A.D. 1782 . . . . . N° 1321.

SPECIFICATION

OF

JAMES WATT.

STEAM ENGINES.

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WATT'S SPECIFICATION.

TO ALL TO WHOM THESE PRESENTS SHALL COME, I, JAMES WATT, of Birmingham, in the County of Warwick, Engineer, send greeting.

WHEREAS His most Excellent Majesty King George the Third, by His Letters Patent under the Great Seal of Great Britain, bearing date at Westminster, the Twelfth day of March, in the twenty-second year of His reign, did give and grant unto me, the said James Watt, His especial licence, full power, sole privilege and authority, that I, the said James Watt, my exors, admors, and assigns, should and lawfully might, during the term of years therein expressed, make, use, exercise, and vend, within that part of His Majesty's Kingdom of Great Britain called England, His Dominion of Wales, and Town of Berwick-upon-Tweed, my Invention of "CERTAIN NEW IMPROVEMENTS UPON STEAM OR FIRE ENGINES FOR RAISING WATER, AND OTHER MECHANICAL PURPOSES, AND CERTAIN NEW PIECES OF MECHANISM APPLICABLE TO THE SAME;" in which said recited Letters Patent is contained a proviso obliging me, the said James Watt, by an instrument in writing under my hand and seal, to cause a particular description of the nature of my said Invention, and in what manner the same is to be performed, to be inrolled in His Majesty's High Court of Chancery within four calendar months after the date of the said Letters Patent, as in and by the said Letters Patent, relation being thereunto had, may more at large appear.

NOW KNOW YE, that in compliance with the said proviso, I, the said James Watt, do hereby declare that the nature of my said Invention, and the manner in which the same is to be performed, is described and ascertained in manner and form following, that is to say:—

My said new improvements on steam or fire engines, and my said new pieces of mechanism applicable thereto, are described as followeth; but to prevent misunderstandings and circumlocutions or tautology, I shall first explain the meaning of certain terms which are used in this Specification. First, the cylinder or steam vessel is that vessel wherein the powers of steam or air are employed to work the engine, of whatever form it may be made, though it is most commonly made cylindrical. Second, the piston is a moveable diaphragm, sliding up and down or to and fro in the cylinder, and fitted to it exactly, on which piston the powers of steam or air are immediately exerted. Third, the condensers are certain vessels of my Invention, in which the steam is condensed, either by immediate mixture with water sufficiently cold or by contact with other cold bodies, which condensers are situate either in that part of the cylinder itself which the steam never enters except to be condensed or reduced to water, or they communicate with the cylinder by means of pipes which are opened or shut at proper times, or those pipes called eduction pipes which lead to the air pumps or other contrivance for carrying of the condensed steam, air, and water of injection, are themselves used for that purpose. Fourth, the air and hot water pumps are pumps or other contrivances which serve to extract the air and heated water from the cylinders and condensers. Fifth, the working beam is a double-ended lever, a wheel or wheels, or other machinery, establishing the means of communicating the power from the piston to the pump work or other machinery to be wrought by the engine.

My first new improvement in steam or fire engines consists in admitting steam into the cylinders or steam vessels of the engine only during some certain part or portion of the descent or ascent of the piston of the said cylinder, and using the elastic forces, wherewith the said steam expands itself in proceeding to occupy larger spaces, as the acting powers on the piston through the other parts or portions of the length of the stroke of the said piston, and in applying combinations of levers or other contrivances to cause the unequal powers wherewith the steam acts upon the piston to produce uniform effects in working the pumps or other machinery required to be wrought by the said engine, whereby certain large proportions of the steam hitherto found necessary to do the same work are saved; to explain which principal or improvement I have delineated a section of a hollow cylinder at Figure 1st in the annexed Draw-

ing. The said cylinder is perfectly shut at the lower end by its bottom C, D, and also at the upper end by its cover A, B; the solid piston E, F, is accurately fitted to the said cylinder, so that it may slide easily up and down, yet suffer no steam to pass by it. The said piston is suspended by a rod (or rods) G, H, which is capable of sliding through a hole in the cover (A, B,) of the cylinder, and its circumference is made air and steam tight by a collar of oakum or other proper materials well greased, and contained in the box O; and near the top of the cylinder there is an opening J, to admit steam from a boiler. The whole cylinder, or as much of it as possible, is inclosed in a case M, M, containing steam, or otherwise is maintained of the same heat with boiling water, or of the steam from the boiler. Those things being thus situated, and the piston placed as near as may be to the top of the cylinder, let the space of the cylinder under the piston be supposed to be exhausted or emptied of air, steam, and other fluids, and let there be a free passage above the piston for the entry of steam from the boiler, and suppose that steam to be of the same density or elastic force as the atmosphere, or able to support a column of mercury of thirty inches high in the barometer. Then I say that the pressure or elastic power of the said steam on every square inch of the area or upper side of the piston will be nearly fourteen pounds averdupois weight, and that if the said power were employed to act upon the piston through the whole length of its stroke, and to work a pump or pumps either immediately by the piston rod prolonged, or through the medium of a working beam or great lever, as is usual in steam engines, it would raise through the whole length of its stroke a column or columns of water whose weight should be equal to ten pounds for each square inch of the area of the piston, besides overcoming all the frictions and vis inertiæ of the water, and the parts of the machine or engine. But supposing the whole distance from the under side of the piston to the bottom of the cylinder to be eight feet, and the passage which admitted the steam from the boiler to be perfectly shut when the piston has descended to the point K, two feet or one-fourth of the length of the stroke or motion of the said piston, I say that when the piston has descended four feet or one-half of the length of the stroke, the elastic power of the steam would then be equal to seven pounds on each square inch of the area of the piston, or one-half of the original power; and that when the piston had arrived at the point P, the power of the steam would be one-third of the original power, or four pounds and two-thirds of a pound on each square inch of the piston's area, and that when the piston had arrived at the bottom or end of its stroke, that the elastic power of the steam would be one-fourth of its original power, or three pounds and one-half pound on each square inch of the said area. And I further say that the elastic power of the

steam at the other divisions, marked in the lengths of the said cylinder, are represented by the lengths of the horizontal lines or ordinates of the curve K, L, also marked or delineated in the said cylinder, and are expressed in decimal fractions of the whole original power by the numbers written opposite to the said ordinates or horizontal lines; and I also say, that the sum of all these powers is greater than fifty-seven hundred parts of the original power, multiplied by the length of the cylinder, whereby it appears that only one-fourth of the steam necessary to fill the whole cylinder is employed, and that the effect produced is equal to more than one-half of the effect which would have been produced by one whole cylinder full of steam, if it had been admitted to enter freely above the piston during the whole length of its descent; consequently that the said new or expansive engine is capable of easily raising columns of water, whose weights are equal to five pounds on every square inch of the area of its piston, and that with one-fourth of the contents of the cylinder of steam; and be it remembered, though for example's sake I have mentioned the admission of one-fourth of the cylinders full of steam (as being the most convenient), that any other proportion of the fill of a cylinder, or any other dimensions of the cylinder, will produce similar effects, and that in practice I actually do vary these proportions as the case requires; and also in some cases I admit the required quantity of steam to enter below the piston, and I pull the piston upwards by some external power against the elastic force of the steam from the boiler, which then always freely communicates with the upper part of the cylinder, and which produces similar effects to those described; but the powers which the steam exerts being unequal, and the weight of the water to be raised or other work to be done by the engines being supposed to resist equally throughout the length of the stroke, it is necessary to render the whole acting powers equal by other means. I perform this, first, by means of two wheels or sectors of circles, one which is attached to the pump rods, and the other to the piston rod of the engine, and which are connected together by means of rods or chains or otherwise, so that the levers whereby they act upon one another decrease and increase respectively during the ascent or descent of the piston, in or nearly in the ratios required.

This method, mechanism, or contrivance is delineated in Fig. 2d, and also its application to one of my new invented steam engines, the sole use and benefit of which was granted to me by an Act of Parliament, passed in the fifteenth year of the reign of His present Majesty.

The operation of the engine with this new mechanism added to it is described as follows:—The piston A being at its highest place, and the part of the cylinder under it exhausted of steam and air, the regulating valve which

admits the steam to enter below the piston being shut, and the valve F which allows steam or air to pass to the condenser (G, K,) being open, in order to maintain a good vacuum, the top regulating valve D is opened, and permits the steam from the boiler to enter and act upon the piston, which then begins to descend and to pull round the wheel or sector of a circle to which it is hung. When the point Q of that wheel has moved to R, the piston has descended two feet, and V of the wheel to which the pump rods or other machinery wrought by the engine are suspended, being pulled by the rod (5) connecting it with the other wheel Q, R, S, T, U), will have moved through the space V, W, the regulating valve D is then shut, so that no more steam may be admitted from the boiler during that stroke, but the piston continues to descend by virtue of the expansion of the steam, and when the point Q is come to the points R, S, T, U, the point V is come to the points W, X, Y, Z, respectively, describing spaces which are nearly proportional to the powers of the steam at the corresponding points of the descent of the piston. When the piston has made its stroke and is come to the bottom of the cylinder, the regulating valve F is shut, and the valve E is opened, by which means the steam passes from the part of the cylinder above the piston to the part below it by the pipe C, and so restoring the equilibrium, permits the piston to ascend to its position. The regulating valve E is then to be shut, and the exhaustion regulating valve F is opened; the steam rushes into the eduction pipe G, G, where it meets a jet of cold water which enters through the injection pipe H, which is opened immediately before the regulating valve F. The contact of this cold water immediately reduces the steam to water, and produces a vacuum under the piston, and thereby enables the elastic force of the steam to act again upon it, as has been described; or instead of injecting cold water into the condenser or eduction pipe itself, I bring the steam into contact with thin plates or pipes of metal which have their external surface cooled by contact with water or other cold matter. The condensed steam, the injection water, and the air which entered with it or any other air which has entered by other means, proceed by the eduction pipe to the air pump K, and passing the valves of its bucket or piston are retained and lifted up by it on the return of the stroke, and thereby are thrown into the hot water pump J, which by the next stroke raises up and delivers them into the atmosphere, from whence part is returned into the boiler to supply its consumption of water, and the remainder is conveyed away for any other purpose, or runs to waste. Another variety of this method of equalizing the power is delineated in Figure 3d. The piston is suspended to the arch A by means of a chain or otherwise, and the pump rod is suspended to the arch B. The primary or

