THE STEAM ENGINE.

SECTION I.

AN ACCOUNT OF THE INVENTION AND PROGRESSIVE IMPROVEMENT OF THE STEAM ENGINE.

ART. 1.—WHEN an efficient mechanical power is produced by the generation, or generation and condensation, of the steam or vapour of any liquid, the combination of vessels and machinery for that purpose, is called a Steam Engine. This engine was for a considerable time after its invention called a Fire Engine, and not improperly, for the active agent is heat or fire. The liquid almost universally employed for obtaining steam is water, but it may be obtained from alcohol, ether, and other fluids; fortunately, however, water, the most easily procured, is equal if not superior to any other.

2.—That the application of heat would generate steam from water, and that the steam so generated would isssue with much force from a small aperture in the vessel employed to generate it in, must have been known at a very early period. The eolipile, and some other similar instruments for illustrating natural phenomena, were well known among the Egyptians, Greeks, and Romans. Vitruvius, who wrote during the reign of Augustus Cæsar, refers to the eolipile as an illustration of the effect of heat in producing winds;* but he clearly had no idea of steam being rendered useful as a mechanical power. Philibert de l'Orme proposed placing an eolipile over a fire as a means of impelling smoke up a chimney,† and several applications of this instrument are described in the works of Solomon de Caus, Brancas, Van Drebbel, and various other writers, the greater part of whom are mentioned by M. Montgéry,‡ an author, who has been at considerable trouble to shew that the invention of the steam engine is not of English origin.

* Vitruvius, lib. I. cap. vi. † Traité d'Architecture, folio, Paris, 1567.

‡ Notice historique sur l'invention des machines à vapeur.

3.—But unless it be shewn that an engine had been actually invented, and was undoubtedly applicable to some of the purposes for which the steam engine is now employed, and for which alone it has become valuable, it appears to be mere trifling to search for authorities, and absolutely unworthy of occupying the time or attention of a man of real science. The blast of an eolipile is certainly not a mode of employing steam capable of producing the species of useful effect which is obtained by a steam engine, and, as a proof of its inefficiency, the same principle of action (that is by impulse) has never been rendered applicable to produce mechanical power for useful purposes in a steam engine.

It is not my object, therefore, to inquire when it was first ascertained that steam has force; but, to endeavour to trace the history of its suggestion in a practical form, and of its application in the arts and manufactures; to develope the various changes and improvements the steam engine has received; and to shew, among the host of projectors, those who have really advanced our knowledge, either regarding the principles, the construction, or the arrangement of this powerful prime mover.

It is easy to perceive that I have assigned myself a difficult task, but it is equally evident that if it be accomplished, in a judicious and candid manner, it will form a valuable addition to an interesting branch of mechanical science; hence, I am encouraged to proceed, and trust to leave my reader with an impression, that I have been just in deciding between the claimants of the invention of each of the parts of the steam engine.

1663. *Marquis of Worcester, died* 1667.

4.—The idea of employing the impulsive force of the eolipile, seems to be the only one which had been formed for using steam as a source of motion before the time of the Marquis of Worcester; and he, in a little work entitled "A Century of the Names and Scantlings of Inventions," undoubtedly describes a method of employing the pressure of steam for raising water to great heights.* His work was first published in 1663, and under the sixty-eighth invention we have the following name and scantling:—

