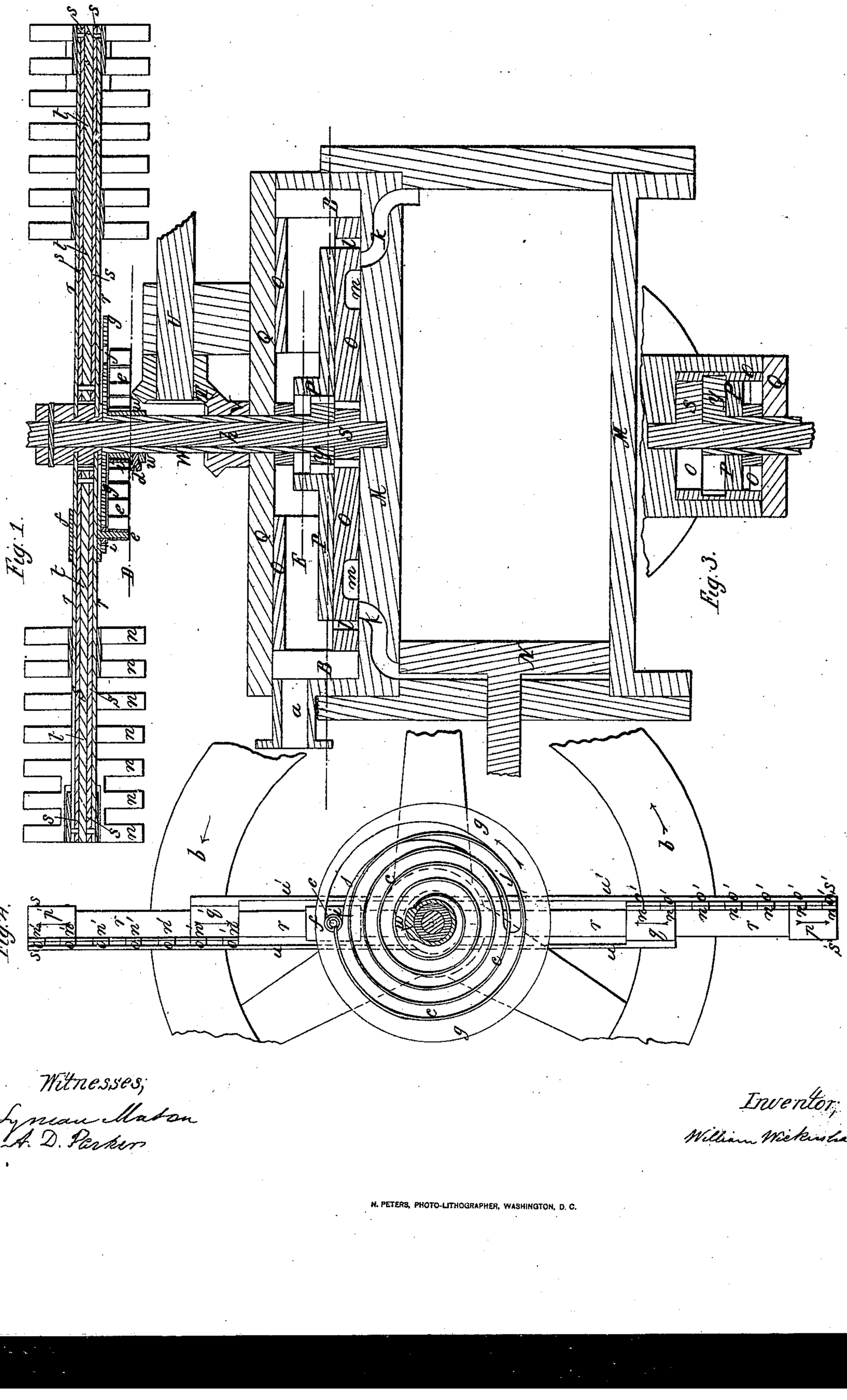
Sheet 1-3 Sheets.

W. Wickersham.

Steam Governor.

No. 95,543. Patented Oct. 5, 1869.



Witnesses;
Lyman Mason
A. D. Parker

Inventor;
William Wickersham

Sheet 2-3 Sheets.

W. Wickersham.

Steam Governor.

No. 95,543. Patented Oct. 5, 1869.

Fig. 17.

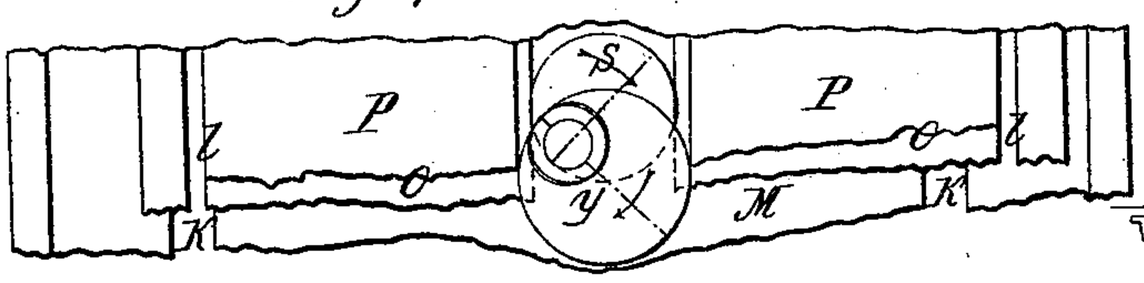


Fig. 8.

