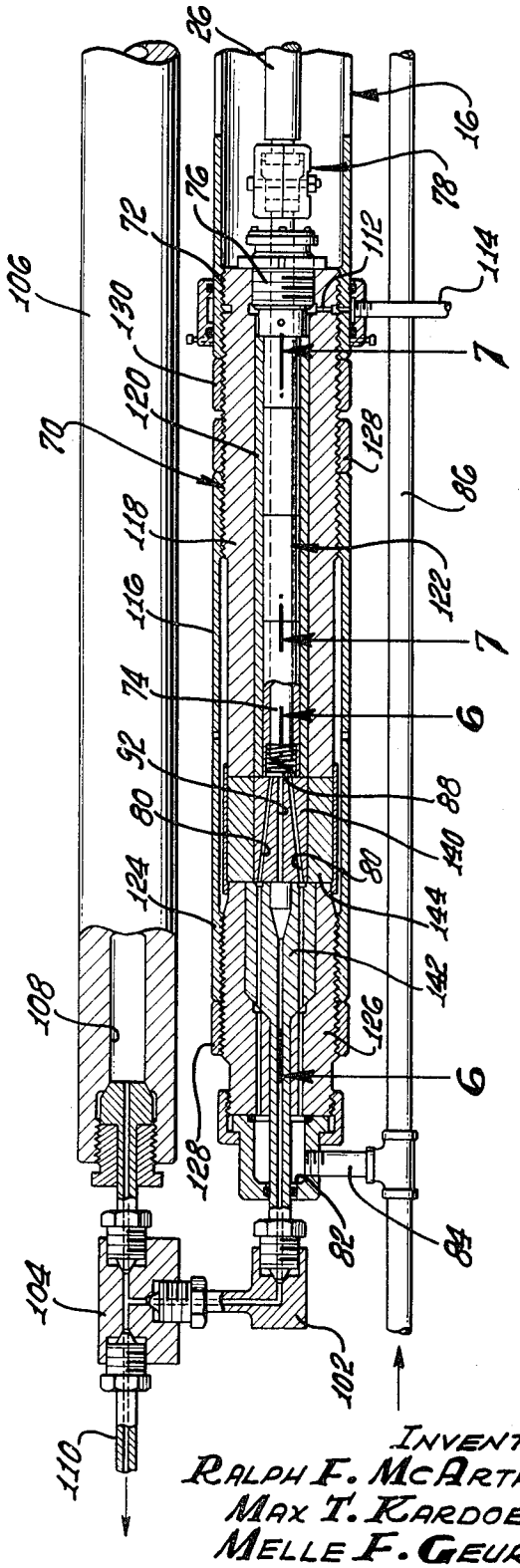


FIG. 2.

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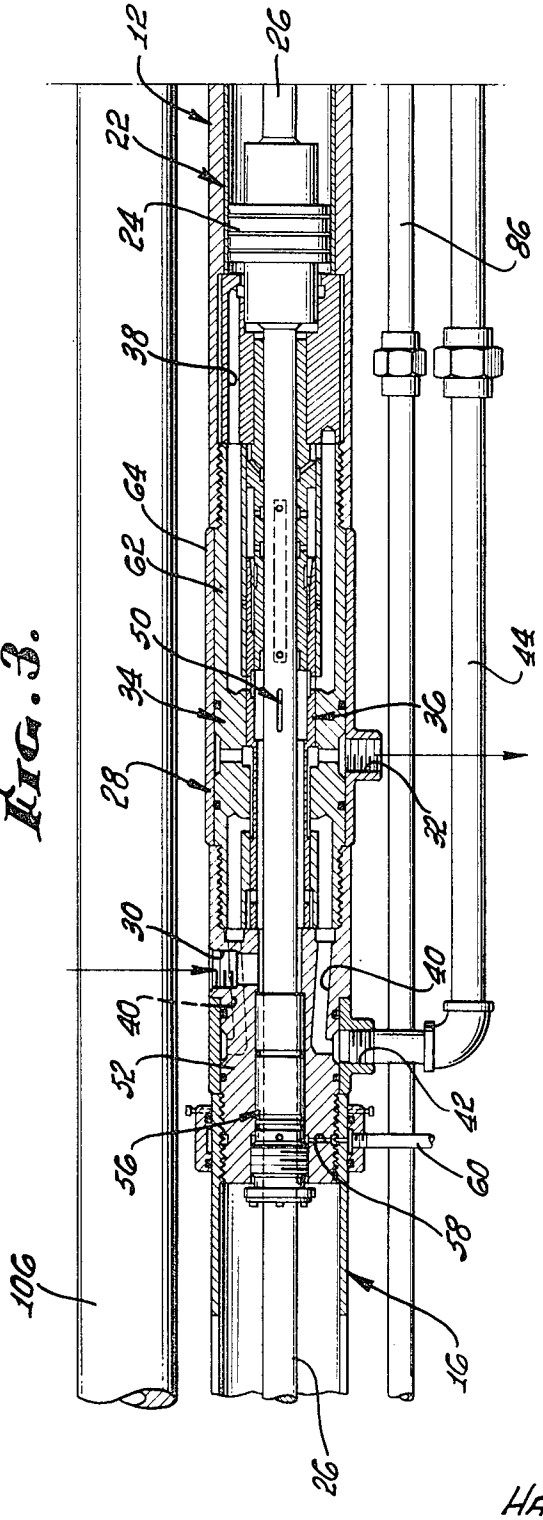


Fig. 3.

