(No Model.)

4 Sheets—Sheet 1.

R. M. MARCHANT.

STEAM ENGINE.

No. 332,670. Patented Dec. 15, 1885.

Fig. 1.

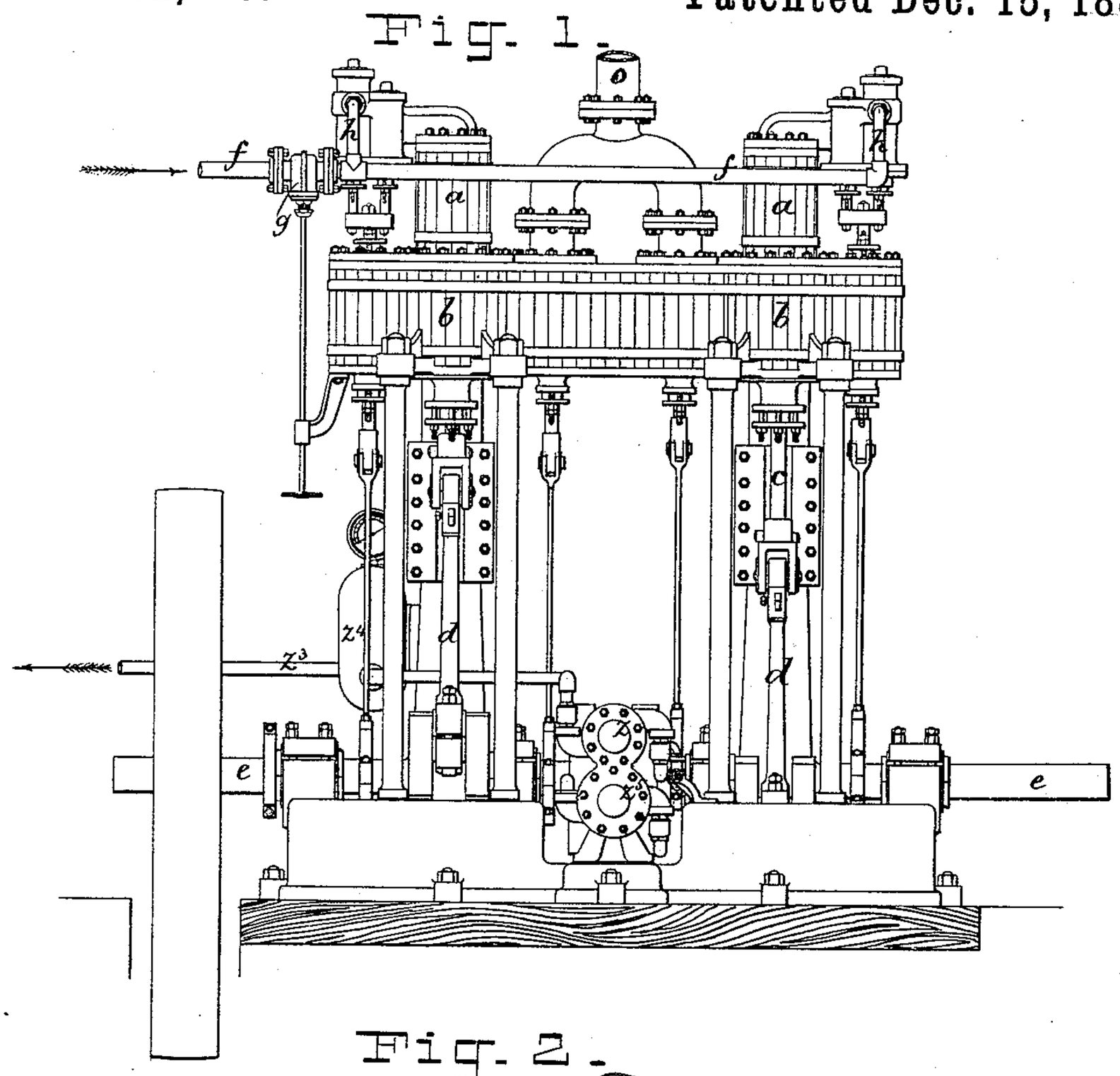
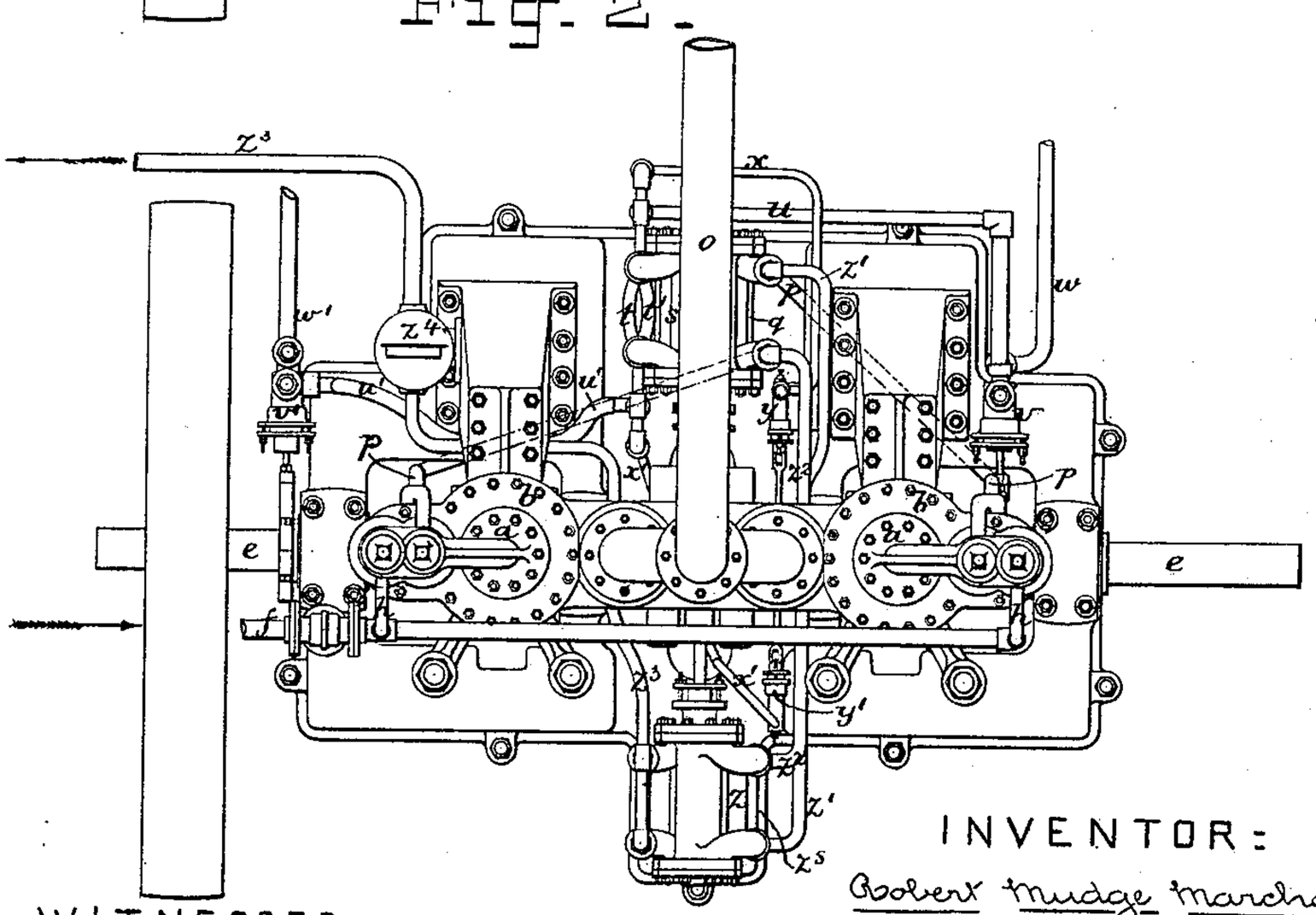