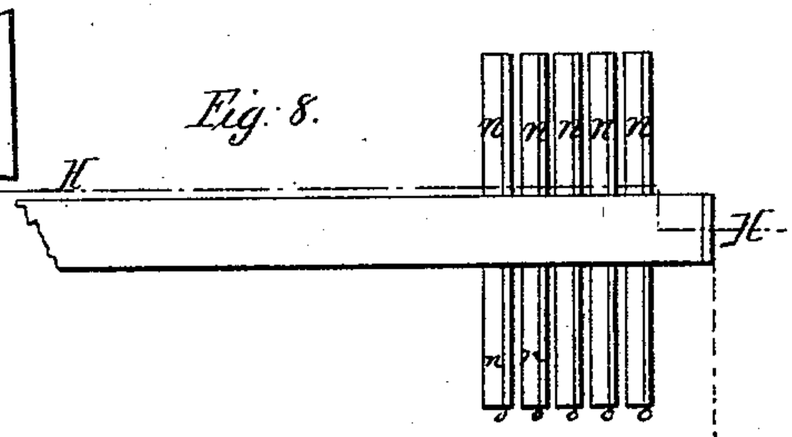


Fig. 7.

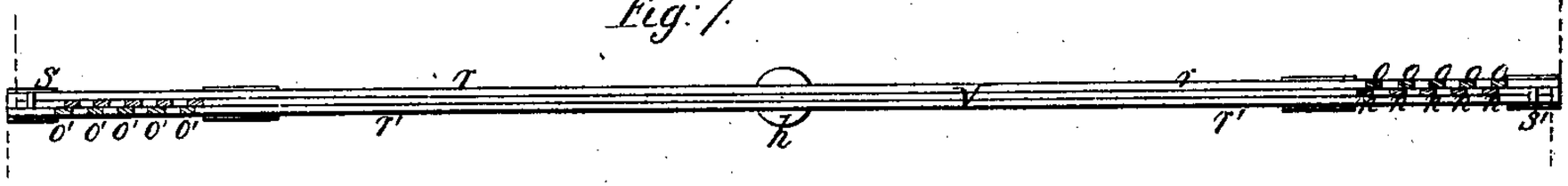


Fig. 6.

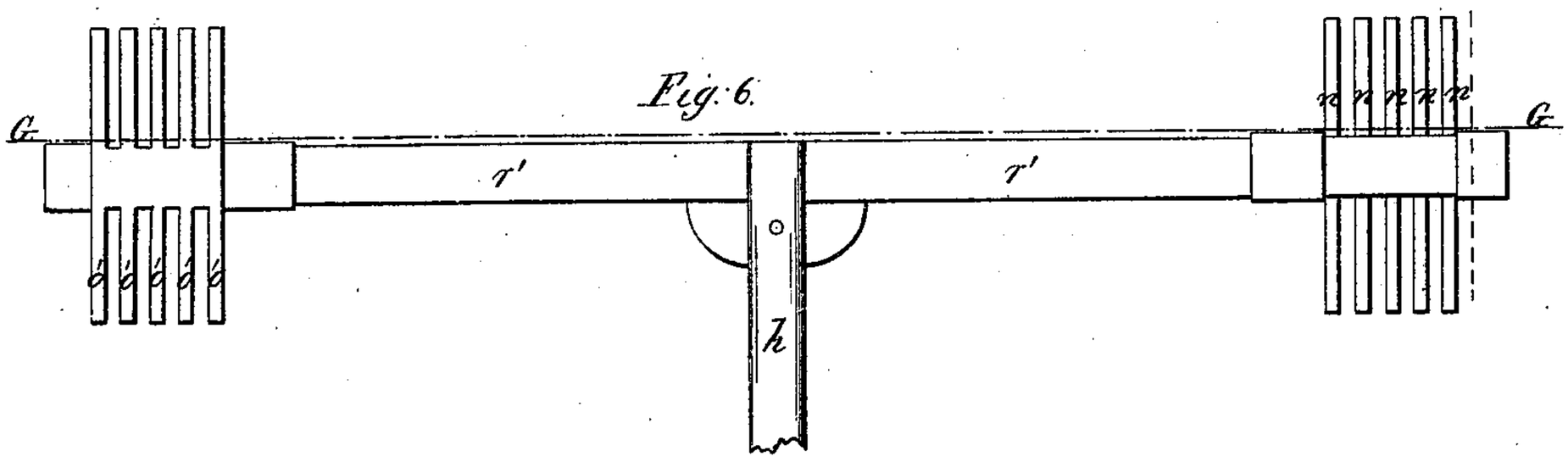


Fig. 5.

Fig. 9.

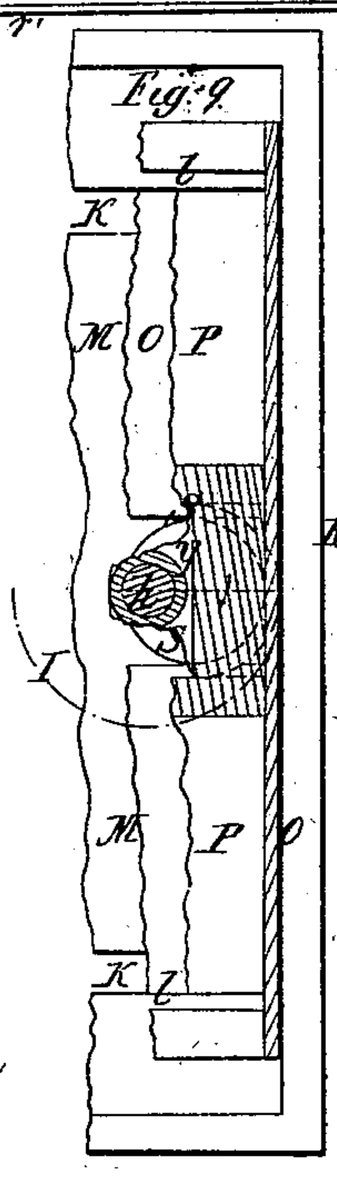


Fig. 10.

