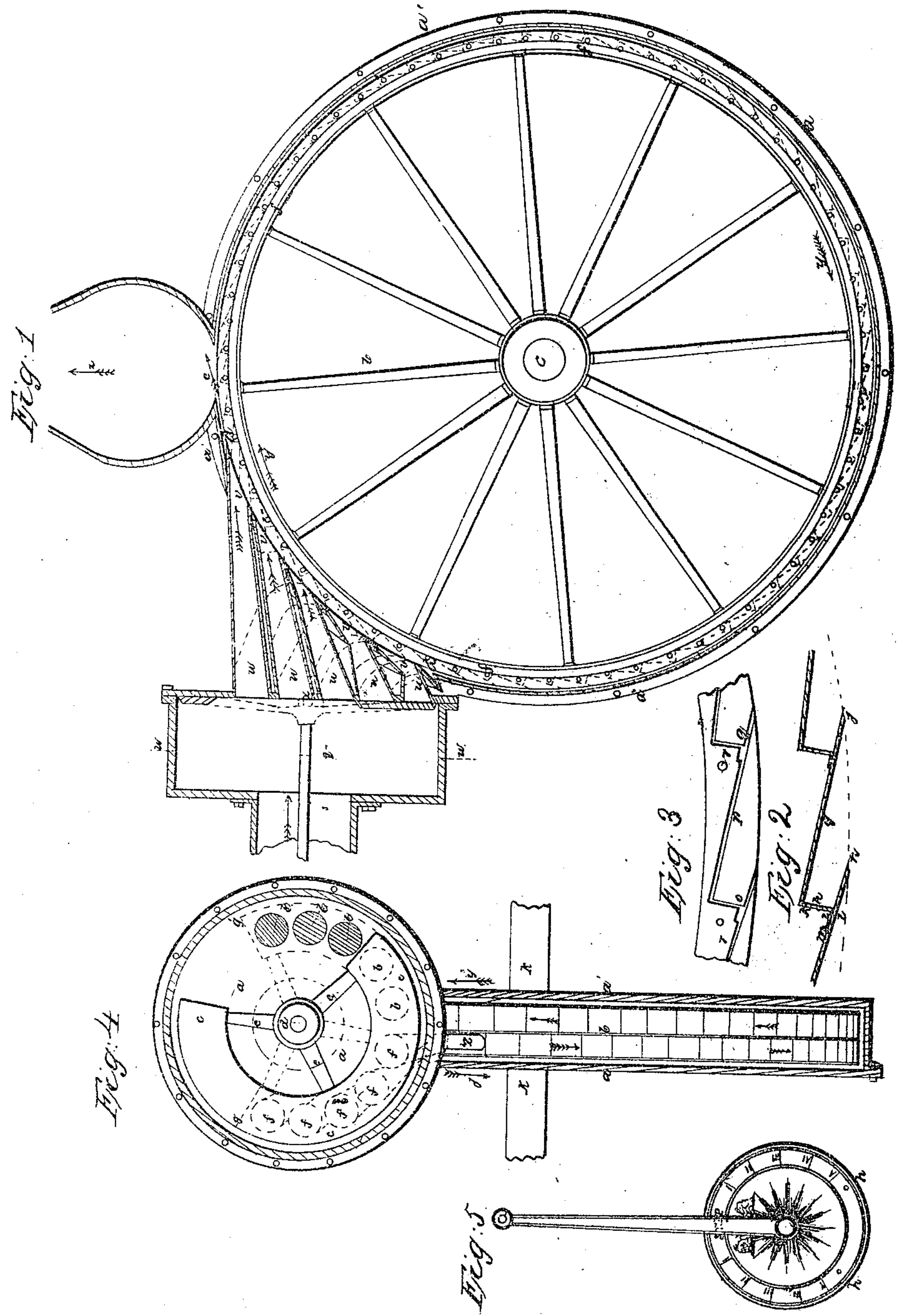
8 Sheets—Sheet 1.

J. Pilbrow,

Rotary Steam Engine.

No. 3,131. Patented June 14, 1843.



8 Sheets–Sheet 2.

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Fig: 2

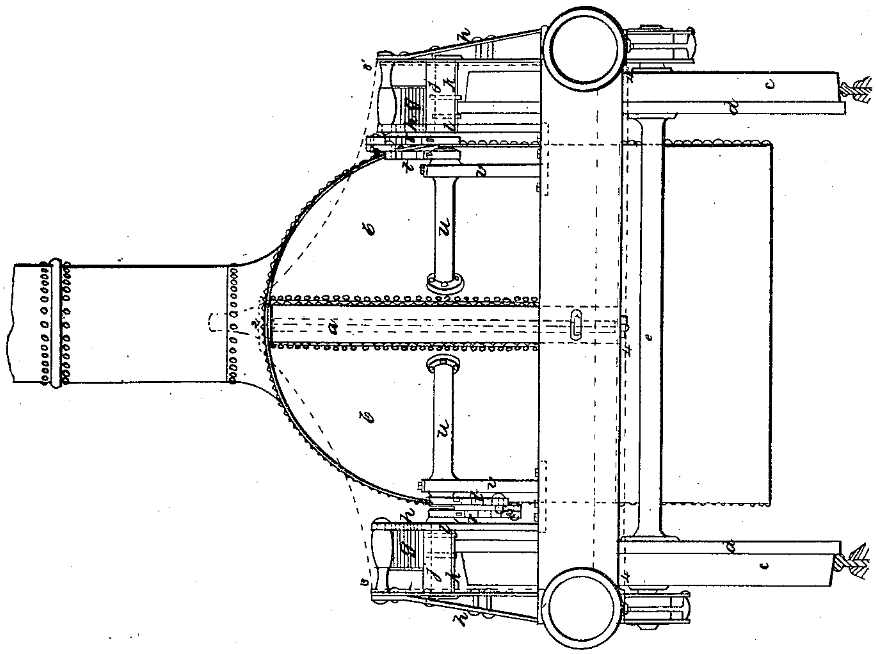
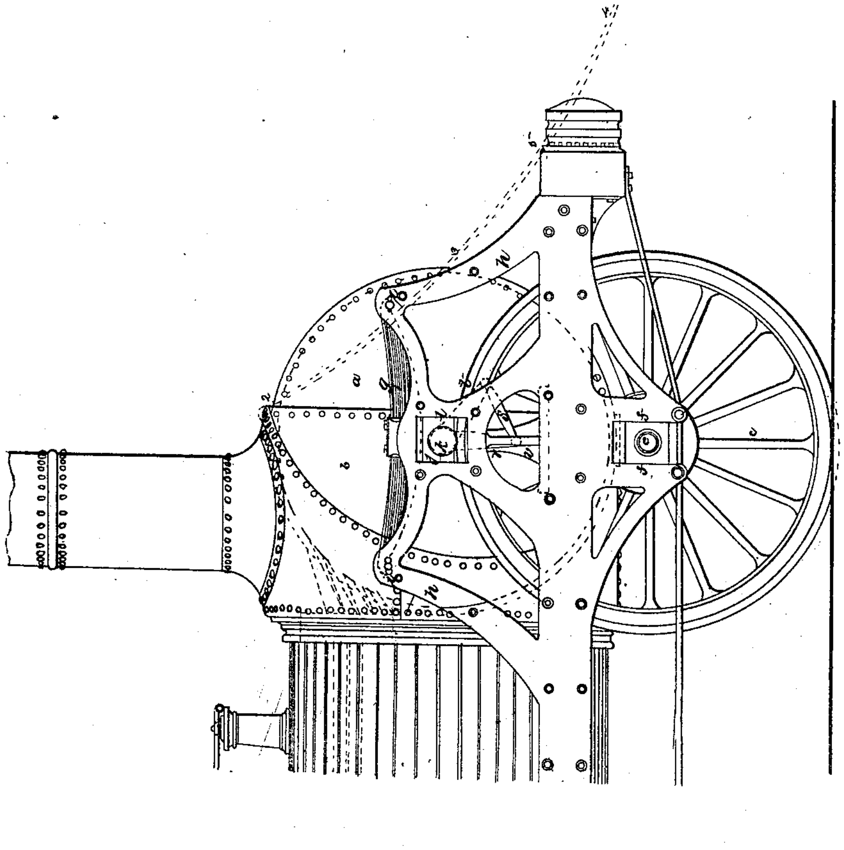


Fig: 1



3 Sheets—Sheet 3.

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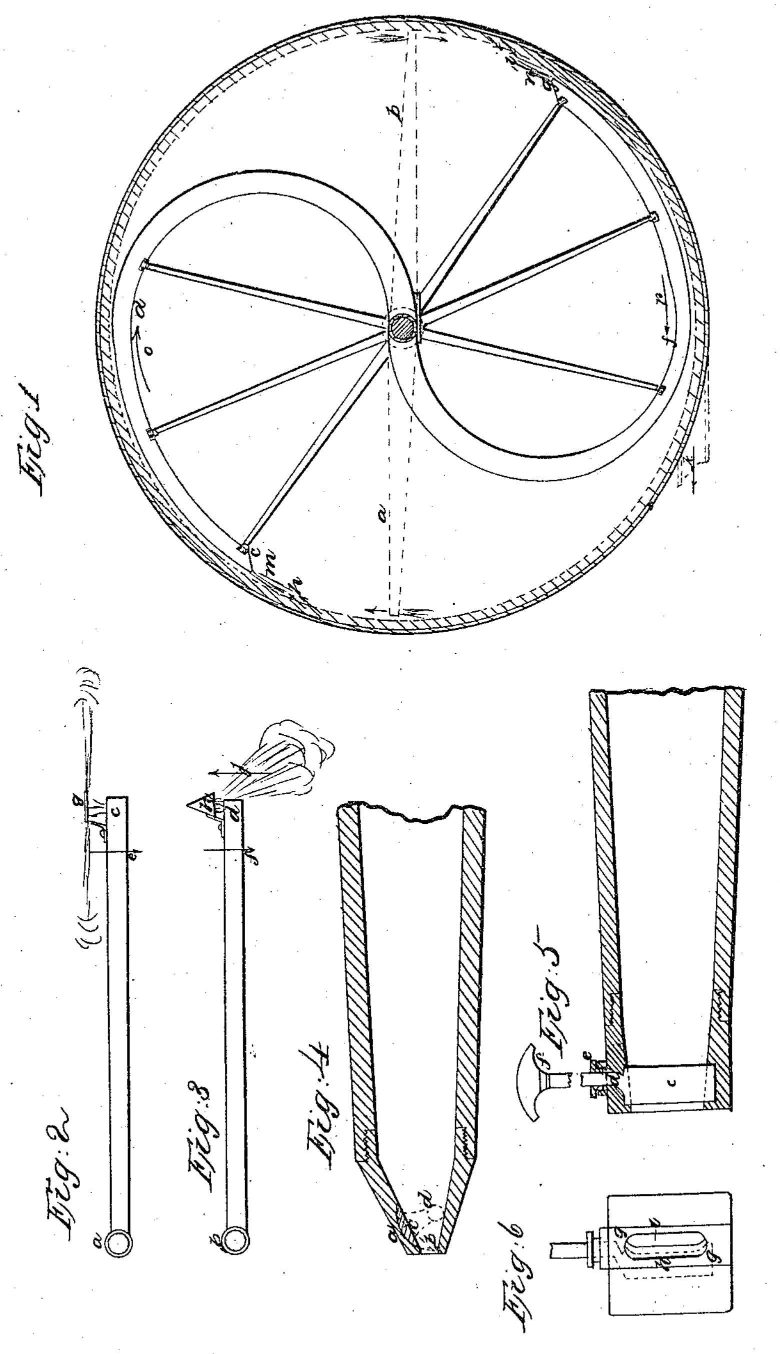

