THE ABORTION

OF THE

YOUNG STEAM ENGINEER'S GUIDE

CONTAINING

An investigation of the principles, construction and powers of Steam Engines. A description of a Steam Engine on new principles, rendering it much more powerful, more simple, less expensive, and requiring much less fuel than an engine on the old construction.	A description of a Machine, and its principles, for making Ice and cooling water in large quantities, in hot countries, to make it palatable and wholesome for drinking, by the power of Steam: invented by the author. A description of four other patented inventions.

ILLUSTRATED WITH FIVE ENGRAVINGS

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YOUNG STEAM ENGINEER'S GUIDE.

ARTICLE I.

OF STEAM.

OF all the principles of Nature, which man by his ingenuity has yet been able to apply as a powerful agent to aid him in the attainment of a comfortable subsistence, Steam, produced by boiling water, will perhaps soon be esteemed first in the class of the most useful for working all kinds of mills, pumps, and other machinery, great or small.

Water-falls are not at our command in all places, and are liable to be obstructed by frost, drought, and niany other accidents. Wind is inconstant and unsteady:animal power, expensive, tedious in the operation, and

unprofitable, as well as subject to innumerable accidents. On neither of these can we rely with certainty. But steam at once presents us with a faithful servant, at command in all places, in all seasons; whose power is unlimited; for whom no task is too great nor yet too small; quick as lightning in operation; docile as the elephant led by a silken thread, ready, at our command, to rend asunder the strongest works made by the art of man.

In our search for the means to apply this agent, we have wandered from the true path of nature. It has long been known, that steam confined would in all cases burst the vessel if a sufficient degree of heat were applied, and no vent given for it to escape; and it was equally well known, that if it had liberty to escape, no heat that we could apply would endanger the bursting of the vessel. Was there ever a plainer case presented to our view in all the works of nature, or an inference more easily drawn, than that by this agent we can obtain any power we may want, by the simple means of confining the steam and increasing the heat? or that to do this we had only to make our boilers strong in proportion to the power we wished to obtain. Yet philosophers have immortalized their names by wandering from this simple path of nature, leading the world astray to stumble in the dark for one hundred years, over the many obstacles which lay in the crooked way; by discovenng that steam might be used as an agent to drive the air out of a vessel, and that this steam could be instantly condensed again by a jet of cold water, and by these means form a vacuum in the vessel, that the air under the weight of the atmosphere, being suffered to rush into the vessel, would produce a power sufficient to work an engine. This was certainly a great discovery, and will ever remain useful; and being improved on, finally produced the greatest and most powerful engines ever invented by human ingenuity. *

*Here the reader should know, that the weight of the atmosphere (which is the air surrounding the earth), has been found to be equal to 15 pounds to every superficial inch of the area of the whole surface of the earth. This air, being so heavily pressed by

To philosophy we are indebted for many our most useful discoveries; yet this since case should put our philosophy to the blush, and teach us, however learned we may be, to listen with thc closest attention, even to what the most illiterate mechanician, who has taken the simple works of nature for his guide, may say. He would have pointed out to us, that it is much easier to apply the elastic power of steam simply to work the engine in the first instance. But we have shut our ears, and continue to use arguments to prove the application ot the simple principle impossible, even after it is applied to engines daily in operation before our eyes.

its own weight, insinuates itself into the cavities of all bodies; and inside as well as outside of all animals which move therein. They are insensible of the pressure, because the elastic spring of the air inside their bodies is exactly equal to its weight outside, and instead of pressing them to the earth it buoys up a part of their weight, the same as any other fluid does, in proportion to its weight, when they walk in it. When we walk in water we can hardly sink to touch the bottom, because the water is of greater specific gravity than our bodies. Balloons rise in air because they are lighter than their bulk of air: our bodies would sink but little in quicksilver. If we by any means extract the air from the inside of a vessel we form what is called a vacuum, there being no air inside to balance, by its elastic spring, the weight outside of the vessel, every inch of its surface being pressed inward by a weight equal to 15 pounds. Steam, let into a cylinder in which a piston is fitted to work, drives out the air, and the steam being condensed by a jet of cold water, forms a vacuum under the piston, and the weight of the air on the upper side presses the piston to the other end of the cylinder, with a power equal to 15 pounds to the inch of its area: thus steam has been used as the best means for forming vacua to apply the weight of the air as a power to move engines.

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ARTICLE II.

COMPARISON OF THE POWERS OF THE OLD AND NEW PRINCIPLES.

ON the principle of using the steam as an agent to form a vacuum, the power of the engine has never been made to exceed 12 or 15 pounds to the inch area of the piston. The vacuum being imperfect in all cases, the practice falls short of the theory; and the boilers being constructed of such form, as to be only sufficient to bear a power of steam, necessary as the agent, a little exceeding the weight of the atmosphere,* were subject to be blown up by overloading the safety valve; the load allotted being 3 pounds to the inch, it is very easy to double it to 6 or 12 pounds, by accident, when, if the steam does not get vent, the boiler explodes.

But on the new principle of working simply by the elastic power of the steam, the power may be raised with safety, from 12 to 120 pounds to the inch area of the piston, which makes this engine ten times as powerful as the other, and because the boilers are constructed of circular forms, (the best possible form for holding a great elastic power,) and so as to bear from ten to forty times the load that is generally required on the safety valve, which is not subject to be laid on by accident, this engine is by far the safest.

*When we speak of steam equal in power to the weight of the atmosphere (which we call atmospheric steam) we mean, steam produced by the boiling heat under the pressure of the atmosphere. 212 degrees, the boiling heat of water-170 degrees, the boiling heat of spirits of wine.

ARTICLE III.

ON SAVING FUEL, AND INCREASING POWER, BY

THE NEW AND SIMPLE PRINCIPLE.

A QUESTION naturally arises; what proportionate increase of fuel is required to increase the power? It has been generally supposed, that double fuel was requisite to produce double elastic power, and keep it up to work an engine; and consequently nothing was to be gained on that principle. Yet, had we closely observed the works of nature, how rapidly the power must increase to produce the effects we have often seen, we would readily have drawn another conclusion.*

*If a bottle of water tightly corked be set near the fire, the cork will presently fly out, or the bottle will burst with a loud report. Put half a gill of water into a musket barrel, ram a tight wad strongly down, put the barrel into a fire, and it will shoot with a force and report equal to powder. A coppersmith made a strong globular but small vessel for one of his customers,who next day came with the appearance of one just escaped from the grasp of death, to relate that he had filled the vessel with water, set it on the fire, and that after some time it exploded with the noise of a cannon; that he had narrowly escaped with life, and was determined never to try another experiment on the power of steam. Other accidents more tragical might be mentioned. But shall we refuse to use as much power as we want because we can increase it to a dangerous degree?

Observing the principles of nature, in the production of such accidental effects as before stated, I, in the year 1784, conceived the principles and arranged the means of working steam engines with a power equal to 10 atmospheres, and applied, in 1786, to the legislature of Pennsylvania for the exclusive right of propelling

Experience now teaches, that if 4 pecks of fuel per hour, will heat a quantity of water to produce steam of elastic power equal to 15 pounds to the inch, or equal to

land carriages by steam in that state, for twenty-one years; but they conceived me to be deranged, because I spoke of what they thought impossible, and refused. I applied next to the legislature of Maryland, who granted me the exclusive right for fourteen years, because, said they, it can injure no man and may cause him to produce something useful. This term I conceived to be too short; the grant however, had the effect to prevent me from relinquishing my studies on steam: time will shew the better policy of the legislature of Maryland in this case.

I cannot suppose that any person, who understands the principles of mechanics, after having seen a rocket rise into the air by the reaction of its fuse, under all the disadvantages with which the power there acts, and after having known that the power of steam is equal to that of the fuse, could any longer doubt of the sufficiency of the power of steam to do any thing, even to carry the whole engine up into the air. If so, why will it not do to propel carriages and boats? For twenty-one years last past I have been endeavouring to convince my countrymen, that principles do exist by which steam engines can be made useful in all cases where a powerful agent is wanted. I sent, early in 1795, drawings and specifications to England and had them shown to engineers there, all without effect. I am sorry to relate, that seventeen years passed before I could conceive it to be my interest to expend one thousand dollars, to try experiments to put my principles in practice. In 1801, I commenced, and at the expense of two thousand dollars, besides my own labour and time, valued at one thousand dollars more, I at last produced an engine realizing in practice the whole of my theory. Having now made perhaps the greatest improvement, and most useful invention on steam engines ever produced by any one man, I expect to be attacked from all quarters: in every state in the union will, no doubt, be found one or more inventors who have made the same invention, as was the case with my improvements on merchant flour-mills, after they

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one atmosphere, 5 pecks consumed per hour, will produce steam equal to 30 pounds the inch, or two atmospheres, and keep the power up to work an engine; * holding true in practice, that every addition of a small quantity of fuel to be consumed in an equal time, doubles the elastic power of the steam, and keeps it up to work an engine; double fuel producing about 16 times the bulk, consequently 16 times the power and effect. This will not appear doubtful, after we are informed, that philosophers have made a set of accurate experiments, to ascertain the elastic power of steam produced by different degrees of heat, from which they deduced the following formula or rule, viz. That every addition of about 30 degrees of heat, by Fahrenheit's thermometer, to the water, be the temperature what it may, doubles the bulk and elastic power of the steam.

were published. In that case I was attacked from a quarter from which I could not possibly expect it; but the justice of my country continues to give me the honour (I wish I could say, and the profit) of my invention.

*1089 pounds of dry oak are equal to 600 pounds of Newcastle coals, in producing equal quantities of heat. Repertory of Arts, series ii. vol.1.

See the experiments in the American edition of the Encyclopedia, vol.17, from which the following scale is constructed.

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SCALE OF THE ELASTIC POWER OF STEAM, PRODUCED

BY DIFFERENT DEGREES OF HEAT IN THE WATER.

Degrees of heat in the wateradding 30 degrees every step	Elastic power to the inchare of piston, or safety valve.	Atmopsheres
212 gives 30	15 pounds, equal to	1
242 30	30	2
272 30	60	4
302 30	120	8
332 30	240	16
362 30	480	32
392 30	960	64
422	1920	128

By this scale it appears that doubling the heat from 212 to 424 degrees in the water, produces 128 times the elastic power of steam; and that as the heat is increased

in an arithmetical progression, by the addition of 80 degrees, the elastic power of the steam is increased in a geometrical ratio, multiplying by 2. But this may be only true at or near the heat of 212 degrees; the geometrical multiple being greater than 2 below 212 degrees, and less than 2 above 212 degrees of heat; falling short 15/1000 parts, at every step of 11 1/4 degrees increase of heat, as has been the result of another set of experiments, made by Dalton.* So that doubling the heat in the water, may not produce more than 75 or 100 times the elastic power of steam.

Let us suppose it to be true, as was heretofore believed, that double power of steam requires double fuel to produce it; then by the scale, if 212 degrees of heat give power equal to 15 pounds, and require 1 bushel of fuel, 242 degrees giving 30 pounds power, will require 2 bushels, and so on to the end of the scale. 424 degrees of heat, double 212, would require 128 times the fuel to produce it, which is quite absurd. It is much easier to conceive, that double heat would produce 128 times the power. Although double fuel will not produce near double heat, yet it is easy to conceive, that it may give

*See the Repertory of Arts, vol i. series 2.

Although experiments have been made with great care and accuracy, to ascertain the fact as to the rapidity of the increase of the power of steam, compared to the increase of heat in the water, yet I find no attempts made to apply the principle, nor even a suggestion to that effect, in any of the books that have ever fallen into my hands. But the result drawn by Dalton cannot be true, because his scale continued, the increase of the elasticity by the increase of heat, would entirely cease before the power could be augmented sufficiently to produce the effects which have been produced.

such heat, as will produce 16 times the power. We should observe also how rapidly the proportionate quantity of heat diminishes, which is required to be added, in order to gain power, as the water rises in temperature.*

SCALE OF EXPERIMENTS.

Temperature of the water Degrees	Elastic power of steam lbs.	Proportional heat to be added to the temperature which the water may be in, to double the power
10	.11	3
40	.23	.75
70	.46	.42
100	.93	.30
130	1.87	.23
160	3.75	.19
190	7.5	.16

220	15	.14
250	30	.12
280	60	.11
310	120	.09
340	240	.085
370	480	.08
400	960	

By this scale of experiments, it appears, that when the water was in the temperature of 10 degrees, the elastic power of the steam was but

11/100 parts of 1 pound to the inch, and the heat required to be tripled, by adding 30 degrees to double the power. But when the heat was raised to 220 degrees, the power was 15 pounds, and required but 14/100 parts of the heat to be added, or 30 degrees to double the power to 30 pounds. Here 30 degrees increase of heat gained 15 pounds, whereas in the low temprature of 10 degrees, the 30 degrees added, gained but 12/100 parts of 1 pound. When the

*See the American edition of the Encyclopedia, vol 17.

water is heated to 370 degrees, and the power of steam raised to 480 pounds to the inch, it requires but 30 degrees additional heat, or 8/100 parts of the heat of the water, to be added to gain 480 pounds more power. If the reader has faith to believe thus far, he is ready to ask, by what unaccountable law of nature is the elastic power of steam produced in this ratio, so variable as to the quantum of additional heat, required to gain a given quantity of power? for hy the last addition of 30 degrees of heat in this scale, we gain 4363 times as much power as by the first addition.

I answer, it is enough for us to know by experience that it is so, to enable us to avail ourselves of the application of the principles. It clearly points out to us the great gain tobe had by working with high temperatures; for if doubling the consumption of fuel produces six. teen times the bulk and power of steam, it enables us to produce eight times the effect, with equal quantities of fuel, and I am inclined to believe, that the application of the principles may be improved to that extent. But we should not rest satisfied, until we are able to assign philosophical reasons why it is so, which leads us to treat of heat.

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ARTICLE IV.

OF HEAT.

HEAT, I conceive to be an elementary principle, existing as a component part of all substances, but in different proportions. Combustibles contain the largest quantities, in that state which Dr. Black, the celebrated Lecturer on Chemistry, has called a latent, or state of secret inactivity.

Combustion is the operation by which this latent principle is excited into action; all that is contained in the body or matter consumed, as well as all contained in the air used in the operation, is changed into a state of activity, susceptible of being transmitted from one body to another, until it finds rest or becomes latent again. The principles are too mysterious for our comprehension, we can only observe the effects. We can see that heat in the operation of combustion, appears to melt the fuel, or dissolve it into a fluid, so thin and rare as to be imperceptible. It is dissipated and flies away into the air, where the heat becomes latent again. The expansive force of fluids formed by heat, is the subject under consideration; the atmosphere is the great reservoir into which all active heat returns to a latent state.* Let us suppose each column of the atmosphere, whose base is equal to a square foot, contains an equal quantity of latent heat, of water in a state of vapour, and of the permanent elastic fluids; and suppose one of those

*It may pervade all space, which ancient philosophers held was filled with what they called ether.

columns of air to be included in a cylinder, and compressed into half the space; then, by the Boylean law, (see article 6) it would have double elastic power, if compressed into one tenth part of the space, ten times the elastic power, if into one hundredth part of the space, one hundred times the power, &c. The aqueous vapour would be pressed into hot water, in the bottom; the latent heat would become active, heat the cylinder, escape into the surrounding air, and then become latent again. Then if the piston were suddenly drawn up, the alr could not expand to its original bulk, having lost its proportion of latent beat and water, until that proportion would be restored. That the results would be as stated has been proven.* These serve to shew that compressed air or strong elastic steam do not contain as much heat in a latent state as weaker, in proportion to their power, and that the Boylean law is an error.

If heat be applied to melt ice of the temperature of 32 degrees of Fahrenheit, 147 degrees of it find rest in

*See the American edition of the Encyclopedia.

Experiments were made to ascertain the elasticity of air, in proportion to its density, by condensing it in a cylinder with a piston. It was found that double density did not produce quite double elasticity, nor quadruple density quadruple elasticity, &c. The experimenters were surprised to find, that great compression made the cylinder hot, and filled a vial, which they had inserted in the bottom of the cylinder, with water. From this experiment we may safely infer, that air and steam do not contain heat in direct proportion to their density, but rather in an inverse ratio, that is, the greater their density the less latent heat they contain in the space they occupy; that a vacuum contains more latent heat than a plenum, and that the atmospheric air is not a permanent elastic fluid.

the water made by melting the ice, and is necessary as a constituent part of the water to keep it in a fluid state, latent and imperceptible to the thermometer, which indicates it to be of the same temperature the ice was in. If we continue to apply heat to the water until we raise its temperature to 212 degrees, it will begin to produce elastic vapour, equal in power to the weight of the atmosphere, which it now lifts and continues to resist. In this vapour under the pressure of the atmosphere, from 800 to 1000 degrees of heat, returned into a latent state, find rest; being, under that pressure, a constituent part of vapour, and necessary to continue it in that state; the thermometer indicating the same degree of heat as of the boiling water, which is 212 degrees. This is proven by Dr. Black.*

If the weight of the atmosphere be taken off the water, it will boil at 70 degrees of heat; but in this case, 1300 or perhaps 2000 degrees of heat in this weak vapour, find rest or become latent rising under no pressure. The less the pressure on the surface of of boiling water, the more heat is required to raise it all into vapour; on the contrary, the greater the pres- sure, or the greater the elastic power of steam, the less the heat or fuel required to raise it all into vapour. The heat cannot find room, amongst the particles of strongly compressed steam, to become latent, but remains active to increase the power. If we increase the pressure on the surface of the water from 1 to 8 atmospheres, it will not boil until the heat be increased 90 degrees above

*See his Lectures, vol.1.

See the celebrated James Watt's experiment to distill in vacuo. Black's Lectures vol 1.

212; that is, 302 degrees, when the power of the steam will be 120 pounds to the inch. (See the scale, art. 3). The water will then begin to boil, and the steam to rise, lifting the weight of 8 atmospheres an equal distance in equal time, which may be compared to a load on an engine. Here it appears that, after the loss of heat occasioned by its becoming latent ceases (as all that loss takes place in raising the temperature the first 212 degrees), we can, by the addition of the small quantity of fuel which will be required to increase the heat 90 degrees, gain 8 times the power, produce 8 times the effect, or carry 8 times the load an equal distance. But we will shew, in the proper place, that steam of power equal to 8 atmospheres can be applied to work an engine, to produce much more than 8 times the effect. See art. 7, where it is shewn that it produces 22.6 the effect, or perhaps 32 times.

As heat appears to melt or dissolve the fuel in combustion, into a thin elastic fluid, with which it passes off into the air to return to a latent state; so it appears to dissolve the water into a much thinner fluid called elastic steam, with which it passes off into the air, there to find rest in a latent state. The quantity of beat passing off, appears to be in some ratio to the space into which the steam is permitted to expand and occupy; perhaps in direct proportion, that is, double space may be capable of receiving double quantity of heat in a latent state. One cubic inch of water rising freely into steam in vacuo, carried with it 1300 or perhaps 2000 degrees of heat in a latent state, while the same quantity rising under the pressure of the atmosphere, which confines the steam to a less space, carried off but 1000

degrees of heat in a latent state; from which we may safely infer, that as the pressure is increased from 1 to 2, and so on to 8 atmospheres, or the steam confined to a smaller space, by giving it a greater load, that the heat carried off in a latent state will be lessened from 1000 to 750, 500, 250, 125 degrees, or in some other ratio not yet ascertained.

As heat enters water, formed by melting ice, slowly, and becomes latent in the water, so it also leaves the water slowly, becoming sensible or active again as the water freezes. But on the contrarry, as the heat leaves hot water quick as lightning (comparatively speaking) when the compression is taken from off its surface, be coming latent in the form of elastic vapour, so also it leaves the vapour instantly, to enter water or other matter of a lower temperature, and the vapour is condensed, forming the same quantity of water which was used in its formation; the heat becoming active and sensible to the thermometer, which will indicate the rise of temperature in the water used to condense it: all which has been proven by Doctor Black, although not shewn in the very same point of view.* When we consider the irresistible power of steam, we may say, with propriety that we have at our command a physical agent, whose operations are quick as lightning, and powerful as thunder.

From the foregoing facts we may safely draw the following inference, viz. That the quantity of water necessary to condense any quantity of elastic steam, under any pressure, will be such as is just sufficient to

*See his Lectures, vol 1.

receive all heat from the steam, into the water, leaving it of the temperature at which water is just ready to boil under such pressure; therefore the colder the water, the less will be required. If the condensation be made under no pressure, or in a vacuum, it will require a much larger quantity of cold water, because it will not bear to be heated to 70 degrees, the boiling heat of water in vacuo.*

*A competent knowledge of those principles, leads us directly to the discovery of a variety of curious and important improvements and inventions, which may lead on to others, viz.

1. Steam engines which will be inexhaustible in their operation. Once filled with water they will require no supply; no sediment can accumulate to cause the boilers to burn out; they will therefore last much longer.

2. Stills to suppress the watery vapour and essential oils which give the spirits a bad flavour, and to take off the spirits pure at one operation, which may be made perpetual, or without intermission.

3. Boilers for distillers and brewers, by which their largest vessels can be heated to any degree, in a much shorter time, and with less expense.

4. Inexhaustible boilers for heating apartments where fire would be dangerous, if used in the common way.

5. Furnaces and boilers may be so constructed, that all the heat, which in common furnaces ascends the flue or chimney, may be poured immediately into the water, to generate steam; and all the elastic fluid generated by the consumption of the fuel, applied to aid the steam in working the engine; lessening the weight of the engine to about one-tenth part, and the consumption of fuel to about one-fourth part, and yet produce as much power as the best English engines. An engine thus constructed will be the most suitable for

the great purposes of propelling boats against the stream of the Mississippi, and carriages on turn-pike roads, &c.

Here it appears almost impossible to form a perfect vacuum, by condensing the steam with water, by the use of condensers to steam engines; all their use being to take off the resistance of the atmosphere, which can be effected in part only, and considering the very small quantity of additional fuel required to overcome that resistance, their advantages seem to vanish. For if the condensing water be heated to 160 degrees, then, by the scale of experiments, (art. 3.) the power of steam left in the condenser will be 3.75 pounds to the inch; this deducted from 15 leaves 11.25 pounds, which is all the resistance taken off by the condenser. Again, if we supply our boiler with this condensing water of the temperature of 160 degrees, it will lower the temperature in the boiler perhaps 30 degrees, from 310 to 280 degrees, and by that means reduce the elastic

But the expense of the experiments necessary to bring these principles into operation would be too great. No prudent man will risk the attempt, until the prospects of a sufficient reward brighten. We unite in a belief, that fate has ordained that the ingenious man shall never be rich; not considering that it is the injustice and impolicy of most governments, that have passed the decree. Who would get rich if the property he acquired by his industry was to become common as soon as he gained it? or even if it was to be the case at the end of fourteen years. What prudent man will spend his thoughts, time, labour and money, for property no better secured to him. Ingenuity makes none poor, but on the contrary, has made many rich, whose prudence directed them to the pursuit of permanent property. To ingenuity we owe all our superiority over savage nations. England has made herself more rich and powerful than other nations, by her more liberal policy of securing to ingenious men, the exclusive right to their inventions, so long as to afford them an opportunity of being amply rewarded.

power of the steam from 120 to 60 pounds, (see the scale, article 3.) which would be losing 22.4 pounds, the average of 60 pounds, to gain 11.25.* (See the scale article 6.)

RECAPITULATION.

I have shewn,

1st, That a great quantity of heat is expended in raising the temperature of water to a boiling degree, or 212 degrees, to produce steam of elastic power only equal to the pressure of the atmosphere, which is equal to 15 pounds to the inch surface of the water.

2dly, That the elastic power of the steam increases in a geometrical ratio, as the heat increases in an arithmetical ratio; every addition of about 30 degrees or heat in the water, doubling the elastic power of the steam; so that doubling the heat of the water increases the power of the steam about one hundred times.

3dly, That the proportional quantity of heat to be added to double the power, decreases in a rapid ratio as the heat in the water increases; that by adding 30 degrees of heat to the high temperature of 370 degrees, we gain 4363 times as much power as we gain by adding 30 degrees to the low temperature of 10 degrees.

4thly, That the heat escapes in a latent state in weak steam, in much greater quantity in proportion to the power, than it does in strong elastic steam; that this loss of heat in a latent state may be in direct

*But if this supply-water be driven first into a vessel, through which the flue of the furnace is made to pass, to heat it to the temperature of the water of the boiler before it enters, it will not then reduce either the heat or power of the steam.

proportion to the space in which the steam is suffered to expand. This has been proven by John Dalton.*

1st, He placed a thermometer in the centre of a large receiver, and condensing the air by forcing more in, the thermometer rose quickly several degrees, and opening the cock to let the air escape, it sunk quickly several degrees lower than the temperature of the atmosphere. Why were these effects produced? I answer, because when the air was condensed, there was not room for the heat to remaln in the receiver in a latent state; and in its efforts to find room, it became active, ran into the thermometer, expanded the quicksilver; and caused it to rise: but if left in that state, the heat soon passed through the glass receiver, and an equilibrium being restored, the thermometer settled to its proper degree. When the cock was opened, the air escaping, left more room for latent heat than could be filled by the heat left in the receiver, therefore the heat in the thermometer left it, and the mercury contracted and fell to meet the temperature of the space inside of the receiver, but being left in that state, the equilibrium was soon restored, by the heat of the surrounding atmosphere entering through the glass receiver.