Fig. 2.



WITNESSES:

E. B. Bolton

Geo. Bainton

INVENTOR:

Robert Mudge Marchant

By his Attorneys:

Burke, Fraser & Connett

(No Model.)

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Fig. 3.

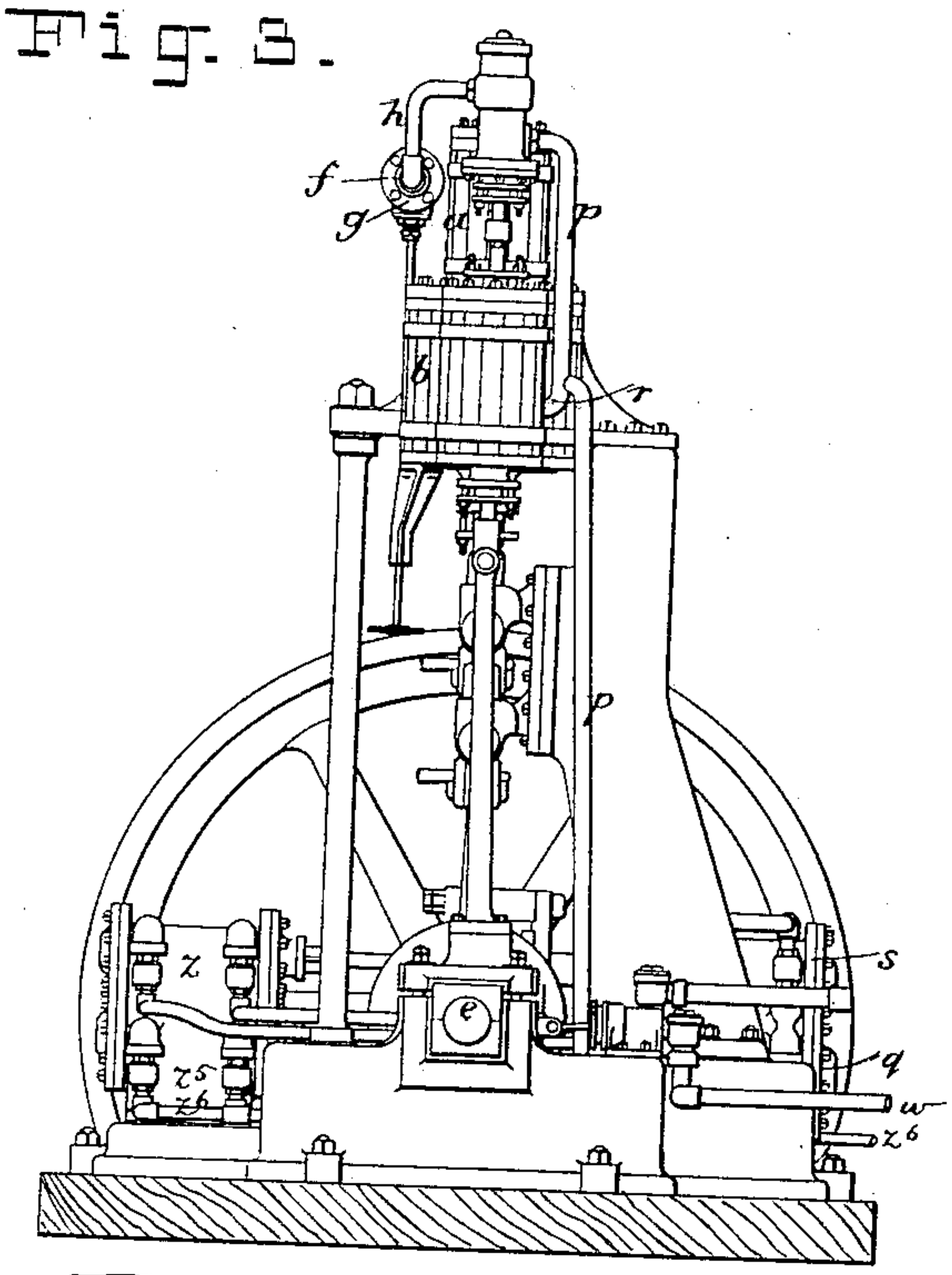
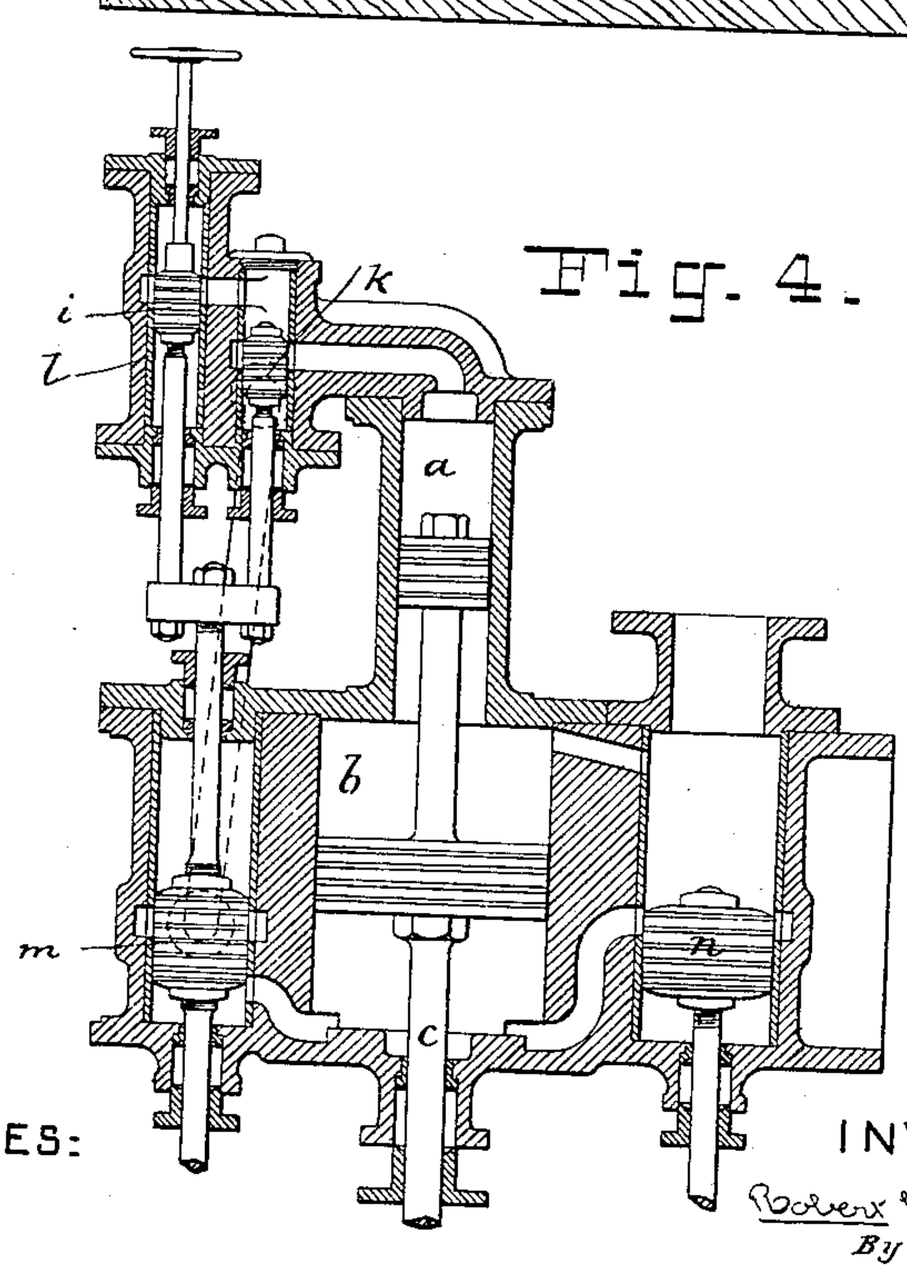