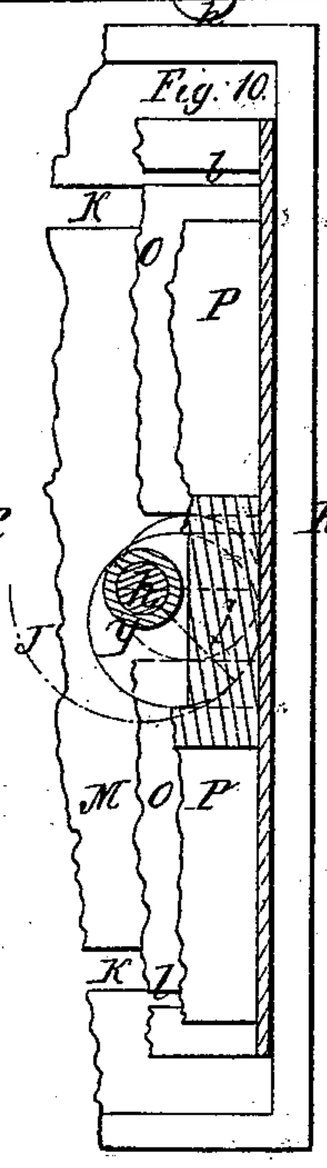
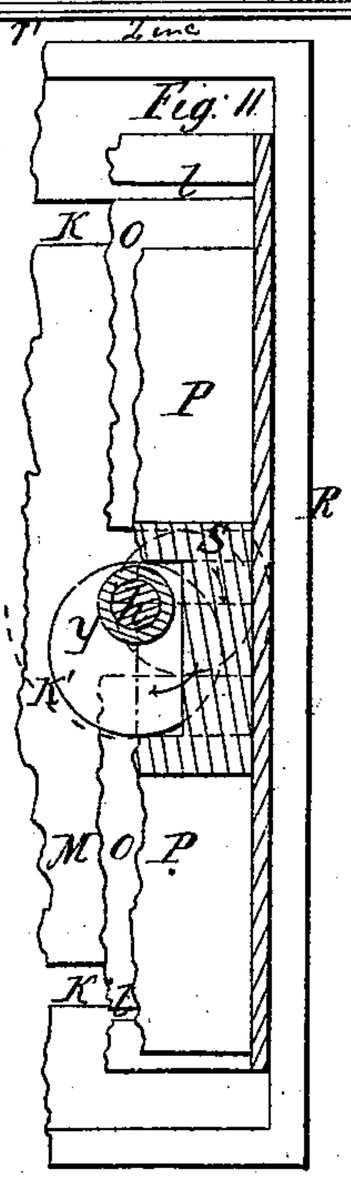


Fig. 11.



Witnesses;
Lyman Mason
A. D. Packer

Inventor;
William Wickersham

W. Wickersham.

Sheet 3-3, Sheets.

Steam Governor.

No. 95,543. Patented Oct. 5, 1869.

Fig. 2.

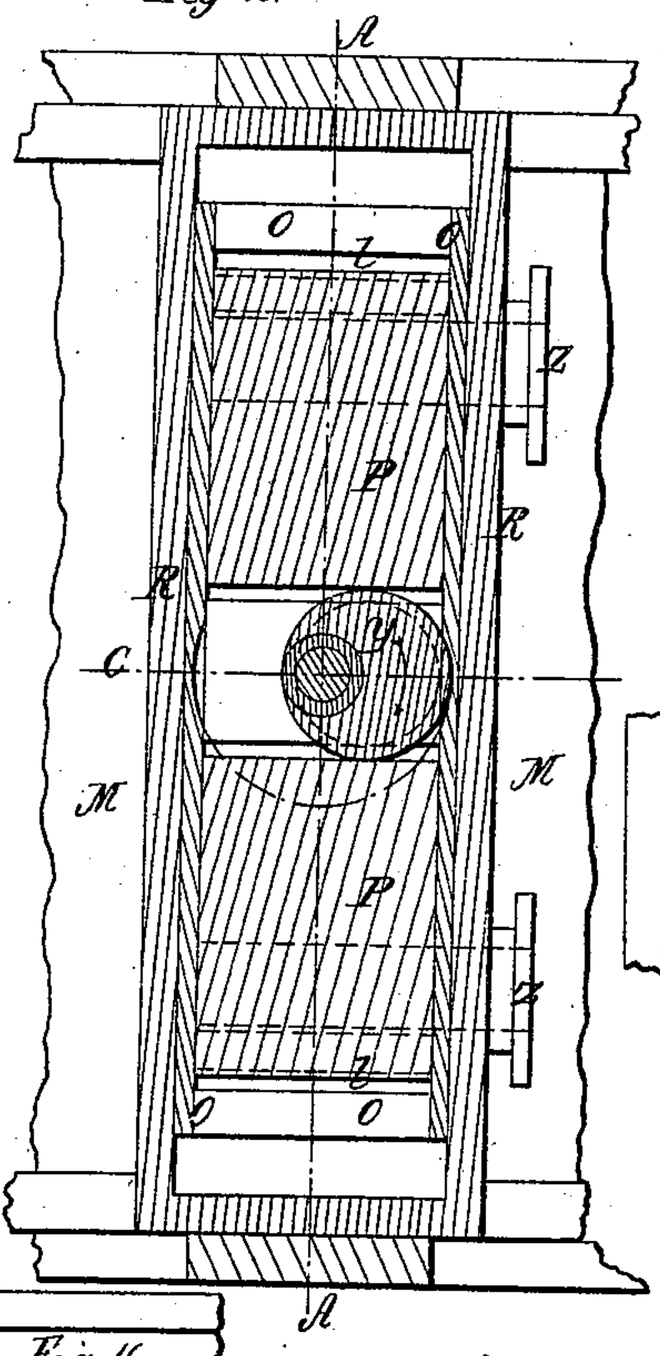


Fig. 18.