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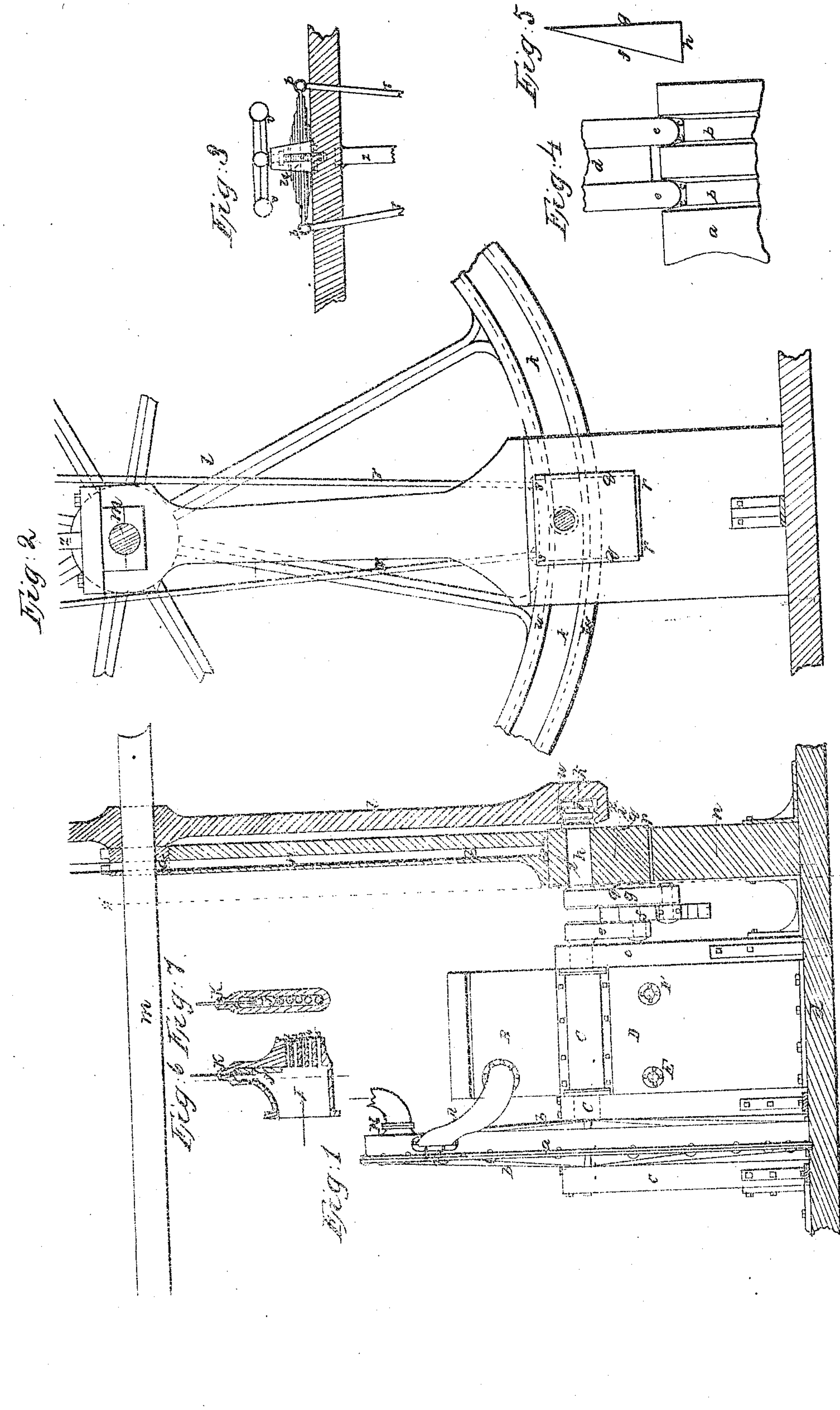

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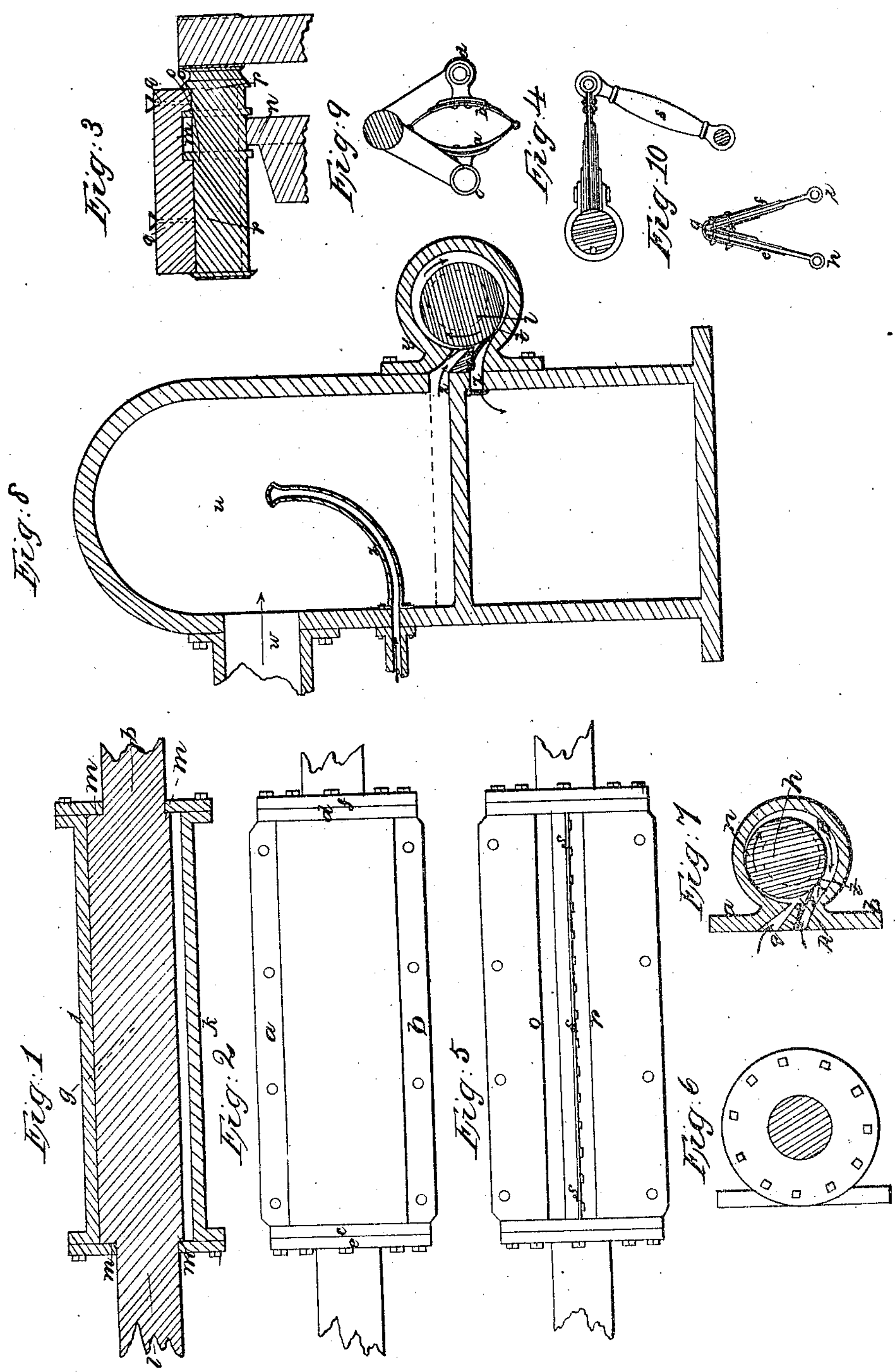

8 Sheets—Sheet 6.

J. Pilbrow,

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Fig: 2

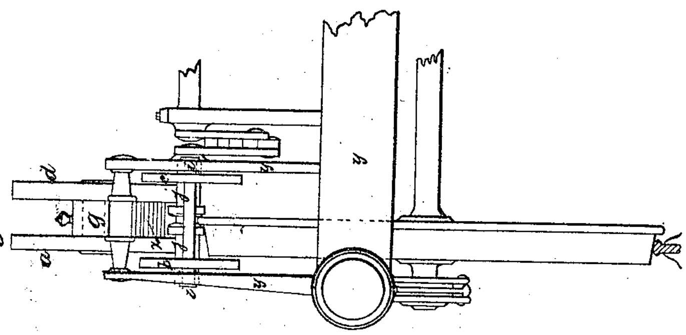
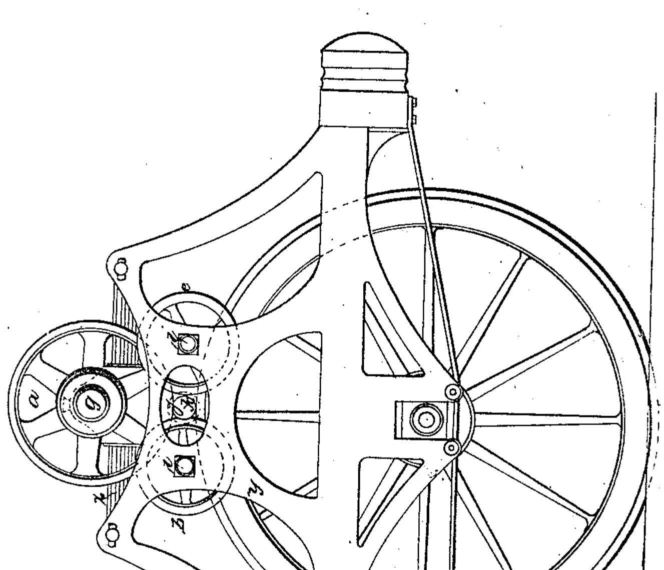


Fig: 1



8 Sheets—Sheet 7.

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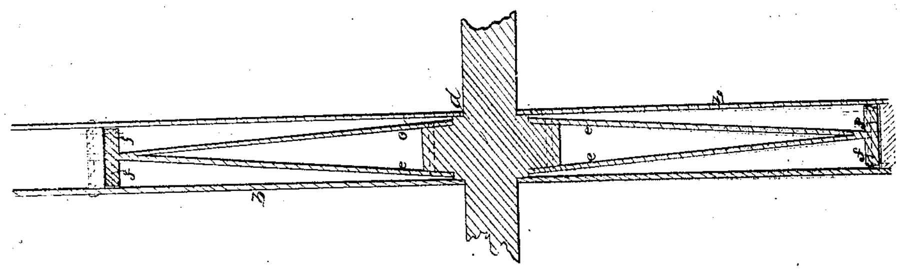

