

April 9, 1968

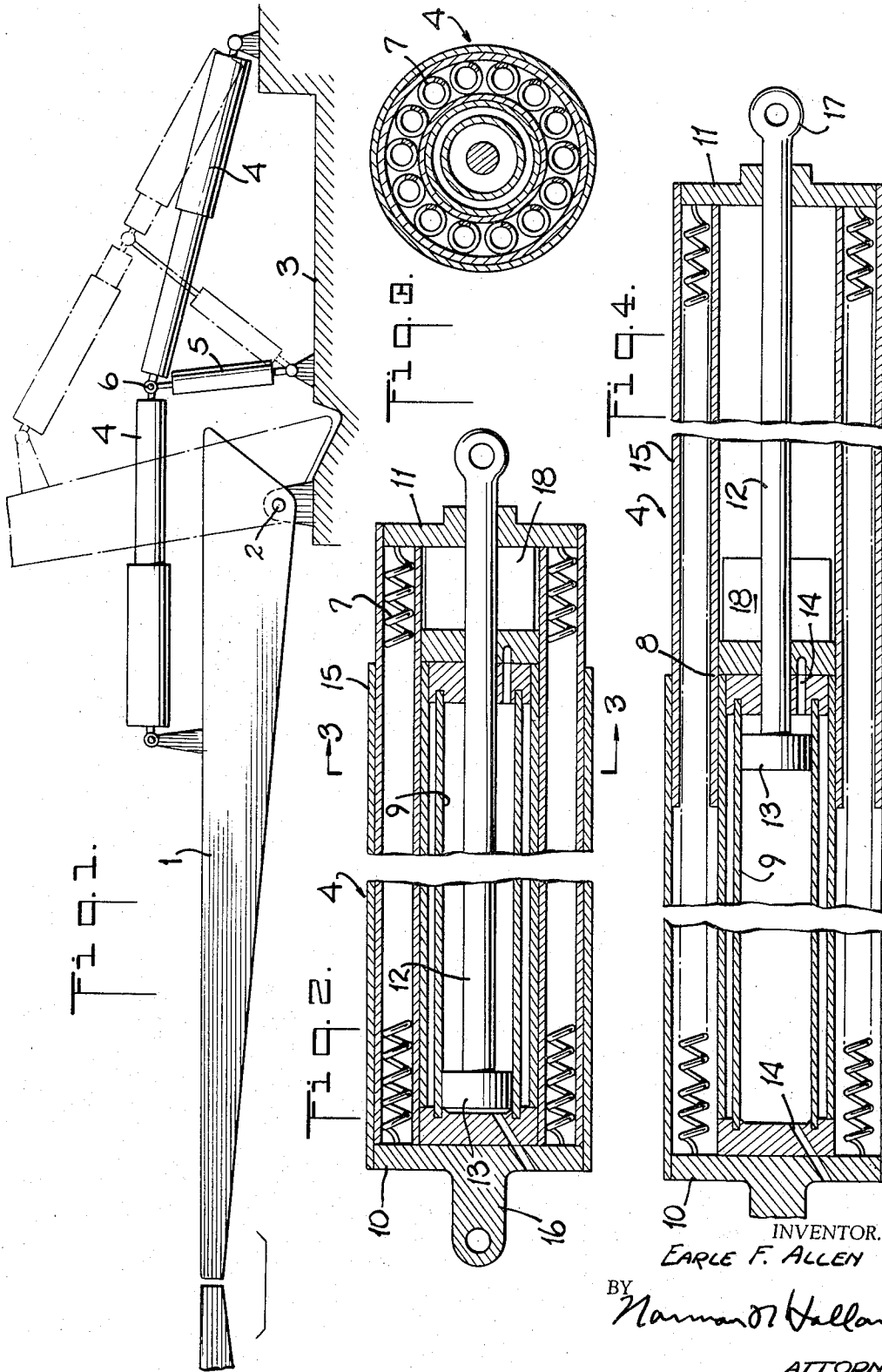
E. F. ALLEN

3,376,795

HYDRAULIC DRIVE CYLINDER

Filed Oct. 21, 1965

3 Sheets-Sheet 1



April 9, 1968

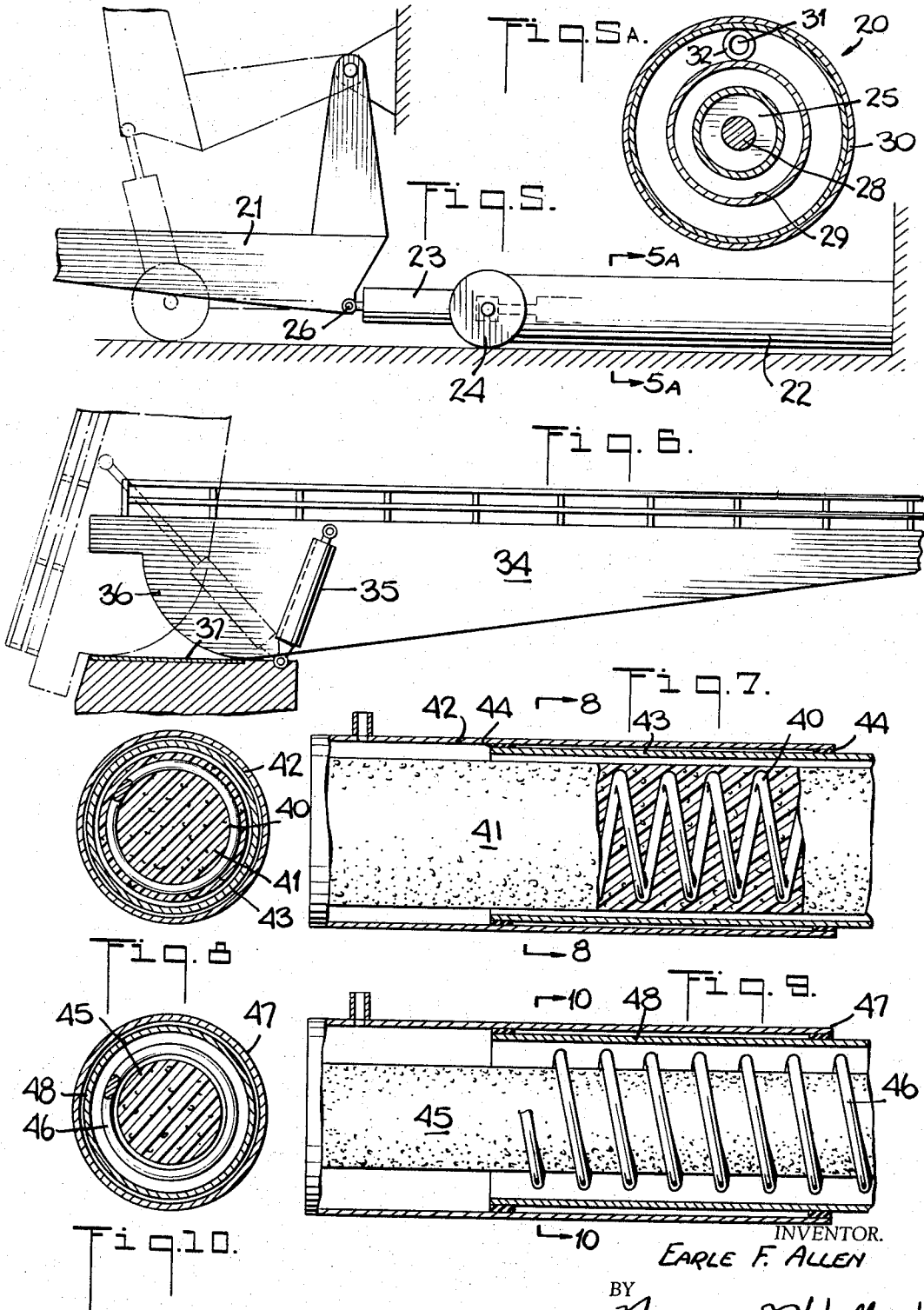
E. F. ALLEN

3,376,795

