3 Sheets--Sheet 1.

G. B. DIXWELL.

Reciprocating Steam-Engine.

No. 160,311.

Patented March 2, 1875.

Fig. 1.

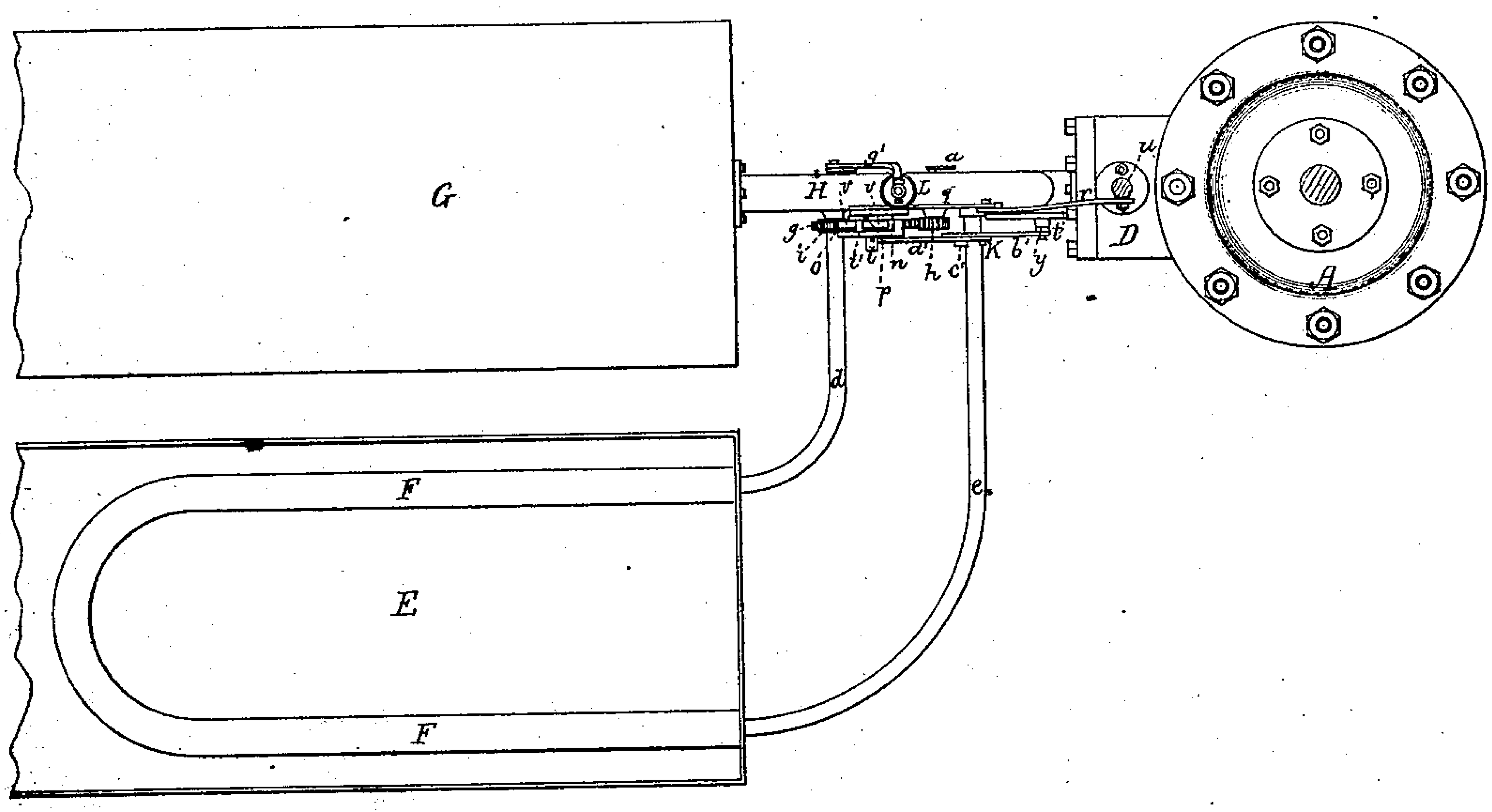
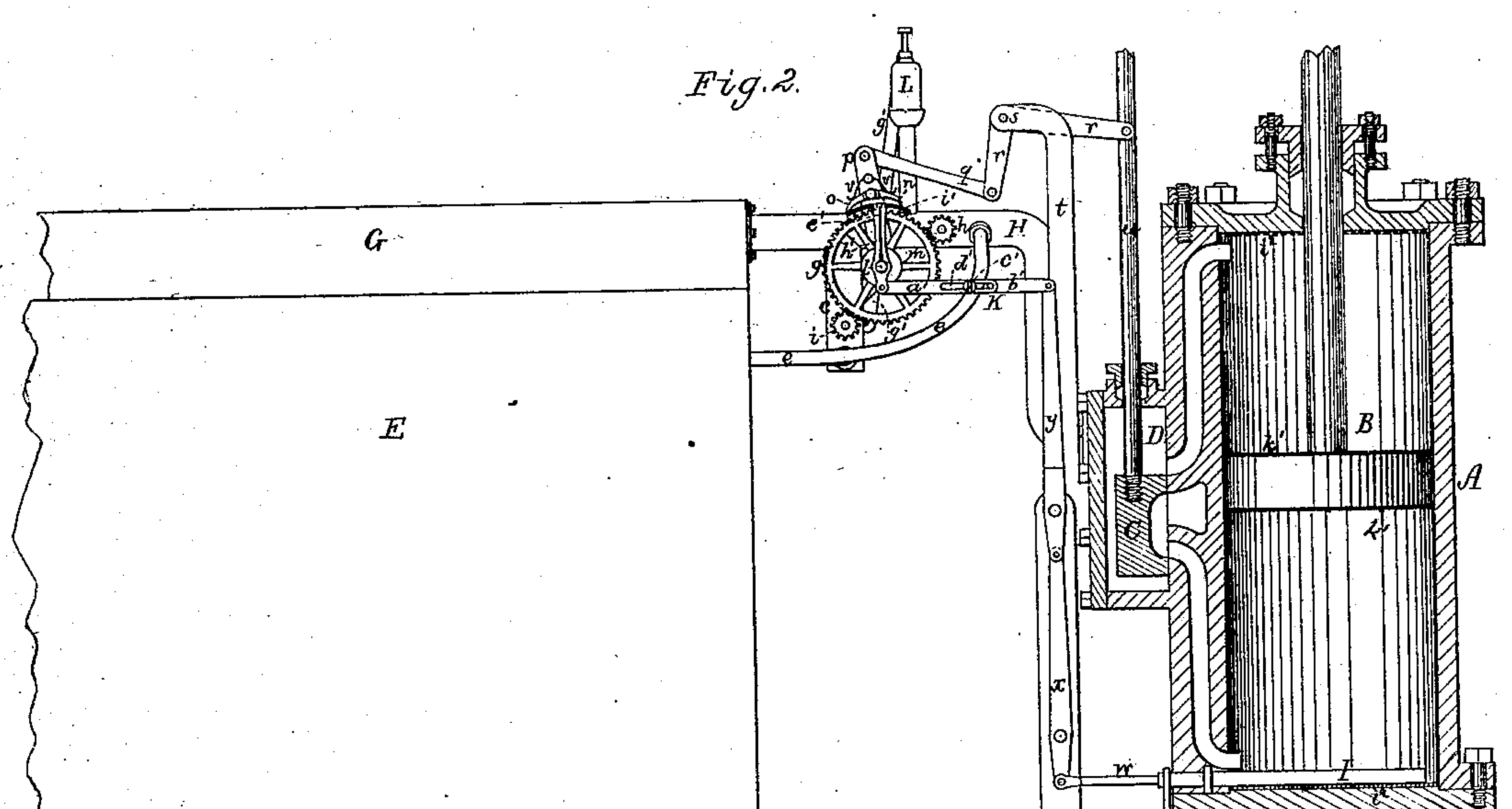