2dly, Exhausting the receiver, the thermometer fell suddenly several degrees, because this increased the capacity of the space within the receiver for receiving and retaining heat in a latent state, which deprived the thermometer of its heat. But an equilibrium was soon restored, by a supply from the surrounding atmosphere.

*See his experiments...Repertory of Arts, vol. ii. series 2.

These experiments clearly prove that a vacuum has a greater capacity for heat in a latent state than a plenum; and no other inference can be rationally drawn from the premises. They also clearly account for the wonderful effects produced by my new principle of confining the steam, and increasing the heat in the water, by which the elastic power of the steam, is increased; so that doubling the fuel, produces about 16 times the effect; enabling us, with small, simple, and cheap engines, to obtain power equal to the larger, more complex, and expensive ones, heretofore used, and with one-third part of the fuel. Although we cannot account philosophically for all these operations of nature, yet we may be satisfied with a knowledge of the facts.

It appears therefore, that to begin to use steam when it has arrived to only atmospheric power, is to stop at the point where the heat begins to produce power without loss, after which every degree of heat we add, serves with effect to increase the power in a rapid ratio. The less we confine the steam, the more fuel will be necessary; and the more we confine the steam, or the heavier we load the engine, the less fuel will be required to produce the effect we wish. Every stroke of the engine will draw off nearly an equal quantity of heat, let the load be light or heavy, and we may at least safely eonclude, that the increase of fuel or heat used, will bear no proportion to the increase of load. (See art. 3,)

ARTICLE V.

OF THE CONSTRUCTION OF BOILERS.

As we mean to work with steam of great elastic power, say 120 pounds to the inch, above the atmosphere, it is necessary, in the first place, to discover true principles, on which we may calculate the power exerted to burst our boilers, by any given power cf the steam; that we know how to construct them with a proportionate strength, to enable us to work with perfect safety.

A circular form is the strongest possible, and the less the diameter of the circle, the greater elastic power it will contain. Therefore we make cylindric boilers not exceeding 3 feet diameter, and to increase their capacity we extend their length to 20 or 30 feet, or more, or increase their number. They must be set nearly in a horizontal position, with the furnace under one end confining the flue to the underside to the other end; giving the fire a large surface to act on. This is the most simple form and suits well where fuel is cheap. But to save fuel we construct boilers consisting of two cylinders, one]nside of the other; the inner a little below the centre of the outer one, when laid in a horizontal position, to give room for steam, in the upper side above the surface of the water. They are of equal length, both made list to the same heads or end-plates. The space between them contains the water, and the inner one contains the fire, which is surrounded by the water. This boiler is enclosed in brick work, and the flue returned along the under side of the outer cylinder which gives the fire a larger surface to act on, than the other plan, and will not re-

quire more than two-thirds of the fuel; but it is much more expensive to make.

These boilers are made of the best iron, rolled in large sheets and strongly riveted together. The ends may be made of soft cast iron, provided the fire or flue be kept from immediate contact with them. As cast iron is liable to crack with the heat, it is not to be trusted immediately in contact with the fire.*

To ascertain the power exerted by the steam, to burst one of these boilers, and the thickness of iron necessary to hold it; let us premise, that it is known by experiments made with care, (see art. 11) that a bar of good, sound, wrought iron, 1 inch square, will bear from 68 to 84,000 pounds, (but let us say from 64 to 75,000 pounds) hung to the end of it, to pull endwise, in a fair straight direction; consequently a bar one-tenth of an inch thick, and one inch wide, will hear at least 6400 pounds.

RULE.

Multiply the diameter of the boiler in inches, by the power of the steam in the boiler, in pounds, shown by the weight on the inch area of the safety valve, and the product is the power the steam exerts to break each

*It has been said that using a great degree of heat will burn the stuffing of the piston of the engine. But I have boiled linseed oil in a wooden boiler, with a furnace inside of it, without burning the wood, which will not bear a greater degree of heat then the hempen stuffing, and by the scale of heat(art.11) linseed oil boils at 600 degrees of heat. If the scale(art.3) be continued or extended to that degree of heat in the water, the elastic power of steam would be 122,880 pounds to the inch, which shows the futility of such objections, even supposing the scale to be incorrect, and that linseed oil will boil at a much lower degree.

ring of one inch wide, in any two opposite places. Take half of that product for the power to break it in any one place, and divide by 6400, and the quotient will be the thickness in decimal parts of an inch, that the iron must be to hold that power.

EXAMPLE.

What is the power exerted to burst a boiler 36 inches diameter, when the steam is ready to lift the safety valve loaded with 1500 pounds to the inch? and what thickness must the iron be to hold that power?

Then by the rule, 36 multiplied by 1500, the product is 54,000 pounds, the power to break every ring of 1 inch wide in any two opposite sides: and 54,000 divided by 2 quotes 27,000 pounds, the power exerted to break each ring of 1 inch wide in any one place; and 27,000 divided by 6400 quotes 42/100 parts of an inch, the thickness of the sheet iron that will hold that great power, of 1500 pounds to the inch. Few will believe this until they clearly understand the pnnciples. I proceed therefore to demonstrate the rule to be true.

DEMONSTRATION.

Suppose the circle, 36 inches diameter, be inscribed in a square, whose sides are 36 inches in length; draw diameters to the circle, parallel to the sides of the square; and, suppose steam to exert a power in the square, equal to 1500 pounds to each inch; it is evident that there will be 1500 pounds on every inch of the length of any two opposite sides, exerted in opposite directions balancing each other, to separate the sides, which are held together by the other two sides; add that to find

the power exerted to break any two opposite sides, we must multiply the length of one of the sides, 36 inches, by 1500, the power of the steam, and the product is 54,000 pounds, to break the two sides; half of which is

27,000, to break one side in any one place.

Again, suppose the circle to intercept the steam from acting on the square, then it is evident that each semicircle intercepts the steam which acted against its corresponding side of the square, and that the power to break the circle in any two opposite places is just equal to the power to break the two sides of the square; which was to be demonstrated.

This may be demonstrated by the proportions of the circle, and the known laws of mechanical powers. Let us suppose the circumference of the circle, which is 113 143/1000 inches in length, to be a cord with one end made fast, and a power be applied to draw the other end of it in a straight line, so as to draw the whole l13 143/1000 powers of the steam, 1500 pounds each, amounting to 169,714 5/10, up to the centre; then these powers multiplied into their distance moved, which is 18 inches, will produce 3,054,865; and the power at the end of the cord, 27,000, multiplied into its distance moved, viz. the whole length of the circle, 1l3 143/1000 inches, produces the same sum, 3,054,865, agreeing with the known law of mechanics, viz. that the power inultiplied into its distance moved, is equal to the weight multiplied into its distance moved. The power at the end of the cord, 27,000 pounds, representing the strength of the hoop necessary to hold a power of 1500 pounds to the inch,

exerted inside of it: which was to he demonstrated.

I have never found a solution of this so useful problem that so often occurs in practice, in arranging steam engines, water-works, pipes of conduit, &c. And, no doubt, but the simple rule, here laid down, will meet with opposition; but it is nevertheless true, and will stand the test of time and experiment. I rejoice at having discovered, that a circular vessel will hold a far greater power of steam than I at first conceived it would.

In order that we may work with a power of steam equal to 120 pounds to the inch, with peffect safety, I have, by the rule already demonstrated to he founded on true principles, calculated the following table, shewing the power exerted to burst each ring of 1 inch wide of the boilers of different diameters, and the thickness of iron necessary to hold steam of power equal to 1500 pounds to the inch area.

A TABLE

OF THE DIAMETERS AND STRENGTH OF BOILERS.

Diameter of the boiler ortube in inches	Power to break everyring of one inch ofthe boiler in anyplace, in pounds weight,when the steam is1500 pounds to the inchon the safety valve.	Thickness of thesheets of goodiron necessary tohold the power,in decimal partsof an inch	Power exertedon the headsto burst themout, in poundsweight
42	31,000	.48	2,077,500
40	30,000	.46	1,884,000
36	27,000	.42	1,525,500
30	22,500	.35	1,069,000
25	18,750	.29	735,000
20	15,000	.23	471,000
15	11,250	.17	
12	9,000	.14	
10	7,500	.12	
8	6,400	.094	
7	5,250	.082	
6	4,500	.07	
5	3,750	.058	
4	3,200	.047	
3	2,250	.035	
2	1,500	.023	
1	750	.012	

Diameter ofthe boiler ortube in inches	Strength of boilerto hold the head on,in punds weight	Number of inchscrew boltsnecessary to have strengthsufficient to hold on the heads	Thickness of the cast iron head in the middle in inches
42	4,052,400	32	5
40		29	4,5
36	2,037,440	24	4
30		16	3.5
25		11	3
20	918,777	8	2.5

A boiler constructed from this table will hold steam with power equal to 1500 pounds to the inch; a power almost beyond conception, and which we will never need to work any engine. To find the numher of inch screw bolts necessary to hold on the head, divide the force to burst the head off; by 64,000, the strength of one bolt.

to the end, where it should just balance the atmosphere when another valve opens to let in a similar puff of steam to drive the piston up again; while other valves open to let the steam escape from before the piston. Thus the piston is driven by strong puffs of steam, the same as an air-gun drives its bullets; with this difference, the air-gun is soon exhausted, but the fire keeps up the power of the steam; the whole power of the steam is expended on the piston, before it leaves the cylinder, except what is necessary to resist the atmosphere. This is supposing the engine to work without a condenser.

ARTICLE VI.

OF THE MEANS OF APPLYING STEAM.

Supposing that no doubt can now remain in the mind of the intelligent reader, of our being able to work with steam of power equal to 120 pounds to the inch, with great advantage and safety, we will proceed to consider of the most economical means of using or applying this power, so that it may produce the greatest effects.

The engine may be constructed similar to that of Bolton and Watts, except the gears for working the valves, which should be so arranged as to open the valve, when the piston is up, to let in a puff of the strong steam to drive it down, but to shut again as soon as enough has got in, which, when suffered to expand, will fill the cylinder with atmospheric power only; the steam entering the cylinder with a power of 120 pounds to the inch, drives the piston with great force; but the valve being shut at 1/8 part of the stroke, the steam expands and decreases in power, all the rest of the stroke,

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A TABLE

Showing the proper time to shut off the steam, according to the power in the boiler; and how the power and load it will carry at every part of the stroke diminishes, in order that the steam may spend all its power; supposing the lengths of the stroke divided into eight equal parts, and working without a condenser.

	Power of steam in the boiler, 120 pounds to the inch	Load, deducting 15 pounds for the resistance of the atmosphere.	Power of steam in the boiler 60 pounds to the inch.	Load, deducting 15 pounds for the resistance of the atmosphere.	Power of steam in the boiler 30 pounds to the inch.	Load, deducting 15 pounds for the resistance of the atmosphere	Power of steam in the boiler 15 pounds to the inch.	Load
1	120	105	60	45	30	15	15	0
2	60	45	60	45	30	15	15	0
3	45	30	45	30	30	15	15	0
4	30	15	30	15	30	15	15	0
5	26.25	11.25	26.25	11.25	26.25	11.25	15	0
6	22.5	7.5	22.5	7.5	22.5	7.5	15	0
7	18.25	3.25	18.25	3.25	18.25	3.25	15	0

8	15	0	15	0	15	0	15	0
		52.5		22.5		7.5		0
		269.5/8		179.5/8		89.5/8		0
		33.7		22.4		11.2		0*
		15		15		15		15
		48.7		37.4		26.2		15**

*Average load without a condenser.

**Average load with a condenser

The foregoing table is founded on the supposition that the elastic power of steam is governed by the same laws, which govern the elastic power of permanent elastic fluids, viz. That their elasticity is in the inverse pro-portion with the space they occupy; or, as their density, called the Boylean law, (article 4.) If compressed into half the space their power is doubled, and if expanded into double space, their power is reduced to one half. But this is not strictly true with steam, because it is not a permanent elastic fluid. There will not as much heat enter into 1/8 part of the cylinder, with steam of 120 pounds to the inch elastic power, as will he sufficient to cause it to expand to fill the whole cylinder with elastic power, equal to 15 pounds to the inch, to resist the atmosphere (see article 4); it will not bear, therefore, to he shut off so soon. If a sufficient quantity of steam be admitted, to contain heat to expand it to fill the cylinder with power equal to the resistance of the atmosphere, the average load of the stroke will be greater than is shown by the table.

When the steam is 120 pounds to the inch, as in No.1 of the table, by the law it requires to be shut off at 1/8 part of the stroke, to give the steam time and room to spend all its power in driving the piston to the end, and to fill the cylinder with steam, equal to 15 pounds to the inch, just sufficient to resist the atmosphere the effective load being always 15 pounds less than the power of the steam, diminishes from 105 pounds to the inch, the load when the valve shuts, to 0 at the end of the stroke.

To find the average load or the load the steam will carry the whole stroke, and resist the atmosphere, add

ARTICLE VI.

OF THE MEANS OF APPLYING STEAM.

Supposing that no doubt can now remain in the mind of the intelligent reader, of our being able to work with steam of power equal to 120 pounds to the inch, with great advantage and safety, we will proceed to consider of the most economical means of using or applying this power, so that it may produce the greatest effects.

The engine may be constructed similar to that of Bolton and Watts, except the gears for working the valves, which should be so arranged as to open the valve, when the piston is up, to let in a puff of the strong steam to drive it down, but to shut again as soon as enough has got in, which, when suffered to expand, will fill the cylinder with atmospheric power only; the steam entering the cylinder with a power of 120 pounds to the inch, drives the piston with great force; but the valve being shut at 1/8 part of the stroke, the steam expands and decreases in power, all the rest of the stroke,

to the end, where it should just balance the atmosphere when another valve opens to let in a similar puff of steam to drive the piston up again; while other valves open to let the steam escape from before the piston. Thus the piston is driven by strong puffs of steam, the same as an air-gun drives its bullets; with this difference, the air-gun is soon exhausted, but the fire keeps up the power of the steam; the whole power of the steam is expended on the piston, before it leaves the cylinder, except what is necessary to resist the atmosphere. This is supposing the engine to work without a condenser.

A TABLE.

Showing the proper time to shut off the steam, according to the power in the boiler; and how the power and load it will carry at every part of the stroke diminishes, in order that the steam may spend all its power; supposing the lengths of the stroke divided into eight equal parts, and working without a condenser.

	Power of steam in the boiler, 120 pounds to the inch	Load, deducting 15 pounds for the resistance of the atmosphere.	Power of steam in the boiler 60 pounds to the inch.	Load, deducting 15 pounds for the resistance of the atmosphere.	Power of steam in the boiler 30 pounds to the inch.	Load, deducting 15 pounds for the resistance of the atmosphere	Power of steam in the boiler 15 pounds to the inch.	Load
1	120	105	60	45	30	15	15	0
2	60	45	60	45	30	15	15	0
3	45	30	45	30	30	15	15	0
4	30	15	30	15	30	15	15	0
5	26.25	11.25	26.25	11.25	26.25	11.25	15	0
6	22.5	7.5	22.5	7.5	22.5	7.5	15	0
7	18.25	3.25	18.25	3.25	18.25	3.25	15	0
8	15	0	15	0	15	0	15	0
		52.5		22.5		7.5		0
		269.5/8		179.5/8		89.5/8		0
		33.7		22.4		11.2		0*
		15		15		15		15
		48.7		37.4		26.2		15**

*Average load without a condenser.

**Average load with a condenser

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The foregoing table is founded on the supposition that the elastic power of steam is governed by the same laws, which govern the elastic power of permanent elastic fluids, viz. That their elasticity is in the inverse proportion with the space they occupy; or, as their density, called the Boylean law, (article 4.) If compressed into half the space their power is doubled, and if expanded into double space, their power is reduced to one half. But this is not strictly true with steam, because it is not a permanent elastic fluid. There will not as much heat enter into 1/8 part of the cylinder, with steam of 120 pounds to the inch elastic power, as will he sufficient to cause it to expand to fill the whole cylinder with elastic power, equal to 15 pounds to the inch, to resist the atmosphere (see article 4); it will not bear, therefore, to he shut off so soon. If a sufficient quantity of steam be admitted, to contain heat to expand it to fill the cylinder with power equal to the resistance of the atmosphere, the average load of the stroke will be greater than is shown by the table.

When the steam is 120 pounds to the inch, as in No.1 of the table, by the law it requires to be shut off at 1/8 part of the stroke, to give the steam time and room to spend all its power in driving the piston to the end, and to fill the cylinder with steam, equal to 15 pounds to the inch, just sufficient to resist the atmosphere the effective load being always 15 pounds less than the power of the steam, diminishes from 105 pounds to the inch, the load when the valve shuts, to 0 at the end of the stroke.

To find the average load or the load the steam will carry the whole stroke, and resist the atmosphere, add

the different loads at each division together, and to that sum (for the deficiency that is occasioned by not dividing the stroke into an infinite number of divisions) add half the load at the time the valve was shut, that is half of 105 pounds, equal to 52 5/10 pounds, and it makes 269.5 for the effect of the stroke; which divided by 8, the number of divisions, and it quotes 33.7 pounds, the average load; to which add 15 pounds and it makes 48.7 pounds the average load, when a condenser is used to take off the resistance of the atmosphere.

When the steam is 60 pounds to the inch power, as in No.2, in the table, it requires to be shut off at 2/8 of the stroke, and the average load against the atmosphere is 22.4 pounds to the inch, and with a condenser, 37.4 pounds.

When 30 pounds to the inch power, as No. 3, it requires to be shut off at 4/8 of the stroke, the average load against the atmosphere being 11.2 pounds to the inch and with a condenser 26.2 pounds. And when the steam is 15 pounds to the inch power, as No. 4, it requires to be shut off at the end of the stroke, the average load against the atmosphere being 0, and with a condenser of 15 pounds to the inch.

Now it is evident that, as the cylinder is to be filled with steam in each case, just equal in power to the resistance of the atmosphere, or equal to 15 pounds to the inch, therefore it contains an equal quantity of heat in each case; although die effects are so different, that when we work without a condenser, the strong elastic steam, 120 pounds to the inch, carries a load of 33.7 pounds to the inch; while steam of 60 pounds power, carries but 22.4 pounds; steam of 30 pounds carries

11.2 pounds, and steam of 15 pounds carries 0, above the resistance of the atmosphere, and with a condenser to take off that resistance, the loads are 48.7, 37.4, 26.2 and 15 pounds to the inch, by the law of permanent elastic fluids on which the table is founded. But as it has been shown (article 4) that strong elastic steam does not contain heat in proportion to its power compared with steam less elastic; it is probable that in No. 1 the valve must be kept open ~ of the stroke, which would increase the average load to about 80 pounds to the inch; so that it appears that on this new principle, by confining the steam until its elastic power rises to 120 pounds to the inch, we can produce about 6 times the effect from equal quantities of heat, that can be produced, if we use it with power equal to 15 pounds. And if this be done with equal quantities of heat drawn from the boiler, we may conclude that nearly equal quantities of fuel will be used in each case, because the compression of the strong elastic steam on the surface of the water in the boiler, creates no obstacle to the heat passing from the fire into the water, but rather facilitates it; because solid bodies receive heat more freely than porous ones.

Suppose the cylinder requires to be filled 1/3 part with steam of 120 pounds to the inch, to admit heat sufficient to expand the steam to fill the cylinder with a power equal to 15 pounds to the inch, and divide the cylinder into 9 parts, then by the principles laid down, the load at the end of the several divisions, will be nearly as follows, when we use a condenser.

1	120
2	120
3	120
4	100
5	80
6	40
7	34
8	27
9	15
10	60 Half the power when shut off
11	716/9

79.55 pounds, the average load being more than six times the load of the old principle, which is not above 12 pounds. This is effected by drawing from the boiler an equal quantity of heat at each stroke, in each case. This however is a mere inference drawn from the premises supposing that a vacuum has a greater capacity for receiving heat than a plenum, (see art. 4.)

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ARTICLE VII.

COMPARISON OF THE PRINCIPLES.

To compare the two principles, viz. That of working with atmospheric steam to form a vacuum, which owing to its imperfection, seldom carries a load exceeding 12 pounds to the inch, with the new principle of working with strong elastic steam, equal to 120 pounds to the inch, which, shut off at 1/8 part of the stroke, (as No.1 in the table, article 6) carries a load equal to 48.7 pounds to the inch.

By article 3, every addition of a small quantity of fuel doubles the power and bulk of the steam; so that there remains no doubt but that doubling the fuel, that will produce atmospheric steam, will increase its elastic power to 120 pounds to the inch and move 8 times the the load an equal distance; producing 8 times the effect on that simple principle. But when we consider that we shut off at 1/8 part of the stroke, and are enabled to strike 8 times the number of strokes, carrying a load of 48.7 pounds, which, multiplied by 8 is equal to 389.6, the effect. Hence it appears that by doubling the fuel to obtain the strong steam, 32 times the effect is produced by the new principle.

But we rather believe that the steam will not bear to be shut off sooner than at 1/4 the stroke, which increases the average load to about 68 pounds to the inch, and enables us to strike only 4 times the number of strokes; then 4 multiplied by 68 is equal to 272, which, divided by 12, the load of the old principle, quotes 22.6 times the effect.

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Again, let us suppose a boiler with a furnace to consume 1 bushel of coals in an hour, with a cock opened so wide as just to let the steam (when its power is 15 pounds to the inch) escape freely into a vacuum. It has been ascertained that the velocity would be 1332 feet per second. Then suppose we increase the consumption to 2 bushels per hour, leaving the aperture the same; we believe the elastic power would be increased to 120 pounds to the inch, and the velocity of the steam would be as the square root of the pressure, viz. 3769 feet per second, we may say as quick as lightning, and the effects will be as the pressures multiplied into their velocities by the known laws of mechanics. Then, 15 multiplied by 1332 is equal to 19,980, the measure of the effect produced by 1 bushel of coals per hour, and 120 multiplied by 3769 is equal to 452,280 the measure of the effect produced by 2 bushels of coals per hour, 452,280 divided by 19,980 quotes 22.6, that is 22.6 times the effect produced by doubling the fuel.

We have not made experiments sufficiently accurate nor discovered data from which we can calculate the different effects with accuracy, but we know enough by experience with an engine in actual use, working on the new principle in the most simple form, without a condenser, to be assured that the gain of power and saving of fuel is very great; and may say with safety, that doubling the fuel on this principle, produces at least 16 times the power and effect.

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ARTICLE VIII.

OF THE SUPPLY PUMP.

WE supply the boiler with water by a small forcing pump, wrought by the engine, which requires about one thousandth part of the power to work it, to force a little water into the boiler at every stroke, and we experience great loss of power by using cold water as a supply; for although it lowers the heat in the boiler but litfie, yet as it has been shown, that a small increase of heat, say 30 degrees, doubles the power, so a small diminution of heat, say 30 degrees, reduces the power to one half; say from 120 pounds to 60 pounds to the inch, (see article 3.)

Therefore we construct a strong, small vessel called the supply boiler, to be heated either by the steam passing through it, after leaving the engine, or by passing the flue of the furnace through or under it, after leaving the boiler. The supply pump brings the water up from the well or stream, or if one be used, out of the condenser, forcing it into the supply boiler, which it keeps always full, out of which it passes by a small pipe into the principal boiler, and may be thus heated by the smoke flue, to the same degree with the water in the boiler before it enters. This may appear incredible, until we consider that the steam which works the engine, carries off the heat from the boiler, which is not the case with the supply boiler, from which no steam escapes. And as we may suppose that cold water receives heat more freely than hot, we sometimes

make our boilers in several separate parts, passing the flue of the furnace through them all, and forcing our supply water into that part farthest from the fire, to pass from one to the other by small connecting pipes meeting the fire; on these principles we obtain a greater quantity of heat from the fire into the water.

ARTICLE IX.

OF THE CONDENSER.

THE weight of the atmosphere resists the motion of the piston of our engine, when we work without a condenser, with a power equal to 15 pounds to the inch of its area; the use of the condenser is to take off this resistance, and is very useful when we work with weak steam, (see No. 4 in the table, article 6.)

In its usual form it consists of a metal vessel, air tight, immersed in cold water, to receive the steam as it leaves the engine. The steam is first let in plentifully to drive out all the air through a valve fixed for that purpose. A cock is then opened to let a continual jet of cold water enter, meeting the steam, which it condenses into water again, and forms a vacuum in the condenser for the steam to enter freely, which takes off the resistance of the atmosphere from the piston of the engine: and if the vacuum be made perfect, it increases the effect of the engine 15 pounds for every inch area

of the piston. But the air which arises from the first boiling of water would immediately fill the condenser, again destroy the vacuum and stop the engine; to keep the vacuum perfect, therefore, the air pump becomes necessary to extract this air, as well as the jet water, and that made by the condensed steam, and part of this water is returned into the boiler to supply it, and as there is a continual admission of fresh water by the jet, there is a continual generation of air, by boiling, to obstruct the vacuum, also a continual accumulation of sediment, forming a non-conductor of heat on the bottom of the boiler, which obstructs the passage of the heat from the fire into the water, causing the boilers to burn out; besides much trouble and expense in cleansing them.

