vc

AN ESSAY

ON THE

NATURE AND APPLICATION

OF

STEAM,

WITH

AN HISTORICAL NOTICE OF THE RISE AND PROGRESSIVE IMPROVEMENT

OF THE

STEAM-ENGINE,

BY

M. A. ALDERSON,

Civil Engineer,)

Being the Prize Essay on this Subject at the London Mechanics' Institution in the Year 1833.

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TO

GEORGE BIRKBECK, ESQ. M.D.

F.G.S. M.A.S. ETC. ETC.

PRESIDENT OF THE LONDON MECHANICS' INSTITUTION.

SIR,

THE following "ESSAY ON THE NATURE AND APPLICATION OF STEAM," owing as it does its origin to your enlightened liberality, to no one can I more appropriately dedicate it than to yourself.

The example you have set in exciting a laudable emulation amongst mechanics in scientific attainments, has been the cause of a change in their views and pursuits, of which though no one can foresee the end, all concur in believing that it will be for the lasting good of themselves and of the community.

Actions, not words merely, best attest a man's sincerity, and when, as in your case, they are uniformly directed to promote the acquisition of useful knowledge, and thereby to benefit and add to the welfare of his fellow-man, they command our esteem, and can never be sufficiently admired.

Example and precept are each good in their way, but precept, however zealously and eloquently inculcated, unaided by example, is comparatively feeble and inefficient.

The lucid example you have set will continue to excite a laudable emulation in the votaries of science each to excel the other in their various pursuits and avocations, causing and encouraging them to economize and employ well that most invaluable precious gift and staple commodity of life —TIME!

Your exemplary fortitude and patient perseverance in successfully combating and conquering every opposing obstacle and difficulty in the pursuit and attainment of knowledge, animates and cheers the *young* aspirant, and stimulates and spurs on the *aged* veteran to renewed exertions in their praiseworthy career.

In you they behold the man of science and the philosopher, who not only "points to heaven but leads the way," the constant tenor of whose life "proves by the ends of being to have been."

To have my name associated with one illustrious in the arena, and almost synonymous with science, is an honour of which, without vanity, I may be justly proud,—an association of which I should be more ambitious were I conscious that I merited such an honourable distinction.

That you may long and always happily live in the full fruition of health, and enjoy, in its utmost plenitude, "the soul's calm sunshine and the heart-felt joy" inseparable from the ceaseless practice of such virtues, is the ardent prayer of,

SIR,

Your most obedient and obliged

humble servant,

M. A. ALDERSON.

7, Paris Street, West Lambeth,
London, March, 1834.

PREFACE.

At a time like the present, when new projects are daily brought before the public either for improving, perfecting, or altogether superseding the power of steam, it is thought that a brief and comprehensive treatise, embodying the principles and application of this powerful agent in all its branches, would not be unacceptable.

To those engaged in such pursuits, a work of this sort, embracing all the successful improvements made by the engineers and projectors of the present day, together with those of their predecessors, must be as acceptable as it is trusted it will be found useful.

To the general reader, a familiar description of what has been hitherto considered difficult, if not repulsive, will, it is hoped, tend to gratify a laudable curiosity, and to increase the numbers of the votaries of science; even should steam be altogether superseded, to such it will and always must be interesting if only as matter of history. Haply this last dilemma is not likely to take place, for no elemental substance or power has hitherto been discovered at all able to compete with that immensely expansive and yet easily condensed vapour—STEAM.

As a subject of general interest at the present period, when the application of steam to the purposes of locomotion, as successfully effected on railways and contemplated on the common roads, brings it home to the immediate notice of all, every one must be desirous, more or less, of becoming acquainted with the nature and properties of that power, the practical application of which is effecting such great innovations and such important improvements. Considered as an abstract subject of study or speculation, it is much more pleasing and useful than those over-refined theoretical sciences and studies which, taking in general higher ground, do not lead to such important practical results.

To those engaged too ardently in the latter pursuits, may be applied the beautiful description which Milton gives of the occupation of some of the fallen angels.

> Others apart sat on a hill retir'd,
> In thoughts more elevate, and reason'd high
> Of Providence, foreknowledge, will, and fate,
> Fix'd fate, freewill, foreknowledge absolute,
> And found no end, in wand'ring mazes lost.*

* Paradise Lost, book ii. line 557.

The object and aim of the Author has been to concentrate, in a brief and perspicuous manner, whatever of knowledge and information he has practically acquired on a subject eminently fraught with paramount importance to science, manufactures, and commerce.

As a first and most powerful mover of all kinds of machinery steam has the pre-eminence over all others, and like the rod of the Israelitish Prophet swallows up every competitor.

In this work the economy of which it is susceptible, as far as its power has hitherto been developed, and the various modifications that have taken place in its mechanical application, are clearly and succinctly detailed and placed in juxta-position, and their utility and worth duly estimated.

The STEAM-ENGINE, indigenous to this nation, and generally considered to have been chiefly and primarily instrumental in raising and maintaining its manufacturing and agricultural superiority, prosperity, and consequent wealth and happiness, claims and obtains an indefeasible priority over all other mechanical inventions and discoveries.

Contemplated in its origin, progress, and present state, as the proud result of the amazing effects of genius and of science, combining the past with the present, the Steam-Engine is an honour to the human mind. The history of its rise and progress, therefore, as the most important application of steam, in a work of this nature necessarily takes the lead.

Aware, however, that little has yet been laid before the public respecting the numerous other applications of this powerful agent, a large portion of this work has been devoted to the elucidation of the many advantages possessed in its application to the various purposes of warming rooms, heating drying-houses, manufacturing sugar and salt, cooking, &c. &c. the whole of which are treated of in such a way as to furnish sufficient information for the manufacturing of most of the apparatus mentioned.

This Essay having been honoured by the award of the highest premium ever yet given by the London Mechanics' Institution, and on that occasion having received the encomiums of high scientific characters, who are known to thoroughly understand the nature of the subject here treated of, it is of too much importance to the author to suffer the publication to appear unaccompanied by the genuine testimonials it has produced. It is but justice, then, to quote the following from the speeches made on the presentation of the premium.

There having been five essays sent in on this subject, Dr. Lardner, who adjudged the prize, said, " he had the " pleasure of examining them, and he could safely say, " from a pretty extensive experience in examining manu- " scripts from persons of the highest pretensions, that the " very worst of them exceeded the ordinary standard even " in purely literary qualities. Each of them contained a " clear and satisfactory account of the nature of Steam- " Engines, written with surprising ease and facility, " collecting together all the facts, and arranging them " in clear, distinct, and well selected language. The " ground of preference was not only the superiority of " the materials, but its being as a whole more clear, and " written in a better literary style, with superior draw- " ings."

Dr. Birkbeck observed " that the author of the success- " ful Essay had discovered two notices of this power which " had escaped preceding writers, and he had also detected " in Homer's description of the Phæacian fleet of king Al- " cinous, in the eighth book of the Odyssey, an allusion to " navigation in his kingdom, which is no inaccurate de- " scription of steam navigation."

Dr. Birkbeck then presented the prize, £20, offered by himself, to Mr. M. A. Alderson, the successful candidate, with an appropriate speech.

The following quotation from the Transactions of the Society of Arts, in the year 1825–6, will prove that the author had previously made this subject his study, and with some success.

> "To Mr. M. A. Alderson, the Gold Vulcan Medal, "or Thirty Guineas, for the best drawings and de-"scription of the Condensing Steam-Engine in its "most improved state."

Which premium he had the honour of receiving from the hand of his Royal Highness the Duke of Sussex.

M. A. A.
Holbeck, near Leeds.

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ERRATA.

Page 51, line 15, *for* Phœacian, *read* Phæacian.

„ 61, „ 2, *for* engines, *read* carriages.

„ 64, „ 5, *for* Plates XV. and XVI. *read* Plates VII. and VIII.

AN ESSAY

ON THE

NATURE AND APPLICATION

OF STEAM.

STEAM! all powerful steam! the subject of this essay, is one that has exercised the ingenuity of scientific men for a series of years. It is a subject of great importance to all classes of society and to almost every country. Every one can observe its effects in the ponderous and powerful machines called "*Steam Engines*," now universally used in this and almost every other civilized country for the various purposes of driving machinery in manufactories, supplying cities and towns with water, impelling along railroads carriages containing the most heavy and costly merchandize, cattle, and passengers, with a velocity which may be said to outstrip the wind, and, despite the tides, propelling vessels on rivers and seas, at a rapid and a certain rate, heretofore dependent upon the winds, which are mutable even to a proverb; and in various other inventions which more or less affect the interests and influence the actions of ıl mankind.

Whilst those unacquainted with the application of steam can only observe and wonder at its effects; and those who understand both its nature and effects are only intent upon perfecting their theories or improving their machines, it furnishes to the political economist matter of inquiry and reflection of the most interesting and paramount importance, tending, as the power of steam undoubtedly does, from its potent action and extensive application, to produce to an unprecedented extent almost every manufactured article of home consumption and foreign commerce.

It will be proper in the first instance to explain something of the nature of steam, and then pass on to its application.

STEAM, then, may be defined the offspring arising from the union of the two elements *Fire* and *Water;* and as fire and water are proverbially known to be "good servants but bad masters," so, too, we may say of their amazingly expansive and terrific offspring, *Steam,* which, when kept in due subjection, is the most useful and powerful servant of man, but, when once it gets the upper hand, is the most dangerous and destructive thing known, gunpowder itself not excepted.

Water, in the process of conversion into vapour or steam, combines with more than *five times* the quantity of caloric, or fire, than is required to bring it -cold water to a boiling heat, and occupies a space eighteen hundred times greater than it does when in its original form of water; one cubic inch of water expanding into about a cubic foot of steam.

From practical experience, the best of all teachers, the explosive force of steam is found to be much greater than that of gunpowder. Some volcanic eruptions and earthquakes, it is supposed, owe their terrible effects to the powerful agency of steam, by the collision of the waters of the ocean with subterraneous fires.

Steam, when raised in open vessels, is powerless as smoke, and rises plentifully from water exposed to the action of fire in such vessels; when it reaches that degree of temperature indicated by 212 degrees of Fahrenheit's thermometer, and however long exposed to the action of the fire, or to whatever degree of heat the intensity of the fire is increased, it will never, under these circumstances, cause the thermometer to rise higher.

Steam was in this way raised for ages; its useful qualities being undiscovered or unheeded, and was itself only regarded as the indication and effect of boiling water. When steam was first raised in a close vessel, and of a higher temperature than 212°, it then first became useful for mechanical and chemical purposes; and whoever was the first to submit steam to the action of fire in a close vessel, may be termed the inventor of the steam generator or boiler, the basis of the steam-engine, the mighty importance of which, perhaps, never entered his contemplative mind.

Almost every fluid besides water throws off vapour when exposed to the action of caloric; but as these different vapours are not steam in the popular sense of the word, the consideration of their qualities cannot meet with more than a passing notice here.

Numerous are the experiments which have been made on water and caloric, with a view to ascertain their qualities and fully comprehend their effects; but the former being more tangible to the senses, is also more manageable to investigate, and the conclusions drawn from experiments upon it are more satisfactory.

Water itself is a compound substance, consisting of two gases, which scientific men have agreed to call by the names of oxygen and hydrogen. It is found in four states, namely, solid or ice, liquid or water, vapour or steam, and in a state of composition with other bodies.

The most simple state of water is that of ice; and the difference between liquid water and ice is merely, that water contains a larger portion of caloric, as may be seen by the following experiment.

Take any quantity by weight of ice or snow at 32° of Fahrenheit's thermometer, and mix it with an equal weight of water heated exactly to 172°. The snow instantly melts, and the temperature of the mixture is still only at 32°. Here the water is cooled 140°, whilst the temperature of the snow is not increased at all; so that 140° of caloric have disappeared. There can be no doubt, then, but water owes its fluidity to its latent caloric or heat: this portion of heat is called the "*caloric of fluidity.*"

Aqueous vapour, or steam, is water combined with a still greater quantity of caloric; but however long we boil a fluid in an open vessel, we cannot make it in the smallest degree hotter than its boiling point; the reason of which is, that when the water or other fluid has arrived at this point, the vapour absorbs the heat and carries it off as fast as it is generated. Vapour raised at a lower temperature cannot be considered as steam; for water, as may be seen by the following experiment, requires a vast quantity of caloric to convert it into steam.

Take a cup of hot water, put it under the receiver of an air-pump, and set the pump to work; the water will soon begin to boil furiously, and the receiver will be covered with vapour. If the receiver be now taken off, the water will be found barely lukewarm, owing to the vapour having carried off the greatest part of its heat.

Aqueous vapour, owing to the large quantity of caloric that is combined with it, takes a gaseous form and acquires great expansive force and power. At the pressure of the atmosphere, steam occupies a space eighteen hundred times greater than in the form of water, and yet continues equal in its expansive power to the atmospheric pressure. Steam when generated in a close vessel is colourless and perfectly transparent, but on issuing out into the atmosphere it assumes a white and misty appearance owing to its partial condensation.

In vacuo, water is found by experiment to boil at about 70° of Fahrenheit's thermometer, and under the common atmospheric pressure of this climate at 212°.

It appears from experiments made by eminent scientific men (such as Watt, Southern, Black, and Ure,) when the theory of steam came to be extensively investigated and its principles fully developed, that steam, acting by its expansive force upon a column of mercury in a vertical glass tube hermetically sealed at the apex, and having at the top of the said column a vacuous space commonly called the Torricelian vacuum, such in fact being the common barometer; it appears from their experiments, that the following would be the results at the various temperatures mentioned.

Steam at 212° will sustain a column of mercury 30 inches in height, and so will the atmosphere in a barometer; at 220° of heat it is equal in its expansive power to the pressure of 40 inches of mercury; at 240° to 50 inches; at 270° to 82 inches; at 290° to 114; and at 343° to 240 inches.

It has been found by experience, that boilers in common use require 8 feet of surface to be exposed to the action of fire, to boil off one cubic foot of water per hour, which in the larger sorts of engines is reckoned equivalent to one horse power; and that a bushel or 84 lbs. of Newcastle coals so applied will boil off from 8 to 12 cubic feet. It is believed, with every attention on the part of the engineer, that from 13 to 14 cubic feet of water is the largest quantity hitherto evaporated in a low pressure boiler with a bushel of coals; though it is asserted by some, on the authority of the late Mr. Crichton, who assisted the celebrated James Watt in his various experiments, that with a properly constructed boiler, "with all appliances and means to boot," Mr. Watt had succeeded in evaporating as much as 18 cubic feet of water with that quantity of coals, or in that proportion; but as "one swallow does not make a summer," so this example should be regarded, rather as an exception, than rashly adopted as a rule.

It is found by experience that the time required to convert a given quantity of boiling water into steam, is six times that required to raise it from the freezing to the boiling point.

Water being the greatest component of steam, it may be proper to more fully investigate its qualities. It is composed, we find by chemical experiments, of 85 parts by weight of oxygen and 15 of hydrogen in every 100 parts of fluid. Both these terms are derived from the Greek language; the former signifies to generate acids, the latter to generate water. Hydrogen appears capable of uniting with oxygen in one proportion only, and water is the result of the composition: this fact may be proved by the following experiment:—

Put a little alcohol in a tea-cup, set it on fire, and invert a large glass bell over it. In a short space of time aqueous vapour will be seen to condense upon the inside of the bell, which by means of a dry sponge may be collected, and will be found to be pure water.

Several methods have been contrived whereby water may be decomposed, and the exact proportion of its constituent parts ascertained. It has been done by passing it through an iron tube over red-hot charcoal as follows:—

Take a piece of iron tubing, or an old gun-barrel, fix it in a chafing-dish of burning charcoal, and pass water into it in small proportions, the result will be hydrogen gas, as the oxygen of the water by the agency of heat becomes fixed in the iron of the gun-barrel, and sets at liberty the hydrogen, which may be collected in a receiver.

Had modern projectors paid proper attention to the above experiment, it would have saved them the expense of many useless patents and much subsequent disappointment. Indeed, in many instances, the consequence of the want of scientific information in sanguine schemers has been the cause of their utter ruin. It requires very little reflection to know that the extension of the surface of the boiler containing water and exposed to the action of fire, will cause an increase of steam. Hence the attention of modern improvers of the steam generator (particularly since the application of steam to the purposes of locomotion) has been directed chiefly to increasing the surface of the boiler exposed to the fire, without materially increasing its bulk. By carrying this principle to a great extreme, several modern inventions have approximated so near to the foregoing experiment as to end in a similar result; for, instead of generating steam, they decomposed the "stuff" of which it is made, and produced hydrogen gas, the lightest and almost the least expansive of all ponderable things; this mixing with the little steam which they did raise, weakened its effect to such a degree, that engines and boilers, which their overweening projectors wished to rate at as much as twenty horses' power, would not do the work of four.

It is very necessary to bear in mind the specific gravity of water, because this is always taken for unity in the specific gravity of other substances.

A pint measure of water, then, weighs very nearly one pound, consequently, a cubic foot of water will weigh 1000 ounces, or $62\frac{1}{2}$ pounds avoirdupoise, being about 48 lbs. for a cylindrical foot. It is 816 times heavier than atmospheric air.

Thus we have endeavoured to predicate all the phenomena commonly known of water as connected with steam, the accumulated knowledge of practical, observant, and scientific men through a long period of years.

Heat, the other component of steam, is the well known sensation which we perceive on touching any substance whose temperature is superior to that of the human body.

Chemists have agreed to call the matter of heat caloric, in order to give precision to chemical language and to distinguish the matter of heat from its effects, because whenever caloric becomes fixed in any body it loses its property of affording heat. To examine all the qualities belonging to heat would require a volume exceeding the limits of this essay, and it will be quite sufficient for our purpose to state a few of its most prominent qualities connected with this subject. By its qualities only can it be examined, since it is a "*Proteus*" which has eluded the most vigilant search of all philosophers.

Caloric is uniform in its nature; but there exist in all bodies two portions of caloric very different from each other. The one is called "*sensible heat*," or free caloric, the other "*latent heat*," or combined caloric; it is also sometimes termed, and perhaps with more propriety, *caloric of fluidity* and *caloric of vaporization.* "*Sensible heat*" is the caloric disengaged from other bodies, or if united, not *chemically united* with them. "*Latent caloric*" is that portion of the matter of heat which makes no sensible addition to the temperature of the bodies in which it exists. Caloric, as it penetrates bodies, frequently forms a chemical combination with them, and becomes essential to their composition: this is always the case when a solid is converted into a liquid, or when a liquid passes into the gaseous state. But if caloric be superadded to a body when in a state of saturation, it merely traverses its surface, and passes on to some of the adjacent bodies.

If a pan of snow be hung over a fire, the snow will receive a great accession of caloric from the fire without being at all sensibly warmer. The caloric, as it enters the snow, becomes chemically combined with it, and the fire will not in the least alter its temperature till the whole becomes fluid.

Caloric, in a *latent* state, exists in all substances with which we are acquainted, though it combines with different substances in different proportions. Caloric pervades all bodies, which is not the case with any other substance known.

Whenever caloric quits its latent state, how long soever it may have lain dormant or inactive, it always resumes its proper qualities and character, and affects the thermometer and the sense of feeling as if it had never been latent.

One body is said to have a greater capacity for caloric than another, and the propriety of the term may be shewn by the following experiment.

Dip a lock of wool and a piece of sponge in water, and observe how much more water the sponge is capable of taking up than the wool. Hence the sponge may be said to have a greater capacity for water than the wool.

The same bodies have at all times the same capacity for caloric, unless some change takes place in the bodies; and whenever a body has its capacity for caloric increased, it requires a larger portion of the matter of heat to raise it to a given temperature than another body does which has a less capacity for caloric, as may be made appaıent by the following experiment.

Take one pound of water at 100° and one pound of water at 200°, the mixture will be found to give the exact mean temperature of 150°; but one pound of mercury at 100° and one pound of water at 200°, will produce a heat much higher than the mean temperature. Mercury has not, therefore, so great a capacity for caloric as water.

Caloric is the cause of fluidity in all substances which are capable of becoming fluid, from the heaviest metal to the lightest gas. All fluids are formed from solids by an addition of caloric, and if this caloric were abstracted, solids would be reproduced. It insinuates itself among the particles of substances to which it is applied, and immediately separates them in some measure from each other. Thus ice is converted into water, and by a further portion of caloric into steam. Though the temperature of steam be no more than 212°, yet it has been demonstrated by Mr. Watt that it contains near 1200° of caloric, and it is this that preserves it in the form of steam. On this subject we may come to a satisfactory approximation by means of the following experiment by Dr. Black.

> He placed two cylindrical flat-bottomed vessels of tin, five inches in diameter, and containing a small quantity of water at 50°, on a red-hot iron plate of the kind used in kitchens; in four minutes the water began to boil, and in twenty minutes the whole was boiled away. In four minutes, therefore, the water received 162° of temperature, or $40\frac{1}{2}°$ in each minute. If we suppose, therefore, that the heat continues to enter the water at the same rate, during the whole ebullition, we must conclude that $(40\frac{1}{2}° \times 20 =)$ 810° additional heat has entered the water and is contained in the vapour.

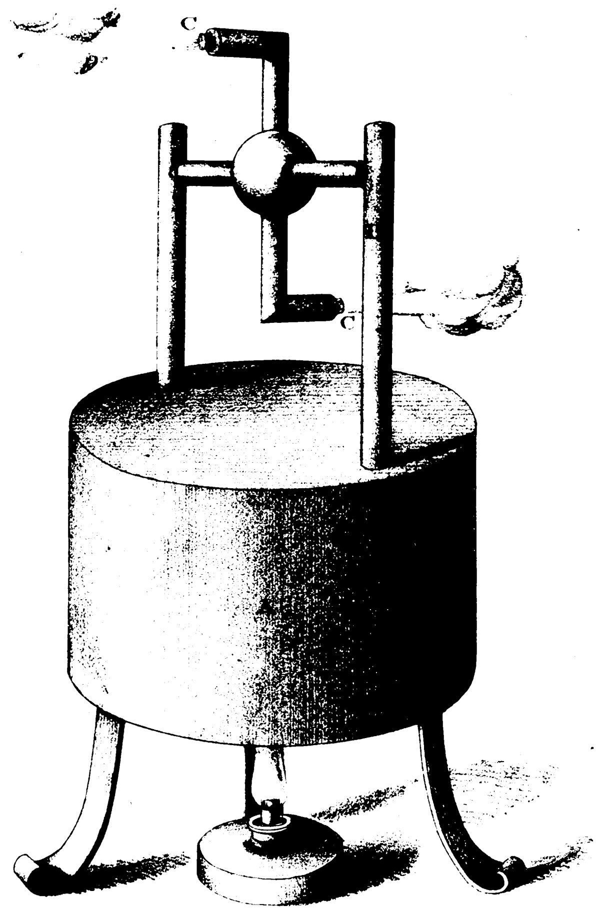
On the other hand vapours during their conversion into a liquid form, evolve or give out much caloric. The heat given out by the condensation of steam is rendered apparent by the following experiment.

