C. H. STUART & C. SCOTT-SNELL.

APPARATUS FOR COMPRESSING ELASTIC FLUIDS.

APPLICATION FILED FEB. 17, 1908.

969,123. Patented Aug. 30, 1910.

3 SHEETS—SHEET 1.

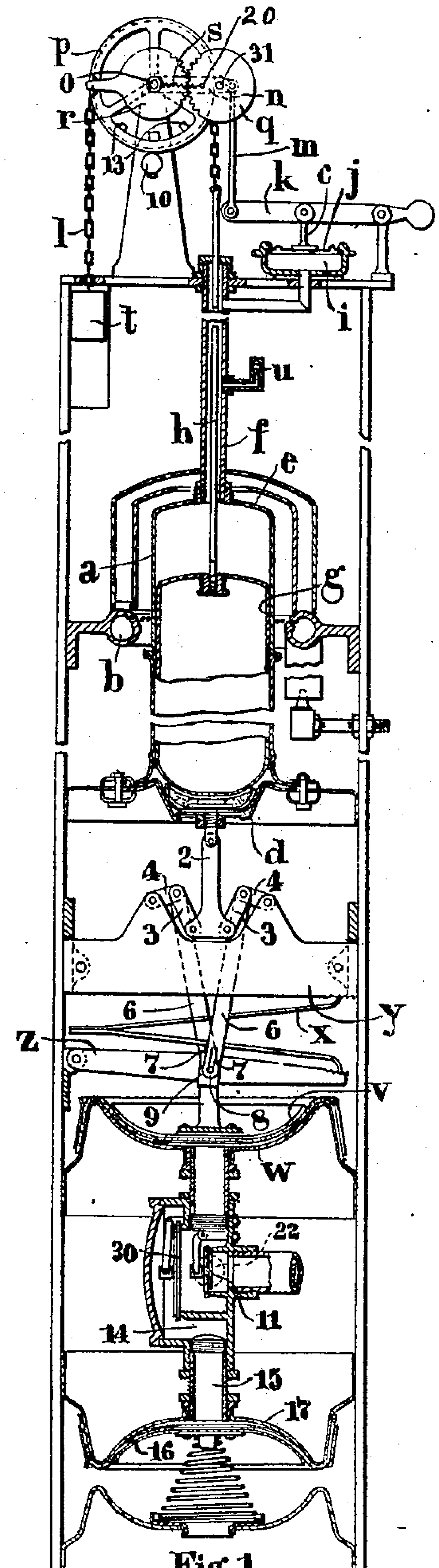

Fig. 1.

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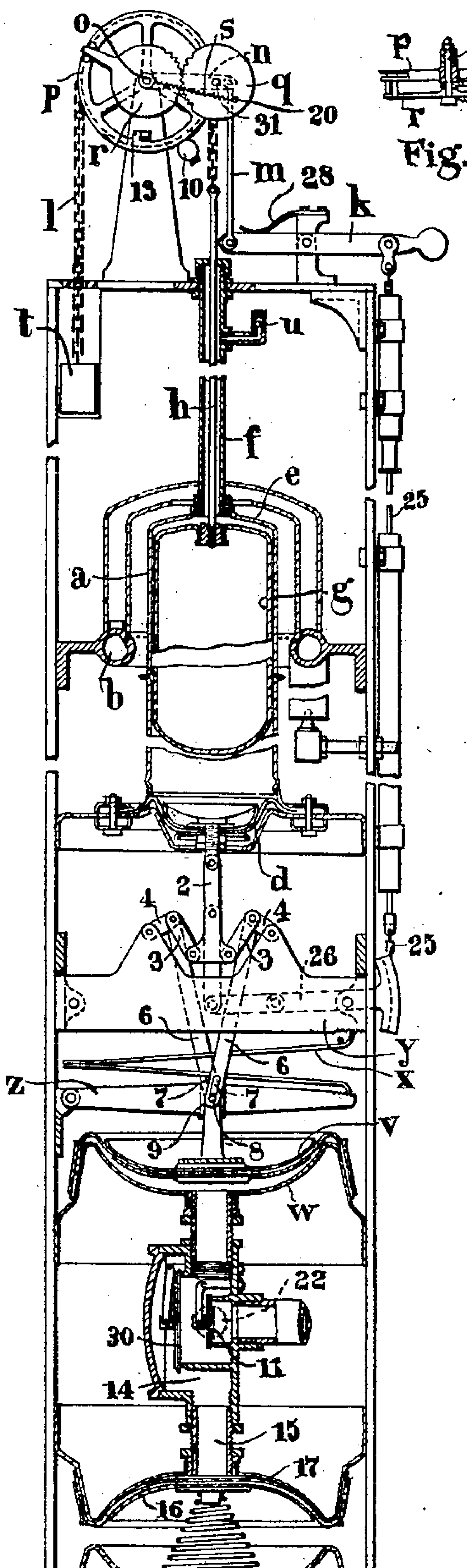

Fig.2.

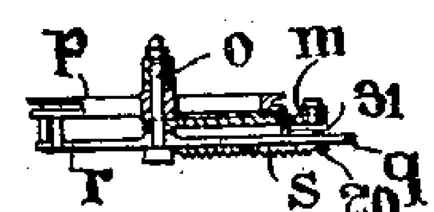

Fig.3.