Fig. 2.



Witnesses.
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L. N. Moller

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Fig. 4.

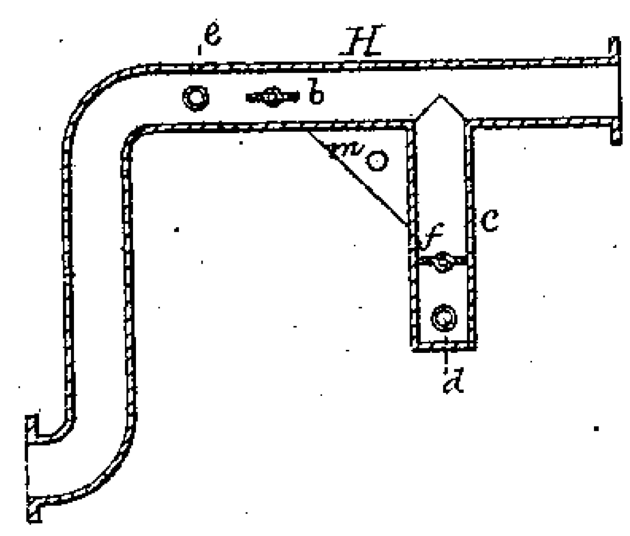
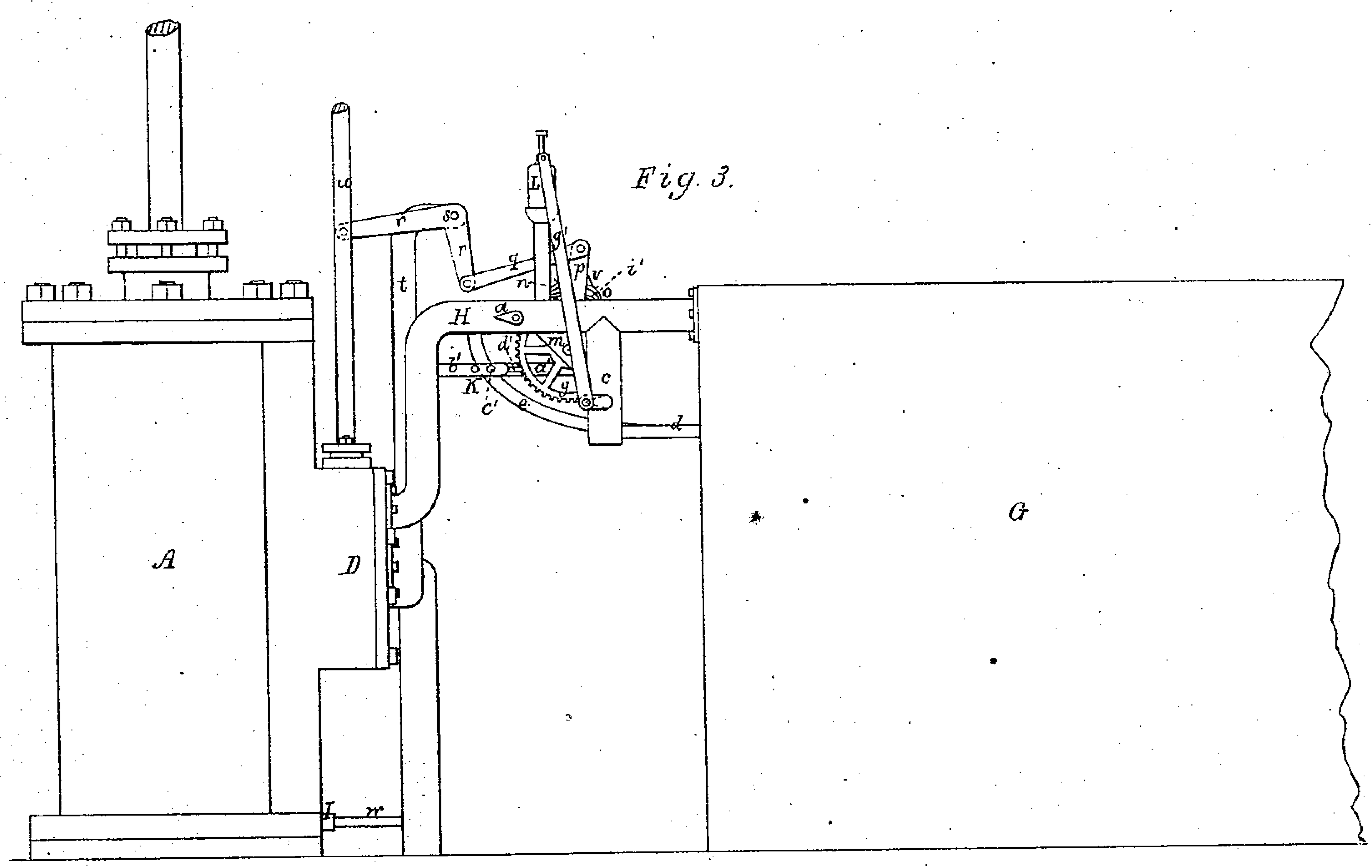


Fig. 3.