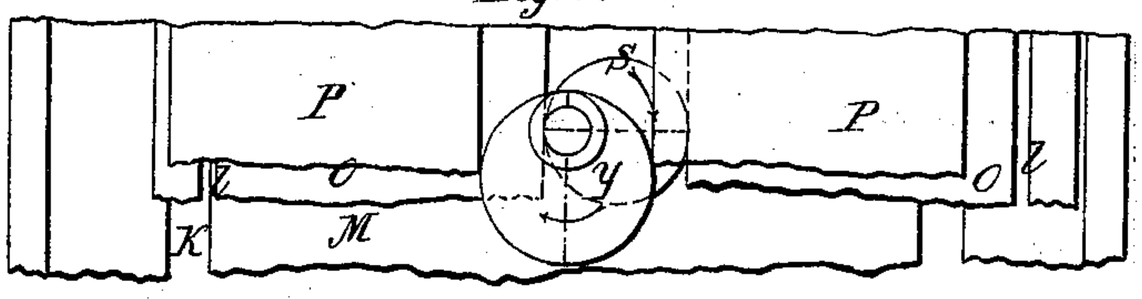


Fig. 16.

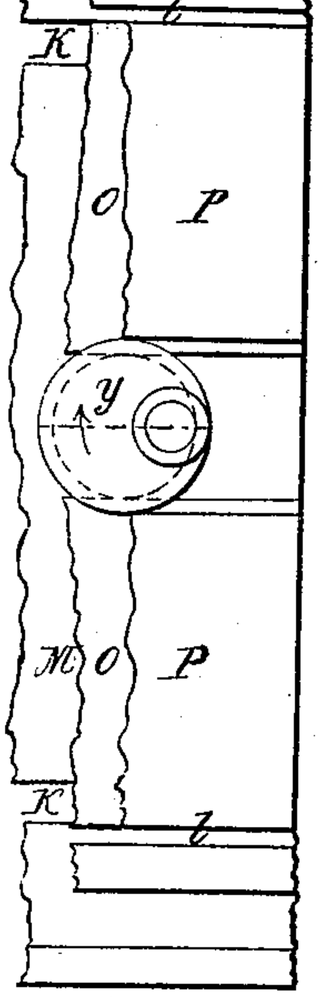


Fig. 12.

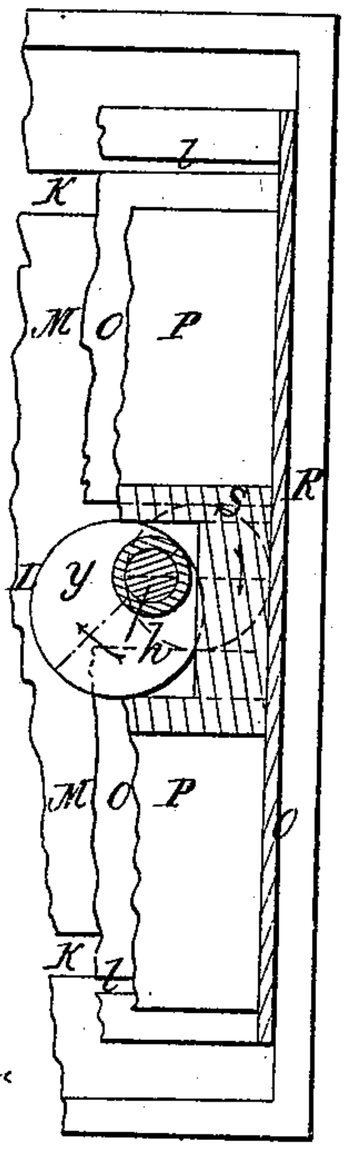


Fig. 13.

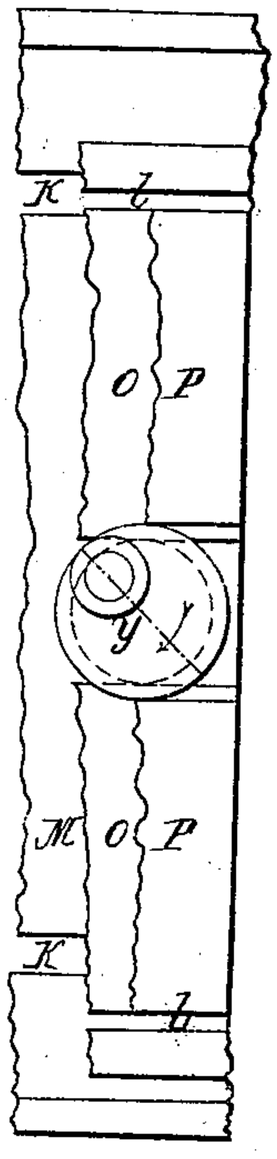


Fig. 14.

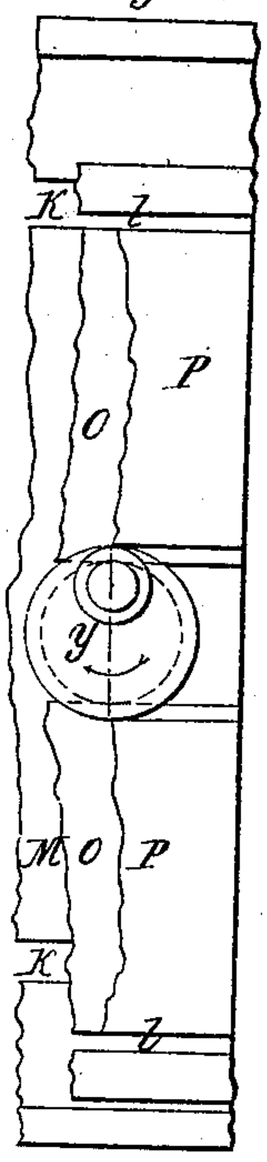
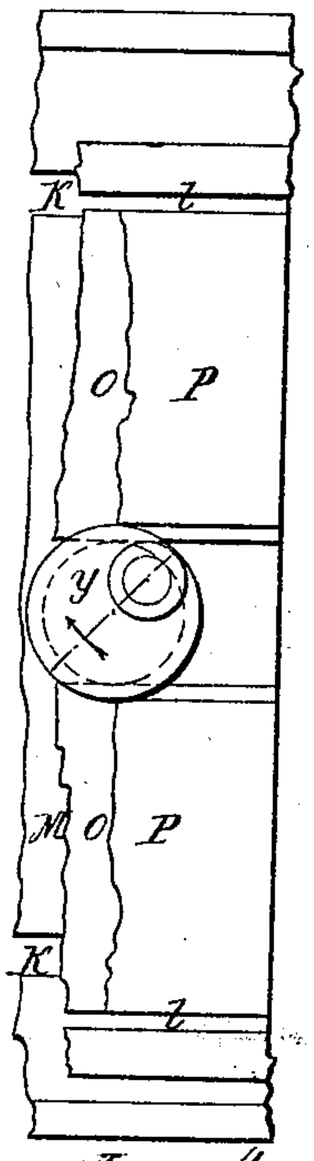


