ARAGO, Dominique François Jean

# LIFE

OF

# JAMES WATT.

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WITH

MEMOIR ON MACHINERY CONSIDERED IN RELATION TO
THE PROSPERITY OF THE WORKING CLASSES.

BY M. ARAGO.

TO WHICH ARE SUBJOINED,

HISTORICAL ACCOUNT OF THE DISCOVERY OF
THE COMPOSITION OF WATER,

BY LORD BROUGHAM;

AND

EULOGIUM OF JAMES WATT,

BY LORD JEFFREY.

THIRD EDITION,

WITH ILLUSTRATIVE NOTES AND ENGRAVINGS ON WOOD.

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# ADVERTISEMENT.

The following translation of Arago's Memoir of Watt has been republished from the October Number of the Edinburgh New Philosophical Journal.

The intrinsic interest of the subject, and the labour bestowed upon the translation, encourage the publishers to believe that the present Memoir will be an acceptable contribution to the scientific biography of this country.

The Memoir on Machinery, by the same distinguished author, has been considered an appropriate addition to the Life of a man who has done so much to extend its power and usefulness.

The eloquent Panegyric by Lord Jeffrey, and the Account of the Discovery of the Composition of Water by Lord Brougham, it is hoped, will still further enhance the interest of the

Work, and recommend it alike to the man of science and the general reader.

To the present Edition have been added a variety of Wood Engravings, illustrative of the text. For the notes marked N, as well as for all the descriptions of the engravings, the publishers have been indebted to Mr James Newlands, Architect and Engineer, whose research and accurate knowledge of the subject eminently qualify him for the task.

It is, therefore, believed that the present edition will be found still more worthy of the attention of the public than those which have preceded it.

EDINBURGH, 27 NORTH BRIDGE,
*7th December* 1839.

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Gentlemen,—After perusing the long list of battles, assassinations, plagues, famines, and direful calamities of all sorts, which the annals of some country presented, a philosopher exclaimed, " Happy the country whose history is uninteresting !" To this apophthegm another may, with great propriety, be added, at least in a literary point of view, namely, " Hard the task of the man who is called to recount the history of a happy people !" If the exclamation of the philosopher lose nothing of its force when applied to individuals, its counterpart frequently, with equal truth, characterizes the task of the biographer. Such has been the nature of my reflections while studying the life of James Watt, and while collecting the kind communications of the relatives, the acquaintances, and the friends of the illustrious mechanist. That life, devoted to labour, to study, and to meditation, furnishes none of those striking events whose recital, thrown with a little address among the details of science, tempers their dulness. I shall, however, relate it, were it for no other reason than to shew in how humble a sphere were elaborated those mighty projects which were destined to elevate the British nation to an unheard of height of power; and I shall endeavour more particularly to characterize with minute accuracy those splendid inventions which will for ever associate the name of Watt with the steam-engine. I am well aware of the disadvantages which attend this plan, and am prepared for the criticism: "We expected an historical eloge, and have heard only a dry and barren lecture." If my discourse, however, be comprehended, I shall willingly submit to the reproach. I shall do my best not to fatigue your attention, remembering that clearness constitutes politeness in a public speaker.

*Childhood and Youth of James Watt; his appointment as Instrument-maker to the University of Glasgow.*

James Watt, one of the eight Foreign Associates of the Academy of Sciences, was born at Greenock in Scotland on the 19th day of January in the year 1736. Our neighbours on the other side of the Channel, have the good taste to think, that the genealogy of a respectable and industrious family is as worthy of preservation, as the musty parchments of some titled houses which have become celebrated only by the enormity of their vices or their crimes. Hence it is that I can state with certainty that the great-grandfather of James Watt was a farmer settled in the county of Aberdeen; that he fell in one of Montrose's battles; that the conquering party, as was then the custom (and I was going to add as is still the practice in civil broils), did not consider death as sufficient expiation for those opinions on account of which the poor farmer had bled; that they, moreover, punished him in the person of his son, by confiscating his small property; that this unfortunate child, whose name was Thomas Watt, was taken care of by some distant relations; that, in the very isolated situation to which he was thus reduced, he devoted himself to serious and assiduous study; that, in more tranquil times, he established himself in Greenock, where he taught mathematics and the elements of navigation; that he resided in the Burgh of Barony of Crawford's-dyke, of which, for several years, he held the office of baron-bailie, or, in other words, was chief magistrate; and that, finally, he died in the year 1734, at the age of ninety-two years.*

