Chapter XLI.—AUTOMATIC CUT OFF ENGINES.

AN automatic cut off engine is one in which the valve gear is so acted upon by the governor as to keep the speed of the engine uniform under variations of the load the engine drives, and notwithstanding variations in the boiler pressure. This it accomplishes by varying the point in the piston stroke at which the live steam is cut off. This is economical because it enables the engine to use the steam more expansively than is possible with engines having throttling governors, which govern the engine speed by wire drawing the steam.

There are two principal forms of automatic cut off engines, first, those in which the steam valve spindle or rod is released from the parts that move it to open for admission, while dash pots, weights, or springs close the valve to effect the cut off; and second, those in which the travel of the valve is varied so as to alter the point of cut off.

The first usually employ fly ball governors which actuate cams or stops to trip the valves for the steam cylinders. The second usually employ wheel governors or speed regulators, as they are sometimes termed.

The distinctive features in the action of the first, of which the Corliss engine is the most important, is that as two admission and two exhaust valves are used, therefore the amount of the valve lead, the point of exhaust and amount of the compression remain the same at whatever point in the piston stroke the cut off may occur; whereas in the second, the lead increases, the cut off occurs earlier, and the compression increases in proportion as the cut off occurs earlier in the piston stroke. In this class of engine the steam valve travels as quickly when opening the steam port for a short and early period of cut off as it does for a late one, hence the amount of steam port opening is as full, with reference to the piston motion, for an early as it is for a late point of cut off. In other words, there is the same amount of steam port opening for the first, second, third, and fourth inch of piston motion, let the point of cut off occur at whatever point in the piston motion it may. In engines which vary the point of cut off by reducing the travel of the slide valve, this is accomplished by using double ported valves or griddle valves.

Fig. 3378 represents the arrangement of the valves in a Corliss engine, V and V¹ being the steam valves and V² and V³ the exhaust valves. These valves, it will be seen, extend crossways of the cylinder and are circular. In the figure the valves are shown in the position they would occupy when the piston was at the crank end of the cylinder, as in the figure.

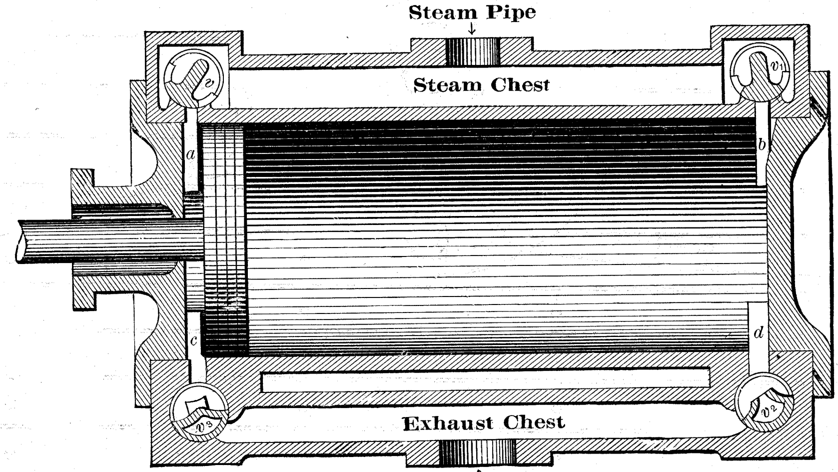


Fig. 3378.

The principles of a Corliss valve gear will be understood from the following, which is derived from a book by the author of this work, and entitled *Modern Steam Engines*.

In 3379 and 3380 the valve gear (which is the distinctive feature of the engine) is represented with the parts in the position they occupy when the cut off occurs at half stroke, the piston having moved from the head end of the cylinder. In Figs. 3381 and 3382 the parts are shown in position with the crank on the dead centre and the piston at the crank end of the cylinder, valve *v* having opened its port to the amount of the lead.

Referring to Fig. 3379, motion from the eccentric is imparted by the rod M to the wrist plate Y, to which are connected the rods C, C′, for operating the admission valves, whose shafts are seen at S, S′, and the rods F, F′, for operating the exhaust valves, whose shafts are seen at T, T′.

The mechanism for the steam or admission valves may be divided into three elements: first, that for operating the valve to open the port for admission; second, that for closing the valve to effect the cut off; and third, that which determines the point in the stroke at which the cut off shall occur.

The first consists of the rod M, wrist plate Y, and the rods C and C′, which operate the bell cranks *r r*, *r′ r′* which are fast on the valve shafts S, S′. Upon the ends of bell cranks *r r*, *r′ r′*, are pivoted latch links *u*, *u′*, which have in them a recess for the latch blocks, of which one is seen at *e* (the rod R′ and its connection with the valve stem being shown broken away to expose *e* to view). During the admission the latch block abuts against the end *y* of the recess *w* and is tripped therefrom by the cam *n′*. The ends of arms *g* of the latch links abut against the hub of the arms *d*, *d′*, upon which are cams *n*, *n′*, and at *a*, *a′* are springs for keeping the ends *g* of latch links *u*, *u′* against the hubs and cams of *d*, *d′*.

Referring now to the valve mechanism at the head end only, suppose the piston to be at the head end of the cylinder, and latch block *e* will be seated in the recess provided in *a* to receive it, and as the bell crank moves, the latch block will be raised by the latch link, which is carried by a crank arm corresponding to that seen at *x* at the crank end of the cylinder, and as this crank arm is fast upon the valve spindle, the lifting of *e* will open the valve for admission. As soon, however, as the end *g* of the latch link meets the cam *n'*, the latch link will be moved so that the end *y* of its recess will leave contact with the latch block *e* and the dash pot will cause rod R' to descend instantaneously and close the valve, thus effecting the cut off. The period of admission, therefore, is determined by the amount of motion the latch link *u'* is permitted to have before its end *g* meets the cam *n'*, which trips the latch link, and therefore frees *e* from the latch link recess.

The point at which the cut off will occur, therefore, is determined by the position of the cam *n'*, because if *n'* is out of the way, the end *g* of the latch link will not meet it, the latch link will not disengage from the latch block *e*, and the cut off would be effected by the lap of the valve, and independently of the dash pot. As in Fig. 3379 the parts are shown in the positions they occupy at the instant the cut off is to occur, therefore the cam *n'* has just tripped the latch link, and the end of *e* has just left contact with the end *y* of the recess *w* in the latch link *u'*.

The point in the stroke at which the tripping of *u'* from *e* will occur and effect the cut off is determined by the governor, because *d'* is connected to the governor through the rod G'. In proportion as the governor balls rise, *d'* is moved from left to right, and the end of cam *n'* meets *g* earlier, or, vice versa, in proportion as the governor balls fall, the arm *d'* is moved to the left, *g* will meet the end of cam *n'* later, and the point of cut off will be prolonged.

