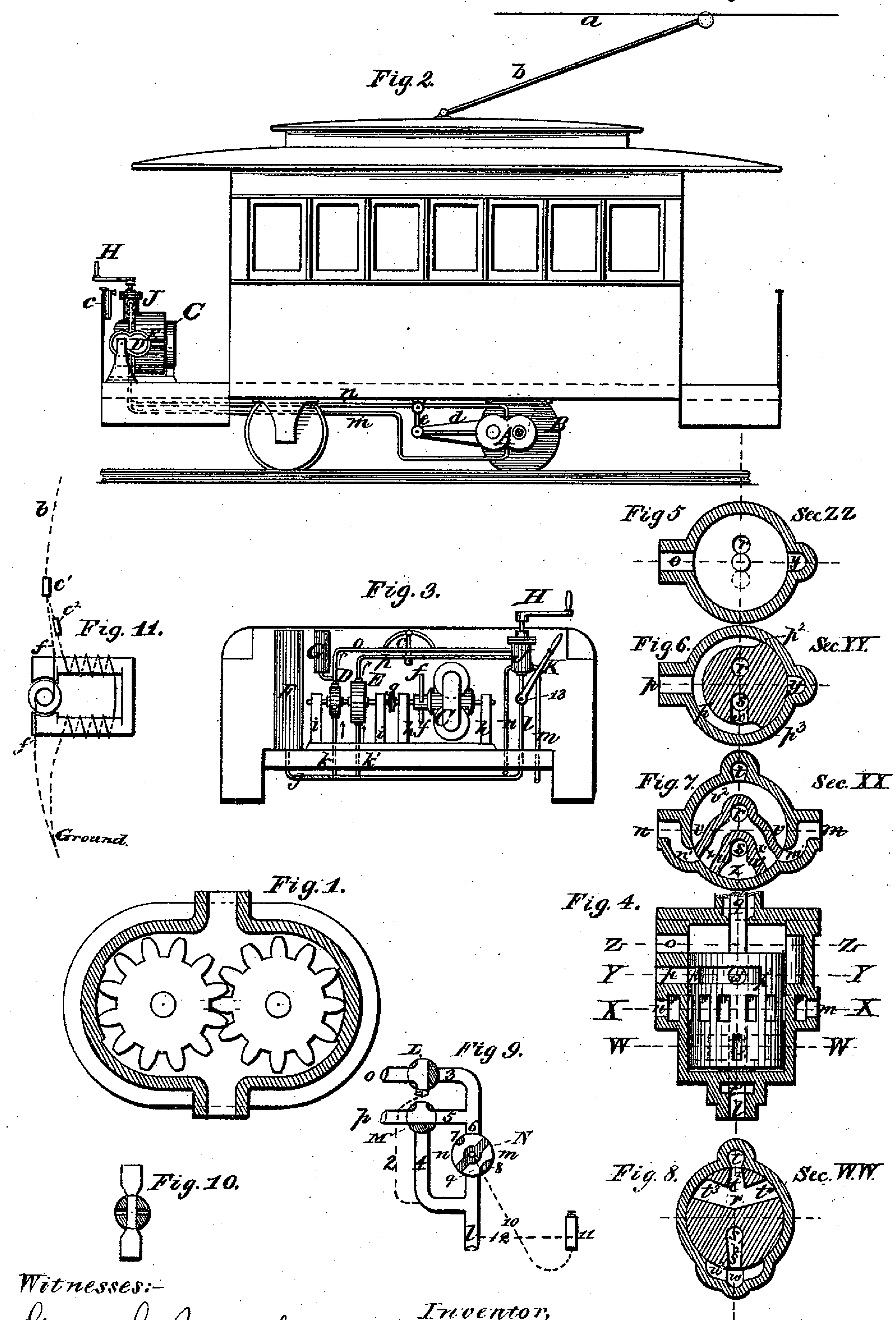
(No Model.)

# C. E. EMERY.

## ELECTROHYDRAULIC CAR MOTOR.

No. 519,469. Patented May 8, 1894.

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## ELECTROHYDRAULIC CAR-MOTOR.