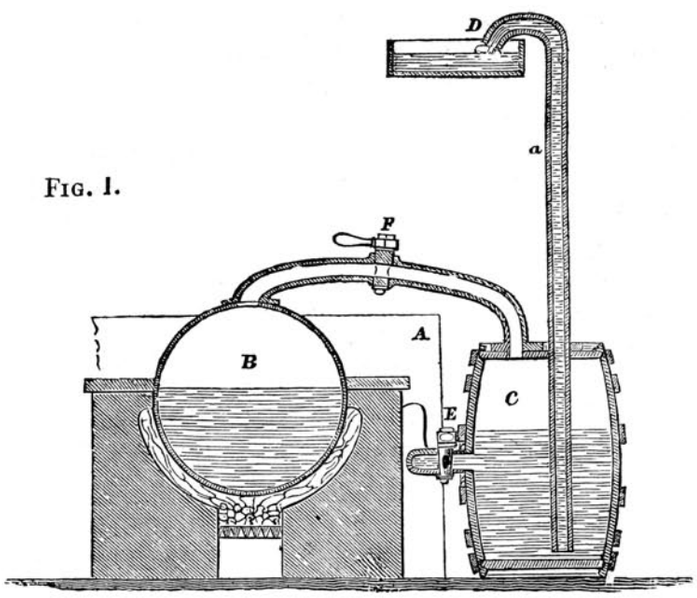
"LXVIII. *A Fire Water Work.*—An admirable and most forcible way to drive up water by fire, not by drawing or sucking it upwards; for that must be, as the philosopher calleth it, *infra sphæram activitatis*, which is but at such a distance. But this way hath no bounder if the vessels be strong enough; for I have taken a piece of a whole cannon, whereof the end was burst, and filled it three-quarters full of water, stopping and screwing up the broken end, as also the touchhole, 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 my vessels so that they are strengthened by the force within them, and the one to fill after the

* Another engine, which the marquis terms a "Water-commanding Engine," seems to have been the one for which he obtained an act of parliament, allowing him the monopoly of the profits arising from its use.

other, I have seen the water run like a constant fountain stream forty feet high. One vessel of water rarefied by fire driveth up forty of cold water. And a man that tends the work is but to turn two cocks, that, one vessel of water being consumed, another begins to force and refill with cold water, and so successively, the fire being tended and kept constant; which the selfsame person may likewisely abundantly perform in the interim between the necessity of turning the said cocks."

This description puts it beyond a doubt that the Marquis of Worcester knew that steam, heated in a close vessel, acquires an immense degree of force, and that this force could be effectively applied to raise water. The effect of condensation he does not appear to have been at all acquainted with, and therefore, his mode of operation must have been exceedingly simple, and probably, of the nature exhibited in the annexed figure:—Where B is the boiler; C, one of the vessels with a pipe to deliver the water to an elevated cistern D.

FIG. I.



Now suppose the vessel C to be supplied from a cistern of cold water A by a pipe, so that it would be filled on opening the cock E, and this cock being closed; if, when the steam in the boiler is of sufficient strength, the cock F be opened, the pressure of the steam on the water in C would cause it to ascend from C, through the pipe *a* into the cistern D. The vessel C being emptied and the cock F being shut, it would refill with water on opening the cock E. Another vessel C and its cocks and pipes are necessary to complete the

species of water engine indicated by the description, and these may be on the other side of the boiler.

Such a mode of raising water would be most expensive from the quantity of condensation when the steam came in contact with cold water, but it was fully capable of producing the quantity of effect mentioned, for it is only equivalent to raising twenty cubic feet of water or 1250 lbs. one foot high by one pound of coal, or about the 200th part of the effect of a good steam engine. Hence, it appears, that to the Marquis of Worcester must be ascribed the first invention and trial of a practical mode of applying steam as a prime mover, and of applying it to one of those great purposes for which it has been so useful to society.

1683. *Sir Samuel Morland, died* 1695.

5.—From a part of a manuscript in the Harleian collection in the British Museum, it appears that a mode of raising water by steam, similar to that of the Marquis of Worcester's, was proposed, among other methods, to Louis XIV, of France, by Sir Samuel Morland. It contains no description of the method he intended to employ, but there is sufficient to indicate that its author was not without knowledge of his subject.