Fig. 4.



WITNESSES:

E. B. Bolton

Geo. Bainton

INVENTOR:

Robert Mudge Marchant

By his Attorneys:

Burke, Fraser & Connett

(No Model.)

4 Sheets—Sheet 3.

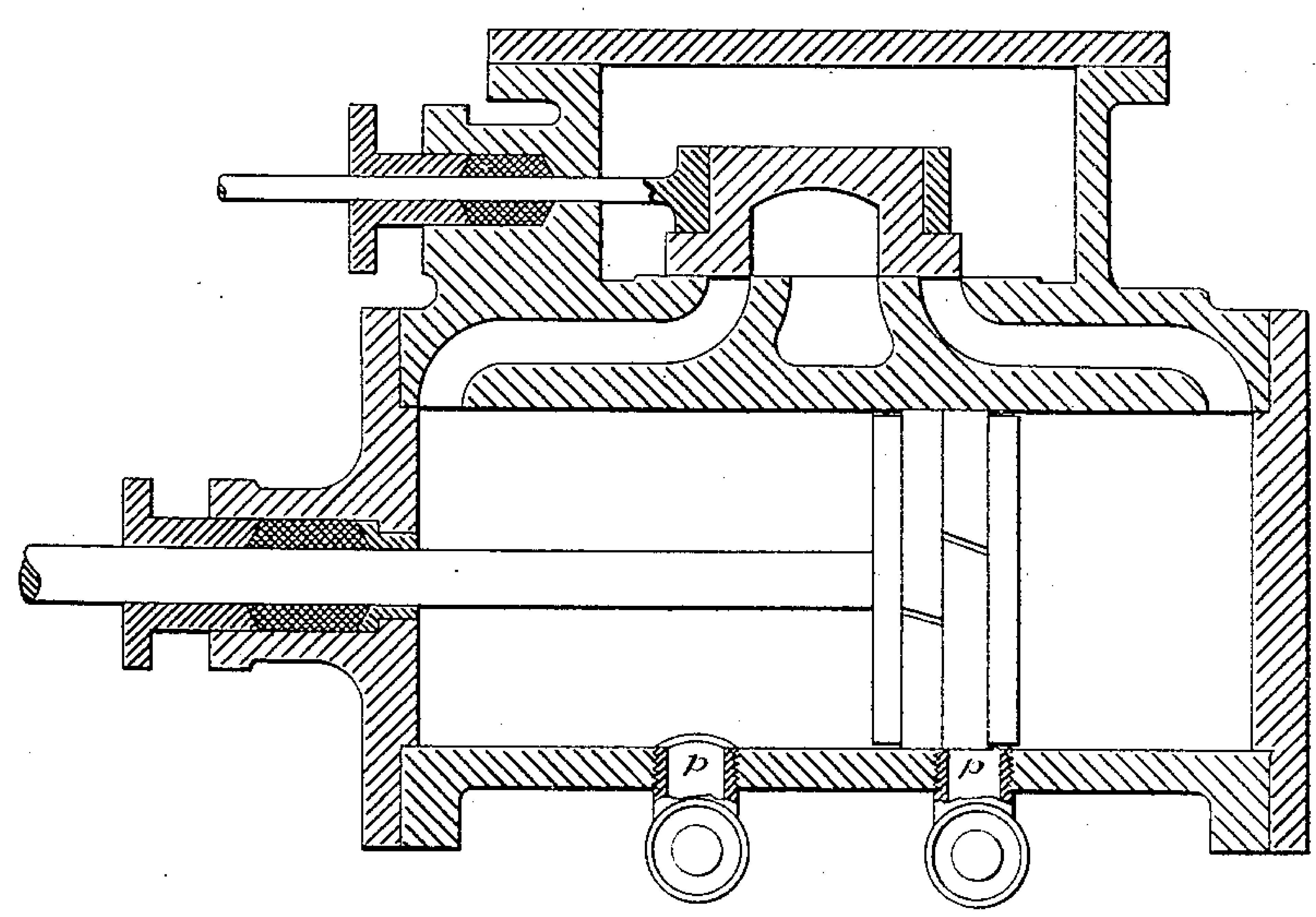
R. M. MARCHANT.