cylinder arch A by means of the arm O, P, and the rod or chain O, C, acts upon the working beam B, C, to the arch of which the pump rods are suspended, by which means, while the piston descends through the equal spaces J K, K L, L M, M N, the pump rod is made to ascend through the unequal spaces D E, E F, F G, G H, which are nearly proportioned to the elastic forces of the steam at the respective points. My second method or piece of mechanism for equalizing the powers of the steam is by means of chains, which are wound upon one spiral and wound off another as the piston descends, which spirals are fixed upon two wheels or sectors of circles to which the chains of the piston and pump rods are attached, and is represented in Figure 4th. The piston is suspended from the side A of the wheel A, B, and the pump rods from the side C of the wheel D, C, which wheel D, C, being pulled by the chains J, R, K, the points of its circumference move through the unequal spaces K L, L M, M N, N O, (almost exactly proportioned to the powers of the steam,) while the points of the circumference of A, B, move through the equal spaces E F, F G, G H, H I. My third method or piece of mechanism for equalizing the powers of the steam is by means of a friction wheel or wheels attached to or suspended from one sector or wheel, and acting upon a curved or straight part of another sector wheel or working beam. Two modes of this contrivance are delineated in Figs. 5th and 6th, of which it is only necessary to observe that the pistons of the engines are suspended to the arches A, A, and the pump rods to the arches of the working beams B, B, and that these contrivances afford the means of equalizing the powers of the steam very exactly. My fourth method or piece of mechanism for equalizing the power of the steam is by causing the centre of suspension of the working beam or great lever to change its place during the time of the stroke, whereby the end of the lever to which the piston is suspended becomes longer, and the end to which the pump rods are suspended becomes shorter, as the piston descends in the cylinder. An easy method of doing this is represented in Fig. 7. A, B, represents the working beam; B, the end to which the piston is suspended; A, the end to which the pump rods are suspended; C, D, a hollow curve of wood or metal fixed to the lower side of the working beam; E, the end of a friction roller, which rolls between the curve C, D, and the plane or support F, G. This friction roller is divided into three parts, as may be seen in its horizontal view K, L, M; the two end parts K, M, which roll upon the supports F, G, are fixed firmly upon an axis; the middle part L, which rolls under the curve C, D, can turn round on its axis, therefore when by the action of the piston on the working beam the end B is pulled downwards, the roller proceeds towards C, to the part of the curve which is then the highest, and thereby lengthens the lever by which the piston

acts on the pumps, and shortens that by which the pumps resist the cylinder, and that in any ratios which may be required, according to the form of the curve. My fifth method, piece of mechanism, or contrivance for equalizing the power of the steam consists in placing upon, suspending from, or fixing to the working beam of the steam engine or some other beam, wheel, or lever connected with it, a quantity of heavy matter in such a manner that the said heavy matter shall act against the power of the piston at the commencement of the descent of the said piston, and as the piston descends shall gradually move towards that end of the beam to which the piston is suspended, or otherwise shall act in favour of the piston in the latter part of the stroke. Three methods or varieties upon this principle are represented at Figs. 8, 9, and 10. Fig. 8 operates by means of a heavy cylinder A, of iron or other material, which rolls in a hollow curve B, C, on the back of the working beam, and will consequently change its place and proceed towards the cylinder end of the beam as the piston descends. In Fig. 9th, the same is performed by a heavy weight of iron or other matter A, fixed above the beam or wheel, so that its centre of gravity at beginning the motion lies nearer the pump end of the beam than the centre of suspension of the beam, whereby it acts against the piston, and at last comes to be at the same side of that centre with the end to which the piston is suspended, and thereby acts in its favour. Figure 10th shews a method of fixing the working beam itself so as to perform in some degree the office of the weight in Figure 9th. Fig. 11th shews a fourth method whereby I perform the same thing, by causing a quantity of water or other liquid to oppose the ascent of the piston in the beginning of the stroke, and to assist it in the latter part. A and B represent two cylinders or other formed vessels, filled with water or some other liquid above their pistons C and D, the rods of which are fixed (or suspended) to the working beam of the engine, or such secondary or auxiliary beam as may be applied to this use, on the opposite sides of its axis. These cylinders are open at bottom and at top, and at the top part they are connected together by a lander or trough, close or open; when the piston descends it raises the opposite end of the working beam and the piston of cylinder B, and thereby causes the water it contains to run over into A, the piston C of which becoming loaded thereby in proportion as piston D rises, gradually comes to assist the piston of the steam vessel in the latter part of its motion. These cylinders, containing water, be either placed below the working beam or above it, or may be suspended to a secondary working beam constructed for that purpose or necessary for some other use, connected with the piston rod or pump rod or other part, and placed so that the water cylinders may be out of the engine-house in some place where it

may be found to be more convenient. My sixth method, piece of mechanism, or contrivance for equalizing the powers of the steam consists in employing the surplus power of the steam upon the piston in the first parts of its motion, to give a proper rotative or vibratory velocity to a quantity of matter, which retaining that velocity shall act along with the piston and assist it in raising the columns of water in the latter part of its motion when the powers of the steam are defective. Two methods by which I perform this are delineated in the Drawing of the engine, Fig. 12th. The heavy fly X, X, is put in motion by means of a pinion or smaller wheel Y, fixed upon its axis, and the teeth of which pinion or smaller wheel are acted upon by the toothed sector Q, Q, fixed upon the arch of the working beam, or the said fly is by other means connected with the motion of the said working beam. When the piston pulls down the end of the working beam, the toothed sector Q, Q, gives motion to the pinion, and thereby gives velocity to the fly, and when the descending or ascending velocity of the arch or sector of the working beam comes to be less than the velocity which the pinion and fly have acquired, then the velocity of the fly continuing, causes the pinion to act upon the sector in its turn, and assist the powers of the steam, until its velocity is spent, or the piston has reached the bottom of the cylinder; and the said fly operates in like manner during the ascent of the piston, but turns then in the contrary direction. In the second variety of this method, a fly or heavy wheel is put into a continued rotative motion by a crank, by any of the rotative motions for which I have obtained His Majesty's Royal Letters Patent, dated in the present year of His reign, or by any other means which shall or can produce a continued rotative motion. And the said rotative machinery is connected with or joined to either end of the working beam, to or with the piston rod itself, to or with the pump rods, or to or with any other moving part of the engine or pump rods which is found proper.

In the Drawing, Figure 12th, T, U, W, V, V, represent the application of my fifth method of producing rotative motion from steam engines, as a method or contrivance for equalizing the power of the steam. The piston being at the top of the cylinder, and the working beam in the situation delineated, the engine begins its strokes, and by means of the connecting rod T, T, pulls upwards the toothed wheel W, which is fix't to the connecting rod in such manner that it cannot turn upon its own axis, and is confined by means of a link or chain reaching from its centre to the axis of the other toothed wheel U, or is otherwise so contrived that it cannot recede from it; therefore, when the action of the engine pulls the wheel W upwards it revolves round the other wheel U, and causes it (U) to revolve upon its own axis, and the fly or heavy

wheel V, V, being fixed upon the same axis, it is also put into motion, and because of the great power of the steam in the first parts of the stroke, the fly acquires a great velocity, whereby through the medium of the two wheels and the connecting rod, it acts upon the working beam, and assists the action of the steam in the latter parts of the stroke. When the piston has compleated its stroke downwards, the lower edge of the wheel W has passed over the upper edge or highest part of the wheel U, and the velocity of the fly continuing, the wheel U acts upon the wheel W, and assists the unbalanced weight of the pump rods in raising the piston to the top of the cylinder. But be it remembered, that I, (the said James Watt,) do not mean that anything which I have herein set forth touching or concerning this second variety of applying my sixth method or contrivance for equalizing the powers of the steam, shall be construed or thought to be intended to preclude any other person or persons from using or applying to the moving, turning, or working of mill-work or other machinery where continued rotative motions are required, any contrivances or inventions for producing rotative motions from steam engines, provided that such rotative motions or machinery be not of my invention, and such engines be not applied principally or solely to the raising of water, the true intent and meaning of the aforesaid last article of this writing being to specify the means by which I apply continued rotative motions, as some of my methods or contrivances to equalize the expansive powers of the steam in engines, which are principally or wholly for the raising of water from mines, rivers, ponds, marshes, lakes, and other places.

My second improvement upon steam or fire engines consists in employing the elastic power of the steam to force the piston upwards, and also to press it downwards alternately, by making a vacuum above or below the piston respectively, and at the same time employing the steam to act upon the piston in that end, or exerted upon the piston only in one direction, whether upwards or downwards.