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3 Sheets--Sheet 3.

G. B. DIXWELL.

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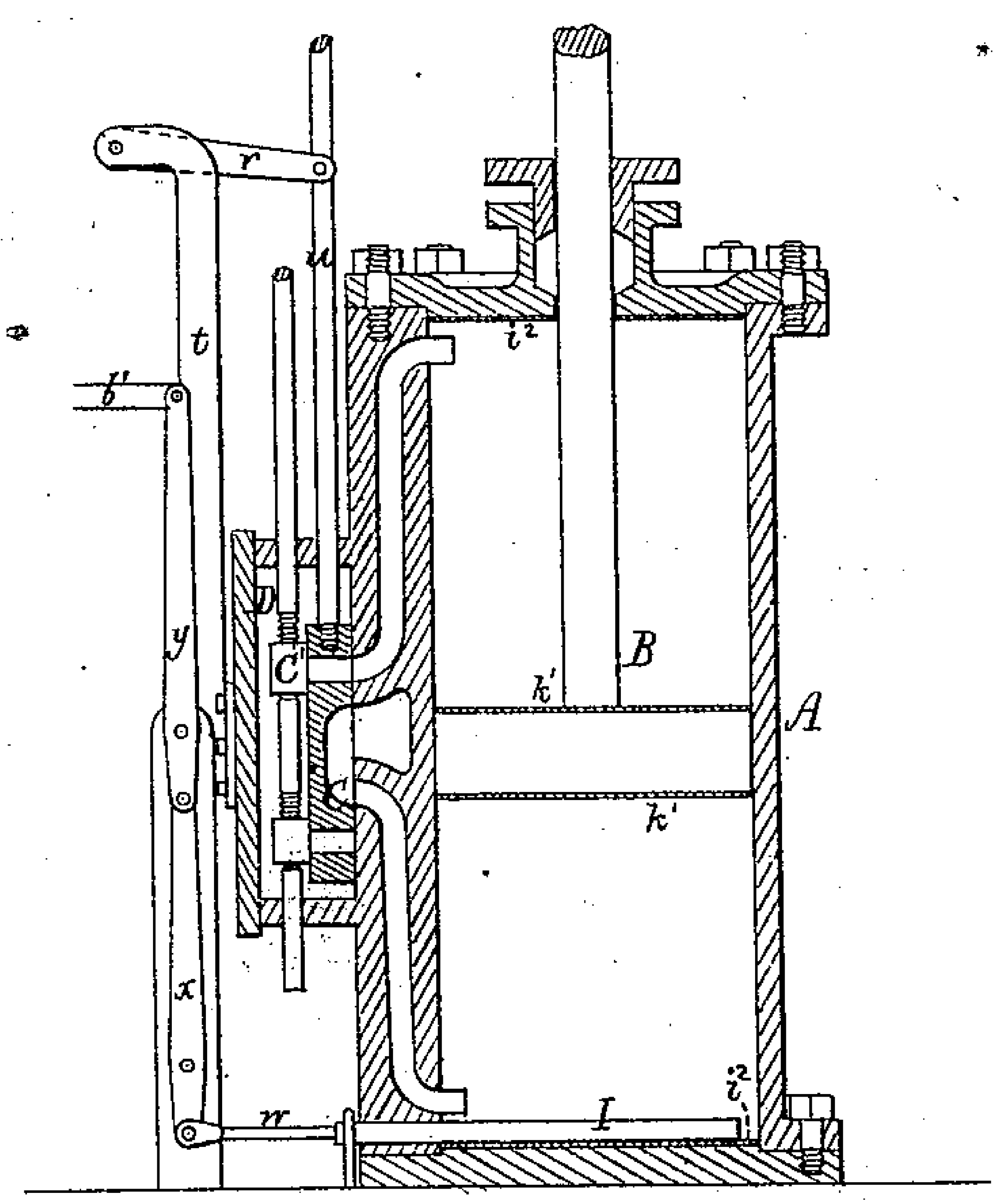
Fig. 5.



Witnesses,
S. N. Piper
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by his attorney
R. H. Eddy

UNITED STATES PATENT OFFICE.

GEORGE BASIL DIXWELL, OF BOSTON, MASSACHUSETTS.

IMPROVEMENT IN RECIPROCATING STEAM-ENGINES.

Specification forming part of Letters Patent No. **160,311**, dated March 25, 1875; application filed November 25, 1874.