SPECIFICATION forming part of Letters Patent No. 519,469, dated May 8, 1894.

Application filed March 27, 1891. Serial No. 386,687. (No model.)

*To all whom it may concern:*

Be it known that I, CHARLES E. EMERY, of Brooklyn, Kings county, New York, (office New York city,) have invented a certain new and useful Improved Electrohydraulic Car-Motor; and I do hereby declare that the following is a full, clear, and exact description of the same, reference being had to the accompanying drawings, making part of this specification.

In the application of an electric motor for the propulsion of vehicles, a serious difficulty arises from the fact that a much greater force is required to start the vehicle than to maintain its motion afterward, and as the wheels and all mechanism moving therewith are stopped when the vehicle is stopped, an electric motor which at a high velocity developes sufficient power in the form of a small force moving through a great distance cannot, when the velocity is zero, exert sufficient force to start the car without using a motor unnecessarily large at other times or multiplying the speed from the driving wheels to the motor so much that the latter runs at a much higher speed than necessary to develop the requisite power at the regular speed of the car, and even with these high gear ratios it is necessary to employ a very heavy current in starting, which increases the expense and reduces the potential, thereby interfering more or less with other cars on the same line.

It has been stated that in the perfect electric car the electric motor will run continually at constant speed and the ratio of the gearing between the motor and the driving wheels be varied to suit the speed of the car.

The object of this invention is to secure approximately the last named condition, by causing the electric motor to operate one or more pumps for circulating oil, water or other fluid under pressure, and with such fluid to operate the driving wheels with one or more hydraulic motors. It is proposed to operate several pumps of different sizes by the motor; to use a small pump to start the car, a somewhat larger one for moderate speeds of car and the two together or a third larger one for higher speeds, and so on, or to provide several hydraulic motors of different sizes to operate the driving axles and supply one or more with fluid put under pressure by an electric motor, thus enabling the electric motor to be run at the same speed for several different speeds of the car and at approximately the same speed for intermediate speeds of the car. With this arrangement it is practicable to keep the electric motor running when the car is stopped, by letting the water pumped return to the suction through a "pass-by," and the hydraulic motors may be made to propel the car in opposite directions by simply reversing the direction of the fluid through them. The system permits the use of an electric motor, with the field magnets arranged in series with the armature or wound on any of the compound systems; but it is preferred to use a motor with such adaptations that it will run at substantially the same speed under different loads, so that the quantity of current used will be approximately proportioned to the load at all times. At unusually high velocities, as in going downhill, the electric motor will act as a brake, and in addition, by partially closing the outlet of the hydraulic motor operating the driving wheels, this may also be used as a brake.

The kind of pump or hydraulic motor employed for the purposes of the invention is of no importance so far as the method of operation is concerned. A series of ordinary reciprocating pumps, arranged at different angles to a crank, so as to operate successively, and many forms of rotary engine will, with proper adaptations, act either as pumps or motors. Either of the well known three or four cylinder engines is well adapted for the motor to operate the driving wheels, but it is desirable to use as a pump some one of the simpler forms of the rotary engine adapted to run at high speeds, so that it can be directly connected to the electric motor, and which will deliver a substantially uniform flow. A fan or centrifugal pump is theoretically the best form of rotary pump to accomplish the purpose, since, independent of friction, the work performed is proportioned to the fluid discharged and when the discharge is at zero or less than the capacity of the pump, the surplus water is simply carried around by the vanes. With this form of pump but one would be necessary with a capacity sufficient for the maximum speed. The pressure available with such a pump is, however, so limited, comparatively, that in general some form of rotary pump with a positive action is more desirable.