Fig 2

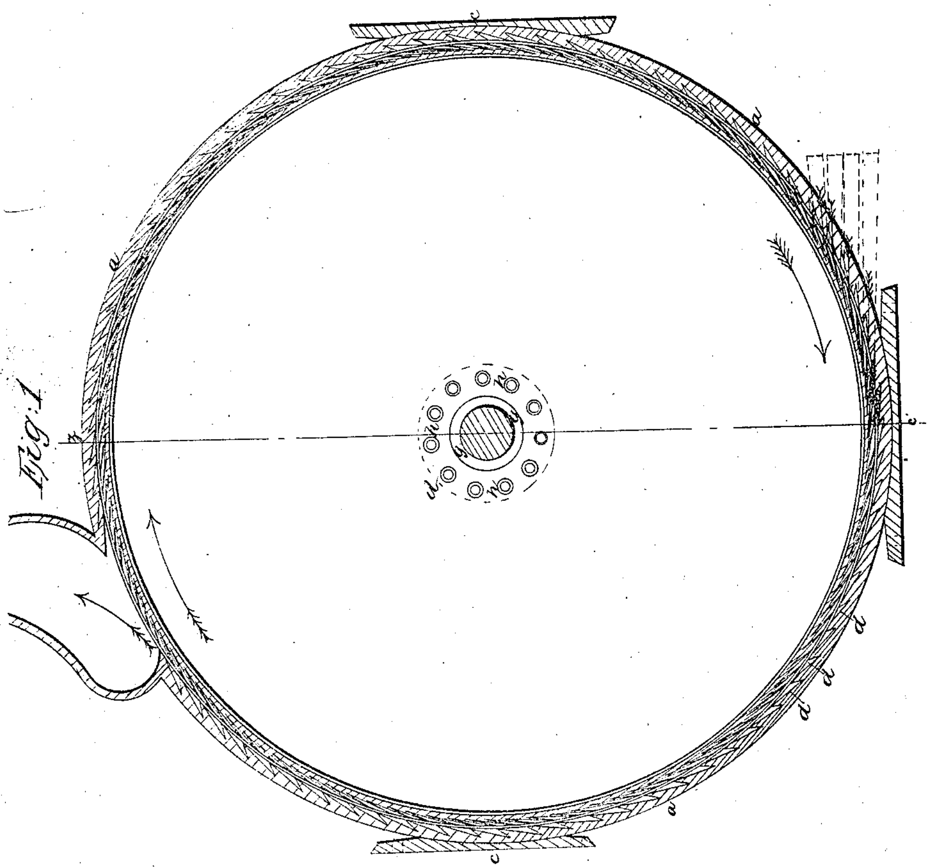

Fig: 1

8 Sheets—Sheet 8.

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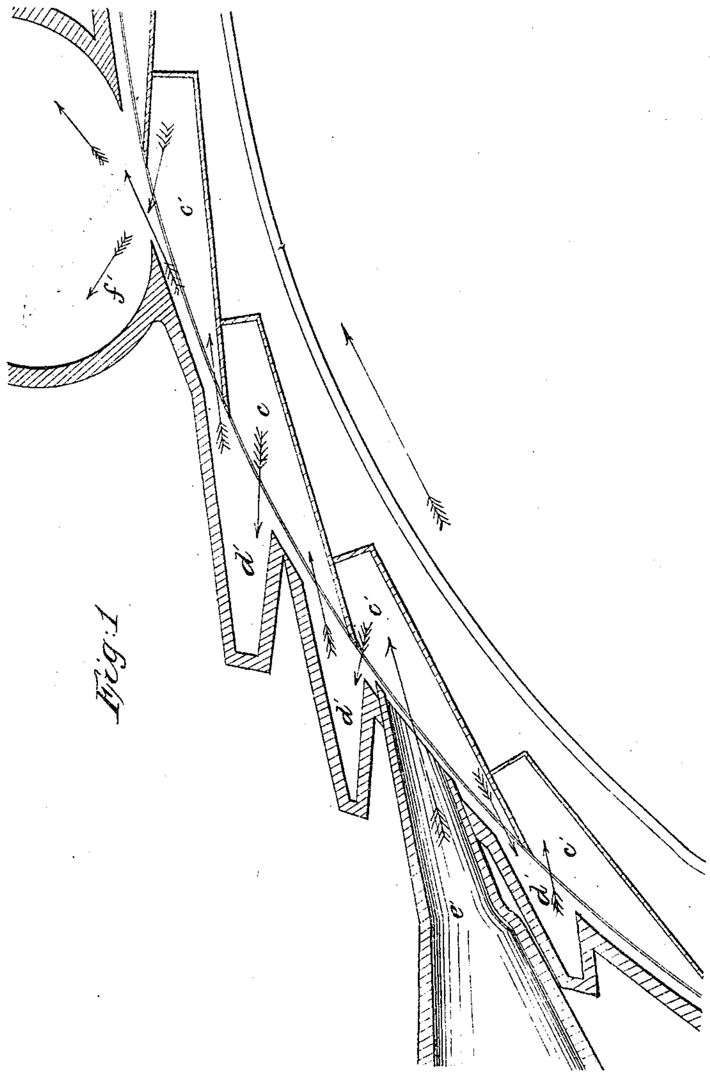

Fig. 1

UNITED STATES PATENT OFFICE.

JAMES PILBROW, OF TOTTENHAM GREEN, ENGLAND, ASSIGNOR TO CHARLES COLLINS.

INJET REACTING ROTARY STEAM-ENGINE AND THE MANNER OF CONNECTING IT WITH MACHINERY TO BE PROPELLED.

Specification of Letters Patent No. 3,131, dated June 14, 1843.

To all whom it may concern:

Be it known that I, James Pilbrow, of Tottenham Green, in the county of Middlesex, England, engineer, and a subject of the Queen of Great Britain, have invented certain new and useful Improvements in Steam-Engines or in the Application of Steam or other Suitable Elastic or Aeriform Fluids to Produce Motive Power, which improvements, combined together, form a steam-engine characterized by me, to distingish its principles from those of other engines, as the "Injet-Reaction Rotatory Engine," and that the same is fully described and represented in the following specification and accompanying drawings.

Wishing publicly to record the origin of my discovery, I shall depart somewhat from the usual form of specification, believing that the results of my experiments will create a great alteration in the application of steam, and that my engine will entirely supersede those now in use. The properties of steam have hitherto been considered of that peculiar nature as to render it impossible to obtain its full power and extreme duty from expansion, except by using it according to the present system; that is, by letting it into a hot or close cylinder on a piston and stopping its further entrance by cutting it off to allow it to expand. Feeling however a strong conviction that the whole power was to be obtained by some more simple means, than the present costly complicated and ponderous machine, and that a power so easily raised need not be so laboriously applied, I undertook a long series of experiments to discover how this might be done. I first commenced on the most simple form of engine known to us, that of Hero's, and ascertained the true causes of its loss of power, and found after many inventions to obtain by this simple machine the full power and duty from expansion, that though I could considerably increase its power by the form of arm shown in Figure 1, Drawing C, yet that I could not obtain the whole duty from expansion and consequently that an engine on this principle could never be brought to compete with Mr. Watts' condensing engine. The failure however of my plans to obtain these results, disclosed to me the remarkable fact that a current of steam in rapid motion, that is issuing from an orifice, loses almost entirely that power of lateral expansion which it possesses when cut off and allowed to expand from a state of comparative rest. When I had confirmed this phenomenon by other experiments I was satisfied that steam possessed an impulsive power of the utmost efficiency entirely different from what had ever been supposed, for its full expansive force not being given out laterally must have gone somewhere, and as it could only expand in the line of its issue I became acquainted with this new and singular property of steam; that is possessed in its mere velocity alone a propulsive force from its lineal expansibility, equal in power and duty to the gross effect obtained when cut off and allowed to expand under the best circumstances. I had next to transmit this new principle of steam power to machinery with the least possible loss from friction, and other deductions, by some engine as simple as the principle and this I supplied as hereinafter described. But I wish first to show that there exists in nature an analogy between steam and water as moving powers, when applied by their simple velocity, that it may be seen how much more in harmony with her laws is this discovery than the present system of applying steam. The two great forces of the universe, producing all motion, are attraction and repulsion, and as motion is motion wherever found, whether in steam, water, or a cannon ball, all motion must be power, power in proportion to the intensity of motion. Water obeying the former law has been immemorially employed in its natural state to give motion to machinery merely by its velocity of gravitation. But no proper advantage has ever been taken of the force of the velocity of steam, which, governed lik all elastic fluids by the latter law (repulsion), issues at a speed infinitely exceeding that of water, increasing in velocity in proportion to the heat among its particles. Yet it has been considered by all writers on the steam engine and on the properties of steam, that it possesses but a feeble power by emission, to turn a wheel in comparison with the quantity expended. But this error has arisen only because no one has ever thought of ascertaining the fact by actual experiment of a proper kind, and thus the extreme force of the velocity of steam has remained undiscovered to the present advanced state of science. Instead therefore of using steam with the same simplicity as water, the power which steam possesses from velocity has hitherto been destroyed, the steam being "cut off" as it is called to allow it to expand from a state of comparative rest. Having thus departed from the simplicity of nature a complication of beams, levers, connecting rods, pistons, valves, eccentrics and expansive gear, and vast cylinders of ponderable matter became necessary to enable the steam to expand over large areas of surface, merely to give back to the more simple operations of nature, that power which is taken from her by complexity; whereas by using it in its more natural and therefore more simple state, precisely the same advantages may be obtained by machinery as cheap, simple and easy of construction as the water wheel. But, as in all practical sciences there is only one way of obtaining the most beneficial results, I have found that there is a great difference in the duty of steam by the peculiar manner in which it is applied by its velocity as is found in effect in the application of water. I shall therefore first describe a few experiments, being some of those which led to my invention to show the accuracy required.

The operation of Barker's mill and of Hero's emission engine is well known, and though there is no resemblance between their moving powers, the one acting by gravity the other by repulsion, there seems to be a strict analogy between their results proportioned to the power and velocity of each, so that whether water or steam be used in the following experiments; the modes of action being similar, that of impulse or transference of motion, the operation and direction of the arm will be the same. And it will be seen hereafter that I obtain by my application of the velocity of steam, the same duty therefrom as is obtained by the best over-shot water wheel, namely a clear available effect of about two-thirds of the whole power of the steam employed, that is two-thirds of its power, and of its extreme duty from expansion, the steam being expanded in my application of it as low as the atmosphere in high pressure engines, and to the vapor point, or state of condenser vacuum in condensing engines; degrees of attenuation which cannot be obtained by the present system on account of the piston.

Figs. 2, and 3, in Drawing C represent arms on Hero's principle attached in the usual way to a hollow axle (*a* or *b*), supplied with steam and having orifices at the extremities (*c* and *d*). When used in the usual way, the arms will revolve by unbalanced pressure, in the direction of the arrows (*e* and *f*). But when a flat plate is attached to the area, immediately before the orifice (*g* Fig. 2), the steam will impinge thereon and being broken up will change its course as therein represented, and the arm will become stationary, showing that the force of impingement equals that of unbalanced pressure. If, however, a cavity (*h* Fig. 3), be fixed, instead of the plate, opposite the orifice, at such an angle that the injet of steam can be returned by its reaction (*i*) clear of the arm, without impinging thereon the arm will revolve in the contrary direction to that of the previous unbalanced pressure, and in the direction of the arrows (*j*), with more power than that with which it revolved the contrary way, previous to the cavity being fixed thereon; proving that the cavity not only received the same amount of impingement as the flat plate (*g* Fig. 2,) received, (which was shown to be at least equal to the unbalanced pressure), but by this peculiar injet and re-action or reissue of the steam, its whole velocity was arrested, and the cavity thus acquired another power of equal amount, sufficient to overcome and carry around the effect of unbalanced pressure only. But if the steam on its reissue or reaction from the cavity (*h*) is permitted to impinge at all against the arm (*d*), the arm will then only revolve in the direction of the arrow (*j*) with diminished power in proportion to the amount of such impingement; and, if all the steam on its reissue or reaction from the cavity (*h*) is allowed by altering the angle of the cavity to strike fully against the arm (*d*), the arm will then remain stationary, as when the flat plate (*g* Fig. 2,) was used. When I had discovered how this double power was to be obtained by arresting and transferring the whole velocity of the steam by such peculiar injet and its clear re-action or reissue, and how its full effect might be impaired, or wholly neutralized as just described, I found myself possessed of a new method of applying the power of steam by its velocity alone, and this became the germ or principle of my improvements in the steam engine; for to carry it out I had only to invent such machinery as would give me this double power in the same direction of motion without deduction for the unbalanced pressure in the experimental arm (*d*) to counteract the full effect of the whole force of the velocity, and also without loss of power from another source, that of any back action or impingement of steam against the back of the cavity next in succession. The following therefore is a description of the engine and apparatus by which I propose to effect these objects, the drawings of my improvements in steam engines being contained in eight sheets of drawings lettered A, B, C, D, E, F, G, H.

Drawing A, Figs. 1, 4, represent sections of a case (*a'*, *a'*, *a'*, *a'*), showing a wheel (*b'*) within the same which revolves therein, together with the axle (*c*). This case for a high pressure engine may be made of cast or sheet iron of suitable thickness to resist the pressure of the atmosphere, caused by a partial vacuum from the rapid action of the steam wheel. The whole of the inside I prefer should be polished or made perfectly smooth to prevent friction of the used steam when it reissues from the cavities. For a condensing engine the case must be made strong enough to resist the atmospheric pressure, at those parts where jets of steam are admitted, and from thence to the eduction passage several cavities (*d d*) Fig. 1. Drawings G and H should be made with or attached to the inside circumference of the case for the purpose of receiving the used steam and returning the same into the cavities of the steam wheel and where a double row of cavities are used around the steam wheel, the rows of cavities on the case must be reversed accordingly. These cavities around the case must be placed in such a position to the cavities of the steam wheel that on the used steam issuing therefrom and rushing into the cavities in the case, it may be returned therefrom into the cavities on the steam wheel, at the same angle as that at which the steam first issued from the jet pipes, and the used steam will then, as the wheel revolves, be thrown out at the eduction passage (*e*). The course of the steam through the nozzles and cavities is denoted in Drawings G and H by arrows marked thereon.

The periphery of the steam wheel has a series of cavities formed around it (as shown by the dotted lines in Drawing A and at *c'*, *c'*, *c'*, Drawing H), for the reception of one or more jets of steam. Each of the cavities represented in the wheel (*b'*) Drawing A may be three quarters of an inch deep by one inch and a half long and half an inch wide, these cavities being better shown on an enlarged scale by Figs. 2 and 3 of Drawing A, and being made in the following manner.

Pieces of copper of suitable thickness are cut into dimensions of three and one-half inches long by one inch and three-fourths wide and bent in the form described by *g h i* Fig. 2, being from *j* to *k* two and one-half inches long; from *k* to *l*, half an inch; and from *l* to *m* half an inch long. When a sufficient number to go around the circumference of a wheel are so bent they are to be united firmly together at *i*, by riveting or otherwise, so as to make each cavity three-fourths of an inch deep, and when so formed all around for the periphery of the wheel, each side is to be inclosed between rims of copper, or iron, or other metal of suitable thickness, in the following manner.