Fig. 15.



Witnesses,
Lyman Mason
A. D. Parker

Inventor;
William Wickersham

United States Patent Office.

WILLIAM WICKERSHAM, OF BOSTON, MASSACHUSETTS.

Letters Patent No. 95,543, *dated October* 5, 1869.

IMPROVEMENT IN STEAM-ENGINE GOVERNORS.

The Schedule referred to in these Letters Patent and making part of the same.

To all whom it may concern:

Be it known that I, WILLIAM WICKERSHAM, of Boston, in the county of Suffolk, and State of Massachusetts, have invented a new and useful Steam-Governor; and I do hereby declare that the following is a full and exact description thereof, reference being had to the accompanying drawings, and to the letters of reference marked thereon.

The first feature of my invention relates to a time-shaft, and its connection with the valve; and consists of a shaft so connected with the valve, that while it turns a given number of revolutions in a given time, it will impart to the valve the same number of movements forward and backward in the same time.

The second feature of my invention relates to two shafts, in connection with the valve and cut-off slide, one governed by time, and the other moved and governed by the main shaft of the engine, the time-shaft giving motion to the valve, and the engine-shaft giving motion to the cut-off slide, and these all so arranged that when the two shafts have their eccentrics, cranks, or cams, which give motion to the valve and cut-off slide, on the same side, as they revolve together the port will be open nearly the whole stroke of the piston, and when the engine-shaft is in advance of the time-shaft to any degree within an arc of one hundred and eighty degrees, (to which it is limited,) the port will be closed during the last portion of the stroke of the piston to nearly the same degree, and, by thus diminishing the steam whenever the engine-shaft makes any advance on the time-shaft, and this diminution of steam becoming greater according to the greater degree of advance, the engine-shaft is substantially and practically held to or governed by time.

The third feature of my invention relates to the equalization of the force of the spring on the fan, which force is constantly liable to variation; and consists in applying the force nearer to the centre of motion of the fan, proportionally as the force increases.

The fourth feature of my invention relates to the automatic adaptation of the surface of the fan to the changing resistance of the air by temperature; and consists in so connecting the fans with metallic bars, formed of metals of unequal expansibility, so arranged and formed that by this unequal expansion the effective surface of the fan will be so varied that while the resistance of the air varies, its resistance on the fan will be always the same, with the same velocity of the fan.

The fifth feature of my invention relates to the form and construction of the fan; and consists in making the fan with two series of leaves and spaces, one series attached to the bar which has the greater expansion, and the other attached to the one which has the less expansion, in such manner that the unequal expansion of the bars will cause the leaves of one series to partially cover the spaces of the other series, thereby enlarging the effective surface of the fan.

The sixth feature of my invention relates to the device by which any desirable speed may be fixed to the engine, which speed will be continued uniformly by the governor; and consists of a ring around the shaft, controlled by the engine, to which the inner end of the spring is attached which drives the fan, so arranged on the shaft that it can be turned to any position on the shaft, or any number of times around the shaft, and then fixed by set-screws, giving the spring any degree of tension, and thereby giving the time-shaft, which turns with the fan, any desirable speed, which speed is given to the engine-shaft.

Figure 1 is a perpendicular and longitudinal section through the red line A, showing the cylinder, piston, ports, balance-valve, and the eccentric which works it, and the machinery above, which impels it and regulates its movement; also, the cut-off slide within the valve, which operates as an automatic cut-off, with the eccentric, and machinery for working the same.

Figure 2 is a horizontal section through the steam-chest, in the red line B.

Figure 3 is a perpendicular cross-section through the steam-chest, in the red line C.

Figure 4 is a horizontal section of the two eccentric-shafts, in the red line D, and an under-side view of the spring, the fans, and other machinery above this section.

Figure 5, sheet 2, is a horizontal section of the fans, composed of three sheets, the middle one of steel and the two outside ones of zinc, in the red lines G, and in the lowest temperature, having the steel and zinc plates, forming the fan, of even length.

Figure 6 is a side elevation of the same.

Figure 7 is a section of the same in the red line H, after the temperature has been sufficiently raised to expand the zinc sheets in excess of the steel sheet to such a degree as to cause the zinc leaves of the fan to extend half way across the spaces between the leaves of the steel part of said fan.

Figure 8 is a side elevation of one end of the same.

Figure 9, sheet 3, is a horizontal section in the red line E, and illustrates the position of each eccentric relatively to the other, (their elongated sides in the same direction,) which keeps the port open while the piston moves the whole length of the cylinder, the time the port is open being represented by the red line or arc I.

Figure 10 illustrates the same, when the shaft-eccentric is forty-five degrees in advance of the time-eccentric, the red arc J, of one hundred and thirty-five degrees, representing the portion of a revolution of the shaft in which the port would be open.

Figure 11 shows the same, when the shaft-eccentric is ninety degrees in advance of the time-eccentric.

Figure 12 shows the same, when the shaft-eccentric is in advance of the time-eccentric one hundred and thirty-five degrees.