In the drawings: Figure 1 is a cross section of a form of engine adapted for use in this connection as either a pump or a motor. Fig. 2 represents an elevation of an electric car with hydraulic transmission apparatus, one of the driving wheels being removed to show the motor. Fig. 3 represents an arrangement of the electric motor and the pumps across one platform of the car. Fig. 4 is a vertical central section of a valve adapted to regulate and distribute the current from two pumps to the hydraulic motor and to reverse the latter, the valve proper being in elevation. Figs. 5, 6, 7 and 8 are horizontal cross sections of the above valve at the different planes shown by the dotted lines and references. All are represented as viewed from the top with valve in mid position. Fig. 9 represents, by diagram, an arrangement of three and four-way cocks to accomplish the purpose of the valve shown in Fig. 4. Fig. 10 is a diagram cross section of a special cock of ordinary type. Fig. 11 is a diagram showing shunt winding for the electric motor.

The simple form of rotary engine shown in Fig. 1 is well adapted either for a pump or motor, and is shown applied for both uses in the other figures, it being understood that any other form of pump or any other form of motor may be employed. Fig. 1 simply represents two spur wheels geared together and at the sides running close to the inclosing case. The ends of the wheels, front and rear, fit closely between parallel ends of the case. Central openings are provided in the small chambers at the top and bottom of the case, either of which may be used as an inlet and the other as an outlet. As a pump the outer teeth of the two wheels carry through more water from one chamber to the other than the inner teeth bring back and the pressure is on the outlet side, while as a motor, when the current is in the same direction, the pressure is on the inlet side. Reversing the direction of the wheels reverses the direction of the current when used as a pump, and reversing the current reverses the direction of the wheels when used as a motor. The apparatus has the advantage of extreme simplicity. By making the teeth comparatively short, the flow is very nearly uniform, and with the facilities now available for manufacturing gear wheels they may be run, particularly in fluid as in this case, practically without noise.

On the elevation of a car, shown in Fig. 2, the electric motor and the pumps are arranged on the front platform, and a hydraulic motor attached to the rear axle and connected by pipes *m* and *n* with the pumps in manner to be described. Evidently, if desired, a separate motor may be employed for each axle and all be connected to the same pipes. If the axles are in swinging trucks, the pipes on the car must connect with those on the trucks through flexible coils or joints near the truck centers, in manner already worked out for steam locomotives with cylinders driving the wheels of a truck. The electric motor and pumps may be arranged under the car or under a seat, or in any location desired, and at any angle in relation to the car axles, as pipe connections only are to be run to the hydraulic motor therefrom. The arrangement of the electric motor and pumps, either on the front platform where they can be covered up, or in a small inclosure within the car, at one side of the aisle for instance, has the advantage that all parts are readily accessible for adjustment and lubrication, and, moreover, the same may be protected from frost and dirt much better than under the car.

It is to be understood that the electric motor is to be connected with an electric line. This may be done through a conductor *x*, shown by dotted lines, and a trolley *b*, arranged to bear on a trolley wire *a* independent of the car, and similarly through a conductor *y* and a similar trolley to a second trolley wire, or through the metal parts of the car and car wheels to the ground when that forms the return circuit. The trolley wire *a* and return conductor are of course to be connected to a dynamo at a central station as is customary. Evidently, however, the conductors *x* and *y* may connect in any customary way with an underground system of conductors or with the terminals of a storage battery carried on the car itself. It should be understood also that there will be proper means of obtaining electrical resistance to regulate the amount of current taken from the line, and *c* represents the handle of a regulator or rheostat to be used for this purpose, which should also be operable so as to cut off the current entirely if desired, and may in addition be arranged with multiple contact points to throw out some of the coils, to put some of the same in multiple arc, or the coils and armature in series, or in any other way modify the distribution of the current, as is now customarily done in practice.

In the diagram of a shunt wound motor, Fig. 11, adaptable for that shown at C, $c'$ represents resistance in the line from trolley, and $c^2$ resistance in the shunt to the field coils.

The resistance boxes and minor details of the electrical apparatus are omitted on the car, to permit clearness of illustration of the other parts. Although a diagram of a shunt-wound motor is shown, it is not necessary to limit the construction to this form. Either a series-wound motor may be employed, as is more generally done, or a compound of series and shunt-winding adopted which will cause the speed of the motor to be more nearly uniform under varying loads.