Two corresponding annular rims, each about one inch wide are to be grooved at *o p q*, the said groove being about one eighth of an inch deep and of the precise form of the cavities, in order that the metal composing the same may be accurately fitted therein, this groove being shown in Fig. 3, Drawing A. One rim being thus fitted to each edge or side of the cavities around the entire wheel, the whole may be securely fastened together by screw bolts or rivets passing through each rim at the holes (*r*, *r*,) Fig. 3, and with one such fastening at least to each cavity, to prevent any steam passing through the interstices therein. The series of cavities will then be complete and will form the periphery of the wheel, and can be attached to the nave by spokes or by a plain disk; or a disk of the required strength and size of the wheel, can be cast entire with the proper grooves at each side of the extreme circumference (if for a double row of buckets), or with only one groove all around for a single row, and these grooves can afterward be cleared out, and the cavities fixed therein and thus form a very powerful and very cheap steam wheel. The steam is admitted from the boiler by a pipe (*s*) Fig. 1, Drawing A, sufficiently large to keep fully supplied, the circular steam chamber (*t*), from which the steam passes along its several passages or pipes (*u*, *u*, *u*,), which pass through the periphery of the case a^1 and terminate in nozzles of the required area and placed as near to the periphery of the wheel as they can be without touching and to conform to the circle thereof as shown at *v*, *v*, *v*, *v*, *v*. It is important that each steam way to each nozzle or orifice should be not less than 7 times the area of such orifice. Fig. 4, shows at *a* thereof a section of the steam chest (*t* in Fig. 1) cut through at the line *w w*, and shows also a section of the case and view of the steam wheel. The inside of the back of the steam chest (*a a* Fig. 4) is ground true and smooth, showing the outlets (*b*, *b*, *b*, *b*, *b*,) for the steam, which correspond with the steam passages (*u*, *u*, *u*, *u*, *u*, in Fig. 1). Two thirds of an annular plate of metal (*c c c* Fig. 4), ground to work true upon the surface of *a*, *a*, is connected to the nave and spindle (*d* Fig. 4), by the spokes *e*, *e*, *e*. The end of the spindle which runs through the nave of the said annular plate (*c c c*), works in a bearing to keep it in the center as shown at *x*, in Fig. 1. This spindle runs through the steam pipe to the fore part of the boiler, if in a locomotive engine, and terminates in a handle shown in Fig. 5, to enable the engineer to regulate the admission of the steam. Those passages represented by dotted circles (*f, f, f, f, f*, in Fig. 4) are passages for the steam to reverse the engine, whose entrances are stopped by the annular plate. The three passages shown open (*b, b, b*,), and the two passages represented by dotted circles (*b b* Fig. 4,) are to propel the wheel one way and the other five passages, represented by dotted circles (*f, f, f, f, f*, Fig. 4) are to reverse the motion.

The two passages shown by dotted circles (*b b* Fig. 4), are intended to be opened as auxiliary power if required to assist the train up inclined planes. When the annular plate is moved to (*g g* Fig. 4) all the orifices are closed, and the steam is entirely shut off from the wheel, when moved farther to the left the number of steam passages (*f, f, f, f, f*,) opened on the opposite side for the steam to reverse the wheel will be in proportion to the space over which the annular plate is so turned to the left. The back of the steam chest is thus divided into 3 equal parts, of which five passages for steam to propel the wheel one way, occupy the first part, five passages for steam to reverse it occupy the second part, and the remaining third is blank.

At the front part of the engine, the handle when upright will shut off the steam entirely, as shown by the word "stop" in Fig. 5, and will turn over a brass plate or index, having marked thereon, on one side I, II, III, IV, V, according to the number of steam passages to propel the wheel, and on the opposite side I, II, III, IV, V, according to the number of passages to reverse the wheel; on the index also will be fixed two projecting studs *h, h*, Fig. 5, which will stop the handle and prevent the engineer opening two opposite steam passages at the same time. The lower part of Fig. 4, shows the end view of a wheel having a double row of cavities on its periphery and made as before described, but placed in opposite directions to each other, to enable the wheel to be propelled either way according to the direction in which the steam is admitted through the passages in the steam chest (*t* Fig. 1,) as before described. If the steam be admitted through the passages (*b, b, b, b, b*), in Fig. 4 and (*u, u, u, u, u*, in Fig. 1), the wheel will revolve in the direction of the arrows *y, y, y*, as drawn in Figs. 1, and 4, and if admitted by the passages *f, f, f, f, f*, in Fig. 4, (to the last hole of which the nozzle *z* in Fig. 4, belongs), and of which passages *f, f, f, f, f*, and the dotted lines in Fig. 1, drawn near the letters *u, u, u, u, u* show the direction of the passages leading from the steam chest, the wheel will revolve the reverse way in the direction of the arrow *j* Fig. 4.

Drawing H exhibits the relative positions of the cavities of a wheel and its case together with one of the steam nozzles or jets, and the eduction passage; *c′, c′, c′* being the cavities of the wheel; *d′, d′; d′*, those of the case, *e′* the induction pipe, and *f′* the eduction passage; the said Drawing H, representing only a portion or part of a wheel in which but one jet is used.

As it is necessary to prevent the air from entering the case, where the axle *k, k*, Fig. 4, passes through *d*, and it is desirable to avoid the trouble of stuffing boxes, I have the outside of the nave of the steam wheel ground true and flat and also that part of the inner surface of the case which touches it, and by the same effort with which the air seeks to enter the partial vacuum in the case, will the sides thereof be pressed against the nave of the wheel, and an air tight joint be formed, which will always be self adjusting and may be lubricated by small oil cups fixed on the outside of the case. For the purpose of forming such air tight joint, the steam case must be made of such a substance, as will be just pliable enough to yield to the pressure of the atmosphere. But in order that the surfaces of each may wear equally at every part of contact, the circle of revolution must be kept as small as possible, sufficient only for the object, otherwise the attrition will not be the same at every part; for the outer edge will revolve over a larger surface than the center and wear more the greater distance therefrom. But kept within proper limits my engine will possess a stuffing box of the utmost efficiency with the least possible expenditure of power, and one that requires no attention to keep in order, for the longer the wear, the more perfect will be the mutual adaptation of surfaces.

The manner in which the before described engine is set to work is as follows. The engineer will turn the handle shown in Fig. 5, and the steam will pass from the the steam chest (*t* Fig. 1), through the passages *u, u, u*, (and the other two passages *u, u*, may also be opened to assist the engine to start if found needful), in direction of the arrows *y, y*, shown in Fig. 1, when the steam will rush with its full power into the cavities of the wheel and the whole of its velocity be arrested thereby. These cavities must be set at such an angle to its circumference most favorable to propulsion, as will permit the steam to reissue therefrom in the opposite direction to its entrance, without striking against the back of the cavity next in succession.

Particular attention must be paid in inclining the cavities and in adapting and fixing the jets of steam thereto to preserve that particular angle, as will best effect this combination. By this peculiar direction of the injet of steam and its clear reaction or reissue, about double the effect is obtained to its mere impact or impingement against a vane or flat surface; for all the velocity of motion or impulsive momentum of the steam is thus arrested, and by this application of it turned back, and the power so required to totally change the direction of the steam, is received in the cavities of my wheel, which will revolve with all the available power of the steam and its extreme duty from expansion, in the direction of the arrows *y*, *y*, Fig. 1. At starting and before the wheel has attained its allotted velocity hereinafter described, the wheel will be exceedingly powerful. It will not only receive the full effect derived from the velocity of the steam, but it will be set in motion by the additional power of the used steam, which will reissue from the cavities of the wheel, and enter the cavities around the case, from which it will again be returned into the cavities of the wheel by action and reaction, and thus be used over and over again, until the wheel attains a velocity greater than what remains in the used steam or until it is thrown off by the action of the wheel, and its centrifugal force, in the direction of the arrows *e* and *z* through the eduction passage (*e* and *z*), which in a locomotive engine will form the blast pipe as shown in Fig. 1.

The figures in Drawing A, to which the foregoing description refers are laid down to a scale of two inches to a foot, and are these proportions of my engine, which are intended for a locomotive boiler, which evaporates about 60 cubic feet of water an hour at 60 lbs. pressure on the square inch, above the atmosphere. Such a steam wheel revolving at 34,830 feet a minute at about which velocity I prefer the periphery of my engine at such pressure to revolve, will, I think, give about the net actual power of one hundred and fifty three horses, after deducting for loss by the velocity of the steam wheel. And the same proportion of parts and velocity are applicable for any high pressure engine, on my principle, where the boiler evaporates the same quantity of water an hour at the same pressure. Three jets of steam of the united area of 2.37 square inches as shown in the drawings and table hereinafter given, are sufficient to discharge such quantity of water evaporated into steam per hour, the other two jets for propelling or reversing being intended only for auxiliary power; for if used continually they would run off the steam too rapidly for such supply.

The velocity of the steam wheel may produce a partial vacuum even at the circumference, in which case the steam would flow with a greater expansive velocity, and perhaps render necessary some alteration in the proper speed of the wheel, and in the table of velocity hereinafter given; but practice can alone determine this result with the required accuracy.

Though a boiler evaporate double or four times the quantity of water an hour, the wheel itself need not be enlarged to turn it to account. All that is required is an additional number of jets, whose united areas shall be sufficient to discharge the steam for the power required. These jets must be placed around the wheel at the proper angles described and additional cavities must be attached to the steam case inside, to turn back the motion of the steam in the direction of the wheel, and the eduction passage must be then placed a little way after the last jet of steam. I can thus increase a high pressure engine on my principle and plan to any power required from 100 progressively to 1000 horses without increasing the size or weight of the engine; and even in condensing engines on my plan, the additional weight will not exceed ten tons for the highest powers. The axle frame and cavities being made of suitable strength and the boilers proportioned to the power required, by the simple addition of more jets of steam (one to every one or to every other cavity if required), the power of the engine may be increased to the extent desired. The way of supplying the steam to the jets may be varied by a belt or band of steam of suitable capacity to supply them, (and properly clothed to prevent condensation), surrounding the case, or it may be inside the case and inside the wheel and the wheel revolve around such belt of steam in which case the cavities on the periphery of the wheel must be made angular and open at both ends, or of such other shape as will permit the steam to enter at the inside of the wheel and be discharged at the outside. I prefer however the method described in the drawings.

Although I may prefer my steam wheel to go at the velocity of 34,830 feet a minute as given in the tables, yet it would be a great gain to practical science to reduce the speed of the wheel considerably below one third of the velocity of the steam, if it can be done without losing too much duty thereby. Now I think that this important object may be obtained, to a very great extent, even probably to the speed of the driving wheels themselves. I intend using a case with cavities all around the circumference or as many as may be found necessary, placed as nearly as possible tangential to the circumference of the steam wheel, inclosed in such case as shown in Drawing G at *d*, *d*, *d*, &c. The cavities in the case are made in the following way. The circumference *a a a* Fig 1, is first a rim of solid metal of suitable thickness, and of a width answering very exactly to the width of the cavities around the steam wheel. It is then cut into saw like notches of the required width and very nearly tangential to the circumference of the steam wheel, and to these notches sides of metal are then fixed by screws or otherwise, and thus the circumference of the steam case is made with the cavities therein. To this hoop or rim of cavities are screwed the two side plates *h h* Fig. 2, and thus the steam case is formed.

The steam nozzle, eduction pipe and air tight stuffing boxes have been before described. The following will be the way in which the steam will act in such a case to enable me to reduce the speed of the wheel, and which is partly described before. The steam upon rushing into the cavities of the wheel, being an elastic expansive fluid will immediately rebound therefrom into the cavities of the steam case, with a velocity diminished by the motion taken from it by the speed of the wheel. It will as immediately recoil or rebound from the cavities in the case into the cavities on the wheel, and again lose the same portion of its velocity by the speed of the wheel. In the same way it will rebound back again into the cavities of the case, and from thence into the steam wheel again, losing at every impulse it gives to the steam wheel, the same portion of its velocity, and striking each time the cavities of the steam wheel at that reduced in jet or effect which is due to such lessened velocity. This action and reaction will be kept up until all the velocity is taken out of the steam by its continued impulse and loss of motion on the wheel, and it is thrown out at the eduction pipe in high pressure engines, or seeks the condenser in condensing engines, to which this arrangement is equally applicable. To what extent I shall be able to reduce the speed of my steam wheel by this means, practice only can determine, as no theory can estimate how much of the power of the steam may be lost in passing from cavity to cavity, beyond what it parts with in useful effect each time it enters the cavities of the steam wheel, by the speed at which the wheel revolves. That I shall be able to reduce the speed very considerably, my experiments before described fully show. For when the angle of the cavity (*h*) on the experimental arm (*b*) Fig. 3 Drawing C, was so altered that all the steam on its reissue from the cavity (*h*) could impinge upon the arm (*b*) so little was the velocity or power lessened by the mere friction of the atmosphere and change of motion and even by condensation, that although it was in the open atmosphere, the arm stood still, showing that the excess of power which the cavity (*h*) previously had over the flat plate and over the unbalanced pressure in the arm *b* was exactly neutralized or given back by the steam, impinging on the arm *b*.