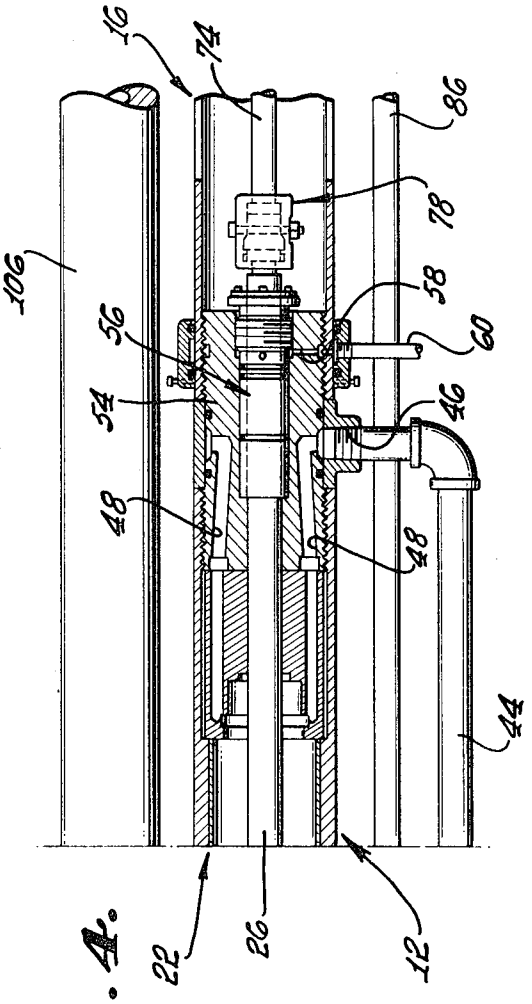


Fig. 4.

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FIG. 5.