In Fig. 2, A represents a hydraulic motor of the type shown in Fig. 1, the axle of the driving wheels, B, forming the shaft of one of the gear wheels of the motor. An arm, *d*, attached to the motor, connects at its end through a link, $e$, with the body of the car, and the pipe connections, $m, n$, being flexible, the axle with the motor readily accommodates itself to the inequalities of the track and the movement of the car body on its springs. When the axle bearings are arranged in a truck swinging independent of or detachable from the car body, the link $e$ should connect to the truck frame.

C is an electric motor and $f, f$, the commutator brushes.

D is a small pump and E a larger pump shown of the type illustrated in Fig. 1. One of the cog wheels of each pump is secured to a shaft, which is connected preferably by a coupling at $g$ directly to the armature shaft of motor C, though gearing may be used if desired. The electric motor and pumps are supported on a suitable bed plate and the armature shaft preferably has bearings, $h, h$, separate from bearings $i, i$, of the pumps, so that either may be separately removed. In some cases the pump bearings would be upon the casings of the pumps themselves instead of being separated as shown. The connections to the bed plate for supporting the electric motor and pumps are omitted for clearness of illustration.

F is a receiver of the oil or other fluid to be circulated under pressure. It is connected through a suction pipe $j$ with suction branches $k$ and $k'$ to the small and large pumps respectively, and by the return connection $l$ with the bottom of a regulating valve J. The upper and lower openings of the motor, A, connect respectively through the pipes $m$ and $n$ with side openings in the valve J, and discharge pipes $o$ and $p$ from the small and large pumps D and E respectively connect also with the distributing valve as shown.

To provide for the slight want of uniformity in the delivery of the pump D, an air vessel, G, is provided; a similar arrangement may be provided for pump E.

An enlarged sectional view of the distributing valve J is shown in Fig. 4 with various openings lettered the same as the connecting pipes. It is a cylindrical valve fitted in a cylindrical case, operated by a stem $q$ and an external handle H. The different arrangement of the openings at different elevations will be understood by reference to the various cross sections, Figs. 5, 6, 7 and 8, made on the planes in Fig. 4 shown by dotted lines, which are referred to opposite the other views.

If it be supposed that the electric motor is in operation so that the tops of the gear wheels forming the pump turn inward, the pumps D and E will draw oil through the suctions $k$ and $k'$ and force the same through pipes $o$ and $p$ to the openings similarly lettered in Fig. 4. The fluid discharged from the small pump D through pipe $o$ enters above the valve and as shown in Fig. 5 passes directly into a vertical channel, $r$, in the valve, extending downward to the elevation W, W, and escapes by a lateral opening, $t^2$, Fig. 8, to a side port, $t$, which extends from the elevation X, X, to the base of the valve casing, passes at $t'$ across the bottom of the latter and connects with the pipe $l$, from which the fluid returns, as stated, to the suctions $k$ and $k'$, and the pump D is therefore, so to speak, "short-circuited," and only overcoming friction. The fluid discharged from the large pump E through the pipe $p$, as shown in Figs. 3, 4 and 6, freely enters a groove, $p'$, extending nearly around the valve, from which, by a side opening, $w'$, it enters the vertical channel $s$, which extends from that point down to the plane W, W, where, as shown in Fig. 8, it is discharged through a side opening, $s^2$, into a cavity, $w^2$, which by means of a channel $w$ connects under the bottom of the casing with the other side channel at $t'$ and the outlet pipe $l$, so that with the valve in the position shown the large pump is also short circuited. The connection $j$ to tank F provides for the expansion of the fluid by temperature and any leakage in the apparatus. The tank F may be made flat and located on the top of the car to keep a head on the pumps. The pipes $m$ and $n$ from the hydraulic motor A enter at the right and left of the valve J at the elevation X, X, and connect to ports $m'$ and $n'$, bent symmetrically to one side, to shorten the width of valve, and the distribution to such ports is regulated by two semicircular bars, called valves, from similarity in appearance and function to other valves. The branches of the inner bar or valve, $u, u'$, inclose a cavity, $z$, connected with vertical channel $s$, and through the same as described with large pump E, and the passage $x, x'$, outside of valve $u, u'$, and inside of that designated $v, v'$, is connected with the vertical channel $r$, and so in manner described with the small pump D. The outer edges of valve, $v, v'$, being narrower than the ports $n', m'$, in the mid position shown, any motion of the car causing the gears of the electric motor A to revolve will circulate fluid from $m$ to $n$ or $n$ to $m$ past the edges of the valve $v, v'$, so that the car may be run by gravity, be pushed along the track or pulled by horses, in case the car from location or accident is not provided with the electric current.