This improvement, as applied to one of the steam engines of my Invention, is delineated in Fig. 12th. The lower part of the cylinder B being exhausted of air, steam, and other fluids, the regulating valve *f*, F, being open, and the regulating valves E and N being shut, the regulating valve D is opened, which admits the steam from the boiler to press upon the upper side of the piston, by the action of which steam the piston descends, pulls down the cylinder end of the working beam, and raises the end to which the pump rods are suspended. When the piston is arrived at the bottom of the cylinder or end of its stroke, the valve F is shut, and the valve E is opened, which admits the steam under

the piston, and at the same time the valve D is shut, which prevents the steam from coming from the boiler into that end of the cylinder, and the other valve N in the upper nozle or regulator box is opened, which permits the steam to rush from above the piston into the eduction pipe G, G, where it meets the jet of injection water, which condenses it and produces a vacuum in the upper part of the cylinder, which, destroying the equilibrium, permits the steam under the piston to force it upwards. Then the piston rod, being fast in the piston, and having the toothed rack O, O, fixed to its upper end by means of the teeth thereof, which are engaged in the teeth of the toothed sector, which is fixed to or forms a part of the arch Q, Q, of the working beam, or by means of double chains or any other practicable method, the piston or its rod raises the cylinder end of the working beam, and also a heavy weight concealed or contained in the arch thereof, or otherwise fixed, attached, or suspended thereto, which weight ought to be equal or nearly so to the force or power of the steam when acting upon the piston in the ascending direction. When the piston is arrived at the summit of its motion, the regulating valves E and N are to be shut, and the regulating valves D and F opened, whereby the piston again commences its motion downwards, as has been described, and during the descent of the piston, the weight Q, Q, fixed or suspended to the working beam, assists the power of the steam on the piston in raising the column of water in the pumps, or in working other machinery.

In Fig. 13 is delineated a front view of the cylinder, and a section of the condenser of this engine, wherein the pipes which convey the steam from the boiler and to the condenser are properly distinguished and explained.

This improvement permits the engine to be used either with the uniform exertion of the whole power of the steam on the piston, both in the descent and ascent, or by making the weight of the columns of waters in the pumps, or the resistance of other machinery which it may be required to work equal to the full power of the steam upon the piston when acting in one direction only, and the weight on the working beam equal to half that power, it may be used as a double expansive engine, and wrought in the manner I have herein set forth in the description of my first improvement. And in such case, the fourth, fifth, and sixth contrivances herein described for equalizing the powers of steam, are peculiarly applicable to this mode of constructing the engine. Wherefore I have delineated the two varieties which I have described of the sixth method, as applied to this engine; and be it remembered, that either or both of them may be used at the same time, though only one is strictly necessary, and that any other two or more of the aforesaid six

contrivances, or of the varieties thereof, may be applied to one engine at the same time, that is to say, such of them whose nature admits of such combination.

My third improvements on steam or fire engines consists in connecting together by pipes, or other proper channels of communication, the steam vessels and condensers of two or more distinct steam engines, each of which has its seperate working beam and other constituent parts of a steam engine, or is otherwise so constructed that it can work pumps or other machinery, which are either connected with or are independant of those wrought by the other engines, and which two engines can take their strokes alternately or both together, as may be required. The construction of the said machine is described as followeth, and an external front view of the steam vessels or cylinders and condenser of the two engines is delineated at Fig. 14th of the Drawing hereunto annexed; the section or side view of the two engines is not delineated, because when viewed in that direction, only one of them can be seen, the other being hid by it, and the engine which could be seen would appear the same as the engine delineated in Fig. 2d, or in respect to the working beams as the engine delineated at Figure 12th; these compound or double engines admitting the application of any of the equalizing machinery which has been herein-before described. In Fig. 14th the cylinder of the primary engine No. 1, receives steam from the boiler by the steam pipe (8, 9), which steam enters the cylinder by a regulating valve situated at D, its piston being at the upper ends of its stroke, and the part of the cylinder which is below the piston being exhausted, the elastic power of the steam presses down the piston until it arrives at the bottom or termination of its stroke, the regulating valve D is then shut, and the middle regulating valve at E is opened, which admits the steam to enter under the piston, whereby the engine is enabled to raise up the piston to the top of its stroke where it was at the beginning, the middle regulating valve E, is then shut, and the regulating valves F and P are opened, the valve F permits the steam to pass through the eduction pipe N into the perpendicular steam pipe R of the secondary engine, and to press upon its piston, under which piston there is a vacuum. The steam which is or was contained under the piston of the primary engine No. 1, being of the same density with the atmosphere or nearly so, will, while the piston of the secondary engine (No. 2) remains stationary, act upon it with the full power belonging to its density or elasticity, and will thereby cause to it commence its motion downwards, but as the piston of (No. 2) moves downwards, the density and elastic force of the steam will diminish in proportion as the spaces which it occupies are

increased, so that in case the cylinders of the two engines are of an equal capacity, when the piston of No. 2 has arrived at the bottom or lower end of its stroke, the density and elastic force of the steam will be only one-half of what they were while the piston remained at the top; therefore if a simple lever, wheel, or working beam is used for this secondary engine (No. 2), the engine ought only to be loaded with a column of water or other work, equal to half the number of pounds on each square inch which the primary engine No. 1 is able to work with. But if the secondary engine No. 2 is furnished with any proper contrivance for equalizing the powers of the steam, it may, in case the cylinders of the two engines are of equal capacity, be made to do seven-tenths of the work which is done by the primary engine (No. 1). When the piston of the secondary engine (No. 2) has come to the bottom of its stroke, the middle regulating valve O is opened, and the steam rushes into the condenser G, K, and in its way meets the jet of injection water, which condenses it, and thereby the upper part of the cylinder of the secondary engine and the lower part of the cylinder of the primary engine are exhausted of steam. The piston of the secondary engine (No. 2) having then a vacuum both above it and below it, is pulled up easily by the working beam of that engine, and there being a vacuum under the piston of the primary engine (No. 1) the steam from the boiler exerts its power upon it and presses it down, and the other motions are repeated, as has been described.

These compound engines may also be wrought in other manners, of which I shall describe one of the best:—Let the eduction pipe N be supposed to be removed, and a steam pipe S (which is delineated in red ink) be made to communicate between the perpendicular steam pipe C of the primary engine and the top regulator box or cross pipe Q of the secondary engine, then the piston of the primary engine (No. 1) being pressed to the bottom by steam, shuts its top regulating valve D, and opens the top regulating valve Q of the secondary engine, the piston of that engine will immediately begin to descend with a decreasing power (as has been remarked before); when the piston of the secondary engine No. 2 has come to the bottom of its stroke its middle regulator O is opened, whereby the steam rushes out of the cylinders of both the engines into the condenser or condensers, and there being vacuum both above and below the pistons of both engines, the equilibrium of both is restored, and both the pistons are permitted to be raised by the unbalanced weight of the pump rods or other weights or machinery applied for that purpose. It is proper in this mode of application to make a small pipe leading from the lower part of the cylinder of the primary engine to the eduction pipe or condenser

of the secondary engine, whereby the vacuum under and above both pistons may be maintained of an equal degree of rareness or perfection.

For the more clear understanding of these improvements and contrivances, I have delineated them on the parchments hereunto annexed, according to the schales specified on the respective Drawings, and have adapted them all, except Fig. 1st, to engines whose cylinders are thirty inches in diameter, and the length of the stroke of whose pistons is eight feet; but I make the cylinders larger or lesser, longer or shorter, and vary the proportions and shape of them, and of the other parts, according as their uses may require; and as each improvement, method, piece of mechanism, or contrivance admits of numberless variations, I have set forth and delineated only such as I esteem to be among the best, and which are the most easy to be executed.

My fourth new improvement on steam or fire engines consists in applying a certain mechanical contrivance called a toothed rack and sector of a circle, or toothed racks and toothed sectors of circles, for suspending or connecting the pump rods or pistons with the working beams, levers, or other machinery used in place of them, in place or instead of chains, which have hitherto been used for these purposes. This new improvement or mechanical contrivance is delineated at O, Q, Fig. 12th, and requires no other explanation than to say that it is delineated by a schale of one-fourth of an inch to each foot of the real size, according to its proper dimensions for a cylinder thirty inches in diameter; and the said rack and sector are supposed to be made of hammered or cast iron, but it may be made of wood or other materials by giving it dimensions suitable to the strength of the material of which it is made; and in order to accommodate the same to cylinders of other sizes, the strength of its parts must be increased or diminished in proportion to the powers of the respective cylinders to which it may be applied. I have described and delineated all my aforesaid new improvements upon and new mechanical contrivances applicable to steam engines as applied to or connected with the new steam engines of my own invention as being the most perfect hitherto made; but it must be remembered that I do apply the same to the common steam engines known by the name of Newcomen's steam or fire engines, and that they are also applicable to any other species or variety of steam engines which works with a piston moving in a cylinder or steam vessel, and that they will in such engines produce greater or lesser effects in proportion to the degree of perfection of the engine to which they are applied. It is also to be remarked that though I have described all the engines standing erect and having the piston rods coming through holes in the top of

the cylinder, that the same or nearly the same effects will be produced though the piston rods come through holes in the bottom of the cylinder, and the working beams or equalizing machinery be placed under them, or although the cylinders and working beams are placed inclined or horizontally, and that in certain cases I use them in such different positions.