HYDRAULIC DRIVE CYLINDER

Filed Oct. 21, 1965

3 Sheets-Sheet 2



INVENTOR.
EARLE F. ALLEN

BY
Norman D. Halland
ATTORNEY

April 9, 1968

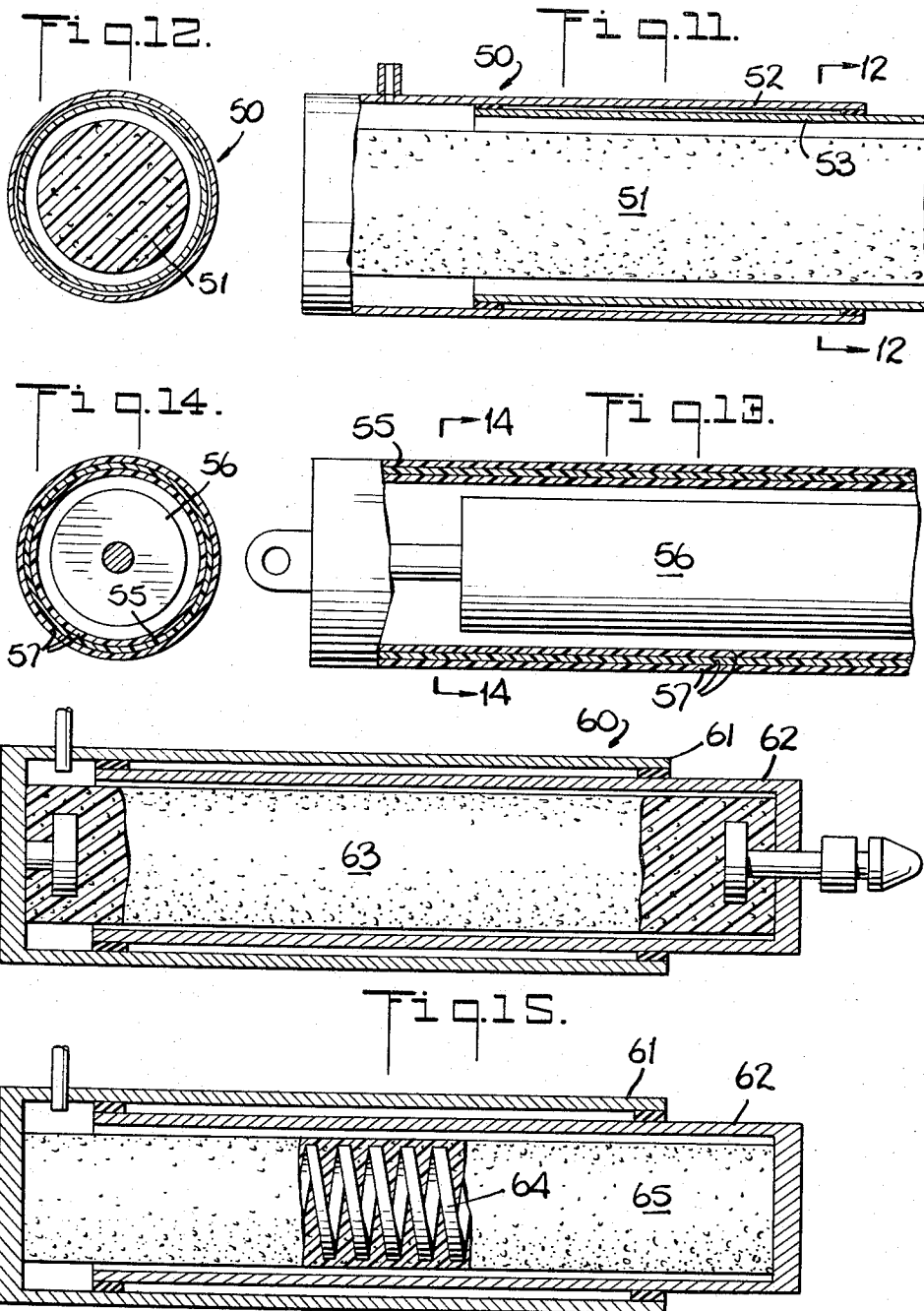
E. F. ALLEN

3,376,795

HYDRAULIC DRIVE CYLINDER

Filed Oct. 21, 1965

3 Sheets-Sheet 3



INVENTOR.
EARLE F. ALLEN
BY *Nathan O. Hallam*
ATTORNEY

1

3,376,795

HYDRAULIC DRIVE CYLINDER

Earle F. Allen, Norwell, Mass., assignor of one-half to
Valentine E. Macy, Jr., New York, N.Y.

