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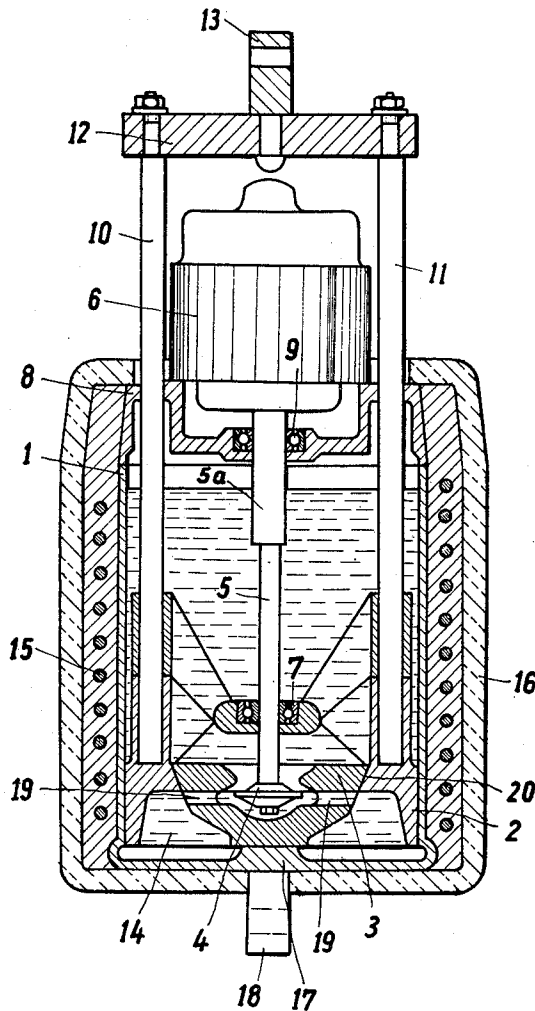
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ELECTROHYDRAULIC ADJUSTING APPARATUS