To avoid all which, we improve the condenser by making a jet vessel of metal, purposely for receiving and cooling our jet water; immersing it in cold water, under or near the condenser. Out of this vessel the jet rises into the condenser as before. The air pump, which serves also for our supply pump, extracts the water and air from the condenser, and forces back into the jet vessel as much water as it will receive; keeping it always full; the residue (after the air is suffered to escape through a valve for that purpose fixed in the top of an air vessel, which is fixed in the pipe leading the water from the pump into the supply boiler) is forced into the the boiler to supply it. A small air vessel is attached to the jet vessel, the spring of which keeps up a continual jet. The water enters the jet vessel at one end and the jet issues at the other, which gives the water time to cool, to fit it for the purpose of condensing. By these

means we admit no fresh water, but continue to work with the same quantity with which we begin; distilling it over and over repeatedly, we soon get rid of the air, and our vacuum becomes more perfect: from water distilled many times over no sediment can accumulate to cause our boilers to burn out, nor air to obstruct our vacuum. Our boiler may be said to be inexhaustible, and will last much longer, and require less fuel.

In some situations it may suit better to make the condenser sufficiently capacious to expose so much surface to cold water, as to condense the steam without a jet; laying it in running water, and (when it can be done conveniently) so fixed that the water can be turned off at pleasure, which would enable us to expel the air more completely before we begin to work. The water formed by the steam in this condenser being driven back into the supply boiler by the air pump, makes it inexhaustible as before.

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ARTICLE X.

OF THE VOLCANIC STEAM ENGINE.

IN our pursuit of means to prevent the loss of the heat which is carried up the chimney of the furnance, let us have recourse to the works of nature: view the natural volcanoes, where the fire burns without the aid of atmospheric air; where all the elastic fluid generated by the fire dissolving the fuel, (see article 4) and all the steam formed by the water that may occasionally come in contact with the fire, united, forms the most terrible and powerful of all steam engines; in which the furnace, boiler, and working cylinder are united in one, working on the simple principle of applying great elastic power; casting up mountains, and making the earth quake as she brings her strokes. To apply these principles as far as we can, we make a cylindric boiler, about 36 inches diameter, 8 or 10 feet high, with a furnace inside of it 18 or 19 inches diameter. Both the boiler and furnace are united to the same heads, the fire being inside of the ivater, and the smoke-flue turned downwards through the water to the bottom, where the smoke is vented and rises in many streams of small bubbles, that it may impart all its heat to the water to generate steam. The elastic fluid generated by the combustion of the fuel, which we may suppose is 2000 times the bulk of the fuel, and the air used to kindle the fire, expanded by the heat to double its original bulk, unites with the increased quantity of steam, to work the engine with great

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elastic power. But until we can discover a fuel that will burn without the aid of atmospheric air, or until we can find means for kindling the fire with a blast of highly rarefied steam, as may be the case in volcanoes, we use a forcing air pump to force in air to kindle the fire. This form of engine will work with much less fuel, and be much lighter than any other. It would therefore be more suitable for boats or land carriages, &c. I made a small boiler on this principle, which operated favourably; but being weary of the trouble and expense of putting new principles into practice, I declined the pursuit until better prospects open, or a more favourable opportunity offers. *

When this principle is put in operation, in addition to those already explained, I conclude that all the principles of nature suited to aid us in working steam engines, are taken in, excepting one which would enable us to work a steam engine without fuel; which I conceive is only to be done by collecting the rays of the sun to boil our water, to generate steam, which may be done by plain mirrors and perhaps with much less expense, than may at present be supposed.** It remains for us to

*The fire will burn more freely in this furnace, in proportion as the air is compressed round the fuel, for the same reason that a candle burns brighter in the receiver of an air pump when the air is condensed, and dimmer as it is exhausted.

**Many may think this idea chimerical, until they consider that water exposed to the single perpendicular rays of the sun, in a suitable vessel, will soon acquire the heat of human blood, 92 degrees, notwithstanding the constant evaporation going on, which carries off the heat as fast as generated. Experiments may determine how many single rays must be collected to triple the heat, from 92 to 276 degrees in the water, which, by the table, (art. 3)

improve in the application of those principles until we discover others, if there be any.

would produce steam of elastic power 60 pounds to the inch. This would work a very powerful engine, to raise water in hot countries for various purposes. The rays collected to a focus by a convex lens, 36 inches diameter, produced a far greater degree of heat than any furnace ever had. How many lens can we suppose would he necessary to boil water to work an engine? But we need not go to the expense of lens; 100 plain mirrors containing each 9 superficial feet, and which might he constructed of 9 small glasses of one foot each, fixed in a frame, may collect rays sufficient for a powerfiul engine. How did Archimedes burn the fleet which invaded Syracuse?

I am fully of opinion that the time will come when water will he raised in great quantities by the heat of the sun at a very small expense, for various purposes; but the expense of such inventions cannot, in many instances, he borne by those who have the mental powers to design them; at least it is highly imprudent for them to risk it. In such cases aid from government becomes necessary.

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ARTICLE XI.

SCALE OF HEAT

From the highest degree of heat produced in an air-furnace to the greatest degree of cold hitherto known, which was produced at Hudson's Bay, in December 1784, by a mixture of vitriolic acid and snow. See the American edition of the Encyclopedia, vol.xviii.p.500.

Fahrenheit Wedgwood's

	Fahrenheit	Wedgewoods's Scale
Extremity of Wedgwood's scale	322770	2400
Greatest heat of his small air-furnace	21877	160
Cast iron melts	17977	130
Greatest heat of a common smith's forge	17327	125
Welding heat of iron, greatest	13427	95
Welding heat of iron, least	12777	90
Fine gold melts	5237	32
Fine silver melts	4717	28
Swedish copper melts	4587	27
Brass melts	3807	21
Heat by which his enamel colours are burnt on	1857	6
Red heat fully visible in day-light	1077	1
Red heat fully visible in the dark	947	0
MERCURY BOILS, also linseed and other expressed oils	600	
Oil of Turpentine boils	560	
Sulphuric acid boils	546	
Lead melts	540	

Lead melts	460	
Tin melts	408	
Sulphur melts	244	
Nitrous acid boils	242	
Cows' milk boils	213	
WATER BOILS	212	
Human urine boils	206	
Brandy boils	190	
Alcohol boils	174	
Serum of blood and white of eggs harden	156	
Bees-wax melts	142	
Heat of the air near Senegal sometimes	111	
Hens hatch eggs about	108	
Heat of birds from	103 to 111	
Heat of domestic quadrupeds from	100 to103	
Heat of the human body from	92 to 99	
Heat of a swarm of bees	97	
heat of the ocean under the equator	80	
Butter melts	74	
Vitriolic acid of the specific gravity of 1780 freezes at	45	
Oil of olives begins to congeal	43	
Heat of hedgehogs and marmots in a torpid state	39.5	
WATER FREEZES and snow melts	32	
Milk freezes	30	
Urine and common vinegar freeze	28	
Human blood freezes	25	
Strong wines freeze	20	
A mixture of one part of alcohol and three parts of water freezes	7	
A mixture of snow and salt freezes	0 to 4	
Brandy, or a mixture of equal parts of alcohol and water freezes	7	

Spirits of wine in Reaumur's thermometer froze at Torneo	34	
MERCURY FREEZES	39 tp 40	
Cold produced by Mr.Macnab at Hudson's Bay, by a mixture of vitriolic acid and snow	69	

A TABLE

Of the strength of Metals ascertained by experiments; the weight hung to an inch bar, with a straight pull. See the American edition of the Encyclopedia, vol. xvijj. p.10.

Metal		lbs.
Gold, cast		20,000
		24,000
Silver, cast		40,000
		43,000
Copper, cast	Japan	19,500
	Barbary	22,000
	Hungary	31,000
	Angelsea	34,000
	Sweden	37,000
Iron, cast		42,000
		59,000
Iron, bar	Ordinary	68,000
	Stirian	75,000
	Best Swedish & Russian	84,000
	Horse Nails	71,000
Steel, bar	Soft	120,000
	Razor temper	150,000
Tin, cast	Malaca	3,100
	Banca	3,600

	Block	3,800
	English block	5,200
	English grain	6,500
Lead, cast		860
Regulus of antimony		1,000
Zinc		2,600
Bismuth		2,900
Brass, a mixture of copper and zinc		51,000

"The expansion of bodies by heat is very various, and in solids does not seem to be guided by any certain rule. In the forty-eighth volume of the Philosophical Transactions, Mr. Smeaton has given a table of the expansions of many different substances, from which the following particulars are extracted. The degree of heat employed was 180 degrees of Fahrenheit's thermometer, and the expansion is expressed in 10,000th parts of an English inch."

Substance	10,000th parts of an English inch
A foot of white glass barometer tube	100
Martial regulus of antimony	130
Blistered steel	138
Hard steel	147
Iron	151
Bismuth	167
Hammered Copper	204
A mixture of 3 parts of copper with 1 of tin	218
Cast brass	225
A mixture of 16 parts of brass with 1 of tin	229
Brass wire	232
Speculum metal	232
Spelter solder, 2 parts brass and 1 zinc	247

Fine pewter	274
Grain Tin	298
Soft solder, 2 parts lead and 1 tin	301
A mixture of 8 parts of zinc and one of tin, a little hammered	323
Lead	344
Zinc or spelter	353
Zinc hammered an inch per foot	373

ARTICLE XII.

DIRECTIONS FOR WORKING A STEAM ENGINE ON

THE NEW PRINCIPLE.

It has been shown that a vacuum will probably receive and contain a greater quantity of heat in a latent state than a plenum, (see article 4): and it is evident that the piston of an engine leaves a perfect vacuum behind it in the cylinder at every stroke, which is to be filled with latent heat from the fire, besides active heat to give power to the steam to carry its load; now it appears plain, that if the engine be started before the steam has acquired a sufficient power, and let it move briskly with the load it is'able to carry, that the piston will create vacua so fast, as to carry off all the heat of the fire, as fast as generated, to supply the latent heat to fill the vacuum: it will therefore be very difficult to use the power of the steam to its proper degree, and thus fuel may be consumed without producing the desired effect. To save the fuel retain and confine the steam in the boiler until the power is raised to a greater degree than is sufficient to carry the load, which will be shown by the lifting of the safety valve with the weight farther from the centre than it is commonly hung; then start the engine, and the power will be reduced to its proper degree before the cylinder becomes hot; take care that the engine does not dart with too quick a motion, and it will carry off less heat in a latent state at every stroke, but more in an active state, producing power in the steam to carry its load, and the engine will work on, if the fire be kept up, and produce great effects.

If propelling a boat against the Mississippi, fix the valve to shut off quick, say at 1/6 or 1/4 part of the stroke, when in an eddy or slow current; let the supply pump work to fill the boiler, and augment by these means the elastic power of the steam so as to be ready to lift the safety valve with a double load by the time you arrive at the strongest current; to ascend which alter the valve to shut off at 1/2 the stroke, and stop the supply pump until you have passed the rapid, (see article 8,) and the power of the engine will be quadrupled, which may be kept up by increasing the fire until you surmount the difficulty: you may regulate the power by closing and opening the throttle valve to let more or less steam out of the boiler into the cylinder; but there will be a great loss of power this way, because it would be working with weak steam in the cylinder while you have strong in the boiler, and returning to the old exploded principle.

If propelling a land carriage, on turnpike roads, while on level or descending ground, gear the wheels to move fora~rd quickly, and fill the boiler, reserving the steam, as above stated; so as to quadruple the

power of the engine by the time you arrive at the foot of a hill; then alter the gears to move the carriage with

or 1/2 velocity, as the ascent may require, and you ascend with 8 or 16 times the power, with 21 or 1/4 velocity, which enables you to ascend any hill on which the wheels will not slide. If the driver of a 5 horse waggon could have at his command 75 more to hitch on to help him, he would easily ascend hills. At all steady work, such as grinding, sawing, &c. fix the valves to shut off so as to keep up the power in the boiler and you will

produce much greater effects from the same consumption of fuel, (see article 4.)

These principles have been proven as follows:

I constructed for the Board of Health of Philadelphia a machine for cleaning docks, called the Orukter Amphibilos or Amphibious Digger. It consisted of a heavy flat bottomed boat, 30 feet long and 12 feet broad, with a chain of buckets to bring up the mud, and hooks to clear away sticks, stones, and other obstacles. These buckets are wrought by a small steam engine set in the boat, the cylinder of which is 5 inches diameter and the length of stroke 19 inches. This machine was constructed at my shop, 1 1/2 miles from the river Schuylkill where she was launched. She sunk 19 inches, displacing 551 cubic feet of water, which at 62.5 pounds, the weight of a cubic foot, gives the weight of the boat 34,437 pounds, which divided by 213, the weight of a barrel of flour, gives the weight of 161 barrels of flour that the boat and engine is equal to. Add to this the heavy pieces of timber and wheels used in transporting her, and the number of persons genelally in her, will make the whole burden equal to at least 200 barrels of flour. Yet this small engine moved so great a burden, with a gentle motion up Market.street and around the Centre Square; and we concluded from the experiment, that the engine was able to rise any ascent allowed by law on turnpike roads, which is not more than 4 degrees.

When she was launched we fixed a simple wheel at her stern to propel her through the water by the engine. Although she is square at each end and fully constructed for sailing, (excepting that she is turned up short at

bottom) and drew 19 inches water, yet we concluded diat if the power had been applied to give the paddle wheel the proper motion we could have stemmed the tide of the Delaware. It has been ascertained by accurate experiments,* that a boat formed to the proper angle at her bow and stern, will pass much easier through the water than one formed as this was; and that the increase of length does not sensibly increase the resistance: we may therefore safely conclude, that an engine 4 times as powefful would propel a boat 16 feet wide, 90 feet long drawing 2 feet water, the weight of which would be 86 tons, equal to 903 barrels of flour, about 7 or 8 miles an hour through the water, every thing being properly and well constructed. This force would be sufficient to propel the like burden against the stream of the Mississippi at the rate of 4 miles an hour. Considering the temporary manner in which the works were constructed for this experiment of propelling the Orukter both by land and water; the great friction there was to be overcome, and the disproportion of the load to the engine, there cannot remain any doubt but that a steam carriage may be constructed to carry 100 barrels of flour 50 miles in 24 hours, on any well made and well regulated turnpike road; and when every thing is properly arranged for supplying the machine with water and fuel at proper stages, one such carriage will clear as much net profit as 10 five horse waggons. Conceiving that those who are proprietors of turnpike roads are the only persons

*See the American edition of the Encyclopedia, vol. xvi. art. "Resistance."

whose interest directs them to engage in the enterprise, I made the following statement, to be laid before the managers of the Philadelphia and Lancaster Turnpike Company.

TO THE LANCASTER TURNPIKE ROAD COMPANY:

GENTLEMEN,

PERMIT me to lay before your respectable body the following statement.

I conceive that carriages may be constructed, to be propelled by the power of steam engines which I have invented, to transport merchandise and produce from Philadelphia to Columbia, and from thence to Philadelphia, much cheaper than can be done by the use of cattle.

	Dolls
The enigne I estimate at	1500
The carriage	500
Say for unforseen expenses	500
Total	2500

This carriage I allow to carry 100 barrels of flour, and to travel 3 miles per hour on level roads, and 1 mile per hour up and down hills; say about 40 miles per 24 hours; making a trip from Columbia to Philadelphia in 2 days.

It requires 5 horse waggons, of S horses each, to transport 100 barrels the same distance in 3 days. The expense I estimate as follows:

	Dolls
5 Horse waggons at the cheapest rate, 100 dolls. each	500
25 horses at 100 dolls. each	2500
Gears for 25 horses at 7.75 dolls.	193.75
5 waggon covers at 7 dolls.	35
30 bags for feed at 1 doll.	30
5 jack screws at 6 dolls.	30
5 whips at 75 cents	3.75
5 feed troughs at 2 dolls.	10
5 grease cans at 33 cents	1.65
	3304.15
Expense of the steam waggon	2500
	2500
First cost in favour of the steam wagon, exclusive of the drivers	804.15
The steam waggon will perform the journey in two days, and carry 100 barrels of flour at 1 doll. 25 cents	125
The expense of fuel, 20 bushels of coals per 24 hours, 40 bushels at 37 1/2 cents, or wood equal thereto	15

3 men at 1 doll. per day for 2 days	6
	21
Profits of the steam waggon per journey, or 52 dollars per day	104
The horse waggons will perform the journey in three days and carry 100 barrels at 1 doll. 25 cents	125
The expense of feed for 25 horses at 33 1/3 cents per day, 3 days	25
5 men drivers at 1 doll.	15
	40
Profits on 1 journey, 85 dolls. which is 28 dolls. 33 cents per day	85

54

The expenses of repairs, of horses, waggons, and gears of each horse waggon will be fully equal to the repairs of the steam waggon.

	Dolls
From the profits of the steam waggon per day	52
Deduct for repairs	2
Nett profit of the steam waggon per day	50
From the profits of the 5 horse waggons per day	28.33
Deduct for each 2 dolls.	10
Nett profit of all the 5 horse waggons per day, or 3.66 dolls. each per day	18.33

Add to all this that the steam waggon consumes nothing while standing, will roll and mend the roads, while the horse waggons will cut them up.

Upon the whole it appears that no competition could exist betwween the two. The steam waggons would take all the business on the turnpike roads.

I have no doubt but you will duly appreciate the importance of such an improvement, and conceive it to be your interest to appropriate the sum necessary to put it in operation. I have invented the only engine that will answer that great purpose, as well as many others for which power may be wanted.

It is too much for an individual to put in operation every improvement which he may be able to conceive and invent.

I have no doubt but that my engines will propel boats against the current of the Mississippi, and waggons on turnpike roads with great profit. I now call upon those whose interest it is to carry this invention into effect. All which I respectfully submit to your consideration.

Gentleman,

Your obedient humble servant,

OLIVER EVANS.

Philadelphia, Sept.

26th, 1804

ARTICLE XIII.

OF PROPORTIONING THE CYLINDER TO

THE BOILER IN THE CONSTRUCTION OF STEAM ENGINES.

THE limits of this work will not admit of full directions for constructing steam engines: but the engineer must be guided by very different principles in his arrangement of a steam engine, to be wrought on the new principles already laid down, from those which should guide him, in arranging one to be wrought by atmospheric steam, where, the larger the cylinder, provided the boiler be sufficient to fill it with steam at every stroke, the more powerful the engine, while the reverse is the fact in this case, viz. The less the cylinder through which all the steam the boiler will make, is made to pass, the more powerful the engine, and the greater the effects it will produce, provided the boiler be strong enough to contain the power of the steam. Doubling the diameter of the cylinder doubles the friction, and quadruples the resistance of the atmosphere; it also quadruples the vacuum formed behind the piston, requiring to be filled with latent heat at every stroke, (see article 12.)

To show this more clearly by an example: Suppose we had an engine, on the new principle, arranged so that the boiler would supply the cylinder of 30 inches area, with steam of power 120 pounds to the inch. Then 30 multiplied by 120 is equal to 3600 pounds, the load; but suppose the friction of the piston to b(150 pounds, added to 450 pounds, the resistance of the atmosphere, makes 600 pounds which taken from

3600 pounds leaves 3000 pounds, the nett load the engine will carry.

Then suppose we enlarge the cylinder to double the diameter, which doubles the friction to 300 pounds, and quadruples the resistance of the atmosphere to 1800 pounds, making 2100 pounds, total resistance. The area of the cylinder, 120 inches, multiplied by 1/4 the power, reduced now to 30 pounds to the inch by the Boylean law (see articles 4 and 6) is equal to 3600 pounds, the load; from which take the increased resistance, 2100 pounds, leaves 1500 pounds for the nett load of the enlarged cylinder; just half the load of the small one. But this is supposing the Boylean law to hold true with regard to steam, and that it is a permanent elastic fluid, which it is not. When we consider that the vacuum formed behind the piston (see article 12) was quadrupled also by doubling the diameter of the cylinder, and would probably absorb all the heat in a latent state, we may safely infer, that the cylinder enlarged, would not overcome the resistance of the atmosphere and friction, and would therefore carry no load at all, provided the piston moves with equal velocity in each case.

The power of a man is equal to raising 30 pounds 2 1/2 miles per hour, 8 or 10 hours in 24; and the power of a horse is equal to 5 men, or equal to raising 150 pounds 2,1 miles or 13200 feet per hour. This has been ascertained by many experiments, and long established as data on which to found our calculations. Then, to ascertain the diameter of a cylinder and length of stroke, to produce a given power; 13200 feet per hour, divided by 60 is equal to 220 feet per

minute, the velocity of the piston. Suppose we take 36 for the number of strokes the engine is to strike per minute; then 220 feet divided by 36 quotes 6.1 feet for the length of the double stroke, say 6 feet; that is 3 feet length of stroke, 36 down and 36 up strokes per minute to make the piston pass about 2 1/2 miles per hour.

Suppose again the piston to carry an average load equal to 50 pounds to the inch instead of 80 pounds, to make allowances, (see article 6), then every 3 inches area of the piston is equal to a horse's power.

The side of a square being 1, the diameter of a circle of equal area is 1 128/1000: therefore to find the diameter of the cylinder for any number of horse's power take the following

RULE.

Multiply the number of horses by 3, extract the square root and multiply by 1 128/1000: the product will be the diameter of the cylinder, 3 feet length of stroke, 36 strokes per minute.

The diameter of a circle being 1, the side of a square of equal area will be 7854/10000 therefore to find the area of any cylinder, multiply the square of the diameter by .7854 of a decimal and the product is the area.

To produce the power of a horse, a piston 3 inches area must move 220 feet, or 2640 inches per minute, with a load of 150 pounds; and 2640 multiplied by 3 is equal to 7920 cubic inches of space the piston forms into a perfect vacuum behind it per minute to be filled by the heat, (see article 12.) Therefore to find the power of any engine, multiply the area of the piston by the length of stroke in inches and by the number of

strokes per minute, and the product is the space it passes through, or the vacuum it forms behind it; which divided by 7920 quotes the number of horses' power, when the piston carries an average load of 50 pounds to the inch area.

To find the number of strokes an engine must strike per minute to produce any number of horses' power, multiply the number of horses' power by 7920, and divide by the cubic inches of space the piston passes through at one stroke, the quotient is the number of strokes the engine must strike per minute, carrying 50 pounds to the inch area.

A horse can work only 8 hours steadily in 24, therefore 3 relays are necessary, and an engine of 10 horses' power will do the work of 3 times 10, equal to 30 horses.

Bolton and Watt's best steam engines, on what I call the old principle, require 1 bushel of the best NewCastle coals, from Walker's pits, (England) to do the work of a horse per day. It has been shown (article 6) that my new principle will produce at least 3 times the effect from equal fuel; one bushel of coals to do the work of 3 horses; and can be built at half the price

COMPARATIVE STATEMENT

Of the cost of building and expense of working two steam engines, 10 years, the one on the old and the other on the new principle.

	Dolls	Dolls
Suppose an engine on the old principle to cost		10,000

Interest at 6 per cent. 10 years		6,000
Will consume about 60 bushels of coals at 33 1/3 cents, per day, 300 days per year, 10 years		60,000
		76,000
An engine of equal power, on the new principle will cost	5,000	
Interest 10 years	3,000	
Coals for 10 years will be about one-third the consumption	20,000	
		28,000
		48,000

This difference is worthy the attention of those who wish to use steam engines.

A TABLE

Of the areas of cylinders of steam engines to produce different powers with 3 feet length of stroke, 36 strokes per minute, carring an average load of 50 lbs. to the inch area.

Number of Horses' power, or bushels of wheat the power will grind per hour	Area in inches	Diameter in inches and decimal parts	Number of horses that the engine will do the work of per day of 24 hours
1	3	1.92	3
2	6	2.76	6
4	12	3.9	12
6	18	4.79	18
8	24	5.53	24
10	30	6.18	30
12	36	6.77	36
14	42	7.3	42
16	48	7.81	48
18	54	8.28	54

20	60	8.74	60
22	66	9.16	66
24	72	9.57	72
26	78	9.96	78
28	84	10.3	84
30	90	10.7	90
35	105	11.94	105
40	120	12.36	120
50	150	13.82	150
60	180	14.47	180
70	210	16.31	210
80	240	17.48	240
90	270	18.54	270
100	300	19.54	300

ARTICLE XIV.

OF DISTILLATION.

A KNOWLEDGE of the principles already stated, (see article 4) leads us to discover an improvement on distillation. When we consider that water and spirits may be prevented from boiling, by increasing the pressure on their surface, and that by boiling under a great pressure a much greater quantity of the fluid is raised by equal quantities of heat in a state of vapour, and much less fuel is used to obtain equal quantities of the fluid by raising it into vapour and condensing it again, as in distillation, and that spirits boil at a less degree of heat or under a greater pressure than water, we can by in creasing the pressure on the liquid in the still, suppress the watery vapour until the spiritous vapour rises rapidly. The essential oil which gives a bad flavour to spirits may perhaps be suppressed in the same way, and the spirits brought off pure at the first distillation, with much less fuel, by a rapid process. To this improvement another may be added, to make the operation perpetual, by constructing the still of a cylindric form, letting the beer in at one end, and the dregs out at the other, in a continual stream; the spirits are extracted during the passage: the operation may thus be continued at pleasure.