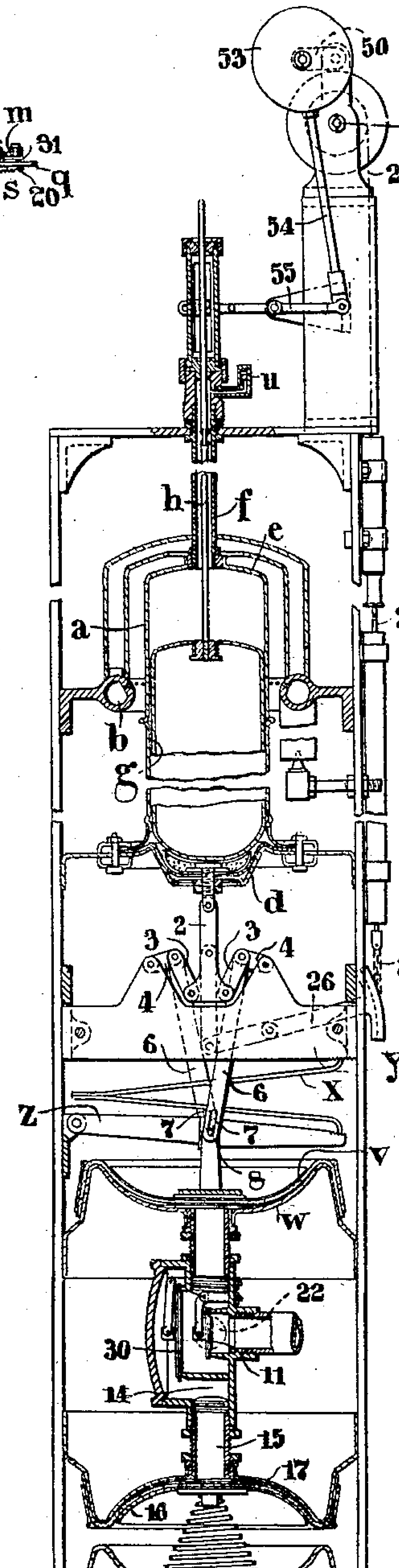

Fig.4.

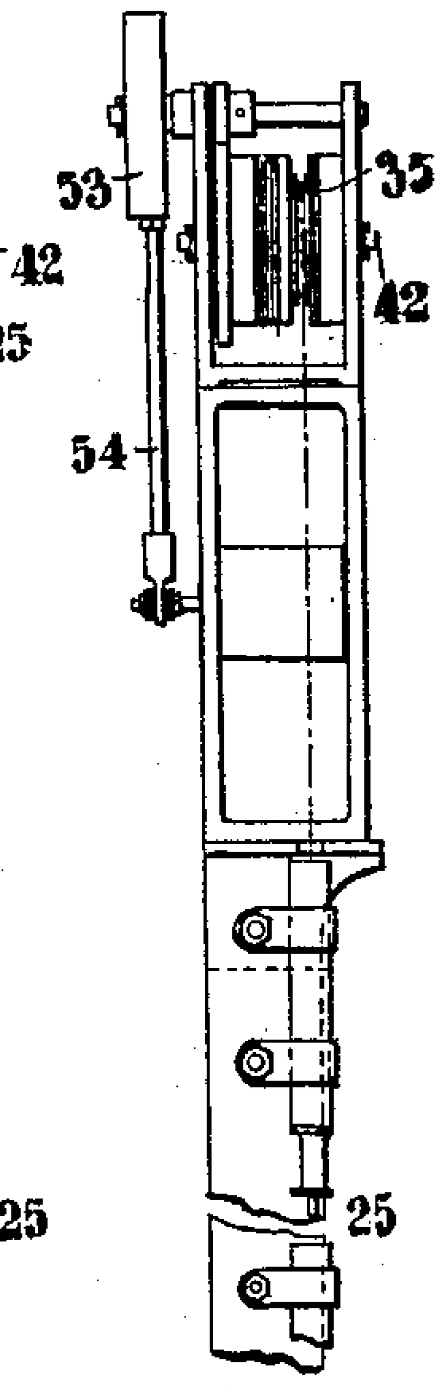

Fig.5.

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3 SHEETS—SHEET 3.