Mix 100 gallons of water at 50° of temperature with one gallon of water at 212°. The temperature of the water will be raised about $1\frac{1}{2}$°. Condense, by a common still tub, one gallon of water from the state of steam, by 100 gallons of water at the temperature of 50°, the water will be raised in temperature 11°. Hence 8 pounds of water condensed from steam raised the temperature of 100 gallons of cold water $9\frac{1}{2}$° more than 8 pounds of boiling water; and by an easy calculation it appears that the caloric imparted to the 100 gallons by the steam, if it could be condensed in one gallon of water, would raise it to 970°. A pound of water, therefore, in the form of steam contains more caloric than a pound of boiling water in the proportion of 970° to 212°.

The large quantity of caloric latent in steam renders it an exceedingly convenient vehicle for concentrating and conveying heat. Steam, therefore, is used on an extensive scale in manufactories, for boiling water in large wooden vessels remote from the boiler in which the steam is raised, being conducted from it and to the vessels in cast-iron pipes.

From these sources does steam derive its immense expansive power, and from this, combined with the

Plate I.



FIRST STEAM ENGINE.

M. A Alderson, delt

On Stone by C. Burton

Day & Haghe, lithog

facility with which it is condensed, and its easy application to all situations where fuel is to be had, does it possess its advantages over every other substance hitherto known as a "prime-mover" of all kinds of machinery.

The first mechanical movement on record by means of steam is ascribed to Hero, of Alexandria, and is sufficiently simple but is of no use except as a playful and beautiful toy exhibiting the *action* without much of the *power* of steam; there does not appear to have been any modern improvement springing from this as a parent source, and for ages there was no advance beyond it. "*The force*" of steam "*could no further go*" in that direction, and a new principle and mode of application had yet to be invented ere its powerful and beneficial effects could be fully developed.

The invention consists of a vessel to raise steam suspended over a fire and having a tube with two legs bent in opposite directions, with apertures in each leg. This tube is suspended like an axle upon a solid and a hollow support, the hollow one communicating with the boiler, as shown in plate 1.

The steam being raised in the vessel A, passes through the hollow support B, from which there is no outlet but through the two apertures CC; issuing from them it strikes the surrounding atmosphere and produces by re-action a continual whirling motion in the legs and axle.

It is a singular fact that, in later times, Sir Isaac Newton hit upon a similar contrivance to demonstrate the expansive force of steam, or, as he expresses it, the elastic power of vapours, as we find by reference to a work called " An Explanation of " the Newtonian Philosophy," at page 199, and paragraph 790, which reads as follows :—

" The quantity of elastic vapours produced by " the action of fire will appear by the '*Æolopile,*' " which is a ball with a tube fixed in it, having a " hole whose diameter is not quite the twentieth " part of an inch.

" Let this ball, partly filled with water, be laid " upon a fire, the moment that the water is changed " into vapour those vapours go through the hole; " but if the heat be so increased as to make the " water boil violently, the vapours compressed in " the upper part of the ball will, by their elasticity, " endeavour to recede from each other every way, " and violently rush out through the hole. We " have a more sensible effect of the elasticity of va- " pours, if the hole be made bigger and stopped, " and then the ball be laid upon the fire till the " water boils violently; after this, if the ball be set " upon little wheels, so as to move easily upon an " horizontal plane, and the hole be opened, the va- " pours will rush out violently one way, and the " wheels and the ball at the same time will be car- " ried the contrary way."

Here we have a complete steam-carriage by

Newton on Hero's principles. The illustrious Newton, therefore, it appears, was the inventor of the steam-carriage!

The Steam-Engine being the most important application of aqueous vapour, it may be worth while to devote a little inquiry into the history of its origin and improvement.

The first engine of which we read is the one above described, as the invention of Hero, and it is generally stated in histories of the steam-engine, that from the period of Hero's invention down to about the year 1563, no mention occurs in any work of steam as a "*First Mover;*" but in opposition to that opinion, it must be stated that we find in Malmsbury's History, under the date of 1002, the following paragraph.

"In the church of Rheims are still extant, as "proofs of the knowledge of Gerbert, a public "professor in the schools, a clock constructed on "mechanical principles, and an hydraulic organ in "which the air escaping in a surprising manner by "the force of heated water, fills the cavity of the "interior of the instrument, and the brazen pipes "emit modulated tones through the multifarious "apertures."

This really appears to be the earliest "*modern*" application of steam, and it is rather surprising that it should so long have been overlooked. In 1563, one Mathesias hinted at the possibility of constructing an apparatus similar in its operation and properties to those of the modern steam-engine. In 1624, Solomon De Caus, a French engineer, described an engine acting by the elasticity of steam. But the first person who, in modern times, applied it in a "*practical*" though not in a "*powerful*" manner, was Giovania Branca, who resided at Rome in the beginning of the seventeenth century.

The work which contains a description of the machine here alluded to was published at Rome in 1629, and intituled, "*A new Volume of Machines,* "*illustrated with beautiful Figures, with Latin and* "*Italian Descriptions.*" This work is exceedingly rare, and it is believed the only two copies in England are, one in the possession of Major Coleby, of the Ordnance-Office, and the other in that of Dr. Faraday, of the Royal Institution. The engine of Branca consists of a boiler, with a safety-valve to prevent accidents which might arise from explosion; a pipe, resembling the spout of a tea-kettle, conveys the steam, with some force, against a float-wheel, driving it round, and giving it a continuous rotary motion, whilst a pinion, on the same arbor, by means of two wheels, is made to give motion to the pestles that belong to two mortars.

Next we come to the pretensions of the Marquis of Worcester, who, of all those whose names are associated with the history of the steam-engine in its infant stages, is by far the most celebrated. The earliest description that we have of a machine for raising water by fire employed in raising steam from water is from the Marquis, who, in the year 1663, published a small pamphlet, intituled, "A Century "of the Names and Scantlings of Inventions." This little work was addressed to the king and parliament of that day, and published with a view to obtain encouragement from the public for the prosecution of one hundred projects, which it details.

The article No. 68 of this century is as follows:

"An admirable and most forcible way to drive "up water by fire, not by drawing or sucking it "upwards, for that must be, as the philosophers "call it, *infra sphæram activitatis*, which is but at "such a distance; but this way hath no bounder, "if the vessel be strong enough, for I have taken "a piece of a whole cannon, where the end was "burst, and filled it three parts full of water, stop-"ping and screwing up the broken end, as also "the touch-hole, and making a constant fire under "it, within twenty-four hours it burst, and made "a great crack; so that having a way to make the "vessels strong enough, so that they are strength-"ened by the force within them, and the one to "fill after the other; I have seen water run like a "constant fountain-stream forty feet high, one ves-"sel of water rarified by fire driveth up forty of "cold water, and the man that tends the work has "but to turn two cocks, that one vessel of water "being consumed another begins to force and re-"fill with cold water, and so on successively, the "fire being tended and kept constant, which the

" self-same person may likewise abundantly per-
" form in the interim between the necessity of
" turning the said cocks."

This passage certainly contains a description of an engine for raising water by the repellant power of steam; and from his expression of one vessel of water converted into steam forcing up forty vessels of water to the height of forty feet, it is very probable that he had actually tried the experiment by a working model.

This is considered by most as the origin of this powerful auxiliary to the labours of man, and which, aided as it has been by subsequent improvements, has enabled England to support a proud pre-eminence both in arts and manufactures. The Marquis concluded his work with a promise to leave to posterity a book wherein, under each head, the means of putting his several inventions into execution, were to be described with the assistance of plates; but as this work never appeared we can only judge of his abilities by the specimen he has left. He appears, says Dr. Rees, to have been a person of much knowledge and ingenuity; but his obscure and enigmatical account of his inventions seems 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, resembling more the puff of an advertising tradesman, than the patriotic communications of a gentleman.

Previously to pursuing the history of the steam-engine it may be useful to point out its general principles.

The force of the steam-engine is derived from the property of water to expand itself in an amazing degree when heated above the temperature at which it becomes changed into vapour or steam. This vapour being an exceedingly elastic fluid, can be retained within the close vessel or boiler to which the heat is applied, even when it has an expansive force sufficient to make it fill, if left at liberty, twenty or thirty times the space in which it is confined; in this state steam will exert a proportionate force or pressure to burst open the sides of the vessel in which it is retained. This force may either be applied to expel or raise water from any vessel into which the confined steam is admitted, or to give motion to a moveable piston, which is so accurately fitted to the interior capacity of such vessel as not to permit the escape of steam between them.

Another source of the power of the steam-engine is the facility with which steam of a great expansive force can be cooled by the application of cold water, and condensed into the small quantity of water from which it was originally produced.

A partial vacuum can thus be made in a very large vessel in an instant, and even in the same vessel which was a moment before filled with confined steam exerting a great force to escape. The pressure of the atmosphere, which tends to fill up this vacuum, can be made to produce the ascent of water into a vessel to any height less than twenty-four or twenty-five feet, though sometimes, by attention, it has been raised to twenty-eight.

The pressure of the atmosphere may also be made to give motion to a piston, by admitting the atmospheric air to press upon one side of it, whilst there is a vacuous space formed on the other by the condensation of the steam which had previously filled the cylinder, as in the *Atmospheric Engine;* or, by making the steam by its expansive force move the piston, by pressing on one side, whilst the vacuum by condensation is formed on the opposite side, as in the "*Condensing Engine.*"

Notwithstanding the great variety of different constructions of the steam-engine, all of them except what are called high pressure derive their force from one of these three principles, or from combinations of them. But "*High-Pressure Engines,*" from the difficulty of condensing steam of a very high temperature, act on a different principle. For example, the steam being admitted on one side of a piston in a close cylinder, when it has driven the piston as far as it can go in one direction, is allowed to escape into the air; whilst, at the same time, the steam from the boiler is admitted on the opposite side of the piston. The steam so admitted, besides the work it has to do, has to drive the other steam out against the pressure of the atmosphere; so that to work such steam to advantage it must be of a very high temperature indeed, as it always, "from the counterpoise of so great an opposition," loses the constant quantity of the atmospheric pressure, namely, 14 lbs. upon every square inch of the piston's surface.

All the foregoing combinations may be made to work either with high or low pressure steam on what is called the expansive principle, first introduced by Hornblower, and patented by him in the year 1781; by cutting off the supply of steam from the boiler to the cylinder at any portion of the piston's stroke, thus leaving the steam to act only by its own expansive force; and this principle, in conjunction with the above, forms another variety of applications.

It will be observed in the preceding paragraph, that pressure and temperature are used as synonymous terms; and it must be added in explanation, that as the pressure under which steam is generated is increased, so also is its temperature, but not in an equal proportion, as may be seen by the following table, the result of popular experiments.

Table of the Force of Steam and the Heat of it.—At the temperature of 212° of Fahrenheit's thermometer the force of steam from water is just equal to the pressure of the atmosphere, but by increasing the heat, effects will be obtained which are described in the following table:—

Steam predominating over the pressure of the atmosphere upon a safety valve, if its elastic force be equal to	5	pounds per square inch requires to be maintained by a temperature equal to	$227\frac{1}{2}$	degrees of heat by Fahrenheit's thermometer; and at these respective degrees of heat steam can expand itself to about	5	times its volume, and yet continue equal in elasticity to the pressure of the atmosphere.
	6		$230\frac{1}{4}$		6	
	7		$232\frac{3}{4}$		7	
	8		$235\frac{1}{4}$		8	
	9		$237\frac{1}{2}$		9	
	10		$239\frac{1}{2}$		10	
	15		$250\frac{1}{2}$		15	
	20		$259\frac{1}{2}$		20	
	25		267		25	
	30		273		30	
	35		278		35	
	40		282		40	

With reference to this table, furnished by Woolfe, it is generally stated in works on this subject, that by small additions to the temperature an expansive force may be given to steam, so as to be equal to 400 times its natural bulk, or to any other extent, provided the vessels, &c. that contain it be strong in proportion. This observation would be just, but, unfortunately, the theory on which it is founded is incorrect; and although it has been deemed advisable to give the table as it stands, it must be accompanied with the statement that the last column has been found by experiments lately made to be erroneous. The other columns of the table, the only really useful ones, may be relied upon as being correct.

A machinist of the name of Moreland, and dignified with a title, appears to have given the subject of steam some consideration, but not to have been a successful improver; we shall therefore pass on to Papin, who appears to have made a most important improvement in the generation of steam, if it be true what is very generally asserted, namely, that he was the inventor of the safety-valve. This invention he applied to the softening of bones, by boiling them in a close boiler subject to a great pressure, by which contrivance he said he "extracted marrowy nourishing juices from bones and beef, even the oldest and hardest cow beef, and other meats, whose horny and shrivelled fibres baffled the skill of the most experienced cooks to prepare for mastication with common boilers, when done in his digester came forth succulent and pulpy:" in fact, so extraordinary was the effect of this "*High-Pressure Steam*" process, that the coarsest bones and most obdurate gristle glided gently into the stomach in the attractive shape of savoury soups and glutinous jellies. This process of Papin's is most extensively used at the present day in the various hospitals and public charities in France, as also in some of this kingdom.

The digesting process being found to be attended with danger, he in the account of his " Engine," as he calls it, printed in 1681, and when he resided in London, proposed to guard against the fatal effects which would follow from the bursting of the boiler, by adding a contrivance which is now known by the name of the safety-valve, consisting of an opening made in the cover or roof of the boiler, and closed by a valve acted on by a lever, on the end of which was suspended a weight. The safety valve as used at the present time is only a very slight improvement indeed upon that of Papin.

He invented several ingenious machines; but never succeeded in producing an effective steam-engine, though he tried an immense number of experiments for that purpose; we must, therefore, turn our attention to Savery, who was cotemporary with Papin, and who may be considered as the first person who attempted to realize the scheme of the Marquis of Worcester with any success. He obtained a patent in the year 1698, " for a new invention for raising water and occasioning motion to all kinds of machinery by the impellant force of fire." About this period apprehensions were entertained that mines, otherwise of immense value, would have to be abandoned, unless more powerful and economical means were adopted of draining the water from them. Hence this was the most valuable purpose to which any new motive force could be applied. This object Captain Savery proposed to effect, and published a very candid address to the public on the subject, wherein he speaks of his engines with all the earnestness of a man conscious of having made a most important discovery; and in the most open manner invites an appeal to experiment, and an examination of the actual performance of his engines as a test of their merits. These engines Savery proposed to apply for raising water for palaces and gentlemen's seats, for draining fens and MINES, for supplying houses with water in general, and for pumping water from ships. He erected many of them in different parts of England.

The power of this kind of engine was limited only by the strength of the pipes and vessels. For he says, "*I will raise* you water 500 or 1000 feet high could you find us a way to procure strength enough for such an immense weight as a column of water *that height*." The advantage derived from Savery's engine was counterbalanced in public opinion by the great risk of accident from an explosion of the boiler.

The construction of the engine was as follows:—a pipe descended into the water of the mine, and terminated in a large receiver which might be compared to a square chest. The upper orifice of the pipe was covered by a valve opening upwards. The receiver was connected with a boiler which was about half filled with water, and set in a furnace, as boilers for supplying steam are at present, so that the heat of the water could be constantly kept up for the requisite supply of steam.

The pipe that connected the boiler and the receiver contained a cock by which the communication between these vessels could at any time be opened or suspended. At the commencement of the action a quantity of steam was let into the receiver, which it filled, driving out the air it contained through a valve properly situated for the purpose; the steam cock was then closed, in consequence of which, as the receiver cooled, the steam which had entered was condensed, and the space it occupied became nearly a vacuum. By this means the pressure of the atmosphere was removed from that part of the water in the mine, which entered the pipe, rising from it to the receiver; and, therefore, as in the supply pipe of a common pump, the pressure on the rest of the surface forced the water up the pipe and caused it to fill the receiver.

The equilibrium being thus restored, the valve of the pipe from the well was closed by its own weight; the steam-cock was now opened, and the effect was to drive the water out of the receiver through the valve at which it had previously driven out the air. This valve was in a pipe which was placed perpendicularly over the receiver. Thus the receiver was again left filled with steam, and a quantity of water equal to its capacity was discharged from the mine. In continuing the operation a cock was opened which let into the receiver a quantity of water in the form of a shower; this produced a speedy condensation of the steam: the water again rose and was again driven out as before.

Such was the attempt made by Savery to form a powerful engine by the use of steam. Its construction was very simple, but it had several important defects. As the water was forced into the receiver by the pressure of the atmosphere, the distance between the receiver and the surface of the water in the well was limited in consequence of the imperfection of the vacuum from 22 to 26 feet, and the discharging pipe could not be continued to any great length above the receiver, without requiring a proportionate density of steam to overcome the pressure of the column of water which pressed back upon the receiver. Thus if the column rose 33 feet above the receiver, the steam required was equal to the resistance of two atmospheres. Indeed, the great elastic force of the steam demanded frequently burst the vessels. Another great defect also was the rapid destruction of steam by its coming in contact with the cold water in the receiver, the contents of which were slow in yielding to its pressure, and with the rapid destruction of steam was necessarily connected a heavy demand for fuel.

About the beginning of the last century, Newcomen, an ironmonger, and Cawley, a glazier, of Dartmouth, conceived the idea of improving Savery's engine; but their exertions terminated in the adoption of a new principle of memorable consequence in the history of this invention. In the engine by Savery the operation of the steam was two-fold, namely, by the direct pressure from its elasticity, and by the indirect consequence of its condensation, which affords a vacuum. This last may be said to be the only principle employed by Newcomen.

In the engine by Newcomen a boiler for producing steam was used as in that by Savery; there was also a steam-pipe which opened into the bottom of a hollow cylinder; the entrance of the steam into the cylinder could at any time be cut off by a valve or cock used for the purpose; to the cylinder which was open at the top was adapted a solid piston that slided up and down in it, and was rendered air-tight by a stuffing of hemp, with which it was surrounded.

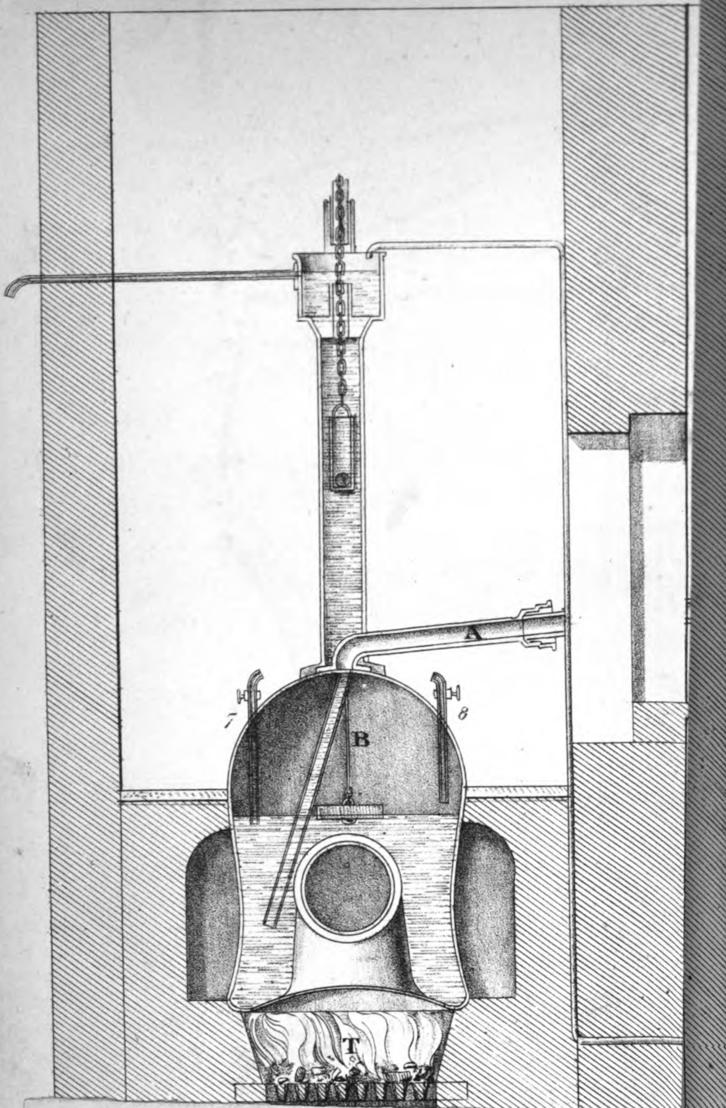
Suppose in one of these engines the piston to be at the top of the cylinder, a quantity of steam from the boiler is let in, and fills the space below it; the air which the cylinder contained being driven out by the superior force of the steam through a valve adapted for the purpose.

As soon as the cylinder is filled with steam, a jet of water from an elevated reservoir enters at the bottom of the cylinder, and the steam is immediately condensed. As the pressure of the atmosphere on the upper sides of the piston is about fifteen pounds on every square inch of its contents, the counterpoise to this pressure afforded by the steam is no sooner removed by the condensation than the piston rapidly falls to the bottom of the cylinder. The steam-pipe being now re-opened the piston rises again, because the elasticity of the steam which impels it exceeds the atmospheric pressure; but when the steam is again condensed, the piston falls a second time, and as rapidly as before. Having thus obtained a "RECIPROCATING MOTION," Newcomen applied it to the working of a force pump, by the intervention of a great beam or lever suspended on gudgeons at the middle, and swinging like the beam of a balance; and this part of his engine is in use to this time. A rod from the centre of the piston was attached to one end of this beam by a short chain, and to the other end by a similar piece of chain was connected the rod of the forcing pump; every time, therefore, that the piston sank in the cylinder, the rod of the pump which extracted the water from the mine was drawn up, and as this end was purposely made heavier than the piston end, the piston rose when the steam was let under it, although this steam might have so little elasticity as only just to counterpoise the weight of the atmosphere.

Whatever objections might be offered to the engine of Newcomen, still it was a great effort of mechanical genius, and he and his coadjutor Cawley must ever be considered as substantially the inventors of the steam-engine. They presented to the world a machine, the power of which is unlimited! For it is obvious that, by increasing the size of the cylinder, the atmospheric pressure of the piston may always be made to exceed the column of water which is to be raised. The alterations which have been made in the construction of engines, although they have required much ingenuity, and have made prodigious accessions to their convenience, can only be considered in the light of improvements.

Numerous have been the improvers of the steam-engine, yet the name which deservedly ranks the highest in the public estimation, is that of Watt, a gentleman whose ingenuity was as boundless as the application of his improvement was important.