STEAM ENGINE.

No. 332,670.

Patented Dec. 15, 1885.

Fig. 5.



WITNESSES:

E. B. Bolton

Geo. Bainton

INVENTOR:

Robert Mudge Marchant

By his Attorneys,

Burke, Fraser & Connett

(No Model.)

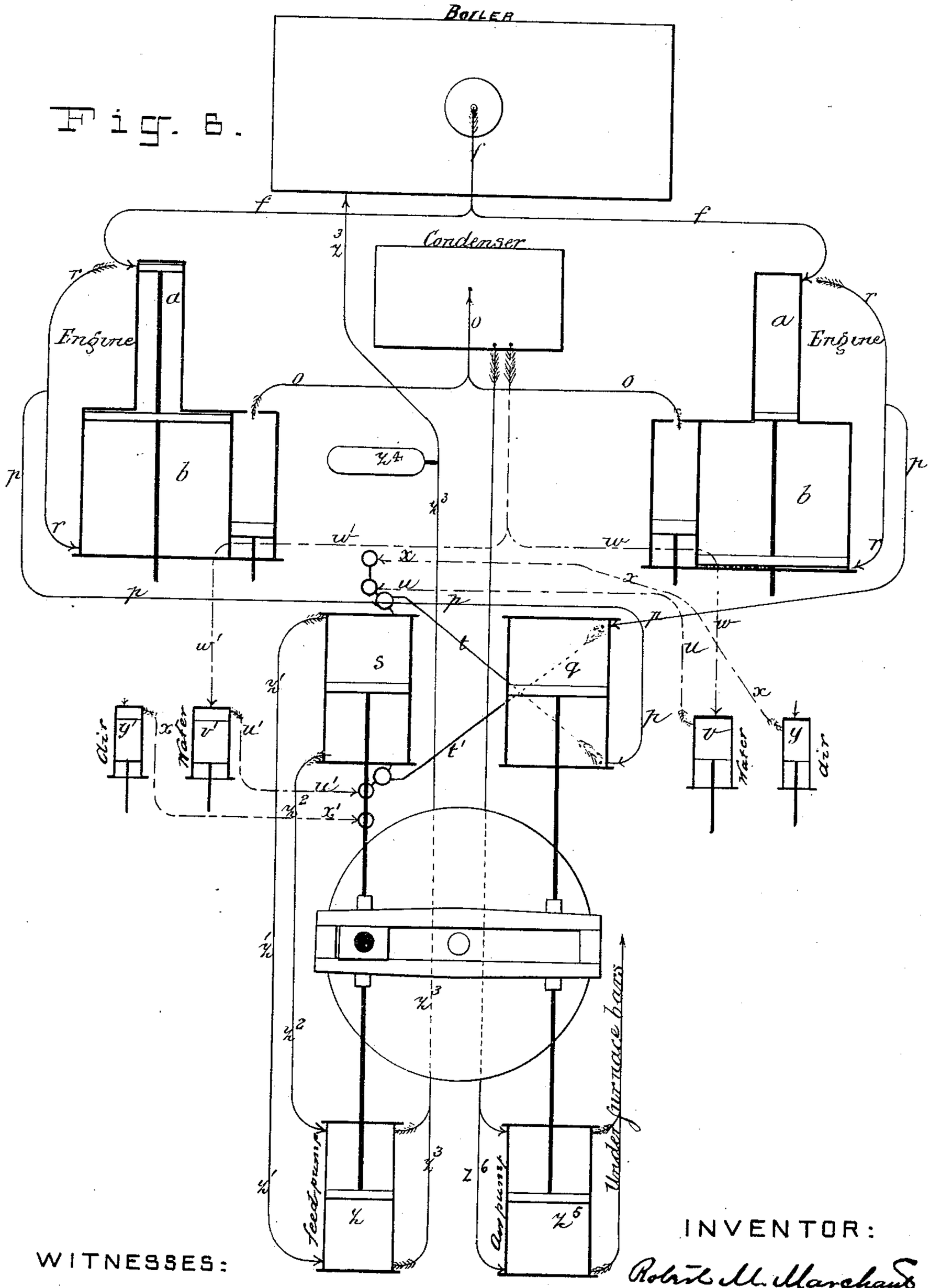
4 Sheets—Sheet 4.

R. M. MARCHANT.

STEAM ENGINE.

No. 332,670. Patented Dec. 15, 1885.

Fig. 6.



WITNESSES:

E. B. Bolton

Geo. Baumford

INVENTOR:

Robert M. Marchant
by his attys.
Burke, Fraser & Bowman

UNITED STATES PATENT OFFICE.