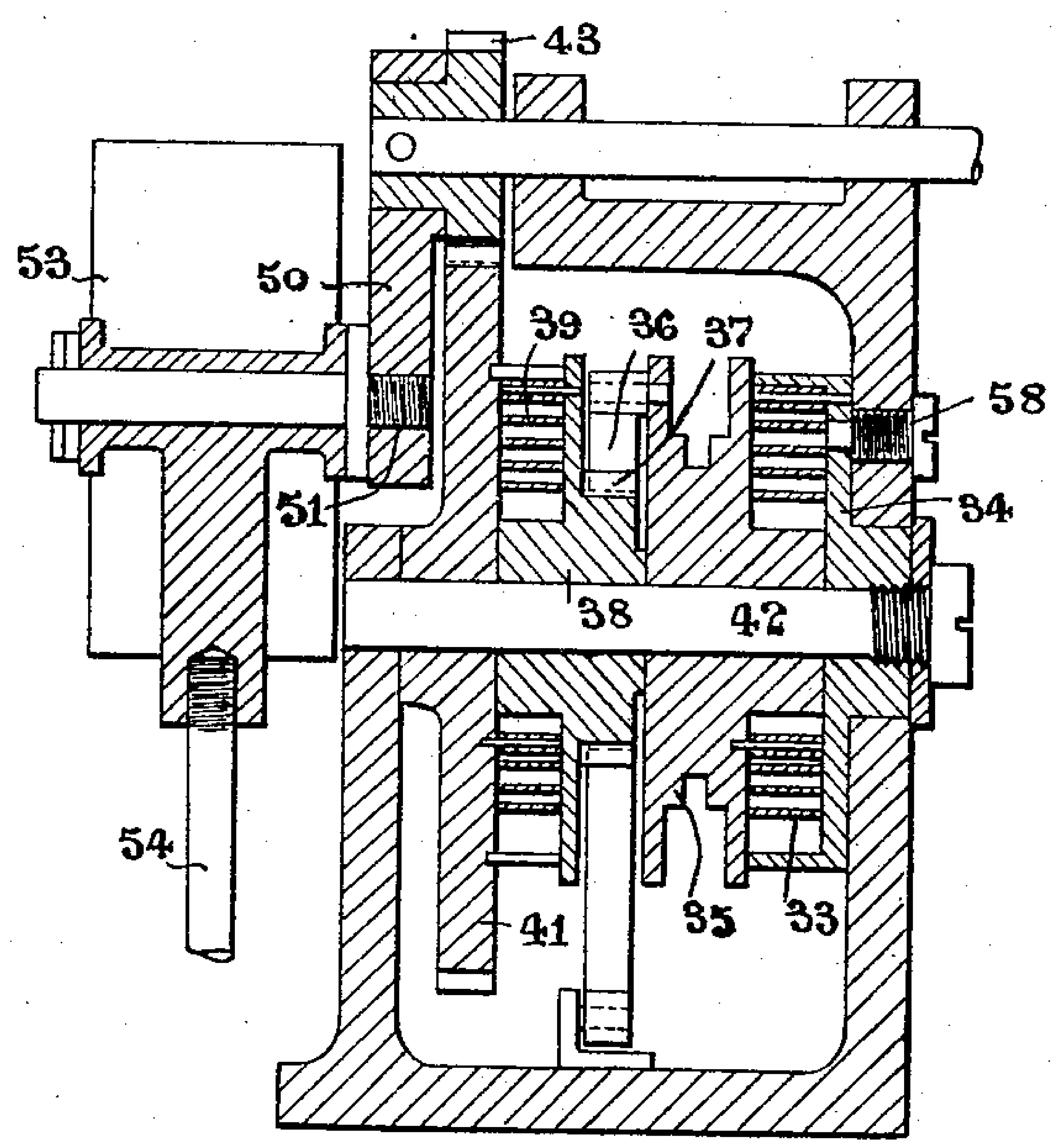

Fig. 6.

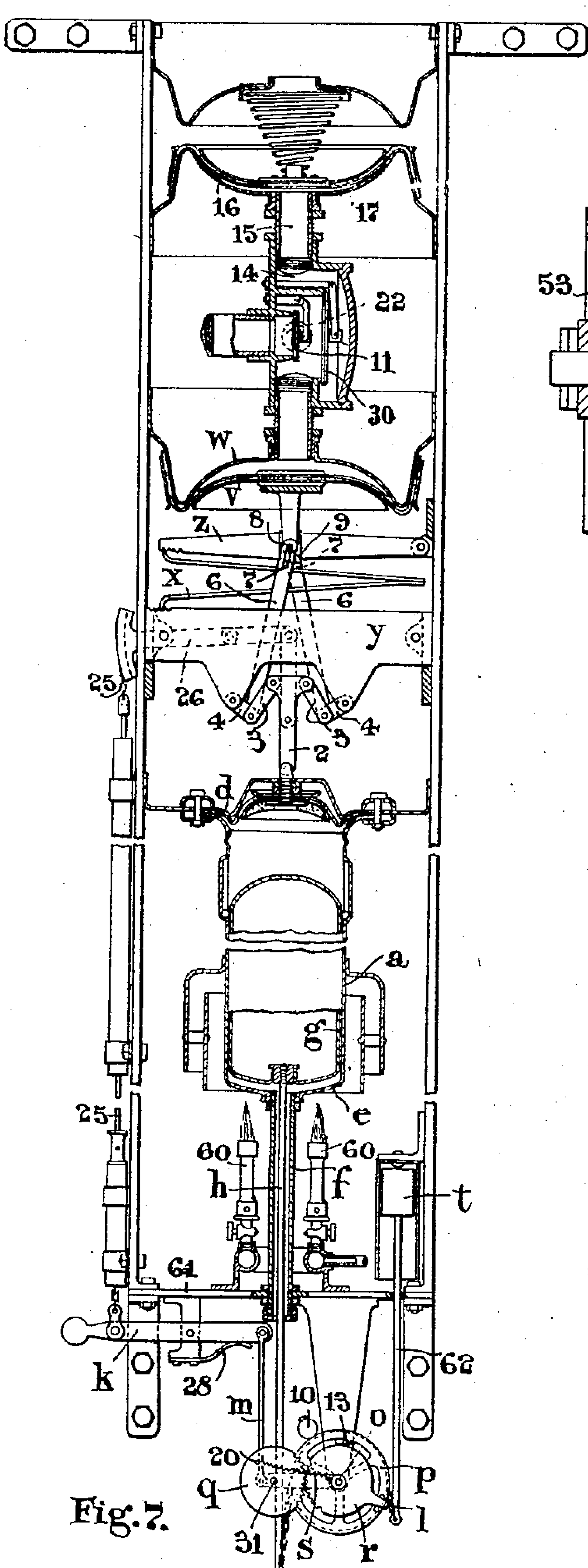

Fig. 7.