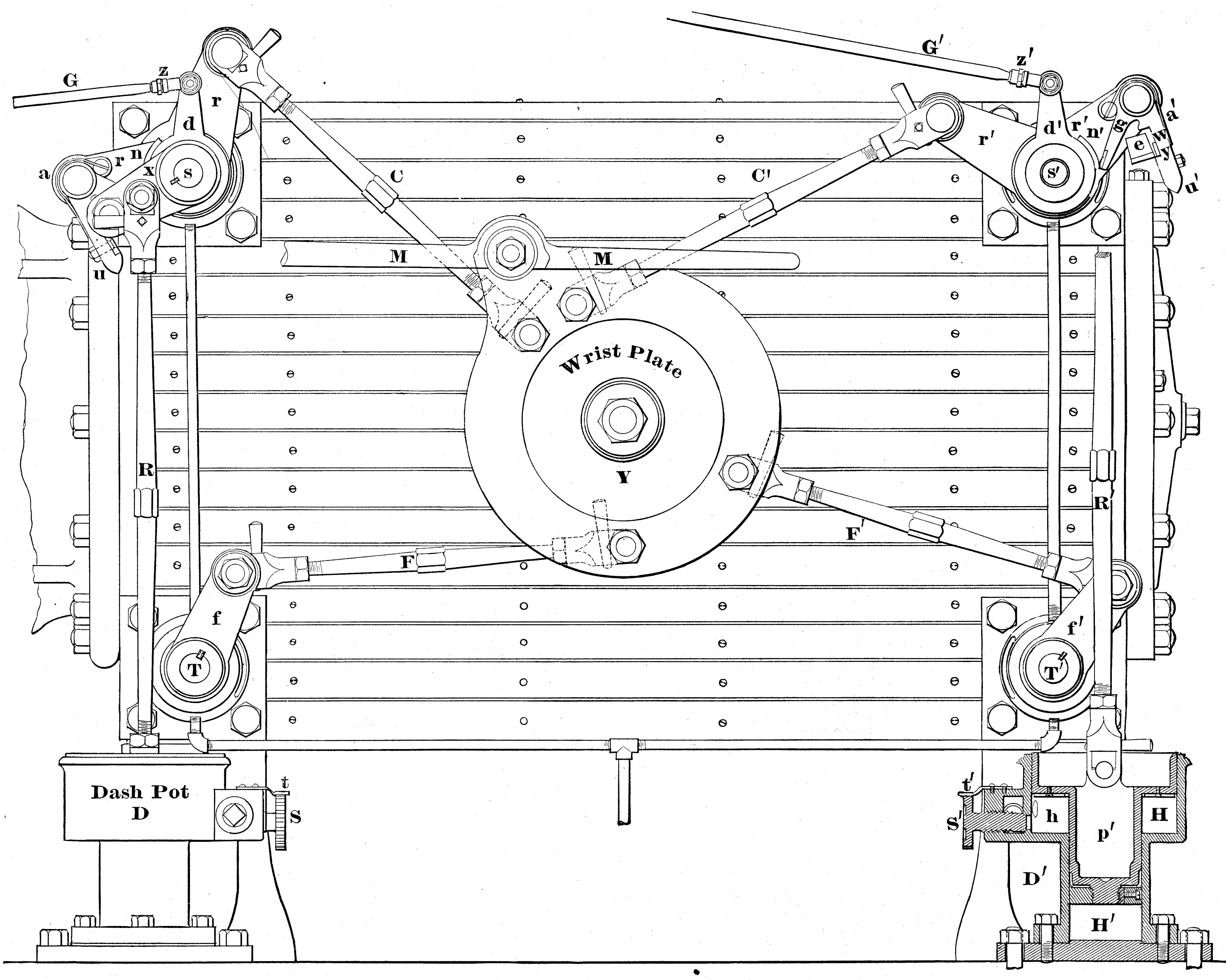
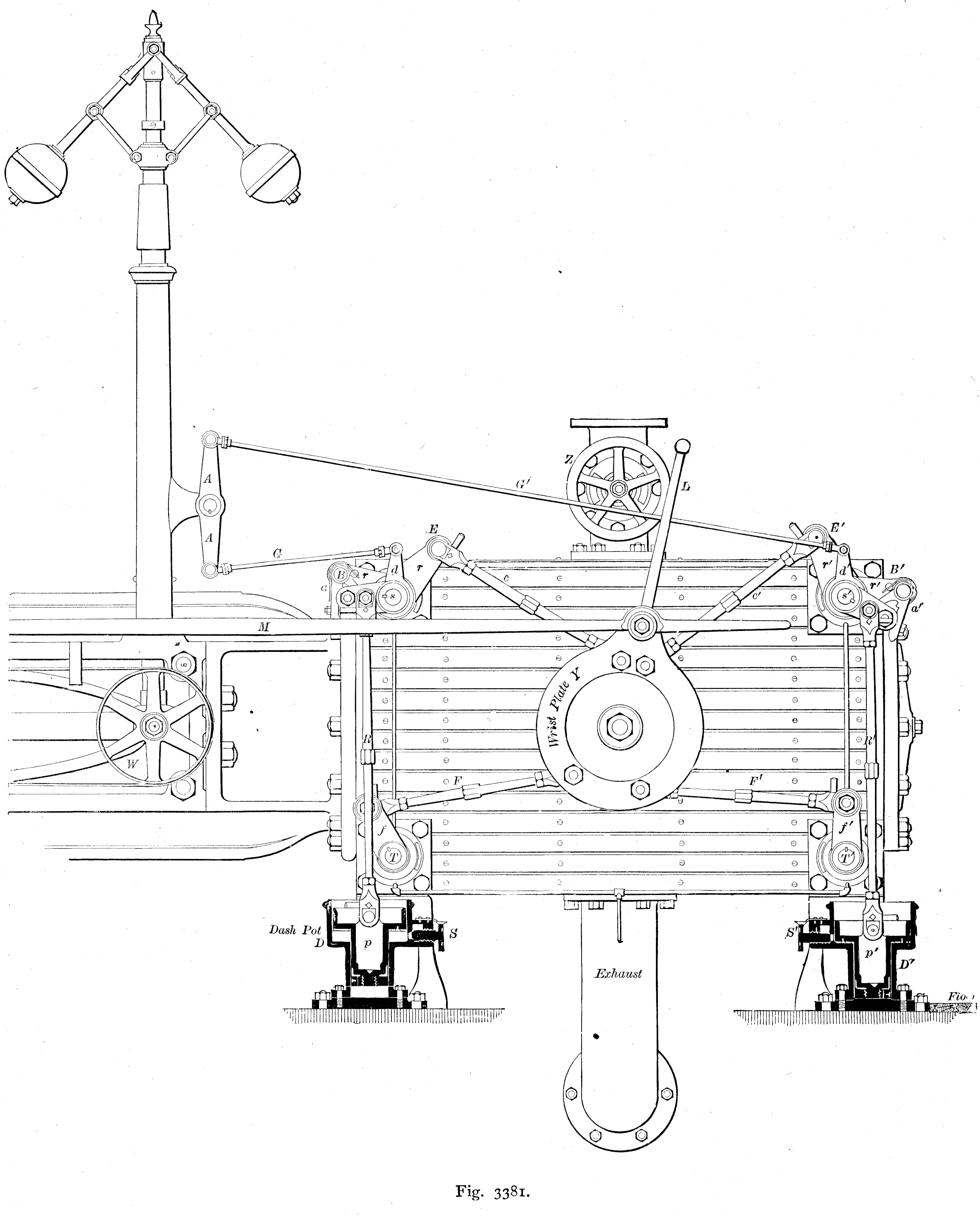


Fig. 3379.

We now come to the means employed to close the valve quickly and without shock when the latch block is released from the latch link. Referring then to the crank end of the cylinder, the latch block for that valve is carried upon arm *x*, to which is attached the rod R from the dash pot piston (the arm corresponding to *x*, but at the head end being shown removed to expose the latch block to view). We may now turn again to the head end of the cylinder, rod R' corresponding to rod R at the other end, and it is seen



Z
G'
L
A
A
G
E
E'
B
d
r
r'
d'
B'
a'
c
c'
M
Wrist Plate Y
W
R
R'
F
F'
f
f'
T
T'
Dash Pot
D
p
S
S'
p'
D'
Exhaust

Fig. 3381.

that R′ connects to a dash pot piston *p*′ having a stepped diameter, the lower half fitting into bore H′, and the upper half fitting into a bore H. The piston *p*′ fits the bore H′ and fills it when the rod R′ is at the bottom of the stroke, hence as *p*′ is raised there is a vacuum in H that acts to cause *p*′, and therefore R′ and *x*, to fall quickly and close the valve the instant the latch block is released ing it, after which the remaining air in H can only find exit through the opening left by the end of the valve S′, and this amount of opening is so regulated by the adjustment of S′ that a certain amount of air cushion is given, which prevents *p*′ from coming to rest with a blow. The head of valve S′ is milled or knurled, and a spring *t*′ fits, at its end, into the milled indentation, thus holding