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4 Sheets-Sheet 1

Fig. 1



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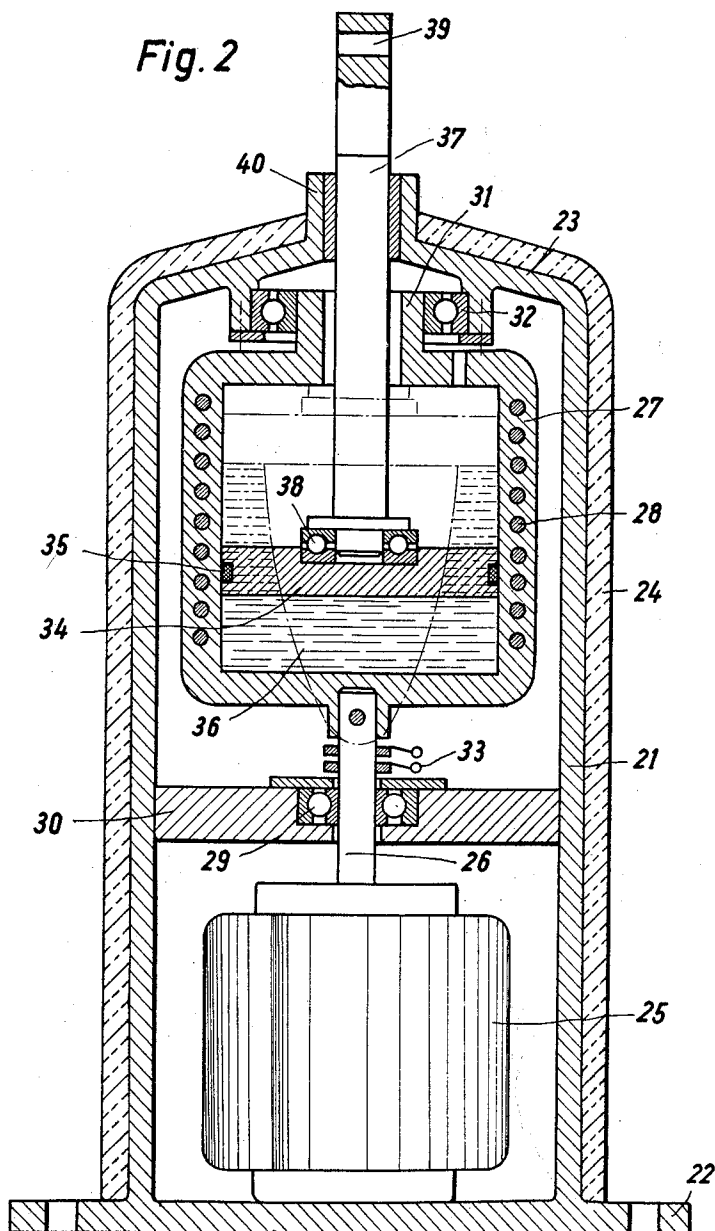
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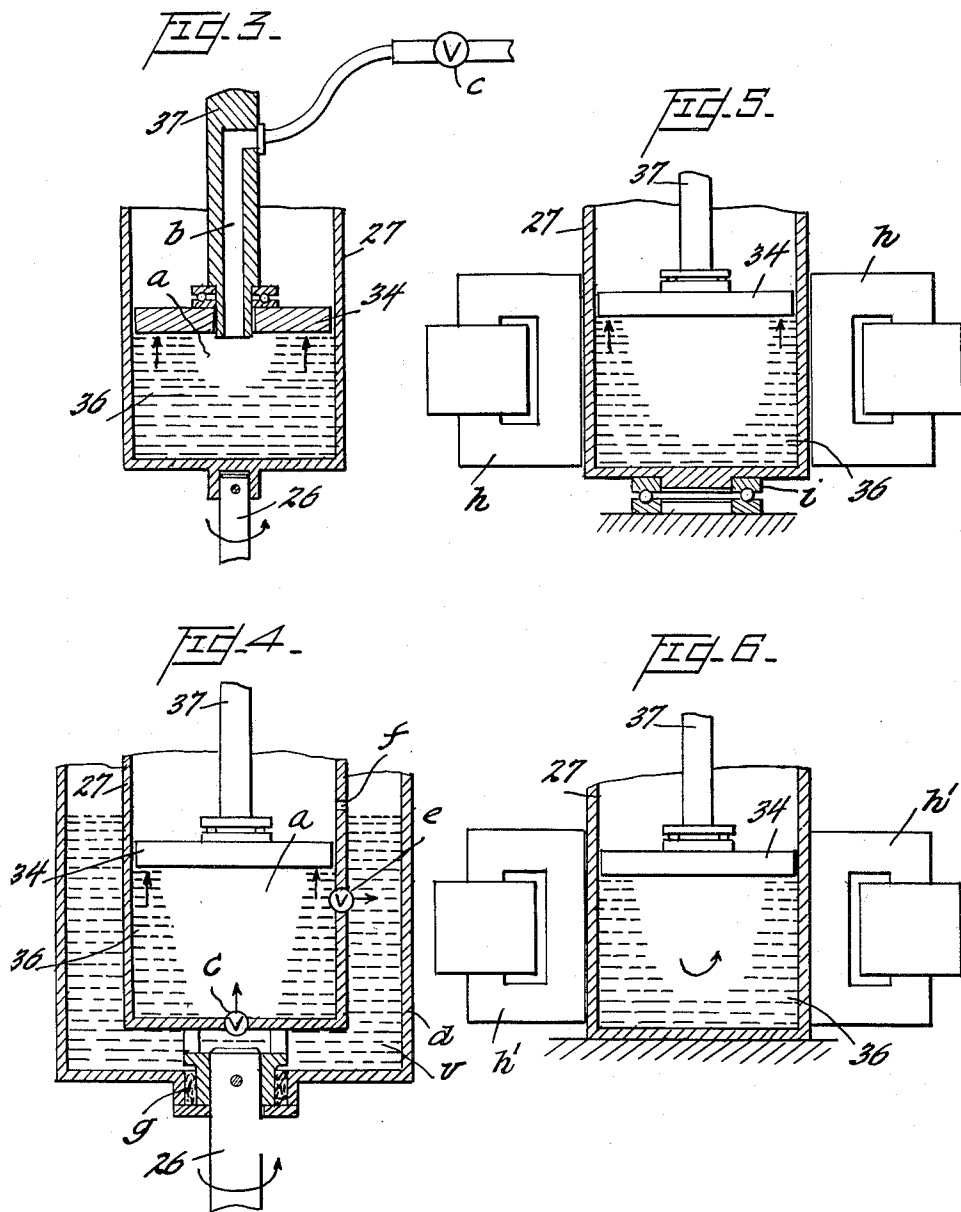