It will be seen that steam applied on the principle of my discovery has not only a percussive force of a certain amount, but that it combines with that force an enormous velocity, and will continue striking an object with the power of that velocity until the velocity be destroyed. Now this velocity may be considered a reservoir of power, which the first injet does not exhaust, if the wheel moves at a slower rate than the steam and it will continue giving out this power as long as its velocity continues and getting less and less. So long then as the steam continues uncondensed, this action and reaction will be kept up until the steam has transferred by continual impulse all the motion it had on its first entrance, and consequently different increments or variations of pressure will be obtained. Two illustrations will show what power it is probable will be obtained from applying in this manner the well known law that action and reaction are equal and contrary. First, we will suppose the steam wheel to be going at 10,000 feet, instead of 34,830 feet a minute. The following table will then show the power, the injet or force being found by the same rules hereinafter described, namely by the square of the expansive velocity of the steam, which by taking the table hereinafter set forth as a guide, and the same quantity of water evaporated per hour under the same pressure will give the following result.

Number of the injets.	Increments of the injets.	Speed of the wheel in feet per minute.	Area of jets.	Pounds raised 1 foot high per minute.	Horse-power.
1	112.84				
2	90.22				
3	70.12				
4	52.56				
5	37.52	10,000	2.37	9,803,742	297
6	25.0				
7	15.3				
8	7.5				
9	2.6				
	413.66				

The speed of the wheel being 10,000 feet a minute and the velocity of the steam at 60 pounds above the atmosphere being 104,940 feet a minute, the first injet will be the force due to the steam striking a cavity at rest with a velocity of the square of the difference between the velocity of steam and the speed of the wheel, which as shown in the table hereinafter given is 112.84 pounds per square inch. The other injets are ascertained by the same rules.

Second, we will suppose the cavities of the wheel revolving at only 4,000 feet a minute, but under the same circumstances in other respects. Suppose the velocity of the steam is 104,000 feet a minute here the first injet will be the square of the difference between 104,000 feet, the velocity of the steam, and 4,000 feet the speed of the wheel, the force of which will be 26.3. And the following table will show the result.

Number of the injets.	Increments of the injets.	Speed of the wheel in feet per minute.	Area of jets.	Pounds raised 1 foot high per minute.	Horse-power.
1	126.3				
2	116.4				
3	106.0				
4	97.4				
5	89.1				
6	80.8				
7	73.0				
8	65.5				
9	58.4				
10	51.8				
11	45.5				
12	39.6				
13	34.1	4,000	2.37	10,566,448	321
14	29.1				
15	24.3				
16	20.2				
17	16.3				
18	12.9				
19	9.9				
20	7.2				
21	5.0				
22	3.2				
23	1.8				
24	0.8				
	1,114.6				

We see by these tables that when the wheel revolves at 10,000 feet a minute, the duty is 297 horses, while at 4,000 feet a minute the duty is 321 horses. Now supposing that by the change of motion and condensation of steam (though the case will be kept as well clothed as the cylinders of the present engines), the power is reduced one half of these results, still the first table would leave a power of 148.5 horses and the second 160.5 horses. If the speed of the wheel be 34,830 feet a minute, as shown in the table hereinafter given, the result as there shown will be a power 153.41 horses, without any consideration of the additional power which may be obtained from reaction of the steam from the cavities of the case upon the above principle. For what my engine will lose in velocity it will get back again in power, not by the present large areas of surface, but by absorbing the power of action and reaction contained in the immense velocity of steam, thus obtaining a continual impulse in the cavities of the wheel until the steam is brought to a state as nearly of rest as can be reduced in practice. The cavities around the case must not exceed the width of the cavities of the wheel, or the steam will be allowed to spread too much. But the openings of the cavities of the case the other way must be something more than those of the cavities around the wheel, so that they shall not answer thereto, mouth to mouth, in order that the steam may find its way, from the alternate cavity of the case and wheel, until it finds its way to the eduction pipe. The cavities around the wheel must revolve as true and as close to the cavities around the case, as it is possible for machinery to make them, without touching, in order that the steam may not escape between the openings.

The parts c, c, c, Fig. 1, Drawing G, represent flanges or cleats for the purpose of fastening the case to the required position. The steam wheel in Drawing G shows another form of cavity, which may be found in some cases preferable and will give, I think, the best effect of all the shaped cavities I have tried.

Fig. 2 is a transverse section of the wheel and case, cut through at the line L C of Fig. 1, and made in the following way: d Fig. 2 is the axle and nave, of solid metal, to the beveled part of which are screwed or bolted the two disks of metal e, e, which approach each other toward the extremities and are there welded or brought in contact. To each side of the part so brought together is attached the annular ring of saw-like notches, (reversed to each other for reversing the motion of the wheel), to the outside of each of which will be fastened a flat rim of metal and the whole securely fastened together by screws or rivets, as shown at f, f, f, f, Fig. 2, Drawing G, and made steam tight. These cavities will be then complete. This last rim of metal is supposed to be removed in Fig. 1, Drawing G, to show the cavities of the wheel in section. These cavities must be as small as possible, and as tangential as possible, as shown in Drawing G, which is on a scale of two inches to a foot. A section of the axle is shown in Fig. 1, Drawing G, the circle g g being part of the nave of the wheel, which forms the airtight joint with the sides of the case, and h, h, h, are bolts or screws to fasten the metal disks to the nave as before described.

The way in which I connect my steam wheel to locomotive engines by my "roller and wheel connection" is shown in the drawings in Drawing B of which the following is a description. The engine in its case as before described, is partly inclosed in the smoke box, the portion of which that protrudes is shown by a Fig. 1. The smoke box is formed as usual except that the two outside angles are beveled off as shown at b. The wheels of my engine (c, c, c, Figs. 1 and 11) are connected by a common straight axle (e) the ends of which work in the usual bearings or plummer boxes, except that such bearings, for my engine, are not connected with the springs, but have room to play up and down in guides formed by the frame as shown by *f*, *f*, Fig. 1. The driving wheels are of the usual form except in having the flanges wider and flat as shown at *d d* Fig. 2, unless I should find it desirable to apply to the wheels of locomotive engines the principle of the inclined groove and spherical edge which I call "the beveled groove and spherical tongue connection" to obtain greater adhesion as shown in drawing D Fig. 4, hereinafter described. The springs *g*, *g*, *g*, are elevated a sufficient height above the driving wheels, which are here represented as 4 feet in diameter. These springs are confined by any convenient arrangement of the frame, or as shown by *h*, *h*, *h*, *h*, *h*, *h*, in Figs. 1 and 2, the ends of the springs being allowed to play in elongated holes or slots, as shown by *i i* Fig. 1. Beneath the springs, at their center, are attached thereto brass boxes or bearings, *j*, *j*, *j*, Figs. 1 and 2, in which are fitted steel or other hard metal rollers *k*, *k*, *k*, which rest upon the widened flanges of the driving wheels before described, and have full freedom to revolve in such brass boxes or bearings. The ends of these boxes pass through the spaces made in the framing at *l*, *l*, *l*, *l*, *l*, Figs. 1 and 2, the sides of which spaces prevent such boxes from moving in a horizontal direction, but permit them to play freely up and down vertically; answering to the elasticity and variation of the springs (*g*, *g*, *g*.) The said rollers are so to project beneath the boxes or bearings (*j*, *j*, *j*,) as always to rest upon the wheels as shown in Figs. 1 and 2, and are to be confined to their ends in the said boxes by a projecting rim.

A section enlarged of the brass box or bearing *j*, *j*, *j* and the roller *k*, *k*, *k* of Figs. 1, and 2, is shown by Fig. 3, Drawing E. That portion of the box at *m*, which is directly over the flange of the wheel (*n*), is slightly hollowed, so as not to be in contact with the roller at that spot, and the roller itself has two slightly projecting rings (*o*, *o*,) around it at a short distance from each side of the flange (*n*) of the wheel. The object of this arrangement is to permit those parts (*p*, *p*,) of the roller, which are in contact with the brass box or bearing, to be lubricated in any convenient way or as shown at *q*, *q*, and, at the same time, to prevent the oil from destroying the adhesion or friction of that portion of the roller, which is in contact with the flange of the wheel.

To the inside of each roller is fixed a crank (*r r r*) Fig. 3, Drawing B, which may either be composed of springs as shown in the enlarged drawing of Fig. 4, Drawing E or without them when a spring connecting link will be used as afterward described. A connecting link (*s*, *s*, *s*, *s*) Drawing B, which I call a compensating link, joins this crank to another similar crank (*t t t*), which last crank is fixed to the axle (*u u*), of the steam wheel contained in the case (*a*). This mode of connecting the steam wheel by the division of the axle, and its reunion or junction with the rollers, by means of cranks and spring compensating links will save the steam wheel from any derangement, jar, or concussion, and is an adjustment which will enable the engine to work smoothly, durably and uniformly. The axle is kept in its proper position by the standards (*v*, *v*, *v*,) Figs. 1, & 2, which are firmly fixed in the framework of the engine. The boiler and furnace are fixed in the usual manner to the frame of the locomotive and through the medium of the springs (*g*, *g*), and rollers (*k*, *k*) are supported on the flanges at the upper part of the driving wheels as shown in the drawings Figs. 1, and 2, instead of being supported on the axles in the usual way. Now if the axle (*u u*), is caused to revolve by the steam wheel, either way that it is desired, it will give, through the medium of the cranks and connecting links before described the same rotatory motion to the rollers, and by the pressure thereon, caused by the weight of the engine, these rollers being in contact with the periphery of the driving wheel, will have the same frictional power by contact or adhesion to the wheel, as the wheel has to the rail, which will necessarily cause the wheel to revolve in a direction opposite to that of the steam wheel and rollers, and with a speed proportionate to the difference between the diameters of the rollers and driving wheel, and thus the locomotive will be propelled by the pressure of the axle *f*, *f*. The proportion, between the diameters of the driving wheel and rollers, must be determined by the speed desired to travel and by the rate at which the steam wheel revolves. In the drawings the driving wheel is shown to be four feet in diameter, and the roller three inches and two tenths, and if the periphery of the steam wheel revolves at about 35,000 feet a minute, such proportioned rollers will propel the locomotive at about 30 miles an hour. The boiler will be supplied with water by the usual pump, to be worked by an eccentric upon any one of the axles of the wheels. The other parts of a locomotive frame and appurtenances for my engine do not require description as they may be made in the usual way.

Should the rapidity with which the roller of the steam wheel axle revolves, be found to produce too great an amount of friction, under the pressure necessary to obtain adhesion between the roller and the periphery of the driving wheel, I propose to use the anti friction wheels shown in Drawing F, where in Fig. 1, represents a side elevation of part of the frame of a locomotive engine and Fig. 2 the end elevation of the same. Instead of using the box *j* before described in Drawing B, I substitute the six anti friction wheels lettered *a*, *b*, *c*, *d*, *e*, *f* Figs. 1, and 2, three of which *a*, *b*, *c* are seen in the side elevation of Fig. 1, having three corresponding behind them, and the end view of four of them *a*, *d*, *b*, *e*, is seen in the end elevation Fig. 2, having two corresponding wheels behind the wheels *b*, *e*.

The two bearing wheels *a* and *d*, are firmly fixed on the same axle *g*, which passes through a plummer box or bearing shown by the dotted lines in Figs. 1, and 2. This bearing is fastened to the upper part of the spring *x*, that is by means of a strap from the spring, or other suitable contrivance, so that the spring is thus suspended upon or connected with the axle of the two anti-friction wheels *a*, *d*, which spring, by the weight of the engine, presses the said two anti-friction wheels upon the roller *k* at *j*, *j*, *j*, Figs. 1, and 2, and gives the required vertical bearing on the roller to produce adhesion to the periphery of the driving wheel. To keep the roller *k* in its horizontal position the four smaller antifriction wheels are used two at each side, as shown in the drawings, two of the said wheels being unseen in the end view of Fig. 2. The ends of the axles of each pair work in bearings in the side frame shown at *i*, *i*, *i*, *i*, Figs. 1, and 2, all of which will be lubricated in the usual manner. In Drawing F is represented my method of using the beveled groove roller into which the flange of the drawing wheel enters to give more adhesion than by plain surfaces as before described. This drawing also is laid down one inch to the foot. For steam navigation and other machinery I propose to use a similar arrangement of six anti-friction wheels to keep the roller of the axle of the steam wheel in contact with the large wheel or wheels for the screw propeller. The movable bearing (*i i*) described in Drawing D will be composed of these six anti-friction wheels, two of which will be above the roller (*h*) and keep it in contact with the upper or lower part of the large wheel, by means of the pressure caused by the screw Fig. 3 Drawing D, and the rods (*r r*) which will be attached to the movable bearing (*i i*) as before described.