Filed Oct. 21, 1965, Ser. No. 499,723

5 Claims. (Cl. 92-130)

ABSTRACT OF THE DISCLOSURE

A hydraulic drive cylinder incorporating a hydraulic motor and having concentrically arranged spring means which acts coaxially with the hydraulic force and stores energy which is used as a counterbalance to the load being moved by the cylinder. The spring means is connected to the oppositely telescoped ends of the cylinder and consists of steel or elastomer or a combination of both. The spring means may also be incorporated in individual hydraulically sealed telescoping cylinders which communicate with their own source of hydraulic fluid. Solid elastomer cylinders with steel springs embedded therein as well as laminated elastomers are also disclosed for use in this device.

The present invention relates to an improvement in hydraulic drive devices and more particularly to an improved hydraulic drive means wherein the drive unit includes an integral energy storage or counterbalancing means. Hydraulic drive cylinders are widely used for power sources and particularly for manipulating relatively heavy structures or loads. In many such applications the power required of the hydraulic drive cylinders is reduced by the addition of counterweights or spring devices on the load which partially offset the gravity forces resulting from the unbalanced nature of driven structures. One example of such a structure is a lift bridge of the bascule type wherein a relatively long bridge span is pivotally mounted at one end for movement between a generally horizontal load supporting position and a raised open position. The power units used to handle such bridges at present are conventionally counterbalanced by massive weights to reduce the power required by the span driving units. Other structures such as derrick or crane booms or heavy tools on construction equipment and the like also are designed with large weights to counterbalance the normally unbalanced movably operated elements.

Where such structures are powered by hydraulic cylinders it has been proposed that these counterweights be eliminated and replaced by storage means such as coil springs mounted in or adjacent to the hydraulic cylinders for providing the necessary counterbalancing force. The power unit of the present invention provides an improved hydraulic drive of this type wherein the novel arrangement of the energy storage members provides an improved combined hydraulic drive cylinder and counterbalancing unit incorporated in an integral structure of minimum size and conveniently adapted for handling very heavy counterbalancing forces without an appreciable increase in the overall size of the power unit itself. These results have been obtained as will be described below by a unique arrangement of the counterbalancing elements and materials and in one embodiment by the use of elastomers or a combination of metallic spring elements with a cooperating elastomer.

Accordingly an object of the present invention is to provide an improved hydraulic drive cylinder.

Another object of the present invention is to provide an improved hydraulic drive incorporating an integral counterbalance or energy storage device.

Another object of the present invention is to provide an improved counterbalancing means incorporating metallic and elastomeric energy storage.

2

Other and further objects of the invention will be obvious upon an understanding of the illustrative embodiment about to be described or will be indicated in the appended claims, and various advantages not referred to herein will occur to one skilled in the art upon employment of the invention in practice.

A preferred embodiment of the invention has been chosen for purposes of illustration and description and is shown in the accompanying drawings, forming a part of the specification, wherein:

FIG. 1 is a side elevational view of hydraulic units in accordance with the present invention applied in the operation of a lift bridge;

FIG. 2 is a vertical sectional view of a preferred embodiment of the hydraulic drive cylinder incorporating counterbalance spring members;

FIG. 3 is a vertical sectional view of the cylinder of FIG. 2 taken along line 3-3 on FIG. 2;

FIG. 4 is a vertical sectional view corresponding to FIG. 2 showing the cylinder in its extended position;

FIG. 5 is a side elevational view of drive cylinders according to the present invention applied to a bridge span;

FIG. 5a is a vertical sectional view taken on line 5a-5a on FIG. 5;

FIG. 6 is a side elevational view of another embodiment of a bridge drive in accordance with the present invention;

FIG. 7 is a vertical sectional view of another embodiment of a drive cylinder in accordance with the present invention;

FIG. 8 is a vertical sectional view of the drive cylinder of FIG. 7 taken along line 8-8 on FIG. 7;

FIG. 9 is a vertical sectional view of another embodiment of a drive cylinder in accordance with the present invention;

FIG. 10 is a vertical sectional view of the drive cylinder of FIG. 9 taken along line 10-10 on FIG. 9;

FIG. 11 is a vertical sectional view of another embodiment of a drive cylinder in accordance with the present invention;

FIG. 12 is a vertical sectional view of the drive cylinder of FIG. 11 taken along line 12-12 on FIG. 11;

FIG. 13 is a vertical sectional view of another embodiment of a drive cylinder in accordance with the present invention;

FIG. 14 is a vertical sectional view of the drive cylinder of FIG. 13 taken along line 14-14 on FIG. 13;

FIG. 15 is a vertical sectional view of an additional embodiment of the drive cylinder in accordance with the present invention; and

FIG. 16 is a vertical sectional view of a still further embodiment of the drive cylinder in accordance with the present invention.