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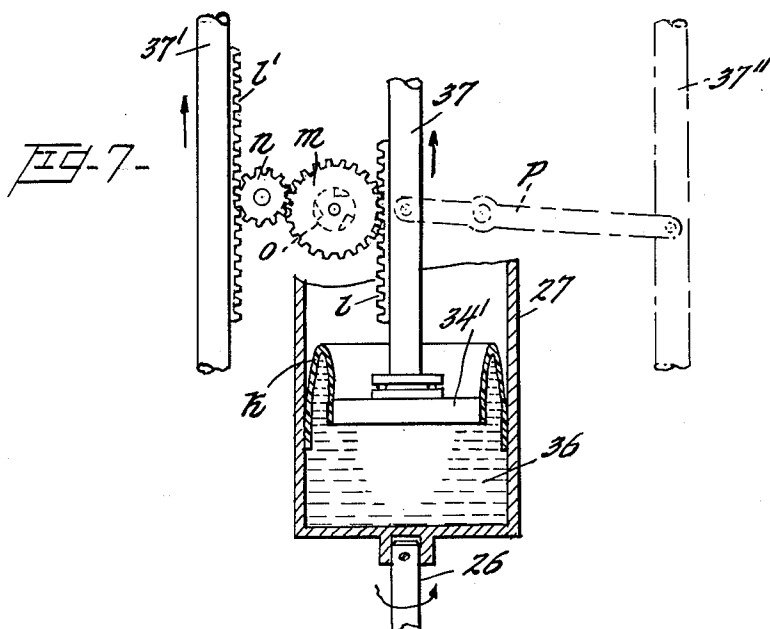
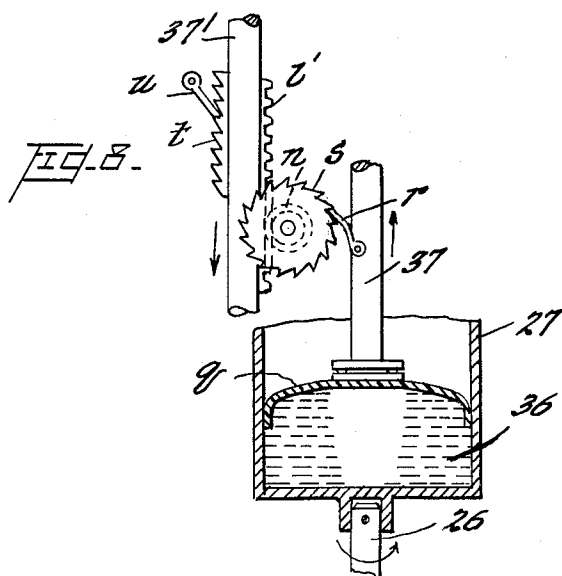
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ELECTROHYDRAULIC ADJUSTING APPARATUS