The title of the part which treats of the power of steam is, "The Principles of the New Force of Fire, invented by Chev. Morland in 1682, and presented to his most Christian Majesty, 1683;" and these principles are explained as follows:—"Water being converted into vapour by the force of fire, these vapours shortly require a greater space (about 2000 times) than the water before occupied, and sooner than be constantly confined, would split a piece of cannon. But being duly regulated according to the rules of statics, and by science reduced to measure, weight, and balance, then they bear their load peaceably (like good horses) and thus become of great use to mankind, particularly for raising water, according to the following table, which shews the number of pounds that may be raised 1800 times per hour, to a height of six inches, by cylinders half filled with water, as well as the different diameters, and depths of the said cylinders."

Cylinders.		Weight of the Load to be raised.
Diam. in feet.	Depth in feet.	
1	2	15 lbs.
2	4	120 —
3	6	405 —
4	8	960 —
5	10	1875 —
6	12	3240 —

These numbers are obviously proportional to the capacity of the cylinders.

The table is continued in the original to shew the effect of a number of cylinders of the largest of the above sizes, each one being capable of raising 3240 lbs.

Morland has given the increase of volume, which water occupies in the state of vapour at common pressures, so nearly, that we may suppose it to be the result of experiment, while his allusion to the force of steam being sufficient to burst a cannon, and his proposal of the method to a foreign prince, render it probable that he was not a stranger to the volume the Marquis of Worcester had published twenty years before.

Morland's researches seem to have had little influence on the progress of the practical application of steam.

6.—In 1695, Dr. Papin suggested the idea of employing the expansion and contraction of steam to form a partial vacuum under a piston for raising water, and making the pressure of the atmosphere on the upper side of the piston the moving power.* The real authors of the atmospheric engine were very likely indebted to this suggestion, but neither Papin himself, nor his rival, Savery, discovered how to turn this suggestion to advantage. Indeed, it was proposed in a form which was not practicable, the fire was to be alternately applied to, and removed from, the cylinder, and the expansion of the water in it, by heat, was to raise the piston, and its contraction, by cooling, when the fire was removed, was to cause a partial vacuum, and, consequently, the descent of the piston was to be produced by the pressure of the atmosphere. If such a scheme was ever tried, the result must have been sufficiently discouraging for Papin to abandon it and adopt a new one, which it will be found he actually did, after seeing an engraving of Savery's engine.

1698. *Thomas Savery.*

7.—These projects were speedily followed by a direct practical application of the steam engine to raising water, for which "letters patent," were granted to Captain Thomas Savery, in July 1698, (these being the first on record granted for a steam engine,) and, Dr. Robison says, it was "after having actually erected several machines," of which, Savery gave a description in a pamphlet he published in 1699,† called "The Miner's Friend," which was republished with additions in 1702.

In June 1699, Captain Savery exhibited a model of his engine before the Royal Society; and the experiments he made with it succeeded to their satisfaction.‡ It consisted of a

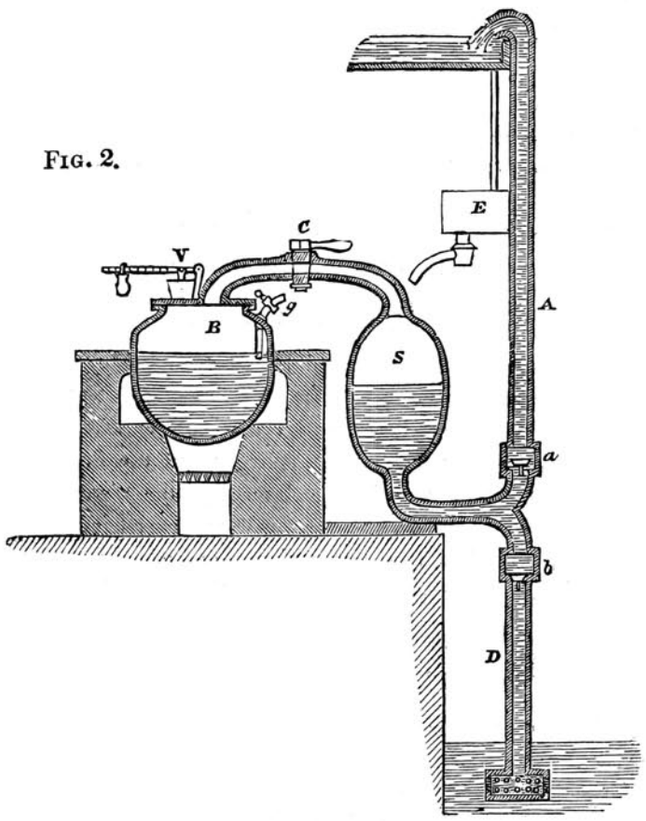
* Phil. Trans. Abridg. IV. 155, 1697.