The other anti-friction wheels will with the former surround the roller, and thus keep it in its place. Each pair of wheels will be fixed to one axle. And all the six anti-friction wheels will be moved together vertically up or down in the movable bearing (*i i*) by the screw described in Fig. 3, Drawing D. In the front of the locomotive engine I place a screen shown by the dotted lines 2, 3, 4, in Figs. 1, and 2, Drawing B, the frame of which may be composed of wood or iron and covered with sheets of metal. The form is shown by the dotted lines 2, 3, 3′, 4, 4′, 4″ in Fig. 2, and the side view is shown in Fig. 1, by 2, 3, and 4, and this screen may be fastened to the frame of the engine at any convenient places, such as at 2, 3 and 5 in Fig. 1. The object of this screen is to lessen the resistance of the atmosphere, which the engine now receives, and to turn that which it must still receive to a useful account; an advantage which is obtained by the atmosphere pressing on this screen, and thus giving greater adhesion of the wheels to the rails, which will also render the engine less liable to pitch; and these advantages will be obtained in proportion as the screen is allowed to approach a horizontal position. For instance if the chord of the arc of the screen forms an angle of 45° with the plane of the rail, and the resistance over the whole of the engine, without the screen, amounts to 300 pounds, the engine will only receive a resistance of 150 pounds, and the remaining 150 pounds would be thrown in a vertical direction and be in favor of the adhesion of the wheels and tend to prevent the engine jumping off the rail.

For steam navigation or other condensing engines I apply the steam upon the same principle and use the same kind of steam wheel as for locomotive engines but with only one row of cavities around the periphery; and I add thereto the following eccentric rotatory air pump, Fig. 2. Drawing E represents an outside view of a hollow barrel or cylinder, where *a* and *b* are flanges cast thereon to attach it to the condenser and hot well as hereinafter described, at each end of the barrel are also two flanges (*c* and *d*) cast thereon, to which the two caps (*e* and *f*), (a side view of one of which is shown in Fig. 6), are bolted. Through this barrel passes the axle of the steam wheel before described, being enlarged at that part within the barrel in a manner shown at *g*, Fig. 1, and which forms an eccentric shown by *h* and *i* Figs. 7 and 8. The parts *j* and *k* in Fig. 1, are a section of the barrel just described and *l*, *l*, that of the axle of the engine. The caps *e* and *f* before described, will ground as water tight as possible to the shoulders and axle *m*, *m*, *m*, *m*, in Fig. 1.

Fig. 7, shows a transverse section of the barrel and eccentric axle, which axle will be made to revolve with the part *n*, as nearly as possible water tight with the inside of the barrel. This bearing has two openings lengthwise through its whole extent shown at *o* and *p*, Fig. 5, which is the back view of Fig. 2. The said two openings will take the direction shown at *q* and *r* Fig. 7, in one of which, (screwed to the solid part which makes the division between the said openings), will be a piece of metal to form an elastic spring, as shown at *s* running the whole length of the barrel, the edge of which spring will gently press upon the surface of the eccentric axle as shown at *t*, *t*, Figs. 7, and 8. The eccentric axle must be turned so true and the spring be so adapted thereto, that they may form together an air and water tight joint, and thus prevent any communication between the two openings *q* and *r*, or between one part of the barrel and the other. Fig. 8, represents the condenser (*u*) and hot well (*v w*), being the eduction passage from the steam case containing the steam wheel, and *x* the injection pipe.

The section of the before mentioned air pump is shown at *y*, screwed in its proper place to the side of the condenser, with the openings *q* and *r*, fitting to corresponding passages *z*, *z*, leading from the condenser and also to the hot well. The way in which my ecentric rotatory air pump will act is as follows. The eccentric axle, partaking of the motion of the steam wheel, in the direction of the arrow (*n*) Fig. 7, the space A will gradually become enlarged and the space B be contracted and the water and air will pass through the passage *q* to fill the vacancy, while the water and air contained in B will be urged through the passage *r*, by the eccentric taking the position as shown in Fig. 8, and thus the air pump will continue its revolutions and expel the injection water and air into the hot well *v*. When the eccentric is in the position shown in Fig. 8, the spring will be pressed back into the passage *r* Fig. 7, as there shown, allowing the eccentric axle to pass around. In the hot well *v* a long narrow flap (*z*), running the whole length and working upon a hinge, will act as a valve to the passage, *r*, and prevent air or water from passing from the hot well to the air pump, when the engine is stopped or stationary.

I consider that the following proportions are about those dimensions which will be required for an air-pump on my plan for a condensing engine, which is working off a cubic foot of water, evaporated into steam per minute namely. The barrel should be about 18 inches long, 4 inches in diameter in the bore and the eccentric about 3½ inches in diameter, which leaves an extreme space of half an inch for the expulsion of the injection water and air into the hot well. the axle making not less than about 3,000 revolutions a minute.

Drawing D represents my method of connecting my steam engine with a paddle wheel shaft for steam navigation or with other machinery requiring a slower motion than my steam wheel, which invention I also call "the roller and wheel connection." Fig. 1, (*a*) represents the case containing the steam wheel before described at Fig. 1, Drawing A, having only one row of cavities around the periphery thereof, and Fig. 2, shows Fig. 1, cut through at the line *z c'*. The case is here shown to be made stronger by outside ribs (*b*, *b*) if found necessary, and which case is kept steady by suitable frame work (*c c*) and fastened to the foundation plate (*d*). The eduction pipe A leads the steam from the steam case to the condenser B where it is condensed in the usual way, by injection from which it is withdrawn by the air pump C and discharge into the hot wheel D as described in Drawing E. The pipe E is to carry away the waste water from the hot well, and F is the pipe to supply the feed pump which can be worked by an eccentric on the main shaft.

The steam is let into the cavities of the steam wheel at H on the opposite side to the pipe A, Figs. 6, and 7, represent transverse and longitudinal sections of the termination of the large supply pipe H, conveying the steam from the boiler to the steam chamber I. From this chamber the steam will rush into the cavities of the steam wheel, through the passages 1, 2, 3, 4, 5. The slide J will be worked by hand by the rod passing through the stuffing box K, and will open or close as many passages as are desired. The axle of the engine or steam wheel passes through the air pump C described before (and in Drawing E), and works the crank (*e*) which may be connected to the other crank *g* by a spring link (*f*), which I call a spring compensating link as shown in Figs. 9 or 10, Drawing E. The crank (*g*) gives motion to a short axle *h*, which passes through a bearing (*i i*) hereafter described and which terminates in the roller *j*. This roller is received into an iron hollow *k*, cast or otherwise made in the circumference of a larger wheel (*l*) as shown in section in Fig. 1, and which wheel is fixed upon the paddle shaft (*m*), in steam boats, or on the main shaft of machinery in general. The part of the framing (*n n*) shown in section Fig. 1, will support a bearing at its upper part (*o*), for the main axle, and will have an aperture, at its lower part (*p*) to receive the movable bearing (*i i*). This movable bearing must be so made as to receive the axle (*h*) firmly and securely and to fit the aperture (p Fig. 1, and p p, Fig. 2), and be made to keep its position laterally by a fillet shown by the dotted lines q, q, q, q, Figs. 1, and 2, but it must be allowed sufficient room to play vertically up and down, as it may be elevated or depressed by the rods r, r, r, Figs. 1, and 2. These rods are firmly fixed in the bearing as shown at s, s, s, the upper parts of which rods will go through the deck in steam vessels and be fitted to each end of a sufficiently powerful spring t t Fig. 3, and through this spring will pass a broad threaded and powerful screw, which will be turned by a handle or lever as represented at u, v, v, Fig. 3. By turning this handle or lever, the screw will elevate or depress the spring, which, through the medium of the said rods r, r, r, r, r, Figs. 1, 2, 3, will elevate or depress the bearing (i) the axle (h) and the roller j Fig. 1. By this means the roller j will be brought in contact, either with the upper part of the hollow k of the large wheel at w, or with the lower part at x Figs. 1, and 2, and by friction, adhesion or contact will turn the wheel (l) one way or the other as the vessel or machinery, to be moved thereby is required to be propelled or backed. The spring t t before referred to will keep the roller j sufficiently in contact with the wheel (l), and yet allow by its play sufficient compensation for any slight inequality in the periphery of the said wheel. If preferred to have this arrangement for propelling, easing, or backing the vessel below deck, the principle is capable of as easy arrangement below as above deck. The space between the upper part of the bearings of the axle (m) and the under part of the screw box u Fig. 3 will be occupied by a sufficiently strong prop or support z, z, Figs. 2 and 3, for the screw (u) to fit in, and thus prevent any strain upon the bearings. The paddle wheels or machinery may by this arrangement be eased, suddenly stopped and reversed, while the steam wheel continues its maximum velocity, and yet without concussion or derangement, which would otherwise be produced by a rapid speed being suddenly arrested or imparting a portion of its velocity to matter at rest. For though the steam wheel continue its utmost velocity, it will only impart the required motion to the paddles or other machinery gradually and smoothly; for the great wheel will slip for a while until its inertia of rest is overcome and it obtains its uniform speed. And should a heavy sea strike the paddles or any other unlooked for impediment (such as masses of ice or wood suddenly arresting the paddles) neither strain nor concussion can be produced as in the present engine, for my steam wheel will still continue its smooth and easy velocity, while the large wheel will accommodate itself to the obstruction, by slipping for the moment until the unwonted resistance be removed, and only that resistance proportioned to the power is restored which was originally calculated the engine would have to overcome. And when the vessel is stopped all the usual chances or danger of the boiler bursting, through the safety-valve getting out of order will be removed if the steam wheel is allowed to continue its motion, for it will then act as a safety valve, and carry off all the steam that would otherwise accumulate and pass off at the usual safety valve, for it is chiefly when the vessel has been stopped or just previous to being again started, that so many lives have been lost by the boilers exploding. In the numerous stoppages on the river, this will save the engineer the frequent attention to the injection cock, which once turned at starting may continue till the vessel reaches its destination.

One action only is required for stopping or reversing the vessel with my engine; three with the present; the steam supply valve gear, and injection. The supply and bilge pumps can be attached to the main shaft, or worked in any of the usual methods familiar to engineers.

Where the plain surfaces before described for the adhesion of the roller to the wheel may not be sufficient for the purposes of great power, (on account of too much strain on the bearings, necessary to obtain the required contact, being found objectionable), I propose to use, as a modification of the principle before described, as well for locomotive engines, navigation and other purposes, an arrangement which I call "the beveled groove and spherical tongue connection, the plan of which is better shown in an enlarged drawing in Fig. 4, Drawing D. Part of the roller (a) is shown, having one, two, or more deep grooves (b, b,) turned around it, the sides of which grooves are beveled or approach each other toward the bottom of the same as shown in the drawing Fig. 4, c, c, c, c, the circumference of a wheel, of which part only is here shown at d (which is to be turned by this roller), has around it one, two, or more projections e, e, truly semicircular or otherwise properly curved at their edges and made to fit into the grooves in the roller, and which will place opposite portions of their semicircular edges in contact with the inclined or beveled sides of the grooves as shown by c, c, c, c. The following is a description of this arrangement, the principle of which, Fig. 5 will illustrate, being found on the principle of the wedge or inclined plane. The side of Fig. 5, represents the inclined or beveled side of the groove b Fig. 4, which is in contact with the semicircular edge of —*c*— the perpendicular *g* of Fig. 5, and base —*h*— forming a right angle triangle, of which it is the hypotenuse. By this form of contact the degree of pressure which causes —*c*— in Fig. 4, to advance toward *b*, will be increased as relates to the point of contact at —*c*— of the bevel of the groove or hypotenuse of the angle, in proportion as the side *g* exceeds the base *h* in Fig. 5, by which plan adhesion may be obtained to any required amount, by vertical pressure of a comparatively small degree. For instance if the adhesion or contact required between the roller and the hollow wheel for steam navigation or other purposes was ten tons; by making the perpendicular *g* Fig. 5 Drawing D exceed the base *h* 10 times; that is let *g* be one inch and a quarter and —*h*— one 8th of an inch, the axles and bearings would only bear a pressure of one ton. By applying this principle to the tread of the wheels of locomotive engines, the adhesive power may be so increased as will enable them to surmount gradients so steep as to be impossible to be surmounted by the present engines, while the tractive power may be increased to the required amount by letting on more jets of steam as before described. If for instance the adhesion between the wheel and rail were ten tons before this principle were applied, it would be increased to 100 tons by using the proportions just mentioned. By having therefore auxiliary engines with wheels so made, ready to draw the trains up steep inclines may prevent the use of stationary power, and the necessity in many cases of making such easy gradients at so great a cost. In so applying this principle the wheels must be made with a hollow in the periphery, in the same way as the rollers are described in Drawing D Fig. 4, and the rails will form the tongue.