To all whom it may concern:

Be it known that I, GEORGE BASIL DIXWELL, of Boston, of the county of Suffolk and State of Massachusetts, have made a new and useful invention, having reference to Steam-Engines; and do hereby declare the same to be fully described in the following specification, and represented in the accompanying drawings, of which—

Figure 1 denotes a top view, and Fig. 2 a front elevation, and Fig. 3 a rear elevation, of a steam-engine cylinder and boiler with my invention, the cylinder, piston, and valve-chest being exhibited in Fig. 2 in vertical section. Fig. 4 is hereinafter described. Fig. 5 is a section of the engine-piston and the cylinder with its steam-chest, valve, and variable cut-off, the latter being one form of cut-off, for which any other proper and well-known kind may be substituted.

My invention has for its object a peculiar use of superheated steam, whereby all cylinder condensation is suppressed, and such further advantage is obtained from the superheating as can be gained without danger to the working parts of the engine.

It is well known that the loss arising from cylinder condensation in engines using saturated steam is great, and that it becomes greater as the measures of expansion are increased.

To understand why the condensation increases with the expansion, we must examine the action of the steam in the cylinder, which appears to be as follows: The work done up to the point of cut-off is chiefly done in the boiler, and the condensation arising from the conversion of heat into power takes place almost entirely in the boiler; but the heat, which is equivalent to the work done during expansion, must be derived from the steam in the cylinder, and the condensation must, therefore, be greater with a greater measure of expansion; but the actual amount of condensation is found to be several times as great as that which would counterbalance both radiation and the heat converted into work, although bearing a very close ratio to the sum of these.

This appears to be caused in the following manner, viz: The refrigeration which occurs during the first stroke of the piston causes a certain amount of dew or mist to be formed in the cylinder, which dew or mist evaporates in part during the expansion and the return stroke, and chills the interior surfaces, so that these upon the next stroke condense a portion of the steam which enters from the boiler; but, besides this condensation from chilled surfaces, there will be upon the second stroke a fresh condensation growing out of radiation and work done, so that the quantity of dew or mist to be evaporated, and the quantity of consequent chilling of interior surfaces will be greater on the second stroke than on the first, and so with each subsequent stroke. The action of the metallic surfaces is cumulative, and the condensation must go on increasing until it is so great that the portion or percentage of mist which remains unevaporated and passes out as spray equals the amount formed at each stroke by radiation and work performed.

Explain it as we may, the fact remains that the actual condensation in cylinders cutting off short is about five times the equivalent of that caused by radiation, and by the conversion of heat into work; and if we could superheat the steam to the precise amount required to balance the refrigeration in question we should suppress cylinder condensation at a comparatively trifling expense.

This has been already attempted, but hitherto with very partial success, which is accounted for as follows: With a small measure of expansion only a slight refrigeration has to be met, while with a large measure of expansion a great amount of refrigeration takes place, so that the superheating which is necessary for an engine cutting off at one-eighth stroke is about three times that which suffices at half-stroke. If, then, we use the latter measure of superheating, namely, that sufficient for half-stroke, condensation must take place when the larger ration of expansion is used, and the advantage sought from the larger expansion will not be secured. If, on the other hand, we use the amount of superheating required for the larger rate of expansion the cylinder will be overheated, and the working parts injured or destroyed whenever we revert to the fuller stroke. Both these accidents have occurred in practice.

A moderate degree of superheating has been used and been found not to suppress cylinder condensation, and, on the other hand, a high degree of superheating has been tried, and many valuable engines have been injured thereby.