If any person is willing to bear the expense and fatigue of the experiments, to put this improvement into complete operation, he will find a full specification, with explanations and drawings thereof, filed in the Secre-

tary of State's Office (called the Patent Office) of the United States. As a compensation for such trouble and expense, I am willing to contract with such person, in writing to be legally executed, to convey one half of the exclusive right of using and selling, to be used, the said improvemerits.

ARTICLE XV.

OF VIBRATING MOTIONS OF MACHINERY.

FEW mechanicians have considered what power is expended in giving quick vibrations to heavy parts of machinery; such as saw gates, engine beams, &c. Writers on the principles of mechanics have generally agreed in laying down as an axiom that the weight of a body in motion multiplied into its velocity is a true measure of its momentum: but few have informed us that the weight of a body multiplied into the square of its velocity is the true measure of the effects it will produce; which is the truth.* We are thus frequently led into great errors, and to suppose that a double impulse will give double velocity to a body; whereas a quadruple impulse is required to give double velocity; and if so, a quadruple resistance is required to check a double velocity,** consequently the power required to produce

*See the Millwright's Guide, art. 6. **Ibid.

vibrating motions, is, as the squares of their velocities multiplied into the weight of the bodies moved. Aware of those principles, I have guarded against the use of the heavy lever beam in the construction of my steam engines; as by an injudicious arrangement nearly the whole power of the engine may be expended in giving a quick motion to a heavy beam. The natural vibrations of a beam are regulated by its length as much as those of a pendulum; and if we attempt to vary this motion to a quicker one we expend much of the power of the engine to do it. I know no better way of explaining this than by the laws of spouting fluids.* Suppose water to issue from under a head of 1 foot; it moves with that power 8.1 feet per second: here, a power equal to 1/8 of the weight of the body moved is expended to give that velocity. Suppose water to issue from under a head of 4 feet; it moves with that power 16.2 feet per second: in this case, a power equal to 1/4 the weight of the body moved is expended to give it velocity. If it issues from under a head of 16 feet it moves with velocity 34.4 feet per second, and a power equal to 1/2 the weight of the body is expended to give it velocity. If it issues from under a head of 64 feet, its velocity is 64 feet per second: here the power expended to produce the motion is equal to the weight of the body moved. But as an equal power is required to check the motion, therefore to give a body a vibrating motion equal to 32.4 feet per second, requires a power equal to the weight of that body, and 64.8 feet per second requires a power equal to double the weight of that body.

*See the Millwright's Guide, art.45.

Great as this evil may appear, yet in most cases it almost entirely vanishes, where the vibrations are produced by the revolutions of that simple instrument, the crank, attached to the axis of a wheel, to which the

power is applied, as in the constrtiction of saw-mills; where the power is applied immediately to move the vibrating body attached by a connecting rod to a crank on the axis of which is put a heavy fly wheel, as in steam engines without lever beams. In both cases, the line of vibration continued, should pass through the centre of the circle described by the crank, coinciding with the diameter of the circle. In the case of saw-mills where the power is applied to the wheel and the crank moves the saw, while the crank is receding from the vibrating line, it moves the saw with a very gradual accelerated motion, and as it approaches the line of vibration it

retards the motion again as gradually. If the saw is not applied to do work, the momentum communicated to it and its frame by the crank in giving the motion is recommunicated or returned to the crank during the retarded motion; therefore very little power will be required to keep up this vibrating motion. While the saw is cutting, the momentum is expended performing the work. In the ease of steam engines, the reverse takes place, the power being immediately applied to produce the vibrating motion in the piston, which communicates momentum to the fly wheel, while the crank recedes from the vibrating line; and the momentum communicated to the piston and all attached to it is communicated to the fly wheel, while the crank approaches that line, and very little power is required to keep up this vibrating

motion, without producing any other effect. When the engine is at work, the power is expended to produce the effects, and the momentum of the fly wheel regulates the motion and carries the crank past the vibrating line, (where it would stop) and brings it to a position to receive the power from the vibrating motion to keep up the circu1ar motion of the fly.

The late ingenious Robert Leslie of Philadelphia, to whose memory and judgment great deference ought to be paid, was of opinion that the case is widely different when moving a heavy lever beam past its natural vibrating velocity, although it be attached to a crank.* We know that if the beam be nicely poised but little power is required to cause it to vibrate with its natural motion, which is as exactly governed by fixed principles as the vibrations of a pendulum; but what power is required to give it any greater number of vibrations per minute proportionate to its length and weight, I have not known to be ascertained; nor can I say whether or not the momentum received from the crank, while it recedes from the vibrating line, will be returned to it, with the same exactness, while approaching that line as has already been stated, but I am inclined to believe it will not. My ideas are not mature on the subject, not having given it a full investigation, although 1 think it important.

*I was well acquainted with Mr.Leslie. He was generally correct in his ideas of the principles of mechanics, and made many useful discoveries and improvements.

ARTICLE XVI.

DESCRIPTION OF A STEAM ENGINE ON TIlE NEW

PRINCIPLE.

EXPLANATION OF PLATE I.

PLATE I. represents a perpendicular section of the different parts of a steam engine on the new principle explained in this work, but they are differently arranged in the construction.

a The end view of the boiler, consisting of two cylindrical tubes, the best form for holding a great power, the lesser inside of the greater. The fire is kindled in the inner one, which serves as a furnace, the water being between them. The smoke passing to the other end, is turned under the supply boiler, *b*, to heat the water for supplying the waste occasioned by workmg; *c* the supply pump, which brings water up, and forces it into the supply boiler, at every stroke of the engine.

The steam ascends the pipe, and if the throttle valve *d* be lifted to let the steam into the engine, and valves *e* and *f* be opened, the steam drives the piston *g* to the lower end of the cylinder, as it appears in the plate, the steam escaping before the piston through the valve *f*. As soon as the piston is down the valves *e f* shut and *h i* open, the steam enters at *h* to drive the piston up again, and escapes before the piston through the valve *i*. These 4 valves are wrought by 2 wheels, *k l* with cams on their sides, which strike against 4 levers, not shown

in the plate, to which the stems of the valves are attachcd, and which open and shut them at the proper time. The motion of the piston *g* gives motion to the lever *m n;* and the rod *m o*, connected to the crank, puts it in motion, and the fly wheel *q r* keeps its motion regular; the spur wheels *s t*, of equal size, move the valve wheels *l k;* the lever *m n* works the supply pump *c*. Thus the motion is continued, and the cog wheel*v* of 66 cogs going into the tunnel *u* of 23 cogs, gives the stone *w* 100 revolutions per minute, when the piston strikes 35 strokes. This cog wheel may move any other work, or instead thereof a crank may move a pump or saw, as this engine may be made to strike from 10 to 100 strokes per minute, as the ease may require; and if the working cylinder be 8 inches diameter, it will drive a pair of 5 feet millstones, or other work requiring an equal power.

The steam, after it leaves the engine, escapes up the pipe *x x*, through the roof of the house, or into a condenser, if one be used, or through the supply boiler to heat the water.

y A safefy valve, kept down by a lever graduated like a steelyard, to weigh the power of the steam; this valve will lift and let the steam escape, when its power is too great.

If the pipe of the safety valve be turned into the flue of the furnace, then, by lifting the valve, the ashes may be blown out of the flue.

This engine is of a simple construction, easily exeeuted by ordinary mechanics: the valve seats are formed by simple plates, with holes in them and are easily cast.

In working this engine to drive ten saws, we find that if we put her in motion as soon as she has power to drive one saw, and suffer her to move briskly, she carries off the heat from the boiler nearly as fast as it is generated, and fuel may be consumed and time spent to little purpose; but if we confine and retain the steam in the boiler, until it lifts the safety valve with a power sufficient to drive ten saws, she will start with that load, and carry it all day, and consume but little more fuel.

It takes up but little room in the building. The draught is drawn from half an inch to a foot, except the millstones, and two wheels that move them; they are a quarter of an inch to a foot.

| YOUNG STEAM ENGINEER'S GUIDE |ARTICLE XVII |

ARTICLE XVII.

EXPLANATION OF THE SCREW MILL INVENTED

AND PATENTED BY THE AUTHOR.

This mill is intended for breaking all hard substances,

and to prepare them for entering millstones to be pulverized.

No.1 plate II. is a perpendicular section of the mill with the screw set horizontally, which has been found the best position.

A B the screw, which is for breaking plaster at the rate of 2 tons per hour, is made by twisting a flat iron bar 5 or 6 inches broad, 1 1/2 inch thick, making the screw part 12 or 15 inches long. It is set to revolve about 40 times in a minute, over a grate fixed in the bottom of a hopper strongly made and plated inside with iron; the upper corner of the bars of the grate next to A is made highest, to catch against the lumps of plaster, to prevent them from slipping too freely before the screw, which is made to turn so as to drive the plaster towards B, and causes the screw to press hard against the steel plate A, fixed there to keep the screw steady to its place. The plaster, in large lumps, is thrown into the hopper at C, and broken by the stroke of a large hammer, so that the screw will take hold of it, and as it is broken by the screw it falls through the grate D, and is guided by a sloping spout B E into the millstones, or into an elevator, to be raised to the millstone hopper. A screen may be set in

the bottom of this spout to let all that the screw makes sufficiently fine, pass through, to be guided by a second bottom F to the proper place, without passing through the stones.

G H a fly wheel on the shaft, connected with the screw to give it motion. This fly is necessary to regulate the motion of the screw, and by its momentum to overcome all extra resistance, occasioned by large or hard lumps, and to equalise the stress on the cogs of the wheels which give the motion.

No.2 represents a perpendicular plane section of a screw mill with the screw set perpendicular, to revolve in a hopper closed at bottom so as not to suffer lumps of too large a size to pass through. The bottom part of this hopper may be made of cast iron fluted or furrowed, so as to prevent the substances, to be broken, from sliding round with the screw; or it may be open, in form of a grate, to let the lumps pass through, when sufficiently reduced. Or a hole may be made in a stone to form the lower part of the hopper. Or the upper millstone may be made stationary, and the lower one made fast to the screw, to turn and perform the grinding in this case, the eye of the upper stone forms the lower part of the hopper. Or the millstone may be set vertically, instead of horizontally, and the screw set horizontally to run in a hopper but without a grate, as in No.1, the screw passing through the eye of the stationary stone, and made fast to the running one, then turning the screw turns the stone, and the screw drives the substance as broken, through the eye of the stationary stone, in between them to be ground, which does

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very well. I made a handmill on this simple structure, with which I had several thousand bushels of plaster ground by hand; it is perhaps the best handmill for that purpose: the running stone is much larger than the stationary one, and serves the purpose of a fly. This mill I sold for the purpose of breaking charcoal for a steel furnace, for which it answers very well. The millstone is fixed at the end A, and the crank put on B, and turned so as to drive the plaster or coal, &c. as broken between the stones: its simplicity renders it the more useful; it has neither wheel nor cog belonging to it: * or the screw may be attached to the cock head of the spindle of the millstone, when fixed in the common way, and a hopper put round the screw to break the hard substance and let it fall into the eye of the stone. This screw mill may be changed into a great variety of forms and be still on the same principle and be a good machine: but perhaps no form will be found better than No. 1, for breaking plaster, charcoal, Indian corn

*This invention I made and reduced to practice during the winter of 1795-6. It was with difficulty I could find any person willing to apply it to water-mills. Several years passed before I could prevail with any one to try it. Mr. John Rhynehart of Chester county was the first to adopt it; and when he got it a going, he came and advised me to take out a patent immediately, saying, it was an excellent machine; it answered so well for breaking plaster, and also Indian corn, with which people came considerable distances with waggon loads to get ground for their cattle. It is now getting into pretty general use, and there has at least a dozen of inventors started up already, all claiming the invention; so easy is it to invent a machine already in use.

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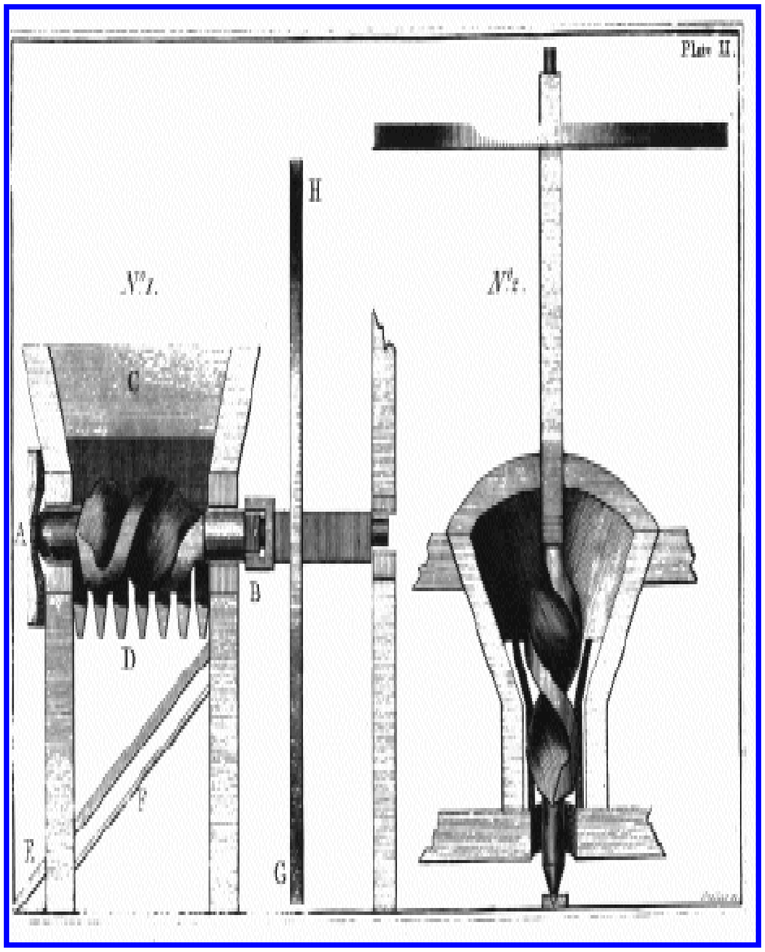
in the ear, to grind the cob with the grain, for food fot cattle, several kinds of paints, lead and other ores, different kinds of barks, &c. and perhaps no cheaper and more simple machine can be invented for a variety of such purposes.

Those who may wish either to make or use the said mill, may obtain permission by applying by letter directed to the inventor in Philadelphia, on paying 10 dollars for the license, for common uses. And those who make or use said mill, and refuse or neglect to pay for a license, will be treated as the act of congress in such cases made and provided directs.



ARTICLE XVIII.

USEFUL INVENTIONS BV DIFFERENT PERSONS.

PLATE III represents a front view of the patent Straw-cutter, invented and improved by Moses Coates and Evan Evarts. The principle of this improvement, secured by the patentees, is in hanging the knife on four centres or joints, at a proper angle, in such position as to slide the edge across the straw at the same time that it is pressed down through it, which causes it to cut with much more ease than in the common way. This is the principal improvement, and is well worthy the notice of those who have much straw to cut, as it can be done with less than half the labour of the mode now in use. Thev have also made several other improvements on the machine, viz. in the apparatus for moving the straw forward, and in fixing the knife to be worked by both hands, &c. as appears by the drawing and explanations given by the inventors themselves. Thev sometimes form the steel of this machine aslant so as to cause the knife to cut off the straw at an angle of about 45 degrees, which makes it etit much easier than at right angles, or square across.

EXPLANATION OF THE PLATE.

I. OF THE STRAW-CUTTER.

B B a board screwed to the feet.

K K the knife screwed to a board.

C C the connecting bars.

H OI the hold-fast, 2 pieces beveled to draw the knife to the steel ; the connecting bars set between them.

L the handle of the knife. The knife must be ground strait on the side next the steel.

D A the drag that moves the straw.

R the under roller and a fork. There are 6 iron plates set edgewise in the under roller which is fixed under the box, to come through the bottom board one inch: there are also 6 iron plates on an upper roller with 27 crooked forks fixed in them, with the round part foremost that they may clear themselves from the straw as the roller turns to push it forward.

G another part o£ the drag put on the end A which is raised by a pin in the lower connecting bar and gives motion to the drag.

The rollers are set 17 inches from the steel; a frame is hung to the upper roller with a weight of 30 pounds attached to it, to press it on the straw, and it is raised or lowered by a lever hung under the box.

A strip of hard wood, dressed beveling and put on the front part of the box, for the lower end of the knife to slide on, will bear the upper end of the knife to the steel, and cut clean. At the instant you raise the knife raise or draw your foot from the treadle that the straw may move forward at the same time. It will cut 100 square inches at one cut. It is well calculated to cut corn-fodder for cattle.

The irons may be had, or smiths may obtain the privilege of making them from either of the following mentioned persons: Oliver Evans, Philadelphia; William Morgan, Georgetown, Potomac; George Worral, Lancaster; Moses Coates, Chester county, or Evan Evans, City of Washington.

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II. OF THE FLOUR-PRESS.

No.2 represents an elevation of the Flour-press, invented, improved and patented by ---- Clarke and Evan Evans. The principle secured by the patent is in fixing the fulcrum of the lever to be moveable instead of stationary as is common. The long arm of the lever lengthens and the short arm shortens during the whole operation of pressing, which causes the power to increase with the resistance. The machine works quick while it meets with little resistance, and powefful when the resistance is increased. Time is not unnecessarily expended, as a barrel of flour can be packed by it in half a minute. This is the principal improvement of the invention, and is well worthy the attention of millers.

A the barrel of flour.

B the funnel.

C D the driver.

E F the lever.

G H the connecting bars, fastened by a strong pin to each side of the lever at G, and to the driver at H.

I two strong posts put through the floor, and keyed below the joists at K.

The lever works between them on a strong pin L, and when brought down by the hand, moves the pin G, in the dotted circle I, and the connecting bars draw down the driver C, forcing the flour into the barrel; and as it becomes harder packed, the power of the machine increases, as the pin G, approaches the posts I. The under sliding part of the lever is drawn out to increase its length, and is assisted in rising by the

weight M, fastened to a line passing over the pullies

N 0.

When the pin G is brought down within half an inch of the centre of the posts or plumb line, the power increases from 1 to 288; and with the aid of a simple wheel and axis, say the difference between the wheel and axis is as 1 to 15, from 288 to 8640; that is to say, one man will press as hard with this machine as 8640 men could do with their natural strength. It is extremely well calculated for a printing press, cotton, tobacco, cyder, or, in short, any thing that requires a powerful press.

CERTIFICATE.

We do certify that we have proven the above packing machine,

and find its principles to be such, that the power increases with the resistance, so as to render it a most excellent machine for packing flour with ease and despatch. It is simple and cheap in its structure.

OLIVER EVANS,

CHARLES TAYLOR, Engineer.

The above Machines can be seen at Oliver Evans's flour-store, corner of Ninth and Market streets, Philadelphia, or at William Morgan's Georgetown, Potomac, at either of which places, or of George Worral, Lancaster, Moses Coates, Chester county, or the subscriber, City of Washington, may be purchased the privilege for the Straw-cutter, for four dollars; and the Press for flour at the following rates: One run of stones, ten

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dollars; two ditto, seventeen dollars ; three ditto, twenty-two dollars; four ditto, twenty-seven dollars, and eight ditto, fifty-four dollars.

EVAN EVANS.

Those who infringe on the patents will be dealt with as the act of congress directs.

MACHINE FOR REMOVING EARTH.

As no greater improvements have ever been made in any country than those of navigable canals and turn-pike roads, many of which remain to be made in this country, I have given a plate and description of a machine, invented and improved by Gershom Johnson, for removing earth short distances, by the force of cattle, which has proved very useful for that purpose. The inventor asserts that with this machine, drawn by three horses, he can do more work than 20 men.*

Plate IV represents a side view of the machine.

B E the box for holding the earth, fixed to the

*Fortunately for the inventor, he did not take out his patent when he paid his money into the patent office; if he had done so, his term would now have been nearly expired, without having yielded him any emoluments equal to his expense and attention. The spirit for improvement in making turnpike roads and canals which prevails at this time will call for the use of this machine, and he will probably be well rewarded.

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shovel which scoops it up. B the edge of the shovel, made of sheet-iron, 4 feet wide, strengthened by a steel plate in front 8 inches wide. R a piece of timber to strengthen the shovel. Q one of the hind wheels. F one of the handles. G a treadle. H a chain connecting the treadle to the handle. I one of the iron bars connecting the shovel to the axel of the fore wheels L.

THE OPERATION.

The cattle are hitched to the bars I, and the man at the hadnles guides the point of the shovel B between the solid and loose earth to scoop up a load, driving a quantity before the shovel. If the load proves too heavy he puts his foot on the treadle and raises the point of the shovel B a little, which causes it to drop part of the load, especially in hollow places; and when the machine arrives at the place where the load is to be deposited, he throws up the handles suddenly which drives the shovel into the solid earth, and the force of the cattle turns the shovel over, bottom up, the bar N to rest on the iron bars I, and discharges the load. The shovel remains in this position, the bars O sliding on the ground, until the machine arrives at the place to take up another load, when by the rope P the shovel is drawn to its proper position. It will load and discharge two loads a minute by the force of the cattle.

APPENDIX.

A CONCISE history of the Steam Engine, from its first discovery to the present day, will perhaps be accept able and useful to those who may not have an opportunity of reading the Encyclopedia, or other rare and expensive philosophical works, where a fuller account thereof is to be found. It may also excite the curiosity of ingenious young men to procure those works and read them; and to acquire a knowledge, which may qualify them to be more useful to their country.

"The steam engine was beyond all doubt invented by the Marquis of Worcester during the reign of Charles II. This nobleman published, in 1663, a small book intitled A CENTURY OF INVENTIONS; giving some obscure and enigmatical account of a hundred discoveries or contrivances of his own, which he extols as of great importance to the public. He appears to have been a person of much knowledge and great at ingenuity: but his description or accounts of these inventions seem not so much intended to instruct the public, as to raise wonder; and his encomiums on their utility and importance are to a great degree extravagant.* His ac-

* He was perhaps as capable of invention as any man ever was, Suid we think him extravagant, only because we (do not understand him. The human mind seems incapable of believing any thing that it cannot conceive and understand to be possible, excepting what respects the dogmas of religion, to which we often yield implicit faith, without inquiring into the possibility or even probability tbereof. I speak from experience; 10' when it was first asserted that merchant flour mills could be constructed to attend themselves, so far as to take the meal from the stones and this wheat from the waggon, and raise them to the upper stories, spreadingthe meal to cool, and gathering it by the same operation into the bolting hopper, to be bolted, etc etc. until the flour was ready for packing; the projector was answered, " You cannot make water run up hill, you cannot

make wooden millers." It was thought impossible, and the inventor to be as wild in his idea', and his assertions as extravagant as any of the Marquis of Worcester's ,' Century of Inventions," are now believed to be: but we are now forced to acknowledge, that what he said concerning the steam engine, was trade, as well as of the telegraphe, the conversive statue, &C and in proportion as we understand him, and see his inventions in operation, we will believe, and cease to charge him with having been extravagant in his encomiums on their importance and utility,

I beg leave to differ with the writer, in his assertion that the Marquis's description of his steam engine, is not sufficiently clear and explicit, so as to enable an ingenious workman to discover its principles, construct an engine and put it in practice.

shovel which scoops it up. B the edge of the shovel, made of sheet-iron, 4 feet wide, strengthened by a steel plate in front 8 inches wide. R a piece of timber to strengthen the shovel. Q one of the hind wheels. F one of the handles. G a treadle. H a chain connecting the treadle to the handle. I one of the iron bars connecting the shovel to the axle of the fore wheels L.

THE OPERATION.

The cattle are hitched to the bars I, and the man at the handles guides the point of the shovel B between the solid and loose earth to scoop up a load, driving a quantity before the shovel. If the load proves too heavy he puts his foot on the treadle and raises the point of the shovel B a little, which causes it to drop part of the load, especially in hollow places; and when the machine arrives at the place where the load is to be deposited, he throws up the handles suddenly which drives the shovel into the solid earth, and the force of the cattle turns the shovel over, bottom up, the bar N to rest on the iron bars I, and discharges the load. The shovel remains in this position, the bars 0 sliding on the ground, until the machine arrives at the place to take up another load, when by the rope P the shovel is drawn to its proper position. It will load and discharge two loads a minute by the force of cattle.

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count, however, of the steam engine, although by no means fit to give us any distinct notions of its structure and operation, is exact as far as it goes, agreeing precisely with what we now know of the subject. It is No.68 of his inventions. His words are as follow: ' This admirable method which I propose of raising water by the force of fire has no bounds if the vessels be strong enough: for I have taken a cannon, and having filled it 4ths full of water, and shut up its muzzle and touch-hole, and exposed it to the fire for 24 hours, it burst with a great explosion. Having afterwards discovered a method of fortifying vessels internally, and combined them in such a way that they filled and acted alternately, I have made the water spout in an uninterrupted stream 40 feet high; and one vessel of rarefied water raised 40 of cold water. The person who conducted the operation had nothing to do but turn two cocks; so that on vessel of water being consumed, another begins to force, and then to fill itself with cold water, and so on in succession.'* It does not appear that the noble inventor could ever interest the public by these accounts."

OF CAPTAIN SAVARY'S STEAM ENGINE.