Fig. 9, Drawing E represents my spring-connecting compensating link, for the cranks of my axle and roller, to allow the boxes or bearings to be elevated or depressed, and is formed of two elliptical springs *a* and *b*, which are joined in the usual manner at their extremities and the centers of the springs are attached by a movable joint to the extremities of each crank at *c*, *d*, separating them at about an angle of 60 degrees.

Fig. 10, Drawing E is another kind of spring, which I call an elbow spring connecting link, which I prefer for the same purpose, namely to prevent any jar or concussion, and to compensate for any irregularity of motion affecting the engine shaft. The parts —*e*— and *f* are formed by a series of spring plates, fastened together in the usual way and increasing in strength toward the end (*g*) where they are strapped and bolted together, in the position shown at Fig. 10, and the ends *h* and *i* have eyes for the purpose of being connected to the cranks before mentioned. Should these cranks be found to revolve so quickly, as to cause much atmospheric resistance, they may be inclosed in a circular case to revolve with them. And in the condensing engine on my plan, where the steam wheel will revolve with a much greater rapidity as hereinafter shown, the cranks may revolve in an air tight chamber communicating with the condenser, by which arrangement, they will revolve *in vacuo*. But in the whole engine the air tight stuffing boxes need not exceed two, the condenser and air pump being placed on one side of the steam case and the chamber on the other.

Drawing C Figs. 4, 5, 6, represent sections and an end view of my improved nozzle for supplying steam to the wheel on my principle, which, if only one large supply pipe be used to increase or diminish the power of the wheel must be so formed, instead of as a throttle valve. Fig. 4, which is a plan in section, has at its immediate orifice inside a truly circular curved hollow shown by —*a*— which continues past the orifice to the point —*b*— into which hollow is ground true and fitted a segment of a circular piece of metal C, which is connected with a small spindle —*d*— which terminates in a handle or connection outside, which can be connected with a governor, to contract or enlarge the orifice, according to the wants of the machinery or be turned by hand to shut off the steam entirely. Fig. 5 shows a sectional side view of the same, where *c* is the segment of the circle, *d* the spindle passing through the small stuffing box —*e*— and terminating at any convenient distance by the handle *f*. Fig. 6 represents an end view of the same and shows the whole size of the orifice *g*, *g*, and two different positions of the contracting segment by the dotted line —*h*— and the dark portion *i*. The object of such a nozzle is to contract or enlarge the passage for the steam at the immediate outlet or orifice, for if the contraction be higher up the pipe, the steam would be so diminished in pressure at the orifice as to lose a great portion of its impulsive velocity.

Drawing C, Fig. 1, is the form of arm, I found to give more power in engines on Herr's principle. Instead of the straight arms *a*, *b*, I used serpentine arms, shown at *c*, *d*, *e*, *f*, where the parts from *c* to *d* and from *f* to *g* partake of the circle of rotation, and where the parts from *d* and *f* to the center *e* are made to form an easy curve, the pipe or hollow when the steam runs along gradually enlarging in area to the center *e*. The object of such an arm is, to keep the part which receives the reaction or unbalanced pressure of the steam as far as convenient from the orifice of discharge; for by this arrangement I found that I gained one third more power. Inside the case in which the arm revolves cavities are shown fixed all around, to the receive the steam on its issue from the arms to return it in the direction of their motion. But I describe this form of engine simply because it formed part of my experiments, not as forming any part of my present inventions though I do not think it has been previously used.

The following table of pressures will show the proper force of, or impulsive effect from the simple expansive velocity of steam rushing on my principle into a stationary cavity uninclosed in the open air of the engine room. The diameter of the supply pipe was one inch, and 5 feet 10½ inches long with one bend, and at its termination the orifice of discharge was ⅜ of an inch in diameter or about the ninth of a square inch. The several pressures of steam in the boiler were throughout half a pound more, this half pound being allowed for condensation et cetera.

Table of the force of the injet of steam in a stationary cavity uninclosed and exposed to the atmosphere, and its reissue therefrom calculated upon the square inch from actual experiment, given by an orifice of about the ninth of a square inch:

Steam above the atmosphere at the orifice of the pipe.	Actual result from an orifice three-eighths of an inch diameter.	Effect per square inch from an orifice of a square inch.
Pounds.	*Lbs. Oz*	*Pounds.*
10	2 3	23.3
20	5 4	46.6
30	7 4	70
40	Not tried.	93.3
50	Do.	116.6

The fact of a power being given out, from the expansive velocity of steam, when properly arrested, of more than double what would seem *prima facie* to belong to it, as indicated by the pressure in the boiler, is consistent with the additional force acquired by other bodies, which the following case may illustrate. If a ball weighing 60 pounds be resting on the earth it will press with a force of 60 pounds. But if let fall from such a distance, that on its touching the ground it shall have acquired a certain velocity, it will strike not merely with the original weight of 60 pounds, but with the accumulated force due to the velocity acquired in the descent. Now let the ball at rest represent the initial pressure of the steam at rest in the boiler and the acquired force of the ball represent the expansive power of the steam which gives it that extraordinary velocity when set at liberty and allowed to expand lineally; and though there is no resemblance between the velocity acquired by attraction or gravity, and the velocity acquired by repulsion, the results of more than the initial power being given out, are analogous. The cavity with which these great effects were obtained was ¾ of an inch square and deep which give an area about five times that of the orifice of the jet. It was placed on a balance 6 feet high resting on knife edges made with great precision and accurately weighed to mark the index. But the cavities for practice need not be more than sufficient to receive the full jet of steam which will keep the wheel, even for the greatest powers very compact, and if the base be twice the area of the jet, that is ample; for no additional power is gained by the steam expanding over a larger area, expansion from an unobstructed current of steam being already obtained from its velocity. The above results were obtained as I have stated from a cavity at rest, but when the wheel revolves, all the force of the steam from its velocity, cannot be transferred to the wheel, and the power will consequently fall off, in proportion as the velocity of the wheel approaches the expansive velocity of the steam. But owing to the extreme velocity of the steam and the extraordinary force given thereby, being more than double the pressure in the boiler indicated by the gage, a sufficient proportion of the power may be deducted from the speed of the wheel and for friction, and yet leave such clear available effect, as will with the same consumption of fuel and pressure, more than double the duty of locomotive engines, exceed that of the best high pressure engines, and equal if not exceed the duty of the best Cornish condensing lifting or marine engine. For though my deductions when compared with those allowed for friction and other losses of the present engine may seem to exceed them in some cases, they do not, because the steam in my engine having no piston to overcome is expanded as low as the atmosphere (as the table shows), in high pressure engines, and in condensing engines the steam will be expanded to the vapor point or state of condenser vacuum. It is therefore from these extreme expansive duties that my deductions are taken and are constant; while those of the present engines are taken from the expansive duty, where the steam can only be expanded to a much less degree, varying according to the pressure of steam and friction of the piston, and other parts to be overcome. By thus applying steam by its velocity it can find its own equilibrium and give out its whole expansive power in so doing, while such an extreme degree of attenuation being impossible in the present system, some power must necessarily be thrown away. The rate at which the pressure falls off or increases is as the square of the expansive velocity of the steam, as shown in the following table:

Table showing the best velocity of the steam-wheel to obtain the maximum effect in horse power.

Steam pressure above the atmosphere in pounds per square inch.	The expansive velocity of the steam in feet per minute.	Force of the injet and reaction due to such velocity in pounds per square inch.	Velocity of the cavities or circumference of the wheel in feet per minute.	Difference of velocity of the steam's expansion and that of the wheel or column 2—column 4.	Square of the velocity of the steam at 60 pounds per square inch.	Square of the difference.	As column 6 is to column 3 so is column 7 to column 8, the diminished force.	Column 8×column 4=the effect at the given velocity.	United area of nozzles in square inches to discharge, column 13.	Pounds raised 1 foot high per minute, or column 9×column 10.	Column 11÷33,000 or the horsepower.	Cubic feet of water evaporated per hour.
1	2	3	4	5	6	7	8	9	10	11	12	13
60	104,490	138	10,000	94,490	10,918,160,100	8,928,360,100	112.84	1,128,400	2.37	2,664,308	80.7	60
60	104,490	138	15,000	89,490	10,918,160,100	8,008,460,160	101.22	1,518,300	2.37	3,593,371	108.8	60
60	104,490	138	20,000	84,490	10,918,160,100	7,138,560,100	90.22	1,804,400	2.37	4,276,428	129.5	60
60	104,490	138	25,000	79,490	10,918,160,100	6,318,660,100	79.86	1,996,500	2.37	4,730,605	143.3	60
60	104,490	138	30,000	74,490	10,918,160,100	5,548,760,100	70.12	2,103,600	2.37	4,985,532	151	60
60	104,409	138	32,500	71,990	10,918,160,100	5,182,560,100	65.5	2,128,750	2.37	5,045,137.5	152.8	60
60	104,490	138	34,830	69,660	10,918,160,100	4,852,515,600	61.33	2,136,123.9	2.37	5,062,613.64	153.41	60
60	104,490	138	35,000	69,490	10,918,160,100	4,828,860,100	61.03	2,136,050	2.37	5,062,438.5	153.4	60
60	104,490	138	37,500	66,990	10,918,160,100	4,487,660,100	56.72	2,117,000	2.37	5,017,290	152	60
60	104,490	138	40,000	64,490	10,918,160,100	4,158,960,100	52.56	2,102,400	2.37	4,981,740	150.9	60
60	104,490	138	45,000	59,490	10,918,160,100	3,539,060,100	44.73	2,012,850	2.37	4,770,454.5	144.5	60
60	104,490	138	50,000	54,490	10,918,160,100	2,969,160,100	37.52	1,876,000	2.37	4,446,120	134.7	60
60	104,490	138	55,000	49,490	10,918,160,100	2,449,260,100	30.9	1,699,500	2.37	4,017,815	121.7	60
60	104,490	138	60,000	44,490	10,918,160,100	1,979,360,100	25.0	1,500,000	2.37	3,555,000	107.7	60
60	104,490	138	65,000	39,490	10,918,160,100	1,559,460,100	19.7	1,280,500	2.37	3,034,785	91.9	60

Column 1, is the pressure of steam in the boiler above the atmosphere. The 2nd column is the expansive velocity of the steam in feet per minute, at which that steam will issue to the atmosphere, founded on the experiments of Mr. Banks, given by Dr. Gregory in his mechanics vol. 1, 3d edition 1815, p. 518-519. Column 3 is the force in pounds per square inch of the injet, and reaction of the steam on my principle from a stationary cavity, due to such velocity, as found by my experiments, by which I ascertained that the 3d column would vary as the squares of the velocity (or 2nd column). Column 4, is the velocity in feet per minute, at which the cavities of the wheel recede from the steam; that is, the velocity of the circumference of the wheel, which when deducted from the velocity of the steam (2nd column) will leave the velocity or pressure at which the steam will rush into the cavities of the wheel, when revolving at the speed of the 4th column, and will give the 5th column. The 6th column is the square of the 2nd, and the 7th column is the square of the 5th. Now as the square (col. 6) of the expansive velocity (col. 2,) is to the force (col. 3), so is the square (col. 7) of the difference (col. 5), to the diminished force in col. 8, which when multiplied by the velocity of the wheel (col. 4) and again by the area in square inches of the orifices of discharge or jets of steam necessary to give issue to the steam required for the power, will represent a power, equal to the number of pounds, raised one foot high in a minute (col. 11). This divided by Mr. Watts' estimate of a horse's power 33,000 lbs. gives the power of my engine (col. 12). Col. 13 is the number of cubic feet of water evaporated per hour under the pressure of col. 1, to give the power of col. 12. This table was commenced by giving the wheel the nominal velocity 10,000 feet a minute, and calculating progressively as shown to 65,000 feet a minute, to illustrate the variation in results at different velocities to show the best speed of the wheel to give the maximum effect. By this table it will be seen that the greatest results are obtained when the wheel revolves at precisely one third of the velocity of the steam or 34,830 feet a minute. At whatever pressure therefore the steam may be above the atmosphere, the wheel must always revolve at one third of the velocity of the steam to obtain the maximum effect. As regards the area of the jets, the proportions necessary to discharge steam at different pressures above the atmosphere vary inversely as the square roots of the densities or pressures of the steam, that is to say 2.37 square inches (col. 10) being sufficient to discharge a cubic foot of water a minute, evaporated into steam, under a pressure of 60 pounds above the atmosphere, as the square root of 60 pounds is to 2.37 square inches, so is, inversely the area of the jet required to the square root of the given pressure. And this last law will also apply to the areas of jets for steam rushing into a vacuum.