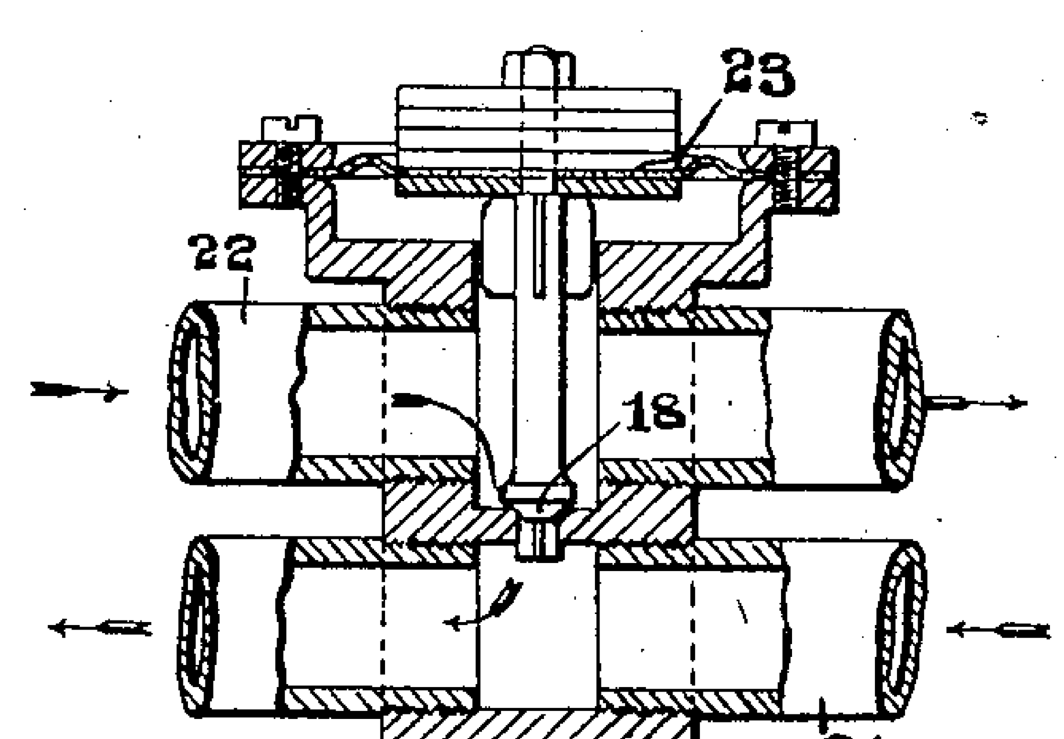

Fig. 8.

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UNITED STATES PATENT OFFICE.

CLAUDE HOUSTON STUART AND CHARLES SCOTT-SNELL, OF LONDON, ENGLAND.

APPARATUS FOR COMPRESSING ELASTIC FLUIDS.

969,123. Specification of Letters Patent. Patented Aug. 30, 1910.

Application filed February 17, 1908. Serial No. 416,414.

To all whom it may concern:

Be it known that we, CLAUDE HOUSTON STUART and CHARLES SCOTT-SNELL, subjects of the King of Great Britain and Ireland, and residing at 25 Victoria street, Westminster, London, S. W., England, have invented certain new and useful Improvements in Apparatus for Compressing Elastic Fluids, of which the following is a specification.

This invention relates to apparatus for compressing elastic fluids and is particularly applicable in connection with the compression of air or gas in gas lighting. Hitherto such compression has mainly been effected by reciprocating pumps, rotary blowers or high speed fans actuated by power derived from water pressure, gas engines, electric motors or hot air engines; or the air or gas to be compressed has itself been expanded by heat and thereby ejected to the services at a pressure above atmosphere. For the purpose of the present invention, however, we employ a hot air motor of the type in which a displacer operates within a chamber which is externally heated at one end and cooled at the other, this motor being used to operate a pump.

The object of the invention is to produce an improved hot air motor of this type and compressing plant which shall be simple in construction and highly efficient in operation, and in which the partial or complete cessation of demand upon the compressed fluid or the reverse effect of undue lowering of the pressure in the service shall not cause the motor either to stop or to race.

The present invention consists in a pumping apparatus comprising a pump and an improved hot air motor in which the cylinder is provided with a diaphragm piston or the like which is connected by a non-rigid connection with the pump, the motor being adapted so that the operative stroke on the pump may be obtained under the action of vacuum only, its displacer being actuated from a moving part of the motor under the control of the operating fluid in the cylinder through an elastic or flexible connection which causes the movements of the displacer and said diaphragm, piston or the like to be of similar periodicity but allows them to vary in relation to one another for purposes hereinafter explained.