FIG. 1 shows a bridge span 1 pivotally mounted at 2 on a solid abutment 3. The span 1 as illustrated is driven by a toggle-like combination of hydraulic drive cylinders or power units 4 and 5 coupled to a common pivot point 6 and having each of their ends attached to the abutment 3 or span 1 as illustrated. The two main drive cylinders 4 are illustrated in their extended position when the span is at its lower position. As the span is moved to this position and as will be more fully described below a substantial portion of the span weight or moment is counterbalanced by an integral energy storing element spaced concentrically of the cylinders 4 and providing a substantial portion of the force required to raise the span 1 to its open position as indicated in the dash-dot lines.

FIGS. 2 through 4 illustrate a drive cylinder or power unit 4 incorporating such an energy storing means in the form of a plurality of coil springs 7 concentrically mounted about the tubular casing 8 of the hydraulic

cylinder 9 and attached to opposite ends 10 and 11 of the power unit housing and so that the springs 7 are under tension when the unit 4 is in its extended position and when the bridge span 1 is lowered to the position illustrated in solid lines in FIG. 1.

The hydraulic drive 4 including the springs 7 is hereinafter referred to as a power unit. It has a center piston rod 12 and piston 13 slidably mounted in a cooperating and sealed inner cylinder 9 providing the hydraulic drive portion of the power unit 4. Suitable ports 14 are provided for introducing the hydraulic liquid under pressure to the opposite sides of the piston 13. A housing is provided for the counterbalancing springs 7 which comprise 14 springs in the preferred embodiment equally spaced concentrically of the power unit cylinder 9, between spaced and slidably engaged telescoping inner and outer cylinders 8 and 15. A suitable connecting means 16 is provided on the end plate 10 and the end plate 11 fixedly mounts the piston rod 12 which has a convenient coupling 17 provided at its outer end. A fail safe hydraulic brake as described in my United States Patent No. 3,203,513 is illustrated at 18 to lock the piston at any position.

The above described concentric mounting including the telescoping cylinders permits the use of a plurality of smaller springs to be used in a suitable arrangement to provide the necessary counterbalancing force. This use of a number of small springs provides an important and large factor of safety over where the single spring is used and in addition permits a much larger spring force to be used with improved deflection characteristics as will be made clear in the following discussion of a typical design for such power units.

The following description provides an illustration of the relatively great advantages which are obtained by the use of power units in accordance with the invention as applied to the spans of a lift bridge opened and closed by these units. FIG. 1 illustrates a two-span lift bridge spanning a 120 foot channel with each of the spans comprising a 60 by 80 foot leaf formed of conventional designs for such spans and preferably of aluminum so that the individual spans themselves weigh about 168,000 pounds each. Such a leaf under presently used and typical bridge designs would require a counterweight on the inner end of each span to balance the weight of the span. Such a counterweight whose center of gravity is necessarily closer to the span pivot than is the center of gravity of the span itself must be considerably heavier than the span and for a bridge as described would typically consist of a weight of about 600,000 pounds thus adding appreciably to the size and cost of the bridge foundations and the pivots 2.

A drive system will now be described for opening and closing the above described spans in which this extremely heavy counterweight is replaced by a steel spring counterpoise weighing only about 50,000 pounds or elastomer springs or combination steel and elastomer springs weighing only a fraction of the weight of the steel springs.

For the above span, the initial raising is performed by the jacking drive cylinders 5 which may be a conventional hydraulic drive cylinder. To raise the bridge spans from their relatively level position to an inclined position of about 6.5° where the main power units 4 take over the lifting operation, it has been calculated that a pulling force at the bridge connection of about 100,000# is required which requires a drive force from the jacking cylinders 5 of about 44,000#. A counterbalancing force of about 100,000# is now required in power units 4 on each side of the span. In the power units 4 employing fourteen springs of the type illustrated in FIGS. 2 through 4, a spring force in these extended springs of about 7,200# per spring is required. The following calculations show how this requirement may be conveniently met with relatively small springs having an outer diameter of 5 in. and formed of 1 in. diameter spring steel and with each of the springs deflecting about 12 ft. from a relaxed

length of about 18 ft. to an extended length of 30 ft. when the drive cylinders are in the position shown in solid lines in FIG. 1. This is shown by the following typical calculation for a spring of these dimensions:

The following calculations indicates the spring size for providing a counterbalancing spring force of about 100,000# with fourteen springs 7 surrounding the power cylinder 9. This requires a force of about 7,200# from each of the springs 7.