My fifth new improvement on steam or fire engines consists in making the steam vessels in the form of hollow cylinders, or in the form of other regular round hollow vessels, or in the form of greater or lesser segments or sectors of such bodies or vessels, and I place in the centre or axis of the circular curvature of such vessels a round shaft or axle passing through and extending beyond one or both ends of such steam vessel; and I shut up the ends of the said steam vessel with smooth plates, which have proper appertures for the said axle or shaft to pass through; and within the said steam vessel I fix to the said axle a piston or plate extending from the said axle to the circular circumference of the steam vessel, and also extending from one end of the steam vessel to the other; and I make the said piston steam-tight by surrounding the parts which fit to the steam vessel with hemp or other soft substances, soaked in grease, oil, or wax, or by means of springs made of steel or other solid and elastic or pliable materials; and to the said steam vessel I fix one or more plates or divisions, extending from the axle to the circumference of the steam vessel, and where these plates or divisions join to or approach the axle, or where the said axis passes through the end plates of the steam vessel, I make such joining steam and air tight by the means above recited. In the steam vessel, on each side of the said piston, I make one or more channels or appertures for receiving and discharging the steam, which channels I furnish with proper valves for that purpose. I also apply to the said engine proper condensers and air pumps; and the pumps which raise water, or such other machinery as is required to be wrought by the said engine, are put in motion or worked by a wheel or wheels fixed to or upon the external parts of the said axle, or by any other mechanism which may be suitable, and the said engine so constructed is wrought by admitting the steam between the fixed division and the moveable piston, and exhausting or making a vacuum on the other side of the said piston, which accordingly, by the force of the steam, moves into the said vacuum and turns the axle or greater or lesser portion of a circle, according to the structure of the machine. The piston is returned to its former situation by admitting steam on the other side of the said piston, and drawing the piston back by some external power, or by exhausting the part of the steam vessel which was first filled with steam.

An engine constructed upon this principle is delineated at Figures 15th, 16th, and 17th, in the annexed Drawing, according to a schale of one-fourth of an inch to each foot of the real size; but I make them greater or lesser, and vary the shape and size of the steam vessel and other parts according to their use. The operation of the engine is as follows:—The steam vessel A, A, A, being exhausted of steam and air, and the regulating valves K and I being shut, and L and H open, the steam coming from the boiler through the pipe M, enters the steam vessel by L and G, and causes the piston C to turn round into or towards the exhausted part of the steam vessel A, X, and thereby turns the axle B and the machinery attached to it until the piston C comes to X; the regulating valves L and H are then shut, and K and J are opened; the steam which had entered by the pipe G, and had acted upon the piston, returns through G and J into the condenser or eduction pipe O, where it is condensed, and the steam from the boiler, entering through K and F, forces the piston C to return to its first situation. The pump rods U, W, or other machinery, are wrought by the wheel S, S, fixed on the axle B, B, or otherwise, see Figs. 16th and 17th, and the condenser pump (or pumps) is wrought by the wheel 2, fixed to any part of the said axle or otherwise. It is to be understood that the said steam vessel is to be firmly fixed so that it cannot move, and that the gudgeons or pivots of the said axle must be rested upon proper supports, which things could not be exhibited in the Drawing without confusion. I also cause engines made according to this fifth improvement to revolve with a continued rotative motion, by making their steam vessels compleat cylinders or other circular figures, and in place of the fixed division or divisions, I place one or more valves in their steam vessels, which shut or close the area between their axles and their circumferences, and which valves open by turning upon a hinge or joint, or are drawn back by a sliding motion like a drawer, or otherwise are constructed so that they may be removed when the piston comes to them, and thereby suffer it to pass by the place where they were (see the Drawing, Figure 18th), and so begin a new revolution in the same direction; or I make a fixed division or divisions, as has been described, and I fix one or more valves to the axle, which valves are capable of folding down and of applying themselves to the axle and of forming a part of its circumference, so that they can thereby pass by the division, and when they have passed it they are raised up by springs or otherwise, so as to perform the office of a piston or pistons. I have not described the boilers which supply any or all of these engines with steam, because I use such as are commonly applied to other steam engines, or any kind of boiler which is

capable of producing steam in sufficient quantities; neither have I described the machinery which opens and shuts the regulating valves, as it is similar to that which is in common use, and may be varied at pleasure.

In witness whereof, I have hereunto set my hand and seal, this Third day of July, in the year of our Lord One thousand seven hundred and eighty-two.

JAMES (L.S.) WATT.

Sealed and delivered (being first duly stampt), in the presence of

JOHN SOUTHERN.
PETER CAPPER.

AND BE IT REMEMBERED, that on the Third day of July, in the year of our Lord 1782, the aforesaid James Watt came before our said Lord the King in His Chancery, and acknowledged the Specification aforesaid, and all and every thing therein contained and specified, in form above written. And also the Specification aforesaid was stampt according to the tenor of the Statutes made in the sixth year of the reign of the late King and Queen W^m^ and Mary of England, and so forth, and in the seventeenth year of the reign of His Majesty King George the Third.

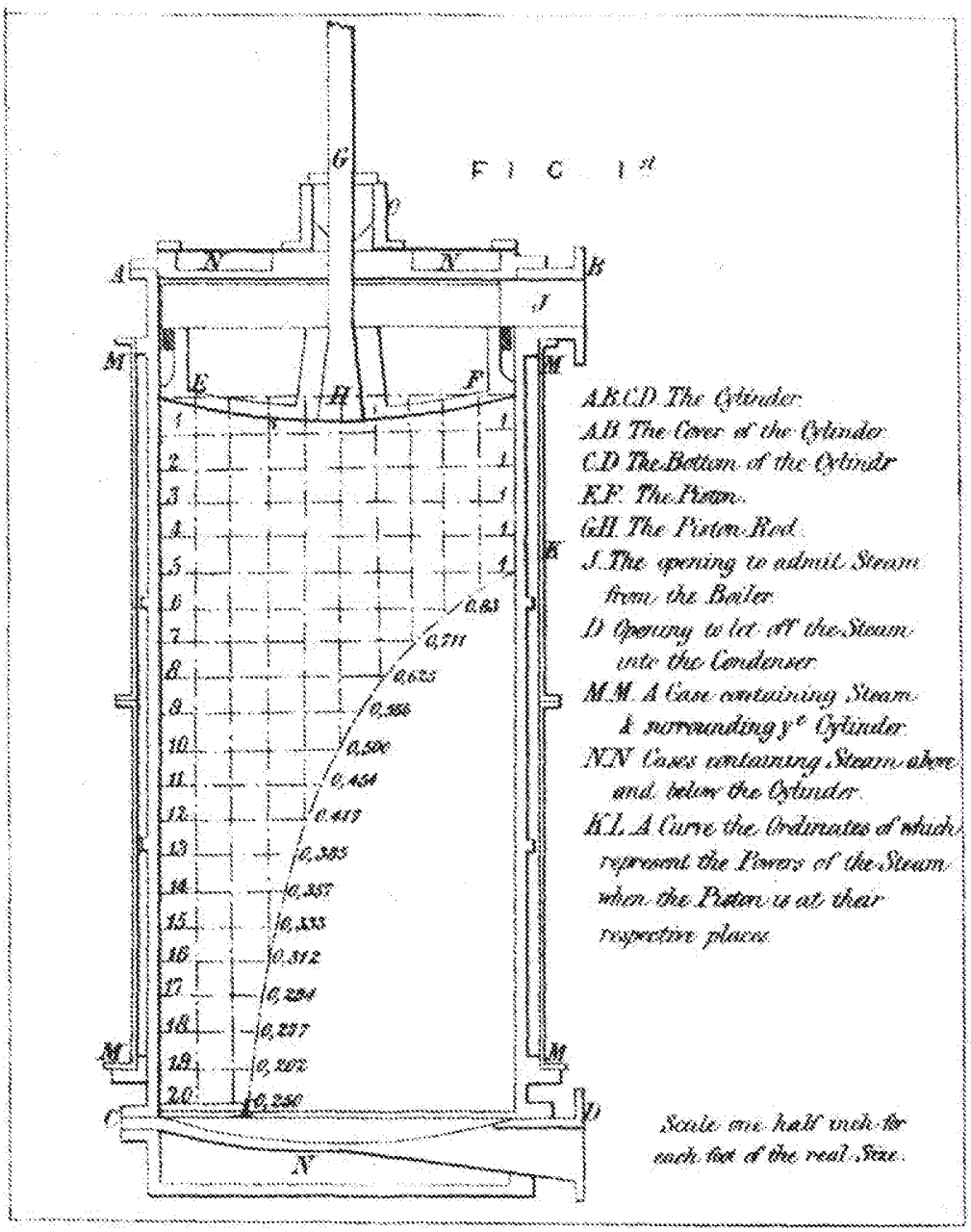
BARKER, Extm.

Inrolled the Fourth day of July, in the year of our Lord One thousand seven hundred and eighty-two.

LONDON:
Printed by GEORGE EDWARD EYRE and WILLIAM SPOTTISWOODE,
Printers to the Queen's most Excellent Majesty. 1855.