Mr. James Watt was a maker of mathematical instruments in Glasgow, and was employed by the university of that city, in the year 1763, to repair a working model of a steam-engine, which was used by the professor in his lectures to his pupils. During the experiments that he made with his engine, he observed the great loss of steam which was occasioned by its coming in contact with the cold surface of the cylinder. It was not however till two years afterwards that he brought forward the two most material of his improvements, which were, first, that of making the steam itself depress the piston instead of the pressure of the atmosphere, and, second, that of condensing the steam in a separate vessel. By the first he considerably augmented the power of the engine, because the force with which the piston descended in Newcomen's


A
B
7
8
T

limited to the weight of the atmosphere; but ncreasing the elasticity of the steam which he d, he could make it equal to twice the atmosric pressure, thus making an engine of the ne size raise a column of water of twice the ght. His second improvement effected a great ing of heat, because by surrounding the cylin- with a case, it was constantly kept at nearly same temperature as the steam, consequently ere was no loss by condensation of the acting pour.

Mr. Watt added other appendages to the steam-ngine, which rendered it still more perfect, such as the governor, parallel motion, &c.; the use of which will be mentioned in the following explanation of the steam-engine now in general use.

Plates II. & III. show a longitudinal section and ground plan of a low pressure condensing steam-engine and boiler of eight horses' power, as constructed by Messrs. Fenton and Murray, of Leeds, on the principles of Bolton and Watt.

A is the steam-pipe which conducts the steam generated in the boiler, B, to the slide-valve C, which is kept close to the surface against which it works by the pressure of the steam.

D is the steam-cylinder which is surrounded by a case for the purpose above-mentioned, the cylinder is covered by a close lid through a stuffing-box, in the centre of which the piston-rod moves.

E, the piston, which by a stuffing of hemp is made to fit so exactly the interior of the cylinder, as to allow no steam to escape by its sides. e Is the piston-rod attached to the parallel motion, and the piston E which moves the beam F, and the other end of this beam by the connecting rod g gives motion to the heavy fly-wheel G by means of the crank h. H is an eccentric circle on the axle of the fly-wheel, G, it gives motion to the slide-valve C in a manner easily understood by inspection.

I, is the throttle-valve and lever connected with a governor for regulating the admission of steam into the cylinder.

K, the cylinder of an air-pump for extracting the air and water, which condenses the steam from the condenser L.

M, a small cistern filled with water; into this cistern enters a pipe from the condenser L, the top of which pipe is covered by a valve, called the blow-valve; previously to beginning the motion of the engine, the air which is contained in the steam-cylinder and passages from it is discharged through this valve.

N, the eduction-pipe, which conducts the steam from the cylinder to the condenser L.

O, the pump which supplies the cold water into the cistern S, in which the condenser and air-pump stand.

P, a rod connected with the injection-cock for admitting a jet of water into the condenser from the cistern, and which is continually flowing during the working of the engine.

qq, Cast-iron columns, of which the engine has four; they stand upon an iron plate, to which the principal parts of the engine are fixed.

Before the engine is set to work, the cylinder D, the condenser L, and the passages between them, are filled with common air which it is necessary to extract. To effect this, the valve C is moved on its face, and a communication is made between the steam-pipe A, the space below the piston in the cylinder D, the eduction-pipe N, and the condenser L. The steam will now forcibly drive the air contained in the eduction-pipe and the condenser, through the blow-valve in the cistern of water M. The steam admission-valve is then closed, and the steam which has thus expelled part of the air, is converted into water partly by the coldness of the condenser, but principally by a jet of cold water, which is suffered to play upon it through the injection-valve from the cistern S. This steam being condensed, all the space which it had occupied would be a vacuum, did not the air in the cylinder D expand itself and fill the space, which the original quantity of it had filled, but by a repetition of the means for extracting a part of the air, the whole is driven out at the blow-valve, and the cylinder remains filled with steam alone. Suppose then the whole of the cylinder, from the underside of the piston downwards, to be filled with steam, and that the farther admission of steam to that side of the piston is cut off while a free communication between it and the condenser remains open, it is obvious there will soon be a vacuum in the cylinder, because the steam will be condensed by a jet of water playing into the condenser. At this moment the steam is admitted upon the upper side of the piston, which is therefore instantly pressed down to the bottom of the cylinder.

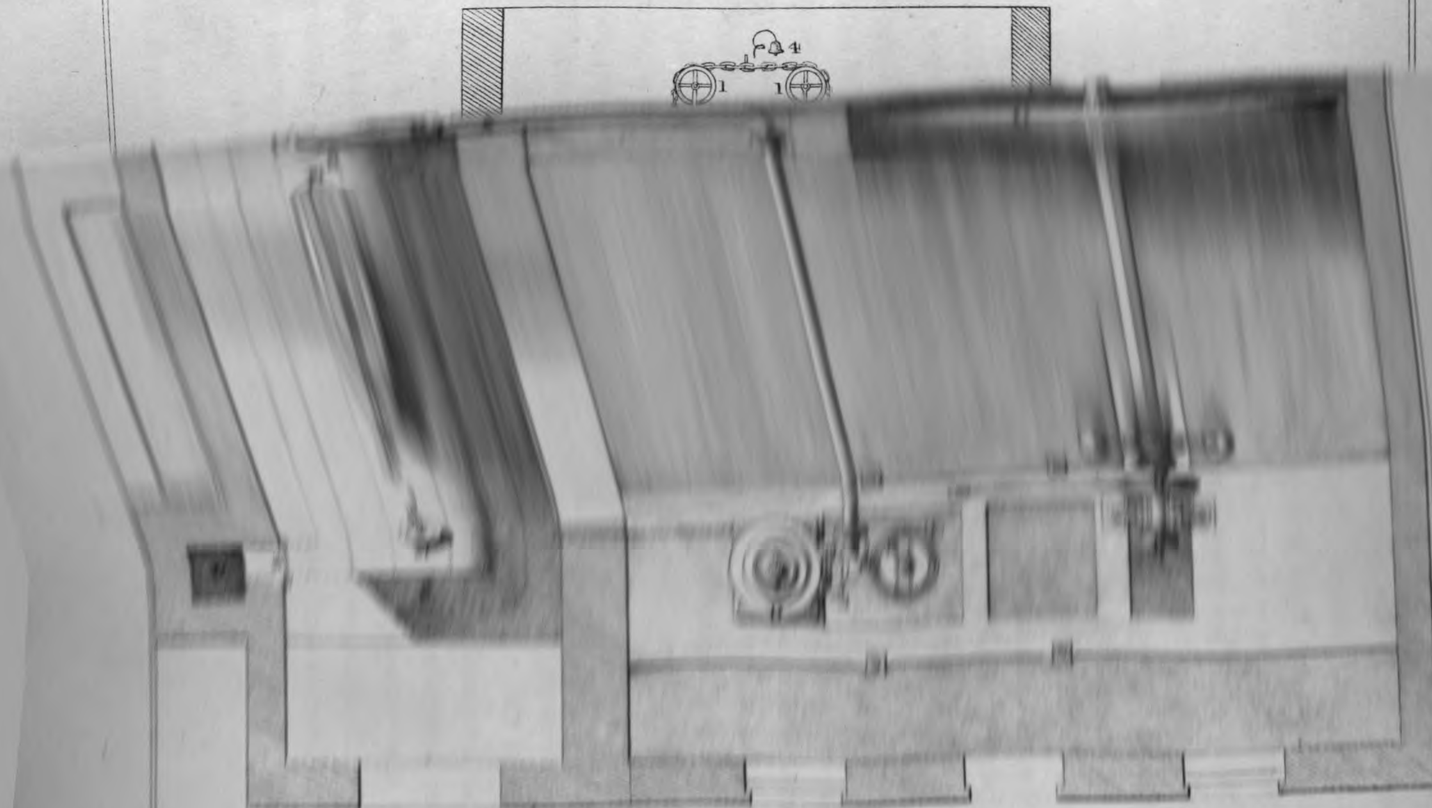
As soon as the piston has arrived at the bottom of the cylinder, the steam is admitted to the underside of it, and as the communication from the upper side of the piston to the condenser is opened, whilst a further admission of steam to that side is prevented, the steam that depressed the piston passes into the condenser, and the engine makes its stroke upwards. Thus the piston is made to continue its "RECIPROCATING MOTION" in the cylinder, and the distance of its movement is called the length of its stroke.

To explain the force with which the piston is depressed, it must be observed that the pressure of the steam generally exceeds that of the atmosphere; but supposing it only the same, and making an allowance of one-third for friction, there is then an immense power at command. A piston of 24 inches diameter, or 452 inches area, will descend at the rate of 220 feet per minute, with a force of 4520 lbs., or it would balance a column of water of this weight acting upon the other end of the beam. As this power is accumulated in the " FLY WHEEL,' it is not wonderful that it produces such astonishing effects.

The air-pump, K, is connected to the condenser, L, by means of a pipe containing a valve, m, which opens towards the pumps. The bucket, l, of the air-pump contains two valves, as does also its lid, n, which, like those of the bucket, open upwards. It is obvious that when the piston, E, of the cylinder is depressed, the bucket, l, of the air-pump will be depressed also, and its valves opened, whilst the valve m closes; hence the condensed steam, and water, and any elastic fluid which has passed the valve m, will pass through the valves of the bucket l; on the ascent of this bucket the water and gas, which have thus got above its valves, will be discharged through the valves of the lid n. As the water contained in the cistern above the lid n is very hot, it is used to feed the boiler, and it is forced into it by a pump attached to the beam F, as represented at r. The extremity of the beam F, in moving up and down, describes the arc of a circle, but it is necessary that the piston-rod should rise and fall vertically. Newcomen effected this by making the end of the beam into the arc of a circle, whose diameter was equal to the length of the beam; a chain went over this arc, and was fixed to the higher end of it; this simple contrivance effectually answered the purpose, because in his engine the effective stroke was only downwards, but here, in a double-power engine, where the stroke is both upwards and downwards, a chain would yield in rising, and be altogether unsuitable. An apparatus is therefore used, called the "PARALLEL MOTION," which will be easily understood by inspection. By this means the piston-rod not only rises and falls vertically, but is perfectly rigid in communicating its motion to the beam.

If the heat of the fire T under the boiler should be suddenly increased, the elasticity of the steam would also be suddenly increased, and would have a tendency to make the engine move with a greater velocity; and if the fire should be neglected, a contrary effect would take place. To counteract this, a contrivance is used, called a governor, or conical pendulum, consisting of an upright spindle, to which are appended two levers, and upon the lower ends of these levers are fixed two large balls. The action of this beautiful contrivance is this:—when the governor is made to revolve, the centrifugal force of its balls makes them recede from each other, and this motion is communicated, by means of levers, to the throttle-valve I, which admits the steam into the cylinder. Let us suppose that too much steam is admitted, and therefore that the engine is moving with too great a velocity, the velocity of the governor will also be increased, and this will make the balls expand, which causes the

Plate III.



PLAN.

throttle-valve to close the passages a little and diminish the supply of steam. Now if the engine be moving too slow, the balls will contract, and by opening the throttle-valve a larger quantity of steam would be admitted. The impelling power being thus increased and diminished, the engine is made to work with such regularity of motion as almost to rival the sun in precision and regularity.

Plate III. fig. 2, is a longitudinal section of the boiler and house containing it. B is the boiler, of wrought-iron plates, rivetted together and strengthened by strong wrought-iron stays inside; the bottom plates should be about three-eighths of an inch thick, the sides a quarter of an inch, and the top three-sixteenths of an inch. C is the upright steam-pipe through which the steam to the engine is supplied. D the safety-pipe, with a discharging pipe, to carry off the steam when it is at such a strength as to overcome the weight d on the "*Safety Valve.*"

E is the feed-pipe for supplying the boiler with water, this pipe receiving its supply from the "*Hot Well,*" by means of the "*Hot-water Pump*" already described. F is a cylindrical float inside the feed-pipe, suspended over the pulley 1, by the chain 2, passing on to the damper 3. This damper and float balancing each other, when the water in the boiler gets of too high a temperature, it causes the float to rise in the steam-pipe, which, lowering the damper, diminishes the draught of the chimney, and, consequently, the heat of the fire and the strength of the steam. On the other hand, as the temperature diminishes, the float F descends and the damper rises, to increase the draft, and before it is open to its full extent it rings a small alarum bell, 4, which gives notice to the engine-man that the fire is neglected.

G is a stone float for regulating the quantity of water supplied to the boiler by the feed-pipe; it is suspended from the lever H by a brass wire, and balanced on the surface of the water by the weight i, the standard K forming the fulcrum of the lever.

l, Is a conical plug, ground so as to fit water-tight into a hole in the bottom of the feed-pipe, and suspended from the lever h. It is here represented as closed; but suppose the surface of the water lowered, the float following the surface draws down the end of the lever and opens the valve; the water then rushes down the feed-pipe into the boiler, which, raising the surface and along with it the float, the valve is again closed, and thus any material variation in the quantity of water in the boiler is prevented.

M is the man-hole, for enabling the engine-tender to get inside and clean the boiler. 5 is a valve opening inwards for preventing accidents in case the steam should be suddenly condensed in the boiler, as it would in that case open and let in the atmospheric air.

6, Is a mercurial steam-gauge for ascertaining when the steam is at the proper temperature for starting the engine. There is a similar one also generally fixed to the casing of the steam-cylinder. In plate 2 are two cocks shown at 7 and 8, for enabling the attendant to ascertain the state of the water in the boiler, which is done in a manner easily understood on inspection, and will not therefore require any further explanation here.

In plate III. X is the ash-pit, the side walls of which support the boiler, and are formed as high as the underside of the grate-bars, Y, of common brick, as is also the bridge Z, except that part of it immediately exposed to the action of the fire, which, together with the rest of the seating up to the underside of the boiler, is formed of fire-bricks. The flues S and the chimney U, on the plan, fig. 1, are built of common bricks.

For every fire consuming one bushel of coals per day the chimney should be 30 feet high, and one foot higher for every additional bushel consumed, measuring from the body of the fire. T is the fire-place and door, and V a small door for clearing the flues.

To return now to the engine: in all machines the moving power and the resistance are subject to fluctuations of intensity; it becomes, therefore, an object of great moment to have in most compound machines some means of accumulating the excess of the motive power, and of expending that excess when the motive power operates too feebly. This equalization of motion is usually, in the steam-engine, obtained by what is called a fly, which is generally made in the form of a wheel. A fly acts upon the principle that a body being put in motion with a certain velocity, at a certain expense of power, will continue to move until its motion is stopped by a resistance equal to its momentum, or sum of the power and the velocity which first caused its motion. A fly is indispensable in the steam-engine, because the power transmitted by the crank is extremely variable throughout the different periods of the stroke. At first beginning the crank being in a line with the connecting-rod, the force of the piston has no action at all to turn the crank; but as the crank begins to make a sensible angle with the connecting-rod, the force of the piston begins to operate upon the crank to turn it round, and this with a force increasing with the angle at which the connecting-rod acts upon the crank until they are at right angles to each other, and then the whole force of the piston operates to drive round the crank.

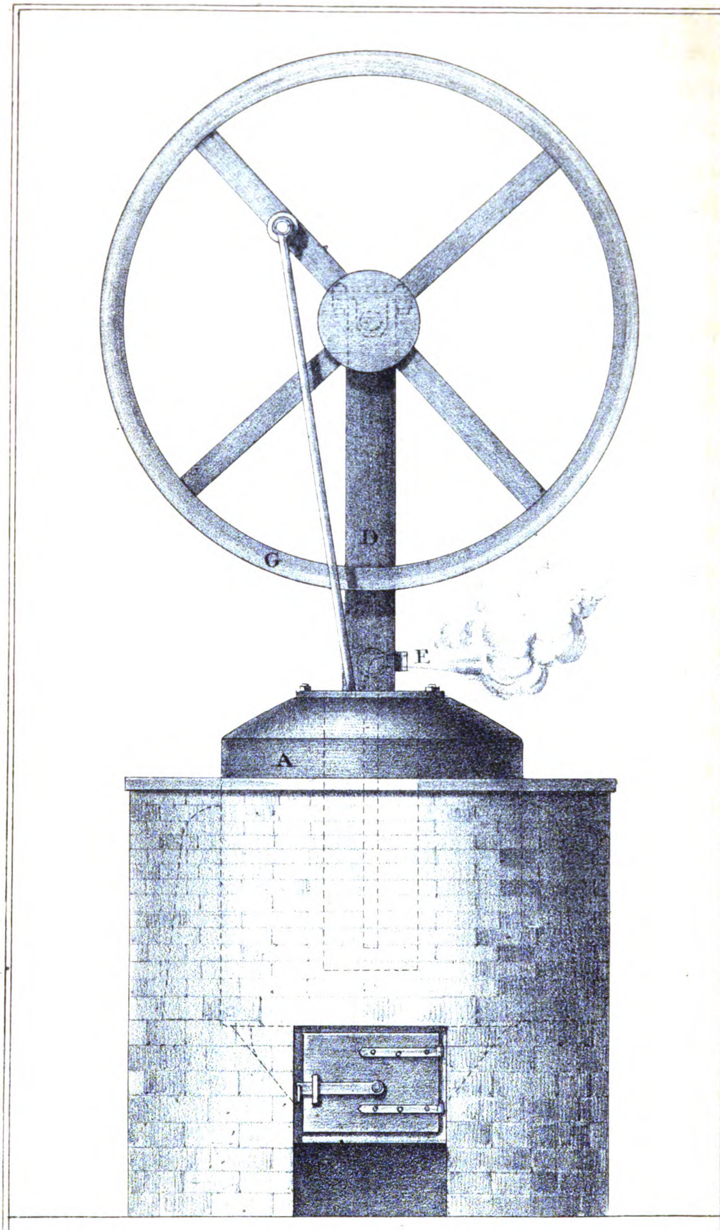
The force of the engine is collected in the fly, and on account of its great weight a small variation in force does not sensibly alter its motion, whilst its friction and the resistance it has to overcome, prevent it from accelerating. If the motive-power tend to move the machine too fast, it keeps it back; and if the power weaken, it impels the machine forwards. This accumulating power of the fly induces many to suppose that it really adds power or mechanical force to an engine, not considering that if it communicated a power which it did not receive, it must, contrary to the nature of matter, possess a principle of motion within itself. The friction or resistance which the air opposes to any body in motion, and the friction of the pivots which support the axis of a fly-wheel, are considerable deductions from the power communicated to it, so that instead of a fly-wheel gaining power, it requires a constant exertion of power to keep it in motion, even when no other resistance is applied to prevent it. The apparent creation of power by a fly consists in its accumulating into one moment the exertions of many.

It is in the property which the steam-engine possesses of regulating itself, and providing for all its wants, that the great beauty of the invention consists. It has been said that nothing made by the hand of man approaches so near to animal life. Heat is the principle of its movement; there is in its tubes circulation, like that of the blood in the veins of animals, having valves which open and shut in proper periods; it feeds itself, evacuates such portions of its food as are useless, and draws from its own labours all that is necessary to its own subsistence. To this may be added, that they now regulate so as not to exceed the assigned speed, and thus do animals in a state of nature. That the safety-valves, like the pores of perspiration, open to permit the escape of superfluous heat in the form of steam. The steam-guage, as a pulse to the boiler, indicates the heat and pressure of the steam within, and the motion of the piston represents the action and the power of which it is capable. The motion of the fluids in the boiler represents the expanding and collapsing of the heart; the fluid that goes to it by one channel is drawn off by another, in part to be returned when condensed by the cold, similar to the operation of veins and arteries. Animals require long and frequent periods of relaxation from fatigue, and any great accumulation of their power is not obtained without great expense and inconvenience. The wind is uncertain; and water, the constancy of which is in few places equal to the wants of the machinist, can seldom be obtained on the spot, where other circumstances require machines to be erected. To relieve us from all these difficulties, the last century has given us the steam-engine for a resource, the power of which may be increased to infinitude: it requires but little room—it may be erected in all places, and its mighty services are always at our command, whether in winter or in summer, by day or by night—it knows no intermission but what our wishes dictate.

The steam-engine, then, we may justly look upon as the noblest machine ever invented by man—the pride of the machinist, the admiration of the philosopher.

The "HIGH-PRESSURE-ENGINE," from its be-

Plate IV.



ELEVATION.

M. A. Alderson, delt. *Day & Haghe, 17 Gate St. Lithogs* ing a decidedly different application of steam, as a motive-power, to any hitherto mentioned, and being also a later invention, will very properly find a place here.

It consisted, at first, of an open-topped cylinder with a piston; the cylinder was fixed inside the steam-boiler, and was provided with a two-way cock wrought by a crank to let off and on the steam. It was worked, at its upward stroke, by the action of high-pressure steam, the safety-valve having a weight equal to about 20lbs. over the atmosphere per square inch. The downward stroke was produced by the pressure of the atmosphere, the steam which had previously raised the piston blowing to waste. To equalize the motion a fly-wheel was used, and as the cylinder was open at the top, the piston-rod had plenty of room to work, and was at once attached to the fly-wheel, and thus produced a continuous rotary motion without the intervention of either beam or parallel motion.

An engine of this sort is represented in plates IV. and V.; plate IV. being an elevation, and plate V. a section of the same. This engine is reckoned equal to two horses' power, but it will do a great deal more duty, and four bushels of coals will work it for twenty-four hours when properly attended to. As the water in the boiler will last for five hours constant work, it is seldom that they have a supply-pump worked by the engine, though it is quite clear that one might be added with advantage.

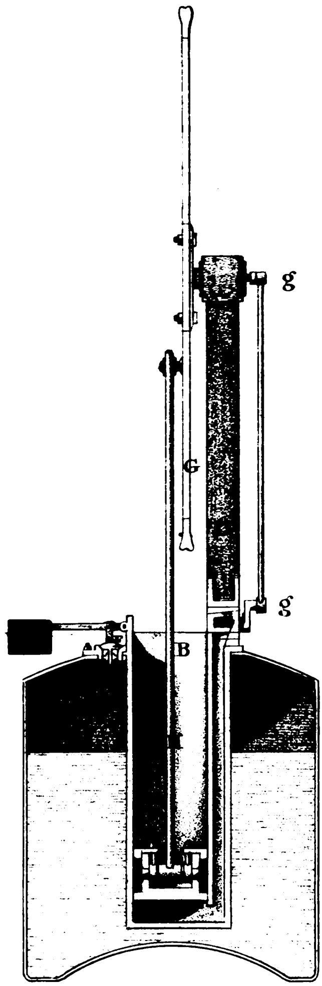
A is the steam-boiler, B the working cylinder, C the piston which drives round the fly-wheel G by means of the piston-rod H. D is the standard for the fly-wheel shaft, E a two-way cock worked by a rod and the two cranks g g. E is the safety-valve. A balance should be fixed on the fly-wheel to assist the engine on the downward stroke.

This description of engine is much used for draining fens and irrigating land; they are made from two to four horses' power, and having few parts, are not liable to get out of order, and require little attention.

The addition of a cylinder lid to the above engine, and a four instead of a two-way cock, made it act entirely by steam; and it was considered that if the saving of the cylinder from cooling, by its having a close top, did not entirely compensate for the additional steam required to work the engine in this way, yet the impulses were more equal, and it enabled the proprietor to work at a much higher temperature, and consequently to have a much greater power in the same space.