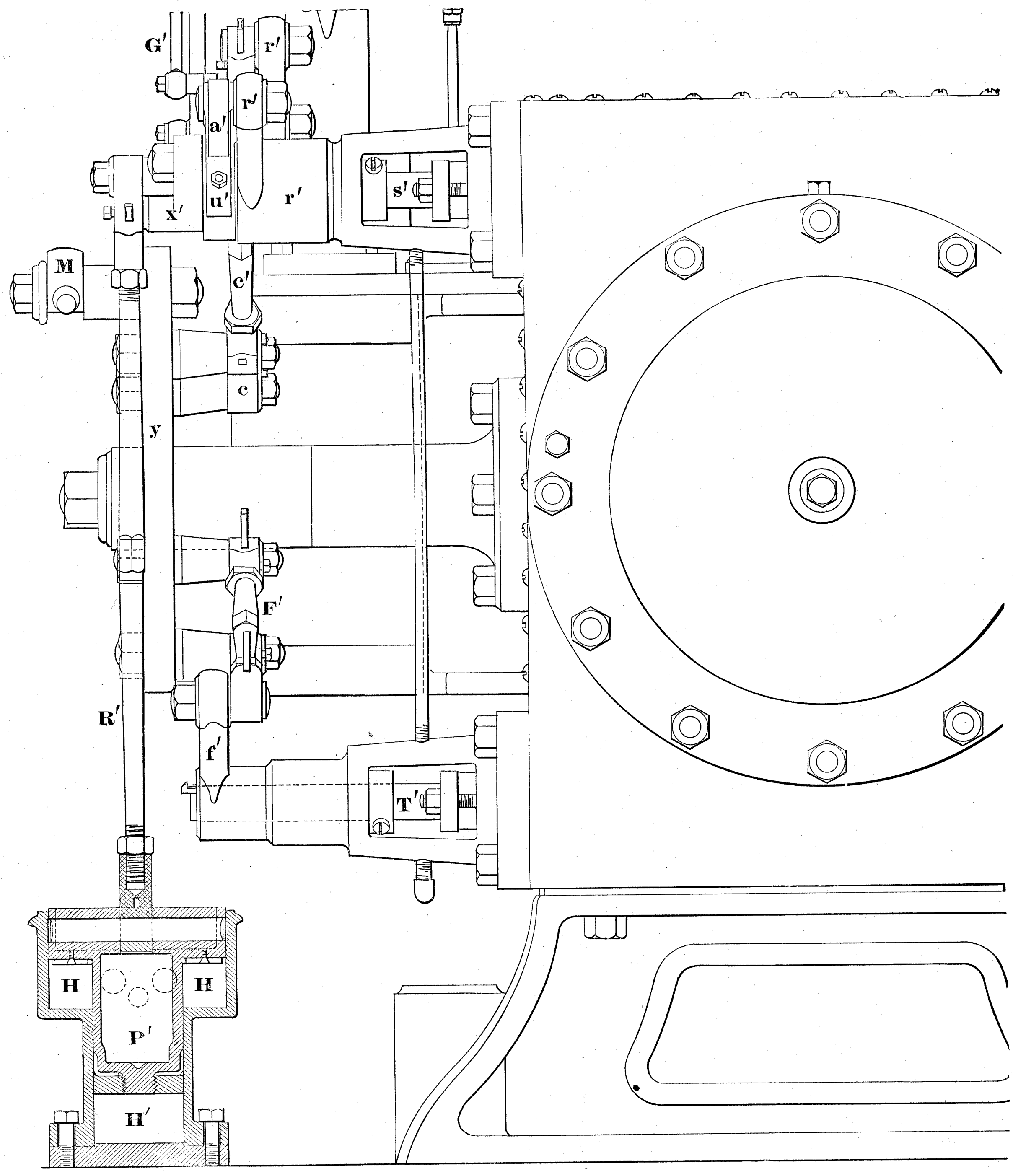


Fig. 3380.

from the latch link. To prevent the descent of rod R′ and piston *p*′ from ending in a blow, a cushion of air is given in H by the following construction:

At S and S′ are valves, threaded to screw and unscrew, the ends forming a valve for a seat entering H.

As the rod R′ and its piston *p*′ descend, the air in H finds exit through a hole at *h* until that hole is closed by the piston *p*′ covering it in its adjusted position. The under surface of the upper part of *p*′ is covered by a leather disc, while the part that fits in H′ is kept air-tight by a leather-cupped packing.

The connection of the cam arms *d* and *d*′ with the governor is shown in Figs. 3381 and 3382, in which the parts are shown in the position they would occupy when the crank is on the dead centre and the piston at the crank end of the cylinder. The rod G′ connects the cam arm d' with the upper end of lever A, which is connected to the governor and vibrates on its centre as the governor acts upon it.

Now suppose the speed to begin to diminish, and the governor balls to fall, and the direction in which A will move will be for its lower end to move to the right, thus moving d to the right and carrying its cam away from the end of the latch link, which will therefore continue to open the port for a longer period of admission. Or, referring to Fig. 3381, it is plain that, if the governor balls were to lower from a reduced governor speed, G′ would move to the left and cam n' would be moved away from contact with the end g of the catch link, which, not being tripped, the admission would continue. On the other hand, suppose the governor balls to rise from an increase of governor speed, and d' (Fig. 3379) would

haust valves are employed, the point of release, and (as the same valve edge that effects the release also effects the compression) therefore that of the compression, may be regulated at will by adjusting the lengths of the rods F, F′, Fig. 3379, which have at one end a right and at the other a left hand screw, so that by turning back the check nuts and then revolving the rods their lengths will be altered.

Similarly the amount of admission lead may be adjusted by an adjustment of the lengths of rods C, C′, which also have right and left hand screws. Referring now to the admission valve v, it is seen that its operating rod C is at a right angle to bell crank r, r, hence the amount of valve motion will not be diminished to any appreciable extent by reason of the wrist plate end of rod C moving in an arc of a circle, and the point of attachment of rod C to the wrist

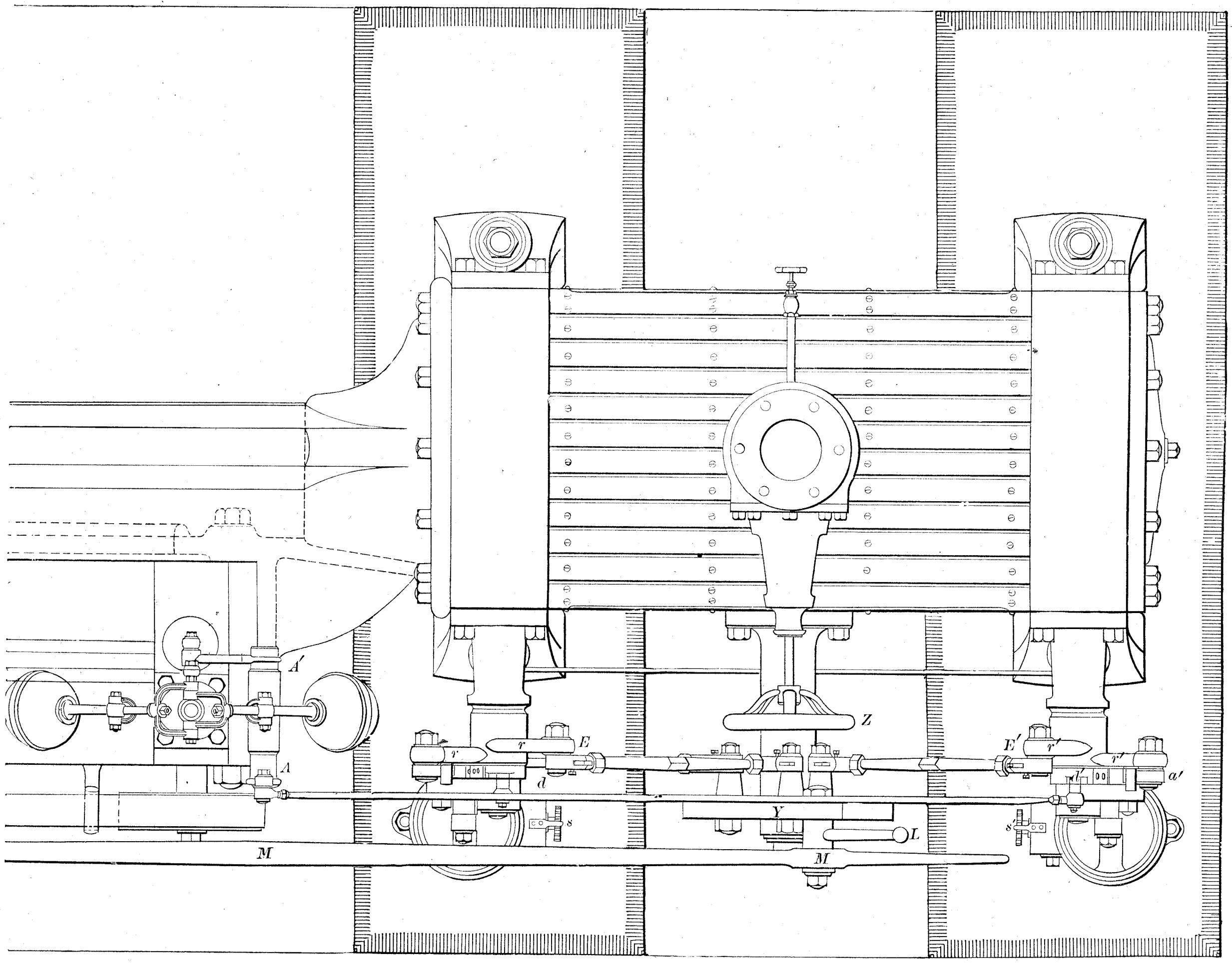


Fig. 3382.

be moved to the right, and the cam n' meeting g earlier, correspondingly hastening the cut off.