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4 Sheets-Sheet 4



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ELECTROHYDRAULIC ADJUSTING APPARATUS
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 Claims priority, application Germany Feb. 26, 1960
 15 Claims. (Cl. 60—52)

The invention relates to an electrohydraulic arrangement for converting a rotating movement into a reciprocating movement, such as, for example, an electrohydraulic adjusting and lifting apparatus having a piston guided adjustably in a cylinder and to which the pressure of a liquid operating medium is applied. Owing to the effect of this application of pressure the piston moves within the cylinder and, according to the pressure of the operating medium, exerts a greater or lesser adjusting force at the piston rod of the apparatus. This adjusting force can then be put to use for the most diverse engineering purposes, for example for operating brakes, valves, control equipment, machine tools, such as punching machines, shears, and also for controlling couplings, doors, grilles and the like.

In view of the great importance of adjusting and lifting arrangements of this kind for engineering in general, they have become known in a variety of constructional forms. In the majority of these arrangements, the design is such that a piston is arranged to be slidable in a working cylinder and a centrifugal or geared pump driven by an electric motor is mounted in the base of said piston. In the piston body ducts are provided through which the operating medium of the pump can pass from one side of the piston to the other.

In operation, this pump produces a pressure difference between the two sides of the piston which is then available as the adjusting force acting at the piston rod. This pressure difference, and thereby also the adjusting force acting at the piston rods, depends, inter alia, on the specific gravity of the operating medium. In addition to oils of a special type, other liquids such as, for example, Clophen, have therefore also already been proposed as an operating medium, and in this way increases in the lifting force of 1.5 to 1.8 times the value of special type oils have been achieved.

Furthermore, German Patent 363,427, dated November 9, 1922, discloses an arrangement for converting a rotating movement into a reciprocating movement which is characterized in that the pressure of a quantity of liquid in rotation is made to act on one or more freely movable pistons in such manner that by altering the speed of rotation of the apparatus the piston or pistons are reciprocated. In this arrangement, which, however, has evidently not been used hitherto for hydraulic adjusting equipment, but must probably be rated only as the state of the art on paper, solely, normal liquids have been referred to as the operating medium.

The problem set by the invention is to increase the capacity of such adjusting apparatus, i.e. the power available at the piston rod, suddenly and by a multiple and obtain piston forces which can otherwise be attained only with the means of pure hydraulics and, in this way, to create the conditions for the use of such adjusting and lifting apparatus on the broadest basis.

According to the invention, this aim is achieved in that, instead of the liquids customarily employed heretofore, metals or metal alloys, preferably those which have a melting and solidifying point between about 60–200° C., such as, for example, Wood's alloy or Lipowitz alloy, are used as operating medium for the apparatus, these metals being brought into the liquid state, or a state in which they are capable of flowing, when or before the apparatus is

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put into operation. Thus, within the scope of the invention, the operating media employed are media which, in the operative state of the apparatus, could be described so to speak as very heavy liquids with properties similar to those of mercury and which, accordingly, are also capable of producing effects of a very special kind on the driven side of the apparatus concerned. As compared with mercury, however, the very heavy liquids used within the scope of the invention have the advantage that they are substantially cheaper and easier to handle and, in particular, they are non-poisonous and harmless in use.

The liquefaction of the metals or metal alloys used within the scope of the invention may be effected in many different ways. However, in most cases, liquefaction by electric heat will be preferred, for example resistance, induction or eddy-current heating means will be employed, such as are customary, moreover, in modern metallurgy, especially as such heating means can be manufactured so that they are particularly simple, space-saving and reliable in operation.

In order to exclude damage and premature aging of the operating medium through oxidation and other chemical processes it may be advantageous to keep or store the fusible metal under an atmosphere of protective gas or some other suitable protective layer. According to another feature of the invention, undesirable overheating of the metal can be avoided in simple manner in that the operating temperature of the apparatus is controlled by means of a thermostat or the like. The consumption of heat for liquefying the metal and keeping it hot may be very low if the apparatus itself, and in particular those parts or surfaces which are in contact with the hot metal, are protected against heat losses by means of an insulating jacket. In these cases, the metal is in a liquid state shortly after the heating has been switched on, so that with suitable design the apparatus is ready for use within a short time. During the period of operation, the thermostat provides constant readiness for use, the insulating jacket ensuring that the consumption of electric energy for maintaining the liquid state of the operating medium remains within reasonable limits.

An additional essential feature of the invention is the fact that, with suitable design and control of the heating means, it is also readily possible to obtain by means of the operating medium itself a rigid and form-locking clamping or fixing of the piston in the desired end position quite simply by causing the metal disposed below the piston to solidify. The piston can then be supported directly against the solidified underlayer of metal in the position in question and thereupon take over even large forces in this position with the drive switched off. This circumstance is very important, inter alia, for the application of the adjusting and lifting means according to the invention as clamping devices and the like in conjunction with machine tools and/or within the limits of automation.