In this invention the diaphragm referred to above is given, by the changes of absolute pressure within the cylinder, a continual "hunting" movement following the movement of the displacer and when the apparatus is running the number of reciprocations or impulses of the diaphragm is the same as that of the reciprocations of the displacer, but the amount of lag of the diaphragm behind the displacer in "hunting" it on the vacuum stroke varies in accordance with the load.

In compressing gas or air when pressure has to be maintained constant but the volume required is variable it has been usual hitherto to employ either one of two systems to meet the conditions imposed. In one system the pumping device is operated under constant load, that is with full power, but the surplus elastic fluid is allowed to regurgitate or flow back through a special valve; in the other system the prime mover is slowed or intermittently stopped by automatically checking its supply of working fluid by making suitable controllable connection with a reservoir or the service on the delivery side of the apparatus. The present invention however may be carried out in a plant in which a regurgitating valve may be provided or in which the use of such a valve may be avoided, without the necessity of slowing or stopping the motor element. In our invention the diaphragm above referred to is connected with the pump by a non-rigid connection and the pump is arranged to do its stroke in one direction under the action of a weight, spring or the like; in consequence of this, the operating diaphragm may, when the demand on the pump ceases or diminishes or suddenly increases, still continue to work without acting on the pump piston or diaphragm and may move the pump piston or diaphragm through just such part of its stroke as is necessary in view of the altered demand.

In the above mentioned non-rigid connection between the motor diaphragm and pump is an equalizing device which will allow of the completion of the operative stroke of said diaphragm against the resistance of the pump notwithstanding the occurrence of a reduction of the vacuum in the motor cylinder toward the end of the operative movement of the motor diaphragm.

Referring now to the accompanying drawings, Figure 1 is a vertical section of a combined motor and pump according to one form of our invention. Fig. 2 is a similar view of another form of the invention. Fig. 3 is a sectional plan of part of the elastic connecting device between the displacer and diaphragm. Fig. 4 is a sectional elevation of a further form of the invention, Fig. 5 is a part end elevation of Fig. 4 showing the elastic connection employed, Fig. 6 is an enlarged sectional elevation of the elastic connection used in the apparatus according to Figs. 4 and 5. Fig. 7 is a sectional elevation of a modified form of the device in which the positions of the pump and motor are inverted, Fig. 8 is a detail view of a suitable form of regurgitating valve for use when required.

In carrying the invention into effect according to the form shown in Fig. 1 in which a regurgitating valve is provided in the pump, we employ a cylinder, *a*, which at one end is heated by a ring burner, *b*, and at the other end is cooled either by radiation or by a water jacket. The bottom of the cylinder is closed by a diaphragm, *d*, while the top of the cylinder is closed by the end, *e*, which carries a tubular extension, *f*. Within the cylinder is a displacer piston, *g*, which is connected through an elastic connection with a part of the apparatus which is subject to the fluctuation of absolute pressure within the cylinder.

In the form of the invention illustrated in Fig. 1, the displacer carries a rod, *h*, which passes through a gland at the top of the extension, *f*, and is hung from a chain, *l*, passing over a wheel, *p*, and having at its upper end a counterweight, *t*. The tubular extension is in communication with a chamber *i*, which is closed at the top by a small diaphragm, *j*. The elastic connection is preferably as follows:—A rod, *c*, connects the diaphragm, *j*, to a pivoted lever, *k*, the inner end of which remote from its pivotal support is connected by a rod, *m*, with one end of a rocking lever, *n*, which is loosely journaled at the other end upon the axle, *o*, of the chain wheel, *p*. Freely mounted upon the rocking lever, *n*, is a toothed wheel or quadrant, *q*, which is in engagement with a toothed wheel, *r*, carried on the axle, *o*, and in driving connection with the chain wheel, *p*. A spring, *s*, connected to the axle, *o*, and to the toothed wheel, *q*, at 20, completes the the elastic link between the diaphragm, *j*, and the displacer, *g*.

The travel of the diaphragm, *j*, may be made small because the elastic or flexible link allows the displacer a greater range in response to momentum engendered, and the impulse created by the movement of the displacer tends by its action on the operating diaphragm to destroy and reverse the said movement. A continual "hunting" is therefore set up having in effect the same result as the cranks as usually set in a hot air engine.

The extension, *f*, is provided with a pressure relief valve, *u*, and the chain wheel carries a small weight, 10, which tends to keep the displacer in its normal position when the apparatus is not working.

The diaphragm, *d*, of the motor is connected to a pump member which may be a diaphragm, piston or the like and is shown here as a diaphragm, *v*, closing a dish-shaped pump casing, *w*. The diaphragm, *v*, is loaded constantly, as by a weight, or by a spring, *x*, bearing on a cross bar, *y*, and on a lever, *z*, pivoted to the frame and connected to a cross head, 9, carried by the diaphragm, *v*.