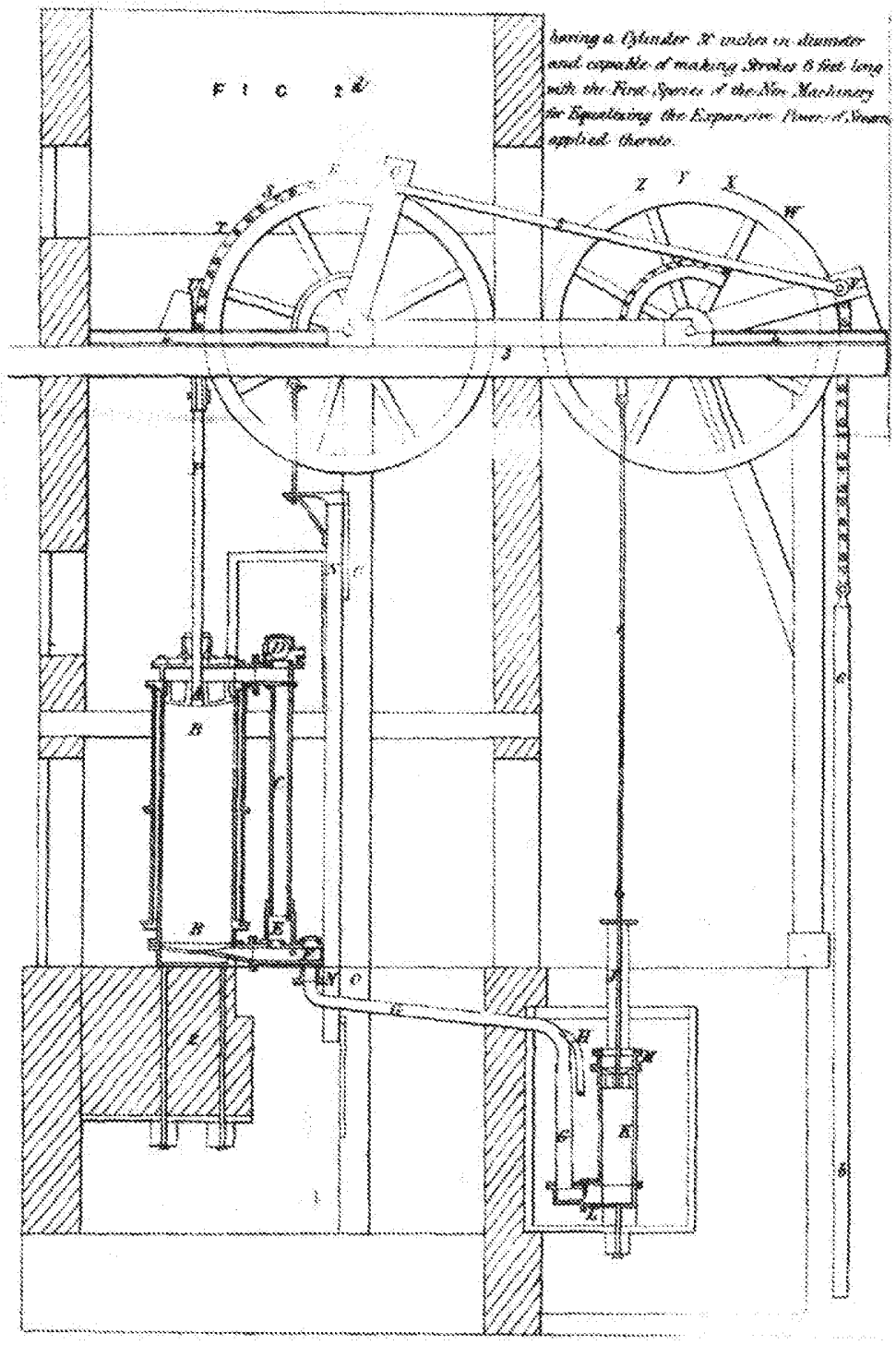
A.D 1782. Mar. 12. N° 1321

WATT'S Specification



Explanation of Fig. 2d

A. The Piston. B.B. The Cylinder or Steam Vessel. C. The perpendicular Steam Pipe which conveys the Steam from the upper to the under end of the Steam Vessel. H The place of the Top regulating Valve. E. The place of the Middle regulating Valve. F The place of the Exhaustion regulating Valve. G.G. The Eduction Pipe. H. The Injection Pipe. I The Hotwater Pump. K. The Air Pump. L. A Valve at the Eduction Pipe foot to prevent the regress of the Water. M. The Passage to the Hotwater Pump. N. The Plug tree by the motion of which the regulating Valves are opened and shut. O. One of the Posts which guide the Plugtree. P. The Beam Rod. Q.R.S.T.U. The Wheel to which the Piston Rod is suspended. V.W.X.Y.Z. The Wheel to which the Pump Rods are hung. 1. The Condenser Pump Rods. 2. A heavy Platform to which the Cylinder is fastened. 3. The Spring Beams. 4. 4. The Springs. 5. The Rod which connects the two Wheels which form the Working Beam. 6. The Pump Rods.



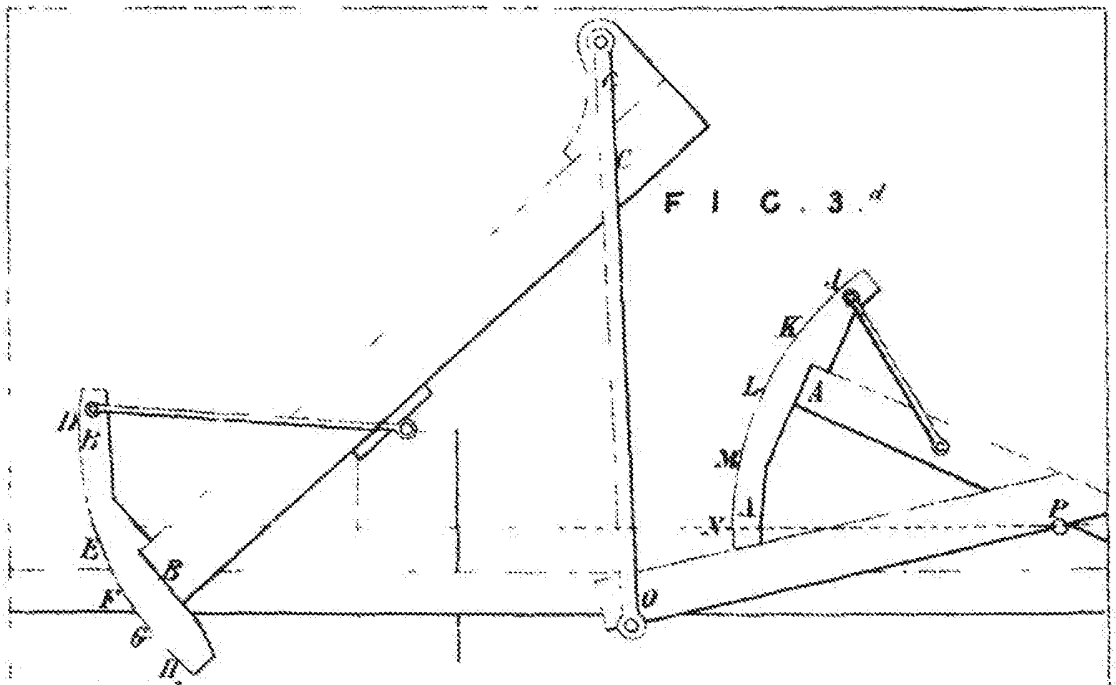


Fig 3d A Second View of the First Species of the New Equalizing Machinery
The Piston Rod is hung to the Arch A A and by means of the Rod OC pulls down the end C of the Beam BC to the Arch B of which y^e pump rods are suspended

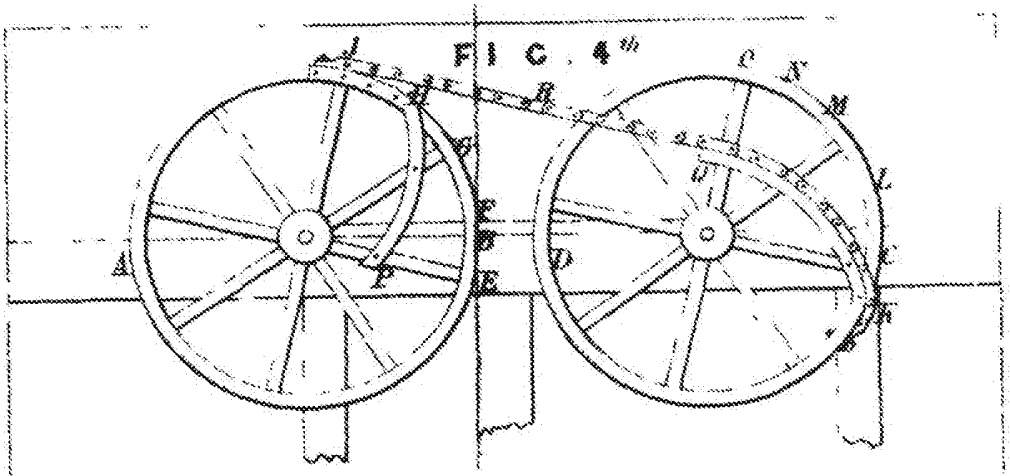


Fig 4th The Second Species of the New Machinery for Equilizing the Expansive Powers of Steam
The Piston of the Steam Vessel is hung by Chains or otherwise to the side A of the Wheel AB and by means of the Chains IRK and the Spiral Wheels IP & QK pulls round the Wheel DC to which the Pump Rods are suspended from the Arch OC.

The Scale of Figures 5th & 6th is one Sixth of an Inch for each Foot of the real Size of the Machines

FIG 5th

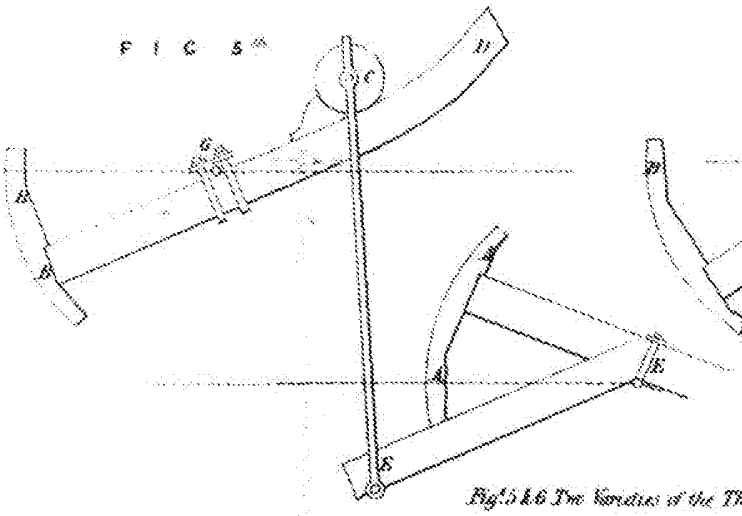


FIG. 6th

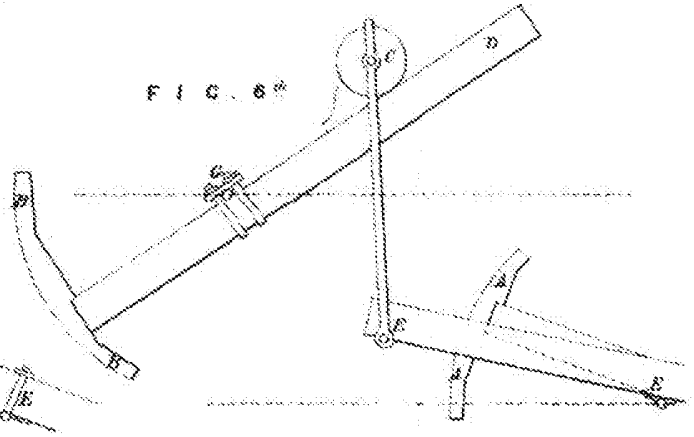


Fig.s 5 & 6 The Varieties of the Third Species of the New Machinery for Equalizing the expansive power of Steam.