Experiments on a large scale have shown that a temperature of 400° Fahrenheit may be safely used within the cylinder; but a heat much above this point appears to decompose the oils now used in lubrication and to destroy the working parts. With better lubricators a higher heat may, perhaps, be used hereafter; but 400° Fahrenheit appears to be the practical limit at present. The temperatures, however, to which it is necessary to superheat in order to balance the refrigeration occurring at a short cut-off are very high, much above 400° Fahrenheit, and it would therefore appear, and in fact it has come to be generally considered, exceedingly dangerous to employ such temperatures, even when a short cut-off alone is to be used. Experiment, however, has shown this to be an erroneous opinion. The steam may be heated to the necessary temperature in the superheater, and yet no such high temperature will ever appear in the metal of the cylinder, for a thin film of the metal takes up instantly the heat of the entering steam, and the weight of the film in question exceeds by so many times the weight of the steam that the joint temperature is reduced almost to that of saturated steam. This is what takes place up to the point of cut-off. During the remainder of the stroke the metal gives off its extra heat to the expanding steam, and maintains it in the superheated state to the end. There is no danger then in adding to the normal temperature of saturated steam an amount of heat equivalent to the refrigeration which takes place in the cylinder at the cut-off we are using. This will bring the steam, at the cut-off, only to about the temperature of saturated steam, and we not only need have no fear of the amount of heat in question, but we may go on superheating still further until the steam at the point of cut-off has a temperature of 400° Fahrenheit. Here we meet the limit of safety under existing conditions. For instance, let us suppose an engine to be cutting off at one-tenth. We may superheat the steam to such a temperature as will suppress all condensation and also bring the steam in the cylinder to 400° Fahrenheit, and provided no change is made it will work on indefinitely in safety; but if for any purpose the cut-off be changed and the engine be set to working at a cut-off of, say, one-half, the interior of the cylinder will be immediately exposed to a heat of over 600° Fahrenheit, and will be speedily injured.

My invention, therefore, is for regulating the temperature of superheated steam, so that (whatever cut-off be used) the heat within the cylinder shall not exceed 400° Fahrenheit, or such other temperature as may be selected as perfectly safe. This may be done by first ascertaining by experiment for each particular engine what heat in the superheater corresponds to 400° Fahrenheit at each different cut-off; then, upon changing the cut-off, the heat in the superheater is varied to correspond, and this may be done by varying the fire and the draft of the superheater, or by mixing saturated steam with the superheated steam, &c.; but these are imperfect methods, and I prefer to keep watch over the temperature of the steam in the cylinder by means of a thermometer or pyrometer placed within the clearance-space or in an adjacent cavity, and to diminish the heat of the steam when the pyrometer indicates a higher temperature than 400°, or such other temperature as may be selected, and to increase the heat of the steam when a lower temperature is indicated. This regulation of the temperature of the steam I prefer to effect by means as represented in the accompanying drawings, such consisting of a boiler, a superheater, and an apparatus for automatic regulation. This last may not always be used, as the engineer on duty may sometimes adjust the regulating-valves according to the indication of the pyrometer.

Having thus premised, I will now proceed to describe my invention.

In the drawings, A denotes a steam-engine cylinder, with its piston B, valve C, and steam-chest D. In Fig. 5 the variable cut-off applied to the valve C is represented at C′.

A boiler for said cylinder is shown at E, with its upper part removed in order to exhibit the cooler or conduit F within such boiler. This boiler may be supposed to be one of a series, as generally used for large engines. The said conduit is to serve the purpose of a cooler to the superheated steam. The flue or conduit F may be either above or below the water-surface, but I prefer to place it below the said surface, so that the heat given up by the superheated steam will evaporate a certain quantity of water and nothing be lost. Behind the boiler is seen the superheater G, (or boiler for generating superheated steam,) from which a pipe, H, proceeds directly to the steam-chest D. In this pipe there is a throttle-valve, *b*, the position of which in the pipe is indicated by an index-finger, *a*, upon the outside of the pipe and fixed on the valve-spindle.

Figure 4 is a section of the pipe H, its branch pipe *c*, and their valves.

When the valve *b* is closed no steam passes directly from the superheater to the steam-chest, but the whole of it makes a detour through a branch pipe, *c*, nearest the superheater, thence through another pipe, *d*, to the cooler F, from whence it escapes through another branch pipe, *e*, into the pipe H from the superheater, and thence into the steam-chest. It may appear strange to use one of the boilers of an engine as a cooler, but an example will show that the device is not unreasonable. Let us suppose that steam of sixty pounds' pressure is being used at a cut-off of one-third, the temperature of the boiler would be 292° Fahrenheit, while the temperature in the superheater must (in order to balance radiation and conversion of heat into work) be about 480° Fahrenheit; and this will only prevent condensation and keep the steam within the cylinders at the point of cut-off at about 300° Fahrenheit. In order to keep the steam within the cylinder at the point of cut-off at 400° Fahrenheit, we should have to add still another 100° Fahrenheit, so that the total heat in the superheater would be about 590° Fahrenheit. It is, then, evident that a flue passing through the water of a boiler of which the temperature is 290° Fahrenheit will be a very efficient cooler for steam of nearly double its temperature; and it is calculated that the flue in the boiler need not exceed in surface the aggregate of piston and cylinder surfaces to which steam is subjected when working at a cut-off of one-third. The method proposed has the advantage of keeping a constant flow of steam through the superheater, (which is thereby prevented from becoming red-hot,) and a further advantage of loosing no heat, inasmuch as what is taken from the superheated steam goes to evaporate a quantity of water.