ROBERT MUDGE MARCHANT, OF LONDON, ENGLAND.

STEAM-ENGINE.

SPECIFICATION forming part of Letters Patent No. 332,670, dated December 15, 1885.

Application filed May 25, 1885. Serial No. 166,566. (No model.) Patented in England April 26, 1883, No. 2,120; in France December 18, 1883, No. 159,237; in Germany December 25, 1883, No. 27,834, and in Belgium December 28, 1883, No. 63,697.

To all whom it may concern:

Be it known that I, ROBERT MUDGE MARCHANT, of London, England, have invented certain new and useful Improvements in and connected with Steam-Engines, of which the following is a specification.

The object of my invention is to utilize nearly the whole of the steam which has been used in steam-engines by returning it to the boiler, partly in the state of steam and partly as condensed water, whereby, among other advantages, I effect a great economy in that very large proportion of the fuel which represents the cost of manufacture or production of that latent heat which is required for the formation of a vapor out of a liquid; and my invention consists in taking off a portion of the steam from the engine-cylinder as soon as it has done its work at high or full pressure and returning this portion, by means of pumps, to the boiler in the manner hereinafter described, and in applying the remainder of the steam for working the engine by expansion and vacuum, and then condensing this steam, the water resulting from this condensation being passed on, with air or other gas or vapor, to the pumps before referred to, so as to saturate the steam therein, this saturated steam, or mixed steam and water, being returned, with the air or other vapor, by the pumps to the boiler. The pumping of steam in the presence of a liquid of its own temperature produces a mere churning action, the steam being alternately compressed in the liquid and again (on the return-stroke) separating itself therefrom. It is therefore necessary to introduce into the pump a foreign element which will act under that law of physics which teaches us that in a mixture of gases "the total pressure is equal to the sum of the individual pressures," and that it by no means follows that each gas exercises the same pressure in making up such sum or total pressure. I therefore, in accordance with this law, add to the existing pressure of the steam, by means of pressure communicated from another gas or vapor, that further pressure which is required to make a pressure equal to the boiler-pressure, so that the charge of steam with the required minimum of such foreign element shall go forward to the boiler, and that a continuous circuit of the steam shall be thus effected, the conditions being high-pressure steam and temperature, water of the same temperature, and so much of a foreign vapor as is necessary to supply the required difference or excess of pressure. The churning and useless action thus becomes a forward and operative action, and the circuit is established by means of the pressure supplied to the foreign element and added by it to the existing pressure of the steam. Air is a convenient foreign element for this purpose. I compress it in the pumps, and the pressure so produced on a minimum of air is so added to the pressure of the steam as to effect, under the law referred to, the required pressure in the pumps, so that I obtain a regular and continuous circuit of the whole charge of steam and water with a minimum of air. The air and steam retain their independent characters as distinct vapors, the steam entering the water without increasing its pressure, and the air receiving the added pressure and communicating it to the charge, "the total pressure being the sum of the individual pressures." The air remains above the steam and water, and when the outlet-valves are at the bottom of the pump, as I place them, the air remains in the pump-clearances, and gives back on the return-stroke the pressure communicated to it, the excess air passing forward with the charge of steam and water, such excess being limited to what is necessary to complete the forward movement of the steam and water by a clean delivery.

In order to carry out my invention to the best advantage, I construct a special engine, which I will first describe. I will then describe the application of my invention to existing engines. The point at which the steam is taken off to the pumps is most important. It should be effected at or soon after that point where the high-pressure action in the cylinder terminates, and therefore before or soon after the steam begins to be applied to expansive action. The proportion of steam taken to the pumps will be about two-thirds of the charge supplied to the high-pressure cylinder, and the pumps will be so proportioned and set and work (stroke for stroke with the engine) in connection with the engine-shaft as to take

any required proportion of the steam at the point of such full-pressure delivery from the engine-cylinder.

For my special engine I prefer a tandem arrangement of cylinders, the smaller cylinder (or cylinders) receiving throughout the stroke a full charge of steam at the boiler-pressure, and the larger cylinder (or cylinders) being about eight times the capacity of the smaller cylinder, and making the return-stroke by the expansive force of its proportion of the steam which has done duty at full pressure in the small cylinder. The boiler should be sufficiently strong to contain high-pressure steam. As regards the pumps, there should be little clearance, the pumping from one pump to another being effected by what is known as the "stage" process of pumping, by which the steam is gradually compressed to the required pressure. A full-pressure charge being delivered into the barrel of the first pump, this charge propels the pump-piston expansively. There is an air-pump to draw off from the surface-condenser any air which becomes separated from the steam as the latter condenses, and an arrangement for giving the required air (or foreign-vapor supply) to the steam-pumps. There should be a self-acting lift-valve in connection with the boiler, through which the charge is delivered without the possibility of back action from the boiler. The steam, after doing its duty in the large engine-cylinder, is condensed in the surface-condenser, and is then delivered as water into the barrel of the second or other pump with or just behind the steam which is being forced into this pump. The first action of such steam under propulsion is to become partly condensed, until by such condensation the water is raised to its own temperature, after which the whole charge is transmitted by means of the compression of the air, (or other foreign vapor,) which has been already described as effecting "a total pressure which is the sum of the individual pressures" —that is, of the steam-pressure and the air (or foreign vapor) pressure.