D is the spring coil size and d is the spring wire diameter.

K is a constant for coiled steel.

Assume $D/d=5$ (stress for spring steel), $\tau=120,000$ p.s.i. (acceptable $d=1''$).

For $D/d=5$, $K=1.3$

$$P = \frac{\pi d^3 \tau}{8DK} = \frac{\pi \times d^2 \times 120,000}{8 \times 5 \times 1.3} = 7260d^2$$

Use $P=7200d^2$. For 1" wire $P=7200$ lbs./spring.

Stroke of power units (δ) = 12'.

G = constant for coil spring steel.

$$\text{Number of free coils } n = \frac{Gd^4 \delta}{8PD^3} = \frac{Gd\delta}{8 \times 7200d \times 125} =$$

$$\frac{11.5 \times 10^6 \times \delta}{7.2 \times 10^6} = \frac{1.6\delta}{d}$$

For a deflection of 12', $n=1.6 \times 144=230$ coils.

Closed length of spring = $230 \times 1/12 = 19'$.

Since the above described counterweight springs essentially balance the span weights in the beginning of the lifting operation, the maximum hydraulic force required from the power units is determined by the highest wind pressure forces which must be controlled when the bridge is at its fully raised position of at about 75° as illustrated.

Assuming a wind force of 5# per sq. ft. upon the span of this illustration which has an area of 4,800 sq. ft. the total wind force will be 72,000#. This results in a force on the drive cylinders 4, taking the moment arm lengths into consideration for this bridge position, of 48,000# with an additional 7,500# required to balance the bridge weight at this condition. The power units thus require a drive force of 55,000# which is easily obtained in units having centrally positioned piston with a diameter of about 12 in.

It is therefore seen that a pair of spans providing a 120 ft. overall bridge length are readily controlled by a spring balanced hydraulic drive system including relatively small hydraulic drive cylinders each being only about 3 ft. in diameter and having a length of only about 18 ft. These units replace counterweights weighing as much as 30 tons or more and conventional electromechanical drive systems of great complexity and with correspondingly lower dependability.

FIGS. 5 and 5a illustrate a power unit 20 of the general type described above where the counterbalancing units are in their position of maximum force with the drive cylinder closed and with the spring units compressed. The driven element 21 representing a bridge span or other large pivotally mounted beam or channel is raised and lowered by a drive system including a main drive cylinder 22 and a smaller moving cylinder 23 which are pivotally connected at their adjacent ends to a pair of wide track load supporting wheels 24. As the cross-sectional FIGURE 5a shows, the main drive includes a hydraulic piston 25 which is extended upon application of the hydraulic force to drive the wheels 24 forward and to swing the member 21 from its lower position as indicated in solid lines to its raised position as indicated at dash-dot lines. The smaller drive cylinder 23 is also extended during the raising action to compensate for the upward swing of the coupling point 26 during this action.

The main power unit 22 includes a centrally located hydraulic cylinder piston 25 and piston rod 28 as shown in sectional FIG. 5a mounted concentrically with an inner cylindrical brake surface 29 adapted for engagement with

5

an expanding brake shoe mounted on the piston rod and of the general type illustrated in my United States Patent No. 3,203,513. The outer portion of the main drive power unit 22 comprises telescoping cylindrical cover portions 30 spaced from the brake surface 29 forming an annular cavity in which a plurality of the counterbalancing spring units 31 are positioned. Each spring 31 itself has a pair of telescoping cylindrical guides 32 which extend to permit the expansion of the springs as the springs lengthen towards their normal unstressed condition.

This construction is thus seen to provide the same advantages discussed above for the power unit of FIGS. 2 through 4 in a drive cylinder where the counterbalancing spring force is provided by a plurality of individual units spaced concentrically with and positioned about a central hydraulic drive cylinder and where the springs replace the heavy counterweight and also reduce the drive requirements for the hydraulic cylinders.