The governor is driven by a belt from a pulley on the crank shaft to the pulley W, Fig. 3381, whose shaft conveys motion to the governor spindle through the medium of a pair of bevel pinions in which v represents (referring again to Fig. 3378) the steam or admission valve for the crank end port, and v^1 that for the head end port, while v^2 is the exhaust valve for the crank end, and v^3 that for the head end of the cylinder. All four valves are shown in the positions they would occupy when the crank was on the dead centre and the piston at the crank end of the cylinder, hence the valve positions shown correspond to the positions the parts of the valve motion occupy in Fig. 3381.

The faces of the valves are obviously arcs of circles of which the axes of the shafts s, s' are the respective centres. Valve v has opened its port to the amount of the lead, which in this class of engine varies usually from $\frac{1}{32}$ to about $\frac{1}{16}$ inch. As separate ex-

plate is such that, during the admission, the valve practically gives as quick an opening as though rod C continued at a right angle to r. But, if we turn to valve v', which has closed its port and covers it to the amount of the lap, we find that bell crank r' and its operating rod C′ are in such positions with relation to the wrist plate, that the motion of the latter will have but little effect in moving the bell crank r'. This is an especial feature of the Corliss valve motion and is of importance for the following reasons :

The lap of the valve (which corresponds to the lap of a plain D slide valve) is usually, in this class of engine, such as to cut off the steam at about $\frac{7}{8}$ stroke, but the adjustment of the cam position is usually so made that, from the action of the governor, the latest point of cut off will occur when the piston has made $\frac{5}{8}$ of its stroke, the range of cut off being from this to an admission equal to the amount of the lead.

As the eccentric is fixed upon the shaft, the speed at which the valve opens the port for the admission is the same for all corresponding piston positions. Thus suppose the piston has moved an inch from the end of the stroke, and the valve speed will be the same, whether the cut off in that stroke is to occur at quarter stroke or half stroke, and as the valve continues to open the port until it is tripped, therefore, at the moment it is tripped, the direction of valve motion must be suddenly reversed.

As the duty of its reversal falls upon the dash pot, it is desirable to make this duty as light as possible, which is accomplished by the wrist motion, which acts to reduce the valve motion after the port is opened a certain amount for the admission.

We have, therefore, that during the earlier part of the admission, the port opening is quick because of the eccentric throw being a maximum, while during the later part of the port opening, this rapid motion is offset or modified by the wrist motion, thus lessening the duty of the dash pot and enabling it to promptly close the valve.

jority of them vary the point of cut off, by means of shifting the eccentric across the shaft, so as to reduce the eccentric throw, and therefore the valve travel. This causes the valve to cut off the steam earlier.

The eccentric, instead of being fixed upon the crank shaft, has an elongated bore, and is hung on an arm that is pivoted at its other end after the manner of a pendulum. This arm is called the eccentric hanger.

A wheel governor is usually employed to shift the eccentric across the shaft. In some cases, however, two valves are employed, one effecting the admission, the release, and the compression, and the other the cut off.

When two valves are employed, the lead, the point of cut off, the point of release, and the point of compression may be maintained equal for all points of cut off; whereas, when a single valve is employed, the lead, the point of release, and the compres-

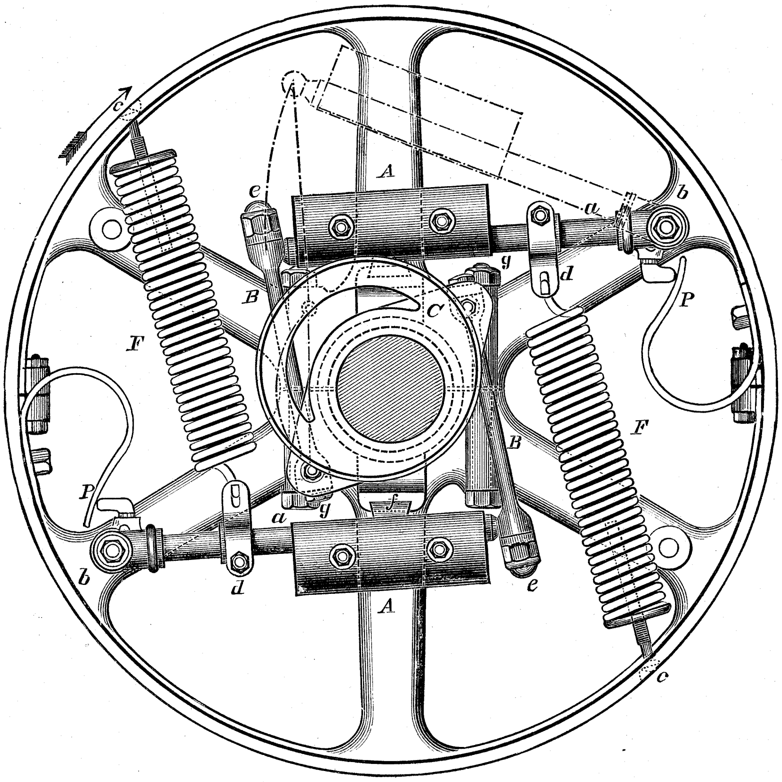


Fig. 3382*a*.

The range of governor action, so far as the governor itself is concerned, is obviously a constant amount, because a certain amount of rise and fall of the governor balls will move the cams a given amount. But the range of cut off may be varied as follows: At Z, Z′, are adjustment nuts, by means of which the lengths of rods G, G′ may be varied.

Lengthening rod G obviously moves arm *d* and its cam *n* further from the end of the latch link *u*, and therefore prolongs the admission period.

Shortening the rod G′ causes cam *n′* to move around and away from the leg *g* of the latch link, and prolongs the admission.

The adjustment of the lengths of G and G′ may therefore be employed for two purposes; first, to prolong the point of cut off, and maintain the speed when the engine is overloaded, or to hasten the point of cut off for a given engine speed, and thus adjust the engine for a lighter load.

HIGH SPEED AUTOMATIC CUT OFF ENGINES.

What are termed high speed engines are those whose pistons run at a velocity of more than about 600 feet per minute, some making as high as 800 or 900 feet in regular work. High speed engines are usually provided with an automatic cut off, and a ma-

sion will vary with the point of cut off, or, in other words, will be different for every different point of cut off.

The general principles upon which a wheel governor is constructed is, that two weights or weighted levers in moving outwards from the engine shaft, from the action of centrifugal force, move or rather shift the eccentric across the shaft, reducing its throw, and therefore by reducing the travel of the valve hasten the point of cut off and reduce the power of the engine.

In the governor of the Buckeye engine, the centrifugal force may be varied by increasing or diminishing the distance of the weights from the pivots of the arms on which they swing.

This is shown in Fig. 3382*a*, in which it is seen that the weights A are adjustable along the arms *a*, *a*. The points of attachment *d*, *d* of the springs to the weight arms are also adjustable.

When reversing is done, by shifting the eccentric across the shaft, the lead cannot be kept equal, but will, if the eccentric is swung from a pivot that is on the line of centres, when the crank is on a dead centre, be greater at the head end than at the crank end of the cylinder. The discrepancy may, however, be equalized by swinging the eccentric from a pivot that is not on the line of centres at a time the crank is on a dead centre.

But this equalization will only exist at some one point in the eccentric position, or in other words, if the eccentric is shifted across the crank shaft, simply to reverse the engine, and not to vary the point of cut-off, it will naturally be moved, in reversing the engine across the shaft, to a given and constant amount, and in

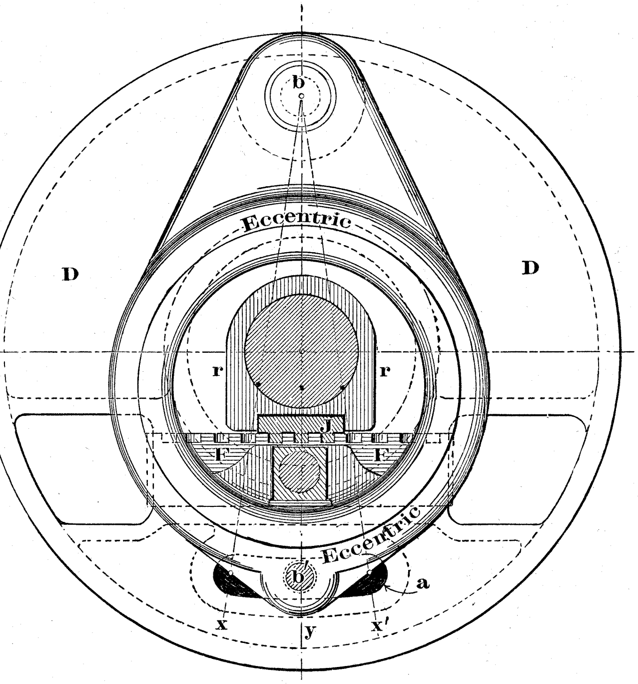


Fig. 3383.

this case, the pivot on which its hanger is hung may be so located with reference to the line of centres and the crank (the latter being on a dead centre when the point of suspension of the eccentric hanger is found) that the lead is equal for both the backward and forward gears.