In this way it was employed in the propelling of carriages on rail-roads. Its successful application to this purpose was effected by Mr. Richard Treveithic, in the year 1804, in a carriage running on the Myrthyr Tydvil railway, which answered completely.

It was speedily adopted on almost all moderately level rail-roads in the coal districts, first in South



SECTION.

Scale, ½ Inch = 1 Foot.

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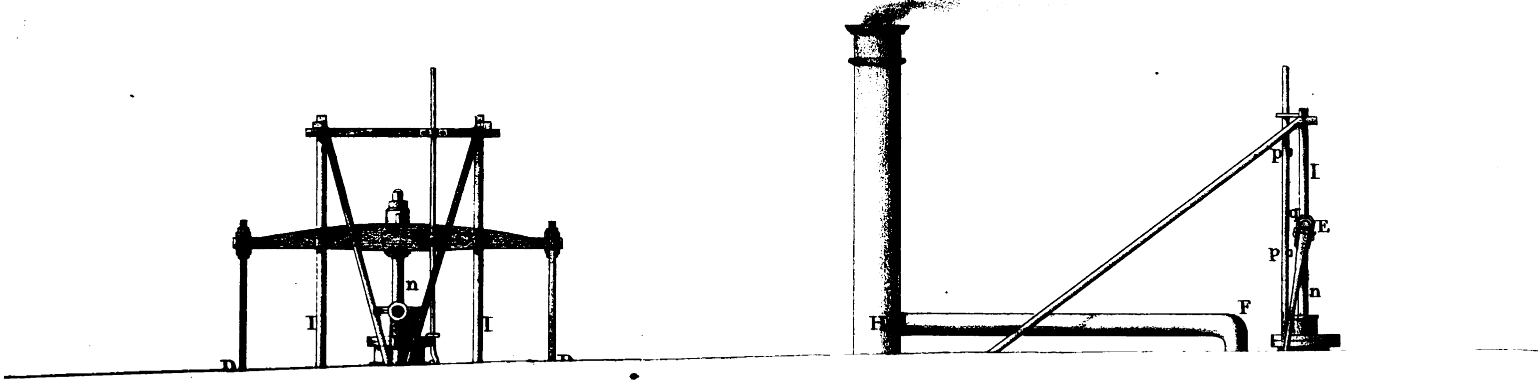
TREVETHIC'S LOCO-MOTIVE ENGINE.



Wales and in the neighbourhood of Newcastle upon-Tyne, and in various other parts of this kingdom. It was also partially used in America.

In plate VI. is given a representation of this machine. Fig. 1 is a side elevation, and fig. 2 represents the end.

A is the steam-boiler, with fire-place and flues inside, at one end of the same is also inserted the working cylinder B. The cross bar C, which is worked by the piston-rod n, gives motion to the two connecting rods D, which work the carriage wheels O. E is the steam-valve; F the pipe for the escape of the waste steam up the chimney; G the safety-valve; H the chimney; I the guide rods for the cross bar, and for preserving a vertical motion in the piston-rod. K is the fire-door of the boiler. Upon the cross bar C there is a small projection at q, which strikes upon two similar projections p p of the valve rod, as the cross bar rises or falls, and by that means opens or shuts the valve or cock E to let off or on the steam which gives motion to the piston.

The crank, as represented at L, is found the most simple and efficacious mode of communicating motion to the wheels of the carriage, which it does in a manner easily understood. It is clear, if a rotary motion is given to the wheels O, that, unless the plane on which it stands was as slippery as glass or ice, the machine must move along such plane until impeded by an obstacle equal to the power of the engine and the acquired momentum; this motion of the carriage enables the crank to pass the centres without the assistance of a fly-wheel. When the rails are moderately level this arrangement answers, but when they are at an inclination two cylinders are employed instead of one, and the piston rods and cranks are made to work at right angles to each other, so that when one is at the extremity of its stroke, the other is but half.way up or down and at full work, by which means the centres are passed without any variation in the motion of the carriage. This enables them to have a toothed wheel bolted to one of the wheels of the carriage, which works in a corresponding rack laid on the side of the railway, by means of which almost any acclivity may be ascended.

Notwithstanding modern improvements in the construction of the engines and boilers of this species of machinery, there is no alteration in the principle; and there are at the present time in use engines on almost the oldest construction which do their work amazingly well. I would mention particularly those of Mr. Blenkinsop, the patentee of the last-mentioned invention of double cylinders, toothed wheels, and rack rails, manufactured by Messrs. Fenton and Murray, for conveying coals on the railway from Hunslet to Leeds, where may be seen those strange-looking "*Steam Elephants*" travelling at a rapid rate, and each dragging ten or a dozen heavily laden coal-waggons in its train.

The application of steam to the propelling and accelerating the speed of vessels on the water, occupied the thoughts of some of our earliest engineers, and the first patent for that purpose was granted to Mr. Jonathan Hulls in the year 1773. But it was attempted to be effected through the intervention and by means of an engine, at that time of very imperfect construction, and was therefore soon laid aside. When, however, Watt had effected his improvements, it became more manageable for this and every other mechanical purpose; and its application to the propelling of ships and boats has ultimately been crowned with complete success.

The adoption of this new mode of conveyance on water was, however, very partially resorted to for some time after it was first introduced.

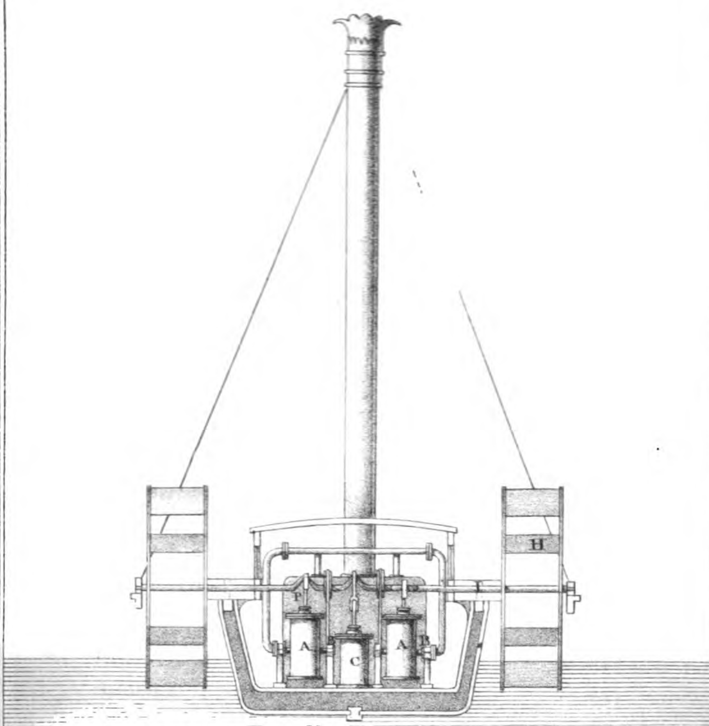
Steam-engines were first erected in small vessels, and used as tow-boats long before the present mode of having the engines fixed on board the vessels intended for the conveyance of goods and passengers was adopted. In this way, as early as the year 1803, the Charlotte Dundass, steam tow-boat, constructed by the late Wm. Symington, plied on the Forth and Clyde Canal, and afforded satisfactory proofs of her capability, by dragging two laden vessels, of 70 tons burthen each, 19½ miles in 6 hours, against so strong a head-wind, that no other vessel could proceed that day in the same track.

Fulton, an American, who witnessed those experiments, as also a great many more by our countrymen, his cotemporaries, not succeeding in this country nor in France, settled in the United States of America. Improving upon the experiments of his predecessors, he was the first to make a complete steam-ship; and having procured powerful steam-engines from England, he so far surmounted all difficulties, that the application of steam for this purpose has ever since continued and rapidly augmented.

Plates VII. and VIII. exhibit a plan, elevation, and section of one of the most improved steam-vessels of the present day for light draught. The engines, by Messrs. Maudslay & Field, are on the low pressure and condensing principle. The cylinders A, instead of being fixed, are hung on moveable hollow axes B: one axis of each cylinder admits the steam, whilst the other serves for the eduction channel of the waste or exhausted steam to the condenser and air-pump C. By this contrivance, the parallel motion, beams, &c. are dispensed with; the piston-rod p itself being immediately coupled to the shaft I of the paddle-wheel H, which is cranked for the purpose, as may be seen by reference to the plates, and by the reciprocating motion of the piston it impels it round. The cylinders, by giving way, vibrating as they do on their centres, permit the piston-rod to go out of a vertical direction, and at the same time work through an air-tight stuffing-box. The beams, connecting-rods,

Plate VIII.

STEAM VESSEL.



SECTION.

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side-rods, and cross-bars, usual in other engines, are thus dispensed with, besides duplicates, in case of accident at sea, of these heavy appendages. The tonnage of the vessel is, therefore, materially increased, and an immense saving of room effected.

These vessels are thus impelled by the force of steam at a rate varying from 7 to 12 miles an hour, and are found to be more safe than sailing-vessels even in a storm, independent of the immense advantage possessed by them of travelling against both wind and tide.

In the steam-ship, then, we see realized what was considered as one of the boldest poetical fictions, in one of the best and oldest poems extant; I mean the description of the Phœacian ships of old, of King Alcinous, in Homer's Odyssey, which runs thus :—

* * *

" So shalt thou instant reach the realm assign'd,
In wond'rous ships, self mov'd, instinct with mind;
* * * * * *
Though clouds and darkness veil the encumbered sky,
Fearless, through darkness and through clouds they fly,
Tho' tempests rage—tho' rolls the swelling main,
The seas may roll, the tempests swell in vain;
Ev'n the stern god* that o'er the waves presides,
Safe as they pass, and safe repass the tides,
With fury burns; while careless they convey
Promiscuous ev'ry guest to ev'ry bay."

Vide Pope's Translation of the Odyssey, book viii. *p.* 175.

* Neptune.

The engines we have hitherto considered all derive their motion from the action of steam in a cylinder, upon a piston producing a rectilinear motion, which, before it can be used for driving round machinery, &c. must be converted into a rotary motion, and which is effected in several different ways already described.

This appearing to many a roundabout way, they tried to invent a machine where the steam should produce at once a rotary motion, and this is found more difficult than is apparent at first sight; for steam is found to have little or no power by impulsion, but only by expansion; it requires, therefore, something steady against which tô exert its force (as the lever requires a fulcrum) before it can give motion to a piston, or, as it would be termed in a rotary engine, a vane.

To contrive something answering to the cylinder bottom of the reciprocating engine, is what is most wanted in the rotary engine. At Plate IX. is represented one of the best of them at present in use, the invention of Mr. Job Ryder, but we must observe that all rotary engines have, in practice, been found to be inferior to the reciprocating engine. It is, however, considered a desideratum in mechanics, to produce a steam-engine which shall, without the intervention of pistons and beams, and the cumber of cylinders, produce a complete rotary motion; and this is thought especially necessary to effectuate locomotion by steam on the common

ROTARY STEAM ENGINE.

Fig. 1.

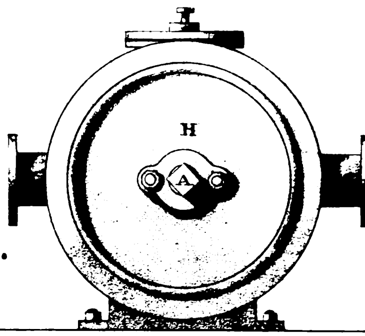


Fig. 2.

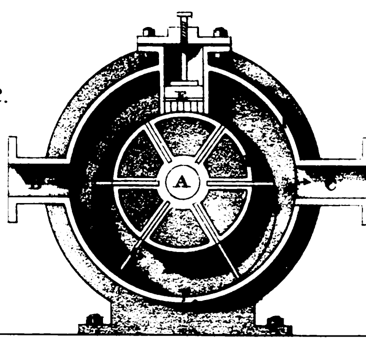
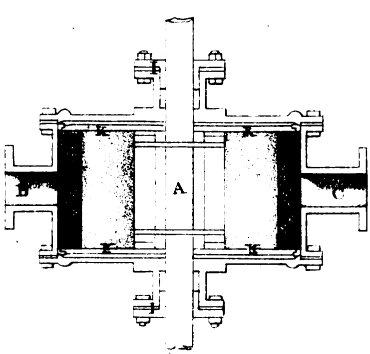


Fig. 3.



M. A. Alderson ... *Burton*

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roads, and so do away with the necessity of rail-ways. It must be added, it is the opinion of many enlightened engineers of the present day that this desirable object can and will shortly be effected.

Fig. 1 is a side elevation of the above engine; fig. 2 a vertical section, and fig. 3 a horizontal section or plan. A is the fly-wheel or engine shaft; B the steam-pipe; C the eduction-pipe; D a hollow cylinder for the purpose of increasing the diameter of the shaft; E a packing-box, with brass packings; F an eccentric circle, in which the moveable vanes G revolve; H an air-tight cylinder of cast-iron enclosing the whole; I air and steam-tight stuffing-boxes. On the sides K are brass packing-plates, which are kept tight against the edges of the vanes by means of springs, to prevent the escape of steam.

Consider A as the fly-wheel shaft of a common reciprocating engine, and one of the vanes G as the crank; the steam in this instance acting immediately upon it instead of by means of the piston, beam, and connecting-rod. The steam passes from the boiler into the branch B, and fills the whole of the space from d to G, every part being immovably fixed, except the crank or vane and shaft, which are kept stationary, only by their inertness and the weight to be driven; being, therefore, the weakest part, the steam drives them round, and passes on to the condenser through the eduction-branch C; or into the atmosphere when high-pressure steam is used. Each vane is connected to its opposite by pins going through the shaft, and is made to slide during its rotary motion by means of the eccentric circle F, so as to pass the brass packing and box E, which is the fulcrum against which the steam exerts its power, and constantly exerts it, producing by its reaction on the vanes a continuous and steady rotary motion in the fly-wheel shaft.

The steam at present under investigation is considered, as before stated, to be the vapour, arising from water when subjected to the action of fire; but as other liquids throw off vapour under similar circumstances, and as this vapour has been applied to purposes, some of them similar to those already described, for steam, it becomes necessary to notice them.

The vapour of ether and alcohol being produced at a much lower temperature than that of water, it was thought it might be used for giving motion to a steam engine, instead of common steam, which would have produced a saving of fuel; but the necessity of condensing by injection was a stumbling-block in the way, which could never be surmounted; for by exposing as thin a surface of steam as possible in a condenser immersed in water, and cooled only by contact, they could never kill or condense the steam which was expended, with sufficient quickness. It is not pretended that they could not produce a mechanical movement by these means, but only that they could not produce a more cheap and powerful one than by common steam. To use such vapour at a high pressure, and so avoid the necessity of condensing, was, from the volatile and inflammable nature of the liquid from which it was raised, impossible, and to suffer the condensing water to mix with the alcohol, would be absurd and ruinous; in short, they must either condense by contact, and so use the condensed liquor over again, or the project is worth nothing, and this no one has ever yet found it possible advantageously to effect.

It would be improper in a work of this sort to pass over the labours of Woolfe, who, however parodoxical it may appear, though erroneous in *theory*, as a practical engineer, has been surpassed by few. For the mechanical application of the principle contained in the table inserted at page 24, he procured a patent, and it will be seen by reference to that table, that he imagined that steam, preponderating over the safety-valve, expanded itself, for every pound additional pressure once its volume, and still continued in its elasticity equal to the weight of the atmosphere. By increasing the weight to a considerable extent, he contended that an immense power was gained and a great saving of fuel effected. In applying this practically, Woolfe, improving only in a very slight degree upon Hornblower's invention, proposed to use high-pressure steam in a cylinder of small diameter, whilst, instead of letting the steam escape into the open air when it had driven the piston one stroke, it was conducted into a cylinder of larger diameter, the piston of which worked in conjunction with the piston of the high-pressure cylinder, being both connected to one beam, on which they simultaneously acted. In the second cylinder the steam, acting by its expansive power, became so attenuated, and so much lowered in temperature, as to be easily condensed, which, being effected, the steam from the first to the second cylinder might be said to expand into vacuo—minus the friction, the weight driven, and the imperfection of the steam vacuum, thus improving the high-pressure engine, considering the first cylinder as such, and gaining from the same steam the addition of a low-pressure engine. This arrangement appears beautiful in *theory*, but there are considerable drawbacks in *practice*, and it is now seriously questioned whether any saving worth the original outlay is effected by this mode of going to work.

There are a great many engines of this sort at present in use, and we can instance a splendid specimen at the lead works of Messrs. Maltby & Co. near Waterloo-Bridge.

Latterly the improvement has been applied in a different way; he has high steam as before described, but instead of two cylinders has only one; the steam supplying the cylinder is effectually cut off from its communication of supply from the boiler, when the piston has performed a very small portion of its stock, say one-third or one-fourth, or in proportion to the strength of the steam, and expands till, by the time it has driven the piston to the top, it has attained the tenuity of low-pressure steam when it is condensed : thus uniting the advantages of the low-pressure and high-pressure engines, (and it must be stated the disadvantages too,) and avoiding the expense and inconvenience of two cylinders and double tackle.

In an essay on the nature and application of steam, the STEAM-ENGINE naturally takes the lead ; its immense power and great importance as a FIRST MOVER, after it was once introduced, kept it continually before the public, and other applications sprang from it without much exertion on the part of the machinist or study of the philosopher.

The heat emanating from the boiler and pipes of the steam-engine would suggest the idea of employing it as a means for heating rooms, and we soon find it introduced in manufactories for warming them, affording at once heat, with safety from fire, and regularity of temperature at a considerably less expense than fuel for common coal-fires. Thus was another important use for steam discovered ; others followed ; but whatever variety there may appear in the different applications of steam on a superficial view, they may nearly all, upon due examination, be classed under two different heads—namely, "MOTIVE FORCE" or "POWER," and "WARMING" or "HEATING," different substances to which steam is applied, as a convenient vehicle for conducting and imparting to them the required temperature.

The former principle we have examined, and it now remains to explain the practical application of the latter. We have seen that, gradually and step by step, the steam-engine slowly arrived at its present improved state; but the other, requiring little invention, sprang, as it were, like the fabled Minerva, into perfect existence at once. The steam-engine, indeed, may be likened to the stem of a huge English oak, of which the other applications of steam are but the leaves and branches.

In other appliances of steam there was not such a range for variety, and its employment for other purposes, though not so important nor so early discovered, are more obvious; besides many of the mechanical contrivances used in the steam-engine were available and applicable here.

Before entering into an examination of any particular mode of heating by steam, it will be well to sketch a general view of the whole subject.

STEAM, then, is used for warming rooms, manufactories, and public institutions, of an ordinary temperature; hot-houses, forcing-houses, and woollen, cloth, cotton, and other drying houses, of a very high temperature.

From the facility afforded of varying the heat of steam by increasing or diminishing the weight upon the safety-valve, it is now generally used in chemical operations, which require an *exact* and *certain* degree of heat steadily exerted, and has almost superseded the use of the sand-bath, so frequently mentioned in works on chemistry.

It is used for the boiling of salt, several patents having been taken out for peculiar modes of applying it; and immense salt-works are erected, both here, in England, and on the continent, carried on entirely by steam.

In the manufacturing or refining of sugar it is also extensively employed, and patents are taken out for different modes of using it.

It is also in request for steaming wood, previous to its being used by coach and cabinet-makers, ship-builders, &c. in order to soften its fibres and facilitate the bending of it to the required form.

Patents have been taken out for washing by steam, but as "*the women fowk canna be fash't we'it,*" the ingenious and well-meaning inventors are, we believe, seldom applied to for licenses, and certainly have no ground of complaint for infringement of patent right.

In agriculture it is used chiefly for boiling on a large scale for cattle, potatoes, turnips, &c. and the same for domestic purposes on a small scale, as also for warming baths and cooking.

It is also used for destroying those noxious vermin called bugs, and for hatching chickens; destroying life by its intense heat in the one instance, and producing it in the other by its gentle and continued warmth.

In the application of steam to the purposes of locomotion, numerous experiments have been instituted, for the purpose of altogether avoiding the necessity of carrying engines, boilers, and other heavy tackle, which in the ordinary modes of operation are indispensable. Two methods of effecting this purpose have been proposed, but to both the objections in practice have been found insuperable.

One is by having fixed engines at convenient distances, working continuous endless chains, or ropes, over pulleys, to turn the angles of the road through the whole distance to be travelled, and to which chains the carriages or vehicles to be moved could be attached. The innumerable windings and turnings of the common roads, as they are now constructed, present great obstacles to this plan being ever brought into successful operation upon them; whilst on all moderately-level railways it has been found, practically, much better to make the engines themselves locomotive. In forming new railways, however, it might so happen that it would be inconvenient or impossible to get in every part that necessary approximation to a level, which has hitherto been considered indispensable for rail-roads; in that case, this plan might be made available, in part, by having fixed engines, for the purpose of drawing the carriages up the incline; whilst in returning it would be an advantage, as the engines would descend the incline by their own gravitation.

The other method is by concentrating, by means of fixed engines, as much power in a number of springs as would move any carriage to which they might be applied, similar to the winding-up of a watch; or, which is the same thing in principle, condensing, in a close vessel, some permanently-elastic fluid, such as the common air, to be let out into a cylinder, provided with a piston, &c. upon which it would act as a substitute for steam for gaining the required power.

It is plain, supposing there was no practical difficulty, that there would be a great gain in point of convenience and power by this mode of operation; for, notwithstanding that there is a double loss by friction, it is amply compensated by the advantage gained in being able to travel without the incumbrance of boilers, fire-place, fuel, and machinery.

But the difficulty consists, in the first place, that by condensing the air, you produce a great heat from its giving out, when compressed, its latent caloric; whilst, in the next place, when suffered to expand so as to operate upon a piston, or other machinery for communicating motion, it superinduces a great degree of cold from its absorbing heat, from the adjacent objects, and the surrounding atmosphere.

To get over the first difficulty, it has been proposed to surround the condensing cylinder with cold water; and the second, by applying the heat of fire or steam to the apparatus used for communicating motion. But the apparatus for this latter purpose, the only one we need care about, since the other remains with the stationary steam-engines, required to fill the operating cylinders with condensed air, would be so cumbersome as almost to defeat the intended effect, for the cold produced is so intense that the machine would, unless a great heat was employed, be clogged up by a deposit of ice and snow from the surrounding atmosphere, which is robbed of its natural quantity of caloric to supply the deficiency in the acting medium. A great number of experiments have been made by different individuals for the purpose of surmounting these difficulties; but hitherto without success.