Thomas Watt had two sons. The elder, John, followed, in the city of Glasgow, the occupation of his father. He died in the year 1737, at the age of fifty, having executed a chart of the course of the river Clyde, which was subsequently published under the direction of his brother *James*. This last-named individual, the father of the celebrated engineer, was, during the quarter of a century, councillor, treasurer, and bailie of Greenock, having declined the office of chief magistrate, and was celebrated for the ardent zeal,

* On his gravestone he is designated "Professor of Mathematics."—EDIT.

and the enlightened spirit of improvement, with which he discharged his duties. He was a pluralist (and let no one be alarmed at these three syllables, which have now in France become the object of general anathema; they injure not the memory of James Watt),—he combined three different kinds of occupation; he furnished the several kinds of apparatus, utensils, and instruments which are necessary for navigation; he was also a builder and a merchant; notwithstanding which, towards the close of life, he unfortunately suffered severely from some commercial enterprizes which deprived him of a portion of that honourable fortune he had previously acquired. He died at the age of eighty-four, in the year 1782.

James Watt, the subject of this memoir, was in infancy an exceedingly delicate child. His mother, whose family name was Muirhead, was his first instructor in reading, whilst his father taught him writing and arithmetic. He also attended the elementary public school at Greenock; so that the humble *grammar schools* of Scotland may boast of having educated the celebrated engineer, in the same way that the

*Collège de la Flèche* was wont to enumerate Des Cartes, and Cambridge to the present day prides itself on Newton. To be minutely accurate, however, I ought to add, that habitual indisposition interfered with young Watt's regular attendance at the public school of Greenock; and that, for a great part of the year, he was confined to his chamber, where he devoted himself to study, without any extrinsic aid. As often happens, his superior intellectual faculties, destined to produce such valuable results, began to develope themselves in retirement and meditation.

Watt was so delicate that his parents did not venture to impose any thing in the shape of severe tasks upon him; they left him very much at liberty in the choice of his occupations, and it will be seen he did not abuse the indulgence. A gentleman one day calling upon Mr Watt, observed the child bending over a marble hearth, with a piece of coloured chalk in his hand; "Mr Watt," said he, "you ought to send that boy to a public school, and not allow him to trifle away his time at home." "Look how my child is employed, before you condemn him," replied the father. The gentleman then observed that the child had drawn mathematical lines and circles on the hearth. He put various questions to the boy, and was astonished and gratified with the mixture of intelligence, quickness, and simplicity displayed in his answers : He was then trying to solve a problem of geometry. Influenced by his parental solicitude, Mr James Watt very early put a number of tools at the disposal of the young scholar, who very soon used them with the greatest possible address. He would take to pieces and again put together the various toys that came within his reach, and he was very active in making new ones. Somewhat later he undertook the construction of a small electrical machine, whose brilliant sparks became a lively source of amusement and surprise to his young companions.

Watt, with an excellent memory, might, nevertheless, not have peculiarly distinguished himself among the youthful prodigies of ordinary schools. He never could have learned his lessons like a parrot, for he experienced a necessity of carefully elaborating the intellectual elements presented to his attention, and Nature had peculiarly endowed him with the faculty of meditation. Upon the whole, Mr James Watt augured most favourably of the nassent powers of his child. Some other of his more distant relatives, less discerning, did not share in these hopes. His aunt, Mrs Muirhead, sitting with him one evening at the tea-table, said, "James, I never saw such an idle boy! Take a book, or employ yourself usefully. For the last half hour you have not spoken a word, but taken off the lid of that kettle and put it on again, holding now a cup and now a silver spoon over the steam; watching how it rises from the spout, and catching and counting the drops of water it falls into." It appears that when thus blamed, his active mind was engaged in investigating the condensation of steam.

Who among us, if we had been placed in the same circumstances as Mrs Muirhead, would not, in the year 1750, have resorted to the same language! But the world since that time has advanced, and our knowledge has increased. Moreover, when I shall speedily explain that the principal discovery of our associate consisted in a particular method of converting steam into water, Mrs Muirhead's reproaches will appear to us in a very different light; the boy pondering before the tea-kettle will be viewed as the great engineer preparing discoveries which were soon to immortalize him; and it cannot but appear remarkable that the words *condensation of steam* should come, as it were, naturally to present themselves in the history of the infancy of Watt. I have the more willingly alluded to this singular anecdote, because, for its own sake, it richly merits preservation. And, as the occasion has presented itself, let us impress on youth that it was not modesty alone which prompted the response of Newton, when, in reply to a certain great personage who inquired how the principle of gravity was discovered, he answered, "*By always thinking of it!*" Let us point out, in these simple words of the great author of the *Principia*, what is the true secret of men of genius.