But if the eccentric is shifted across the shaft to vary the point of cut off as well as to reverse the direction of engine revolution, the lead cannot be kept equal.

It is better, in this case, to so locate the point of eccentric hanger suspension as to let the lead be the most at the head end cylinder port, because the piston travels fastest at that end of the cylinder, and therefore requires more lead, in order to cushion the piston.

A construction for shifting the eccentric across the shaft is shown in Fig. 3383, in which D, D is a disc, having at *b* a pivot for the eccentric hanger. The amount the throw line of the eccentric must be shifted to reverse from full gear forwards to full gear backwards is from the line *b x* to line *b x′*, and the shifting is done by two racks F and J, having teeth at an angle of 45° to their lengths. F is fast to the eccentric, and J is carried in a sleeve that slides along the shaft, and sliding it moves the eccentric across the shaft by reason of the teeth of one rack being at a right angle to those of the other.

It is obvious that the eccentric may be moved around the shaft in place of across it, the distance its throw line requires to be moved being the same in either case.

To shift an eccentric so as to reverse the direction of engine revolution, all that is necessary is to place the crank on either dead centre and measure the amount of valve lead. Then loosen the eccentric from the crank shaft, and while the crank is stationary, move it around upon the shaft until it has opened the port full, and nearly closed it again, leaving it open to the same amount as it was before the eccentric was moved, or in other words, open to the amount of the lead.

Fig. 3384 represents a side elevation of a high speed wheel governor engine, designed and constructed by the Straight Line Engine Company of Syracuse, New York, the construction of the governor being shown in Fig. 3385, in which R is the eccentric rod, the eccentric being carried in a lever strap pivoted at A, and connected at B to two links C and D, the former of which connects to the spring E, and the latter to the weighted lever F. The centrifugal force generated by the weighted end of F endeavors to move the eccentric inwards, and thus reduce its throw, which reduces the valve travel and hastens the point of cut off.

On the other hand, the tension of the spring E acts to move the eccentric in the opposite direction, and maintain the full throw of the eccentric and maximum point of cut off. These two forces are so calculated in the design and proportion of the parts that under a maximum load the engine will run at its proper speed, while, if

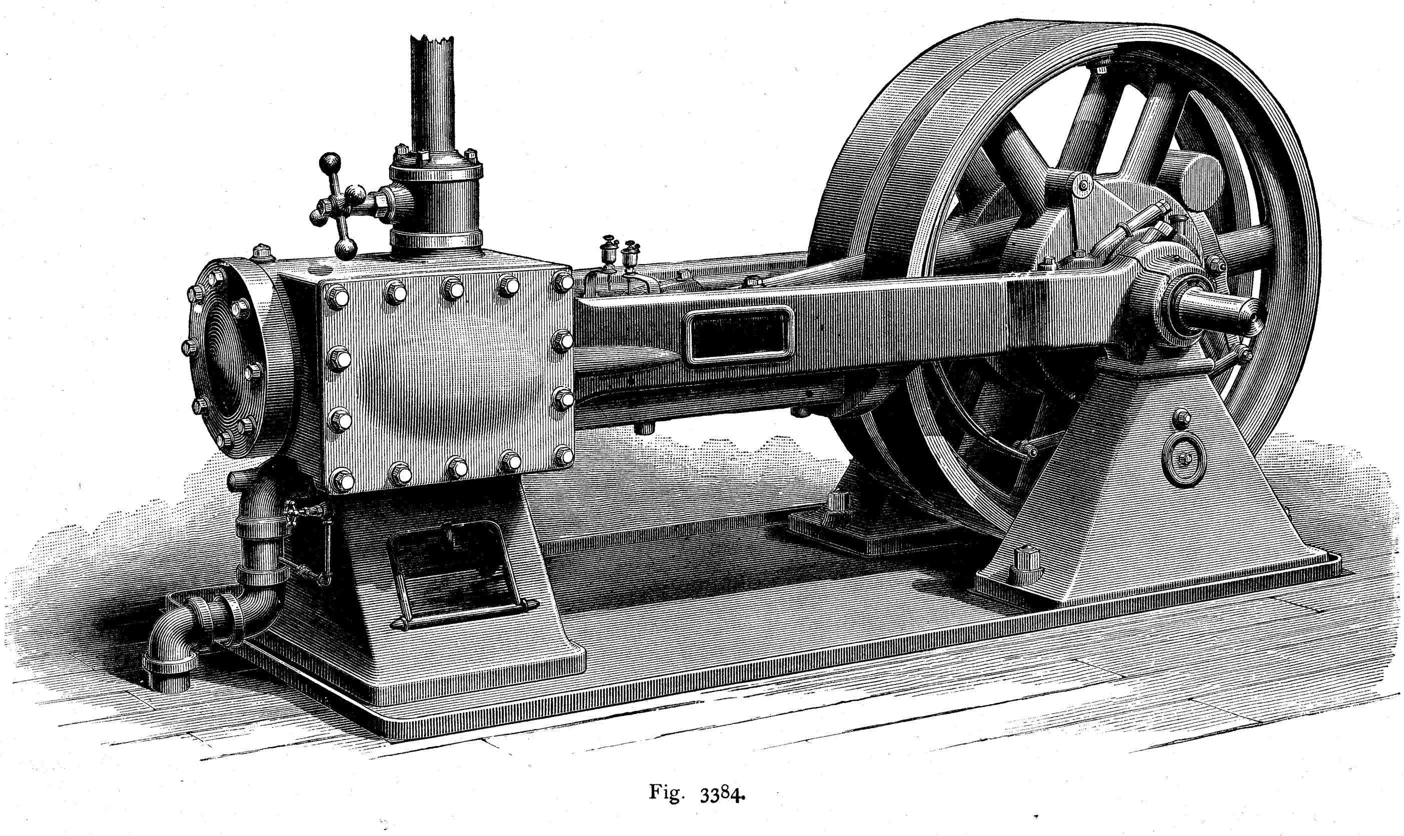


Fig. 3384.

the load decreases, the action of F will hasten the point of cut off enough to allow for the decreased engine load, and thus keep the engine still going at the same speed.

Other novel and interesting details in the construction of this engine are as follows:

The two arms forming the frame are cast with and run in line not mentioned above, that of making the cross head pin fast in the connecting rod, is used in this engine also, but in a somewhat different form. As will be seen by Fig. 3387, the pin is made much larger, and this allows of its being made of "steel casting" and cast hollow with cross bars at each end for centring. These pins are held in the rod by a binding screw which catches in a groove

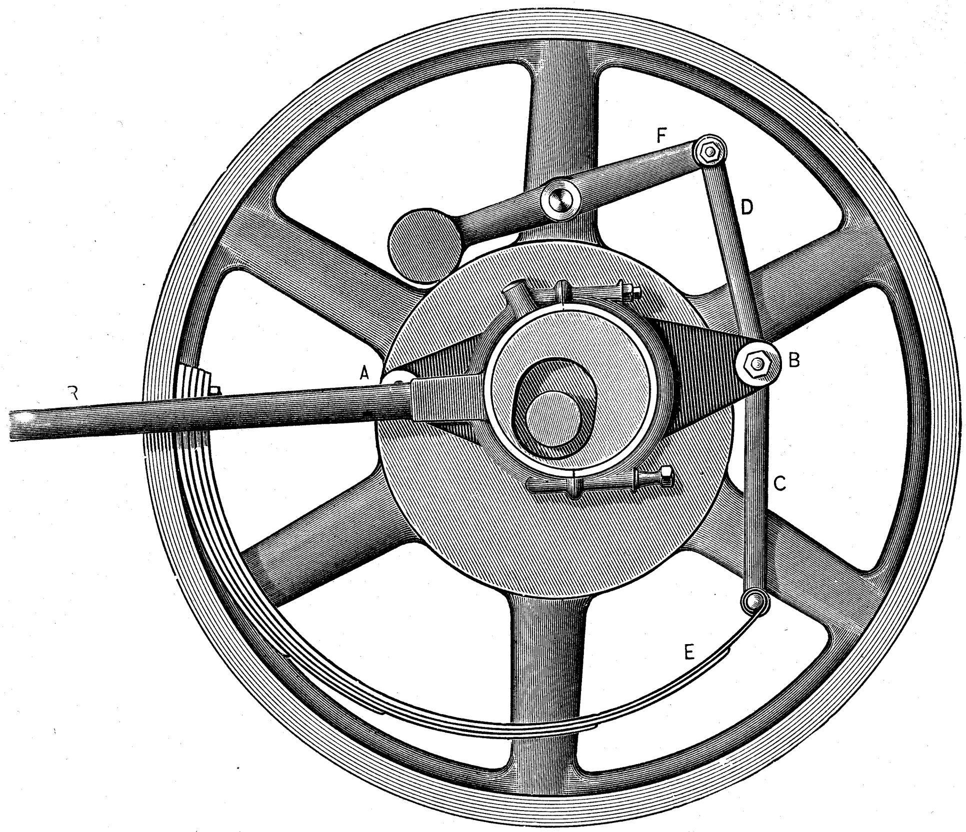


Fig. 3385.

straight lines from the cylinder to the two main bearings, and rest upon these self-adjusting points of support.