Figure 13 is the same as fig. 9, if both eccentrics should revolve together one-eighth round.

Figure 14 is the same, as having revolved one-quarter round.

Figure 15, as having revolved three-eighths round.

Figure 16, as having revolved one-half round; and it will be observed that in figs. 13, 14, and 15, the valve is open, and in 9 and 16 it is closed.

Figure 17 is the same as fig. 11, revolved one-eighth round, and

Figure 18, the same as fig. 11, revolved one-quarter round.

M is the cylinder.

N is the piston-head.

O is the balance-valve.

P is the cut-off slide.

Q is the top of the steam-chest.

R R are the two sides of the same.

S is the eccentric which gives motion to the valves O.

T is a gear on the shaft U, turning the gear V, and its hollow shaft W, and the eccentric Y, and all so arranged that the eccentric Y will revolve once round to one round of the main shaft of the engine.

Z Z are the two exhaust-ports.

a is the pipe leading from the boiler to the steam-chest.

b is the fly-wheel.

c is a spring, attached to the shaft W by the set-screw *d* in the ring *w*, while its outer end is secured to the pin *e* on the slide *f*, which is fitted movably on one of the arms of the fan.

The ring *w* is so formed and fitted on to the shaft W, and so attached to the inner end of the spring *c*, that it can be turned to any position on the shaft, or any desirable number of times around the shaft, carrying the end of the spring along with it, and thereby giving any desired degree of tension or power to the spring, as, by this governor, the speed of the engine has a direct relation to the force this spring exerts upon the fan, and accordingly, when this ring is turned to the position on the shaft which will give the desired speed to the engine, it is secured to this position by the set-screw *d*, and the engine continues to run with a uniform motion at the rate of speed thus fixed.

h is the shaft to which the fans are attached, and which has on its lower end the eccentric S, which gives motion to the valve O. These are so arranged that when the shaft W revolves, (by means of the gear T, which turns it once round to each round of the main shaft of the engine,) it carries the spring *c* around with it, which, in turn, by means of its elastic force, carries the fan around in the same direction, being attached to it by the pin *e*, so that the shaft W, the spring *c*, and the fan, have a common motion together so long as the resistance of the air against the fan, together with the resistance of the work on the eccentric S, is equal to the tension or elastic force of the spring, which limits and fixes the velocity of the fan; then, if the work of the engine diminishes, or the steam is raised, the shaft W and its eccentric Y will move in advance of the shaft *h* and its eccentric S.

But it will be perceived that when this is the case, the spring *c* will be wound up further, and its elastic force on the pin *e* will be greater; and if this greater force is exerted on the arm of the fan at the same distance from its centre of motion, it would cause the fan to move faster whenever the shaft W is in advance of shaft *h*.

To prevent this unequal force of the spring from giving an unequal motion to the fan, and to provide for a desirable uniformity of the same, I have attached a disk, *g*, to the upper end of the shaft W, and have placed a roll, *i*, on the pin *e*, to work in the groove *j* in the disk *g*, and, by observing the drawing in fig. 4, it will be seen that this groove *j* is nearer to the centre of the disk, at the opposite end from the roll *i*, (as shown in the drawings,) than at the place of said roll. The purpose of this is to equalize the varying force of the spring on the fan, by having it, as it is increased, applied to the arm of the fan nearer to its centre of motion, and in such relation as to make the real force of the spring on the fan uniform, however much the shaft W may be in advance of the shaft *h*.

By referring to the same drawing, it will be seen that the groove *j* extends only half way round in the disk *g*, so that the degree of advance of the shaft W, beyond the shaft *h*, is limited to one hundred and eighty degrees, which is sufficient for the purpose of my invention; as, in the first position, that is, with the greatest elongation of both eccentrics in the same direction, they will so act on the valve O and slide P as to keep the port open during the entire stroke of the piston; and, by having the shaft W one hundred and eighty degrees in advance of the shaft *h*, the port will be closed the whole time, and between these points the port will be open from the beginning of the stroke of said piston, but will be closed during the last portion of the stroke in proportion to the degree of advance which the shaft W has beyond the shaft *h*, which will be further illustrated and explained.

k k are the two ports to the cylinder.

l l are the two spaces in the valve connecting the steam-chest with said ports.

m m are the exhaust-ports, which have their outlet through Z Z.

Now, in case the force which gives motion to the fan is uniformly the same, and the eccentric S has the same work to do during each revolution, and the air furnishes a uniform resistance at any given speed, then, when this fan is set in motion by the force of this spring *c*, the motion of the fan will increase until the resistance of the air against it, together with the resistance of the valve O against the eccentric, is just equal to the force of the spring, and then a uniform motion to the shaft *h* will ensue, the constant force balancing a constant resistance, and this uniformity of motion will continue so long as the force remains the same, (for which I have already provided,) and the air continues to furnish a uniform resistance to the fan at any given speed. But this is liable to change by change of temperature, the air becoming less dense and furnishing less resistance as the temperature is raised. For instance, if the temperature is raised 491° Fahrenheit, the volume of the air is doubled, and its power of resistance reduced to one-half, and for a fan moving with a uniform velocity through the air having its temperature thus increased, should have the surface doubled; also, in order to meet the same resistance, and for each degree of increase of temperature, its surface should be increased $\frac{1}{491}$, or nearly so.

For this, I have provided a device, by which the surface of the fan is automatically increased with the increase of the temperature, thereby compensating for the diminishing resistance of the air as its temperature is increased.

On sheet 1, figs. 1 and 4, this device is shown in section in fig. 1, and a bottom view is shown in fig. 4.