The connection between the working parts of the motor and pump is of such kind as to utilize as much as possible the initial moving force of the vacuum in the motor cylinder and to admit of carrying on the inward movement of the diaphragm, *d*, after such force has fallen considerably, due to this inward movement of the diaphragm, *d*, and consequent reduction of cylinder capacity while at the same time it must permit the motor to continue to operate even when the pump is not required to work. A convenient form of such connection consists of a link, 2, attached to the diaphragm, *d*, and to a pair of toggle levers, 3, 4, from the apices of which depend the links, 6, 6, which have in their lower ends long slots, 7, 7, through which passes the pin, 8, of the cross head, 9, which makes the connection non-rigid. Instead of making the connection non-rigid by means of slots, 7, 7, any other means may be used for effecting this end and thus preventing the pump from stopping the motor when the demand on the services ceases or becomes greatly reduced.

When the diaphragm, *d*, is lifted by the vacuum produced in the motor cylinder as hereinafter described the pump diaphragm, *v*, is also lifted, the elastic fluid being drawn in through the valve, 11. As the diaphragm *d*, lifts, the mechanical advantage obtained by the toggle links increases to counteract the loss of pulling effect consequent upon the reduction of vacuum in the motor.

The delivery chamber, 14, governed by the valve, 30, communicates at 22, with the high pressure service and by a passage, 15, with an anti-pulsating device—such for example as a spring pressed diaphragm, 16, forming the yielding bottom for a chamber the top of which is made as an inverted dished plate, 17. A suitable form of regurgitating valve for use in this form of the invention is shown in Fig. 8. It consists of a small valve, 18, having a seating in a passage between the low pressure supply pipe, 21, and the high pressure delivery pipe, 22. The valve is attached to a diaphragm, 23, which is exposed to the high pressure fluid.

The operation of the motor is as follows:—The heat from the ring burner, *b*, produces expansion of the initial volume of air in the cylinder and causes slight increase of pressure which being felt at the diaphragm, *j*, raises the lever, *k*, and through the elastic or flexible connection tends to lift the displacer toward the heated end of the cylinder. The parts put into movement acquire momentum which carries them on, the displacer causing transference of a volume of heated air from the upper end of the cylinder to the lower end which is cold. This produces a vacuum which, being felt on the diaphragm, *j*, ultimately arrests and reverses the motion of the displacer and accessory parts but this reversal again creates a state of slight pressure; this completes the cycle.

To prevent the amplitude becoming excessive, stops, 13, 13, are formed on the wheel, *p*, and the vacuum stroke being much the more powerful, the normal position of the displacer may be arranged so that the displacer shall have a little lift above this point but considerable fall below it.

In the early stages of the reciprocations of the displacer, *i. e.*, before the full amplitude of displacer travel has been attained, the motor diaphragm, *d*, may not be subject to sufficient vacuum to lift the load on the pump diaphragm, *v*. The spring connection between diaphragm, *j*, and the displacer insures independence of action between the displacer and the pump diaphragm as regards responsiveness, or in other words, it allows the displacer to reciprocate without any responsive movement occurring at the pump diaphragm.

In due time sufficient vacuum is attained to overcome the load and the motor diaphragm follows the movements of the displacer, rising on the vacuum stroke and thereby raising the pump diaphragm against the resistance of the spring and then falling under the pull of the pump diaphragm as it performs its delivery stroke by the force of its spring or weight.

If the fluid compressed by the pump be not drawn off by the services, it will pass back through the regurgitating valve to the supply pipe and thus allow the diaphragms, *v* and *d*, to return to their low positions.

When a regurgitating valve is dispensed with, it will be evident that the pump diaphragm on being lifted will remain up if the service make no demand upon the pump, the weight or spring maintaining a constant pressure in the pump without moving the pump diaphragm. In such cases it is better that the part subjected to changes of absolute pressure in the cylinder to which the elastic connection with the displacer is made shall be the main diaphragm, *d*, instead of the secondary diaphragm, *j*, both of which diaphragms are subjected to the same pressure changes. The flexible connection is modified in any convenient manner to suit, while the motor and pump parts may remain unchanged.