There are two fly wheels, both between the main bearings, and one of which carries the governor so that the centre of the valve is brought in line with the centre of the eccentric.

In order to simplify the explanation, the mechanism has been that is milled around one-fourth of its circumference. After the pin is placed in the rod and the binding bolt is inserted, the pin is prevented from working out endwise, and the binding bolt prevents it from turning; but when the binding bolt is slackened, the pin can be rotated one-fourth of a revolution. The scheme is as follows: After running the engine for a while, the engineer is instructed to

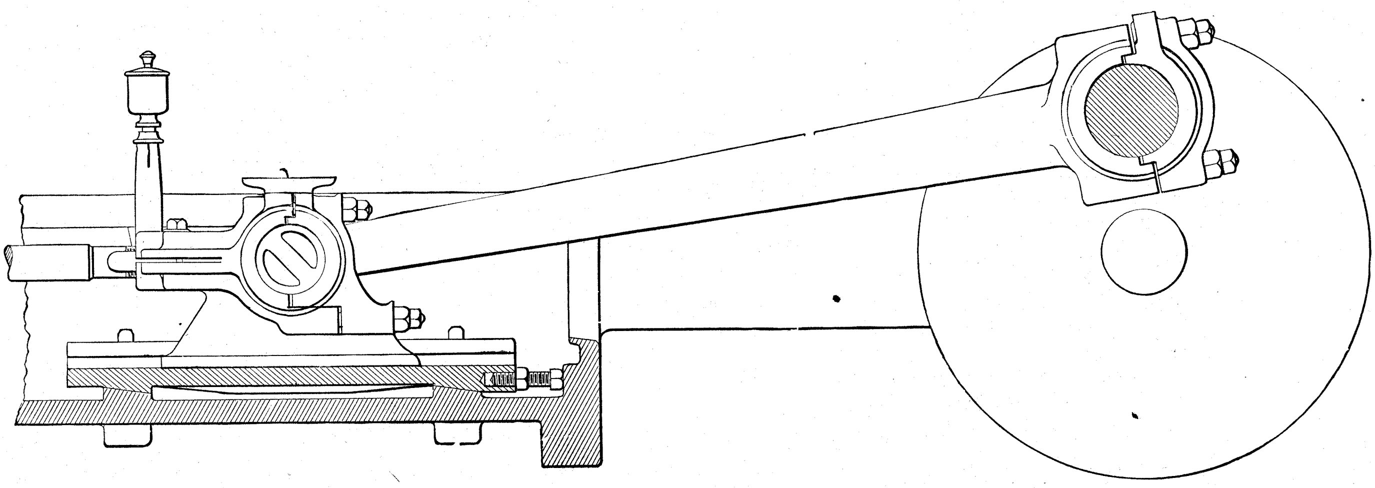


Fig. 3386.

separated into three separate sections. Figs. 3386 and 3387 show such of the details of the parts between the cylinder and crank as are peculiar to this engine. The cross head is of the slipper guide style, and the illustration, Fig. 3386, shows the simple method adopted for adjusting the guide to the proper height to maintain the alignment. Another feature peculiar to the straight slack the binding bolt, give the pin a quarter turn and bind it fast. By repeating this, the pin can be kept more nearly round, probably, than by any other plan. By referring again to Fig. 3386, it will be seen that the plan for taking up the wear in the cross head pin bearings is simply that of setting up the common half box, and the endurance of the arrangement, with the hardened and ground steel pin running in babbitt lined boxes of double the ordinary size and length, must be satisfactory.

The drop oil cups for lubricating the cross head pin are located

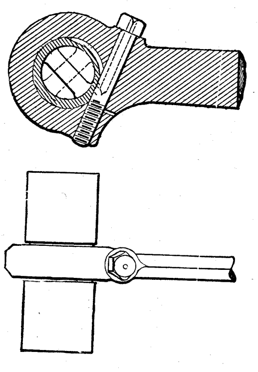


Fig. 3387.

so as to have the drop "picked" off just as the cross head completes its stroke at the cylinder end, and while it is travelling at its slowest speed. The oil, as it leaves the wearing surfaces of the pin, is conveyed to the lower slide.

Figs. 3388 and 3389 show the parts that connect the eccentric with the valve. The method of connecting the rod to the eccentric strap is convenient. The lower joint in the eccentric strap is set up tight, metal to metal, and the upper joint left open $\frac{1}{8}$ of an inch.

STEAM FIRE ENGINE.

In a steam fire engine the prime requisites are rapidity of getting up steam and efficiency with lightness, economy of fuel being a secondary consideration.

Fig. 3390 is a general view of a steam fire engine constructed by the Clapp & Jones Manufacturing Company.

Fig. 3390*a* is a longitudinal section through the boiler and one steam cylinder and pump.

The construction of the boiler is shown in Figs. 3390*a* and 3391, the former being a vertical section of the engine and boiler bearing the steam pipe and exhaust pipe shown in place, and one of the draught tubes shown in section, and the latter a vertical central section.

The outside shell is represented at *a″, a″*. This shell extends the whole length of the boiler. The fire box sheet *b″, b* is less in length, extending only to the lower tube sheet.

The lower tube sheet C″ is perforated by all the tubes; the heavy lines showing the coil tubes in fire box, the others are smoke tubes. The upper tube sheet *d* has holes only for the smoke tubes. The smoke or draught tubes are shown at *e,″ e,″ e″*; these also answer the important purposes of drying and superheating the steam.

F″, F″, F″ are the sectional coil tubes, the main feature of this boiler. They are in the form of a spiral coil, the spiral bend being enough to leave room for five others of the same size between, so that there are six of these coils in each circular row. The number of rows is determined by the size of the boiler and the amount of steam required.

Each coil is connected with the lower tube sheet by screw joints, all right hand, that require no fibrous or elastic packing, an angle elbow being used to get the short bend at the end. The tubes then make about one turn around the fire box, and are joined to the side sheet of the same, with the same union used at its upper end, which makes a joint that never gets loose from any kind of work it may be subjected to. These unions or couplings are made of different kinds of metal, and put together so that no two pieces of iron come in contact to corrode and stick together; and should it, from any cause whatever, become necessary to take these coils out, it can be done, and the same tubes replaced without destroying any part of them, or damaging any piece so that it could not be used again.

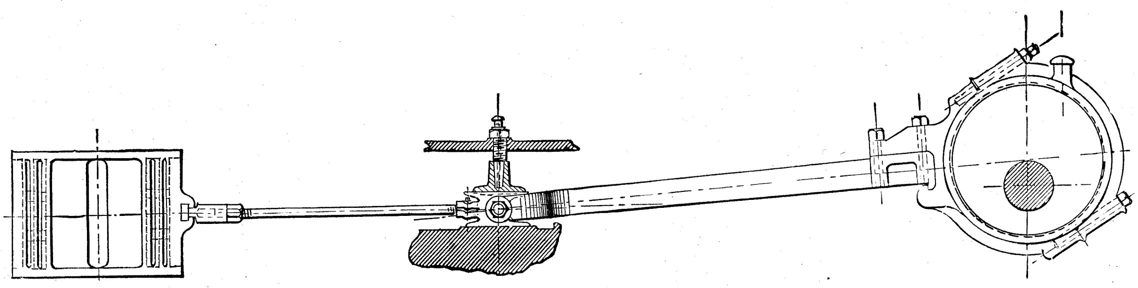


Fig. 3388.