55 The Arms E E and the connecting rods E C are supposed to be double in each Machine that a piston, chariot or rocker may go up between them.

The Piston Rods of the Engines are suspended from the A A and by means of the connecting Rods E C pull down the Friction Wheels C C and the ends of the Beams B B on which they run and, by the motion of these Friction Wheels on the Beams the lower arm (nearly) as the power of Steam diminish.

FIG. 7th

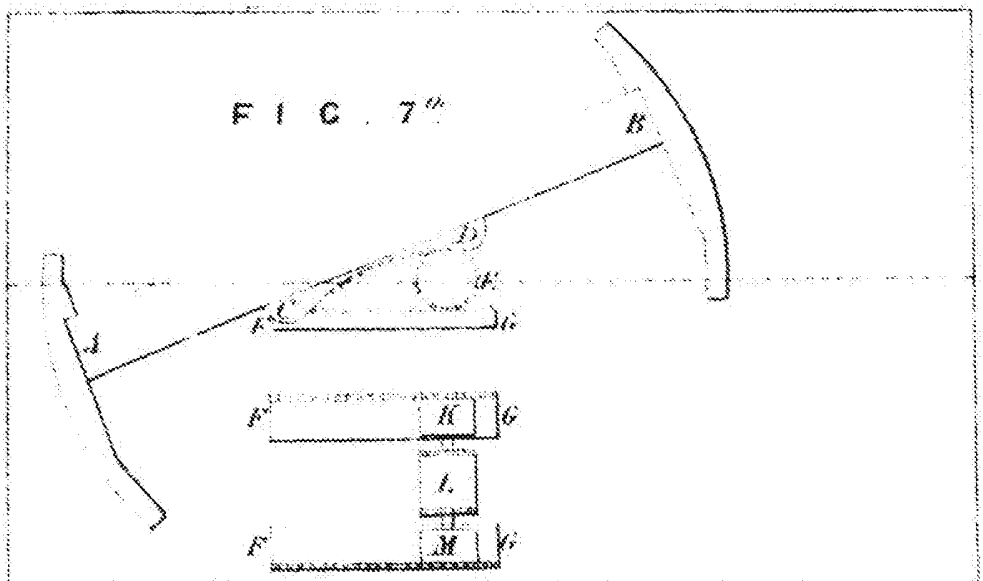


Fig. 7th The Fourth Species of the New Equalizing Machinery

A B. The Working beam. C D. A hollow Curve which rests upon the Roller E and is furnished with teeth to keep it from sliding. F G. A Flat Platform on which the end Rollers rest. K L M is a Horizontal View of the Rollers and Platform. K and M are fast on the axis and Learn turn round on it

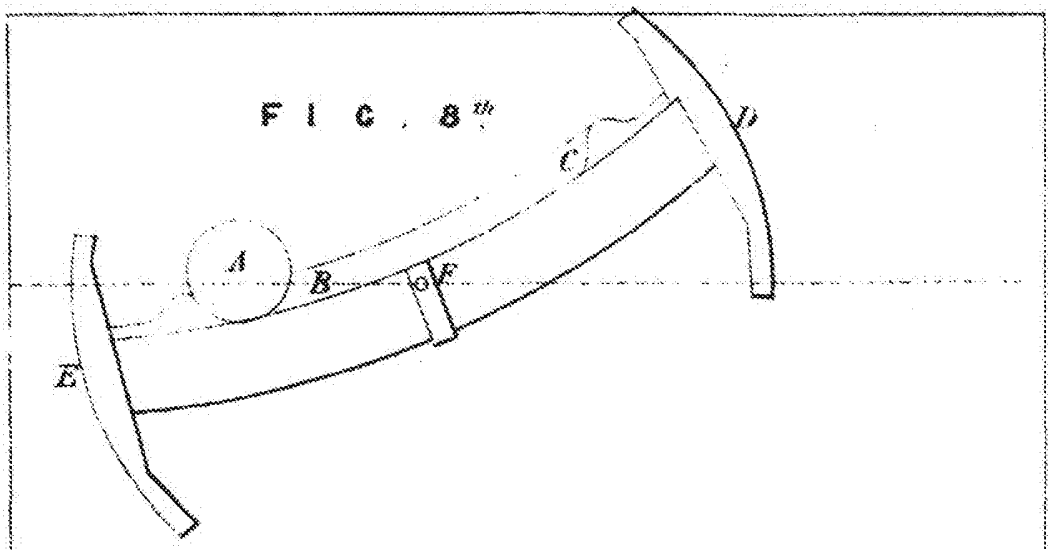


Fig. 8th The First Variety of the Fifth Species of the New Equalizing Machinery

E.D. The Working Beam. A. A. Weight which rolls in a hollow curve B.C.
F. The Axis or Gudgeon.

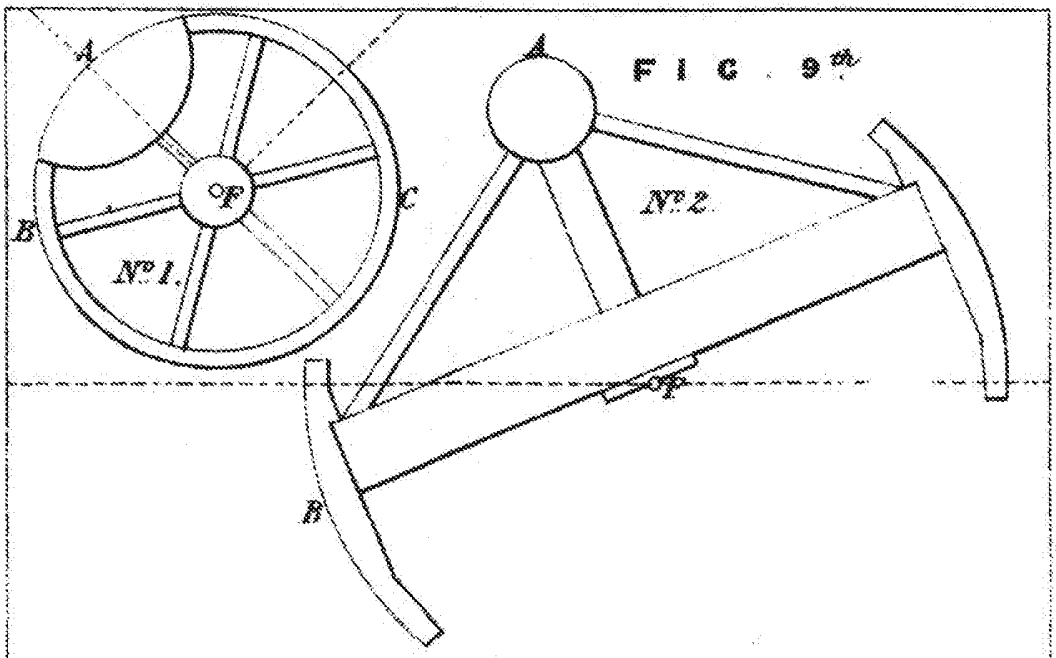


Fig. 9th Nos. 1 & 2. The Second Variety of the Fifth Species of the New Equalizing Machinery in Two Examples

A.A. The heavy Bodies placed or fixed above the Centers of motion of the Wheel B.C. No. 1, and of the Working beam B.C. No. 2. F.F. The Centers of motion.

FIG. 10th

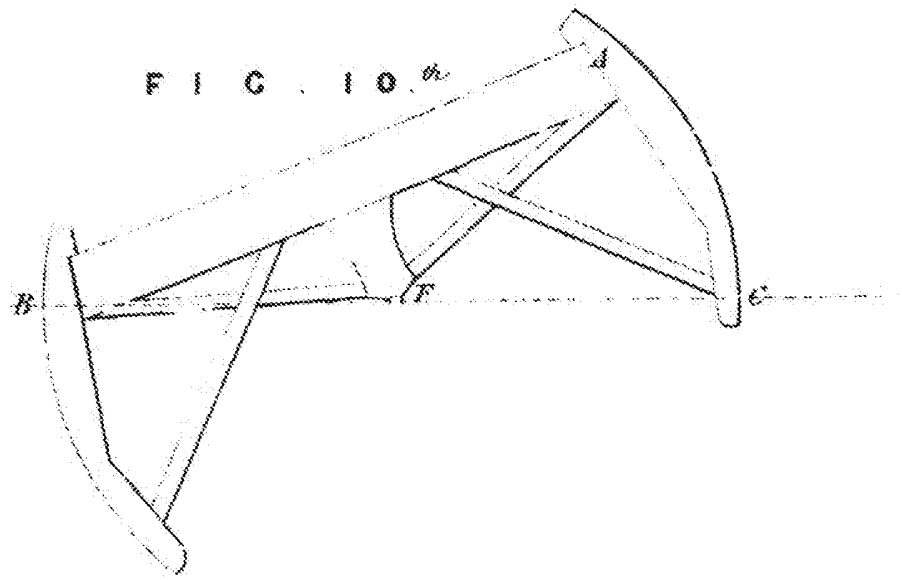
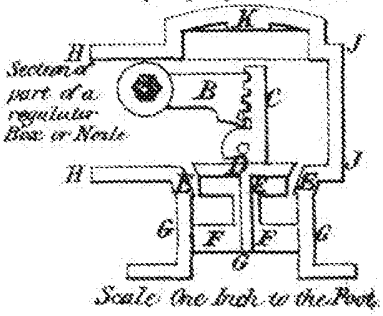