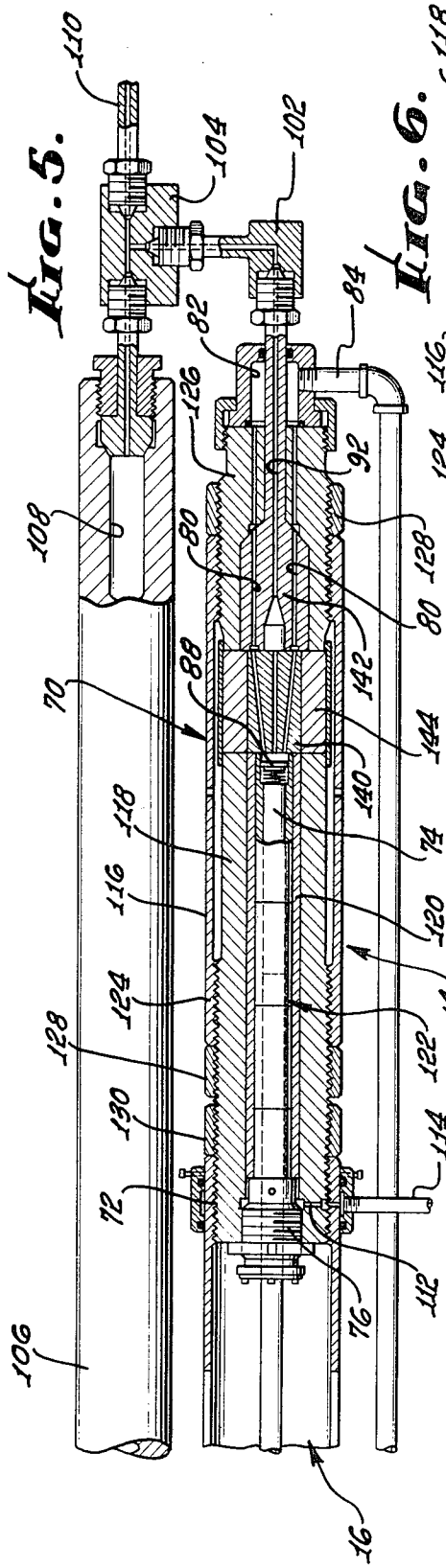
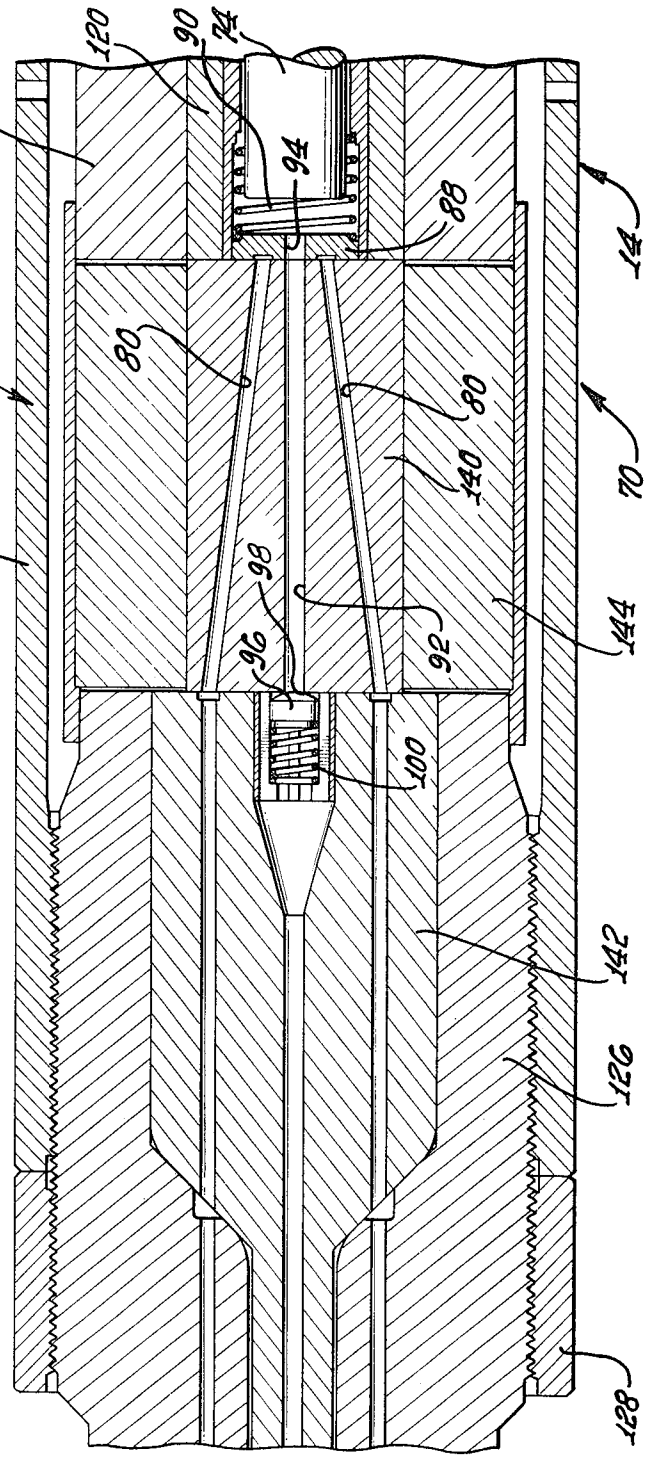


FIG. 6.