The foregoing table of velocities refers only to steam above the atmosphere, and to non-condensing engines. My experiments relating to the expansion velocity of steam issuing in the atmosphere agreed so nearly with those of Mr. Banks, recorded by Dr. Gregory, that I have preferred taking those data which can be generally referred to as a standard. But those data do not apply to the expansive velocity of steam rushing into a vacuum, for there it requires, I found, an expansive velocity, infinitely greater than that in the atmosphere to give the same effective force *in vacuo* as in the atmosphere from equal pressures. It is this increased velocity *in vacuo*, that will give a duty in condensing engines on my plan, equal to if not exceeding that obtained by increments of expansion by the present system. The effective force however is the same from equal pressures, whether *in vacuo*, or in the atmosphere; that is with steam at 7 pounds above the atmosphere, and a vacuum of 26 inches of mercury or 13 pounds making 20 pounds, the same effective force will be given in a stationary cavity *in vacuo*, as is shown in the foregoing table by a pressure in the atmosphere of 20 pounds above it. It is the different velocities of the steam in and out of a vacuum, required to give the same effective force from the same pressures that so greatly vary, and consequently when my steam wheel revolves *in vacuo*, different laws are required to determine the different results that will be produced. The best practice therefore for condensing engines on my plan will vary from that of high pressure engines. When using steam in a vacuum, the effect of that portion of the steam above the atmosphere must be ascertained by the same rules as are given in the preceding table of velocities, just the same as if it were used in the atmosphere. But as regards the other portion of the total pressure, that is, the expansive velocity of the steam below the atmosphere or the state of the vacuum, the effect of this must be found by another rule, the correctness of which, I have not been able quite to satisfy myself upon. I find however a very near approximation to those proportions which would be given by the squares of the state of the vacuum increasing or decreasing by this law; that is taking the atmospheric point at zero and every variation between the atmosphere and the state of the vacuum, increasing toward a perfect vacuum, the expansive velocity would be by this law as the squares of such variations of vacuum. If this be the case, then the effect of the injet of steam and its reissue from a cavity, vary as the square root of the expansive velocity of the steam; and the best velocity of the wheel, will in such case be ⅔ds of the expansive velocity of the steam. To ascertain therefore the total effect in condensing engines, the effect of the steam above the atmosphere, found by the former table of velocities as before described must be added to the effect of the expansive velocity of steam below the atmosphere and the sum will be the whole power and give the duty of expansion for any pressure and state of vacuum, when multiplied by the velocity of the wheel and the area of the jets of issue. This duty will increase rapidly according to the vacuum, as it is well known the duty does by the extent of expansion in the present engine.

That the expansive velocity of steam in a vacuum is so much greater than the velocity of steam in the atmosphere is shown by my experiments by the following fact; that a state of vacuum equal to 12½ pounds with steam at atmospheric point, gave the same forcible effect by injet in a stationary cavity in that vacuum, as steam at 12½ pounds above the atmosphere did in a stationary cavity in the atmosphere, though in the latter case nearly double the quantity of matter was injected so that if the expansive velocity of steam in a vacuum had not made up the difference of effect, by the considerably increased velocity of a mass only half as great, the effective force given out could not have been the same. In the case then of steam above the atmosphere, the expansive velocity of steam is as the square roots of the pressure, but in a vacuum it will vary as the squares of the state of the vacuum, assuming the correctness of my last class of experiments, and the injet of steam in the cavities follow in the former case, the laws of the squares of the expansive velocity of the steam, but in vacuum the injet or effective force will vary as the roots of the expansive velocity of the steam above the atmosphere therefore the wheel will revolve at one 3d and in a vacuum at ⅔ds of the expansive velocity of the steam to give that mean of velocity and power as will produce the maximum effect.

I will now conclude with a few general observations on my engine and the present, as relates to the principle and advantages of each in a scientific view. The principle of my discovery depends for its verification upon a very simple but universal law of nature before referred to, and which when noticed the mind immediately recognizes as a truth in science, applicable as well to steam as to all other bodies, fluid or solid, independent of its confirmations by my experiments. This law is, that all motion is power, power in proportion to the mass and velocity of motion, and to the amount of its beneficial transfer to the medium of communicating it. Now whatever body has a momentum or motion given to it greatly exceeding that of the surrounding medium, whether it be a cannon ball, an unobstructed current of steam, or an air blast for a furnace or from a blow pipe, it cannot impart laterally any portion of that force which it derives from the velocity imparted to it. Its force lies only in the line of its direction in which and in which only it must give out the same power as it received; and to obtain the whole of force from bodies so moving, they must be arrested before any part is lost by distance or at that point where the different nature of the body is found to impart its greatest force. Steam at 60 pounds above the atmosphere, (the pressure at which it is generally used in locomotive and other high pressure engines), has an expansive velocity exceeding 1741 feet a second, which is greater by about 500 feet a second than the rate at which a cannon ball is most beneficially expelled. Thus the speed is about 104,490 feet a minute and 6,269,400 feet 1187 miles 680 yards an hour and even at the atmospheric point only, when rushing into a vacuum its expansive velocity is still greater. So infinitely exceeding the speed of the strongest hurricane, we can compress this immense expansive power and making up in its far greater intensity what the wind has in surface, we can employ it by a controllable machine successfully to blow and contend against winds and tides. An unobstructed current of steam, thus rushing forward at this wonderful velocity, must necessarily possess a surprising force from velocity, and cannot from the very nature of motion expand equally in all directions laterally as well as linealy or its great velocity would not exist. To obtain its expansive powers in all directions its velocity must be first and immediately destroyed by cutting it off before its power is expended lineally. This error in science is done by the present system, and to make up in power what is lost in velocity, immense areas of surface are necessary, which has given rise to all the complexity of the modern steam engine, and to an immense mass of ponderous and useless matter, requiring so much valuable space and tonnage, simply because the true properties of steam have never before been discovered, and the beautiful simplicity of nature departed from.

It is now apparent by my table of pressure that the natural force and condition of steam is velocity; and as simplicity is the perfection of science, this can only be arrived at by ascertaining the true properties of those agents which are placed at our command, and applying them in pursuance of those simple laws which regulate their existence; whereas the present engine is in harmony with no motion in the universe, but stands alone, a singular departure from the laws of nature. But we now see how simply she acts in this great power, as in all things, and how much more in harmony with all her known laws is this discovery, and the transmission of steam power by its velocity by a machine, as simple as the water wheel. Even in my condensing engine where there is an air pump, and the steam is expanded lower than in the best Cornish lifting engines, (owing to the absence of the piston to overcome), there is neither expansive gear nor beam, nor eccentric, nor slide, nor connecting rods, nor valve moved by the engine nor complicated machinery of any kind, a pipe, a wheel and an axle enlarged at one part, and inclosed, to transmit, in the simplest way, the extreme duty from expansion, and from the whole steam engine, which is self adjusting, and the longer used, the more smoothly and equally will the parts wear and the touching surfaces become adapted to each other. Compact, simple, and durable, scarcely liable to derangement, the total weight of a marine engine of 320 horses power on my plan will not amount to the weight of the duplicate parts alone (15 tons) of the engine of the same power of Her Majesty's ship Cyclops, thus saving 123 tons for additional stowage; and even for an engine of 1000 horses power, the total weight will not exceed 20 tons.

For the great purposes therefore of steam navigation and inland transit my engine is particularly applicable, for in the latter the speed of traveling is limited by the present reciprocating engine wasting so much fuel at high velocities. As an elementary machine possessing a mere rotatory motion I do not attribute to my machine any superiority over a reciprocating engine of slow motion, as a means of communicating power as a substitue for the crank. But though there is no loss of steam power, in the crank transmitting that power to the machinery, the application of steam to produce a reciprocating motion is radically unsound in science as a principle, for it is only adapted for a slow motion of reciprocation. The Cornish engines are the slowest in the world, the speed of piston averaging 60 feet a minute, and these do the most duty of any in the world. When this speed is increased to 200 feet a minute, as in the marine engine, the duty falls off more in proportion to the difference of pressures, expansibility and boilers, or at least when the speed of piston is further increased to 500 feet a minute as in the locomotive engine, there is found a still greater loss in duty, as the steam can not be fully expanded as by the new system, and one half the power is consumed in overcoming the resistance of the used steam that cannot escape fast enough, and thus one half the fuel is wasted. To increase the speed of the piston to 700 feet a minute, to travel faster would cause so great a waste of fuel as to become impracticable, whereas with my engine the speed is only limited by curves and atmospheric resistance. It is on this comparison again principle with principle, that the application of steam by velocity is found to be sound, because equally advantageous at whatever speed the machinery is required to be driven, and for whatever purpose, while the present system is unsound, because it can only be used to the greatest advantage for one purpose, and that at so slow a speed as to be inadequate to the present requirements of civilization. The science and facilities of traveling are therefore in advance of the means and these I believe my engine will supply.

The best effects will be given by my engine in proportion as the three following requisites are combined.—1st, In proportion to the quantity of motion abstracted from the velocity of the steam and beneficially transferred to the wheel and the used steam be got rid of. Now the greatest effect from the impulsive velocity of the steam, is only obtained by arresting its velocity before any of it is expended and by entirely changing the direction of its motion and returning it parallel to its advance; for if the jets of steam be so directed either that any part of its volume still continue in the same direction in which it issues from the jet, or if the steam be diverted in any other line than that parallel to its advance, so in proportion will be the loss of power, as shown by the experiments before described. 2ndly. In proportion as the jets of steam and the cavities approach a tangent to the circumference of the wheel, and yet permit the used steam to reissue without striking against the back of the cavity next in succession. 3rdly. In proportion as the wheel revolves at that velocity which the two former conditions being observed, will give the maximum effect.

The foregoing tables and these explanatory remarks are given to assist the public, for I have thought it right in bringing forward a new principle of steam power, and a new application of it, to afford all the information I possess (or believe I possess), calculated in a scientific view to explain the discovery and to assist in carrying it out.

Having given a particular description of the nature of my said invented improvements, and in what manner the same are to be performed, I will now define the extent of my claims.

I claim—

1. A wheel, (having a series of oblique cavities or buckets arranged upon its periphery as described), in combination with an exterior case; (immediately surrounding said wheel on its sides and circumference), whose inner periphery has several corresponding cavities, formed therein, in contiguity with the cavities of the wheel, and also one or more induction pipes or jets inserted therein for the purpose of conveying steam or other elastic or aeriform fluid, (through the agency of which motion is imparted to the wheel), into the apparatus, and also an eduction pipe, for the discharge of the waste steam, or other similar and suitable contrivances for such purposes; the said cavities of the wheel being arranged so as to reflect the jets of steam into the cavities of the exterior case, and these latter in such manner as to return the said steam, or to throw it back again into the former; the whole of the said apparatus, being constructed and operating substantially as herein before explained.

2. I also claim, The particular method above set forth, of reversing the motions of a steam wheel, that is to say, by a second series of cavities and inlet pipes combined with the first series and arranged in the wheel and case in opposite directions to those of the first series thereof, the whole being substantially as before set forth.

3. I do not claim as my invention, the communication of motion by plane, curved, or beveled surfaces taken separately or apart from any arrangement, but that which I do claim is, the combination of the movable grooved axle or shaft *h* Fig. 1. Drawing D, (arranged in a movable box *i*, so as to be elevated and depressed in a vertical direction by a screw or other suitable contrivance), with the grooved wheel *l*, applied to the shaft *m*.

4. I also claim, the method, above set forth, of preventing concussion to my steam wheel, by suspending or arranging it in the manner before described, namely, by dividing the axle and joining it again by means of cranks and spring compensating or other connecting links.

5. I also claim, in combination with the groove and roller arrangement, the suspending of the movable box *i* Fig. 1, (Drawing D, upon a spring, through the center of which the elevating screw *u* passes, the whole being as above set forth, and as shown in Figs. 1 and 3, Drawing D, and for the purposes as herein before explained.

6. I do not claim, the exclusive use of antifriction wheels, but I do claim the combination of the wheels *a*, *d*, of Fig. 1, Drawing F, with the spring *x*, (which sustains the carriage frame N), and the shaft K; and also the combination with the wheels *a*, *d*, and shaft so arranged of the antifriction wheels *b* and *e*, moving in bearings attached to the carriage frame, the whole being constructed and operating substantially in the manner and for the purpose hereinbefore described.

In testimony that the above is a correct specification of my improvements I have hereto affixed my signature this nineteenth day of April in the year eighteen hundred and forty-three.

JAMES PILBROW.

Witnesses:

WILLIAM HARDING,

THOS. WATTS.