I would suggest that the cooling-flue could, when exceptional circumstances required it, be made to traverse a feed-water heater instead of a boiler. It would very seldom be necessary to do this.

Within the branch pipe *c* is another throttle-valve, *f*, which is adjusted to work in connection with the valve *b*, already described, in such a manner that, as one closes the other opens, and when one is entirely shut the other is entirely open. We have already considered the case of the direct pipe from the superheater to the steam-chest being closed, and have seen how the steam then takes a circuitous course through the cooler, and so diminishes the quantity of heat carried into the cylinder. In the opposite case (when the valve in the direct pipe is open and the other closed) all the steam passes direct from the superheater to the steam-chest, and so increases the quantity of heat carried into the cylinder. When one valve is partly closed and the other partly open, a greater or less degree of heat will reach the cylinder in proportion to the relative positions of the valves.

I shall now proceed to describe what I term the pyrometric regulator or governor for the two valves *b* and *f*, such governor operating automatically.

In the drawings, *g* denotes a gear-wheel, which works into two smaller gears, *h i*, that are fixed on the spindles of the valves *b* and *f*. They move the valves in such wise that as the large gear *g* moves in one direction the valve leading to the cooler is closed and the other opened, and in proportion as the large gear *g* moves in the other direction the valve leading to the cooler is opened and the other closed.

Extending over the periphery or teeth of the larger gear *g* is an arcal shield, *i'*, carried by an arm, *h'*, that turns on the pivot or journal *l* for supporting the said gear *g*, each journal being projected horizontally from a bracket, *m*, extending down from the conduit H.

Over the arcal shield *i'* are two pawls, *n o*, arranged as shown, and is or may be pivoted to an arm, *p*, that turns upon the journal *l*, and at its upper end is jointed to a connecting-bar, *q*, that is also jointed to a bent or right-angular lever, *r*, having its fulcrum *s* supported by a standard, *t*. The longer arm of the lever *r* is pivoted to the stem *u* of the cylinder valve C. As the valve-stem has a positive motion when the engine is in operation, a reciprocating motion will be imparted to the arm *p* and the two pawls *n o*, each of which is provided with a spring, *v*, for forcing it downward.

It will be observed that when the shield-lever *h'* is vertical the pawls slide back and forth on the shield without actuating the gear *g*; but when the shield is carried to the right or left, one of the pawls will be forced down into action upon the gear—that is, when the shield is moved to the right, the left pawl catches and moves the large cog-wheel *g* to the left, and when the shield is moved to the left, the right-hand pawl catches and moves the large cog-wheel to the right.

The shield is to be worked by a mechanism which is attached to a pyrometer, I. This last is a copper tube, lying in the clearance-space of the cylinder, and firmly attached to the left-hand side of the cylinder, but playing freely within. To the bottom of this tube an iron rod, *w*, is attached, in such manner that when the copper tube expands with heat toward the right the iron rod follows, and when the copper tube contracts from loss of heat, the iron rod moves toward the left. In thus moving, the iron rod works a system of levers, *x y*, attached to its outer end, and connected with the lever or arm of the shield, as shown. This moves the shield in one or the other direction. The connection-piece K, by which the system of levers proceeding from the pyrometer to the shield is connected with the lever *h'* is made in two parts, *a' b'*, connected by a set-screw, *c'*, going through a slot, *d'*, in one of them. The connection K is then capable of being lengthened or shortened by means of the slot and screws, and this enables us to adjust the shield and pyrometer, so that the large cog-wheel *g* will be uncovered and moved whenever the desired temperature is reached. The shield should be graduated. A stationary pointer, *e'*, arranged in front of it, serves to indicate the temperature existing in the cylinder. The connection K may be in one piece; but I prefer to have it in two, made and connected as described.

The graduation can easily be effected by introducing into the bottom of the cylinder and around the pyrometer cold water, and afterward hot water or steam up to 300° Fahrenheit, and from the graduations up to 300° Fahrenheit those of a higher temperature (as our present limit of cylinder-heat being 400° Fahrenheit) may be inferred.