The fan is made of many leaves, with intermediate spaces between them, and two sheets thus formed are placed together, and are so arranged that one will be moved in one direction, and the other in the other direction, in such manner that the leaves of one will fill the spaces of the other by the unequal expansion of metallic bars.

r r r r are zinc bars, which are attached at their inner ends to the shaft *h*, and at their outer ends to

the steel bars *s s s s*, which, in turn, have their inner ends attached to inner ends of the zinc bars *t t*, and the outer ends of these are attached to the slides *p p'*, in such manner as to give an outward expansive motion equal to the expansion of the zinc bars *r r r r* and *t t*, minus the expansion of the steel bars *s s*, &c.

The slide *p* is attached to the fan-leaves *o' o' o'* and the steel bar *u*, which extends to the slide *q'* on the other arm of the fan, and these slides *q* and *q'* are attached to the fans *n n n* and *n' n' n'*, and all arranged in such manner that the fans *o o o* and *o' o' o'* will, by expansion, be moved outward, as the arrow-points at *p p'* indicate, and the fans *n n n* and *n' n' n'* will be moved inward, as the arrow-points at *q q'* indicate, thereby causing the two series of fan-leaves to cover each others' spaces as the temperature rises, and in that way increase the effective surface of the fans; and these leaves should be made of such a width that the expansive motion of the bars would increase the effective surface of the fan by any given increase of temperature, in the same ratio as the diminution of the resistance of the air by the same increase of temperature.

I do not confine myself to steel and zinc bars for the arms of the fan, but may use any two metals which have a sufficiently unequal expansion for the purpose.

On sheet 2, a more simple form of the fan and the expansion-bars is shown, in which the arms and the fans are composed of three bars, the two outside ones of zinc, and the middle one of steel.

Fig. 6 shows a section through the leaves in the red line G, showing the relative position of the leaves before any expansion has taken place.

Fig. 7 is a side elevation of the same.

Fig. 8 shows a section of the leaves of the fan in the red line H, after the bars have been expanded.

Fig. 9 is a side elevation of one end of the same.

In this arrangement, the zinc bars *r* and *r'* have each a fan formed on one end, while the other end is attached to one end of the steel bar between them, one, *r'*, riveted to the end of the steel bar at *s'*, and its other end formed into a fan corresponding to the fan on the steel bar *v* at the same end, and the zinc bar *r* is attached to the other end of the steel bar *v* at *s*, and all arranged in such manner that when the temperature is raised, the bars *r* and *v*, being secured together at *s*, will have an unequal expansion, and thereby cause the leaves *o o o* on the bar *r* to advance over the spaces of the leaves *n n n* in the steel bar, and the bar *r'*, in like manner, being secured to the end of the steel plate *v*, at *s'*, will, when heated, have a greater expansion than the steel bar *v*, and the leaves of its fan *o' o' o'* will advance over the spaces between the leaves *n n n* on the steel bar, as shown in figs. 8 and 9, thereby increasing the effective surface of the fan.

Now, as the air expands to double its volume by raising its temperature 491° Fahrenheit, its resistance against a fan of the same surface will be one-half; therefore, the effective surface of the fan must be doubled to meet the same resistance, according to theory; and for each degree of temperature the fan must be increased in surface $\frac{1}{491}$; and, as zinc expands by raising its temperature from the freezing to the boiling-point of water $\frac{1}{351}$ of its length, and as steel, (not hardened,) by the same increase of temperature, expands $\frac{1}{927}$ of its length, the difference of expansion can be computed, and the width of the leaves of the fan estimated, by which the expansion of any given length of bars will increase the effective surface of the fan, for the purpose of compensating for the diminished resistance of the air by its increased temperature; or the width of these leaves may be ascertained by a purely practical way.

Take a fan made of a single sheet, as the steel sheet is shown on sheet 2, and try it under different temperatures, and ascertain the difference of surface for different temperatures, giving the same speed to the fan while it is impelled by a uniform force, and this will give the necessary data to adjust the leaves of the fan to the length of the bars *r r'* and *v*.

For the purpose of explaining more clearly the action of the eccentrics S and Y, I have made several drawings on sheet 3, which are partly horizontal sections of the steam-chest in the red line E, fig. 1, in which I have cut away part of the slide P and part of the valve O, in such manner as to show the ports *k k*, the openings *l l* in the valve O, and the ends of the slide P; also, showing the different positions of the eccentrics, and the effect of these different positions on the valve in opening and closing it, and in the operation of the cut-off slide in connection with said valve.

Fig. 9 shows the position of the two eccentrics, the same as in figs. 1 and 2, the two eccentrics having their elongated sides in the same direction, and the valve and cut-off slide are in such position as to open the passage for the steam into the cylinder, immediately on the movement of the two eccentrics in the direction indicated by the arrow-point on the same, and while they revolve through an arc of one hundred and eighty degrees, at which time it is closed, and the valve will be opened at the opposite end of the cylinder, which, in turn, will remain open during half a revolution of the eccentrics, or during the whole stroke of the piston, as indicated by the red arc I.

In fig. 10, as in fig. 9, the valve is in a position to open when the eccentrics begin to revolve; but, in this case, the eccentric Y, which moves with the engine-shaft, is forty-five degrees in advance of the time-eccentric S, and they can move only three-eighths of a revolution before the port is closed, as indicated by the red arc J; and in fig. 11 the shaft-eccentric Y is ninety degrees in advance of the time-eccentric S, and they can revolve only one-fourth of a revolution before the steam is cut off, as indicated by the red arc K'; and again, in fig. 12, the shaft-eccentric Y is three-eighths of a revolution in advance of the time-eccentric, and consequently the steam will be cut off at one-fourth of the stroke, as shown by the red arc L.

The figs. 9, 13, 14, 15, and 16, show the positions of the valve O and the cut-off P relatively to the port K, every eighth of the round through half of a revolution from the first position in fig. 9, where the valve is closed, to fig. 16, where it is again closed, the intermediate ones, figs. 13, 14, and 15, being open, having the opening in the valve at *l* immediately over the port K, and not being covered by the cut-off slide; and during this half revolution the two eccentrics turn together, that is, continue their greatest elongation in the same direction, as they both revolve with the same speed, and consequently the valve is open during the whole stroke of the piston, or within a fraction of it.