† Robison makes it 1695, but this does not appear to be correct. Switzen's date 1699, is taken as likely to be the right one, from his System of Hydrostatics II. 326.

‡ Phil. Trans. Abridg. IV. 198, 1699.

furnace and boiler B; from the latter two pipes, provided with cocks C, proceeded to two steam vessels S, which had branch pipes from a descending main D, and also to a rising

FIG. 2.



main pipe A; each pair of branch pipes had valves *a*, *b*, to prevent the descent of the water raised by the condensation or by the force of steam. Only one vessel S is shewn, the other being immediately behind it. One of the steam vessels being filled with steam, condensation was produced by projecting cold water, from a small cistern E, against the vessel; and into the partial vacuum made by that means, the water was forced up the ascending main D, by the pressure of the atmosphere from a depth of about twenty feet; and, on the steam being let into the vessels again, the valve *b* closed and prevented the descent of the water, while the steam having acquired force in the boiler, its pressure caused

the water to raise the valve *a*, and ascend to a height proportional to the excess of the elastic force of the steam above the pressure of the air.

Captain Savery afterwards simplified this engine considerably by using only one steam vessel. To prevent the risk of bursting the boiler, he applied the steelyard safety valve V; invented by Papin for his digester. The cocks were managed by hand; and, to supply the boiler with water, he had a small boiler adjoining to heat water for the use of the large one, and thus prevent the loss of time, which must have occurred on refilling it with cold water.

Several engines for raising water appear to have been erected according to Savery's plan, and to have succeeded tolerably where the water had not to be raised more than forty feet, but this was not sufficient for mines where a new and powerful machine was most wanted.

The new principles, introduced into the steam engine by Savery, consist of the use of condensation in the steam vessel by cold applied externally. He also used a method of supplying the boiler with hot water, contrived a mode of ascertaining the quantity of water in the boiler, by inserting the cock *g*, called a gauge cock, and applied the safety valve of Papin's digester as a means of preventing accidents.

The defects of his engine are obvious. A cold vessel and cold fluid must at each operation condense, and, therefore, waste a great quantity of steam; and the height to which water could be raised, unless by the use of such powerful steam as to render it dangerous, was too limited to be applicable to mining purposes. Its effect would, however, be vastly superior to that of the Marquis of Worcester's. Whether Captain Savery did or did not know of the previous schemes, his claims to original invention are certainly considerable, and to his enthusiasm and talent, we undoubtedly owe the first effective steam engine.