Behind the steam-pipes, and extending above them, may be a steam-whistle, L, which, on being opened, gives an alarm, whenever the valve f leading to the cooler is entirely opened, this indicating that the temperature selected as a maximum has been exceeded.

The valve of the whistle may be connected with the index-pointer of the lower throttle-valve f by a connection-rod, g, so applied as to cause the whistle to open when the throttle-valve f may be opened.

It may be stated that the top and bottom of the piston and the top and bottom of the bore of the cylinder may be covered with a sheet of wire-gauze. (Shown at i^2 i^2 k' k'.) This will not be necessary in small or medium engines not using an excessive expansion; but it will be highly useful to thus increase the surface and weight of absorbing and radiating metal when a high rate of expansion necessitates a high temperature in the superheater.

Having now described my invention, I would observe that it is based upon four facts or premises, which I have discovered from experiments.

The first is, that superheated steam, unlike the gases, gives up its heat to metallic surfaces, and receives heat from time to time with immense rapidity.

The second is, that the metallic surfaces of the piston and cylinder absorb with immense rapidity the excess of heat existing in superheated steam brought into proximity to them, and by their great weight convert a high temperature of steam into a much lower temperature of metal. Fifty pounds of iron heated 20° Fahrenheit takes up about the same amount of heat as one pound of steam heated 232° Fahrenheit.

The third is, that the said metallic surfaces give back to the expanding steam the heat previously absorbed, in such a manner as to supply the heat which is converted into work, and the heat withdrawn by radiation, and thus prevent condensation in the cylinder.

The fourth is, that different quantities of heat are thus absorbed, and given out with different measures of expansion, so that the steam must, and safely may be, superheated to temperatures proportioned to the said measures of expansion, plus the heat withdrawn by radiation.

From the above it will be seen that my invention, or an important part thereof, for operating a steam-engine piston by superheated steam used expansively in the cylinder, provided with a variable cut-off or mechanism for arresting, at different parts of the stroke of the piston, the admission of steam to the cylinder, is a novel art or method, which consists in elevating the temperature of the steam of the generator or superheater as the cut-off may be lessened, and lowering the temperature of the said steam as the cut-off may be increased, the same being so as to maintain, as described, in the cylinder a safety temperature, such as will prevent condensation of the steam therein, and obtain all the advantages from superheating consistent with safety under existing conditions.

It will also be seen that I have combined a pyrometer or heat-measure with a steam-engine cylinder, provided with a piston, valve-chest, valve, and a cut-off, all being for the purpose or purposes as explained.

Having thus described my invention, what I claim as such is as follows—that is to say:

1. The combination of the cooler F with the superheated-steam generator G, the engine-cylinder A, their connection-pipe H, and a valve, b, arranged in such pipe, all being substantially as described.

2. In combination with the superheated-steam boiler or generator G and engine-cylinder A, and the connection-pipe H, the two throttle-valves b f, and the cooler F, all being arranged and applied substantially in manner and to operate as described.

3. The combination of the steam alarm or whistle, with the superheated-steam generator G and engine-cylinder A, and their connection-pipe H, the two throttle-valves b f, and the cooler F, all being arranged and applied substantially in manner to operate as specified.

4. The pyrometric regulator or governor, substantially as described, consisting of the gears g h i, the vibratory shield i', the pyrometer I, and the vibratory arm p, and its pawls n o, all arranged, applied, and connected substantially as and to operate as explained.

5. The combination of the said pyrometric governor, with the superheated-steam generator G and engine-cylinder A, their connection-pipe H, the valves b f, and the cooler F, all being arranged and applied substantially in manner and to operate as set forth.

6. For operating a steam-engine piston by superheated steam used expansively in the cylinder, provided with a variable cut-off or mechanism for arresting at different parts of the stroke of the piston the admission of steam to the cylinder, the new art or method, substantially as described, it consisting in elevating the temperature of the steam of the generator or superheater, as the cut-off may be lessened, and lowering the temperature of the said steam as the cut-off may be increased, the same being so as to maintain, as described, in the cylinder a high or maximum safety temperature, such as will prevent condensation of steam therein, and effect other useful advantages, as set forth.

7. The combination of the pyrometer or heat-measure with the steam-engine cylinder, its piston, valve chest, valve, and a cut-off-applied thereto, such being substantially as and for the purpose or purposes as specified.

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