Other details of the invention will be described with reference to two examples of embodiment which are illustrated as follows in the drawing:

FIG. 1 is a longitudinal section of an electrohydraulic adjusting apparatus of conventional type which, however, is arranged for the purposes of the invention,

FIG. 2 is likewise a diagrammatic longitudinal section of another embodiment of an adjusting apparatus, namely an adjusting apparatus having a rotating cushion of liquid below the working piston, and

FIGS. 3 to 8 are vertical cross sections showing various modifications of hydraulic adjusting apparatus.

In the case of the embodiment according to FIG. 1, the adjusting apparatus consists in the manner heretofore customary and known of a cylinder body 1 in which a

piston body 2 is slidably guided. In the base 3 of the piston body there is mounted a centrifugal pump 4 driven by way of a multi-spline shaft by an electric motor 6. The multi-spline shaft 5 and the associated part 5a of said shaft which is located at the end where the motor is arranged are supported, on the one hand, in the bearing 7 mounted on the piston and, on the other hand, in the bearing 9 arranged on the cover 8 of the housing. During the movements of the piston 2, 3, the multi-spline shaft 5 can slide telescopically in the part 5a.

Furthermore, on the piston body 2, 3 there are also fitted two rods 10, 11 extending through bores in the cover 8 of the housing and connected at the top by means of a transverse yoke or cross bar 12. The latter serves as a support for the eye 13 which, for example, establishes connection with a shoe brake or some other device on which a short stroke movement is to be impressed by means of the hydraulic adjusting arrangement.

The space above and below the piston 2, 3 is filled with the operating medium 14 which, according to the invention, consists of a liquefied metal of low melting point, for example Wood's alloy. In the case illustrated in the drawing, the liquefaction of the metal required before the apparatus is put into operation is effected by means of a heating coil indicated at 15. Externally, the assembly as a whole is protected against heat losses by means of an insulating material 16. In the case shown, the reaction forces of the apparatus are taken up by means of an eye 18 mounted on the base portion 17 of the cylindrical housing 1, said eye being coupled, for example, to a fixed support.

The embodiment according to FIG. 1 operates in the following manner:

In the basic position, the parts are in the position shown in FIG. 1. In order to set the apparatus into operation, the heating coil 15 is first switched on and the easily fusible metal alloy 14 is thereby rapidly liquefied, for example similarly to the method employed in an induction furnace, outwardly from the inside by short-circuit heat or the like. The motor 6 can then be switched on and the pump impeller 4 thereby set in operation. Said impeller delivers the liquid contained in the cylinder 1 from the upper side of the piston by way of the ducts 19 into the cylinder space associated with the lower side of the piston. The liquid pressure acting in this process on the underside of the piston and which, having regard to the operating medium provided according to the invention, is a multiple of that of the known arrangements filled with oil, causes the raising of the piston 2, 3, the conical sealing surface 20 establishing a force-locking connection of the two piston parts 2, 3. The lifting movement of the piston 2, 3 lasts until the upward travel of the piston is limited in some manner. Return of the piston may be effected, for example, by the weight of the movable parts themselves, by springs, or by the restoring force of the device or arrangement connected to the adjusting apparatus. In this process, the parts 2, 3 of the piston are lifted away one from the other in the region of the sealing surface 20, so that the operating medium can flow through the free opening formed. Constant readiness for use of the apparatus may be ensured, for example, by means of a thermostat which switches on the heating means 15 if required during any intervals in operation. If the construction is suitable, very low heating powers are sufficient in this case for keeping the medium 14 liquid, for example if the radiation of heat is kept low by means of an insulating material 16.