In applying my invention to existing engines I take the stated proportion of the full-pressure charge of steam from the cylinder at the point where such full-pressure charge has effected its work in the cylinder, and before or just after it begins to expand therein, this proportion of steam being taken off by self-acting lift-valves fixed into the cylinder at a point immediately before or just after the expansive action commences, when the steam-supply is cut off by the slide-valve. In other respects the arrangement is the same as already described.

Figure 1 of the annexed drawings is a side elevation, Fig. 2 a plan, and Fig. 3 an end elevation, of a double-acting steam-engine constructed according to my invention. Fig. 4 is a vertical section, on a larger scale, of one of the pairs of cylinders (which are shown as arranged tandem fashion) and of the valves connected therewith. Fig. 5 illustrates the application of my invention to an existing form of steam-engines. Fig. 6 is a diagram or general explanatory view, designed to show more clearly the relative arrangements of the several parts, together with their connections. This view shows the condenser and boiler, although my engine may be made and sold as a complete article of trade or manufacture, and be connected with any existing boiler and condenser.

a a are respectively the small or high-pressure cylinders of the two tandem pairs, and *b b* the large or low-pressure cylinders of the same. The pistons of the two cylinders of the same pair are shown as mounted on the same rod, *c*.

d d are the rods connecting the pistons with the crank-shaft *e*.

f is the steam-supply pipe from the boiler; *g*, the starting-valve; *h h*, the branches for the cylinders *a a*, respectively. Each of these branches delivers the steam to a valve, *i*, Fig. 4, which is worked in equilibrium by means of a passage formed through it for the purpose. These valves govern the supply of steam to the operating-valves *k* of the cylinders *a a*, and are adjustable by means of the screw *l*, so that the supply of steam to the valves *k* can be cut off for any desired portion of the revolution of the engine.

m is the valve of the large or low-pressure cylinder. The valves are so arranged that the supply of steam to each cylinder *a* is cut off before its piston has reached the end of its stroke. There is thus an interval of time between the delivery of steam from the cylinder *a* to the first compressing-pump of the series and the opening of the valve *m*, which delivers the remainder of the steam to the cylinder *b*.

n is the exhaust-valve of the low-pressure cylinder.

o is the exhaust-pipe common to both of the low-pressure cylinders. This pipe *o* leads to a condenser.

p p are the pipes taking off the steam from the high-pressure cylinders to the first compressing-pump, *q*, of the series before or soon after the steam begins to be applied to expansive action in the said cylinders. Branch pipes *r* lead from the pipes *p p* to the valves *m* of the low-pressure cylinders. The two pipes *p p* from the two high-pressure cylinders *a a* communicate, respectively, with the two ends of the first pump, *q*, which is therefore a double-acting pump.

s is the second or intermediate compressing-pump, the two ends of which are respectively connected with the two ends of the first pump, *q*, by the pipes *t t'*, the inner end of the first pump being connected with the outer end of the second pump, and vice versa.

In connection with the pipe *t* is a pipe, *u*, supplied with condensation-water by a pump, *v*, which is connected with the condenser by a pipe, *w*, and in connection with the same pipe, *t*, is another pipe, *x*, supplied with air by

means of the pump or air-compressor *y*. The pipes *t*, *u*, and *x* are each fitted with a valve, the order of the three valves being such that the steam from the first pump, *q*, enters the second pump, *s*, in advance of the condensation-water from the pipe *u*, and that this condensation-water enters the pump *s* in advance of the air from the pipe *x*. The pipe *t'*, communicating with the opposite end of the pump *s*, has similarly-connected with it a condensation-water-supply pipe, *u'*, and an air-supply pipe, *x'*, the pipe *u'* being supplied by a pump, *v'*, connected with the condenser by a pipe, *w'*, and the pipe *x'* being supplied by a pump, *y'*. The pump *s* pumps the steam, saturated with the condensation-water, to the next pump, *z*, of the series, this pump in the arrangement shown being the last pump; but there may be any required number of pumps, the pumping being effected, as already stated, by what is known as the "stage" process of pumping, by which the steam is gradually compressed to the required pressure.