Fig 10th The Third Variety of the Fifth Species of the New Equalizing Machinery

A.B. The Working Beam which is placed so high above its Center of motion

F that its cen. Gravity acts the part of the Weight A in Fig. 9th

FIG. 19th



A Cross Section of a spindle which comes through the side of the Box and moves the Arm or Sector B which acts upon the Rack C which raises the Regulating Valve D which is ground to fit the Seat E.E. and is guided by the Socket F.F. G.G. The Pipe which leads to the Condenser K a Cover which is opened occasionally to rectify the Valve H.H. J.J. part of the Neale

FIG 11th

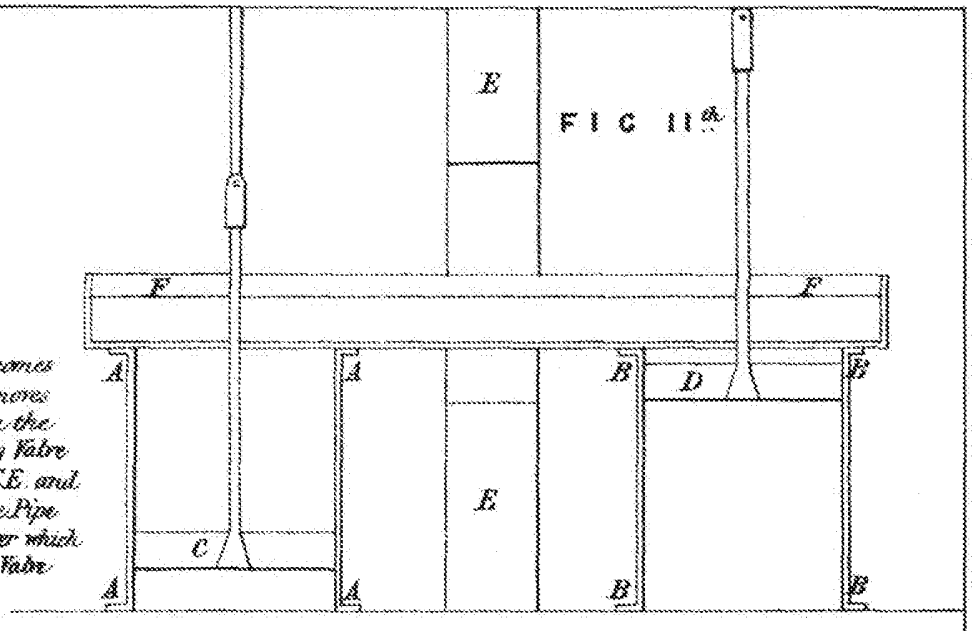


Fig. 11. The fourth Variety of the fifth Species of the New Equalizing Machinery. A.A.B.B. Two Cylinders containing water and connected by the Trough [F.F.] Their Pistons C & D are supposed to be suspended from the opposite ends of a Working Beam whose centre of motion or Gudgeon is supported upon the Wall E.E. and which Beam is so connected with the Piston of the Engine that when the said Piston descends it raises the Piston of the water Cylinder which is then lowest and thereby causes the water which it contains to pass by the trough into the other water Cylinder and by its gravity to assist the descent of ye Piston of the Engine

Fig 12th Represents the New Improved Engine the Piston of which is pressed forcibly both Upwards and Downwards by the Powers of Steam.

A The Piston. B.B. The Cylinder or Steam Vessel. C A Pipe which brings Steam from the Boiler to the lower Regulator Box or Nozzle. D The place of a Regulating Valve which admits Steam into the upper end of the Steam Vessel. E The place of the Regulator which admits Steam below the Piston. F The place of a Regulator which lets Steam go out from below the Piston into the Condenser. N Place of a Regulator which discharges the Steam from above the Piston. G.G. The Eduction or Condenser Pipe. H The Injection Pipe. I The Hotwater Pump. K The Air Pump. L A Valve at the Eduction Pipe foot. M. A Passage from the Air Pump to the Hotwater Pump. O.O. A Toothed Rack which connects the Piston Rod and the Working Beam. P The Piston Rod. Q.Q. A toothed Sector or Arch which also serves for a Weight to assist the Piston in its descent. Q.R. The Working Beam. S.S. The Pump Rod, which is made double when the Rotative Machinery is used. T The connecting Rod of the Rotative Machinery. V The Wheel fixed upon an Axis. W The Wheel fixed to the connecting Rod. V V The Fly. X.X. The Fly of the Reciprocating Rotative motion. Y The Pinion by means of which it is acted upon by the Working Beam. 9 The Pipe which brings Steam from the Boiler.

F I G . 1 2 th

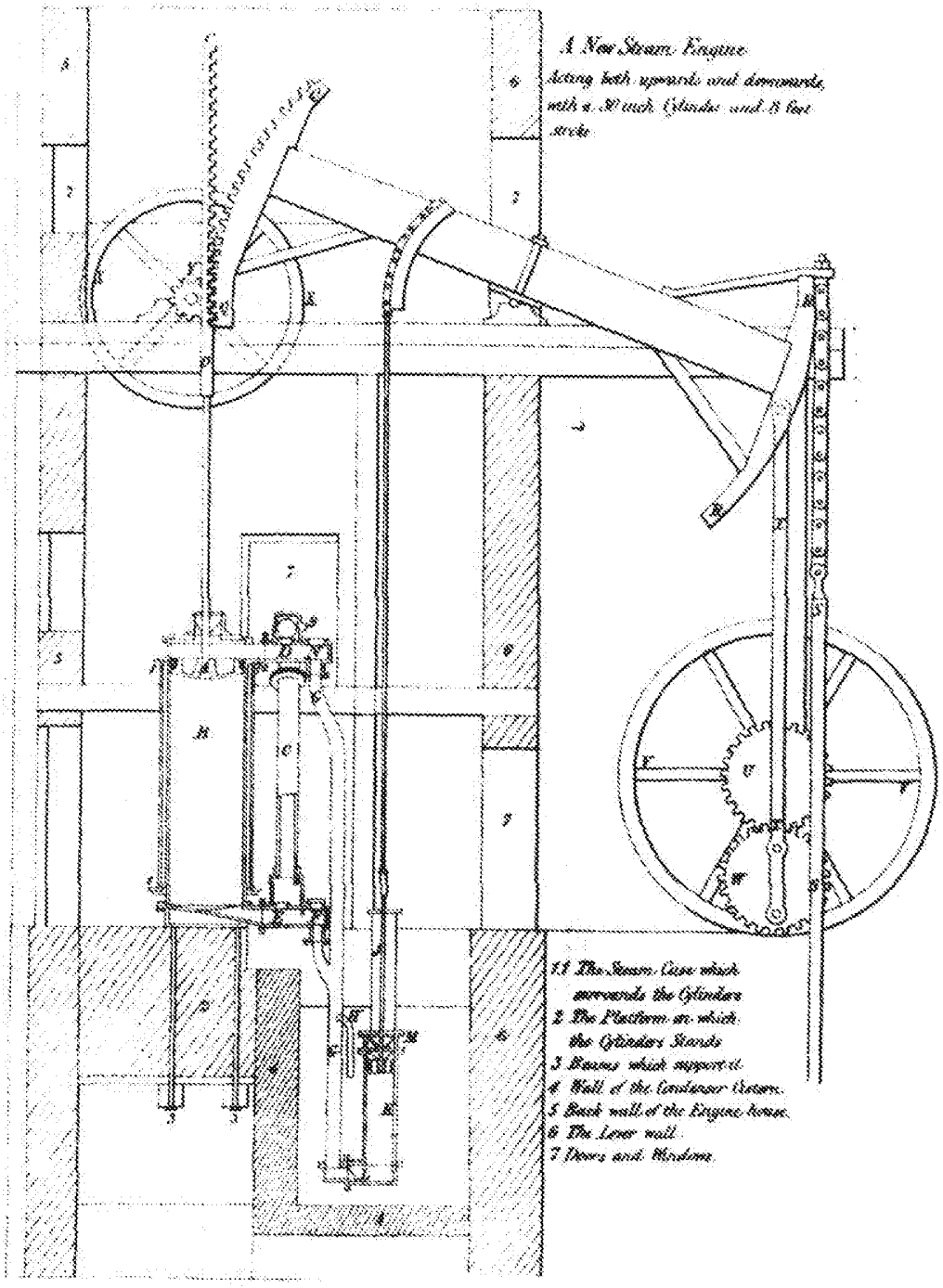
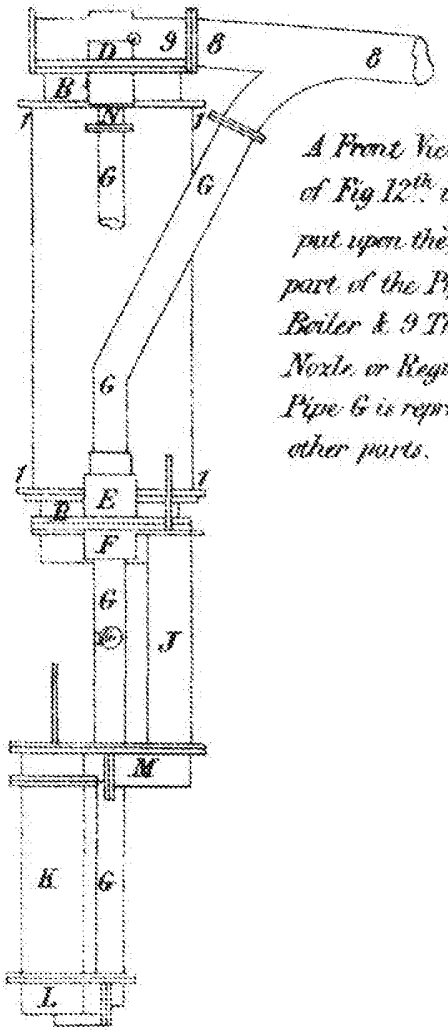


FIG. 13th.