Steam has been extensively and successfully employed for extinguishing that element from whence it derives its power, namely, fire. But although it is stated by some that, when supplied in large quantities, where there is no current of air, it is of itself sufficient to extinguish conflagration, yet the most common mode is by applying its mechanical power to the working of a force-water-pump. This may be done to great advantage in any place where there is already a powerful engine in use for driving machinery, as an air-vessel can be fixed in a tower, in a central situation in the yard, and connected by pipes with the pump of the engine. A play-pipe should be fixed on the top of the tower, connected to the air-vessel with an universal joint, which would command all adjacent buildings. This is done in the flax manufactory of Messrs. Marshall & Co. of Leeds, and at many other places in that neighbourhood; and we have been informed by persons who have seen it tried, that its action is so effective as to make the ejected stream of water break the glass of the windows.

It is a desideratum to apply this active and powerful agent to the common fire-engines, and this has been successfully attempted by Messrs. Braithwaite and Ericson.

The machine is almost as small and compact, and when properly made, nearly as manageable as the common fire-engine, with this advantage, that as soon as the steam is up it never flags or tires. It consists of a boiler, fixed on wheels, with springs similar to a steam-carriage, and a working cylinder and piston, which by a crank of one or more throws works the required number of pumps. An air-vessel is necessary to keep up an equable stream of water from the play-pipe: hose, buckets, &c. are wanted as in the common engine.

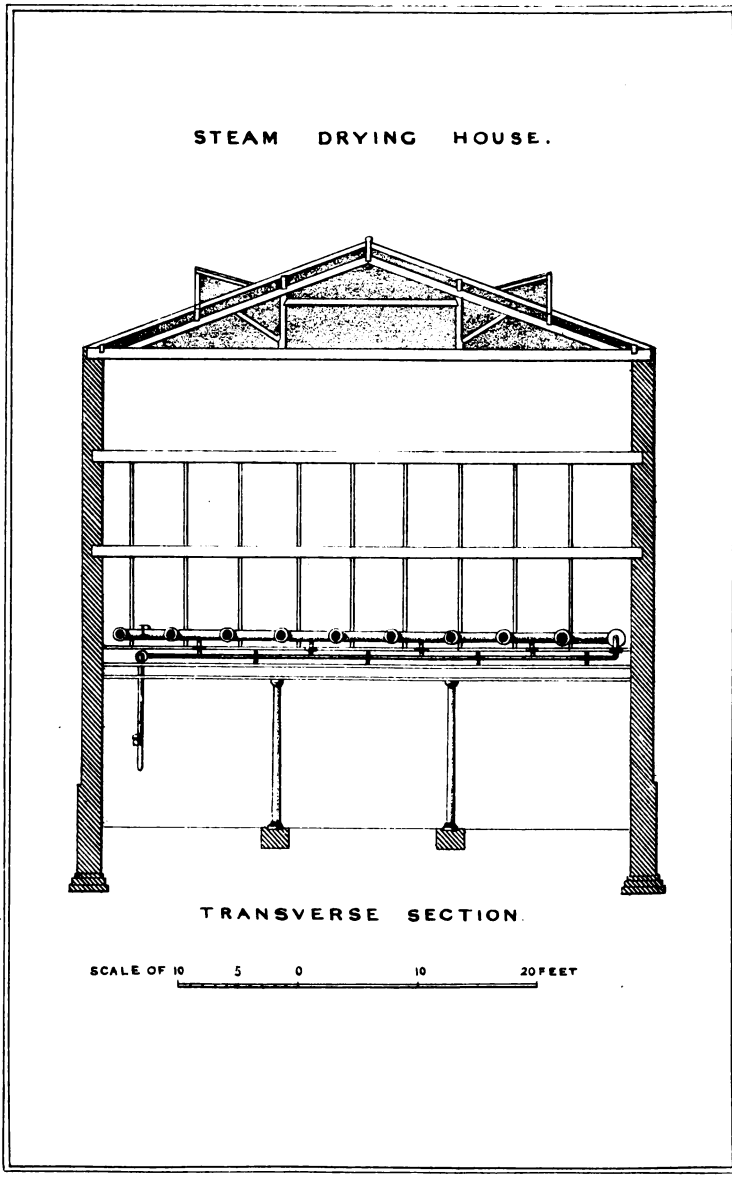
To protect the immense warehouses and other property on the banks of the Thames in and about London, a fire-engine on the common construction is fixed in a wherry, to be rowed where wanted, and worked by hand, thus constituting a floating fire-engine.

An improvement might be made upon this by having a steam-vessel similar to the one represented at plates XV. and XVI. but smaller, with a proper fire-engine apparatus fixed on board, and with sufficient power in the steam-engine to work both the pumps and the vessel. They would thus be enabled to reach any part where wanted in much less time than at present; and from the immense power at which the pumps might be made to work, they would have an overwhelming stream of water at their command. This would tend greatly to the security of property so situated.

These, then, are the chief purposes to which steam is commonly known to be applied in this country; but, as a thousand different ideas daily suggest themselves to ingenious minds engaged in these pursuits, they are by no means all, and, indeed, as the steam-power may be applied to propel any kind of machinery, so also may steam, from which it derives its force, be applied to heat any substance.

We will begin a more particular and practical investigation, and recapitulation, of this subject, by describing how a drying-house of the most improved construction is heated by steam. A boiler B, plate X. and XI. is provided of a size proportioned to the house intended to be heated, and fixed upon its seat immediately adjoining it, or

Plate. XI.



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under the same roof. The steam is conveyed from thence in pipes, P, round the house. The steam, as it increases in distance from the place of its generation, gradually condenses and assumes its original form of water, and is in this state conveyed back into the boiler to be again converted into steam.

To prevent the escape of the steam, and at the same time not impede the progress of the hot water in its way back into the boiler, recourse is had to a syphon, S, which forms at once a receptacle for the water, a trap to the steam, and an additional safety-valve to the boiler and pipes.

The legs of the syphon should be of a length proportioned to the temperature the house is intended to be kept at, in such a way, that when the leg P, adjoining the pipes, is nearly filled with steam, it would, having at that point its maximum of pressure, make the house of the required temperature, a corresponding weight being put in the safety-valve V of the boiler. To do this is easy, great nicety not being required.

We know that a column of water 33 feet high and one inch square, weighs about 14 lbs.; if you wish then for a temperature, corresponding with this pressure, you must have a syphon 33 feet long, and your safety-valve weighted a trifle more; if only half the temperature is required, your syphon need only be half the length, the weight on the safety-valve being diminished in proportion, and so on for any variety of temperature required.

The pipes being laid at a gentle inclination, never retain any water even when quite cold, as the column of water in the inner leg of the syphon being rather longer than the other, preponderates over and drives the water out of it. A small vent-pipe should be fixed in the extreme end of the last length of steam-pipes provided with a cock to let out the air at starting, and to create a draught for the steam when at work.

The plan and sections above referred to show a building of this sort, and being properly lettered and figured, it is presumed will, with the assistance of the preceding description, be sufficiently explanatory. Sugar-houses and hot-houses, as well as drying-houses, are all heated on the above principle.

For chemical purposes and experiments, which before the introduction of steam required the sand-bath, or the intervention of a thin stratum of sand, between the fire and the substance to be heated, steam requires to be applied in rather a different way. A vessel is set in a steam-boiler, and the substance intended to be acted upon put into the vessel; you will thus always have a heat acting upon it equal to the pressure upon the safety-valve. This heat will never vary in temperature so long as the fire is kept up, and the pressure continues the same, and has the additional advantage of diffusing itself equally over every part of the vessel.

It need hardly be added that by varying the pressure on the safety-valve, you in like manner vary your temperature, and that, knowing what temperature you require, you must give it a corresponding pressure.

Steam is used in a similar way for the boiling of salt, and we subjoin a plate of Furnival's patented invention for that purpose. Brine or water strongly impregnated with salt is pumped up from the wells in the places where it is found native, as at Nantwich and Droitwich; what is wanted, then, in the procuring of salt where it is thus found in solution, is the evaporation of the water, which, when exposed to a sufficient and continued heat, leaves the salt quite pure.

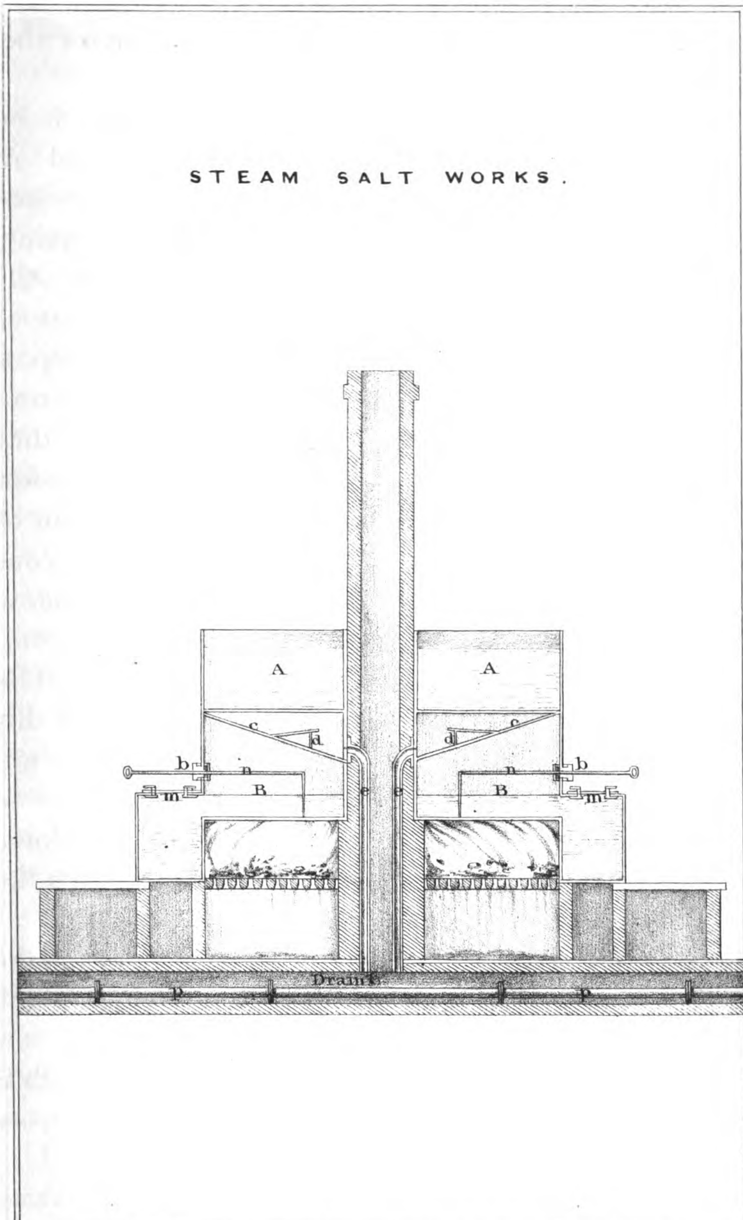
To do this by steam the most obvious way is by a vessel inserted in a steam-boiler, as described in the foregoing application of steam for chemical purposes, which will effect the evaporation required, the brine being put into the vessel so inserted. One would scarcely think that so simple a contrivance should be made the subject of a patent; but we find on reference to patent records, that it is so. The patent obtained by Smith is precisely on this principle, for the salt-water is evaporated by the operation of the fresh-water rarefied into steam in a close boiler, in which the open vessel containing the salt-water is inserted. Furnival's patent is a step (with a ten-league boot) beyond this, and is indeed (nearly) one of the most economical and efficient applications of the power of steam for this purpose possible.

The brine is the same as before described, in Smith's patent, pumped into an open vessel A (plate XII.), inserted in or fixed upon a close steam-boiler B, but the steam-boiler, instead of containing fresh water as before described, contains still stronger brine than is contained in the vessel above; it is brine which has been operated upon in the upper boiler and let down into the lower one to be finished or evaporated to such a degree that nothing but salt remains. To effect this a division of sheet iron C is made in the top compartment of the lower boiler B, in a diagonal direction, containing an opening d, similar to a Dormer window in a leaning roof, which serves to let out the steam, but will not let in the condensed water. The steam raised in the lower boiler rushes through this opening in the iron partition, and acts upon the top boiler so as to evaporate the water of the brine contained in it, and being condensed falls down upon the said partition, and runs off through the waste-pipes e, in the lower part of it.

The waste water being warm, imparts heat to the brine as it is conducted along the pipe p, which is the pipe of a force-pump, for forcing the raw brine from the well into the top boiler, and which is laid along the waste water-drain f, for the purpose of having the brine warmed in its progress.

The rakes n have polished handles, working

Plate XII.



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through air-tight stuffing-boxes b, and are for the purpose of raking the salt to the fore part of the boiler, when it is taken out at the man-hole m. The lower boiler must be provided with a safety-valve in the usual way. The accompanying plate shews the thing very clearly, and being very simple, as almost all good inventions are, will not need any further explanation here.

But it is in the refining of sugar that steam shines out to the greatest advantage, exhibiting such an economical and harmonious combination of chemical agency and mechanical power, as cannot be equalled in any other manufacture.

Sugar-houses require to be kept throughout of a very high temperature, which could only be done, previous to the introduction of steam, by hot-air flues, supplied by coal or coke fires ; hence, considering the inflammable nature of the material, the great risk of conflagration, and the consequent increase of the rate of insurance, which now for houses of the above description presses so heavy upon the proprietors, that it compels them daily to alter their system of warming to that of steam, as it is even in that way a great saving to them ; the rate of insurance-premium, as it is technically termed, for a house heated by steam, owing to the diminished risk, being much less than when they are conducted on the old process.

For heating a sugar-house, the system is precisely the same in principle as that already described for drying-houses, &c. excepting that it requires steam of a higher temperature; but this is only one branch of its application in this manufacture. In the boiling of sugar by fire there is not only great risk from conflagration, but also great danger of spoiling the sugar by charring or scorching it, there being nothing between the sugar and the fire but the thin bottom of the pan. The application of steam, then, to this process, by its safety from fire, and from its diffusing an equal and unvarying temperature over the whole, offers a double advantage; but this is not all, its advantages do not terminate here. It is well known that any substance boils in vacuo, or even in a partial vacuum, much sooner and at a much lower temperature than when subject to the pressure of the atmosphere; this principle is of great consequence where evaporation is the object, though it is clearly of no use in the generation of steam for the purposes of power. In applying it for boiling sugar, a copper pan is provided with a close top, which should be globular to resist the pressure of the atmosphere; a branch pipe is carried from this into an air-pump and condenser, by the action thereof the boiling process is carried on much quicker, and with steam at a much lower temperature than would otherwise be required, producing also a much superior article. The air-pump is wrought by the action of a small steam-engine, which receives its motion from the same boiler that warms the house and boils the sugar. The engine is also generally employed for pumping up the liquid juice, to the different places where it may be wanted in the process of manufacture.

Thus we see that the refining of sugar on the most approved principles embraces almost every improvement made in the application of steam.

In the manufacturing of sugar the application of steam seems to offer, over every other method, the following advantages:—almost complete safety from fire, and a continual saving, therefore, of that amount of insurance paid for extra risks to the insurance offices; the production of a better article at less expense, a complete controul over the temperature of the house, and a simplification of the whole process.

It must, however, be stated, on the other hand, that the apparatus costs more in the first instance than the common mode; but this is of minor importance, for none engage in this business, generally speaking, but people of capital, and a small variation in the original outlay can make little difference where persons embark a round sum for the express purpose of a beneficial investment. To this should be added, that as the steam process is more rapid than the other, there will be a quicker return of the floating capital.

It is a curious fact, connected with this manufacture, that the people carrying it on in London are most of them Germans. There is scarcely one sugar-house in London but what was originally established by German proprietors, and carried on by German workmen; and even when the sugar-houses get into the hands of English proprietors, which of course they sometimes do, the great body of the workmen still continue to be from that country.

Plate 13 represents a plan of a sugar-house on the most improved principles, where they both warm the house and boil the sugar by the agency of steam. It should be observed that this is not always the case, as many houses are warmed by steam where the boiling is still conducted on the old process; and also that they sometimes boil by steam in an open pan.

Fig. 1 is a ground plan, and fig. 2 a section of the above sugar manufactory; the same letters refer to similar parts where they occur in both figures. A the steam-boilers; B the steam-engine; C an air-pump to exhaust the pans; D the vacuum pipe; E sugar-pans boiled by steam, conveyed along the branch pipe e. F the steam pan; G coolers under each pan; H steam-pipes of the drying-stove; I steam-pipes for warming the house; k is a vent-pipe at the end of the series for getting rid of the air and keeping up the current of steam. In the two angles, l, of the stove-room upright steam-pipes are carried through each story to the top of the house.

The other uses of steam, alluded to in our view at the outset, are of minor importance, and neither

PLAN.

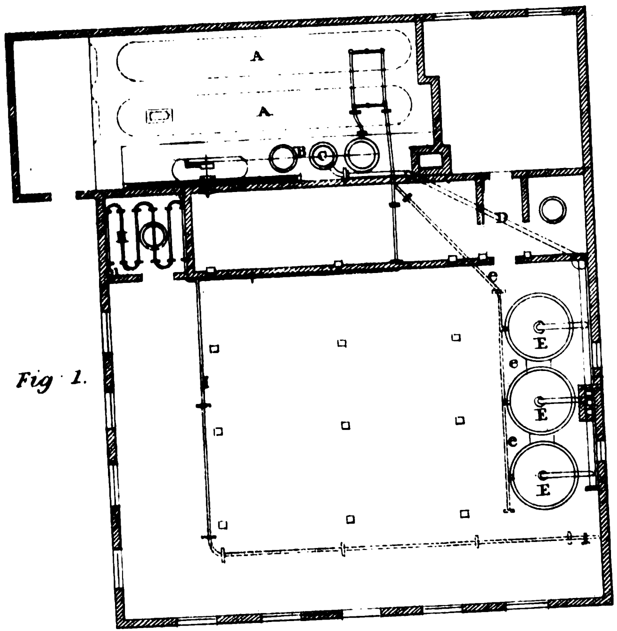


Fig. 1.

SECTION.

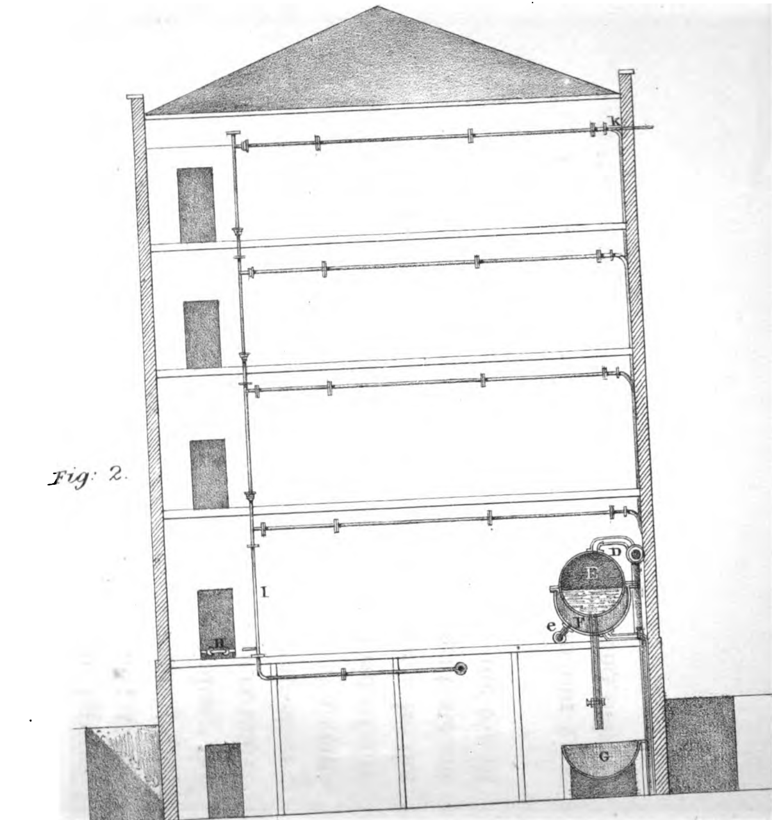


Fig. 2.

require nor deserve the attention which those do already described.

A steam-boiler which would take up very little room in a farm-yard, would prepare a vast quantity of food for pigs and cattle at little expense and trouble. A barrel of wood or metal, hung precisely similar to the vibrating cylinders of the steam-engine already described, one axle only in this instance requiring to be hollow for the admission of steam from the steam-pipe of the boiler, is the only additional apparatus required. This vessel is for the reception of the substances to be acted upon or boiled by the heat of the steam. The advantage of having the vessel suspended on centres is this, the vegetable substances being put into the said vessel, and the lid at the top closed down, the steam from the boiler is turned on until the inclosed substances are sufficiently boiled. When that is done, the cover is taken off, the head of the vessel is brought round upon its centres, and the substances are poured out.

A valve to cut off the communication of steam from the boiler must be fixed in the steam-pipe, and a cock inserted in the top of the boiler to let off the steam previous to taking off the lid.

This simple apparatus is all that is wanted for this purpose, and ought (where economy is an object) to be a fixture in every farm-yard.

For COOKING steam is much used, and particularly in large establishments: almost all the large taverns and the public halls of the city companies are provided with a steam cooking apparatus. A pipe conveys the steam along a sort of side-board, upon which is placed, in properly constructed dishes of tin, the food intended to be cooked. Branch-pipes of small diameter go from the steam-pipe into the several tin dishes, with a cock to each to enable the cook or attendant to shut off the steam. A cock is also fixed in the steam-cooking vessel, to let off the waste steam. These vessels are sometimes made double and sometimes single, according to the kind of food to be cooked; the double ones answer for roast, the steam being contained between the two dishes, the other for boiled.

A syphon is applied to the end of the main steam-pipe to get the proper degree of pressure, in the same way as already described in the steam-warming apparatus.

Patents have been taken out for ships' hearths for cooking by steam, and at the same time rendering salt water quite fresh; the latter process is the same as that already described for making salt, excepting that here the evaporated water is the valuable commodity, and the salt refuse. In this operation the steam is condensed as it rises and collected in vessels for the use of the ship, being the same process nearly as distillation. A ship's company need never run short of fresh water, so long as they retain a large kettle and the means of making a fire. The sea-water being put in the kettle and placed upon the fire, as soon as steam issues out of the spout, wet cloths are applied around it, which condensing the vapour as it rises, it assumes its original form of water, but quite freed from its saline qualities. An apparatus on this principle neatly and properly constructed, and combined with the cooking apparatus already described, but rendered more compact and portable by piling the tin dishes upon each other, the lower one being inserted in the lid of the boiler, forms what is called the "PATENT SHIP'S HEARTH."

For destroying vermin a portable boiler is made similar to Papin's digester, fixed upon a chaffing-dish of charcoal. The spout should have a small tube attached by an universal joint, so that it can be turned in any direction. When the steam is raised of a high temperature, the spout should be applied to the crevices or other places containing the vermin, which by its action it instantly destroys.