One convenient way of arranging the elastic connection when a regurgitating valve is not used is illustrated in Fig. 2, in which the lever, *k*, is shown pivoted near its center and connected near its outer end by a link, 25, consisting of a chain and guided rod, to a lever, 26, which is connected by a link or the like to the link, 2, attached to the motor diaphragm, *d*. As this link, 25, is suitable for tension only, it is necessary to provide a spring, 28, or the like for giving the reverse motion when the motor diaphragm is not affected by the existence of a vacuum in the cylinder. The spring, *s*, is attached to the wheel, *q*, at a point, 20, beyond its center of rotation, 31, so that when the vacuum effort on the diaphragm, *d*, causes the inner lever, *n*, to be raised, the spring, *s*, by the rotation of the wheel, *q*, rolling upon the wheel, *r*, will stretch so that when it is above the wheel center it will partially rotate the wheel, *r*, and the chain wheel, *p*, in a direction to depress the displacer. The lowering of the displacer will destroy the vacuum in the cylinder, release the tension on the chain and rod link, 25, and permit the spring, 28, to reverse the motion of the lever *n*, until in turn the rotary movement of the wheel, *q*, carries the point of attachment, 20, of the spring, *s*, so far down (see Fig. 2) that the spring, *s*, is brought below the axis, 31. "Hunting" is thus continuous whether a regurgitating valve be used or not and in either case the spring, *s*, of the elastic connection alternately stores and gives out energy. Obviously storage of energy beyond that necessary to complete one cycle may be put into the flexible connection by making the spring element of greater length and giving that element a complete revolution or even several complete revolutions. In Figs. 4 to 6 the elastic connection is of such a kind. The spring element of the elastic connection consists in this case of a clock spring, 33 (see Fig. 6) fixed to a containing box, 34, and to a chain wheel, 35, upon which is wound and secured the upper chain of the link, 25. The chain wheel, 35, carries a pawl, 36, which gears with a ratchet wheel, 37, formed on a box, 38, to which is secured one end of another clock spring, 39, the other end of which is attached to a toothed wheel, 41, loosely mounted upon a fixed spindle, 42, on which the two spring boxes also are loosely mounted. The wheel, 41, is in gear with a pinion, 43, which carries a crank arm, 50, in the end of which is a pin, 51. Loosely mounted on the pin, 51, is a counterweight, 53, to which is secured a connecting rod, 54, the free end of which is connected to one end of a lever, 55, the other end of which is connected loosely to the rod of the displacer. Means are provided to prevent the ratchet wheel, 37, running back. An adjusting pin, 58, may be used to hold the drum, 34, in position to give any desired initial tension of the spring, 33. The intermittent pull on the chain link, 25, recoils the pawl, 36, and winds a spring the energy stored in which is given out when the tension in link, 25, is relieved to wind the spring, 39, which always rotates in one direction and gives out the energy received by it to reciprocate the displacer. The operation of the device according to these Figs. 2 to 6 is practically identical with that of the device shown in Fig. 1.

If there is no withdrawal of compressed fluid from the pump after its diaphragm has been raised to its fullest extent, the motor does not stop working, the slots, 7, 7, in the links, 6, 6, of the non-rigid pump connection then allowing complete independence of action of the motor.

If the load on the prime mover be light, that is, if the pump diaphragm need only to be lifted through a small part of its total working stroke to enable it on its return movement to deliver sufficient compressed fluid to meet the demand, the working diaphragm, *d*, may follow up the displacer very closely as it has very little resistance to overcome until late in its stroke. If however, the full load be on, or even if the demand on the pump be greater than it can meet, the motor diaphragm will lag behind the displacer until the displacer has traveled far enough to produce the necessary vacuum to permit lifting of the pump diaphragm through its maximum working stroke. The elastic connection between the displacer and the diaphragm subject to the internal pressure changes allows of this automatic adjustment of motor power to load and avoids racing of the motor when the load is light and stopping or undue slowing down of the same when the load is great.

It will be observed that in all the described forms of this invention, the intermittent movement of a part of the machine subjected to the changes of pressure occurring within the cylinder produces reciprocation of the displacer through the medium of an elastic or flexible connection in such manner that the periodicity of both moving parts may be maintained similar but variations of phase or in the distance of the working diaphragm from the displacer in "hunting" may occur automatically in accordance with the varying condition of the load. If a rigid connection were employed between the displacer and its operating part, the attainment of this result would be defeated; and as practically the same charge of elastic fluid remains in the cylinder throughout its operation, the employment of a rigid connection would cause a cessation of movement.

When the displacer falls in its cylinder it may almost touch the diaphragm for a moment leaving practically no clearance spaces, the whole volume of fluid being displaced to the head of the cylinder where it may be heated to a temperature much higher than would be feasible if in its heated state it had to come in contact with and produce pressure upon a piston in a cylinder as in the usual hot air engine. Further, the heat losses due in the latter case to constant changes of temperature in the cylinder are avoided and by using only the vacuum resulting from condensation, cold fluid only is in contact with the working diaphragm. This apparatus can therefore be used beyond the usual range of temperatures of many hot air engines. It is also obvious that whereas in certain apparatus previously used air or gas has been drawn into a displacer cylinder and subsequently expelled by dilation of a portion of it by heat, the power due to vacuum is left unutilized and the economy suffers accordingly.

The heat in the forms of our invention described with reference to Figs. 1 to 6 being applied at the head of the cylinder and the base being cooled, further losses due to the heat ascending from a lower level as in many forms of heat engine are prevented. In our invention, however, it is not essential that this distribution of heat shall be rigidly adhered to, and in Fig. 7 we have illustrated a pumping plant, according to our invention, in which the device is inverted the heat being applied at the bottom by burners, 60, preferably fed from the high pressure service while the top is cooled. The pump diaphragm is above the displacer cylinder, and a spring element similar to that already described is carried below the burner base, 61, parts corresponding to those already described being similarly marked on Fig. 7. The displacer is balanced by a weight, *t*, supported on guides and having a rod, 62, to which the chain, *l*, is attached which passes over the pulley, *p*, to the displacer rod. Suitable brackets or legs may be provided for supporting the apparatus in the vertical position.

If air be compressed, it may be utilized to take up petrol vapor or the like elastic fluid for lighting or heating purposes equally as well as coal gas or the so-called lifting stroke of the apparatus may draw in air from a carbureter distributing the mixture under pressure into the service.