" CAPTAIN SAVARY, a gentleman of great ingenuity and ardent mind, saw the reality and practicability of the Marquis of Worcester's project. He knew the great expansive power of steam, and had discovered the inconceivable rapidity with which it is reconverted into water by cold; and he then contrived a machine for raising water, in which both of these properties were employed. He obtained his patent after having actually erected several machines, of which he gave a description in a book intitled THE MINER's FRIEND, published in 1696, and in another work published in 1699. Much about this time Dr. Papin, a Frenchman and fellow of the Royal Society, invented a method of dissolving bones and other animal solids in water, by confining them in close vessels, which he called DIGESTERS, so as to acquire a great degree of heat."

"We may add, that much about the same time Mr. Amontons contrived a very ingenious but intricate machine, which he called a *fire-wheel.* It consisted of a number of buckets placed in the circumference of a wheel, and communicating with each other by very intricate circuitous passages. One part of this circumference was exposed to the heat of a furnace, and another to a stream or cistern of cold water. The communications were so disposed, that the steam produced in the buckets on one side of the wheel drove the water into the buckets on the other side, so that one side of the wheel was always much heavier than the other; and it must therefore turn round, and may execute some work. The death of the inventor, and the intricacy of the machine, caused it to be neglected.* Another member of the Parisian

In the year 1791 or 1792, I met with a description of the principles and operation of that curious toy, called the pulse glass. I saw in it principles which I conceived might be applied to mechanical purposes, for raising water or tunling mills. I set my mind immediately to discover

force of the vapour was employed; but it met with no encouragement. The English engineers had by this time so much improved Savary's first invention, that it supplanted all others. We have therefore no hesitation in giving the honour of the first and complete invention to the Marquis of Worcester; and we are not disposed to refuse Captain Savary's claim to originality as to the construction of the machine, and even think it probable that his own experiments made him see the whole independent of the Marquis's account."

Captain Savary's engine, as improved and simplified by himself, is as follows.

It consists of a strong copper boiler, properly built up in a furnace; a receiver in which he formed a vacuum, by expelling the air with steam which was then condensed; a pipe descending from the bottom of the receiver to the water in the well; another pipe ascending to the reservoir into which the water is to be raised; a steam pipe leading from the top of the boiler into the top of the receiver, in which pipe is a cock, which being turned lets the steam rush into the receiver, to drive out the air through a valve inserted in the rising pipe; then a jet of cold water is let out of the rising pipe into the receiver, to condense the steam and form a 'vacuum, which being done, the pressure of the atmosphere presses the water in the well up the lower pipe, and fills the receiver, which is prevented from returning to the well, by the shutting of a valve fixed in the pipe. The steam cock being again turned, lets the steam press on the surface of the water in the receiver, and forces it up the rising pipe into the reservoir; another jet of cold water let into the receiver, forms a vacuum, and the water rises from the well to fill the receiver again, &c. It is hardly necessary to mention, that the top of this receiver must always be within less than ~3 feet of the surface of the water in the well, or else the pressure of the atmosphere will not force the water up into it. The contrivance is ingenious.

academy of sciences (Mr. Deslandes) also presented to the academy a project of a steam wheel, where the impulsive

the means of application. After being engaged in this study, at leisure hours, for 9 years, and having formed a great variety of plans, of which none appeared sufficiently simple, to he worthy of experiment, I conceived the idea of a hollow wheel, to be made of metal, and filled about half fill with spirits of wine, or 'water. After expelling the air sn as to form a vacuum 'ii the upper part of the wheel, it must he closed up tight, so as neither to emit air, nor emit steam. There are no working cocks or valves, or moving parts, excepting the axle on which it is hung ~d which turns out its godgeons like those of the water-wheel of a mill. This wheel being set over a fire, with the flue confined, so as to embrace about

14th part of its circumference, will turn round with a very low degree of heat, on the principles of the pulse glass, but it is then weak in power. The heat of the fire generating steam in the lower and rising quarter of the wheel, forces the liquid to the descending and upper quarter of the wheel, and it turns ro'ind slowly, by the weight of the water, being greater in the descending than in the ascending side of the wheel. I suppose it would produce no effects worthy of notice, on this principle alone. But when I apply, in addition thereto, my new principle of confining and retaining the steam, and increasing the heat, thereby to increase the elastic power of the steam, in a rapid ratio, and by applying a small slower of cold water to the top of the wheel, to condense the steam there a little, say 30 degrees, from 272 to 2420 the power of the steam in the lower quarter of the wheel will he 60 pounds to the inch, and in the upper quarter reduced to 30 pounds; the one being double the other the greater will overpower the lesser, and drive the water with great velocity from the lower to the upper quarter of the wheel, and it will move round rapidly with great power, and perform much work. I constructed a wheel of lead to work on these principles, which moved slowly, agree ably to my calculations; I have therefore no doubt, of the operation of the principles. Considering its great simplicity, having excepting the gudgeons, no working or wearing parts; that being once filled with spirits of wine, which would require much less fuel than water, it requires no supply; that 55 no vapour is suffered to escape the spirits could not diminish in the wheel, I think it the simplest and perhaps most philosophical steam engine ever conceived. Although it would he expensive to erect in the first place, it might excel all others, ever yet constructed. I am however satisfied with what I have already in use; but if I expected to live 100 years longer, and could spare the money and time, I would think it worthy of a 1011 experiment. I have specified it, and described drawings thereof, which I have filed in the patent office, that it may not be lost.

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density of a vacuum being speedily formed, and a piston of a projected machine, which was to propel a piston by means of air, took the hint and conceived the idea of forming this vacuum by means of steam, which gave rise to his celebrated engine that was wrought by the weight of the atmosphere. He constructed an engine consisting of a large boiler, properly set in a furnace, a little above which he set a cylinder, nicely bored and polished smooth within, and fixed a piston air-tight to move up and down therein; the piston was suspended to one end of a lever or working beam, and the pump rod was suspended at the other end, and was considerably heavier than the piston so as to draw it up to the top of the cylinder. The steam being let from the boiler by turning a cock or the like into the lower end of the cylinder, filled it with steam, which being lighter than the air drove the air all out at a small valve or clack fixed at the bottom of the cylinder for that purpose. This done, a jet of cold water was let into the cylinder, to rise through its bottom and strike against the underside of the piston, and falling in a spray dispersed over the inside of the cylinder instantly condensed the steam, forming a vacuum under the piston in the cylinder; when the pressure of the atmosphere on its upper side, about 15 pounds to the inch, being no longer balanced by air nor steam below, acted as the power to drive the piston to the bottom, drawing up the pump rod, to make a stroke. At the instant the engineer saw the piston arrive at the bottom of the cylinder, he opened the steam pipe to let the steam from the boiler into the cylinder, to balance the weight of the air on the piston; the superior weight of the pump rod at the other end of the lever beam, raised the piston to the top of the cylinder, when a jet of cold water was let in again to condense the steam, to form a vacuum, produce another stroke, and so on. 'this engine was offered to the public in 1705, but many difficulties occurred in the execution which were removed one by one, an4 it was it not until the year 1712 that the

But the great defect of this machine, is the prodigious waste of steam, and consequently of fuel; for the steam at every stroke comes in immediate contact with the cold surface of the water, and cold top and sides of the cylinder; and daily experience shows, that a few scattered drops of cold water will condense a great quantity of steam, almost instantaneously; by some experiments, frequently repeated, by the writer of this article, it appears, that no less than 1555 of the whole steam is uselessly condensed in this manner, and not more than ~1 is employed in allowing the water to descend by its own weight, to run out of the receiver; and he has reason to think that the portion thus wasted will be considerably greater if the steam be employed to force the water out of the receiver to any considerable height."*

Numerous attempts have been made to diminish this waste, but all to little purpose. Mr. Blackey has attempted to lessen it, by using two receivers; in the first was oil, and into this only the steam was admitted; this oil passed to and fro between the two receivers, and never touched the water except on a small surface, but this hardly produced a sensible diminution of the waste. This was done about the year 1700.

OF NEWCOMEN'S ATMOSPHERIC STEAM ENGINE.

MR. NEWCOMEN, an ingenious blacksmith of Cornwall, a person of some reading, who was particularly acquainted with the writings and projects of his countryman, Doctor Hooke, and with the principles and construction of captain Savary's steam engine, is supposed to have improved on some hints given him by Dr. Hooke, respecting the himself the writer had taken into consideration, the rapid ratio of the decrease of the elastic power of the steam as the heat is diminished, he could have entertained no doubt but that the waste of power is far greater than he has stated it to be, perhaps not less than nineteen-twentieths

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water cooling the cylinder, which having to be heated up at every stroke, condenses a great part of the steam. We have frequently attended to measure the weight of the steam which filled a very light vessel, that held 12,600 grains of water, and found it always less than one grain. So that we have no doubt of its being much more than 10,000 times rarer than water. Desaugulier says, it is 14,000 times rarer than water, and from some experiments to ascertain the water used at each stroke of the engine, we may safely suppose, that only + of the steam is employed in allowing the piston to rise, the remaining '~ being employed to warm the cylinder. The great obstacle to its extensive use, i~ the expense of fuel; an engine having a cylinder 4 feet diameter working night and day, consumes about 3400 chaldrons (London) of coals per year, or about 400 bushels per day.

To lessen this expense "every one had his particular nostrum for the construction of his furnace, and some were undoubtedly more successful than others. But science was not yet sufficiently advanced: it was not till Dr. Black had made his grand discovery of latent heat, that we could know the intimate relation between the heat expended in boiling off a quantity of water and the quantity of steam that it produced."

OF JAMES WATT'S IMPROVEMENTS ON THE STEAM ENGINE.

ABOUT the time of the discovery of latent heat by Dr. Black, in 1763, Mr. James Watt, a man of a truly philosophical mind, eminently conversant in all branches of natural knowledge, and the pupil and intimate friend of Dr. Black, was amusing himself with repairing a working model of the steam engine, belonging to the philosophical apparatus of the university, the thought occurred to him to attempt the condensation of the steam in a vessel separate from the cylinder.

This he found to succeed beyond his most sanguine expectations, and proved a great saving of steam, consequently

engine seemed to give confidence in its efficacy. The most exact and unremitting attention of the manager was required to the precise moment of opening and shutting the cocks, as neglect might be ruinous. At last, in 1717, Mr. Beighton, a very ingenious and well-informed artist, simplified the whole of the subordinate movements, and brought the machine into the form in which it has continued without the smallest change, until the present day.

We now see the great difference between Savary's and Newcomen's engine in respect of principle. Savary's was really an engine which raised water by the force of steam; but Newcomen's raises water entirely by the pressure of the atmosphere, and steam is employed merely as the most expeditious method of producing a void, into which the atmospherical pressure may impel the *first mover* of his machine. The elasticity of the steam is not the first mover.* This engine still laboured under the great disadvantage of great waste of the steam, occasioned by the injection of

This invention and discovery of Newcomen's, made from the hint given by doctor Hooke, in 1705, just 100 years ago, was the first step (an enormous stride) from the simple path of nature Here they lost sight of the true principle discovered by the Marquis of Worcester, be-fore they had gained sufficient knowledge thereof, to enable them to apply it to a useful purpose; and wandering ever since have had faint glimpses of it, but have never returned to the true path. Had Newcomen constructed a strong boiler, such as used by Savary, and applied the force of his steam simply to lift the piston, and the piston to lift the pump-rod to make the stroke, and let his steam escape uncondensed, lie would have performed at least ireple the work with the same fuel, with out endangering the bursting of his boiler. But finding his engine, be it improved, so far to excel Captain Savary's for most purposes; having got clear of the great difficulties which Savary laboured under, occasioned by his losing almost all his power after he had generated more than sufficient, had it been rightly applied ; having established tables and rules for constructing and proportiolling the engine to the task assigned to it; and finding it extolled as the greatest discovery ever made in the art, was indeed not to be expected that any person under such weighty incumbrances could ever return to the true path. It was only to be expected from one who unincumbered by scientific shackles, was fret to go as nature guided.

It may not be here improper to state the actual performance of some of these engines, as they have been ascertained by experiment.

An engine having a cylinder of 31 inches in diameter, and making 17 douse strokes per minute, performs the work of forty horses working night and day (for which three relays or 120 horses must be kept,) and burns 11,000 pounds of Staffordshire coal per day.* A cylinder of 19 inches, making *25* strokes of 4 feet each per minute, performs the work of 12 horses working constantly, and burns 3700 pounds of coals per day.** A cylinder of 24 inches, making 22 strokes of 5 feet, burns 5500 pounds of coals, and is equivalent to the constant work of 20 horses. And the patentees think themselves authorised by experience to say in general, that these engines will raise more than 20,000 cubic feet of water 24 feet high for every hundred weight of good pit coal consumed by them."

Mr. Watt, among his first speculations on the steam engine, made some attempts to produce an immediate circular motion. One in particular was uncommonly ingenious. It consisted of a drum turning air-tight within another, with cavities so disposed that there was a constant and great pressure urging it in one direction. But no packing of the common kind could preserve it air-tight with sufficient mobility. He succeeded by immersing it in mercury, or in an amalgam which remained fluid in the heat of boiling water; but the continual trituration soon calcined the fluid and rendered it useless. He then tried Parent's or Dr. Barker's mill, inclosing the arms in a metal drum, which was immersed in cold water. The steam rushed rapidly along the pipe which was the axis, and it was hoped that a great reaction would have been exerted at the end of the arms; but it was almost nothing. The reason seems to

Which is about 83 pounds, or about 1 bushel of coals to do the work of a horse.

Which is about 102 pounds of coals to do the work of horse. Which is 91 pounds of coals to do the work of a horse.

of *fuel;* but he was obliged to extract the air from the con denser, by a small pump, to keep up the vacuum, as all water produces more or less air by boiling. His next improvement was to obtain a double stroke, up as well as down. To effect this, he shut up the upper end of the cylinder, passed the piston rod through a stuffing box made air-tight, and introduced the steam above the piston to press it down as well as up instead of the atmosphere. The steam escaped by pipes leading from each end of the cylinder into the condenser, and shutting the atmosphere totally from the inside of the cylinder proved a further saving, as the cylinder remained hot, and did not condense the steam. These are his principal improvements. Many difficulties occurred in the execution, which his fertile mind surmounted as they occurred. He made great improvements in the form of furnaces and boilers, and many others in the subordinate movements, so as to render the machine applicable to most purposes, far more easily governed, capable of being varied in power, to suit any task assigned to it, and as regular in its operations as a water-wheel. " In the engine in its most perfect form, there does not seem to be above -41 part of the steam wasted, in heating the apparatus, so that it is not possible to make it ~ part more powerful."*

The fact is that an engine of this construction, of the same dimensions with a common engine, making the same number of strokes of the same extent, does not consume above 45- part of the fuel that is consumed by the best engines of the common form.

It is evident that when the writer said, '~ that it is not possible to make it one-fourth more powerful," he had no knowledge of the great saving of fuel and increase of power, that would he the result of onfluing the steam, and increasing the heat and elasticity of the steam; or of applying this great elastic power, to propel the piston, by which the power may he increased tenfold, and the fuel be reduced to one-third to perform equal work; yet it seems that this same writer gives the set of experiments which ascertains the Caistence Of the principle

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be, that the greatest part of the steam was condensed in the cold arms. It was then tried in a drum kept boiling hot; but the impulse was now very small in comparison with the expense of steam. This must be the case."*

Steam having no weight we cannot expect it to re-act with much force, by issuing from the rotary tube. This is the reason it produces so little power in this application. I therefore have contrived a steam engine wherein the elastic power of the steam is to force oil or quicksilver (if any means can be discovered to keep it fluid) through the rotary tube; when the engine will work with great power, and produce an immediate rotary motion. I have also contrived two forms of wheels, not before mentioned, making five different forms; all of which I have specified and explained by drawings, &c. according to law, as different modes in which I contemplate using my principle, of confining and retaining the steam and increasing the heat, to increase the elastic power of steam, for the purpose of saving fuel, and lessening the expense of constructing engines, none of which 'will ever be worth notice without said principle. But on mature deliberation I have reason to conclude that none of them will ever excel the cylinder and piston, so far as to be worthy of my time and attention to put them in operation.

It is evident from this account that Mr. Watt, in these experiments, has used weak steam, and placed dependence on the use of a condenser. Had he in his experiment with Dr. Barker's mill, lessened the apertures by which the steam issued, 50 as to confine the steam until the power in the boiler was equal to 100 pounds to the inch, lie would have been astonished, to see it revolve about 1000 times in a minute, supposing the rotary tube to have been 3 feet in length. I have tried the same experitment, but without the least hope of success, on any other principle than by confining the steam to increase its elasticity, to a great degree My rotary tube was 3 feet long, the elastic power of the steam about *56* pound to the inch. It revolved with a velocity of about 700 or 1000 times per minute. The apertures by which the steam issued, about 2-hathes of an inch diameter. It exerted more than the power of two men, and would answer to turn, lathes, grindstones, &C where fuel is very cheap. I have specified and explained it in die patent office.

I here close my extracts from the Encyclopedia, as my limits will not admit of doing justice to the merits of the different inventors and improvers of steam engines ; and I must refer the readers to the work itself, where they may expect to be both pleased and edified, if they wish to understand fully, the most philosophical and useful machine ever invented.

OF LATE INVENTIONS OR IMPROVEMENTS

ON STEAM ENGINES.

A man's useful inventions, subject him to insult, robbery, and abuse.

FRANKLIN.

THE truth of the above observation is daily verified. No man ever made a useful discovery, invention, or improvement, to which he claimed exclusive right, under the protecting laws of his country and was permitted to enjoy such right peaceably. He may expect to be attacked by a host of claimants, who to support their claims, load the inventor with heavy abuse, and he is obliged at great expense to defend himself.

The author when a boy, was led to the study of the possibility of moving land carriages without animal force, which he viewed as a very desirable object. He had heard of various attempts having been made, by means of cranks, wheels, pinions, springs, wind, &c. all of which appeared to him as too futile to be worthy of attention, from the want of original power. Instances had occurred, of the great explosions made by a small quantity of water confined in the breech of a gun-barrel, exposed to a smith's fire. Ilere he saw original power, which he conceived to be unlimited, but had formed no idea of the means of its application, until he met with a description of an atmospheric steam engine.

He was astonished to find that the steam, was not applied as the prime mover, but only as the means to form a vacuum, to apply the weight of the atmosphere. This he conceived to be a great error, and the more he investigated the subject, the more he was confirmed in this opinion; for it appeared clear to him, that the elastic power of the steam rose in some rapid ratio compared with the increase of heat, otherwise the power could not he augmented in so short a time, to a degree sufficient to make explosions equal to gun-powder. He conceived that double heat in the water did produce 8, 10, 16, or 32 times the power of steam, and perhaps more. These ideas existed some years before he conceived the plan of constructing small engines, to be moved by this irresistible power, to work with steam equal in power to 10 atmospheres, that would be capable of moving land carriages with heavy burdens. Not satisfied with the cylinder and piston, because it did not produce an immediate circular motion, he endeavoured to discover means of applying the expansive power of steam to a wheel, which he matured in 1784. This wheel is now described in the patent office, and called his Circular Steam Engine, No.2. He was then confident that he could propel, by means of steam, land carriages and boats to great advantage:

but as the expense was very considerable, in the first instance, he explained the principles to every person with whom he conversed on the subject, in order to induce some one or other to join him in the enterprise. Having matured his improvements on merchant flour mills, he applied to the state legislatures of Pennsylvania and Maryland for exclusive rights, and included in this application the right of propelling land carriages, by the power of steam, and the pressure of the atmosphere. Boats were not included; supposing the exclusive right in those states was not worth obtaining. Pennsylvania granted for the mill improvements only, Maryland for both mill improvements and land crriages-. While waiting on the legislature of Maryland, he

was introduced to a gentleman, (Mr. Masters) an old sea-captain, who had obtained the name of a projector, by having contrived a machine to draw trees up by the roots, which was found not to answer well in this country. This gentleman was possessed of a philosophical and mechanical genius, and was extremely anxious to be acquainted with the principles of the engine, that was to propel land carriages and boats. They. were made known to , and he expressed his approbation by saying, that a large engine on those principles would be useful if applied on board a ship crossing the Atlantic, to increase her despatch, in cases of emergency, by being used in calms, and during head winds. He said he was going to England in a short time, and asked permission of the inventor to explain the principles of his engine to people there Many other instances occurred, by which the principles of the invention might have been early communicated to English engineers. Drawings and explanations nations were sent to them, but it seems they were satisfied that they had arrived at the utmost possible state of perfection, and were therefore not easily moved.

Although the inventor had obtained a patent of the state of Maryland, before the United States' government was authorised to grant patents, he was so engaged with the introduction of his mill improvements, that he could not prosecute his inventions on steam engines, further than filing drawings and specifications of the principles in the patent office in 1792, and trying some experiments which confirmed him in his principles. In the year 1801 he commenced the execution of an engine, and in the winter of 1802, got it in full operation. Its performance excited considerable attention and curiosity.

On the day of Doctor Coxe of Philadelphia called on him with a letter from John Stevens, Esq. of Hoboken, New-Jersey, dated Feb. 7, 1804, propounding a number of questions, respecting the principles and construction of the engine, which he had heard was so powerful as to do the

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great work that had been stated in newspapers which had fallen into Mr. Stevens's hands. After having received assurances, that Mr. Stevens intended no interference with the inventor, he proceeded to answer all his questions, and to explain the principles and construction of his engine, as fully and freely as he had done to any other person; all which Dr. Coxe thinks he communicated in his answer to Mr. Stevens, as far as his memory and short pencil notes enabled him to do. Some time after this Dr. Coxe called again with another letter from the said Stevens, dated February 16, 1803, propounding another list of questions, which, after similar assurances being given, that no interference was intended, nor need to be feared, were answered, and the whole of the principles explained. Dr. Coxe called at two other different times on the same subject, and the inventor is free to say, that to no gentleman whatever, (excepting only Mr. Charles Taylor, steam engineer, and Mr. Robert Patterson, professor of mathematics in the university of Pennsylvania) has he explained the principles of his invention with more care and exactness than he did to Dr. Coxe. This he was the better able to do, having before that time committed the whole thereof to writing, from which he has since compiled his new work on steam engines. In the month of January, 1805, he laid the following

printed circular letter before the members of congress:

THE subscriber with diffidence presumes to lay before the honourable Senators and Representatives in Congress, individually, (hoping it may be well received) the following concise description of the principles of Steam Engines.

The present English steam engine, so much celebrated, consisted, in it first state, of a boiler to generate the steam; to which was connected a cylinder, open at top, in which a piston moved up and down, which was attached to a working beam, hung on its centre, the other end of which was

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connected to a pump. The steam was let into the cylinder below the piston, to balance the atmosphere; and the weight of the pump rod, at the opposite end of the beam, raised the piston up to the top of the cylinder; the steam was then shut off; and a jet of cold water let into the cylinder, to condense the steam, and form a vacuum under the piston in the cylinder.; and then the weight of the air on the top of the cylinder, which is l5lbs. to every square inch of its area, being no longer balanced, was the power which drove down the piston and drew up the pump rod to make a stroke. If they could have made a perfect vacuum by these means, the power of the engine would have been 1 15lbs. to every inch area of the piston; but it was found not to exceed 81lbs. and required large quantities of fuel, great part of the steam being lost in heating up the cylinder at every stroke, which was cooled by the jet of cold water. This is called the single-stroke engine.

The celebrated James Watt improved this engine, by making his steam of power equal to the weight of the atmosphere, and letting it in at the top of the cylinder, to supply the place of the atmosphere to push down the piston, while the steam was condensed below, and also at the bottom, while condensation was going on above, making a double stroke; and to avoid the loss occasioned by the jet cooling the cylinder, he led the steam off from each end of the cylinder into a seperate vessel, into which he let the jet of cold water to condense the steam. He found by these means he could make a more perfect vacuum, and computed the power of his engine at between 11 to l3lbs. to the inch. The expense of fuel was greatly less'ned.

This is Watt's double-stroke steam engine, so celebrated and very justly deemed the greatest of all human inventions. Although it be so limited in its power, to double the power they make an engine of double capacity, and it requires double fuel, This engine labours under the following disadvantages:

There is a continual accumulation of air in the condenser

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not even suggested that this principle might be applied to any use,) which ratio, continued from 212 to 424 degrees double heat in the water, gives 128 times the power of steam; and it is absurd to suppose that it would require 128 times the fuel to be expended in an equal time to produce double heat in the water; and if not, then this new principle will require less fuel to produce equal power.

To apply this wonderful principle, I construct my boilers of circular cylindric forms of small diameters, the best possible form to contain a great elastic power; and to enlarge their capacity, I extend their length or increase their number, which also gives a large surface for the fire to act on, making them sufficiendy strong to contain steam of elastic power equal to 15001bs. to the inch area of the piston, which would give my engine 100 times the greatest possible power of the English principle: but at the same time arranging the work so that 50lbs. to the inch power will be sufficient in ordinary cases, and so that we cannot without considerable trouble and difficulty, ever raise the powers to exceed 150lbs. to the inch in the most extraordinary case; greater power we will never want, which makes the engine perfectly safe from explosion, as it will bear from 10 to 30 times the power that we shall ever have need of using, and be from 5 to 10 times as powerful as Watt's engine. I have an engine in operation in the most simple form without a condenser, which is capable of performing three times the work with equal fuel, compared with the English engine; and succeeds according to theory, working with steam, generally equal in power from 50 to 1001bs. to the inch; doubling the fuel appears to produce about 16 times the power and effect. Its great power and simple structure fits it for propelling boats up the Mississippi, and carriages on turnpike roads, two of the most difficult applications; therefore will apply to all others as a powerful agent.