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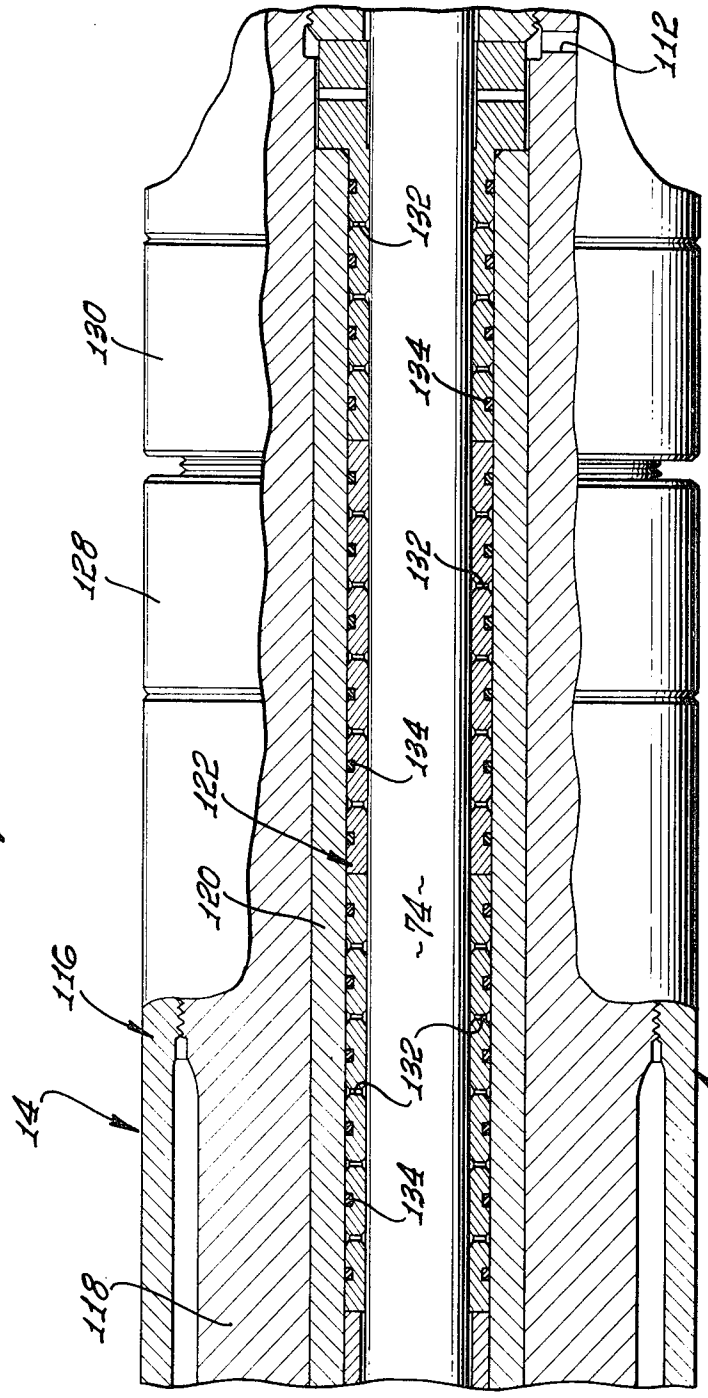


FIG. 7.

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HYDRAULIC INTENSIFIER

BACKGROUND OF INVENTION

The present invention relates in general to an apparatus for delivering a fluid, such as water, at a very high pressure.

More particularly, the invention relates to an apparatus which is operable by a fluid, such as oil, at a relatively low pressure to deliver a fluid, such as water, at a much higher pressure. Consequently, the apparatus is referred to herein as a hydraulic intensifier.

The invention utilizes a fluid operated, double acting, reciprocating engine similar to those disclosed in U.S. Pat. Nos. 2,134,174, 2,204,120 and 2,311,157, respectively issued Oct. 25, 1938, June 11, 1940 and Feb. 16, 1943, to Clarence J. Coberly. Consequently, the disclosures of these patents are incorporated herein by reference.

SUMMARY AND OBJECTS OF INVENTION

General objects of the invention are: to provide a hydraulic intensifier which is operable by oil, or other fluid, at a relatively low pressure, e. g., 2,000 to 5,000 psi, to deliver water, or other fluid, at a very high pressure, e.g., 30,000 to 70,000 psi, or higher; to provide a hydraulic intensifier having such characteristics which is capable of transmitting substantial power, e.g., 50 horsepower, or more, in a relatively lightweight unit which is portable and relatively maneuverable; and to provide a hydraulic intensifier which is capable of long, continuous service with minimum repair and minimum down time for repair.

The invention contemplates achieving the foregoing general objects by providing, and a primary object of the invention is to provide, a hydraulic intensifier which includes a fluid operated, double acting, reciprocating engine and two single acting, reciprocating pumps respectively located at opposite ends of and in alignment with the engine and connected to the engine for actuation thereby, the ratio of the net areas of the engine to pump pistons being such as to provide discharge pressures many times that of the engine input pressures.

More particularly, the invention may be summarized as including, and an important object of the invention is to provide, a hydraulic intensifier which includes: a fluid operated, double acting, reciprocating engine; the engine including an engine cylinder containing an engine piston having engine piston rods extending therefrom in opposite directions; the engine including engine valve means for supplying operating fluid under pressure to opposite ends of the engine cylinder alternately; the engine valve means including an engine valve body connected to one end of the engine cylinder in axial alignment therewith; the engine valve means including a tubular engine valve movable in the engine valve body on one of the engine piston rods between operating positions wherein it supplies operating fluid under pressure to opposite ends of the engine cylinder, respectively; the engine valve means including means on the engine valve and the one engine piston rod for moving the engine valve between its operating positions in response to arrival of the engine piston at the ends of its stroke; two oppositely facing, single acting, reciprocating pumps respectively located at opposite ends of and in alignment with the engine; the pumps respectively including pump cylinders connected to the engine cylinder and the engine valve body; the pumps respectively including pump plungers reciprocable in the pump cylinders and connected to the engine piston rods; each of the pumps including inlet and outlet check valves controlling the admission and discharge of the fluid being pumped; and the cross-sectional area of the pump plungers being small as compared to the net cross-sectional area of the engine piston.