Whereas in the normal adjusting apparatus using, for example, an oil or Clophen charge, the motor must remain switched on constantly, so as to hold the piston in the upper end position, in the case of the invention it is sufficient for this purpose to switch off the heating for the coil 15 and/or connect up a suitable cooling system. In this way, in fact, solidification of the operating medium 14 is obtained, so that the latter fixes the piston 2, 3 rigid-

ly against downward movement. According to the invention, the piston 2, 3 can therefore be fixed in any desired position and for any period practically speaking by a formlocking action by means of the solidifying operating medium. This fact is particularly important for the use of such adjusting apparatus in conjunction with working machines, for example clamping devices for such machines. In the known arrangements, special locking devices have to be provided in addition in these cases for fixing the piston in position, or at least the pump must be left running continuously for the duration of the clamping period. The latter, however, easily results in overheating of the operating liquid.

In accordance with the invention, it is particularly advantageous to employ as operating medium those easily fusible alloys which have a melting and solidifying point between 60–200° C. Alloys of this kind are described, inter alia, in the Journal of the VDI (Association of German Engineers), volume 62 of August 3, 1918, on pages 517 and 518.

The embodiment according to FIG. 2 illustrates diagrammatically another type of hydraulic adjusting and lifting apparatus. In this case, in a housing 21 having a base 22, a top 23 and a heat-insulating jacket 24 there is housed an electric motor 25 which sets a cylinder 27 in rapid rotation by means of the shaft 26. In the case illustrated in the drawing, this cylinder is heated by a heating coil 28, accommodated in the wall. Of course, it would also be possible to employ radiant heating or the like instead of this method of heating. The shaft 26 is mounted by means of a ball bearing 29 in the partition 30 of the housing 21. The free end of the cylinder 27 is supported at 31 by means of a ball bearing 32 mounted in the top 23 of the housing. In the case of FIG. 2, slip rings 33 are also provided on the shaft 26 and serve to conduct the current.

A disc piston 34 is arranged to be longitudinally slidable in the cylinder 27 and is sealed with respect to the cylinder wall by means of an O-ring 35. Below said piston is the operating medium 36 which, as in the case of FIG. 1, consists of an easily fusible alloy, for example Wood's alloy.

In order to achieve a particularly good application of pressure to the disc piston 34, the space below said piston may be connected to a storage chamber rotating, for example, with the cylinder 27 and from which operating medium can flow from outside to the underside of the piston.

Between the disc piston 34 and the push rod 37, which transmits the piston forces to the device or apparatus concerned, there is disposed a longitudinal ball bearing 38. In this way, relative movements in the peripheral direction between the disc piston 34 and the cylinder 27 can be largely avoided. On the contrary, if the friction between the packing 35 and the inner wall of the cylinder 27 is adequate, the disc piston will revolve substantially synchronously with said cylinder and finally perform only reciprocating movements due to the effect of the centrifugal force acting on the operating medium 36. The piston rod 37 is provided at the top with a bore 39 for connection to the device or apparatus to be operated or with a suitably designed connection eye. Finally, a collar 40 is provided on the top of the housing for guiding the piston rod laterally. The arrangement according to FIG. 2 operates in the following manner:

In the initial position, the parts are located substantially as shown in FIG. 2. Thus, there is a certain supply of operating medium below the piston in form of, for example, solidified Wood's alloy. This supply of operating medium disposed below the piston may be made smaller if, as indicated above, there is associated with the cylinder 27 a storage chamber for additional operating medium which, for example, is arranged concentrically with said cylinder and revolves with it. When the motor 25 is switched on, the cylinder 27 is set in rotation.