FIG. 6 illustrates another bridge structure 34 utilizing a power unit 35 in accordance with the present invention and of the general type described above in connection with FIG. 5 where the counterbalancing springs are compressed when the bridge is in its lowered stage and where the weight of the bridge is counterbalanced by this spring compression. This bridge 34 is of the roller bascule type and is particularly suited for the application of a spring loaded drive device in accordance with the present invention. The springs replace all or a substantial portion of the counterweight so that the roller 36 and track 37 are conveniently positioned in a relatively compact form without the necessity of additional track structure or other support weight to accommodate both the structure of and the substantially increased weight necessary for a conventional counterweighted span.

It has been found that the individual spring units for counterbalancing purposes of the type described herein may be combined with an elastomer such as natural or synthetic rubber to provide spring units where the rubber substantially increases the spring force available in counterbalancing elements of extremely small size. It has been found, for example, that unexpectedly high counterbalancing forces in the neighborhood of 600 p.s.i. to 4000 p.s.i. with a possible usable maximum of 8000 p.s.i. with 160% elongation may be obtained and retained for many years of operation even under conditions of constant stress.

For example, in a power unit such as described above and illustrated in FIGS. 2 through 4, the 5" diameter springs used in the numerical example may be replaced by a series of 5" diameter rubber elements similarly positioned and anchored at opposite ends of the drive and which provide 10,000# per rubber unit as contrasted with the 7,200# counterbalancing force by the spring described above. It is thus clear that the elastomer units of this type may be designed for providing similar driving forces and having a decreased outer diameter.

In addition it has also been discovered that a particularly useful counterbalancing unit may be formed from combined spring steel and elastomer units to obtain an extremely efficient counterbalancing element making full utilization of the space available and also providing the advantage that the failure of one material will be at least partially offset by the counterbalancing action of the remaining material.

As indicated above the elastomer may be used as a direct substitution for the spring units, as for example, where 14 rubber tubes are used to replace the cold springs 7 of the power unit as illustrated in FIGS. 2 through 4.

FIGS. 7 and 8 illustrate a combination spring and elastomer unit which may replace the individual spring units such as are shown in FIG. 5a. In FIG. 7 springs 40 are shown embedded or molded into the elastomer element 41 with the molding being done so that the elastomer and the spring are in their relaxed position. Thereafter

6

they may be applied either in a compressed or stretched position depending upon whether the power unit is to provide its counterbalancing force in its closed or extended position. The unit illustrated in FIGS. 7 and 8 has a pair of telescoping outer members 42 and 43. The end surfaces of the telescoping support members have fluid seals 44 at their edges. This permits the addition of hydraulic forces to supplement the forces of the elastomer and springs.

FIGS. 9 and 10 illustrate a spring counterbalancing unit generally similar to that shown in FIGS. 7 and 8 except that the elastomer 45 is positioned within the spring coils 46 so that the spring 46 and the elastomer 45 may be separately formed and assembled within the outer telescoping cylinders 47 and 48. This unit may be employed in the same manner as FIGS. 7 and 8.

FIGS. 11 and 12 show tubular counterbalancing elements 50 which also replace the springs such as are illustrated in FIGS. 5 and 5a and where the entire spring force is replaced by an elastomer. In this embodiment the elastomer 51 is mounted in the individual telescoping cylindrical members 52 and 53 so that the elastomer may be stretched or corked by a relatively low capacity hydraulic system which supplies fluid within the telescoping members 52 and 53 to extend the members and to stretch the elastomer preparatory to the application of the counterbalancing force to the member. For example, the stretched elastomer might be used to provide a counterbalance for a dump truck bed so that the elastomer elements may be tensioned by a low capacity hydraulic system during the time that the dump truck is being loaded or is moving between pick-up and discharge points. Such a system permits the stretch or build-up of a relatively large lifting force from a low capacity hydraulic charging unit.

FIGS. 13 and 14 illustrate the use of an elastomer 55 for providing a counterbalancing force in connection with a hydraulic drive cylinder 56. In this embodiment the elastomer 55 is mounted concentrically of the hydraulic drive cylinder 56 with the tubular elastomer having a plurality of laminations 57. In this way, the series of laminations provide for increased reliability as the laminations apply their force independently of each other to provide a more even force and to provide an element of safety in the event of failure of one of the laminations.