Another object is to provide a hydraulic intensifier of the foregoing character wherein each of the pumps includes an inlet and an outlet communicating with the outer end of the corresponding pump cylinder and respectively controlled by the corresponding inlet and outlet check valves. With this construction, the engine piston rods and the pump plungers are loaded in compression only, thereby avoiding fatigue failures due to tension loading. Still another object is to provide a hydraulic intensifier where the inlet and outlet check valves of each pump are arranged in tandem, i.e., are axially aligned, to avoid discontinuities in highly stressed pulsing sections of the pump, and to reduce the clearance volume to a minimum, thereby minimizing re-expansion losses which result in poor volumetric efficiency.

Yet another object is to provide a hydraulic intensifier including an elongated pulsation reducing chamber extending substantially the full length of the intensifier alongside the engine and pumps, and interconnecting the outlets of the pumps. This elongated chamber contains sufficient water, or other fluid, to smooth out pressure pulsations utilizing the compressibility of the fluid.

An additional object is to provide a hydraulic intensifier wherein each pump cylinder has a concentrically layered construction comprising prestressed layers. With such a construction, the pump cylinders are capable of withstanding the high discharge pressures involved without excessive wall thicknesses. This prestressed construction also resists failure by fatigue far better than does a single-walled configuration.

Another object is to provide a hydraulic intensifier wherein each pump cylinder incorporates means for balancing the internal and external axial pressure gradients to which the innermost layer or liner is exposed. With this construction, the liner may be made of a good bearing type material, e. g., bronze, to achieve a good fluid seal between the plunger and the liner without any danger of failure of the liner in hoop compression.

Still another object is to provide passage means in each of the pump cylinders adjacent the axially inner ends thereof for bleeding off any leakage of pumped fluid between the pump cylinders and the pump plungers therein, and to provide similar passage means in the engine adjacent the respective ends thereof for bleeding off any leakage of operating fluid along the engine piston rods.

An additional object is to provide metal-to-metal fits for controlling leakage in both the engine and the pumps, no dynamic seals utilizing elastomers being employed. A related object is to provide static high pressure fluid seals in both the engine and the pump comprising lapped metal surfaces in preloaded sealing engagement by axially thermally shrinking outer tubes enclosing the members involved.

A further object is to provide a hydraulic intensifier wherein all valving members of the engine and the pumps are internal, no external valving members being required.

Yet another object is to provide radial external fluid connections which are orientable circumferentially to facilitate making field connections.

A still further object of the invention is to provide a structure wherein either pump can be removed readily for repair, or, preferably, for replacement by a factory rebuilt or reconditioned pump.

The foregoing objects, advantages, features and results of the present invention, together with various other objects, advantages, features and results thereof which will be evident to those skilled in the art of achieving very high fluid pressures, may be attained with the exemplary embodiment of the invention described in detail hereinafter and illustrated in the accompanying drawings.

DESCRIPTION OF DRAWINGS

In the drawings:

FIG. 1 is an elevational view of a hydraulic intensifier which embodies the invention;

FIGS. 2, 3, 4 and 5 are enlarged, fragmentary, longitudinal sectional views respectively taken as indicated by the arrowed lines 2—2, 3—3, 4—4 and 5—5 of FIG. 1; and

FIGS. 6 and 7 are further enlarged, fragmentary, longitudinal sectional views respectively taken as indicated by the arrowed lines 6—6 and 7—7 of FIG. 2 of the drawings.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENT OF INVENTION

Referring initially to FIG. 1 of the drawings, illustrated therein is a hydraulic intensifier **10** of the invention which includes as its major components a fluid operated, double acting, reciprocating engine **12** and two single acting, reciprocating pumps **14** respectively located at opposite ends of and in alignment with the engine and connected to the engine for actuation thereby, coaxial spacer means **16** being interposed between the engine **12** and the pumps **14**. As will be explained in more detail hereinafter, the engine **12** is operable by oil, or other fluid, at a relatively low pressure, e.g., 2,000 to 5,000 psi, to cause the pumps **14** to deliver water, or other fluid, at a much higher pressure, e.g., 30,000 to 70,000 psi, or more. The net piston area of the engine **12** is many times that of the pumps **14** to achieve pressure magnifications of the order indicated.

The fluid operated, double acting, reciprocating engine **12** is fundamentally the same as those disclosed in the aforementioned patents, and particularly U.S. Pat. No. 2,311,157. Consequently, the engine **12** will be described only generally herein.

Referring to FIGS. **3** and **4** of the drawings, the engine **12** comprises generally an engine cylinder **22** containing an engine piston **24** having engine piston rods **26** extending therefrom in opposite directions. The engine **12** includes engine valve means **28** for supplying operating fluid under pressure from a supply port **30** to opposite ends of the engine cylinder **22** alternately, spent operating fluid being discharged through a return port **32**. The operating fluid, which may be oil, or any other suitable fluid, may be delivered to the supply port **30** by a triplex pump, not shown, such as that disclosed in U.S. Pat. No. 3,077,836, issued Feb. 19, 1963 to Clarence J. Coberly et al. The return port **32** may be connected to a reservoir, not shown, which furnishes fluid to the triplex pump.