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As long as the heating means 28 has not been switched on, the disc piston 34 remains in the position shown in the drawing. If, however, the heating means 28 is now set in operation, and the operating medium 36 is converted to the liquid state, or the state in which it is capable of flowing, an annular structure of liquid metal is immediately formed below the disc piston 34, said annular structure being indicated in FIG. 2 by chain-dotted lines. This ring of liquid metal exerts a powerful pressure effect on the underside of the disc piston 34, so that the latter moves into the position shown in chain-dotted lines. The adjusting force which is released in this process can be taken off at 39. At relatively low speeds of the cylinder 27, the annular body of liquid metal has substantially the form of a paraboloid of rotation, while at higher speeds it assumes more and more the form of a hollow cylinder. As already mentioned above, an application of pressure to a particularly large area of the disc piston 34, and thereby also particularly large adjusting forces at the piston rod 37, 39, can be obtained by connecting the space below the disc piston 34 to a storage chamber from which liquid operating medium can flow in below the piston 34. In this way, a substantially constant application of pressure to said piston can readily be obtained for the entire duration of the piston stroke. However, it is also possible to obtain special effects by a controlled application of pressure, when, for example, throttling or control means having a suitable characteristic are fitted in the connecting conduit between the space below the piston and the storage chamber. As soon as the force exerted by the ring of liquid is in equilibrium with the counter-force acting on the piston rod 27, the movement of the disc piston 34 ceases without special safety measures being required for this purpose and without any additional load on the operating medium occurring as in the case of conventional adjusting arrangements. If the heating means is switched off in the desired position of the piston, solidification of the operating medium occurs rapidly and thereby also a corresponding fixing in position of the disc piston 34, in a manner exactly similar to the case of FIG. 1.

The apparatus according to FIG. 2 is also immediately suitable for mounting in a horizontal operating position, since, with a sufficient speed of the cylinder 27, the ring of liquid develops practically similarly in any position.

FIG. 3 shows a space *a* below the piston 34 which is in communication through a channel *b* in the piston rod 37 with a container, not shown, for the driving medium 36. There is provided a valve *c* in the connecting line. The non-rotary piston rod 37 is provided in such a way that it passes through a central opening of a sufficient size in the rotation piston 34 so that while the drive takes place the driving medium will be fed from the container to the space *a*.

FIG. 4 shows a pressure chamber *a* below the piston 34 in which a central opening is provided in the bottom of the cylinder 27 which by means of a valve *c* is connected to a container *d* which is non-rotatable. The container *d* is thus provided entirely around the cylinder 27. In the wall of the cylinder 27 there is provided a control opening *f* or a valve *e* through which the driving medium 36 can flow under the action of centrifugal force from the cylinder 27 to the container *d*. In order to provide a tight fit for the container *d* where the rotary drive shaft 26 passes through, it is necessary to provide a stuffing box *g*.

FIGS. 5 and 6 show a cylinder 27 which is surrounded by a magnetic system *h* which will set the driving medium 36 into rotation by means of an electrical rotary field. In the structure according to FIG. 5 there is thus mounted a cylinder 27 on an axial bearing *i*, so that it will rotate with the driving medium. Between the magnetic system *h* and the cylinder wall there must of necessity be provided an air space. By means of the form of appa-

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ratus of FIG. 6 there is provided a driving medium 36 which is set in rotation by the magnetic system *h'*. The cylinder 27 shall not rotate therewith, so that the magnetic system *h'* directly abuts against the cylinder wall.

FIG. 7 shows the operating piston consisting of a piston plate 34' which is connected by a diaphragm *k* with the cylinder 27. The piston plate 34' can be moved by the operating medium 36 the length of the cylinder 27 as governed by the diaphragm *k* connected to the piston 34'. By means of this modification there is further an arrangement provided between the diaphragm *k* and the driving point of the structure which is a device to increase the vertical movement. The piston 37 is provided with a toothed rod *l* which meshes with toothed gear *m*. This gear *m* meshes with a further gear *n* which transfers its movement to an operating rod 37', and actually by means of a toothed rack *l'* which is secured on an operating rod 37'. The gear *m* is also provided with a free running clutch *o* which is part of the transmission.

By means of dot and dash lines there is also shown in FIG. 7 a modification in which a lever *p* shows a simple lifting device. The lever *p* may be of a different length as to its pivot point and acts on the rod 37' to move the latter vertically.

FIG. 8 shows piston structure as a small pressure plate connected to a diaphragm *q* to the cylinder wall 27. As a connecting device there is provided a ratchet wheel *s* which is operated by a pawl *r* connected to the rod 37. The wheel *s* is connected by a gear to a toothed rack *l'* which will transfer movement to the rod 37' and by means of the teeth *t* on the toothed rod 37' prevents an undesired return movement of the rod 37'.