For hatching chickens the eggs are placed in regular order similar to the manner in which the parent bird places them for incubation. The place in which they are deposited is then warmed by steam, conveyed in pipes, backwards and forwards, through the place of deposit, great care being taken to keep the place of an equal temperature of 96° Fahrenheit or 32° Réaumer; for at lower temperatures the living principle appears to become torpid and unable to assimilate the nourishment provided for developing the embryo. The eggs should not be laid upon the bare floor of the oven, but upon a mat, or bed of flax, or other non-conducting material.

We may thus be said to have pursued the subject of steam down the present period, when new modes of applying this powerful agent are daily brought before the notice of the public.

In the year 1824 Mr. Perkins published his experiments on the generation of steam, and held out the prospect of producing it at an amazingly high temperature at little or no risk from explosion. The way he proposed to effect this was by keeping water, in a close vessel, subject to the action of fire under a heavy pressure, and thereby preventing it from assuming the form of steam. From this he proposed to derive *power* with *safety*, the water exerting little or no expansive force, compared with steam when confined in the generator, whilst, from the intense heat and pressure to which it was subjected, it no sooner got liberated by the working of a valve than it flashed into steam, and that of an amazingly high temperature and power.

This fascinating and plausible theory, though new and ingenious, failed in practice, as did also some experiments made in America by some very sanguine schemers, who caught at the hints of Mr. Perkins the moment they were published, and, determining to out-herod Herod, proposed taking higher flights and going still greater lengths. They proposed to make the steam-generator of a capillary tube coiled up and surrounded by fire. Lightness was their principal object, and to emulate the feathered tribe their ultimate aim. Visionary and never to be realised were their aims, and capillary generators are now consigned to " the tomb of all the Capulets."

These schemes all failed in practice for the reason assigned in our chymical analysis of the nature of water, page 8, where it will be seen that steam or water is decomposed by the agency of heat in small tubes. The great heat superinduced in their boilers by the immense pressure under which the water was heated and steam generated, tended to decompose the steam and weaken its effects. It would appear from this that steam has its limits; and the maximum of pressure under which it may be advantageously generated is a problem which it is a great desideratum to have satisfactorily solved.

Mr. Perkins applied his invention to the projection of bullets from a gun-barrel in the same way as gunpowder is used in the common musket. This had, I believe, been thought of before by Mr. Watt, but then he never dealt with " *vapours*" of so high a temperature.

If the report of the French engineers appointed by their government to investigate the merits of a steam-gun sent to France by Mr. Perkins, and tried at the Castle of Vincennes, can be relied upon, its efficacy in warfare is more than doubtful, and it will bid fair to rank amongst those inventions which are in common language styled "*more curious than useful.*" This also we believe to have been the opinion of the Duke of Wellington and a military staff, appointed by the Government of this country, prior to that time, to investigate the merits of this invention.

About the same period that Mr. Perkins proposed his new theory, Mr. Gurney put forth his claims to public notice by his projects for the improvement of locomotive engines. He proposed to use a tubular boiler (not capillary) in which to generate steam. The tubes, being about 1½ or 2 inches in diameter, were bent in such a way that the bottom series formed the grate-bars of the fire, whilst they were returned over the fire in another series, and ended in a cylindrical receiver for the steam. The water in the pipes was thus operated upon by the fire in what the projector considered the best possible way; and in case of explosion, there was little or no danger to be apprehended from the bursting of a tube of such small diameter, though the steam proposed to be used was as much as one or two hundred pounds pressure per inch.

This boiler can never be used to advantage as a generator of steam for marine engines on account

Plate XIV.

Fig. 1.

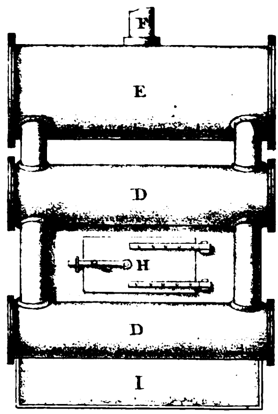


Fig. 2.

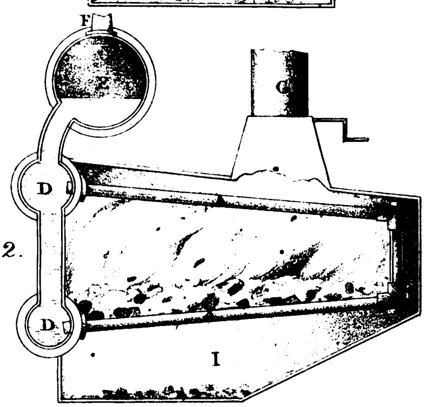
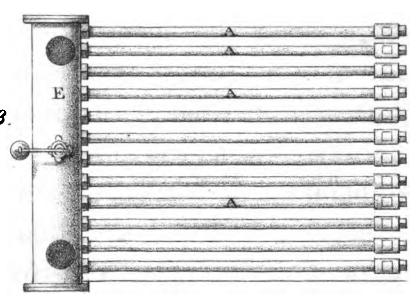


Fig. 3.



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of its liability to fur up with the saline matter contained in the waters of the ocean; and it is not altogether free from the objection offered to the boiler of Mr. Perkins.

A representation is given of this boiler at plate XIV. Fig. 1 is a front elevation, fig. 2 a section, and fig. 3 a plan of the same. A in all the figures is a series of tubes which form in fact the boiler. D two cylinders, into the sides of which the ends of the tubes A are screwed. E a cylindrical reservoir of steam. G the chimney. H the fire-door, and I the ash-pit.

Mr. Gurney chiefly directed his attention to the propelling of carriages on the common roads, which was the ulterior aim of all his experiments, and the utmost extent of his ambition. He succeeded in producing a steam-carriage, which ran on the highway between Cheltenham and Gloucester, but after experiencing much opposition from the narrow prejudices of the surrounding farmers, &c. who, having the repairing of the roads in their own hands, managed them in such a manner that no locomotive carriage could run upon them, he desisted. The tolls charged at the turnpike-gates, too, were heavy, as appears from Mr. Gurney's evidence before the House of Commons, where a special committee was appointed to sit on the subject of steam-carriages, in consequence of a petition which Mr. Gurney had presented, praying the House to take a more liberal view of the subject, and not throw impediments in the way of a project fraught with public good. In several new turnpike acts which have been framed since the introduction of steam-carriages on the common road, the tolls are so heavy as to be almost prohibitory. Mr. Gurney, in his evidence, mentions particularly the Liverpool and Prescot Road Bill, of the previous session, wherein a toll is charged per horse power, which is difficult to determine. His objection to it was, that if the horse power be taken as the common engine horse power, a steam coach would have to pay £2. 8*s*. where a common stage coach pays only 5*s*. In a subsequent part of his evidence he said that he had no objection to a maximum weight of 3 tons being fixed for his steam-carriages, which is the weight of the present four-horse stage coaches when loaded, and to pay the same toll; and that, when steam-carriages exceeded that weight, they ought to pay a very heavy one; but that, when the wheels exceeded four inches in width, the tolls should be less.

From the opposition above mentioned, and the impending evils of heavy legislative enactments, Sir Charles Dance, who had agreed with Mr. Gurney to carry his plans into effect in organizing a line of steam-coaches between the two places above mentioned, withdrew his carriages from the road altogether, so that the public are thus deprived of the benefit of a cheap, a speedy, and a *safe* conveyance.

We understand the fares charged were only one-half those charged by the common coaches, and that they travelled the distance between Cheltenham and Gloucester, 9 miles, in 54 minutes on an average, and frequently did it in 45 minutes. They ran for four months, namely, from the 21st of February to the 22d of June, 1831, during which time they carried nearly 3000 persons and travelled nearly 4000 miles.

These carriages travelled well on the level, and proved, beyond a doubt, that lightness, combined with power, would enable them to ascend acclivities, which had heretofore been thought impossible by all but those whom the rest of the world were pleased to term over-sanguine projectors.

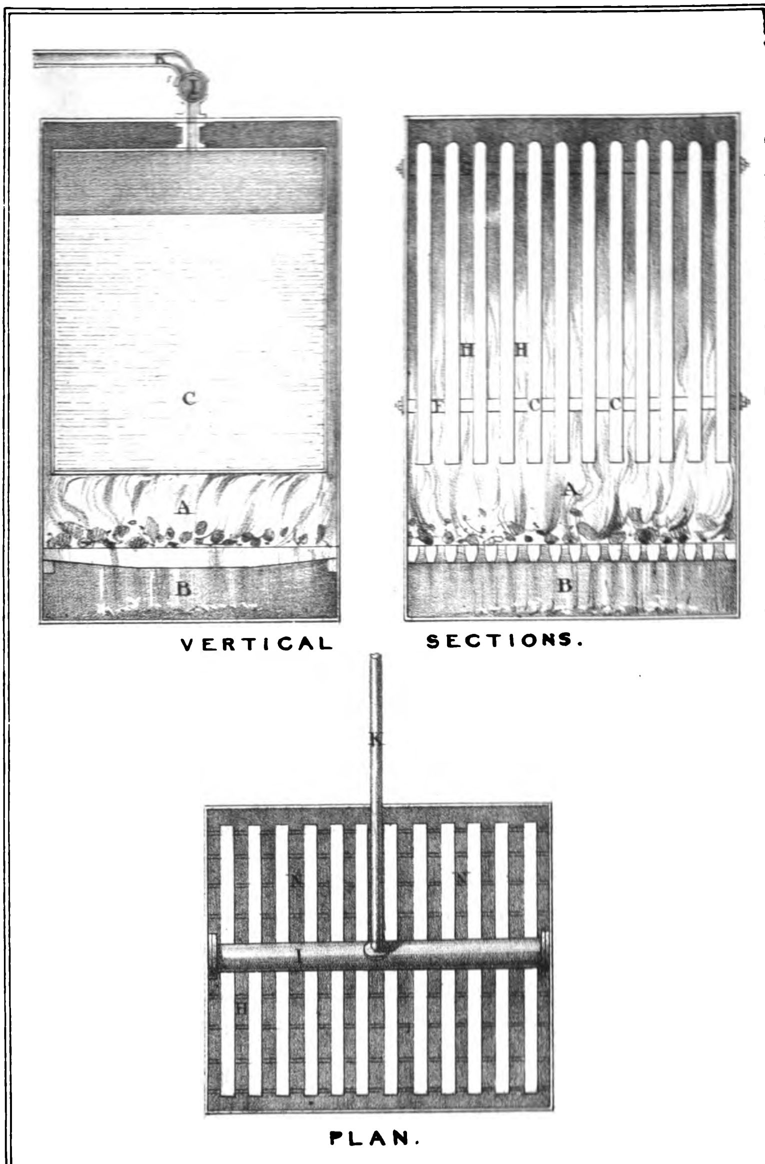
The fuel consumed was coke; about 4 bushels sufficing for 9 miles; the first charge was two bushels; and this charge always remaining, the subsequent charges were in smaller quantities, descending down to the last; the draft of the chimney was increased by the waste steam projected into the bottom of it in a jet, which was found to answer better than bellows or fanners, which had been thought of before, or than any other artificial means which had heretofore been tried. The water used was said to be about 10 gallons per mile; each gallon weighing 10lbs. gives 900lbs. as the weight of the water to be taken in and consumed in one journey.

The engines were of the common high-pressure description, placed horizontally under the body of the carriage, and gave motion to the two hind wheels by means of a crank, or by being attached to one of the felks of the wheel. A safety-valve and a force-pump are indispensable requisites in these and all other similarly constructed engines. In some cases two safety-valves are used, one being out of the reach of the engine tender, generally locked up in a perforated case, which will permit the steam to escape at the pressure intended, without the possibility of accident from the interference of the over-officious. Mr. Gurney states the average pressure on the boiler in their ordinary way of travelling to have been about 70lbs. per square inch, and the working pressure of the piston about 20. His tubes were proved with a pressure of 800lbs. per square inch, and they sometimes, in case of emergency, used steam at as much as 130lbs. pressure per square inch. The iron tube was about one-eighth of an inch in thickness.

Mr. Hancock's boiler next claims our attention, and we subjoin a plate exhibiting its construction; it is of a peculiar nature, and combines in an eminent degree the three principal requisites in a boiler for a carriage, namely, lightness, power, and safety.

A, Plate XV. is the fire place; B the ash-pit; C the steam and water chambers constructed of the best wrought iron; E the connecting tube, which connects the several chambers into one large vessel for water; G the same thing for the steam. Through

Plate XV.



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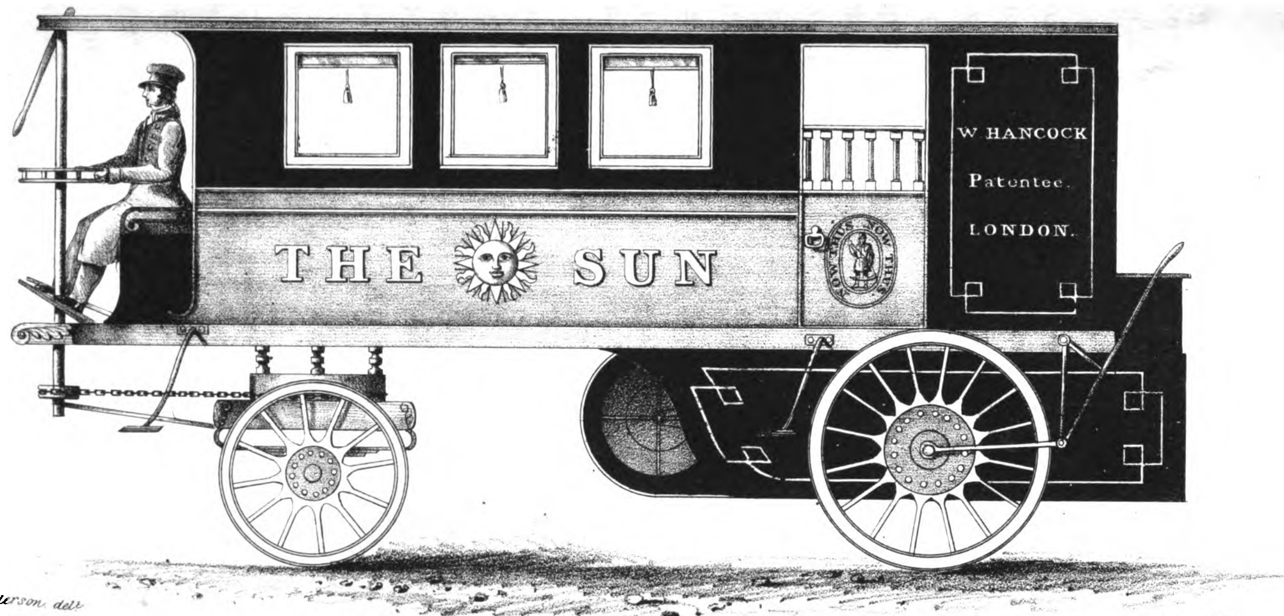
Pl. XVI



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these connecting chambers a bolt is passed for connecting the several vessels firmly together.

On the plan of the boiler are shown fillets of iron NN, which keep the individual compartments at a proper distance from each other, and also form the flues of the boiler as shown in the vertical section at H. The steam rises into the steam cylinder I, through as many small tubes as there are individual chambers, and is conveyed from the said tube or cylinder to the engine by the steam-pipe K. If one part should have the misfortune to meet with an accident and be burst, its power of doing mischief is very limited, as has been fully proved by experience, and from this does it derive its character of safety.

The carriage, of which plate 16 is a representation, to which the boiler just described is applied, has two working cylinders placed vertically over the hind axle, with their stuffing boxes downwards; the axle is cranked, and a connecting-rod from the piston being coupled to them impels them round. The crank-shaft, with the two cranks, is supported by a flexible frame, which provides for any concussion on the road. A chain passes over a pulley on the crank-shaft, and over another large pulley on the hind axle. The wheels turn loose on the axle, and one, or other, or both, are fixed by a clutch when required; this clutch is on the outside of the wheel, and can be screwed out or in, as may be wanted, with great facility. The turning of the carriage round to the off side is prepared for by throwing out the off-side clutch and keeping in the near one, and the turn round to the near side is effected by reversing those movements.

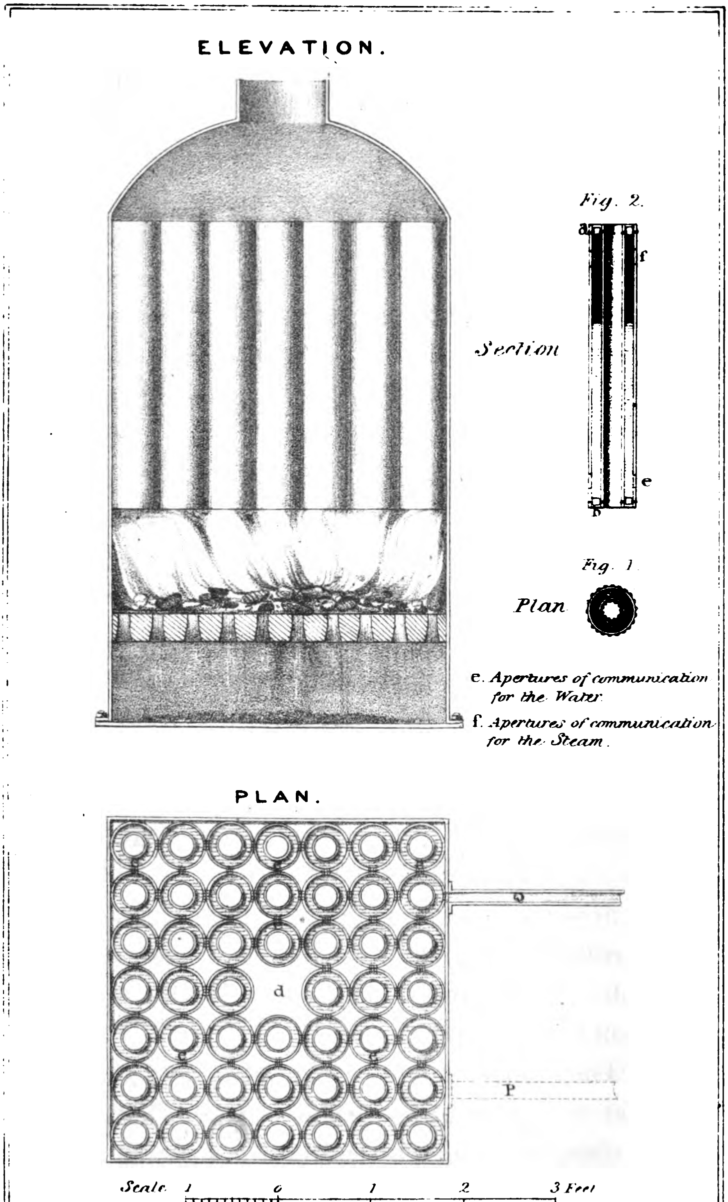
The fire is urged by a rotary fan driven by the engines, and all the waste steam is blown into the fireplace and chimney, and destroyed. The pressure Mr. Hancock states his boilers to have been proved at is 400lbs. per square inch, but that its average working pressure is only from 60 to 100; and also that they expose to the action of the fire 100 square feet, and that it requires a supply of 800lbs. of water for an eight-mile stage, and about two bushels of coke. The weight of the whole carriage, including fuel and water, he considers to be about 3½ tons, and the average rate of travelling to be about 9 miles per hour.

With respect to some of these statements we must be permitted to express our dissent; we fear that the expectations of the patentee are much too sanguine, more especially as regards the weight of water that would be required.

Messrs. Ogle and Summers constructed a steam carriage to run on the common roads, and had a patent for the boiler which they used. Annexed is a plate of the same.

The hollow tubes, a plan and section of one of which is given at fig. 1 and 2, plate XVII. are all double, the flame ascending through the inner one and around the outer one, whilst the water is con-

Plate XVII.



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tained in the space between the two; the ends a and b being the top and bottom of this small boiler.

Turn now to the general plan and elevation on the same plate, and observe that a great number of these tubes are brought together to form the boiler; in this case 48, and they are stated to be equal to 4 horses power.

Openings are formed at the top and bottom of these tubes so as to connect them; the one series of openings for the water, the other for the steam. With this arrangement the water in each separate tube is exposed to a double fire, and an immense surface is kept continually heated.

P is the steam-pipe, and Q is the pipe of a force-pump which supplies the boiler with water; a safety-valve or valves should be fixed to this boiler in the same way as described before for the others. The small tubes and the interstices between the larger ones form the flues of the boiler, whilst the center opening d receives a jet of steam to give it a draught as a chimney. Having this form of boiler they are enabled to use an immense pressure at very little risk, and they state that they can work their boiler at 250lbs. pressure of steam upon the square inch with perfect safety, and thereby obtained upon the common road a velocity almost incredible of between 30 and 35 miles per hour, and have ascended lofty hills in the vicinity of

Southampton at the rate of 16½ miles per hour. However romantic this may appear, Mr. Ogle states, in his evidence before the special committee of the House of Commons, that they never, with the greatest pressure, burst, rent, or injured their boiler, and that it has not once required cleaning after being in use twelve months. Their present experimental boiler contains about 250 superficial feet of heating surface, in a cube space of about 26 feet, (3-ft. 8-in. × 3-ft. × 2-ft. 4-in.) and weighs about 8 cwt, and the carriage and apparatus, including the coke and the water, but not the passengers, weighs about 3 tons. They supply two cylinders with steam, communicating motion by means of their pistons, &c. to a crank-axle, to the ends of which either one, or other, or both wheels are fixed, as may be required.

One wheel is found sufficient under ordinary circumstances, when the elevation of the road does not amount to say one foot in six, to impel the vehicle forward. The waste steam is carried round a double casing of the fire-place, and is then passed into the chimney, and there is no appearance of smoke excepting on lighting the fire with wood, which is necessary to ignite the coke.

Mr. Ogle states that he can stop his carriage and draw it up in less time than is necessary to stop a pair of carriage horses; that a steam-carriage is safer in every respect than one with horses; and that it is under more complete management and controul at the same velocities with the same weights.

Their present carriage is a treble-bodied phaeton, and has three wheels; one before, the rim of which is 4½ inches broad upon a moveable joint to steer by. The maximum weight it can draw with any considerable velocity is considered to be about 3 tons.

With regard to the relative expenses between horse and steam power for the purposes of locomotion, it was stated by Mr. Gurney, in his evidence before the select committee of the House of Commons, that he had estimated the comparative cost of each for a line of road 100 miles in length: the following is a statement thereof. It should be added that the mode of applying the steam was that of a separate carriage or drag.

" The first cost, wear and tear, of the coach " drawn, in every respect is the same in both cases.

" The expense of men to manage is also about " the same. In one case there is a coachman and " guard, in the other an engineer and director.

" Government duty and tolls may also be consi- " dered the same.

" It remains then to show the difference in the " expense of POWER only, upon the assumed 100 " miles of ground. To work a coach well with " horses, 100 miles up and 100 miles down, once " a day, will require 100 horses. A horse a mile "is the present calculation for doing the work. "Suppose the cost of each horse £20 or £30, or "for calculation take £25 the average, it will "amount to £2500.