I have conceived further, and still greater improvements, which I wish to put in operation.

generated by boiling the water, which would destroy the vacuum in a short time, and stop the engine; therefore an air pump is constantly at work to extract it. Also a continual accumulation of sediment, which adheres to the bottom of the boiler, forming a non-conductor of heat, causing the boiler to burn out; they are obliged to stop once or twice a month, let all cool, and open the boiler to go inside to scrape away the sediment.

The boilers are constructed to bear little or no power of steam, their principle being to make the steam inside the boiler equal to the atmosphere outside; and if ever the safety-valve is overloaded, or a double weight laid on by accident, and the steam does not get vent, the boiler explodes; and if ever the steam in the boiler is suddenly condensed by a dash of cold water on its top, &c. it collapses, being pressed in by the weight of the atmosphere. The principles of the engine are dangerous, ever liable to these accidents, and it was generally believed that nothing could be gained by increasing the power of the steam to exceed atmospheric power.

My ideas of the application of the power of steam were very different at the first. I conceived the power to be irresistible; that the power increased in some very rapid ratio, as we increased the heat in the water; otherwise it could not rise to such a pitch in so short a time, as to make the terrible explosions which I had known of: I supposed that doable heat in the water, would give eight, or sixteen, or perhaps thirty-two times the power of steam. On these principles I conceived that I could obtain any power I pleased, simply by confining the steam and increasing the heat, and perhaps with less fuel, and a much smaller engine. After I had commenced the construction of an engine on these new principles, I was informed that some curious and philosophic gentlemen had made a set of accurate experiments, the result of which was that every addition of thirty degrees of heat to the water by Fahrenheit's thermometer, be the temperature what it say, doubles the bulk and elastic power of steam, (but had

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dregs pass off at the other end in a continual stream. And in which, principles are adopted to suppress the watery vapour until the spiritous vapour may rise with a very rapid process, to obtain purer spirits at the first distillation.

The principles of this invention may be conceived, when we consider the common process of distillation, which I suppose to be as follows, viz. The pressure of the atmosphere which is equal to l5lbs. to every square inch surface of the beer in the still, suppresses the watery vapour until the beer is heated to 212 degrees of Fahrenheit's thermometer, or boiling heat; but the spirits being more volatile, its vapour is about double as powerful, and will rise under that pressure at 170 degrees of heat, 42 degrees below the boiling point of water: now, while the heat is kept between those two points, purer spirits are obtained; but the process is too slow, and the distiller to increase it, makes his still boil, which raises large quantities of watery with the spiritous vapour. Now it appears evident, that if we sue the path pointed out by nature, we may, by increasing the pressure, suppress the watery vapour until the spirits rise rapidly, and use less fuel; but this is much more difficult to explain. Any further explanation required, I am willing to give.

OLIVER EVANS.

The foregoing letter was sent by Dr. Mitchill, a senator from the state of New-York, to his friend Dr. Miller, one of the editors of a periodical work, entitled the Medical Repository, to be published therein. John Stevens, Esq. of Hoboken, (New-Jersey) having seen and read it, thought proper to make the following remarks, which were published in the same number of the Repository with the letter.

1st. The inexhaustible steam engine, so called, because it is arranged on such principles that the water in the boiler will not be exhausted by boiling and working the engine; by which means I evade the accumulation of sediment from the water, as it forms a non-conductor of heat on the bottom of the boiler, which will cause it to last 10 times as long. I also evade the accumulation of air to interrupt the vacuum, by which means the vacuum will become more perfect, and the engine have more power, and require less fuel. The principles on which this is done may be easily conceived, if we suppose a still with its condenser so elevated that the worm, after it leaves the condenser, may be turned to lead the spirits back into the still; this still may in theory be boiled for ever, without being exhausted. Thus, after the steam has passed through my engine, it is condensed into water, and returns into the boiler again, and no sediment or air can accumulate from water distilled many times over.

2(1. The volcanic steam engine, in which I attempt to use the principles of the natural volcano, where the furnace and boiler are in one, and where the fire burns without the aid of the atmospheric air to kindle it; but until I shall discover a fuel which will so burn, I use a forcing air pump to kindle the fire. In this engine the boiler and furnace are united, the water round the fire and the flue of the furnace is made to discharge immediately into the water at the bottom of the boiler, and bubble up through it, communicating all the heat of the fire to the water to generate steam; and all the elastic fluid generated by the combustion of the fuel, which I must suppose will be expanded to at least 2000 times the bulk of the fuel, unites with the steam to work the engine, by which means not more than one-fourth part of the fuel will be required, which fits this engine for boats or carriages better than the other.

3d. The perpetual still, arranged upon such principles, that the beer is received at one end, to pass slowly on to the other(r; during which time the sprit is extracted ,and the

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projected improvements, and I shall not only listen to you, but thank you into the bargain. Believe me to be, dear sir, with great esteem and regard, yours, &c.

JOHN STEVENS.

A description of his still follows, explained by a drawing, which I cannot give for want of the plate.

NEW-YORK, JANUARY 12th, 1805.

DEAR SIR,

I AM this moment favoured, by Dr. Miller, with Mr. Evans's project for the improvement of steam engines. He begins with a short history of this noble machine, but has (I will not say through design) omitted mentioning the first attempts made by Captain Savary, in which this very principle of working a steam engine, with steam at a high temperature, and with great elasticity, was resorted to, but without success, although he used boilers, strengthened with radiating bars and bolts within, and strongly hooped without. Here, then, we find the Principe of using strong steam, at a high temperature, is actually as old as the invention of the steam engine itself. Mr. Evans, then, can surely have no well-grounded pretensions to a claim of invention with respect to this principle. That the elasticity of steam is increased by an increment of temperature, is surely no novel discovery. But that this increment should bear a very small proportion to the quantity of heat required for the conversion of water into steam, was a natural and obvious deduction from the important discoveries of Dr. Black respecting latent heat. These discoveries you have yourself, no doubt, heard the doctor detail in his lectures some twenty years ago; and Mr. Belancour's experiments, instituted for the express purpose of ascertaining the ratio of increment of the elasticity of steam, at different temperatures, were made in 1790. Experiments, for the like purpose, were also made by the editors of the Encyclopedia Britannica, and pub15

Remarks on Mr. Evans's project, and an account of other improvements in steam engines, by John Stevens, Esq. of Hoboken: communicated in the following letters to Dr. Mitchill.

NEW-YORK, JANUARY 9th, 1805.

DEAR SIR,

You favour of the 6th instant I have this moment received. Among other projects of Mr. Evans's, I find you enumerate improvements in distillation. Here Mr. Evans and myself are likely to interfere. The idea of distilling with steam is not new. Count Rumford has suggested its practibility in one of his essays. You must observe that Mr. Evans and myself work the steam engine without any condensing apparatus. This steam then, after its discharge from the cylinder, without any diminution of temperature, may be applied to the purpose of distillation. This application of steam naturally suggested itself to me when I first made my experiments on working a steam engine with steam at a high temperature. I have accordingly invented a still adapted to the purpose, simple and cheap in its construction, and calculated to produce spirit of a much better quality than can be obtained in the ordinary way of distilling. A description of my contrivance you will find inclosed; and as it may, in case of interference, prove of use to me, I wish you to preserve this letter and that description, noting thereon the date of its reception.

Of Mr. Evans's volcanic engine, I lately received a description from Dr. Coxe, of Philadelphia, from which, I must confess, I did not form the most exalted opinion of Mr. Evans's project. From the many difficulties that presented themselves, it really appeared to me he was in pursuit of an *ignis fi~tziu.v*.

You say you started a doubt respecting his supposed improvement in distilling. But although he would not listen to it, the doubt exists as strong as ever." Now, my dear sir, I intreat you to take the same liberty respecting my

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years ago, long before I had heard any thing of ~Tr. Evans, it occurred to me that a condenser might be so constructed, as that by exposing a large surface within a small compass, the steam might be so nearly condensed, as to ~ender a jet of cold water unnecessary; but, upon trial, I must candidly confess, it did not answer equal to my expectations. The reason is obvious: the heat could not be conveyed *through* the metal with sufficient rapidity, so that the temperature *within* the condenser should be sufficiently low to condense all the steam.

[Here Mr. Stevens has shown that he was not able to comprehend the principles and construction of this engine; he will surely never claim it hereafter: but if he had seen ray specifications and drawings, then the application would have been obvious from the discoveries perhaps, of Newcomen or Watt.

1. " The volcanic steam engine." But till he shall have discovered a fuel which will burn without the aid of atmospheric air, I shall desist from saying any thing about his intended application of this project, to propelling boats and wheel carriages

[He means, I suppose, until he sees it in operation, then the application will be obvious to any one from the burning and explosions of volcanoes.

ad. " The perpetual still" Here, if I understand Mr. Evans, he assumes a very erroneous principle. He concludes that spirits will rise more readily than water, in proportion as the pressure is increased. But the very ingenious experiments of Mr. Dalton have proved incontrovertibly, " that the variation of the force of vapour from all liquids is the same for the same variation of temperature." Thus the force of the vapour of spirit of wine at *175* degrees is equal to 15lbs. and the force of vapour of water at 212 degrees is equal to l5lbs.-increase the temperature of both degrees, and the elastic force of each will be increased equally, viz. to about 261bs. on the square inch. By some experiments

established therein a dozen years ago. The application of this very important law of increment, developed by these gentlemen, to the improvement of the steam engine, was obvious; the great desideratum was to construct a boiler sufficiently strong to withstand a very great pressure of steam.

[Has Doctor Black, Belancour, the editors of the Encyclopedia Britannica, (or even John Stevens, Esq.) ever pointed out the means by which these principles could be advantageously applied to the improvement of steam engines, or did they even suggest such an idea

To apply this wonderful principle," says Mr. Evans,

" I construct my boilers of circular cylindrical forms, of small diameters, the best possible form to contain a great elastic power; and to enlarge their capacity, I extend their length, or increase their number." Here Mr. Evans, for the first time that I have heard of; assumes to himself a principle, for which I have obtained a patent near two years ago For I would ask, whether his boilers before, or even since, have been constructed upon the principle above stated? The boiler he used at the time my patent was obtained, was a metal cylinder of 20 inches diameter, and 20 feet long surrounded by an exterior one of wood. His present boiler is a like cylinder placed in brick work. The only difference between them is, that in the former the fire was made within the cylinder; in the latter it is made to surround i~ He has made no attempt to diminish the diameter of his cylinder, or to increase the number of cylinders. The latter, indeed, he could not do without a manifest interference with my patent. Of this, I doubt not, Mr. Evans himself would be sensible, where he to peruse my specification filed in the patent office.

But, it seems, Mr. Evans has " conceived further, and still greater improvements, which he wishes to put in operation.

1st. " The inexhaustible steam engine." I have nothing to say about this sociable project other than that many

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All experimenters agree, that the same law governs both, viz. that within a certain range every addition of about 30 degrees to the temperature, doubles the elasticity. In the above scale, the temperature of the spirits is kept 7 degrees below that of the water. When water is 212, and spirits *205* degrees, the difference is 15lbs. to the inch, and every addition of 30 degrees doubles the power of both, and doubles the difference; three steps brings the difference to 60 lbs. when the spirits will rise with great rapidity, and the watery vapour be totally suppressed. It is wondrous that this was not obvious to Mr. Stevens, from the discoveries of Belancour and Dalton, that he might have claimed "the application of it on certain principles, to the improvement of his notable still."]

While on the subject of distillation-Can you not suggest to me some varnish or cement, that will resist the action of alcohol, which I may substitute in the place of metal for lining my wooden alembics? But spirits are preserved for any length of time in wooden vessels. ~ Would wood be affected by spirits at a temperature of 100 to 150 degrees? I am inclined to think that at the *low* temperature of the wash in my still, it may not be necessary to defend the wood from the action of the spirit. I shall at least make a trial.

Mr. Evans, proceeding on the calculations given in the Encyclopedia and by Count Rumford, has been led into an error as well as myself, in estimating the increments of the force of steam with given increments of temperature. It is laid down by these authors, that for every increase of 30 degrees of temperature the elasticity of steam is doubled. But Mr. Dalton has proved that the ratio is not equable and constant, but is a gradually diminishing one.

Temperature	Force of Vapour	Temperature	Force of vapour
9.46	160	19.00	340
	`190	34.99	370
	220	58.21	400
	250	88.75	430

But Mr. Dalton has proved, from a series of very accurate experiments on the elasticity or force of sulphuric ether, at different temperatures, from 32 to 212 degrees, that the increments of force are in a direct ratio to the increments of force of watery vapour from 142 to 322 degrees. The boiling point of ether in the open air being 102, that of water 212 degrees.

It is presumable, therefore, that spirit vapour is governed by the same law of increment, and that Mr. Achard committed some error.

[Had I permitted Mr. Stevens to have palmed such an error or misrepresentation on the public, to remain as an impediment to improvements, and especially to my proposed improvement on distillation, I would have been guilty of a neglect of duty. He says that the force of vapour at 175 degrees is equal to 15lbs. then he should have stated it thus:

Temp of watery vapour	Temp of spiritous vapour	In mer	Elasticity or force of both
209	1730	28.1	36
189	154.6	18.5	34.4
168	134.4	11.05	33.6

experience, in this bewitching department of experiments and inventions, ought to have taught me long ago, the truth and accuracy of Mr. Evans's calculation. Mr. Evans laments that he has already risqued 2000 dollars. Alas! I have risqued more than ten times that amount, and although I have been more than twenty years hard at work, I have as yet derived not one shilling advantage from all my various schemes and projects. If, therefore, now that I think I see some prospect of indemnification, I should discover some degree of solicitude to secure the property of an invention, no one, I 'trust, will blame me.

It may not be amiss to mention, that steam discharged from the cylinder, may be applied to working one of Watt and Bolton's engines; and I think it probable that it would not require more fuel than if worked in the common way. In this case, the whole of the work performed by my engine would be saved.

[I recollect perfectly well having explained this to Dr. Coxe, as I did to others, saying, that all the power which I yet had, was so much over and above the power of Bolton and Watt's engine, that the steam after it left my engine would work one of theirs; and that I could add their power to my engine, by the use of a condenser. Mr. Stevens has not conceived this simple mode, but took up the idea of an additional engine. Indeed, Mr. Stevens, this circumstance added to all the rest, gives the whole a dark appearance; and your endeavours to impress the public mind with an unfavourable opinion of my improvements, and that I have assumed to myself some of your inventions, is both illiberal and injurious to a great degree.]

Mr. Evans tells us, " that the great power and simple structure of his engine, fits it for propelling boats up the Mississippi, and carriages on turnpike roads; two of the. most difficult applications." Difficult indeed it must prove, should he attempt to effect either of these purposes with his unwieldy boiler of 20 feet in length and 3 or 4 feet dimater equal to l3Olbs. on the square inch. This we find is very far short of Mr. Evans's extravagant calculation, that 424 degrees gives steam 128 times as strong as steam at the temperature of 212 degrees. From my experiments detailed hereafter, it will appear that this calculation of Mr. Dalton's is too low; that 424 degrees would give steam equal to *450* in.

[Continue this scale of the diminution of the ratio, and the increase of elasticity by the addition of heat will entirely cease before the elasticity would be sufficient to burst one of my boilers; so that Mr. Stevens removes all danger on that score: but I fear that neither Dalton nor him are right. They have, however, left me a good power; 1301bs. to the inch is quite sufficient.]

Mr. Evans exaggerates enormously the strength of his boiler, when he estimates it capable of sustaining a pressure of 15001bs. on each square inch. Count Rumford has ascertained, by actual experiment, that a bar of wrought iron, an inch square, will require about 63,OOOlbs. to fracture it. Mr. Evans's boiler is composed of wrought iron a quarter of an inch thick, and as it is 20 inches diameter, or about 60 inches in circumference, 60 multiplied by 1500 is equal to 90,OOOlbs. pressure on each inch of the circumference of his boiler. To withstand this pressure, it ought to be an inch and a half thick instead of a quarter. Contrast this with the tubes of which my boiler is composed of an inch diameter, giving about 3 inches in circumference, 3 multiplied by 1500 is equal to 45001bs. which would require a thickness of only one-fourteenth of an inch of wrought iron.

[Here Mr. Stevens has magnified, by his calculations, 15001bs. to the inch circumference of my boiler to 90,OOOlbs. and then proceeds on his error to find the thickness of iron necessary to bear it. I advise him to read the rules, with their demonstrations, which I have laid down.]

Mr. Evans considers his inventions, although of the utmost importance, as a bad speculation. in my own sad experiments

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constructed a rotary engine, on the axis of which revolved a wheel at the stern of the boat like a wind-mill or smoke-jack. It was impossible to make a more simple application of the power. After repeated trials, however, I found it Impracticable to preserve a sufficient degree of tightness in the packing, &c. The yellow fever came on and interrupted my further progress The next winter I was employed in constructing another rotary engine on a new plan; but this, on trial, proved no better than the first. Thus I lost a whole year, and was compelled, reluctantly, to have recourse to Watt and Bolton's engine. I set immediately to work, and some time in May last had my machinery all on board a boat. My cylinder is 4~ inches in the bore, with a 9 inch stroke. The complex machinery for opening and shutting the valves of Watt and Bolton's engine I have reduced to a single movement. The lever beam I have dispensed with altogether, as also with the condensing apparatus and air-pump.

[Here Mr. Stevens expressly states, that he lost a whole year after he had obtained his patent, in pursuit of projects which proved futile, and that he was compelled, reluctantly, to have recourse to Watt and Bolton's engine. Why did he not speak truly, and say Evans's engine .~ for it is not Watt and Bolton that he follows, but he treads in my steps exactly. I had in use during two years before that time all the improvements he had recourse to. The heavy lever beam I had dispensed with altogether, as well as the condenser and air-pump, and used a small forcing pump to supply my boiler. The principle of the great elastic power of steam, discovered by the Marquis of Worcester, (but which had been abandoned for one hundred years, as unmanageable) I had applied to propel a piston in a cylinder similar in its construction and operation to Watt and Bolton's; producing an engine ten times as powerful, expending only one-third the fuel to (10 equal work, and costing only half the price, compared to Watt and Bolton's. Mr.

Stevens has been reluctantly compelled to follow me, by adopting all my improvements.]

. It is plain to be seen, that, to perform these very arduous exploits, Mr. Evans does not mean to employ his own boilers, but to avail himself of the principle he has so dexterously assumed to himself, viz. to increase the number of his cylinders. To place this matter in a striking point of view, I will give yon the dimensions of a boiler I pro-pose putting on board of a vessel to ply as a passage boat betwixt this place and Albany. Length of the boiler, 6 feet3 breadth, 4 feet; depth, 2 feet. A boiler of these dimensions will expose, in the most advantageous manner, upwards of 400 feet of surface to the action of the fire. To expose an equal surface with a boiler on Mr. Evans's plan, would require it to be upwards of 80 feet long; but were it twice that length, it would not give an equal quantity of steam, as it would be impracticable to apply heat to it advantageously.

Pardon the great length to which this letter is protracted:

the objects I conceive myself on the point of accomplishing are of immense importance. You have sent forward Mr. Evans's paper to be inserted in the Medical Repository. This has a wide circulation, not only in the United States, but throughout all Europe. I therefore think, that in justice to myself and the world, I should have an opportunity of asserting and maintaining what I conceive to be my right. I should wish, therefore that you would forward this and my former letter, with a certified copy of my specification, filed in the patent office, without delay, so that 1 may be able to insert extracts therefrom, in the same number of the Medical Repository with Mr. Evans's paper. I am, my dear sir, with the sincerest regard, yours, &c.

JOHN STEVENS.

It may not be amiss to go into a short detail of the progress I have made since obtaining the patent. My object was, in the first instance, to construct an engine, adapted more immediately to the purpose of propelling a boat. This was an error which occasioned the loss of the first season.

My boiler was on a similar construction with the ono described in my specification. It was 2 feet long, 15 inches wide, and 10 or 12 inches high, and consisted of 81 tubes, 2 feet long, and 1 inch diameter. As my boat was nearly 25 feet long, and 5 feet wide, I was not able, with safety, to raise a chimney of more than 3 or 4 feet high. The consequence was, I was unable to establish a sufficient draft between the interstices of the tubes, so as to support a brisk fire; and the power of the engine was, of course, too feeble to give much motion to the boat. I then altered the furnace ~o as to allow room between the tubes and the brick work for a draft. This was applying the heat of the fire to a great disadvantage; but I could do no better. Under these unfavourable circumstances, however, I made another trial, and gave to the boat a velocity of about four miles an hour. After having made repeated trials with her, my son undertook to cross over from Hoboken to New-York, when, unfortunately, as she had nearly reached the wharf, the steam pipe gave way, having been put together with soft solder. This threw the crew into some confusion, and by dashing a pail of water suddenly on the boiler, the immediate contraction of the metal cracked a number of the tubes, and thus put an end to all further experiments with this boiler. To avoid a similar accident, I set about constructing a boiler on another plan. A single plate of brass was placed horizontally, and tubes were screwed into the under side in a vertical direction. It was rate in the fall before we could bring our engine into operation again; but for want of sufficient draft, its performance was not much more powerful than before. It was kept going, occasionally, for a fortnight or three weeks, the boat making excursions of two or three miles up and down the river; and, finally, on the approach of winter, the machinery was taken out of the boat. I will must mention, that in the spring, previously to putting it aboard the boat, the engine was set agoing in the shop. At first, a stove pipe was carried out of one of the windows; but with all our endeavours, though the boiler was perfectly

right, we could not raise the safety valve loaded with about 50lbs. to the square inch. The flue was then carried out above the roof, and in a few minutes a few shavings would set the engine agoing. As I was impatient to try its performance in the boat, I did not apply it to any sort of work, so that I made no estimate of its power to ascertain how much work it would perform with a given quantity of fuel. When on board the boat we repeatedly stopped the engine till the steam would raise the safety valve; when, for a short distance, the boat would go at the rate of not less than seven or eight miles an hour.

I am at present employed in constructing a boiler on a different plan from the last, and which, I expect, will turn out a great improvement on it. And as it will be much larger, and placed in a building with a lofty chimney, I expect to be able to work with a load on the safety valve of l00lbs. or perhaps 2001bs. to the square inch. And as I purpose. pose putting up a pair of mill-stones, I shall also be able to determine the quantity of work performed with a given quantity of fuel.*

Should this, on trial, as I feel fully confident it will, answer my expectations, I shall immediately set about one on a still larger scale, to be placed on board a vessel to ply as a passage boat between this city and Albany.

[Mr. Stevens states that his next boiler will be much larger. His inch tubes will, no doubt, swell to cylinders of

That the Saving of fuel must be very great indeed there cannot be a doubt 0. Evans States that with a 102 (1 of 281bs. to the square inch, three times the work is performed with an equal quantity of fuel. What then 'nay we expect when the elasticity of the Steam equals lOOlbs. or perhaps 2OOlbs. on the square inch. The experiments of Dr. Black and others prove, that when water is converted into Steam, 600 or 900 deg. of heat are absorbed. Now, an addition of less than 400 deg. would bring this steam to the heat of boiling oil, its elasticity would then (according to my experiments) be equal to 40 atmospheres, or 60Olbs. on the square inch. Thus then, if 900 degrees equal one atmosphere, 1300 degrees equal 40 atmospheres; but to raise the temperature of steam in the above proportion Cannot require any thing like 40 times the fuel.

The area of a circle of three-eighths of an inch diameter is very nearly one-ninth of a square inch. Thus then, 12+ lbs. the average of weights raised by the explosions, multiplied by 9, gives 650lbs on the square inch for the elasticity of the steam at rise temperature of boiling oil, which is usually estimated at 600 degrees of Fahrenheit's thermometer. This is an elasticity considerably greater than the result which Mr. Dalton's principles of calculation would afford, but much less than the calculations of Mr. Achard and the editors of the Encyclopedia Britannica would make

it. By the experiments of these gentlemen, it appears that from 150 to 280 degrees (which was as far as their experiments extended) an addition of one inch of mercury for every 10 degrees was very nearly the ratio of increment, if we except the last 10 degrees, which is evidently erroneous. Now, it is not a little remarkable, that the same ratio of increment, extended to 600 degrees, gives an elasticity coinciding very nearly with the result of my experiment. Thus,

350	252
400	382
450	537
500	717
550	922
600	
1152 equal to 767 lbs	

300 degrees gives an elasticity of 147 inches of mercury.

[Flaxseed oil contains a portion of water, and will boil at a lower temperature than 600 degrees: this may have led Mr. Stevens into an error; but whether the result which he has drawn be true or not, experience shows that we can obtain any power that we would attempt to hold in our boilers, and sufficient for any purpose. In the year 18011 constructed, for the purpose of making experiments, a small boiler of cedar wood, 12 inches diameter and 20 inches in height, strongly hooped with iron: inside of this cylinder was put a cast iron furnace 7 inches diameter at the lower and 3

20, then to 30 inches diameter, just as large as will be quite safe to hold the power. Then he may feel fully confident that it will answer his expectations, and that he may work with a load on his safety valve of 100 or perhaps 200ibs. to the inch, as well as Evans. Dr. Coxe saw him have the whole in actual operation, and it has performed well two years already. Mr. Stevens, in his note, shows that he misunderstood me respecting the load on the safety valve, viz. 281bs. lessening the fuel to one-third. He has here spoken leatnedly on the principles which I had explained long before to Dr. Coxe.]