I call pump *z* the "feed-pump," as it feeds the boiler with the mixture of steam and condensation-water, as will be described.

z' z² are the pipes communicating, respectively, between the two ends of the pump *s* and the corresponding ends of the pump *z*. The pump *z* pumps the compressed saturated steam through the pipe *z³*, back into the boiler, this pipe being fitted with a self-acting lift-valve.

z⁴ is an air-chamber intercalated in the pipe *z³*.

z⁵ is an air-pump communicated by the pipe *z⁶* with the condenser, to free the latter of any accumulation of the air which becomes separated from the steam therein. This air-pump may discharge the air either into the atmosphere or under the grate-bars or other suitable part of the engine-furnace, so as to assist the combustion therein. All the pumps are worked from the crank-shaft *e*, which has a third crank, as shown, between the two cylinder-cranks. When the engine is at work and the pumps *s* and *z* have received a sufficient charge of air, the air-pumps *y y'* only make good the waste of this original charge. The outlet valves or ports for the saturated steam or steam and water from the pumps *s* and *z* are at the bottom of the pumps. The air remains in the pump-clearances, and on the return-strokes of the pump-pistons it acts as an air-spring, giving out the pressure which has been communicated to it, only the excess air passing forward with the steam and water.

Fig. 5 is a longitudinal section of the engine-cylinder, such as is used when my invention is applied to existing or ordinary engines. In this case I take off the required proportion of the full-pressure steam from cylinder at the ports *p p*, which are fixed in such position as to take the charge when or just after it has effected its full-pressure action in the cylinder and before or just after it begins to expand therein. From these ports *p p*, I deliver it in the manner already stated, to the pump *q*, Figs. 1, 2, and 3, and I take the exhaust-steam from the cylinder at the end of the stroke, and connect it by a pipe, in the manner already explained, with the condenser, the process or action going on as previously described.

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

1. The combination, with a steam engine and boiler, of a feed-pump for feeding the boiler, a condenser communicating with the exhaust from the engine, a steam-passage communicating with the engine-cylinder and adapted to transfer steam therefrom at high pressure, two or more pumps and their communicating passages, substantially as described, adapted to compress and unite said steam and the water resulting from the condensation of the remaining steam, and to force them to the feed-pump, to be returned into the boiler, and an air-compressor with its discharge-passage communicating with said pumps and adapted to force compressed air or other gas thereto, to effect the sending forward or propulsion of said steam and water, substantially as and to the effect set forth.

2. The combination, with a steam engine and boiler, of a feed-pump for feeding the boiler, a pressure-pump, the inlet-passage thereto communicating with the cylinder, and the outlet-passage thereof communicating with an intermediate pressure-pump, the said intermediate pump, the outlet-passage thereof communicating with said feed-pump, a condenser communicating with the exhaust from the engine, a condensation-water pump with its inlet communicating with said condenser and its discharge communicating with said intermediate pump, and an air-compressor with its discharge communicating with said intermediate pump, all substantially as set forth, whereby a portion of the steam, after having done its work at high pressure in the engine-cylinder, is transferred therefrom and compressed, and the remaining steam, after having acted by expansion, is condensed, and the condensation-water is forced forward with the aid of the compressed air or other gas being united with and separated by the said steam, and the mixed steam and water are finally forced by the feed-pump, aided by the compressed air, back into the boiler.

3. The combination of the engine-cylinder, the steam-inlet pipe, the exhaust-pipe, the condenser, the condensation-water pump *v*, the passage *w* from the condenser to said pump, the compressing-pump *q*, the passage *p*, for high-pressure steam, leading thereto from the cylinder, the delivery pipe or pipes from said pump, communicating with the compressing-pump *s*, and eventually with a feed-pump, *z*, the said compressing-pump *s*, the said feed-pump, the passage *u*, leading from the pump *v* and communicating eventually with said feed-pump, an air compressor or pump, *y*, the

delivery-passage therefrom communicating eventually with said feed-pump, and the feed-pipe z^3, leading from the feed-pump to the boiler, substantially as set forth.

4. The combination of the engine-cylinders, the steam-inlet pipe, the exhaust-pipe, the condenser, the double-acting condensation-water pump or pumps, passages leading thence from said condenser, the double-acting first compressing pump or pumps, passages leading thence from the respective cylinders, the double-acting intermediate compressing pump or pumps, the double-acting air pump or pumps, the double-acting feed-pump for feeding the boiler, the double passages leading from the respective air and feed pumps and first compression-pumps and communicating with said intermediate compression pump or pumps, the double passages leading from said intermediate compression pump or pumps and communicating with said feed-pump, and the passage leading thence to the boiler, with the engine-shaft and connections therewith for operating said pumps in unison with the engine-pistons, substantially as set forth.

5. The combination of the engine-cylinders, the steam-inlet pipe, the exhaust-pipe, the condenser, the condensation-water pumps, the passage leading from the cylinder for taking off high-pressure steam, the first and intermediate compressing-pumps, the feed-pump for feeding the boiler, the air-compressor, and passages leading from said condensation-water pump, compressing-pumps, and air-compressor, communicating eventually with said feed-pump, with the air-suction pump z^5, communicating with the condenser and adapted to draw the air therefrom, substantially as set forth.

In witness whereof I have hereunto signed my name in the presence of two subscribing witnesses.

ROBERT MUDGE MARCHANT.

Witnesses:

JOHN C. NEWBURN,

GEORGE C. BACON.