It is evident from the description that with the valve in the position shown, the fluid is not under pressure except that required to circulate it freely. By, however, gradually pushing lever H forward, thereby moving the bottom of valve $v, v'$, from left to right and bringing the passage $x, x'$ (which as before stated is through $r$ and $o$ connected with the discharge side of small pump D), the short circuiting outlet $t^2$, Fig. 8, is gradually shut and by continued movement of the electric motor a pressure is established which is transmitted through $m$ to the bottom of the motor A, forces the tops of the wheels toward each other, thereby moving the car ahead, the return water from motor passing through pipe $n$ and passages $v^2$ and $t$ to return pipe

$l$. As soon as the handle is pushed forward sufficiently to cut off the short circuiting opening $t^2$ entirely, the full pressure available is developed by the small pump and the whole volume discharged, less leakage, operates to turn the motor A and propel the car ahead, when, after the speed due to these conditions is established, the handle may be pushed farther forward, turning the bottom of valve, Fig. 7, farther from left to right, when the bridge $u'$ of the inner valve, Fig. 7, will be thrown over the opening $m'$, but being narrower than such opening will not stop the flow of fluid, but when such bridge has passed the port $m'$, the pressure from the larger pump will, through $s$, be transmitted to pipe $m$, the short circuiting opening $s^3$, Fig. 8, being by that time closed by passing the end of the channel $w^2$. Meanwhile, however, the small pump, which has been cut off the motor by the closing of passage $x'$, has been short circuited by a branch opening, $t^4$, Fig. 8, from $r$ coming opposite the discharge opening $t$. The speed of the car having become established for such conditions, if the resistance of the car be small enough, the valve may be revolved still farther by handle H, when the end $p^3$ of groove $p'$, Fig. 6, will be brought in full communication with the vertical side opening $y$ which extends above the top of the valve, as shown in Fig. 5, so that the passages $r$ and $s$, and therefore through $o$ and $p$, the pumps D and E will be connected together and both discharge through opening $s$, cavity $z$ and port $m'$ to pipe $m$, so that a still greater volume of fluid will be transmitted and the car run more rapidly for constant speed of electric motor, providing the resistance be less, as stated. It is preferred to provide the handle H with a catch operating in connection with a quadrant, the latter provided with notches to hold the lever at will in the several positions where the valve is opened full to one or both pumps.

Evidently if the handle H be pulled backward, the speed of car will be reduced by a series of steps, providing the motor is arranged to run at constant speed. There will be no propelling effort when the valve is in mid position, and as the valve in all respects is symmetrical on the two sides, a continued movement of the handle, H, backward will cause pressure to be transmitted through pipe $n$ to turn the motor A in the reverse direction. If the car be still going ahead, the handle H may be gradually pulled back of mid position to check the motion, and at will back far enough to bring pressure from one, the other and the two pumps successively, in the order previously stated, and cause the car to run backward at different speeds, while the electric motor and pumps continue running in the same direction as before. At either speed in either direction, the rheostat handle, C, may be operated to vary the current or its distribution as described. Even after the car has been reduced in speed by using only the small pump, it may be run still slower by putting resistance in the electric circuit and taking less current from the line. It should be borne in mind that with this arrangement a higher speed cannot be obtained by the use of more pump capacity, unless the resistance has decreased so that the electromotor can furnish the increased quantity of fluid when it is running at substantially constant speed, but ordinarily the resistance does decrease after the car is fairly started.