FIG. 15 shows a hydraulic drive cylinder 60 including telescoping outer cylindrical members 61 and 62 sealed to contain the hydraulic drive forces and including a central elastomer element 63 anchored at the opposite ends of the cylinder. This takes advantage of the extremely high counterbalancing forces which it has been found may be obtained with such elastomers and provides an extremely compact and efficient power unit with an integral counterbalancing element.

The embodiment illustrated in FIG. 16 includes a steel spring 64 molded within the elastomer element 65 to provide a composite counterbalance providing a certain amount of metallic support for the elastomer as well as the combined forces of the steel and rubber which add an additional element of safety in the event of the failure of the one or the other counterbalancing elements.

It will be seen that this invention provides important improvements in the hydraulic drives for use with driven members requiring counterbalancing forces. The power units of the invention provides these counterbalancing forces with integrally supported spring or elastomer elements or a combination of both and the various preferred mountings for these elements as described herein result in an extremely compact and reliable power unit which is useful in many applications which previously required relatively cumbersome drive units and extremely heavy counterweights.

In addition the power units described herein provide drive units adapted for handling heavy devices or members with considerable safety as the integral construction

provides for counterbalance and driving and also is adapted for the convenient adaptation of fail safe brake elements all within the compact package described.

The novel applications of small distributed springs and also the novel use of elastomers alone or in combination with springs provides relatively large counterbalancing forces in units only slightly larger than those including only the hydraulic drive system itself. In this way not only has an improved power unit been provided but the weight and size of the entire structure may be reduced due to the elimination of the conventional counterweights or extremely heavy prior hydraulic drives or electro-mechanical drive systems.

As various changes may be made in the form, construction and arrangement of the parts herein without departing from the spirit and scope of the invention and without sacrificing any of its advantages, it is to be understood that all matter herein is to be interpreted as illustrative and not in a limiting sense.

Having thus described my invention, I claim:

1. An hydraulic drive device comprising the combination of an hydraulic drive motor having an hydraulic cylinder and cooperating piston and a piston rod, a first pair of telescoping cylinders mounted concentrically and in spaced relationship to said hydraulic cylinder and forming an annular cavity with said hydraulic cylinder, one end of one of said telescoping cylinders being coupled to the piston rod, one end of the other of said telescoping cylinders being coupled to said hydraulic cylinder, a plurality of spring elements mounted in spaced relationship in said cavity and operatively connecting said ends of said telescoping cylinders and each of said spring elements being enclosed in second telescoping cylinders, said second telescoping cylinders operatively connecting said ends of said first pair of telescoping cylinders, and said second telescoping cylinders being hydraulically sealed and adapted for being coupled to a source of hydraulic fluid.

2. The hydraulic drive device as claimed in claim 1 in which said spring elements comprise elastomer and steel.

3. The hydraulic drive device as claimed in claim 1 in which said spring elements comprise steel coil springs.

4. The hydraulic drive device as claimed in claim 1 in which said spring elements comprise elastomer with steel spring embedded therein.

5. The hydraulic drive device as claimed in claim 1 in which said spring elements comprise an elastomer inner element surrounded by a steel coil spring.

References Cited

UNITED STATES PATENTS

15	2,408,915	10/1946	Cones	92—132	X
	2,461,780	2/1949	Smith	92—130	X
	2,497,489	2/1950	Coursen et al.	92—130	X
	2,535,600	12/1950	Rappl	92—132	X
	2,605,099	7/1952	Brown	267—33	
20	2,851,011	9/1958	Chasser	92—132	X
	2,896,583	7/1959	Stixrood	92—132	X
	3,208,767	9/1965	Moulton	267—33	X
	3,298,664	1/1967	Dixon	92—130	X
25	3,308,496	3/1967	Mooney et al.	14—36	

FOREIGN PATENTS

	487,735	11/1952	Canada.
	926,475	4/1947	France.
30	326,477	3/1930	Great Britain.

OTHER REFERENCES

Engineering News-Record, "Hydraulics Operate Bascule Span," May 2, 1963, page 33.

35 MARTIN P. SCHWADRON, *Primary Examiner.*

I. C. COHEN, *Assistant Examiner.*