The extraordinary felicity of anecdote with which our associate, for fifty years, delighted all those with whom he associated, very early developed itself. The proof of this will be found in a few lines which I extract from an unpublished note written in the year 1798, by Mrs Marion Campbell, the cousin and youthful companion of the celebrated engineer.* "He was not fourteen,

* I am indebted for this curious document to my friend Mr James Watt of Soho. Thanks to the profound venera-

when his mother brought him to Glasgow to visit a friend of hers; his brother John accompanied him. On Mrs Watt's return to Glasgow some weeks after, her friend said, "You must take your son James home; I cannot stand the degree of excitement he keeps me in; I am worn out for want of sleep. Every evening before ten o'clock, our usual hour of retiring to rest, he contrives to engage me in conversation, then begins some striking tale, and, whether humorous or pathetic, the interest is so overpowering, that the family all listen to him with breathless attention, and hour after hour strikes unheeded."

James Watt had a younger brother, John,* who, having determined to follow the career of his father, left the other, according to the Scottish custom, at liberty to indulge his own taste in selecting his profession. In the present case,

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tion he has preserved for the memory of his illustrious father, and still more to the exhaustless kindness with which he has answered all my inquiries, I have through his means been able to avoid various inaccuracies which have found their way into the most esteemed biographies, and which I myself, from partial information, had not been able at first to avoid.

* He was lost in one of his father's vessels on a voyage from Greenock to America, in 1762, aged 23.

however, this was unusually difficult, for the young student prosecuted almost every branch of science with equal success. The banks of Loch Lomond, already so celebrated by the recollections of the historian Buchanan, and by those of the illustrious inventor of Logarithms, developed his taste for the beauties of nature and for botany. His rambles among the mountain-scenery of Scotland made him perceive that the inert crust of the globe was not less worthy of attention, and he became a geologist. James also took advantage of his frequent intercourse with the humbler classes in those enchanting regions, for the purpose of decyphering their local traditions, their popular ballads, and their wild prejudices. When his state of health confined him to his father's dwelling, it was chiefly chemistry which formed the subject of his investigations. s'Gravesande's *Elements of Natural Philosophy* initiated him also into the thousand marvels of general physics; and finally, like all valetudinarians, he devoured such works on medicine and surgery as he could procure. These last sciences had so much excited his interest, that he was one day detected conveying into his room the head of a child which had died of some obscure disease, that he might take occasion to dissect it.

Watt, however, did not devote himself either to botany or to mineralogy, to literature or poetry, or chemistry, or physics, or medicine, although he was so well prepared for the prosecution of any one of these various studies. In the year 1755 he went to London, and there placed himself under the instructions of *Mr John Morgan*, mathematical and nautical instrument-maker in Finch Lane, Cornhill. The man who was about to cover England with engines, in comparison with which, so far at least as effects are concerned, the antique and colossal machine of Marly is but a pigmy, commenced his career by constructing, with his own hands, instruments which were fine, delicate, and fragile,—those small but admirable reflecting sextants to which navigation is so much indebted for its progress. He did not continue with Mr Morgan much above a twelvemonth, and "in the year 1757 went to settle in Glasgow, as a maker of mathematical instruments; but being molested by some of the corporations, who considered him as an intruder on their privileges, the University protected him, by giving him a shop within their precincts, and by conferring on him the title of mathematical instrument maker to the University."* There are still in existence some small instruments which were at this time made entirely by Watt's own hands, and they are of very exquisite workmanship. I may add, that his son has lately shewn me the first designs of the steam-engine, and they are truly remarkable for the delicacy and precision of the drawing. It was not without reason, whatever may be said of it, that Watt spoke with complacency of his manual dexterity. Perhaps you will think me over scrupulous in thus claiming for our associate a merit which adds but little to his glory. But I confess that I never listen to a pedantic enumeration of the qualities of which able men have been destitute, without thinking of that would-be general in Louis XIV.'s time, who always carried his right shoulder high, because Prince Eugene had this deformity, and imagined that imitating him in this point, it was unnecessary to carry the resemblance any farther.