Very many modifications in details of construction and routine of operation are practicable. Fig. 9 shows separate valves which can be operated to give the same results as valve J. In this figure L represents a two-way cock readily turned to distribute fluid received at $o$ from the small pump to a return pipe $l$ through a branch pipe 2, shown in dotted lines, or through pipe 3 to a four-way cock N; and M is a two-way cock readily turned to distribute fluid from $p$, through an outlet 4 to the return pipe 1 or through outlet 5 to the four-way cock N. The valve L should be so constructed that $o$, 2 and 3 will be open a little at the same time so as to have an outlet for the pump always open, and valve M should also be so proportioned that $p$, 4 and 5 will also be open a little at the same time for the same reason. Again, the four-way cock N may readily be turned to distribute fluid from either or both pumps received through L or M, or both, to either branch, $m$ or $n$, leading to motor, the opposite branch being meanwhile connected to return pipe $l$. The bridge 7 of four-way cock N should either be omitted or made so narrow that it will not entirely close inlet 6, and the cross bridge of valve should be narrower than ports $m$ and $n$, so as not to close them till bridge 8 opens outlet $l$. If bridge 8 be made wide enough to close outlet $l$ with valve in mid position, it will stop the hydraulic motor by closing its outlet and the arrangement may therefore be used as a brake by gradually closing $l$. To prevent injury in case this be done suddenly, the passage 9 in four-way cock may connect with a central hole in the cock which has an outlet at the end connecting by a pipe 10 with a safety valve 11, the discharge, 12, of which is to lead to return pipe $l$ (as worked out on the safety feeds of marine pumps); or the bridge 8 may have a small hole in it to permit a slight circulation, but retain sufficient pressure to stop the motor and car.

If desired, the return fluid in Fig. 4 may be delivered under the valve instead of to lower passage $t'$ and its outlet to the passage $t'$ and discharge pipe $l$ be regulated by a projection on the bottom of the valve, so as to accomplish the same purpose as widening the bridge 8 in Fig. 9. Preferably, however, when the valve J is used, the various bridges and openings are to be so arranged as to short circuit both of the pumps and the motor, as above described, and the braking is preferably performed by a separate valve in the form of plug cock, shown in Fig. 10 and at 13, Fig. 3, which is to be arranged in the return pipe 1 and operated by a lever K in latter figure. This cock may, as shown in Fig. 10, have a small hole through it to permit slight circulation of fluid, or the pipe 1 above the valve, Fig. 3, may be relieved through a safety valve, as described in relation to Fig. 9.

The same general principles, evidently, will apply when several hydraulic motors of different sizes are used to propel the car and the same supplied with one or more pumps driven by an electric motor. It is possible with two pumps to obtain four combinations. For instance, first, the small pump may be used; second, the large pump and small pump together with the current reversed in the latter so as to deduct its capacity from that of the large pump; third, the small pump may be short circuited and the large pump used alone, and fourth, the capacity of the two pumps may be added together as described. This may be accomplished in Fig. 9 by putting a four-way cock in the place of L, connecting up the two sides of small pump D to the top and bottom outlets and the left-hand outlet to the return pipe 1, in which way either side of the pump may be connected to valve N when the other side will be connected to return pipe 1. The number of combinations possible is too great to permit detailed description. It should be borne in mind that any desired combination may be made by the use of separate valves, after which such separate valves may be joined in one to give the desired sequence of movements. One valve J is shown to illustrate the principle, and other arrangements will readily be made by an expert with this as a sample.

If the winding of motor or arrangement of electric conductors be such that the electrical features can be better arranged for economy or efficiency for each position of the starting lever H, an arm on the shaft of such lever may readily be connected to a commutator lever like C, so as to make the electrical changes coincident with those of the fluid. When the electric motor and pumps are erected on one platform, it is desirable that the car be turned on a loop on the end of the route. When the car is not so turned the operating levers H, K and *c* should be duplicated at the ends of the car and connected mechanically by levers, gearing or chains, as is customary.

The arrangement of the electric motor and pumps on the platform unbalances the car, for which reason the wheels are shown set forward, by which means the rear or driving axle in this case, though less loaded when the car is light, will receive a greater load when the car is filled with passengers and increase the adhesion of driving wheels as required.