"Now three steam-carriages will do the same "work, and the expense of these will be about "£500 each, or £1500 for the three. A saving "will consequently be effected of £1000 in capi-"tal.

"The wear and tear of horses may be stated in "money value at about £5 each per annum on the "100 horses, namely £500 per annum.

"The wear and tear of the three steam-towing "carriages will not exceed £100 each per annum, "£300 for the three; exhibiting in this item an "annual saving of £200.

"The expense of shoeing, keep, provision, at-"tendance, harness, &c. is per day about 3*s*. each, "or £15 for the 100 horses.

"The expense of fuel for two carriages, one up "and the other down, doing the same work, will "be that of 100 bushels of coke, at 6*d*. per bushel, "say £2 : 10.

"Or, if we take 1*s*. per mile per horse power, "it will be about the same. But the expense of "fuel for the steam-carriage will be, on an average "throughout England, about 3*d*. In some coal "districts it will not exceed 1*d*. per mile; while in "other situations it will amount to 6*d*."

Mr. Gurney states that in the above estimate he has not taken the expense of stables into account, which expense is considerable when compared with sheds for coke and water; and further, that from these data he concludes that a carriage may be worked by steam on the common roads at one-fifth the expense of horses.

He states that his boilers are calculated to last, with fair treatment, about three years, and that they require examining only once a fortnight or three weeks, depending upon the locality in which they work; for in some situations, where lime is held in solution in the water in large quantities, they require cleaning oftener, but in other situations, where the water is more pure, they will run for a month, or even two.

These statements seem highly flattering to the views of those who advocate the introduction of steam generally upon the common roads; but we must not forget that the source from whence they emanate renders it possible that circumstances may have given a particular bias to their opinions, and this consideration will make us pause before we give an unqualified assent to them.

We do not say that the expense of "Horse-Carriages" is stated too high, but we believe that the expense of "Steam-Carriages" is rated too low; that relays of carriages would be required more than is stated, which would increase the first outlay, and no doubt there would be a greater annual expense for wear and tear.

With respect to the different degrees of resistance and of traction upon a railway and a common turnpike road, which must be considered in order to arrive at a rational conclusion as to the comparative merits of the two modes of conveyance, it must be stated that, in a railway, the theory acted upon has been to obtain as smooth and as level a way as possible—a perfectly horizontal plane, according to this view of the subject, being a perfect railway. This, in practice, is very nearly approximated to on the Manchester and Liverpool Railway, and is effected in the following manner. Raised edge-rails are provided of rolled iron, two inches broad and one inch thick, in lengths of twenty-five feet each. These are firmly united together, and placed upon cast-iron pedestals, and the whole supported, at intervals of three feet, by stone blocks twenty inches square and twelve inches deep. Into each of these blocks two holes are drilled and filled up with oak plugs, and to these the pedestals bearing the rails are spiked down.

On the embankments, and other places where the foundations may be expected to subside, additional strength and firmness is obtained by the introduction of oak sleepers. The whole length of the road is thirty-two miles, and posts are placed every quarter of a mile to mark the distance.

The greatest rise is only about one foot in ninety-six feet, on the Whiston and Sutton inclined planes, the rest being nearly level. When the engines arrive at these inclines, they fall off in speed, and if the rise was much greater, they would need the aid of rack-rails, with corresponding toothed wheels on the carriages, to prevent them from slipping.

But on the common road the wheels of a carriage have greater adhesive power, owing to its roughness.

It has been stated, that on a smooth iron rail, a carriage propelled by the wheels acting upon such rail when laid at an elevation or rise of one foot in twelve, requires a power to move it up, twenty-one times greater than is required to move the same body along an horizontal plane; but that, on the common road, the additional power required for ascending a plane of such a rise is only about double what is required on the horizontal plane. The force of traction necessary to propel a ton weight on a level railway being about eight pounds, that is about one-two-hundred and eightieth, or say one-two-hundred and fortieth, part of the whole weight; whilst the average force required to draw a ton weight on the common road when level, is about one-twelfth of the whole weight, and is only doubled when the rise is as above assumed.

This theory is ascribed to Mr. Gurney, but practice gives a result less favourable to steam-carriages on the common road; and in proportion as roads are smooth and level, do they become useful for the purposes of locomotion. The more nearly a common road approaches in its construction to a railway, the more available and desirable it is for this purpose; and this accounts for the steam-carriage projectors always choosing the smoothest and most level line of road they can conveniently find to commence their operations upon.

The greatest objection to railways is their first expense, which for a line of any length is enormous; that of Manchester and Liverpool, which is most advantageously situated, is stated to have required a capital of nearly £900,000.*

On the other hand, it may be said that the only thing in favour of the application of steam to the purposes of locomotion on the common road, is the fact of the said roads being ready formed for use.

It has been proposed to lay down a double line of granite paving on the common roads, level with their surfaces, so that it should be no interruption to the crossing of ordinary vehicles, at the same time that it would facilitate the passing of steam-carriages. This approaches very nearly to a rail-road, and would, no doubt, be an improvement, but should be looked forward to, rather as a *consequence*, than as a *cause*, of the success of such carriages; and even then, according to the foregoing theory, in proportion as the roughness of the road is diminished, the difficulty of ascending acclivities is increased.

Still, perhaps, this difficult problem may be thus solved, and by sacrificing a little of the *particular* advantage *possessed* by the superior adhesion of the wheels in ascending inclinations upon roads as at present constructed, a *general* advantage may be *gained* by the greater facility afforded of travelling well upon the level, should the above-mentioned improvement in the roads prevail.

Those who are most strenuous in advocating the introduction of steam-carriages anticipate great advantages to the community from their general adoption, and have indulged in sanguine expectations of the immense advantages to be gained thereby in a national point of view.

Generally speaking, what is advantageous to individuals is beneficial to the community, and a project or invention, when once fairly before the public, makes its way in an exact ratio to its usefulness.

If an individual invents a machine, which he can sell at a remunerating price, and this he can only do to any extent by its being of some advantage to the purchaser, it answers his purposes; and advantage to the community follows as a consequence. Great national benefits are thus based upon individual exertions, and thus even self-interest upholds and strengthens the social compact.

The opposition which this mode of steam communication met with on its first introduction, already mentioned in this work, caused a party to be formed in its favour, who as strenuously insisted upon immense national advantage resulting from it, as the other party who opposed it seemed to dread destruction and ruin.

Most of the arguments made use of in its favour are extremely plausible, though not a little theoretical, and, as some (perhaps of the adverse faction) are inclined to think, visionary.

It will, however, be proper to state a few of those arguments, in order to enable us to arrive at something like a rational conclusion, and if possible clear away the mists of prejudice.

Colonel Torrens, M.P., in his evidence before the Committee of the House of Commons above referred to, stated that, " He considered that the effect which would be produced upon British agriculture by substituting on common roads steam-carriages for carriages drawn by horses, would be most beneficial for these reasons, that agriculture is prosperous in proportion as the quantity of produce brought to market exceeds the quantity expended in raising and bringing it there.

" *If steam carriages be employed instead of carriages drawn by horses, it will be because that mode of conveyance is found the cheapest.* Cheapening the carriage of the produce of the soil must necessarily diminish the quantity of produce expended in bringing a given quantity to market, and will, therefore, increase the net surplus, which net surplus constitutes the encouragement to agriculture. For example, if it requires the expenditure of two hundred quarters of corn to raise four hundred, and the expenditure of one hundred more on carriage to bring the four hundred to market, then the net surplus will be one hundred. If by the substitution of steam-carriages, you can bring the same quantity to market, with an expenditure of only fifty quarters, then your net surplus is increased from one hundred to one hundred and fifty quarters, and consequently either the farmer's profit or the landlord's rent increased in a corresponding proportion. There are many tracts of land which cannot now be cultivated, because the quantity of produce expended in cultivation and in carriage exceeds the quantity which that expenditure would bring to market. But if you diminish the quantity expended in bringing a given quantity to market, then you may obtain a net surplus produce from such inferior soils, and consequently allow cultivation to be extended over tracts which could not otherwise be tilled.

"On the same principle, lowering the expense of carriage would enable you to apply additional quantities of labour and capital to all the soils already under cultivation."

In reply to the question, "Whether, if horses were displaced from common roads, there would not be a diminished demand for oats, beans, and pasture, and land thereby be thrown out of cultivation and labour out of employment?" he said, "If steam-carriages were very suddenly brought into use and horses thereby displaced, I think the effect stated in the question would be produced *for a time;* but practically steam-carriages can be introduced only very gradually, and the beneficial effects upon the profits of trade, by bringing agricultural produce more cheaply to market, will tend to increase profits, to encourage industry, and to enlarge the demand for labour; so that, by this gradual process, there will probably be no period during which any land can actually be thrown out of cultivation, the increasing population requiring all the food which horses would cease to consume. With respect to the demand for labour, that demand consists of the quantity of food and raw materials which can be cheaply obtained; and as by the supposition the displacing of horses will leave at liberty more food and more material, the demand for labour will ultimately be greatly increased instead of being diminished. It has been supposed, I know not how accurately, that there are employed on the common roads in Great Britain one million of horses, and a horse is calculated to consume the food of eight men (?)

" If steam-carriages could ultimately be brought to such perfection as entirely to supersede draught-horses on the common roads, there would be food and demand for eight millions of persons.

" But when we take into consideration that lowering the expense of carriage would enable us to extend cultivation over soils which cannot now be profitably tilled, and would have the further effect of enabling us to apply, with a profit, additional portions of labour and capital to the soils already under tillage, I think it not unfair to conclude, that were elementary power on the common roads entirely to supersede draught-horses, the population, wealth, and power of Great Britain would at least be doubled."

The above is a fair specimen of the sort of argument brought forward by those who support this side of the question; and we think it will not be denied, that if the hypothesis on which this reasoning is based can be realized, that the effects anticipated are not much over-rated.

There is yet a step further which some strenuous advocates of the system are inclined to go, and boldly predict, that the plough and the harrow will soon be worked by steam: this appears much too sanguine; for we have seen that travelling by steam on the common road, is practicable just in proportion as the road is smooth and level. This is not to be looked for in a ploughed field, therefore steam cannot be used to advantage in such situations and for such purposes.

Almost the whole of the foregoing statements respecting steam conveyance on the common roads, were given in evidence before the special committee of the House of Commons, together with a great many more too voluminous to find a place here. The committee in their report, after recapitulating the elicited evidence, strongly recommend steam-carriages to the favourable consideration of the House, and add, "That it surely cannot be contended that the introduction of steam-carriages on the common road is as yet an uncertain experiment unworthy of legislative attention." The 'COMMITTEE' conclude their *Report* in the following words :—"Sufficient evidence has been adduced to convince your Committee"—

"1. That carriages can be propelled by steam on the common roads at an average rate of ten miles per hour.

"2. That at this rate they have conveyed upwards of fourteen passengers.

"3. That their weight, including engine, fuel, water, and attendants may be under three tons.

"4. That they can ascend and descend hills of considerable inclination with facility and safety.

"5. That they are perfectly safe for passengers.

"6. That they are not (or need not be, if properly constructed,) nuisances to the public.

"7. That they will become a speedier and cheaper mode of conveyance than carriages drawn by horses.

"8. That they admit of greater breadth of tire than other carriages; and as the roads are not acted on so injuriously as by the feet of horses in common draught, such carriages will cause less wear of the roads than coaches drawn by horses.

"9. That rates of toll have been imposed on steam-carriages, which would prohibit their being used on several lines of road, were such charges permitted to remain unaltered."

Having stated the above evidence, facts, reasonings, and conclusions, little more need be said on the subject. We, however, may be allowed to predicate, that if steam be, as stated, a cheaper mode of conveyance than horses, and at the same time not dangerous; and if the legislature be determined to remove all obstacles within their province, that steam, like powerful Truth, will eventually prevail.

The evidence and report above-mentioned prove that the first objects are completely effected, and the other, a desirable one, is in progress under the most promising aspect and favourable auspices; we may surely, then, be justified in concluding that steam-carriages bid fair to become in a short time a common mode of conveyance.

The application of steam on the Manchester Railway, which has surpassed all others, must not be passed over in silence. We will now, therefore, turn our attention to that important undertaking; but as it is not our intention to enter upon the consideration of any thing not immediately bearing upon the subject in hand, our notice will necessarily be brief.

The Manchester Railway contest, then, being fresh in the minds of all intelligent persons, we need not here enter into any lengthy detail of the circumstances attending it; suffice it to say, that Mr. Robert Stephenson's engines were preferred to all others, and carried off the prize. The determination of the judges appointed to the award has been fully borne out by subsequent events, as the only rival at all capable of competing with Mr. Stephenson on that occasion has never since been able, though he has made two fresh engines, to make one run effectively.

The Manchester Railway contest commenced on the 6th of October, 1829. Mr. Stephenson's engine, the Rocket, on that occasion, weighed four tons three hundred weight, and travelled backwards and forwards on a mile and a half course of level railway, thirty-five miles in three hours and ten minutes, being upwards of eleven miles an hour, with an attached load of thirteen tons including the persons who rode with it.

After this a fresh supply of water was taken in, which occupied sixteen minutes, when the engine again started, and ran thirty-five miles in two hours and fifty-two minutes, which is upwards of twelve miles an hour, including all stoppages.

The speed of the engine with its load, when in full motion, was at different times thirteen, thirteen and a half, fourteen, and sixteen miles an hour, and had the whole distance been in one direction, there is little doubt but the rate of speed would have been fifteen miles per hour: the consumption of coke was on an average about half a ton in the seventy miles. The pressure of steam upon the safety-valve was fifty pounds per square inch. When its load was taken off, including even the attached car or tender-carriage for fuel and water, the Rocket performed the seven miles in the space of fourteen minutes fourteen seconds, being at the rate of thirty miles an hour, but without water-tank or fuel it could not long have maintained this speed.

A double stroke of the engine, that is once up and once down, driving the wheels of the carriage acted upon once round, furnished an easy means of ascertaining whether the speed of the carriage corresponded with the speed of the wheels, and consequently whether or not the wheels slipped, as it was expected by many " theorists " they would do, in stead of advancing upon the smooth surface of the rail.

The following calculation by Mr. Vignoles and Mr. Price, of Neath Abbey, from the performance of one of the competing engines, the " Novelty," of Messrs. Braithwaite and Ericson, will show, as well as can be ascertained from such observations, that even upon the smoothest rail and at the greatest velocities the wheels do not slip.

The maximum number of strokes was 142 per minute, while 440 yards were traversed in 43 seconds; diameter of the wheels 50.1 inches, circumference 157.4; 157.4 × 142 = 621 yards, being the velocity per minute of the circumference of the wheel, or 21 miles and 300 yards per hour. Then as 60 seconds is to 43 seconds, so is 621 yards to 445 yards.

This calculation of the distance run, shews a difference of only five yards from the actual performance of the engine; and this difference might arise from the most trifling inaccuracy in noting the time—a quarter of a second at each end of the course being sufficient to produce it—so that we may fairly conclude that there was no slipping of the wheels at a velocity of nearly twenty-two miles an hour with a load.

Great improvement has been made in the working parts of the engines now plying on the Manchester and Liverpool Railway, though there is no alteration in their principle, and a corresponding increase of speed and power has been thereby obtained. Mr. Stephenson states that a speed of forty miles an hour with a light load has been attained, and that an engine might be constructed to run one hundred miles within the hour, although at that velocity the resistance of the atmosphere would be considerable.

He further says that engines are now made with eight times the power of the Rocket, yet with little more weight upon any individual point of the rail, the load being equally divided upon six wheels instead of four, and the machinery placed in a more advantageous situation than formerly. Among other improvements is that of making the tubes, which form the flues of the boiler, more numerous, and of smaller diameter than before, and of brass instead of copper. The last new engine on the Manchester Railway ran 23,000 miles with the most trivial repairs, making every day four or five journeys of thirty miles each.

The following is a description and performance of another of Mr. Stephenson's engines.

Diameter of the working cylinders eleven inches, length of the stroke sixteen inches, diameter of the wheels five feet; weight of the engine eight tons, weight of the tender when full of water and coke, four tons; and drew up the inclined plane at Rainhill, which has a rise of one in ninety-six, about forty-five tons gross of goods and waggons at the rate of about eight miles an hour, exerting a force equal to about forty horses' power. The cost of such an engine with tender and all complete, is stated to be from £800 to £1000.

On the 1st of March, 1831, the Sampson, another of the Manchester Railway engines, drew a gross weight of one hundred and fifty-one tons in thirty waggons and carriages, (the nett weight being one hundred and seven tons,) the whole distance from Manchester to Liverpool, thirty-two miles, in two hours and thirty-four minutes, including thirteen minutes of stoppages. The diameter of the wheels was four feet six inches.

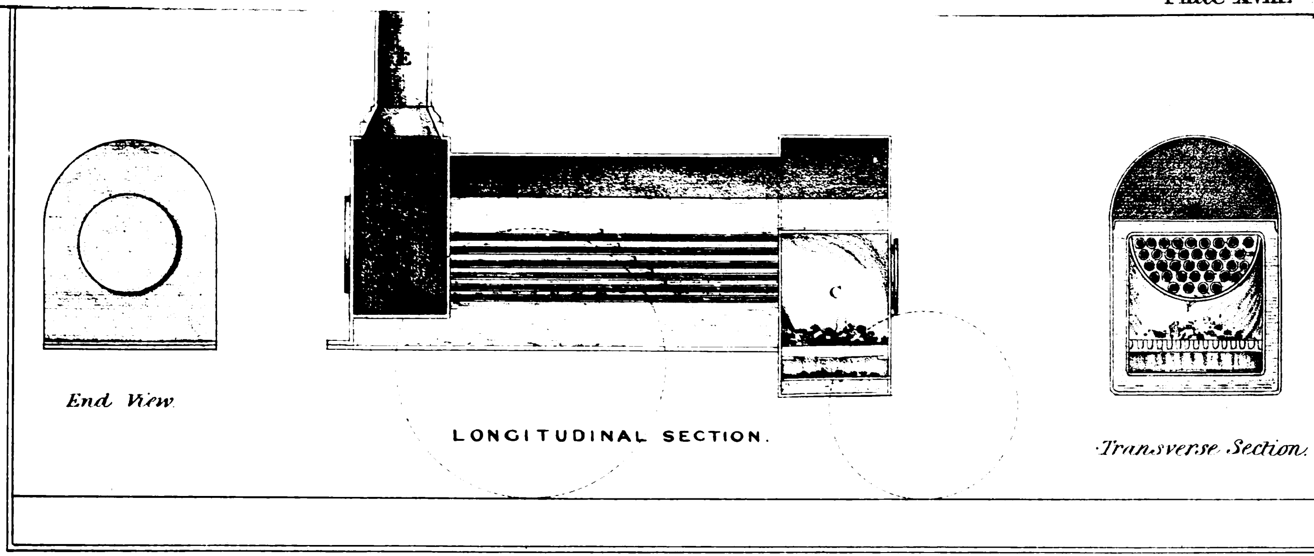
At plate 18, plans and sections are given of one of Mr. Stephenson's machines. A is the steam-boiler, which supplies steam through the pipe (a), to the cylinder (b). A cylinder of this sort is placed on each side of the carriage, and the two, by means of pistons and connecting-rods, act simultaneously upon the wheels B, and so give motion to this powerful and rapid machine.

The steam is raised by the action of the fire, as shewn at C in the section, the smoke and heated air rushing rapidly through a great number of small tubes (d d), into the chimney E, and the draught is increased by a jet of waste steam from the cylinders.

A common safety-valve and also an enclosed one are appendages to this boiler, and should be so to all high-pressure steam apparatus on account of the great risk from explosion. An alarm-pipe (p) is also fixed on the top of the boiler, from which a pipe descends below the level of the water. Should the boiler run so far short of water as to sink below a certain level, the steam would rush rapidly out of a whistle-formed aperture in the pipe (p), and by its noise alarm the engineer. T is the attached car for coke and water, and S is the platform for the fireman.

Long trains of wheeled vehicles are attached

Plate XVIII.



M A Alderson, delt

On Stone by C. Burton.

Day & Haghe Lithogrs to the King.

to these carriages for the conveyance of all sorts of commodities, live and dead stock; and superbly elegant cars are also attached for the conveyance of passengers; the "*Steam-Horse*," above described, drawing them along with the strength of an elephant, and a velocity almost incredible. The expenditure of fuel is very trifling for so splendid a result, but then there are other things to take into consideration besides the value of coke. The first outlay for the railway is immense; the machines which run upon them are costly, (though not more so, perhaps, than those intended for the common roads), and the expense of cleaning them, keeping them in repair, and working them, is very great. All these are drawbacks from the beneficial effects of steam upon railways, and those who are most interested, are now wavering in their choice between the two modes of conveyance which ought to be preferred.

From observation, however, and satisfactory practical results, we are justified in concluding that railways are a decided step in some situations beyond canals; and reason tells us, that if steam conveyance on the common roads can be effected at only the same advantages generally as on railways, from its not being confined to any particular situation, but being alike applicable to all, it will be a still further step in the "*march of improvement.*"

Having thus described, to the best of my humble abilities, "The Nature and Application of Steam," little more need be added. We have shewn that steam as a "*Prime-Mover*" of all kinds of machinery, cannot be surpassed by any invention at present known; that its application for this purpose is almost unlimited, and its beneficial consequences manifold and certain; and that for the conveying of heat for the various purposes enumerated, it is unequalled.

We may thus consider our labours as closed, and trust they will meet with the favourable consideration of the enlightened body to whom, with the utmost deference and profound respect, I now have the honour of submitting them.

APPENDIX;

CONTAINING

RULES

FOR CALCULATING THE PROPORTIONS OF

BOILERS AND ENGINES,

AND THEIR SEVERAL PARTS;

Also, on the

PERFORMANCE OF ENGINES,

AND THEIR APPLICATION TO VARIOUS PURPOSES.

APPENDIX.

1. *Of the Proportions of Boilers.*—A boiler for an engine of small power requires to be larger in proportion than one of a higher power, as it is more affected by the cooling properties of the atmosphere, and also from the energy of action in a small fire and boiler being diminished in a ratio greater than that of their bulk; but yet no regular calculation can be made for these contingencies with mathematical precision; experience alone is the guide here, and has furnished engineers with the following practical results.

A one-horse low pressure boiler, with a common feed, should have a bottom surface of 9 feet and a side surface of about double that area, and would require a constant supply of water in the boiler of nearly 22 cubic feet; whilst the boiler of a 30-horse engine would only require a bottom surface of 4 ft. 6 in. a side surface double that quantity, and only 11 cubic feet of water for each horse power.

Between these two points as data it is easy to calculate sufficiently near for practical purposes all the required different gradations.

When boilers are wanted for engines of much higher power than the last mentioned, it is customary to have two boilers adjoining each other,—the two equalling the required power, being worked in conjunction. It is also found advantageous to add a third boiler, to be available in case either of the others should be out of order or when they require cleaning. Thus a 60-horse engine would require 2 boilers, each of 30 horses' power, and of the foregoing proportions, with a boiler of reserve of similar size.