Watt had scarcely attained his twenty-first year when he was thus connected with the University of Glasgow. His principal friends on the occasion were Adam Smith, the author of The

* MS. of Dr Black.

Wealth of Nations; Dr Black, whose discoveries respecting latent heat and the carbonate of lime have placed him among the first chemists of the eighteenth century; and Robert Simson, the celebrated restorer of the most important works of the ancient geometricians.* These eminent men at first only considered that they had relieved from the vexatious annoyances of the corporations, an expert, zealous, and agreeable workman; but they soon discovered that he was, moreover, a remarkable man, and expressed towards him the warmest friendship. The youth attending the University also considered it an honour to be admitted to his intimacy; so that *his shop*—I repeat, his shop became a kind of academy whither the most eminent persons in Glasgow resorted, to talk over the most difficult questions of art, science, and literature. Nor, in truth, should I venture to describe to you the part that the young workman of twenty-one took in these discussions, if I could not do so in the unpublished words of one of the most illustrious contributors to the Encyclopædia Britannica. " I

* To these it is only an act of justice to add Dr Dick, Professor of Natural Philosophy, of whose merits Professor Robison and Watt always spoke in terms of eulogy.—Edit.

had always, from my earliest youth," writes the late Professor Robison,* "a great relish for the natural sciences, and particularly for mathematical and mechanical philosophy. When I was introduced by Drs Simson, Dick, and Moor, gentlemen eminent for their mathematical abilities, to Mr Watt, I saw a workman, and expected no more; but was surprised to find a philosopher, as young as myself, and always ready to instruct me. I had the vanity to think myself a pretty good proficient in my favourite study, and was rather mortified at finding Mr Watt so much my superior. . . . . Whenever any puzzle came in the way of any of the young students, we went to Mr Watt. He needed only to be prompted; for every thing became to him the beginning of a new and serious study, and we knew that he would not quit it till he had either discovered its insignificancy, or had made something of it. He learnt the German language in order to peruse Leopold's Theatrum machinarum. So did I, to know what he was about. Similar rea-

* An interesting letter by Watt, containing an account of his connexion with Dr Black and Professor Robison, as well as remarks on the origin of his improvements on the Steam-Engine, will be found in the Edinburgh Philosophical Journal, vol. ii. p. 1.—Edit.

sons made us both learn the Italian language. * * * When to his superiority of knowledge is added the *naïve* simplicity and candour of Mr Watt's character, it is no wonder that the attachment of his acquaintance was strong. I have seen something of the world, and am obliged to say I never saw such another instance of general and cordial attachment to a person whom all acknowledged to be their superior. But that superiority was concealed under the most amiable candour, and a liberal allowance of merit to every man. Mr Watt was the first to ascribe to the ingenuity of a friend, things which were nothing but his own surmises followed out and embodied by another. I am the more entitled to say this, as I have often experienced it in my own case."* It is for you, gentlemen, to determine whether it was not as honourable to have expressed this concluding sentiment as to have inspired it.

The diversified and profound studies in which the circumstances of his singular position unceasingly engaged the young artisan of Glasgow, were never allowed to interfere with the labours of the workshop. These he executed during the course of the day, whilst the night was devoted to theoretical researches. Confiding in the re-

* MS. of the late Professor Robison.

sources of his fertile imagination, Watt appeared to luxuriate in the most difficult undertakings, and in those which might be thought most foreign to his tastes. Will it be believed that he undertook the building of an organ, though totally insensible to the charms of music, so much so that he could not distinguish one note from another? Nevertheless the work was accomplished. It is scarcely necessary to say, that the new instrument exhibited important improvements in the mechanical details,—in the regulators, and in the manner of measuring the force of the wind; but one is surprised to learn, that its powers of harmony were not less remarkable, and that they delighted professional musicians. Watt, in fact, resolved an important part of a very difficult problem; he made out the scale of *temperament* by the method of pulsations (des battements), at that time little understood, and the knowledge of which he could not have obtained except in the profound but very obscure work of Dr Robert Smith of Cambridge.

### *History of the Steam-Engine.*

We are now arrived at the most brilliant period of the life of Watt; and I fear also at the most difficult part of my task. The immense importance of the inventions of which I am about to treat, cannot for a moment be doubted ; but possibly I may not succeed in making them clearly understood, without going into minute numerical comparisons. That these comparisons, if they do become indispensable, may be readily followed, I shall here state, as briefly as possible, the abstract physical principles upon which they must be based.