I have lately been engaged in making a number of experiments, to ascertain the elasticity of steam at the temperature of boiling oil. In making similar experiments about two years ago, I employed a lever to keep down the valve, with a weight suspended thereon like a steelyard. This mode of operating was necessarily inaccurate. I now pursued a plan which was not liable to the same errors. A brass tube about ten inches long, and about one inch diameter, was first fixed in a perpendicular direction in an iron vessel containing common paint oil; on the top of this tube, the surface of which was perfectly flat, a valve was accurately fitted; the bore of the tube is precisely three-eighths of an inch in diameter; a tea-spoonful of water was then poured into the tube (which filled it about one-fourth full), the valve raced thereon, and loaded with 73 lbs. After the oil had been made to boil some time, about three fourths of a pound was gradually removed. To do this readily I made use of nails. An explosion then took place, but without much noise, as the steam was but barely able to make its escape.

This experiment was tried repeatedly with little variation; so that the elasticity of steam, at the temperature of boiling oil, may be depended on, as being ascertained with a considerable degree of accuracy. I am certain it cannot deviate from truth, more than one part in a hundred.

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than 280 degrees, at which temperature the elasticity of steam was found equal to about four times the pressure of the atmosphere. By experiments which have lately been made by myself, the elasticity of steam at the temperature of boiling oil, which has been estimated at 600 degrees was found equal to upwards of 40 times the pressure of the atmosphere.

To the discovery of this principle or law, which obtains when water assumes a state of vapour, I certainly can lay no claim but to the application of it, upon certain principles, to the improvement of the steam engine, I do claim exclusive right. It is obvious that, to derive advantages from an application of this principle, it is absolutely necessary that the vessel or vessels used for generating steam should have strength sufficient to withstand the great pressure arising from an increase of elasticity in the steam. But this pressure is increased or diminished in proportion to the capacity of the containing vessel. The principle then, to which I claim exclusive right, consists in forming a boiler by means of a system, or combination of a number of small! vessels, instead of using, as in the usual mode, one large one; the relative strength of the materials of which these vessels are composed increasing in proportion to the diminution of capacity. It will readily occur that there are an infinite variety of possible modes of effecting such combinations; but, from the nature of the case, there are certain limits, beyond which it becomes impracticable to carry our improvements. In the boiler I am about to describe, I flatter myself the improvement is carried nearly to the utmost extent the principle is capable of.

SPECIFICATIONS

Suppose a plate of brass, of one foot square, perforated by a number of copper tubes of an inch diameter and two feet long, the other ends of which to be inserted in like manner, into a similar plate of brass: the tubes, to insure

inches diameter at the upper end, with a flange 12 inches diameter at each end, which served as heads for the wooden cylinder: I fixed a safety valve and cock in the upper end. The space between the furnace and wooden cylinder contained the water which surrounded the fire. A small fire in this furnace soon raised the power of the steam to such a degree as to lift the safety valve loaded with 1521bs. to the inch. I then opened the cock, regulating it so as to keep the valve just lifting. The quantity of steam which continued to escape while the fire was kept up, and the force with which it issued, was astonishing. The degree of heat which produced this immense power did not in the least injure the cedar wood. No further experiments were necessary to prove the practicability of the application of my principles.]

copy OF MR. STEVENS'S PATENT AND SPECIFICATION.

To all to whom these presents shall come, greeting:

I certify that the annexed writing is a true copy of the specification of a patent granted to John Stevens, duly compared with the original on file in this office.

In faith hereof, I, James Madison, Secretary for the department of State of the United States of America, have

signed these presents, and caused the seal of my (L. S.) office to be affixed hereto, at the city of Washing.

ton, this sixteenth day of January, A. D. 1805, and in the twenty-ninth year of the independence of the said States.

JAMES MADISON.

From a series of experiments made in France, in 1790, by Mr. Belancour, under the auspices of the Royal Academy of Sciences, it has been found that, within a certain range, the elasticity of steam is nearly doubled by every addition of temperature equal to thirty degrees of Fahrenheit's thermometer. These experiments were carried no higher

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one year before he took out his patent, far exceeding every application of steam before known or used. And Mr. Stevens, well knowing that I claimed the exclusive right to the Invention, attempted to secure to himself the exclusive right of using this my discovery, which had cost me 2000 dollars in cash to put in useful operation, besides my time which I cannot rate at less than another thousand dollars. But he says he has been twenty years hard at work, spent 20,000 dollars, and succeeded in nothing; therefore he thinks that he is entitled to his claim. The date of his patent (April 11th, 1803) is two months after Dr. Coxe had called on me. He has specified nothing but what was in use before; and all his projects, that he has yet mentioned, on which he has spent his labour and money1 have been tried by others long ago.]

OLIVER EVANS'S REPLY.

extracted from the Medical Repository.

PHILADELPHIA, APRIL 13, 1805. SIR,

AT the several times which Dr. Coxe called on me at your request, to obtain information respecting the construction and principles of my improvements on steam engines, I asked him what was the object of your numerous and pointed questions. Does he intend any interference with my invention? He answered, that you were a gentleman, and was making experiments for your amusement that therefore I need not apprehend any interference. Having received this assurance, I communicated freely, answering all your questions, and explained the principles without reserve, as I have done for twenty-one years past (ever since I first conceived the principles) to every gentlemen whom I conversed with on the subject; and when I was informed by Dr. Mitchill, in December or January last, that you intended to comment on the paper which I had laid before each member of congress individually, to show the the differ-

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their tightness, to be cast in the plates. These plate are to be closed at each end of the pipes by a strong cap of cast iron or brass, so as to leave a space of an inch or two between the plates and their respective caps. Screw bolts pass through the caps into the plates. The necessary supply of water is to be injected by means of a forcing pump into the cap at one end, and through a tube inserted into the cap at the other end the steam is to be conveyed to the cylinder of a steam engine. As the boiler now described embraces the most eligible mode that has yet occurred to me of applying the principle, it is unnecessary to give descriptions of boilers less perfect in form and construction, especially as these forms may be diversified in a thousand different modes.

(Signed) JOHN STEVENS.

signed in presence of as,

JOHN KEESE,

CHARLEs T. KEESE.

The patent is dated April the 11 th 1803.

[Mr. Stevens in his specification, confines his invention to his boiler, which was patented by Mr. James Runisey, August 6th, 1791. Mr. Runisey's words in his specification are as follows: " That is new modes of generating steam in greater quantities, to a greater degree of expansion, and with much less expense of fuel, than by any mode ever before known, by means of a boiler consisting of, or formed by, homogeneous incurvated tubes, connected together and composed of metal least subject to corrode." But Mr. Runisey failed in the application of the principle, therefore, if Mr. Stevens has made any improvement which will cause it to answer the purpose, he is intitled to a patent. These are the principles on which he claims the exclusive right of using strong elastic steam, which was not known to be useful, nor used to any working engine, until I discovered the means of application, and had it in actual operation

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Now, sir, what benefits do you expect to arise from your having laid me under the necessity not only of defending my character, but my interest? Shall we criminate and recriminate each other in public, until we give good people cause to pronounce us fools? I wish to employ my time to a more useful purpose. To be sure, you have greatly lessened the force of your remarks, by informing us that you have been hard at work for twenty years, and expended 20,000 dollars, and have not yet derived one shilling from all your various schemes and projects. Surely, sir, this experience of your's was sufficient to have taught you, that you are not qualified to pass judgment on the works of those who have been successful. It is at least sufficient to convince other people. Can you point out one single instance wherein the man whose work you condemn has failed of success in bringing into operation and use any thing he once attempted?

In answer to your charge I might retort on you as follows:

1. You say I am in pursuit of an ignis fatuus; but experience has taught me, that many who think themselves wise have said, and will say the same thing, until they either understand the principles, or see them in operation.

2. I was not publishing, but only writing to each individual member of congress, therefore there was no need of mentioning Captain Savary's application of strong elastic steam in his first attempts; but you have omitted to mention (I will not say through design) that he soon gave it up for want of a true knowledge of the principles which only could direct to a useful application. I was showing the difference of the principles and powers between Watt and Bolton's steam engine (which has long been esteemed the best) and my own, to show how far my principles exceed their's, as justly to entitle me not only to an exclusive right for using them, &c. but to the fostering aid of congress, so far as to protect me in the exclusive enjoyment of my]mprovements on mills for another term that I might apear

the presensce in principle of the best English steam engines and my own, (which I did not write for publication, nor did I publish it) he then told me that you would treat the subject like a gentleman; therefore I rested so perfectly easy that I did not peruse your comment until yesterday, three months after its date. I assure you I was not a little surprised and disappointed to find, that as far as your credit and influence may extend as a scientific character, your comment tends to stigmatize me, to impede the introduction of my improvements, by increasing the doubts in the minds of the people about the principles of my engine, which has been in actual practice and highly useful operation for three years, far exceeding all others of which I have any knowledge. Although the working cylinder is only 6 inches in diameter and length of stroke 18 inches, she will grind 400 bushels of plaster in twenty-four hours, or saw 200 feet of marble stone; and when my principles are fairly and fully put in operation, the work will be doubled, or perhaps trebled.

1. You say I am in pursuit of an ignis fatuus.

2. You indirectly insinuate that I, through design, omit to mention that Captain Savary wrought his engine with strong elastic steam.

3. That I have dexterously assumed to myself a principle for which you obtained a patent two years ago.

4. You attempt to turn my ideas and my further proposed improvements into ridicule.

5. You say I have assumed very erroneous principles in my improvements of my steam engines, as well as my perpetual still.

6. You say that I have exaggerated enormously the strength of my boiler, and endeavour to show that it is incompetent to the task I assign to it.

7. You say that the application of the discoveries made by Dr. Black, twenty years ago, respecting latent heat, and the very important law of increment, developed by certain gentlemen, to the improvement of steam engines, was obvious; therefore I can have no well grounded claim.

ply the net proceeds to defray the expenses of extending the use and introduction of my improved steam engine, as well as of the expensive experiments, which will be necessary to put in practice my further proposed improvements, which I have specified, and I do assure you, sir, you do not show you understand them.

3. Have I been half so dexterous as yourself; who sent Dr. Coxe to view my principles, then in operation and use one year, (publicly exhibited and explained to every one who inquired after the principles) and to put a number of questions to me, which drew in answer, a full explanation of the construction and principles of my invention, and 'which, when you were in possession of; the improvement became obvious to you, and you went and attempted to take out a patent for, and assumed it to yourself; but herein you have failed for want of a competent knowledge; besides you are not the original inventor.

4. Do you really believe that the fire of volcanoes is kindled by atmospheric air? If you do, please to point Out to us the apertures by which it is possible for the air to enter against a force which casts up rocks two thousand feet high; or else show why fuel, which burns in one place without the aid of atmospheric air to kindle it, will not so burn in another place with the aid it has, be that what it may; or why air cannot be substituted instead of that unknown aid in the manner which I have proposed.

5. Are you sure you are competent to assert, that I have assumed very erroneous principles, while you show you do not understand them yourself? or that Mr. Dalton's experiments are more accurate, or the result he has drawn nearer the truth than those of the editors of the Encyclopedia? That Dalton, as well as yourself, is wrong, is evident, because, if we continue his scale of diminution of the ratio, the increase of elasticity by the increase of heat will entirely encase long before the power be sufficiently augmented to burst the cannon, as stated by the earl of Worcester.

6. Have you any rule for ascertaining the power exerted to burst a boiler, by which you can tell how enormously I have exaggerated the strength of my boiler? The rule by which you seem to have calculated is really false, and your calculations are a specimen of your qualifications, as there is, unfortunately for you, no solution of this useful problem to be found in any book that I can find; you must, therefore, have recourse to your own inventive genius, and it was absolutely necessary you should possess this knowledge to enable you to arrange a steam engine.

7. Was it not equally obvious, that a pipe of 1 inch diameter, would expose more surface to the heat of the fire, and bear a greater elastic power of steam, in proportion to its contents, than one of 20 inches diameter. But who ever made a boiler consisting of pipes of 1 inch only in diameter, to work a steam engine, until it was done by John Stevens, Esq. of Hoboken; excepting only the late ingenious colonel James Rumse,-, about fourteen years ago in the city of Philadelphia, and afterwards in the city of London. His patent is dated August the 6th, 1791, which will expire the 6th day of August next; he, however, as I have been informed, found it would not do in practice, and therefore gave it up as an ignis

fatuns. But shall this discovery, or patent of his, make your claim groundless, or prevent you from pursuing the same ignis fatuus, for which you took out a patent two years ago? I hope not, or else there could be but few well grounded claims.

Your ignorance of the principles of my invention has caused you thus far to commit and set yourself in the way as an obstacle to the introduction of the most useful improvements ever made on steam engines: but you have one consolation; this will serve more to perpetuate on memory than your twenty years hard work, and 20,000 dollars risked.

You may rest perfectly easy in the possession of your boiler, as you have specified it; and of your scheme of'

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experiments, would accomplish the great ends of propelling boats and land carriages. We need not contend, the range is sufficient for us both; let us unite our resources. If I had possessed the sum to expend twenty years ago that you say you have already expended, I do believe that my inventions and improvements might, at this day, have been doing the labour of at least 100,000 men in this country.

When the blind man took the lame one on his back, they both travelled safely; but I am as doubtful of the success of your project of a boiler as you are of my volcanic one; and think I could convince you of the great probability of the success of my plan of pouring all die heat of the fire into the water, instead of passing up the chimney, which is all that can be possibly got from the fuel, and would be lighter, and far more durable and easier repaired than your's; but I will not risk the expense of the experiments until there be a better prospect of reward. I have made a small boiler on that principle, which appeared to answer well; all the heat of the fire entered the water to generate steam, which, united with the elastic fluid, generated by the consumption of fuel, formed the agent to work the engine.

MR. STEVENS'S REPLY.

Extracted from the Medical Repository.

THE only part of the above letter, which I consider sufficiently important to require any notice on my part, is the charge Mr. Evans has thought proper to bring forward against me, of sending Dr. Coxe to him to steal his invention; for which he is pleased to say, " I have taken out a patent, and assumed it to myself." To repel so odious a charge, it will be necessary to go into a detail much longer than I could wish.

Mr. Evans, in the above letter, admits unequivocally, that he has no claim whatever to the boiler specified in

working one of Watt and Bolton's by the steam of one of my engines after it leaves it ; for I can produce more effect from the steam by one cylinder than I can by using two, as you propose: and of your mode of distilling by steam, as described in your comment, I would wish to know when you invented it. But if you will attempt to infringe my patent, the best way will be to decide the matter in a court of law, without troubling the public therewith. I am sorry to be obliged to spend my time thus, as I am engaged in writing for the press, a small treatise on the principles and powers of steam, and of my own improvements, which, when published, many things will become obvious to you that are not so now but then you can easily show that they were so for twenty years past, because my deductions are all drawn from the experiments, discoveries, reasoning, &c. of Dr. Black, and other philosophers, who have lived ~ wrote before me.

I might, in the same time thus spent, have discovered or wrote something useful.

To conclude, seeing you have so dexterously procured your injurious remarks a place in the Medical Repository, I will thank you to obtain a place in the same work for this letter, or adopt any means you please to place me on as good grounds as you found me, and you will much oblige,

Sir, your humble servant,

OLIVER EVANS.

JOHN STEVENS, Esq. of Hoboken,

near New-York.

p 5 After the publication of the above, and you quit all claims to my inventions, I shall consider myself redressed, and shall be willing to correspond with you on friendly terms. We should assist, instead of injuring each other.

If your plan of a boiler should prove useful in practice, and generate more steam, with equal fuel, than mine, I shall rejoice at the improvement, which, united with my improve-

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strength of one atmosphere to two than was necessary at first to raise it to one ; or, in other words, if we add to steam as much more heat as it may already contain, we shall make it more than twice as elastic."

Here, then, we find that the advantages of using strong steam were suggested and pointed out by me before I heard, or, indeed, could have heard of Mr. Belancour's experiments.* But after it had been satisfactorily proved by these experiments, that the increase of the elasticity of steam was in a far greater ratio than the increase of heat, it could not be imagined that I should have remained insensible of the immense importance of the application of this principle to the improvement of the steam engine. The truth is, that ever since the period above mentioned, I have been more or less engaged in various projects for applying this principle to advantage. To enumerate and describe the boilers I have constructed on different plans, with a view to effect this object in the most convenient and eligible mode, would be tedious and unnecessary, more especially as Mr. Evans does not seem disposed to dispute the right of invention of any specific improvements of the steam engine; but generally the exclusive right of applying to this purpose the above mentioned principle.

[His words, on November 23, *1790*, show the extent of his knowledge of the principles at that time to have been mere conjecture and supposition: for if Mr. Blakey had succeeded in his attempt to apply the principle, by the intervention of oil, in the year 1700; or if Captain Savary or the Marquis of Worcester had applied their strong elastic steam to move a piston in a cylinder; or if Mr. Newcomen had applied Savary's boiler to generate strong elastic steam, to propel his piston, the work would have been done, and

These experiments were made in Paris, in 1790, and were never heard of by me until they appeared in the new edition of the encyclopedia Britannica.

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my patent. What, then, is it I have stolen from him ~ He affects, it seems, to take it for granted, that the idea of using steam at a high temperature and great elasticity, never occurred to me before I had obtained information on that head from Dr. Coxe. But the following extract from a statement,* presented in Feb. 1791, to the Board of Commissioners appointed to adjust and settle interfering claims for exclusive patent rights, will prove, in the most satisfactory manner, that the idea of the great advantages resulting from using steam of high temperature and great elasticity, had actually occurred to me many years ago: and, I should suppose, even before Mr. Evans had thought of it himself. In describing what I then thought an improvement of the steam engine, which, at this time, it is unnecessary to explain, I make use of the following words:

For if; by the intervention of water or oil, we should be enabled to make use of steam of four times, for instance, of the usual strength, the advantages we should derive from it would be very great.

1. A cylinder of 2 feet diameter would be as powerful as one of 4 feet diameter.

2. There are sufficient grounds to induce us to believe, at least, that less heat is required to raise steam from the

This statement was drawn up in conformity to the following notification:

Philadelphia, November 2j~, 1790.

Some of the claims for patents, founded on the supposed discovery of new applications of steam to useful purposes, not having been stated precisely as to be satisfactory to the board, and it being their wish to hear all those claims together,

Ordered, That the first Monday of February next be appointed for tile hearing of all parties interested; that notice be given to John Fitch, James Rumsey, Nathan Read, Isaac Biggs, and John Stevens, of this order; and that each of them be required to transmit in writing to the Board, a precise statement of their several inventions, and of the content thereof.

extract from the Miniltes,

HENRY REMSEN, Jun..

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might have saved Mr. Stevens 20,000 dollars, besides much study and labour: but it is left for us to contend about. Admitting all Mr. Stevens's statements are true, then the facts appear to be as follows, viz. In the year 1784, 1 conceived the means of applying the principle, and in 1786 I explained it to the legislature of Pennsylvania, but they refused to grant me the patent. Early in 1787, I explained it to the legislature of Maryland, and obtained the exclusive right of using it for fourteen years, but did not commence the execution for seventeen years after my first discovery of the means of applying the principle, not being able to find any one willing to join me in risking the expense. Mr. Stevens asserts, that in 1790 he had some distant ideas of the existence of the principle, and that he had been at work which he continued for twenty years, but did not succeed. At the end of seventeen years I went to work, put the principles in operation, and succeeded beyond my expectations. A gentleman having seen the engine at work was astonished at its operation, and undertook to announce the discovery to the public, stating its great performance. This Mr. Stevens gets sight of, sends to Dr. Coxe, contains a full account of the construction of my engine, and explanation of my principles. He then took out a patent, attempting to secure to himself the exclusive right of using the discovery on certain principles; which I never heard of his having done, until I read the specification published by himself, in his unprovoked attack on me. Being ashamed immediately to adopt my engine exactly, he spent one year more (the last of his twenty years) on projects of his own, but could not succeed; and was at last reluctantly compelled to follow me exactly, by adopting every improvement which I had made9 calling it Bolton and Watt's engine. If Mr. Stevens had really understood the principle, he might in the course of his twenty years labour have put it in operation before I began, and then his claim would have been much better supported.]

But were we even to admit that Mr. Evans was really the original discoverer of this all-powerful principle he would, l apprehend, even in this case, find it impracticable to secure against infringement a claim of exclusive right to the application of it. How, I would ask him, could he prevent me or any other man from loading at pleasure the safety valve; a practice coeval with the first invention of the steam engine itself? Captain Savary's engines were capable of raising water from 100 to 200 feet high; consequently he was in the habit of loading his safety valve with *50* to 100 lbs. on the square inch.

In this paragraph Mr. Stevens has discovered his original intention in making the attack, viz. to destroy my exclusive right totally. Mr. Watt met with many such attacks. He could not prevent any person from condensing their steam, a practice coeval with the use of the cylinder and piston; but fortunately for him, as Mr. Stevens did not set as judge, he did prevented others from condensing their steam in his improved way, and confined them to what was before known and used. If Mr. Stevens were to set as judge on my case, I should have little hope; but with any other judge or jury I fear not to risk the matter. Although I do not expect to prevent any one from loading their safety valve, in such engines and for such purposes as were before known or used, yet if they attempt to use great elastic power of steam, die application of which I have discovered, explained and made known at a great expense, I expect to be able to prevent

Mr. Stevens himself or any other person from doing so. If not, no patent can be supported; for surely none is better founded. It was be seen that I have made greater improvements on steam engines than any other man; removed the obstacles, and opened a clear and distinct view to still far greater improvements. Compare them with Bolton and Watt's improved Newcomen's engine: They contrived to condense the steam in a vessel separate from the cylinder, and to put steam in above as well as below the

piston, thereby obtaining a double stroke: their plan required the addition of an air-pump, which they applied:

their engine proved more powerful, was easier governed, required only one-fourth the fuel to do die same work, and was pronounced the greatest of human inventions. I have made a total change in the system: I have applied the Marquis of Worcester's discovery, (after its having been abandoned one hundred years) to move a piston in a cylinder; discovered the great advantage of using strong elastic steam, demonstrated, explained and made it known: I have dispensed with the heavy lever beam, condenser and air-pump, and simplified the construction of the boiler, cylinder, piston, and working gears: my plan required a small forcing pump to supply the boiler, which was applied. Thus, I have produced an engine ten times as powerful, more governable, and easier varied to suit any task assigned to it than Bolton and Watt's: it can be constructed at half the price, and will expend only one-third the fuel to do as much work as their's, and is applicable to every purpose to which their's can be applied, besides a great many more. I have specified and explained by drawings, five differently constructed engines all of which will work well to produce immediate circular motion, on my new principle of confining and retaining the steam to increase the heat and elasticity; but these are worth nothing if wrought on the old principle. Indeed, I fear there is nothing left for Mr. Stevens to discover in the art. I hope I am not guilty of egotism in stating facts, when the public good and my own interest require it.]

And now, I hope, I have done with Mr. Evans. Nothing less than the necessity of vindicating myself against the foul aspersion he has thought proper to bring forward against me, could have induced me to have set my pen to paper. I still, however, entertain the most favourable opinion of Mr. Evans's candour and integrity, and am disposed to think, that, when his passion shall have subsided, he will

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sincerely regret the gross abuse he has bestowed on me; and probably the time is not far distant, when he will be convinced of the truth and justness of the remarks I have taken the liberty of making on his various projects, and the angry strain of invective which he now indulges himself in, will ultimately give grace to grateful acknowledgments for the services I have rendered him.

The world are greatly indebted to Mr. Evans for his ingenious improvements of mill machinery; and I sincerely hope, that his distinguished mechanical abilities may still continue to be exerted in a way best calculated to promote his own individual interest, and, at the same time, render essential benefits to the community at large.

[Here Mr. Stevens hopes to have done with me; but why did he begin? What prompted him to make such an unprovoked and illiberal attack? Is truth, when stated by me, foul aspersion; and error, when advanced by him, truth and meekness? I did not say he sent Dr. Coxe to steal my invention; this he has discovered himself, and he is certainly best acquainted with his own motives. Of Mr. Stevens's candour I am doubtful, but I hope my suspicions may prove groundless. Why did he not send me a copy of his reply before he published it, as I had done by sending him my letter in answer to his remarks? Had he done this, and not attempted to hold an undue advantage, after being himself the aggressor, he might have been done with me. "I still, however, entertain the most favourable opinion" of Mr. Steven's patriotism: " the world are greatly indebted to him for his" laudable pursuits; and I hope that when I discover the great good he has done me, by " the remarks he has taken the liberty of making on my various projects," that my "angry strain of invective will give place to grate full acknowledgments." I sincerely wish Mr. Stevens success in his laudable undertakings, and that they may prove beneficial "to the community at large."

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it to boil and the ether is converted into vapour, carrying)g off the heat to fill the vacuum. This is a positive proof that a vacuum will receive and retain in a latent state more heat than a plenum.