Again, in fig. 11 the elongated sides of the eccentrics are at right angles, the shaft-eccentric is in advance of the time-eccentric ninety degrees; but, holding that position, and turning together through forty-five degrees, gives the position seen in fig. 17, where the valve *l* is open, and turning again forty-five degrees gives the position in fig. 18, where the valve is again closed.

The fly-wheel *b* may be found necessary to maintain a uniformity of motion through the whole revolution of the time-eccentric, as its work will be in a measure unequal in its progress round.

Having described the parts, I will now describe the operation.

The steam is let into the steam-chest through the pipe *a*, and the shaft *h* is turned slightly to admit steam into the cylinder, back of the piston-head N, which moves it to the other end of the cylinder, and puts the whole machine in motion.

The shaft U, being so communicated with the main shaft of the engine as to revolve in the same time with it, turns the gear V and the shaft W with an equal speed.

Attached to this shaft W is a spring, *c*, which spring has its other end attached to the arm of the fan through the pin *e*, and thus imparting motion to the fan by a constant yielding force, which force is equalized by the pin *e* being moved toward the shaft *h*, when the shaft W moves in advance of it, which would increase the power of the spring were it not for this inward movement of the pin, the pin *e* passing round in the groove *j*, thereby giving a uniform force to the fan through the spring *c*.

Then, assuming that the force which gives motion to the fan, and the shaft *h* to which it is attached, is uniform, and assuming that the resistance of the work done by the eccentric S, including the friction, is the same for each revolution, and also assuming that the resistance of the air against the fan increases in proportion to the square of the velocity of the fan, then it is clear that when the engine is set in motion, the velocity of the fan will increase until the resistance of the work of the eccentric S in moving the valve, added to the resistance of the air against the fan, will just balance and equal the force of the spring *c*, at which time a uniform motion of the shaft *h* will ensue, and be maintained so long as these two balancing-forces remain the same.

Now, as the resistance of the work to the eccentric S, after the machinery has become worn smooth, can be counted on as substantially the same, the only factor liable to change is the resistance of the air, which, as we have before seen, changes with its temperature; but as this has been compensated for by the increase of the effective surface of the fans by metallic expansion, as before described, this resistance is made uniform and equal through all changes of temperature which the engine-room would be liable to.

This being the case, we then have a uniform motion in the shaft *h*, which, of course, always gives the same number of movements to the valve O in a given length of time; and as the relations of the valve and cut-off slide, and the eccentrics which give them motion, are such that when the elongated sides of the two eccentrics S and Y are maintained on the same side, and move with each other, the valve or passage from the steam-chest to the cylinder will be open during the whole stroke of the piston, or within a fraction of it; and as when the elongated side of the eccentric Y, which moves with the main shaft of the engine, is in advance of the eccentric S one hundred and eighty degrees, the valve will be constantly closed; and as when the eccentric Y is in advance of the eccentric S, any degree between these two points of coincidence and opposition, the valve will be closed during the said proportion of the stroke of the piston, as its degree of advance, or sufficiently near for the purpose, it therefore follows that the motion of the shaft *h* practically governs the motion of the main shaft of the engine, and will hold it to a given number of revolutions in a given time.

Although the fan, using the corrections which I have made, is a cheap and convenient method, and, I think, sufficiently accurate for regulating the time of the motion of the shaft *h*, yet I do not confine myself to this method of giving time to this shaft, as any clock can be used.

The device well known by astronomers as the spring-governor, by which the motion of the transit-instrument is connected with and regulated by any time-piece or chronometer, may be substituted for this fan, and the time of the best chronometer thereby made to govern the motion of the shaft *h*, and accordingly hold the main shaft of the engine to the most correct time, and though more perfect in time, the expense would be much greater.

In case the belt should break or slip off, or, in a marine engine, in case the screw or wheels should get out of the water, by my governor the whole of the steam is cut off in about one round of the main shaft of the engine, thereby preventing any speed that would do damage.

The pin *e* would, in that case, pass to the opposite end of the groove *j*, from its position shown in fig. 4, when it and the fan would be carried round with the same speed of the fly-wheel, keeping the valves continually closed.

The screw of a steamer, getting out of the water, would meet with a similar and equally harmless result.

The economy of steam is another advantage, as, by my governor, only just enough of steam is admitted into the cylinder at each stroke of the piston to do the work during that length of time. This is the ultimatum of good economy, as it not unfrequently happens that steam-engines with bad governors waste from one-fourth to one-third of their steam.

Simplicity, compactness, and small cost, are among its good qualities; but the simple device for which the engine is held to time, is the leading idea of it.

This governor can be applied equally well to water-power as to steam.

Having thus explained my invention,

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

1. The combination of the valve O with the time-keeper and shaft *h*, whereby the valve-movement shall be regulated by the time of the time-keeper, substantially as herein set forth.

2. The combination of the valve O, slide P, and time-keeper, whereby the movement of the valve shall be controlled by the time-keeper, while the movement of the cut-off slide may be controlled by the main shaft of the engine, substantially as set forth.

3. The combination of the slide *f*, pin *e*, and groove *j*, substantially as herein described.

4. The construction and arrangement of the fan and its immediate co-operative parts, as herein set forth, whereby the effective surface of the fan shall automatically vary in accordance with the unequal expansion of the metallic bars, as herein made known.

5. The construction and arrangement of the fans and their co-ordinate devices, whereby the respective leaves of the fans may occupy more or less of the spaces, and thereby increase or diminish the effective surface, substantially as herein described.

6. The combination of the ring *w* with the spring *c*, in the manner and for the purpose set forth.

Witnesses: WILLIAM WICKERSHAM.

A. D. PARKER,

LYMAN MASON.