G″, G″ is the ornamental dome or covering for the upper end; *g″, g″* is the smoke bonnet and pipes for concentrating the hot escaping products of combustion for the purpose of making a draught of air through the fuel. H″ are grate bars, and I″ fire door. J″, J″ is the water line. The height has been determined by experiment, yet should be varied a little to get the best drying effect of the coal. A coal that makes a flame would call for a higher range of the water line, while coal that produces heat without the flame would call for a lower range; this the engineer will soon find. The working of the boiler is as follows: The fire being started in the fire box, as soon as the water in the coils begins to heat circulation commences from natural causes (nor is it at any time necessary to use a hand pump or any other artificial means for keeping it up), the heated water passing up in the steam drum, and the colder water from the leg and drum taking its place, as is shown by the arrows in the leg, till the whole is heated to the steam making temperature. At this point steam pressure begins to show, which goes up very fast, as the water is all so near the steam temperature. Of course, it is better to carry the water at about the height shown, as a uniform pressure of steam is easier maintained, which is always desirable; yet the limit of safety is not reached till the water is nearly all out, or so long as it is not below the connection

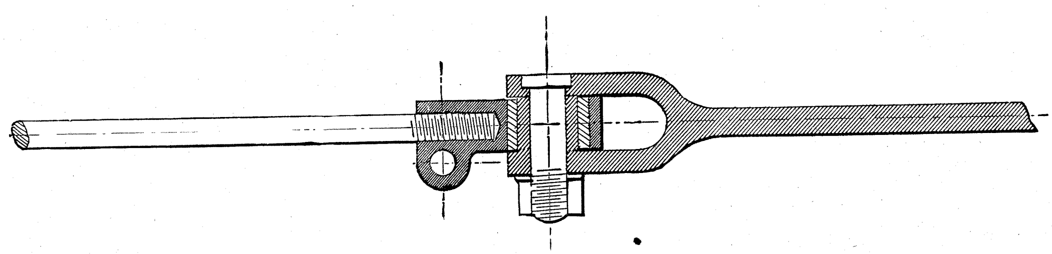


Fig. 3389.

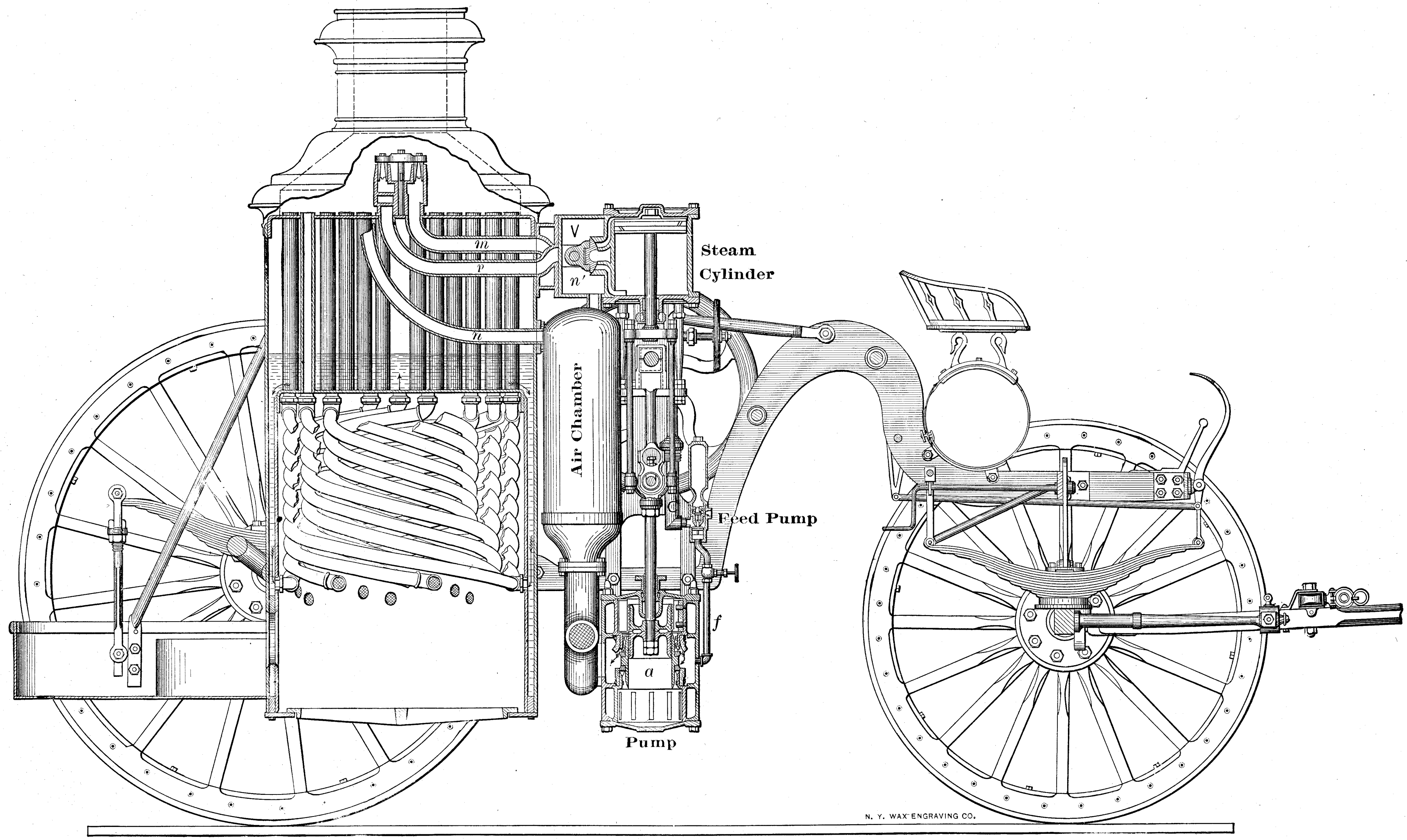

V
m
p
n
n′
Steam
Cylinder
Air Chamber
Feed Pump
f
a
Pump
N. Y. WAX-ENGRAVING CO.

Fig. 3390a

of the coils in the leg; and even at this point the only danger is in the damage to the coils from the heat when there is no water to protect them.

In Fig. 3391*a*, one engine and pump is shown in side elevation, and the other in section, the cranks being at a right angle, one to upon which are the two fly wheels and the eccentrics for the steam valves.

It will be seen in the longitudinal section, Fig. 3390*a*, that the steam valve face is a segment of a circle and therefore answers, so far as the distribution of the steam is concerned, to a simple D

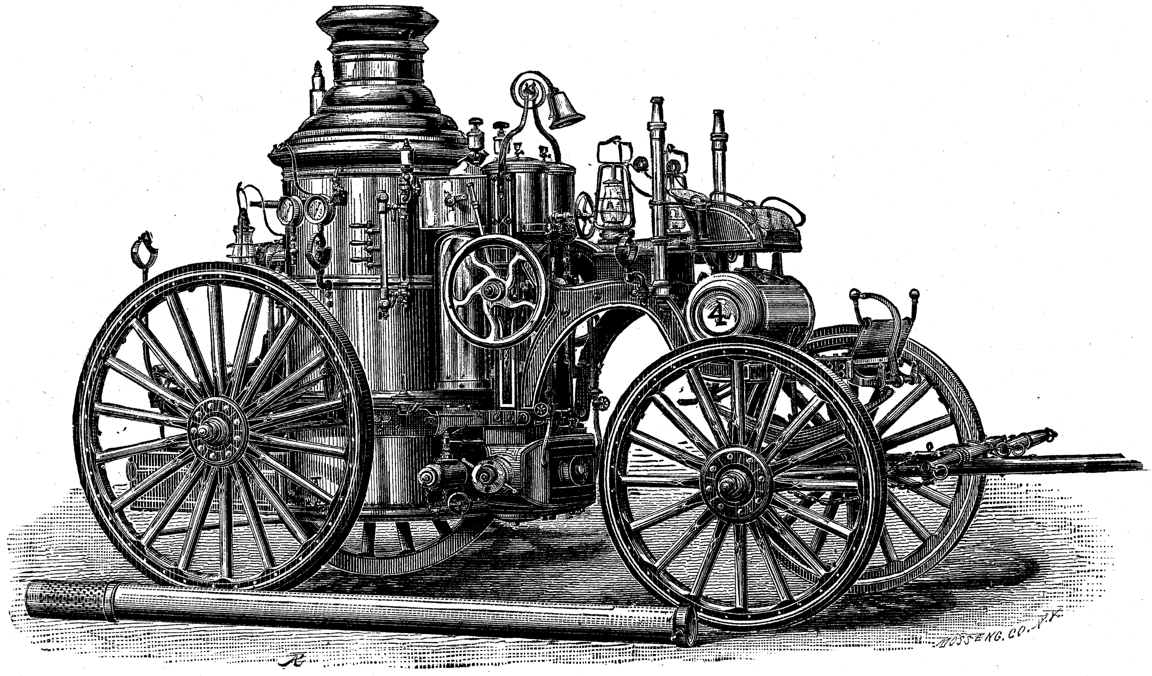


Fig. 3390.