The present application shows an adaptation of the invention for the propulsion of a vehicle, but evidently substantially the same combination and arrangement of parts may be employed as a means of transmitting pressure derived from an electric motor to any point where fluid under pressure can be utilized for power or purposes of any kind, and different volumes of fluid at varying or constant pressure, representing different quantities of work, be furnished at a distance by the primary operation of an electric motor which, if desired, can be run at substantially constant velocity. The present invention is, however, confined to changes of speed by a series of steps such as is secured by connecting a different number or different sizes of pumps to supply a given sized motor, or by connecting a different number of motors or motors of different sizes to receive fluids from a definite pump supply. With this invention the ratio of transmission, so to speak, is definitely changed by what is practically a substitution of different pieces of apparatus, as in a change of gear wheels, as distinguished from an apparatus in which the effective capacity of each pump is changed progressively by admitting air or changing its stroke as has been proposed. The invention contemplates that the apparatus for producing such changes of speed hydraulically in a series of steps will in all cases be combined with an electric motor. It is not necessary that the form of engine employed to utilize the pressure be a rotating one, as evidently the ram or piston of a simple hydraulic cylinder can be employed as a motor to operate cranes, elevators or any other form of mechanism.

If in Fig. 2 it be considered that B instead of being a car wheel is the armature of an electric motor operating motor A as a pump delivering fluid to operate pumps D and E as hydraulic motors, which in turn operate C as a dynamo to generate electric current, or such motors turn a car axle or perform any other useful work, then with the valve J, connections and general arrangement exactly as they are shown, there will, as in the other case, be practically two sets of hydraulic apparatus, one operated by an electric motor and acting as a pump to impart pressure to a fluid, the other utilizing the pressure of the fluid as a hydraulic secondary motor actually performing the work intended, when both sets of hydraulic apparatus form part of what may be termed "a hydraulic transmitting apparatus." With A acting as a pump, connected through valve J with the larger engine E, acting as a motor, one speed will be imparted to the latter and its connecting shaft, but if the connection be to D, which is smaller, the speed of the shaft will be increased. Modifications of speed can be made by supplying fluid to both D and E so that the capacity of one is either added to or subtracted from that of the other, as in the previous case, from which it appears that either of the two sets of hydraulic apparatus above referred to may have multiple units to change the relative capacities of the apparatus for pumping and that for utilizing the pressure of the fluid pumped and be operable at will to change the relative velocities of the two sets of apparatus and thereby the relative velocities of the electric motor in relation to the work indirectly done by it through a pump or pumps and a hydraulic motors or motors. In other words, there may be two or more pumps, preferably of different sizes, which operated at times separately and at other times together, at substantially constant speed, will furnish different volumes of fluid to the axle motor and therefore operate the latter at different relative velocities, or there may be two or more motors of different sizes, which a given quantity of water from one or more pumps will operate at different relative velocities. The motors of a different size may be upon the same axle and used singly or together, and the same arrangement be duplicated on another axle and corresponding parts connected to same pipes, or the motors on different axles may be of different sizes, and the fluid under pressure from the pumps delivered to the motors on either or both of the axles, the car being driven by the motor to which fluid is supplied and at a speed corresponding to the size of such motor. In such case the other motors would be short-circuited. When motors of different sizes are used together the larger motor will develop the greater power and the other assist in the propulsion, whether it be on the same or a separate axle.

What I claim as my invention, and desire to secure by Letters Patent, is—

1. In combination with an electric motor, a series of pumps of different sizes operated thereby, a hydraulic motor operated by the fluid delivered by such pumps and suitable valves and connections all operable at will to transmit fluid from the pumps to the hydraulic motor and operate the same at different relative velocities proportioned to the size and number of pumps at the time in use, substantially as and for the purposes specified.

2. In combination with the frame of a car truck, and in combination with an axle of such car, a hydraulic car motor provided with a lever arm articulated to such frame, and with flexible fluid connections, whereby the frame will be free to accommodate itself to changes in the position of the axle relative to it without interference with the operation of the motor, substantially as and for the purposes specified.

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