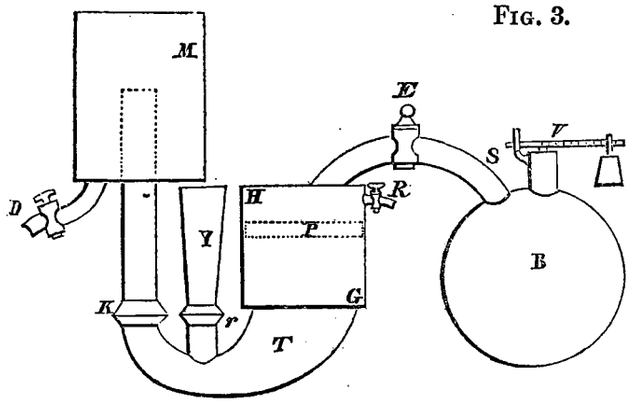
1698. *Dr. Dennis Papin.*

8.—Dr. Papin, professor of mathematics at Marbourg, whose former project I have noticed, (art. 6,) is said to have made many experiments on raising water by the force of fire in 1698, by the order of Charles, Landgrave of Hesse; and in 1707, he published a small treatise on the subject in which he ascribes to the landgrave, the whole merit of the first idea of a steam engine. Papin's trials in 1698, whatever they were, did not end in producing any thing in an useful shape; and, while he candidly acknowledges that Savery's scheme was not borrowed from any thing done in Germany, it appears that he did not follow up his experiments, till after he had seen an engraving of Savery's engine, in June 1705; a pretty conclusive argument, that no satisfactory results had been arrived at in these experiments, and there is a wide distinction between unsuccessful experiments and invention.

To do justice to the claims of Papin, it will be sufficient to describe his engine in its most improved state, and as he gives it after knowing what Savery had effected. It con-

sisted of a boiler B, provided with a safety valve *v*; and a cylinder G H, connected to the boiler by a steam pipe S. The cylinder was closed at the top, and contained a floating

FIG. 3.



piston P; and the base of the cylinder terminated in a curved tube T, which ascended into a cylinder M, the bent tube had a pipe, Y, from a reservoir of water communicating with it, and it was provided with a valve at *r*. Now suppose the cylinder G H, to be filled with cold water by the pipe Y from the reservoir, and the boiler to contain strong steam; by opening the cock E, the steam would be admitted, and, pressing on the floating piston P, cause the water to ascend into the cylinder M; its return is prevented by the valve K, and the steam cock E being shut and the cock R opened, to let the condensed steam escape at the pipe R, the water from the reservoir refills the steam cylinder through the pipe Y, and it is ready for repeating the operation. The water raised to be directed to any useful object by the pipe D.*

A reference to the Marquis of Worcester's plan will shew that Papin did no more than repeat his experiments. The scheme of adding to the effect by the introduction of red hot irons into the cylinder G H, is too absurd to insert; but it is in some measure redeemed by the suggestion that the water raised by the engine might be applied to drive a water wheel; thus giving the idea of a steam engine being applicable to impel machinery.

9.—In 1699, Mr. Amontons published a description of a machine, designed to be moved by the spring of air when expanded by heat, and afterwards condensed by contact with cold water.† The continual access of heated air to water would ultimately render the air saturated with vapour, but even then it would not be more than an air engine, and a very indifferent one, being exceedingly complex.

* Belidor's Archi. Hydrau. II. p. 328.

† Prony's Nouvelle Archi. Hydrau. II. p. 89, (note,) where it is described.

1705. *Thomas Newcomen.*

10.—The trials of Savery's engines made known their defects, yet evidently strengthened the idea that steam could be effectively applied to raise water; and the immense expense of raising water from deep mines, so embarrassed their proprietors, that there were most powerful incentives at that period to engage in further researches on the subject. To this stimulus we are indebted for another construction of the steam engine by Thomas Newcomen, a smith, of Dartmouth, who, in conjunction with John Cawley, a plumber, of the same place, and Captain Savery, obtained letters patent for the invention in 1705.* The novelty of this construction consists entirely in condensing the steam below an air-tight piston, in a cylindrical vessel having an open top; and the idea was very probably taken from the project of Papin in 1695, (see art. 6.:) for it appears that Newcomen was in correspondence with Dr. Hook on the subject, to whom the speculations of Papin were well known; but the mode of effecting the object was entirely different from Papin's. It consists in admitting steam below a piston; and, at first, the steam was condensed by applying cold water to the outside of the cylinder; but injection of cold water by a jet into the interior was soon found to be a more effective method, and is said to have been discovered by accident.† The following is a description of the engine, as far as it was improved by Newcomen. B represents the boiler with its furnace for producing steam, and at a small height above the boiler is a steam cylinder, C, of metal, bored to a regular diameter, and closed at the bottom; the top remaining open. A communication is formed, between the boiler and the bottom of the cylinder, by means of a short steam pipe S. The lower aperture of this pipe is shut by the plate *p*, which is ground flat, so as to apply very accurately to the whole circumference of the orifice. This plate is called the regulator, or steam cock, and it turns horizontally on an axis *a*, which passes through the top of the boiler, and is fitted steam-tight; and has a handle *b* to open and shut it.