More particularly, the engine valve means **28**, which is located at one end of the engine cylinder **22** in axial alignment therewith, includes an engine valve body **34** connected to one end of the engine cylinder. One of operating piston rods **24** extends axially through the engine valve means **28** and slidable thereon within the engine valve body **34** is a tubular, differential area engine valve **36** of the type disclosed in U.S. Pat. Nos. 2,134,174, 2,204,120 and 2,311,157, and particularly the latter.

The engine valve **36** is hydraulically movable between two axially spaced operating positions wherein it supplies operating fluid under pressure to opposite ends of the engine cylinder **22**, respectively. When the engine valve **36** is in the operating position shown in FIG. **3**, it supplies operating fluid under pressure from the port **30** to the adjacent end of the engine cylinder **22** through passages one of which is shown in FIG. **3** and designated by the numeral **38**. When the engine valve **36** is in its other operating position, not shown, it connects the passage **38** leading to the adjacent end of the engine cylinder **22** to the return port **32**.

When the engine valve **36** is in the operating position shown in FIG. **3**, it connects the opposite end of the engine cylinder **22** to the return port **32** through passages **40**, a transfer port **42**, an external transfer passage **44** alongside the engine valve body **34** and the engine cylinder **22**, and through a transfer port **46** and passages **48**, FIG. **4**, at the opposite end of the engine cylinder. Conversely, when the engine valve **36** is in its other operating position, not shown, it connects the opposite end of the engine cylinder **22** to the supply port **30** through the passages **40**, the transfer port **42**, the transfer passage **44**, the transfer port **46** and the passages **48**.

The engine valve means **28** also includes means of moving the engine valve **36** between its operating positions in response to arrival of the engine piston **24** at the ends of its stroke, such means including control port means **50** in one of the engine piston rods **26** which extends through the engine valve means. Thus, as the engine piston **24** approaches each end of its stroke, the control port means **50** causes the engine valve **36** to move to its other operating position to reverse the direction of movement of the engine piston.

As previously indicated, the foregoing structure and operation of the engine **12** are fully disclosed in the patents identified earlier in connection with the engine, and particularly U.S. Pat. No. 2,311,157. Reference is made to these patents for a more detailed disclosure if one is desired.

The end of the engine valve body **34** remote from the engine cylinder **22** terminates in a fitting **52**, FIG. **3**, and the end of the engine cylinder opposite the engine valve body terminates in a similar fitting **54**, the two spacer means **16** respectively comprising windowed tubes **16** connected to such fittings. The two engine piston rods **26** extend into the respective spacer means or tubes **16** through seals **56** respectively carried by the fittings **52** and **54**. Any leakage of operating fluid between the piston rods **26** and the seals **56** is bled off through passages or passage means **58** in the fitting **52** and **54** and through drain lines **60** connected thereto. Such operating fluid leakage may be returned to the operating fluid reservoir, or otherwise disposed of. The engine valve body **34** includes inner and outer tubular members **62** and **64**, the latter being a fluid collecting sleeve which has a slip fit on the inner member.

Turning now to a consideration of the pumps **14**, each includes a pump cylinder designated generally by the numeral **70** and threadedly connected to the corresponding spacer tube **16** at **72**, FIGS. **2** and **5**. Reciprocable in each pump cylinder **70** is a pump plunger **74** the cross-sectional area of which is small as compared to the net cross-sectional area of the engine piston **24**, i.e., as compared to the difference between the over-all cross-sectional area of the engine piston and the cross-sectional area of the piston rods **26**. Each pump plunger **74** projects from its cylinder **70** through a fitting **76** into the corresponding windowed spacer tube **16**. The pump plungers **74** are detachably connected to the respective engine piston rods **26** within the spacer tubes **16** by connectors **78** which permit relative lateral movement of the pump plungers and the engine piston rods to compensate for any minor misalignments. The connectors **78** are accessible through the windows in the spacer tubes **16** to permit disconnection of the pump plungers **74** from the engine piston rods **26**. Thus, whenever it is necessary to repair or replace one of the pumps **14**, it may be detached readily by disconnecting the corresponding connector **78** and then disconnecting the corresponding pump cylinder **70** from the spacer tube **16** with which it is associated. As hereinbefore indicated, any pump **14** requiring service or repair is preferably replaced by a factory reconditioned pump.