The best form of boiler has been found by experience to be cylindrical, with convex ends, but a boiler, as represented in in Plate II. and III. is the most common for low pressure engines employed for manufacturing purposes, a form very similar being now also generally adopted for high pressure locomotive engines, as represented at Plate XVIII. Neither of these are perhaps much inferior in effect to a cylindrical boiler, but do not last so long where the water of supply is apt to run foul.

That the power of the boiler cannot be increased beyond a certain degree, by increasing the intensity of the fire, may be inferred from the fact, that the mode generally in use for the measurement of high temperatures in bodies, previous to the introduction of Wedgwood's Pyrometer, was by dropping cold water upon them, and in proportion as the heat was increased in the body acted on, so was the time required for evaporating a drop of water from its surface. According to Huron's Chemistry as follows: " M. Leidenfrost observes that the hotter any metal is, " so much the more slowly will drops of water evaporate from its " surface, and has applied the knowledge of this general fact to " the measurement of the higher degrees of heat. On iron " heated to the ebullition of water, he has observed that a drop " of water will evaporate in one second. At the heat of 520° " Fahrenheit a drop of water will not evaporate in less than six " or seven seconds, and on melted lead eight or nine seconds."

Very recent experiments upon steam-boilers have proved this theory to be pretty nearly correct, and the only mode of increasing the working power of a steam-boiler is by increasing the quantity of heating surface.

When the boiler is of a rectangular form and without flues, the following *Rule*, which must be modified as before mentioned, according to circumstances, will give a result which will be sufficiently correct in practice.

Rule *and* Example

For a 10-horse low pressure condensing Engine Boiler.

To work well a boiler of this sort will require 5 feet of bottom surface per horse power, which gives an area of 50 feet. The best proportion is from three to four times the breadth for the length, which would give in round numbers about 13 feet for the length and 4 feet for the breadth. The quantity of water would, in this instance, require to be about 15 cube feet per horse power =150 feet for the cubical contents of the boiler; and by an easy calculation this gives 3 feet for the depth of the sides, about 6 inches should be added to this height for the solid work of the side flue to rest against, and a semicircular waggon-headed top gives the capacity for the steam.

This boiler will require a supply of 15 cubic feet of water, at about 120° (the temperature of the water in the hot well) per hour, and as a bushel or 84 lbs. of Newcastle coals may be considered equivalent to 10 cubic feet of water converted into steam, it gives 1 cwt. 14 lbs. of coal per hour as the consumption of a boiler of this power.

This boiler will require from 8 to 9 feet superficial area of fire or furnace bar.

To find the height of the column of water in the feed pipe E, Plate II. for supplying the boiler against any pressure of steam required:

Rule.—Multiply the pressure in pounds, upon a square inch of the boiler, by 2.4, and the product will be the required height in feet above the surface of the water in the boiler.

Example.—Required the height of a column of water in the feed pipe for supplying a boiler with water when the pressure of the steam is 3 lbs. per square inch.

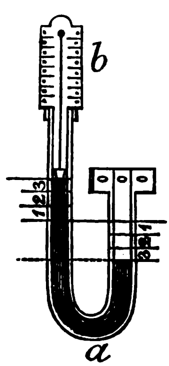
$2.4 \times 3 = 7.2$ ft. above the surface of water in the boiler.

Safety Valve.—Knowing the specific gravity of the metal used for weighting the safety valve, which is generally lead, it is easy to find its required bulk. The positive weight will be equal to the area of the valve in inches, multiplied into the pounds pressure per inch, at which the engine is required to work.

When a lever is used, if the distance between the fulcrum and the centre of the valve, the point acted upon, and the distance from the said point to the point of suspension for the weight, be equal, it will require the same weight which it would if fixed on the top of the valve, as it is in the Example at *d*, fig. 2, Plate III.

If the distance between the centre of the valve and the weight is doubled, while that between the fulcrum and the said point remains the same, the weight required will only be half, and so on for any other proportion.

Steam Gauge.—The pressure or force of steam in the boiler is generally indicated by a column of mercury in a bent iron or glass tube, *(a,)* with a brass index plate *(b)*. This instrument is called the steam gauge. One inch of mercury being nearly equal to 1 lb. pressure of steam in the boiler, the index plate should be divided accordingly, so as to indicate the exact pressure in lbs. of the steam in the inside of the boiler, thus—



Level of the mercury when there is no pressure of steam over the weight of the atmosphere.

ON THE PERFORMANCE OF ENGINES.

We will commence our investigation of this subject by quoting briefly the methods in use for calculating the power of engines by the earlier engineers.

From Blakey on the Atmospheric Engine, 1793.

In a letter to a friend (M. Le Roy, of the Royal Academy of France) he says, "though I laugh at theorists sometimes, I "would not have you think that I have not received some favours "from that stale maid coquet Theory, who is more caressed by "petit maîtres than by me, though I assure you I am much "more in love with old mother Practice, who is always busy in "the exercise of truths, and who would exhaust herself to death "on them, did not daylight run away from her, to oblige this "real school of arts and sciences to take rest. But to show you, "as I said, that this coquet Theory has bestowed some favours "upon me, (though I confess that Practice has corrected the "faults Theory had shown me,) I shall let you know how I "find my passive and active powers in hydraulics," &c. &c.

"Experience has taught me that a cylindrical foot of water "weighs 48 lbs. This *Theory* I knew nothing of till *Practice* "had shown it me. * * * * *

"To know what force is wanted to raise a column of water "12 inches diameter from a depth of 100 feet, I multiply 48 lbs. "by 100=4800 lbs., this shows the weight of the column of "water; and as I must have double that power in a fire-engine "to raise such a weight, in order to master the usual friction in the "cylinder as well as the inertial resistance of all the heavy mate-"rials which are made use of, I multiply 4800 by 2, which "shows that my active power must have 9600 pounds of force. "Having thus found my resisting power and regulated my active "force, I divide 9600 by 1500, (the weight of the atmosphere "on a circular foot,) to find the surface of the piston in the "cylinder, this gives me something more than 6 feet and a half "for its superficial contents, and if this result is multiplied by

"1500, it gives something more than double the weight of the "column of water to be raised to make it work freely, as I have "said, and answers to my rule of giving the advantage to the "active powers as experience teaches all true engineers to do.

"Here is another manner of calculating the force of a cylinder "ready made. I shall suppose a cylinder of 3 feet diameter, its "superficial contents will be 9, which may be calculated as "follows, according to the foregoing rule: $9 \times 1500 = 13{,}500$lbs. "weight of atmosphere on the piston when the vacuum is formed; "this divided by 2 gives 6750lbs. force for half the active power, "divide this again by the weight of a cylindrical foot of water, "48lbs., and it will give 140 feet for the height of a column of "water 1 foot in diameter, to be raised by the 6750 lbs. power, "equal with a velocity of 160 feet per minute, the rate at which "these engines travel, to 540,000lbs. raised one foot high per "minute, or about 17-horse power, if we reckon a horse to raise "a weight of 33,000lbs. 1 foot high per minute. From which "I conclude my engine can raise such a column and continue "working roundly.

"This manner of finding out active and passive powers is so "plain, that it needs no further explanation; and it has induced "me to lay aside all measures by cubes to be afterwards reduced "into cylinders, with fractions, which only serve to puzzle "those, who think there is a merit in knowing how many *skips* "*a flea can make to the moon*, and that there is no under-"standing of arts without making use of hieroglyphic figures, "to find out how one and one make two."

Smeaton introduced many improvements in the atmospheric engine, and had not occasion to make such a large allowance for the acting power as Blakey has done. The following is his method: —

The moving force is the pressure of the atmosphere, which may be stated as .. =		1,00
The loss of force measured in portions of the atmosphere consists of, first, the uncondensed steam corresponding to the temperature of condensation (usually about 160°)	= 0,34	
Second, the force to expel it and the air from the cylinder	= 0,007	
Third, the friction of the piston (*under-rated at*)	= 0,050	
Fourth, the force required to open and close the valves, raise injection water, and overcome the friction of the machinery	= 0,093	
		0,49
All these added together and deducted from the pressure of the atmosphere, gives the nett effective pressure		0,51

Being as near as possible 6lbs. per circular inch. From which data is deduced the following *rule.* Multiply 6 times the square of the diameter of the cylinder in inches, by half the velocity of the piston in feet per minute, and the product is the effective power of the engine, in pounds raised one foot high per minute; to find the horse power divide by 33,000.

Example for a piston and cylinder 9 feet area as before in Blakey. Suppose the length of the stroke 8 feet, and the engine to make 10 double strokes per minute; then $10 \times 8 = 80$ feet per minute, or half the velocity; consequently $6 \times 36^2 \times 80 = 622080$lbs. raised one foot high per minute, and $\frac{622080}{33,000} = 18,28080$, or say 18-horse power.

THE DOUBE-ACTING CONDENSING STEAM ENGINE.

The openings into the cylinder for the admission of steam, commonly called the steam-ports, and also the steam-pipe from the boiler, should be about one twenty-fifth the area of the working cylinder of the engine, or if they are circular one-fifth of the diameter.

Another rule is to make the area of the passage one superficial inch for each horse power. Thus, a 10-horse power engine would have a port hole 10 inches area. A similar result would be given by the first rule nearly—for the diameter of a 10-horse cylinder being 16 inches, the area will be 256, one twenty-fifth of which in round numbers is 10 inches as before.

The length of the cylinder should be about twice its diameter. The velocity of the piston in feet per minute should be about 98 times the square root of the length of the stroke, or in ordinary engines 220 feet per minute.

The air-pump should not be less than one-eighth of the capacity of the cylinder, or half the diameter and half the length of the stroke of the cylinder, and most engineers make the diameter with this length of stroke considerably more, up to as much as two-thirds of the diameter of the cylinder, or about half the area of the piston.

The condenser should be of the same capacity as the air-pump, and be completely immersed in the cold water cistern from which it will receive its injection, the quantity of injection water should be at least 25 times that required for steam, and the diameter of the injection pipe one thirty-sixth of the diameter of the cylinder nearly.

The valves of the air-pump bucket and lid should be of equal size and as large as they can be made, and the foot valve not less than the same area.

The weight in the safety valve should be from 2 to 3lbs. pressure per circular inch.

It is found by experience that with these arrangements, which of course are thought to be the best, that if the force of steam be reckoned 12lbs. per circular inch, yet from losses occasioned by the imperfection of the vacuum, the cooling in the cylinder, the friction of the machinery and tackle, the changing from a reciprocating to a rotary motion, and other more minute causes, that the effective disposable power of the engine will only be about 6lbs. per circular inch of the piston's area. From which we derive the following rule for calculating the power of an engine:—Multiply the square of the diameter of the piston in inches by 6 the nett effective power, and that product by the velocity of the engine per minute in feet, the result will be, the effective power—in pounds raised 1 foot high per minute, which being divided by 40,000, the number of pounds a horse is now reckoned to raise, 1 foot per minute gives the number of horse power of the engine; or if the diameter of the cylinder is required for a given power, reverse the above calculation.

EXAMPLE.—Required the diameter of cylinder for a 30-horse double-acting condensing steam engine:—

$40{,}000 \times 30 = 1200{,}000 \div 220 = \frac{5454}{6} = 909$, the square root of which in round numbers is 30 inches, the diameter required.

All other powers may be calculated in a similar way, but an allowance must be made in engines with a small cylinder, for although the power increases or decreases in proportion to the square of the diameter of the piston, yet the retarding forces, namely, the friction of the cylinder, air-pump, and other pumps, as also the axles, increase or decrease in a direct ratio with their circumference. No two machinists perhaps have the same mode of calculating this loss or gain; but the following table of diameters powers, lengths, and number of strokes, is very near the customary calculations of the most eminent engineers.

Table of the Powers and Proportions of Double Acting Condensing Engines.

Horses Power.	Diameter of Cylinder.	Length of Stroke. Ft. In.	No. of Strokes per Minute.
2	10		
3	12	2 6	44
4	14		
6	16	3 0	36
8	18		
10	19½	3 6	32
12	21		
14	22		
16	23	4 0	28
18	24		
20	25	4 6	26
24	27		
26	28		
28	29	5 0	22
30	30		

For the quantity of coals required they reckon 14lbs. per horse power per hour of the best quality, and 4 gallons of water for injection per horse power per minute.

To find the weight of a fly-wheel for any required power, assume a diameter for the fly-wheel, then multiply seven times the velocity of the piston (a constant quantity which may be stated in round numbers at 1500 feet) by the number of horses power that the engine is equal to, and divide the product by the assumed diameter of the fly-wheel in feet multiplied by the number of revolutions per minute, and the result is the weight of the rim in cwts. nearly.

Example.—Required the weight of a fly-wheel for a 20 horse engine, the assumed diameter being 18 feet, and to make 24 revolutions per minute.

$$\frac{1500 \times 20}{18 \times 24} = 69 \text{ cwt.}$$

The diameter assumed for a fly-wheel is generally eight times the length of the crank, and the depth of the ring one-third of its length.

Having thus found the weight and the depth or width of the rim, its thickness will be found as follows:—

RULE.—Divide the weight found in pounds by the area of the ring in inches multiplied by ·265, and the quotient is the thickness of the rim in inches.

EXAMPLE.—What thickness must a ring be to equal 69 cwt. when the outer diameter is 18 feet and the inner diameter 16 feet 6 inches. First find the area of the circular space or ring contained between the inside and the outside diameters as follows. Multiply their sum by their difference and by ·7854, and the product will be the area.

$$\overset{\text{Ft.}}{18} + \overset{\text{Ft.}}{16}\ \overset{\text{In.}}{6} = \overset{\text{In.}}{414} \times \overset{\text{In.}}{18} = 7452 \times \cdot 7854 = \overset{\text{In.}}{5853}$$

$$\text{Then } \frac{69 \text{ cwt.} = \overset{\text{lbs.}}{7728}}{5853 \times \cdot 265} = \overset{\text{In.}}{5} \text{ the thickness required.}$$

RULE

For calculating the Governor of a Steam Engine.

The governor consists of two balls suspended from a revolving axis impelled by the motion of the fly-wheel shaft. The balls *rise* when the velocity of the engine is increased, and *fall* when it is diminished.

This motion conveyed by means of levers to a valve placed in the steam pipe of a steam engine, forms an exceedingly accurate and very sensitive regulator for supplying the working cylinder with steam and preserving a uniform motion in the engine.

The vertical distance between the point of suspension and the plane in which the centre of the balls revolve is found, both by reasoning and experiment, to be the same in length as a pendulum which makes one vibration forwards and back again in the same time that the balls make one revolution. Suppose, then, the fly-wheel shaft to make 32 revolutions per minute, and the governor axis and balls the same, required the length of the levers.

RULE.—Double the number of revolutions, then say as the sum squared is to 39¼ inches, the length of a pendulum for vibrating seconds in this country, so is 60 seconds squared to the length of the levers required.

EXAMPLE.—$32+32=64\times64=4096$

Then as $4096:(60\times60=)\ 3600::39\frac{1}{8}:34.38$ the length required.

The range of the balls may be settled by considering the greatest rate of velocity which the machinery may acquire without injury to the work it performs, and with this range the governor ought, by means of levers acting upon the throttle valve, to be capable of completely cutting off the steam.

Now the greatest variation should not generally exceed one-tenth of the velocity, that is, one-twentieth on either side of the mean, and the range of the plane of revolution will in that case be nearly one-fifth of the height of the point of suspension above the plane of revolution at the mean velocity.

Thus if the mean height be 34.38 inches, then one-tenth on each side will be as follows:—

34.38 + 1-10th, or 3.438 = 37.818
34.38—1-10th, or 3.438 = 30.942

6.876 = 1-5th of 34.38, the range required.

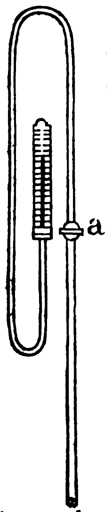
The steam passage or throttle valve should be fully open when the governor balls revolve in a plane corresponding with the foregoing length of $34.38+3.438=37.818$, which they will do at the engine's lowest rate of speed, and be gradually contracted as the engine increases in velocity, and the governor balls rise, first to the mean of its range at the usual speed of the engine, and completely shut off when it reaches its maximum velocity.

There is no exact rule for calculating the weight of the governor balls, but we may state generally that they vary from 20 to 80 or 90 pounds each, according to the power of the engine.

The angle formed by the ball rod with the axis of the governor should be about 30 degrees when they are at rest, and the connecting rod should form about the same angle with the ball rod.

Boat engines are generally regulated by hand, with a handle and index plate similar to the injection cock.

Condenser gauge.—This is sometimes called the barometer from its resemblance to that instrument.



Like the steam gauge already described it is made of a glass or iron tube in the form of a double syphon (as shewn in the annexed figure) with one leg about half the length of the other.

To the end of the longer leg a pipe is joined which communicates with the condenser, and has a stop cock (a) to open or close it.

The two legs are filled up to a certain height with mercury which naturally stands level when the engine is not at work, a light float with a slender stem being made to float on the surface of the mercury in the short leg. Upon the end of the short leg is fixed a properly divided scale, or when a glass tube is used the scale is more frequently fixed behind the leg as in the common barometer, and the float dispensed with.

If the vacuum in the condenser was perfect, it would be equal to 30 inches of mercury, or the index of the scale would stand at 0, but as in the best constructed steam engines the vacuum is not perfect, they generally indicate two or three inches. About two inches is the best usually attained in practice.

HIGH PRESSURE STEAM.

High pressure steam is so called from its being generated under the pressure of a greater weight in the safety valve than is used for condensing engines. The nature of high pressure steam was well understood by Newton, as may be seen by the following quotation from one of his works. " When the heat of water is " increased by the action of fire before it is turned into an elastic " fluid, the parts of the body itself have a most violent agitation

" amongst one another which causes the fluid to boil: for per" forming which effect *the action of the fire need be so much* " *less as the fluid is less compressed.*" In other words the greater the pressure under which steam is generated, the more fire it requires, and the difference between high and low pressure steam is merely, that the latter contains more of that " stuff which steam is made of,"—namely, fire and water, than is contained in the former. For in vacuo water boils at about 90° Farenheit, under the common pressure of this climate at 212°, and when pressed with a column of mercury six inches in height, it does not boil until heated to 218°, each inch of mercury producing about 1° in the thermometer.

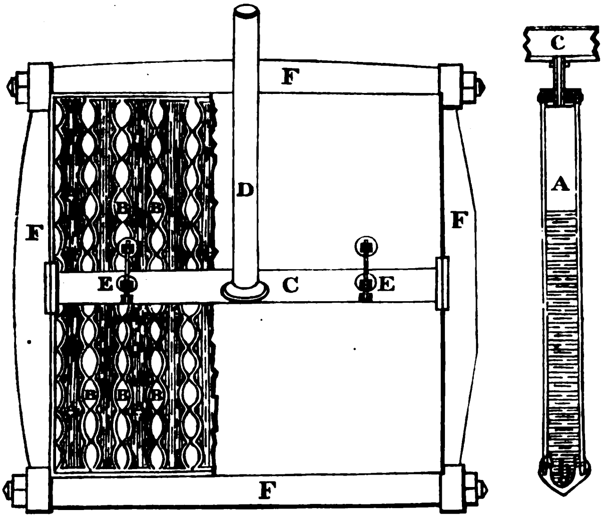
The effective power obtained by means of a high pressure engine is nearly two-thirds of the force of the steam, the pressure of the atmosphere not being taken into the account, full one-third being expended in friction, &c. Hence we derive the following rule for calculating the effective horse power of a high pressure engine. Multiply the cylinders area in inches by the nett pressure per circular inch on the safety valve, and this product by the velocity of the piston in feet per minute; deduct one-third of the product, and divide the remainder by 40,000, the quotient will be the horse power of the engine.

Example.—Required the power of an engine, the cylinder being 10 inches in diameter, 2 feet stroke, the engine making 50 revolutions per minute, and the weight upon the safety valve equal 40lbs. per circular inch.

$$10 \text{ in. diam.} = \overset{\text{Circular Inches.}}{100} \text{ area, and } 50 \text{ revolutions} \times \overset{\text{Ft.}}{4} = \overset{\text{Ft.}}{200} \text{ velocity.}$$

$$\text{Then } \frac{100 \times 40 \times 200 \times 2}{3} = \frac{533333}{40,000} = 13 \text{ horses power.}$$

We will close this account with a description of one of the latest inventions for improving steam-boilers which we have seen, and which is intended to be made use of in a carriage now building to ply on the common road; it is the patented invention of Mr. D. Redmund, Engineer, City-road.



A A Plate XIX. are the steam and water chambers. B The smoke-flues. C The tube for collecting the steam from the several chambers. D Pipe for conveying the steam to the engine. E Two safety valves. F Strong straps of wrought iron round the top, bottom, and middle of the boiler.

Fig. 2. A cross section of one of the steam and water chambers. *h*. Plug or cock for cleaning out the boiler.

N.B. One-half of the plan is drawn with the top covering broken away, in order to show the interior construction.

The whole of the boiler is formed of malleable iron, the sides being rolled and fluted, or they may be wholly made of copper.

We will here briefly recapitulate the chief modifications made in the construction of steam-boilers as recorded in the foregoing pages, and we must observe that most of the improvements which have taken place in boilers have been occasioned by the employment of high pressure steam for the purposes of locomotion.

The common high pressure steam-boiler, independent of its inconvenient size, being found dangerous, was attempted to be superseded by tubular boilers, in which the water was enclosed, and was in them exposed to the action of fire. Such are Perkins and Gurney's inventions, from which they, in a limited degree, derive power and safety.

The steam-boilers of the Manchester railway are the same in principle and in detail as the original boiler of Treneithic, but have tubular flues.

In all these boilers there is an increase of heating surface; the last-mentioned one derives this from dividing the area that would be taken up by an ordinary flue, amongst a great number of small flues, which it is found convenient to make tubular.

If a flue of a foot area in its cross section be divided into only four smaller flues, possessing collectively the same area, they would answer the purpose of conveying the smoke quite as well as the one flue, and would expose an additional surface of 4 feet of heated metal to the water; this multiplied into the length of a common boiler flue, say 8 feet, gives an additional heating surface more than the ordinary flue of 32 feet, and the greater number of small flues you divide the given area into, the greater is the gain.

If there was a corresponding increase of safety, these boilers would be nearly as perfect as could be desired; but though there has been no accident arising from their use, it cannot be denied that they derive their safety from the strength of the materials of which they are made, and the care with which they are put together and worked.

The boilers of Hancock, Ogle, and Macerone, and though last, not least, Redmund's, are designed with a view to effect both these objects, that is, to combine safety with power, and this they do in an eminent degree; but time and experience alone can prove to a complete demonstration which mode of operation is the best.

FINIS.

MARCHANT, PRINTER, INGRAM-COURT.