Having now described our invention, what we claim as new and desire to secure by Letters Patent is:—

1. A hot air motor comprising in combi-

nation a cylinder, said cylinder being heated in one part and cooled in another part, a displacer piston within said cylinder, a motor element subjected to and having movements responsive to changes of pressure within the cylinder, an element connected to said displacer piston and an element connected to said motor element, energy storing means connecting said elements, whereby energy is stored from the combined movements of said displacer piston and motor element and is imparted to the displacer piston at a point in the stroke of said motor element dependent on the degree of loading of the motor.

2. A hot air motor comprising in combination a cylinder, said cylinder being heated in one part and cooled in another part, a displacer piston within said cylinder, a motor element subjected to and having movements responsive to changes of pressure within the cylinder, an element connected to said displacer piston and an element connected to said motor element, said elements being capable of movement relatively to one another and energy storing means connecting said elements whereby the relative movement of said elements caused by the movement of said displacer piston and motor element causes energy to be stored in said energy storing means and to be imparted to said displacer piston at a point in the stroke of the motor element dependent upon the degree of loading of the motor.

3. A hot air motor comprising in combination a cylinder, said cylinder being heated in one part and cooled in another part, a displacer piston within said cylinder, a motor element subjected to and having movements responsive to changes of pressure within the cylinder, an element connected to said displacer piston and an element connected to said motor element, said elements being capable of movement relatively to one another, spring means between said elements, said spring means storing energy by the relative movement of said elements caused by the movement of said displacer piston and motor element, and imparting the stored energy to the displacer piston at a point in the stroke of the motor element dependent on the degree of loading of the motor.

4. A hot air motor comprising in combination a cylinder, said cylinder being heated in one part and cooled in another part, a displacer piston within said cylinder, a diaphragm subjected to and having movements responsive to changes of pressure within the cylinder, an element connected to said displacer piston and an element connected to said diaphragm, energy storing means connecting said elements, whereby energy is stored from the combined movements of said displacer piston and diaphragm and is imparted to the displacer piston at a point in the stroke of said diaphragm dependent on the degree of loading of the motor.

5. A hot air motor comprising in combination a cylinder, said cylinder being heated in one part and cooled in another part, a displacer piston within said cylinder, a diaphragm subjected to and having movements responsive to changes of pressure within the cylinder, an element connected to said displacer piston and an element connected to said diaphragm, said elements being capable of movement relatively to one another, spring means between said elements said spring means storing energy by the relative movement of said elements caused by the movement of said displacer piston and diaphragm, and imparting the stored energy to the displacer piston at a point in the stroke of the diaphragm dependent on the degree of loading the motor.

6. A hot air motor comprising in combination a cylinder, said cylinder being heated in one part and cooled in another part, a displacer piston within said cylinder a motor element closing one end of said cylinder, said motor element being subjected to and having movements responsive to changes of pressure in the cylinder, an element connected to said motor element and an element connected to said displacer piston, said elements being capable of movement relatively to one another and connected by energy storing means, whereby the movement of said displacer piston and motor element causes energy to be stored in said energy storing means and the stored energy to be imparted to the displacer piston at a point in the stroke of the motor element dependent on the loading of said motor.

7. A hot air motor comprising in combination a cylinder, said cylinder being heated in one part and cooled in another part, a displacer piston within said cylinder a diaphragm closing one end of said cylinder, said diaphragm being subjected to and having movements responsive to changes of pressure in the cylinder, an element connected to said diaphragm and an element connected to said displacer piston, said elements being capable of movement relatively to one another and connected by energy storing means, whereby the movement of said displacer piston and diaphragm causes energy to be stored in said energy storing means and the stored energy to be imparted to the displacer piston at a point in the stroke of the diaphragm dependent on the loading of said motor.

8. A hot air motor comprising in combination a cylinder, said cylinder being heated in one part and cooled in another part, a displacer piston within said cylinder a diaphragm closing one end of said cylinder,

said diaphragm being subjected to and having movements responsive to changes of pressure in the cylinder, an element connected to said diaphragm and an element connected to said displacer piston, said elements being capable of rotary movement relatively to one another and connected by a spring whereby the relative movement of said elements caused by the movement of said displacer piston and diaphragm causes said spring to store energy which is imparted to the displacer piston at a point in the stroke of the diaphragm dependent on the degree of loading of the motor.

9. A hot air motor comprising in combination a cylinder, said cylinder being heated in one part and cooled in another part, a motor element subjected to and having movements responsive to changes of absolute pressure within the cylinder, a displacer piston within said cylinder, an extension on the cylinder, a rod carried by the displacer piston and passing through said extension, means for imparting energy stored from the movements of the motor element to the displacer piston at a point in the stroke of said motor element dependent on the degree of loading of the motor.

10. A hot air motor comprising in combination a cylinder, said cylinder being heated in one part and cooled in another part, a displacer piston within said cylinder, an element subjected to and having movements responsive to changes of absolute pressure within said cylinder and an elastic connection between said element and the displacer piston, said elastic connection comprising a primary and a secondary spring, and means acting to utilize the energy given to these springs for reversing the movements of the displacer piston.

In testimony whereof, we affix our signatures in presence of two witnesses.

CLAUDE HOUSTON STUART.
CHARLES SCOTT-SNELL.

Witnesses:
BERTRAM H. MATTHEWS,
T. J. OSMAN.