Each pump cylinder **70** is provided at its axially outer end with an inlet comprising inlet passages **80** extending longitudinally from an inlet chamber **82** having an inlet nipple **84** connected thereto. The two inlet nipples **84** are interconnected by an inlet line **86** disposed alongside of and extending substantially the entire length of the hydraulic intensifier **10**. The inlet line **86** is connected to a suitable source of water, or other fluid to be delivered at high pressure.

The inlet passages **80** of each pump **14** terminate into the corresponding pump cylinder **70** and are closed during the discharge stroke of the corresponding pump plunger **74** by an inlet check valve **88** in the form of a disc seatable against a core or valve seat member **140**. As shown in FIG. **6**, a compression spring **90** biases each inlet check valve **88** toward its seat.

Continuing to refer to FIG. **6** in particular, each pump **14** is provided at its axially outer end with an outlet in the form of an axial outlet passage **92** which communicates with the interior of the corresponding pump cylinder **70** through a central port **94** in the corresponding inlet check valve **88**. Disposed in the line of the outlet passage **92** is an outlet check valve **96** biased axially inwardly against an outlet valve seat **98** by a compression spring **100**. As will be apparent, the outlet check valve **96** is seated during the intake stroke of the corresponding pump plunger **74**.

As shown in FIGS. 1, 2 and 5, the axially outer ends of the outlet passages 92 of the two pumps 14 are connected to elbow fittings 102 which, in turn, are connected to tee fittings 104. The latter are interconnected by a ripple filter 106 located alongside of the engine 12 and the pumps 14 and extending substantially the entire length of the hydraulic intensifier 10. The ripple filter 106 is provided therein with a longitudinal bore 108 of relatively large diameter to provide a pulsation reducing chamber of substantial volume. With this construction, the chamber 108 contains sufficient water, or other fluid, to smooth out pressure pulsations, utilizing the compressibility of the fluid.

Discharge or delivery lines 110 for the high pressure fluid are shown as connected to the respective tee fittings 104 to discharge such fluid at both ends of the hydraulic intensifier 10. However, if delivery at one end only is desired, one of the delivery lines 110 may be omitted and the corresponding tee fitting 104 plugged.

Any leakage of the pumped fluid along the pump plungers 74 is bled off at the axially inner ends of the cylinders through passages or passage means 112 having drain lines 114 connected thereto. The drain lines 114 may return leakage to the source, or to waste.

Each pump cylinder 70 has a concentrically layered construction and comprises, as best shown in FIGS. 6 and 7, an outer layer 116, an outer intermediate layer 118, an inner intermediate layer 120 and an inner layer 122. The outer layer 116 includes a tube 124 threaded at its axially inner end on the layer 118 and at its axially outer end on a fitting 126, FIG. 6. Threaded lock collars 128 engage the ends of the tube 124 and another lock collar 130, FIG. 7, threaded on the layer 118 engages the axially outer end of the corresponding spacer tube 16.

The outer intermediate layer 118 is thermally shrunk onto the inner intermediate layer 120, thereby placing the layer 118 in tension and the layer 120 in compression. Prestressing the layer 120 in compression reinforces it by offsetting the tensile stresses produced by the high pressures in the corresponding pump cylinder 70, and reduces its range of cyclic tensile stress.

Preferably, the inner layer or liner 122 is made of a good bearing type metal, such as bronze. To prevent failure of the liner 122 in hoop compression at the high pressures generated within the pump cylinder 70, the liner is provided, as best shown in FIG. 7, with a plurality of axially spaced groups of circumferentially spaced ports 132, the axially spaced groups of ports being separated from each other by external annular seals, such as O-rings 134, carried by the liner and engaging the layer 120. With this construction, substantially the same axial pressure gradient which exists between the liner 122 and the corresponding pump plunger 74 is applied between the liner and the layer 120 outwardly thereof. Thus, the liner 122 is subjected to pressure gradient balancing to minimize the hoop compression stresses developed therein, and thus permitting the use of a compressively weak but good bearing type metal of the nature indicated, which is an important feature.

The inlet and outlet passages 80 and 92 of each pump 14 are formed at least partially in the core members 140 and 142, FIG. 6, which are placed in compression by thermally shrinking a sleeve member 144 and the member 126, respectively, thereon. This reinforces the core members 140 and 142 against the high pressures in the outlet passage 92. More particularly, prestressing the core members 140 and 142 in compression offsets the tensile stresses produced by the high internal pressures, and reduces their range of cyclic tensile stress.

Another important feature in connection with the valving region of each pump 14 is that the inlet and outlet check valves 88 and 96 are arranged in tandem, i.e., in axial alignment. With this construction, discontinuities in highly stressed pulsating-pressure a sections of the pumps 14 are avoided, and clearance volumes are minimized, which are important features.

Another important feature of the invention is that, with the disclosed arrangement of the engine 12 and pumps 14, the engine piston rods 26 and the pump plungers 74 are loaded in compression, thereby avoiding any possibility of tension fatigue failures.