* Switzer says, on report, that Newcomen was as early in his invention as Savery. Sys. of Hydros. ii. 342.

† Desaguliers' Experimental Philosophy, ii. p. 533. The piston was kept tight by a quantity of water on the top of it; and as they were working by condensing from the outside, they were surprised to see the engine make several strokes very quickly, and found that it was owing to a hole in the piston letting down water to condense the steam. This suggested the idea of injection.

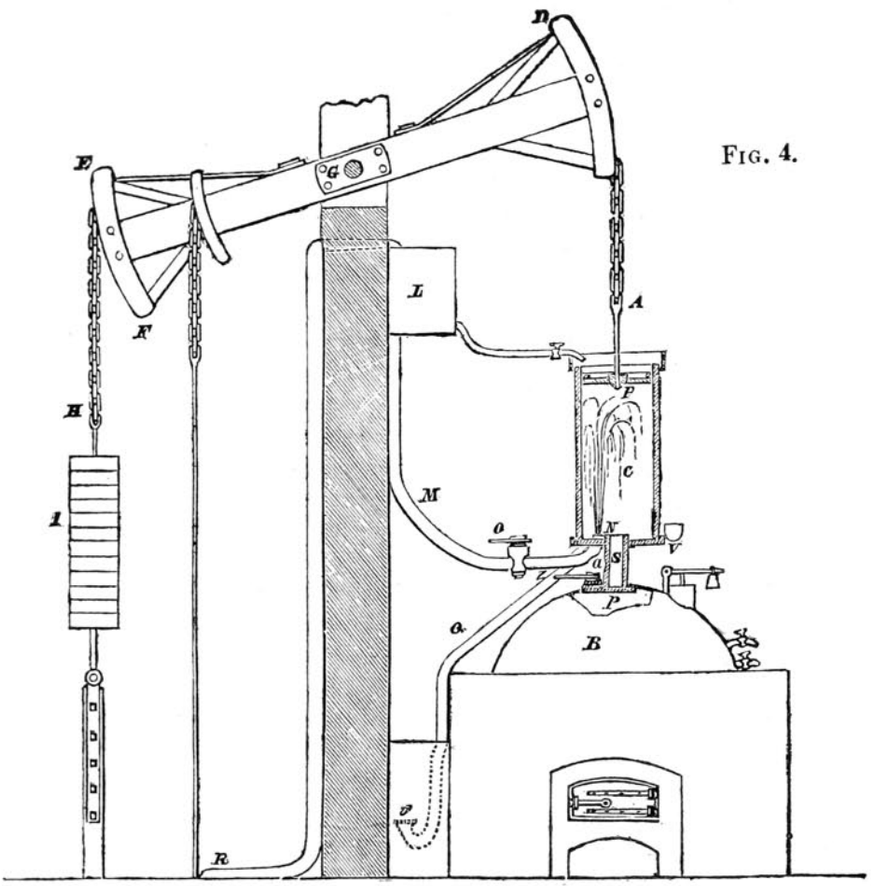


FIG. 4.

A piston P is fitted to the cylinder, and rendered air-tight by a packing round its edge of soft rope, well filled with tallow, to reduce the friction, and its upper surface is kept covered with water to render it steam-tight. The piston is connected to a rod P A, which is suspended by a chain from the upper extremity D of the arched head of the lever, or working beam, which turns on the gudgeon G. This beam has a similar arched head E F, at its other end, for the pump rod H, which receives the water from the mine. The end of the beam to which the pump rod is attached, is made to exceed the weight and friction of the piston in the steam cylinder; and when the water is drawn from such a depth, that the pump