the other. A yoke from the piston rod spans the crank, so that the steam and pump pistons are in line and directly connected. From the lower end of this yoke, a rod connects to the crank shaft

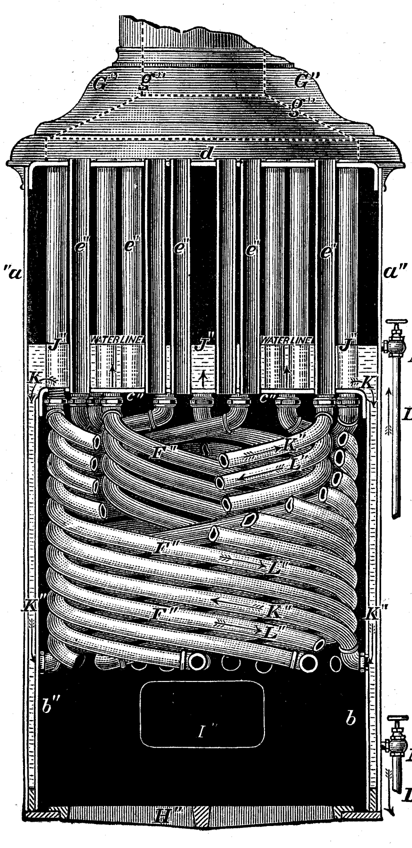


Fig. 3391.

slide valve, which exhausts through the pipes *m*, *p*. The steam pipe *n* enters the bottom of the steam chest at *n'*.

The two main pumps *a* are made in one piece, entirely of composition; one of them is shown in section. The piston is a solid piece of brass, as well as the cylinder in which it works, but are made of different composition, one hard, the other soft, to prevent cutting. The valves are of India rubber; the discharge valve is a ring, one for each end of the pump, as shown at *b*, Fig. 3391*a*. One is shown open, while the other is closed. They are held in place by grooved rings of brass; these rings fit in grooves in the rubber, which, when they are put in the pump, and their set screws are in, with their points in the grooves in the brass rings spoken of above, the discharge valves are complete for work.

The suction valves are shown at K on Fig. 3391*a*, and will be easily understood. They are of a design for this special use and place, which is around the pump cylinder in a circular chamber. The water ways covered by these valves are long and narrow, one valve covering two of these openings, they being held in place by two studs that go through the centre part of the valve, a wire going through these studs, and close to the back of the valve which keeps it up to the seat, the only spring to either of these valves being the elasticity of the rubber. The opening and connection D, D is the inlet to the pump, and where the suction hose goes on, there being a pipe or chamber with branches for the two air chambers, and at each end is a discharge gate and a connection for the leading hose. The part *d* is the feed pump for the boiler supply, *e* is the air chamber on the pipe that leads to the boiler to ease off the shocks caused by the plunger striking the water, when the pump does not fill. It is drawn broken off to show the upper part of the pump barrel and stuffing box. The pipe *f* is the feed water pipe from the pump to boiler, shown from different points in Figs. 3390*a* and 3391*a*. *g* is what we call the suction pipe to the feed pump. It connects to the main pump in the discharge part of it.

A piece of hose pipe connects to the boiler at a point just above the water line, so that hot water or steam (according to the height of the water in the boiler) may be applied to any part that may have become frozen.

Heaters are almost universally used in connection with steam fire engines to keep the water hot, and in many cases to keep a few pounds pressure to shorten the time of going to work should the fire be close at hand. This boiler has an advantage for this kind of heating; the circulation is so perfect and free that all the water in it is heated alike; so when the fire is lighted the steam starts

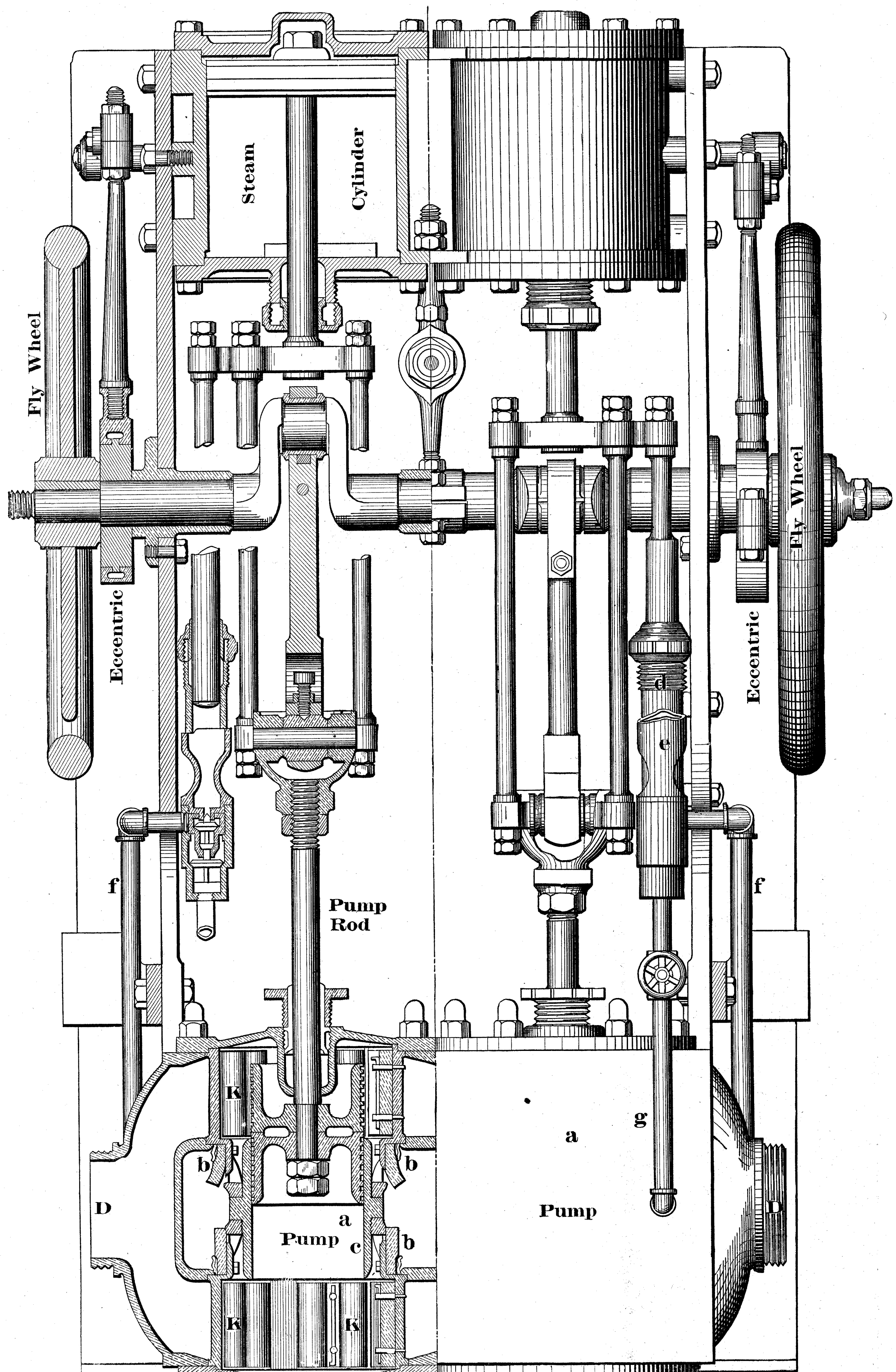


Fig. 3391*a*.

immediately up, instead of having to wait till some cold water has been heated that had not been reached by the very limited circulation in them, there being some parts that the circulation produced by the heater does not reach, leaving, of course, this water cold.

The arrows K″ (Fig. 3391), show the direction of the circulation when working with fire in the fire box; those marked L″ show the direction of it when on the heater which is directly opposite.

The outside pipe connected at about the water line is the outlet from the heater, and the inlet to the boiler, which carries the heated water over the crown sheet, where, as it gets cooler, it enters the coils, descends into the leg, and from there to the pipe near the bottom of the boiler; this pipe leads to the heater, so that the water is kept moving just in proportion to the heat given it; any kind of a heater can be used with the same result.