These principles may probably be applicable to useful purposes. For instance, to cool wholesome water, such as that of the Mississippi, rendering it palatable for drinking, to supply the city of New-Orleans; or of the Schuylkill to supply the citizens of Philadelphia. A steam engine may work a large air-pump, leaving a perfect vacuum behind it on the surface of the water at every stroke. If ether be used as a medium for conducting the heat from the water into the vacuum, the pump may force the vapour rising from the ether, into another pump to be employed to compress it into a vessel immersed in water; the heat will escape into the surrounding water, and the vapour return to ether again; which being let into the vessel in the vacuum, it may thus be used over and over repeatedly. Thus it appears possible to extract the latent heat from cold water and apply it to boil other water; and to make ice in large quantities in hot countries by the power of a steam engine. I suggest these ideas merely for the consideration of those who may be disposed. posed to investigate the principles, or wish them put in operation. And, lest I should be thought extravagant, as was the case with the Marquis of Worcester, I give a

DESCRIPTION OF THE MACHINE.

Make an air-pump and close the lower end of the cylinder by connecting it with a globular glass vessel, if metal will not answer as well: fix the lower end of the cylinder of this pump, so that the glass vessel shall be immersed in the water that is to be cooled, and which is to be contained ~ a tight vessel. Near to this pump fix another much smaller, called the condensing pump, and connect it with a small vessel, called the condenser, immersed in water, fixing

off from the water by the steam, composed from a very small part off the water, yet it is not the steam that contains the 1000 degrees of heat in a latent state, but the space which it occupies; this quantity of heat is necessary to heat up that large space to the temperature of 212 degrees; and the truth is, that only 212 degrees of heat are a necessary constituent part of steam, under the pressure of the atmosphere. It is true that if the heat that is carried off by the steam formed by 1 cubic inch of water expanded into 10,000 or 14,000 cubic inches space, was to be returned into 1000 cubic inches of water, it would raise the temperature of the whole mass 1 degree; but if the heat that is contained in 1 cubic inch of the space occupied by the steam, be returned into 1000 cubic inches of water, it appears by this statement that it would raise the temperature of the water but part of a degree.

The steam of boiling water exactly balances the weight of the atmospheie: if therefore we have occasion to fix a pump to raise hot water, we must place no dependence on the pressure of the atmosphere to force it up through the lower valve, (as it does when the water is cold) because the steam rising from water of the temperature of 212 degrees, will fill the vacuum that would be formed by the working of the pump, and exactly balance the pressure of the atmosphere and prevent the water from rising. In such cases the lower valve must be placed below the surface of the hot water that is to be raised.

Water boils in vaccum at the temperature of 70 deg. and vapour may by compression be reduced to the fluid from whence it arose: hence we may infer, that water will keep cooler in vacuum than when exposed to the pressure of the atmosphere. If an open glass vessel be filled with ether and set in water in vacuum, the ether will boil rapidly and rob the water of its latent heat until it freezes. It is not right to say that the ether becomes so cold that it freezes the water around it. The heat in the water enters the ether, causing

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valve between them. Connect the upper end of these working cylinders by a pipe with a valve therein at the top of the exhausting pump, and connect the bottom of the condenser with the glass globe, by a small pipe, in which insert a cock1 called the ether-cock. The piston rods of the pumps must work through stuffing boxes made air-tight, and each piston must have a valve fixed in it, one to shut downward and the other upward: work these pistons by a lever that is to be put in motion by a steam engine or any other power.

THE OPERATION.

Fill the glass globe with ether, ~o that the piston will touch its surface at every stroke; expel the air from the pumps and condenser, making a complete vacuum in them. Set the machine in motion and every time the piston rises the exhausting piston leaves a perfect vacuum behind it:

the ether then begins to boil and carry off the latent heat from the water; the steam of the ether fills the vacuum, which is again exhausted by the pump, and driven into the condensing pump which compresses it in the condenser, forcing out the heat which robs the vapour of its essential constituent part, and reduces it to ether again; the ether-cock being opened just sufficient to let the ether return to the glass globe to undergo the same operation; and so on ad infinitum. The machine might be simplified by connecting the top of the exhausting cylinder with the condenser, dispensing with the condensing cylinder and piston. The condensation might be sufficiently effected by the exhausting cylinder and piston alone forcing the vapour into the condenser. If the air not expelled it will be forced into the condenser, and remain above the ether formed there without injuring the working or the effect of the engine: but I presume the condensing pump would be necessary to carry the principle to such extent as to boil water by the heat extracted from cold water. A small pump may be fixed so as to be worked by the same

lever, to extract the water from the vessel as fast as 'necessary after it is cooled. The vessel may be kept full by the pressure of the atmosphere forcing the water through a valve at the bottom.

CONCLUSION.

Many persons think that new inventions and discoveries are made by accident, without labour or expense: some may have such a gift. It was a saying among the ancients that " truth lies in a well;" and may we not say that reason and experience are the means by which we draw it out. It has been by the most intense study that I have made discoveries. After having a faint glimpse of the principle, it was with may be and tedious.; steps that I attained a clear and distinct view. I received great assistance from the result of experiments made by others, which arc to b found in scientific work; and righted believed that if government would, at the expense of uncertainty, employ ingenious persons, in every art and science, to make with care every experiment that might possibly lead to the extension of our knowledge of principles, carefully recording the experiments and results so that they might be fully relied on, and leaving readers to draw their own inferences, the money would be well expended; for it would tend greatly to aid the progress of improvement in the arts and sciences.

I now conclude, and renounce all further pursuit of inventions and discoveries, at least until it shall appear clearly to be my interest; lamenting that it should so often prove unprofitable, and even ruinous as it has been to many. I at the same time believe, that more good frequently results to the community from intellectual than corporal labours; yet one pair of hands is worth two mechanical or philosophical heads to the individual himself. I purpose, however, to attend to the improvement of my steam engine, to render it suitable for the various purposes for which it may be required.

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- The Pneumatics of Hero of Alexandria from the original Greek, translated for and edited by Bennet Woodcroft. London, Taylor Walton and Maberly, 1851. 111 pages, about 50 illustrations. Written about AD300. First book describing a steam engine. [Peter Hark and Dan Sonneborn]

- Account of Blasco de Garay's 1543 steamship.

- Henry Dircks, The Life, Times and Scientific Labors of [Edward Somerset] the Second Marquis of Worcester, to which is added, a reprint of his Century of Inventions, 1663. London, 1865. 558 pp. The reprinted Century of Inventions and comments, about 220 pages, are the good bits of this. The rest can certainly be done, if anyone is interested in the English Civil War. [Fran Versace and Sean Singh]

- Thomas Savery, The Miners Friend, or an Engine to Raise Water by Fire, London 1702. [Nicole Parson, Katrina Turner, Julian Woodard, Tesfa Myrie]

- Mårten Triewald, Beskrifning om eld- och luftmachin vid Dannemora grufvor (A Short Description of the Fire- and Air- Machine at the Dannemora Mines.), Stockholm, 1734. English translation. Triewald worked in Britain before returning to build the first steam engine in Sweden. 60 pages, one illustration. Includes some biographical material. [Ben Haas, Nikhil Swadi, Michelle Staffa and Amanda Cantrell]

- Thomas H. Marshall, James Watt (1736-1819), London, 1925. [Michael A. Goldberg, Ryan Tyler]

- Robert Hart, Reminiscences of James Watt, Glasgow, 1859. Contributed by John W. Stephens.

- John Lord, Capital and Steam Power 1750-1800 London, 1923. 242 pages. Good history of the economic aspects of the early steam engine. [Adam Kinne, Sam Gagliardi (4-6), Dari Sutton, Patrick Donavon (7, 8, concl)]

- Francis B. Stevens, "The First Steam Screw Propellors to Navigate the Waters of any Country," *The Stevens Indicator*, 10 (April 1893), pp. 101-129. [Jack Tsai]

- H.W. Dickinson, Robert Fulton: Engineer and Artist, his life and works. London, 1913. 327 pp including some pictures and tables. Parts are fairly technical. [Alex Schlessinger, Rob Wirstrom, Jon Martin, Brandon Yarbough, Jen Jones, Ben Whitestone]

- Thompson Westcott, The Life of John Fitch, inventor of the steamboat Philadelphia, 1857. 415 pages, about 10 engravings. [James Goater (6-10), Grey Bossi (chap 11-14), Matt Poore (index, 2 graphics, chaps 1-5) , Matt Stoner (missing), Tim Dolgos (20.5-24), Eric Thurley (14-16)]

- Oliver Evans, The Abortion of the Young Steam Engineer's Guide, 1805. 139 pages, tables and illustrations. [Joseph Timmons, Nora Di Matteo, Ben Cichy, and Don Aviv]

  Sadi Carnot, Reflections on the Motive Power of Heat and on Machines Fitted to Develop that Power, Translated by R.H. Thurston, New York, 1890. 260 pages, including 1 picture, tables, formulas, and supplementary material. Carnot's work was originally published in 1824 and, although long ignored, forms the scientific basis of modern thermodynamics. Very important book.

- Dionysius Lardner, The Steam Engine Explained and Illustrated; with an account of its invention and progressive improvement, and its application to Navigation and Railways; including also a Memoir of Watt. 7th edition, London, 1840. 522 pages, many illustrations. Written for a popular audience, but very complete. [Tanveer Rahman (Chapter 13,14); Fatima Rahmetullah (Appendix)]

- Robert H. Thurston, A History of the Growth of the Steam-Engine New York, 1878. 490 pages, 147 illustrations and 15 portraits. Thurston was a prominent engineer, and the book is well written. [Jacob Ben Efron, David Drahms]

- Robert H. Thurston, Robert Fulton: his life and its results, New York, 1891. 192 pages, about 10-15 pictures. Thurston was himself a prominent steam engineer. [david leavitt, seth krostich, noah borenstein]

- Andrew Carnegie, James Watt. New York, 1905. 241 pages. Carnegie was a very successful capitalist. [Siddarth Sharma, Rahul Baswan]

- William H. Brown, The History of Locomotives in America, 1871, [Joseph James Scapelliti, Alexander Gershkovich and Michael Arko]

- Sir Charles Parsons, The Steam Turbine, Cambridge, 1911. 57 pages, about 40 pictures and technical drawings. Parsons was largely responsible for the commercial success of the steam turbine. [Corey Smith]

Documents coming soon!

John Dee, *The Mathematicall Præface to the Elements of Geometrie of Euclid of Megara*. London, 1570. 60 pages, a few illustrations. Full of Latin and early English words - excellent short book, but not for the faint of heart. This work was instrumental in bringing both the Renaissance and Scientific Revolution to England, and thereby paving the way for development of the steam engine. [Jodie Lippman]

Rhys Jenkins, "Thomas Newcomen" [Anthony De Figlio]

Edmund Bailey O'Callaghan, ed. [Early steam navigation], in *Documentary History of the State of New-York*, Vol 2:1011-1102. Albany, 1849. Includes: James Rumsey, *A Short Treatise on the Application of Steam, whereby it is clearly shewn from actual experiments, that Steam may be applied to propel boats or vessels*. (Philadelphia, 1788) and John Fitch, *The Original Steam-Boat supported; or, a reply to Mr. James Rumsey's Pamphlet shewing the true priority of John Fitch, and the false datings, &c of James Rumsey*. (Philadelphia, 1788). 92 pages, one small and one LARGE illustration. Very interesting pamphlets, includes letters from Washington and Franklin. [Erin Jones]

Samuel Smiles, *Lives of Boulton and Watt*, 2nd ed. 1866, 514 pages, about 80 illustrations. Watt was the inventor, and Boulton the entrepreneur. A classic work on early steam engine development. [Jennifer Hoffman, Amrita Desai, David Hilton, Robert Koenig]

Francois Arago, *Life of James Watt*, in Arago's 1834 Biographies of Scientific Men, vol 2, pp 350-486. [David Jaffe]

Samuel Smiles, *The Life of George Stephenson and of his son Robert Stephenson; comprising also a History of the Invention and Introduction of the Railway Locomotive.* London, 1868. 533 pages. 90 illustrations. [Shanay Williams (1-100) (436-608), Naketa Strode (101-199), Rosan Dacres (200-299), Corey Legler]

Robert Stuart Meikleham, *A Descriptive History of the Steam Engine*, London, 1824. 228 pages. Microfilm - see below. [Orane Barrett (70-120), Daniel Hall (129-177), Allen Johnson (1-70)]

Dionysius Lardner, *The Steam Engine Explained and Illustrated; with an account of its invention and progressive improvement, and its application to Navigation and Railways; including also a Memoir of Watt.* 7th edition, London, 1840. 522 pages, many illustrations. Written for a popular audience, but very complete. [1. Asif Shah Mohammed (Chapter 1 & 2) 2. Mohammad M. Syed (Chapter 3 & 4) 3. Kumanan Nesiah (Chapter 5,6 and Table of Contents) 4. Muniba Zulqarnian (Chapter 7, 8) 5. Tarini Arogyaswami (Chapter 9) 6. Shonar Majmudar (Chapter 10) 7. Ajay Singh Bika (Chaper 11) 8. Tanveer Rahman (Chapter 12, 13) 9. Fatima Rahmetullah (Chapter 14, Appendix)]

Wm. Barclay Parsons, *Robert Fulton and the Submarine* New York, 1922. 154 pages, about 20 pictures & drawings. [Sam Harris]

Holly Steam Pamphlet, 1878 [Yussef Abbasey]

Herman Haupt's Steam Report, 1879 [Kerstin Babbitt]

William Prall's 1880 pamphlet [Felix Asideu]

Baker's 1881 Pamphlet [Rahul Munjal]

Timby's 1889 pamphlet [Mike Lyons]

William Conant Church, *The Life of John Ericsson*, New York, 1890. 2 vols. 303 and 338 pages. Some illustrations and technical material. [vol 1 - Jonathan A. Herman, vol 2 - Joseph Vitali (on the way)]

Census Bureau, *Central Electric Light and Power Stations 1902*. Washington, 1905. 104 pages of text (including History and Development of Electric Lighting), 20 illustrations, plus 98 tables that may or may not be worthwhile to put on line. [Joel Helfrich]

Reginald Pelham Bolton, *A Municipal Experiment, or the Hall of Records Power Plant* New York, 1917. 221 pages, about 8 pictures, some tables. An excellent analysis comparing the use of small isolated steam power plants vs. large public utility plants in New York City. [David Van Duyne, Josh Pletka (1-80), Jose Abeid]

United States Fuel Administration, *Fuel Facts*, 1918, 59 pages. [David Urbanski, Michael DeGrande]

Morris Llewellyn Cooke, ed., "Giant Power: Large Scale Electrical Development as a Social Factor," *Annals of the American Academy of Political Science*, vol 128, March 1925. 177 pages, 10 illustrations, several tables. A series of articles promoting the social benefits of electrification on a massive scale. Very important work. [Andrew Gannick, Robert Ceglie, Alan Noscow.]

William S. Murray, *Superpower: Its Genesis and Future*, New York, 1925. 227 pages. [Matthew Guttin, Adam Glazer, Sanjit Timberwala]

Guy E. Tripp, *Super Power as an Aid to Progress* New York, 1924. 61 pages, about a dozen illustrations. [Justin Goldman, Dennis Annechino]

R. V. Reynolds, *Fuel Wood Used in the United States 1630-1930* [Joanna Palacios, Cecily Strickland]

Samuell Insull, *Central Station Electric Service: Its Commercial Development and Economic Significance as set forth in the Public Addresses (1897-1914) of Samuel Insull.*, Chicago, 1915. 475 pages, about 150 graphics. [Kevin Filipski, John Scahill, Valerie Plummer, Ryall Carroll]

Samuell Insull, *Public Utilities in Modern Life: Selected Speeches (1914-1923) of Samuel Insull.*, Chicago, 1924. 403 pages [Terrence Kazlow, Shane Ortega (wednesday)]

Story of Electricity, 1919, [Mark Thrall (473-570), Dave Capucilli (339-438), Jack Huang (1-100?)]

Story of electricity, vol 2 [Robert Sawyer, Mike Shea, Dave Franks]

Ida Tarbell, History of the Standard Oil Co., Vol 2. [Zachary Lutwick, Angelito Tan, Asheesh M. - not last chapters.]

Francis Trevithick, *Life of Richard Trevithick*. London, 1872. [Not owned by RRL. I have a photocopy.] 2 vols. 382 and 396 pages. Some illustrations. Trevithick was an early British pioneer of high pressure steam engines. [Susanne Grossman, Maria Cubillos (1:1-220), Chris Canery (1:221-320), Bernard Schmidt (1:321-382), Jose Quero (2:1-113), Michael Bowers (2:114-194), Ronald Rogers (2:195-283), Ray Glennon (2:284-396)]

Forty Years of Edison Service [St. Patrick Reid, Roger Soares]

Richard Margolis, The Bridge Project [James Schulman]

Barlett 1884 steam pamphlet [Scott Teitsch]

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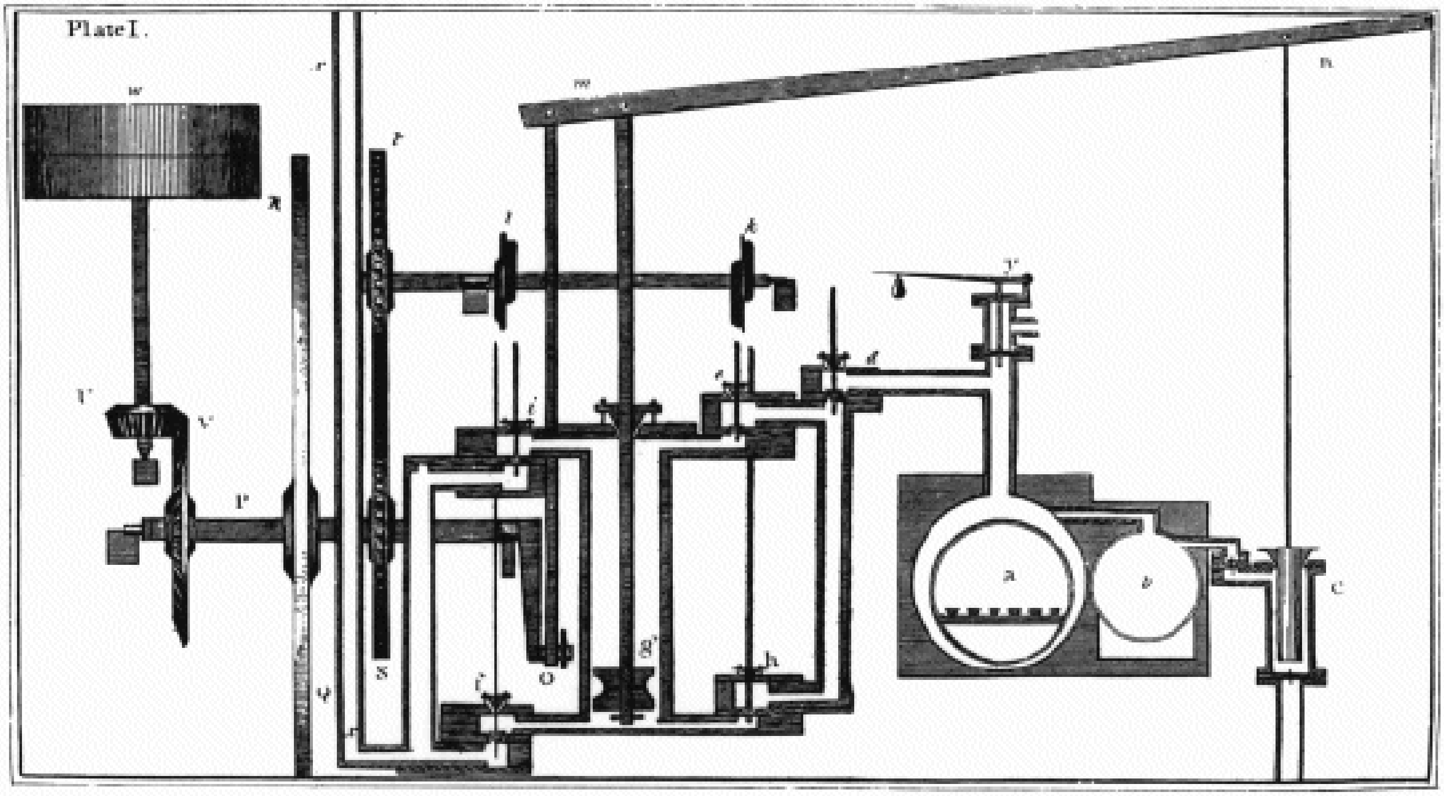
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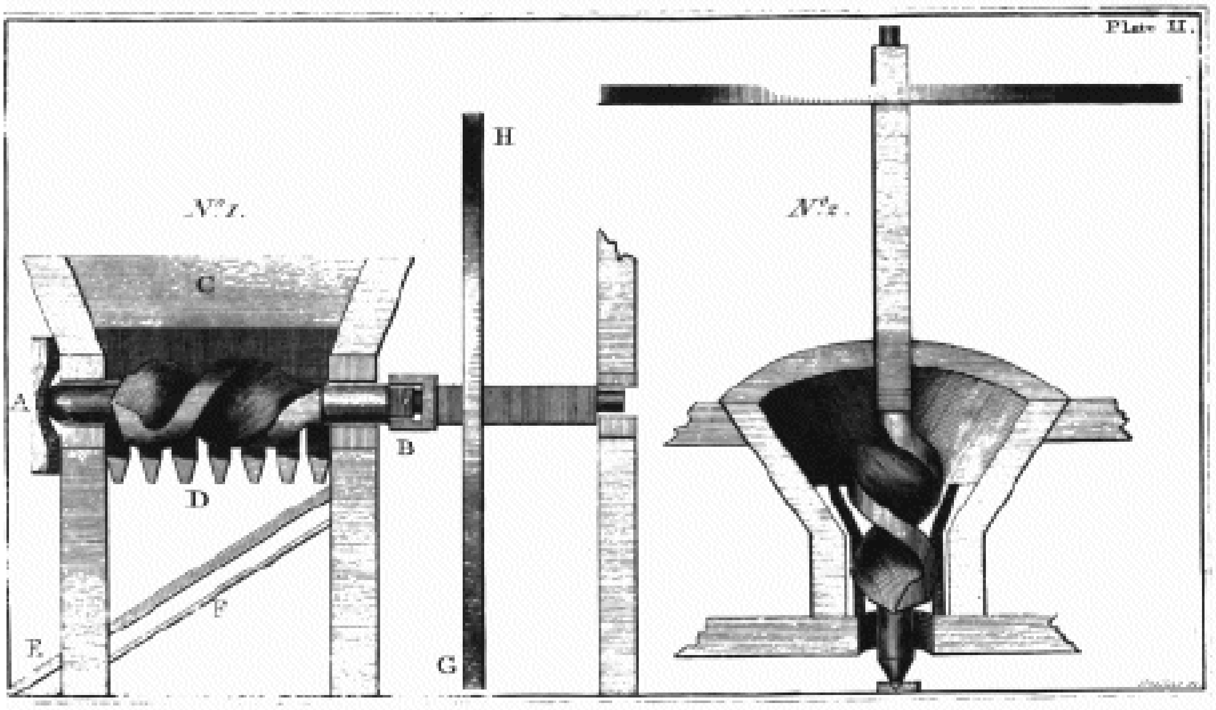
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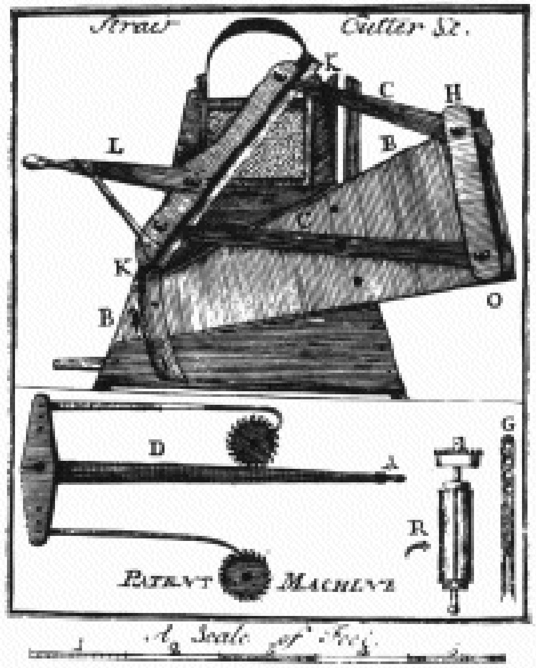
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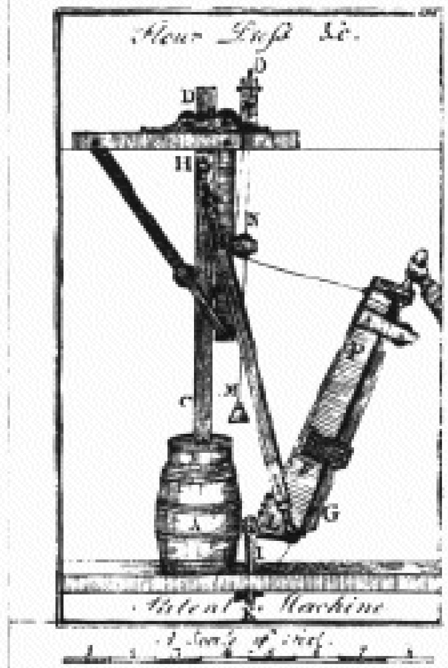
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