The invention is naturally not limited to the embodiments illustrated, but, on the contrary, these are intended only to make the basic idea of the invention comprehensible. Thus, for example, a metal powder which is already capable of flowing or trickling at room temperature and having liquidlike properties could also readily be used as operating medium instead of an easily fusible metal. Such metal powders, consisting of ferromagnetic particles, have become known, for example, as operating media for magnetic powder couplings and/or brakes.

The rotating movement of the operating medium 36 required in the case of FIG. 2 may also be obtained in a manner other than that described, for example by exposing said operating medium to the effect of a rotating or travelling electric field.

Furthermore, the disc piston illustrated in FIG. 2 could readily be replaced by a roll bellows, a diaphragm or a similar element. In order to adjust the comparatively short stroke of such elements to the desired prescribed stroke, a stepping mechanism or an arrangement for doubling or multiplying the stroke could be interposed between the roll bellows or the diaphragm, on the one hand, and the power take-off point of the apparatus, on the other hand.

Furthermore, it is also readily conceivable, within the scope of the invention, to stop the piston in any desired position by, for example, fitting in the wall of the cylinder 27 valves or control devices through which the rotating operating medium can flow back into the storage chamber in a cyclic course.

What I claim is:

1. Electrohydraulic apparatus for converting a rotary movement, by means of pressure developed in an operating medium as a result of the said rotary movement, into a linear movement, comprising a cylinder, a piston mounted to reciprocate in the cylinder, and means to direct the pressure of the operating medium into the cylinder, the said operating medium being selected from a group consisting of a metal and a metal alloy which is in a fluent condition at least during the operation of the apparatus.

2. Electrohydraulic apparatus as claimed in claim 1, in

which the metal has a melting point below 200° C. and is brought to the fluent condition by melting the metal.

3. Electrohydraulic apparatus according to claim 1, wherein said metal is brought to the liquid state by means of induced currents.

4. Electrohydraulic apparatus according to claim 1, in which the metal is maintained in an atmosphere of a protective gas.

5. Electrohydraulic apparatus according to claim 1, in which a thermostat is provided so that the operating temperature of the medium is controlled by means of the thermostat.

6. Electrohydraulic apparatus according to claim 1, wherein the liquid metal is permitted to solidify when the piston has been raised to a predetermined position, the solidified metal serving to retain the piston in said raised position.

7. Electrohydraulic apparatus according to claim 1, wherein a jacket of heat insulating material is provided so that at least the part which comes in contact with the liquid metal is enclosed by the jacket of heat insulating material.

8. Electrohydraulic apparatus according to claim 1, wherein a pump is provided in the lower end of the cylinder, said pump being operable to cause the operating medium in the cylinder to flow from the upper to the lower side of the piston.

9. Electrohydraulic apparatus according to claim 1, wherein the piston is reciprocally mounted in the cylinder which is rotated about its axis at such speed as to cause the operating medium to move under centrifugal force and thereby impart a linear movement to the piston.

10. Electrohydraulic apparatus according to claim 1, wherein a rotating electric field is provided so that the operating medium is set in rotation by means of the rotating electric field.

11. Electrohydraulic apparatus according to claim 1,

wherein a piston rod is provided for the piston and an axial ball bearing is provided as a pivot bearing connected to the piston rod.

12. Electrohydraulic apparatus according to claim 1, wherein a sealing gland is provided for the piston to make a sliding sealing engagement with the cylinder.

13. Electrohydraulic apparatus according to claim 1, wherein a storage vessel for the operating medium is provided so that the space in the cylinder containing the operating medium is connected with the storage vessel.

14. Electrohydraulic apparatus according to claim 1, wherein control devices are provided arranged in the cylinder wall so that the operating medium can flow there-through from the cylinder at a pre-determined time and pressure under the effect of centrifugal force.

15. Electrohydraulic apparatus according to claim 1, wherein a bellows is provided connected to the piston and the cylinder, and in which stepping mechanisms are provided between said bellows and the power take-off point of the apparatus for multiplying the stroke with the comparatively short stroke of the bellows being converted into a long stroke at the power take-off point.

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