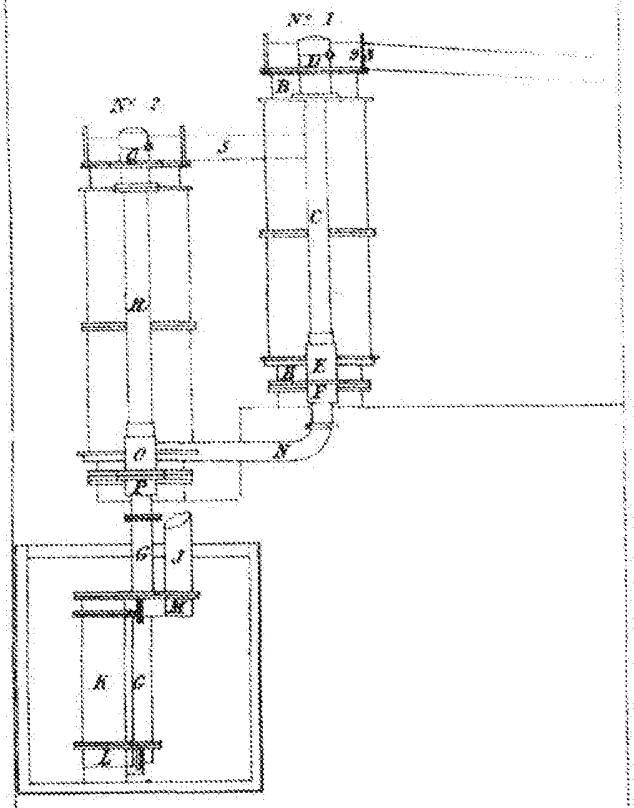


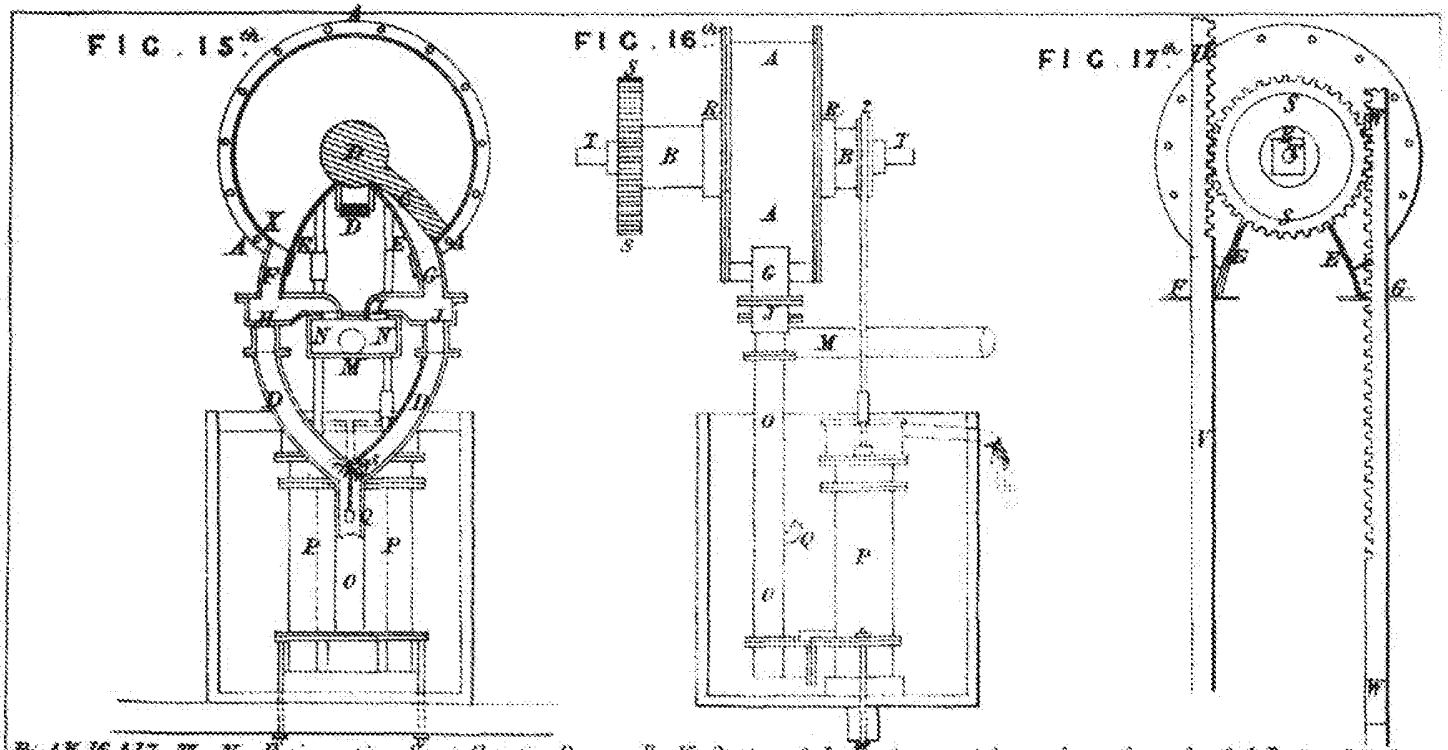
A Front View of the Cylinder and Condenser of Fig 12th in which the same Letters are put upon the respective parts and 8 B represents part of the Pipe which brings Steam from y^e Boiler & 9 The Cross Pipe fixed to the upper Nozle or Regulator Box. N8 The Eduction Pipe G is represented broken off to shew the other parts.

Fig 14th Represents a Front View of the New Compound or Double Engine as seen from the Low Wall.

N°1 The Steam Vessel and some other parts of the Primary Engine. N°2 The Steam Vessel and other parts of the Secondary Engine. D.Q. Places of the Top regulating Valves. C.R. The Perpendicular Steam Pipe. E.O. Places of the Middle Regulators. F.P. Places of the Bottom Regulators. N.G. Eduction Pipes. K.I. Air and Bottom or Pumps. M Pumps from the Air Pump to the Bottom Pumps. S.A. Pipe for communicating the Steam from the Primary Engine to the Secondary Engine instead of the Eduction Pipe N°. 8.9. Pipes which convey the Steam from the Boiler. B. These Engines may have each a Condenser, or the same Condenser may serve both, as is here delineated.
The Side View of these Engines would appear the same as Fig 2 or Fig 12 according to the Construction of their Working Beams. The Bottom Pump is broken off in this Drawing to avoid its interfering with the Eduction Pipe N.

FIG. 14.





Fig^s 15. 16. & 17. The New Reciprocating Semi Rotative Engine. Fig 15. Section of the Engine at right angles to the axle of y^e Engine Cylinder
A A The hollow Cylinder cut open. B The Axle or Axis C The Piston. D A Box filled with some soft substance to make the joining of the diaphram Plates.
E E with the axle Steam and Air tight. F G Pipes which admit and discharge the Steam. H K L A Plates of Valves or Regulators. M the Steam Pipe
from the Boiler. N N The Steam Regulator Box. O C The Eduction or Condenser Pipe. Q The Injection Pipe. P P Condensing Pumps.
Fig 16. A side view of the Engine wherein the same letters are placed in the same parts as in Fig 15. and R R. are Sockets to make the Axle air tight
and S S the Wheel which acts upon the pump rods. T The Wheel which works the Condenser. Fig 17. Outside Front View of the Engine and pump rods
The Condenser and Regulator Boxes are not drawn in this view and the upper part of the pump rod V V is supposed broken off. T The Pivot of the Axle
V V. W W. The Pump Rods and their Racks.

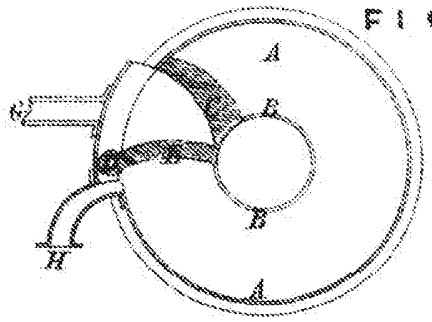


Fig. 18th. A New Rotative Engine.

The Steam enters by the Pipe G and acts against the Valve F and the moveable Radius or Piston C and the Space A A B B being exhausted, the Piston revolves thro' it by the action of the Steam, and turns the Axle B B. When the Piston comes to the valve F the pipe G is shut and the Valve E opens by turning upon the joint D and so permits the piston C to pass by it. The Steam then rushes into the Condenser by the Pipe H which exhausts the Steam Vessel. When the Piston has got to its original place. The Valve F again shut and the Steam admitted through the Pipe G into the Space between the valve E and the Piston C and so continue the motion during the time that the Piston is passing the valve. A heavy Fly is fixed on, or connected with some part of the axle B B on the outside of the Cylinder.

The outside figure of this Engine is nearly the same as Fig 16 but the Steam vessel may be placed either vertically as drawn " " or horizontally as its use may require.