It is important to note that metal-to-metal fits are used throughout the engine 12 and the pumps 14 for all relatively movable parts. No elastomeric or other nonmetallic parts are used for dynamic sealing.

Discussing more general features of the hydraulic intensifier 10, it is sufficiently compact and light in weight that it can be movably mounted for relatively easy maneuvering. At the same time, it is capable of transmitting power in effective quantities. For example, a hydraulic intensifier 10 of the nature disclosed has been constructed which is capable of generating a discharge pressure of 70,000 psi with an operating fluid pressure of 5,000 psi, while transmitting in excess of 50 horsepower, with a total weight for the unit of a little over 500 pounds and a total length of about 11 feet. As will be apparent, such a unit is capable of being maneuvered quite readily.

Although an exemplary embodiment of the invention has been disclosed for purposes of illustration, it will be understood that various changes, modifications and substitutions may be incorporated in such embodiment without departing from the spirit of the invention as defined by the claims which follow.

We claim as our invention:

1. In a hydraulic intensifier operable by a fluid at a relatively low pressure to deliver a fluid at a very high pressure, the combination of:
   a. a fluid operated, double acting, reciprocating engine;
   b. said engine including an engine cylinder containing an engine piston having engine piston rods extending therefrom in opposite directions;
   c. said engine including engine valve means for supplying operating fluid under pressure to opposite ends of said engine cylinder alternately;
   d. said engine valve means including an engine valve body connected to one end of said engine cylinder in axial alignment therewith;
   e. said engine valve means including a tubular engine valve movable in said engine valve body on one of said engine piston rods between operating positions wherein it supplies operating fluid under pressure to opposite ends of said engine cylinder, respectively;
   f. said engine valve means including control means on said one engine piston rod for causing said engine valve to move between its operating positions in response to arrival of said engine piston at the ends of its stroke;
   g. two oppositely facing, single acting, reciprocating pumps respectively located at opposite ends of and in alignment with said engine;
   h. said pumps respectively including pump cylinders connected to said engine cylinder and said engine valve body;
   i. said pumps respectively including pump plungers reciprocable in said pump cylinders and connected to said engine piston rods;
   j. each of the said pumps including inlet and outlet check valves controlling the admission and discharge of the fluid being pumped; and
   k. the cross-sectional area of said pump plungers being small as compared to the net cross-sectional area of said engine piston.

2. A hydraulic intensifier as set forth in claim 1 wherein each of said pumps includes an inlet and an outlet communicating with the outer end of the corresponding pump cylinder and respectively controlled by the corresponding inlet and outlet check valves.

3. A hydraulic intensifier according to claim 2 wherein the inlet and outlet check valves of each of said pumps are axially aligned.

4. A hydraulic intensifier as defined in claim 2 including a pulsation reducing chamber interconnecting the outlets of said pumps.

5. A hydraulic intensifier according to claim 4 wherein said chamber is elongated and extends substantially the full length of said intensifier alongside said engine and pumps.

6. A hydraulic intensifier as set forth in claim 1 wherein each of said pump cylinders has a concentrically layered construction.

7. A hydraulic intensifier as defined in claim 6 wherein each of said pump cylinders comprises prestressed layers.

8. A hydraulic intensifier as set forth in claim 6 wherein each of said pump cylinders incorporates means for minimizing hoop compression in a radially innermost layer thereof.

9. A hydraulic intensifier according to claim 2 including passage means in each of said pump cylinders adjacent its axially inner end for bleeding off any leakage of pumped fluid between such cylinder and the pump plunger therein.

10. A hydraulic intensifier as defined in claim 9 including passage means in said engine adjacent the respective ends thereof for bleeding off any leakage of operating fluid along said engine piston rods.

11. A hydraulic intensifier as set forth in claim 1 including an external passage alongside said engine cylinder and said engine valve body for transferring operating fluid between said engine valve means and the end of said engine cylinder opposite said engine valve means.

12. In a hydraulic intensifier operable by a fluid at a relatively low pressure to deliver a fluid at a very high pressure, the combination of:

a. a fluid operated, double acting, reciprocating engine;

b. two single acting, reciprocating pumps respectively located at opposite ends of and in alignment with said engine and connected to said engine for actuation thereby;

c. the displacement of said pumps being small as compared to that of said engine;

d. each of said pumps including a pump cylinder having a concentrically layered construction and including prestressed layers; and

e. each of said pump cylinders having in a radially innermost layer thereof axially spaced fluid passage means for substantially balancing the internal and external fluid pressures applied to said radially innermost layer at any point along the length thereof to minimize hoop compression in said radially innermost layer.

13. A high pressure pump cylinder as defined in claim 12 including annular seals disposed between each radially innermost layer and the layer radially outwardly thereof and separating said passage means from each other.

* * * * *