As the result of simple change of temperature, water may exist in three perfectly distinct states, —in the solid, the liquid, and the gaseous state. Below 32° Fahr. water becomes ice, at 212° it is rapidly transformed into vapour, and in all the intermediate degrees it is liquid.

The careful observation of the points of passage from one of these conditions into another, leads to discoveries of the highest importance, which form the key to the economical appreciations of steam-engines.

Water is not necessarily warmer than is every kind of ice ; water may be maintained at the temperature of 32° without freezing ; ice may continue at 32° without melting ; but it is very difficult to believe that this water and this ice, both of them at one and the same degree of temperature, differ only in their physical properties, and that there is not some element, apart from water properly so called, which distinguishes the solid water from the liquid water. A very simple experiment will elucidate this mystery. Mix two pounds* of water at the freezing point with two pounds at 167° Fahr., the four pounds of the mixture will be found to be at 99°, that is to say, at the mean temperature of the commixed liquids. The hot water is thus found to have preserved 67° of its previous temperature, and to have yielded 67 other degrees to the cold water. All this is what would readily be expected, and could easily be foreseen. And, now, let us repeat the experiment with a single modification. Instead of the two pounds of water at the freezing point, let us take two pounds of ice at precisely the same temperature. From the mixture of this two pounds of ice with the two pounds of water at the temperature of 167°, there will result four pounds of liquid water, since the ice, plunged into the hot water, must needs be dis-

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* In this illustration, the fractions arising from the differences of the thermometric scales are omitted, and hence the figures are only approximatively correct.—EDIT.

solved, and will yet retain its former weight; but you must not conclude that, from this second mixture, there will result as from the former a temperature of 99°. Very far from it; in this latter experiment, the water will not be above the freezing point, and there will not remain a single trace of the 135° of the heat of the two pounds of water: these 135° will have dissolved all the particles of the ice, and have combined with them, but without having heated them in the slightest degree.

I have no hesitation in adducing this experiment of Dr Black's as one of the most remarkable in modern physics. Observe its consequences. Ice, at its habitual temperature 32°, and water at the same temperature, differ in their essential composition. The liquid, in addition to what is contained in the solid, includes 135° of an imponderable body which is called *caloric.* These 135° are so thoroughly concealed in the compound, I was about to say the watery alloy, that the most delicate thermometer cannot detect its existence. Hence, then, caloric, which is not discoverable by our senses, and which cannot be detected by the most delicate instruments,—in short, *latent heat*, for that is the name which has been bestowed upon it, forms one of the constituent principles of bodies.

The comparison of boiling water, that is to say of water at 212°, with the steam which issues from it, and whose temperature is also 212°, leads to analogous results, but upon a much grander scale. At the moment that steam, at the temperature of 212°, is produced, the water, at the same temperature of 212°, impregnates itself,—*under the form of latent caloric*,—under a form quite insensible to the thermometer,—with an enormous quantity of heat. Again, when the steam reassumes the liquid state, this caloric of composition is disengaged, and goes to heat every thing in its way which is susceptible of absorbing it. If, for example, we were to cause two pounds of steam at 212°, to pass through ten pounds of water at the freezing point, the steam would be wholly liquefied, and the twelve pounds which would result from the mixture would be found at the temperature of 212°. Into the intimate composition of two pounds of steam, there enters therefore a quantity of latent caloric sufficient to raise two pounds of water, whose evaporation is prevented, from the freezing point to the height of 995° Fahr. This result will, without doubt, appear enormous, but it is quite certain. Steam exists only upon this condition. Where-ever two pounds of water at the freezing point are evaporated, whether naturally or artificially, in undergoing the transformation, they must seize upon, and in fact do seize upon, 995° of caloric derived from surrounding objects. This number of degrees (for it cannot be too often repeated), the steam entirely restores to the surfaces of whatever nature, upon which the condensation is ulteriorly effected. And here, we may remark in passing, is the whole secret connected with the art of heating by steam. That individual would have a very erroneous idea of this ingenious contrivance, who supposed that the steam conveyed to a distance in the tubes in which it circulates, nothing more than sensible or thermometric heat. The chief effects are, beyond all doubt, owing to the caloric of composition—the hidden or latent heat—which is disengaged at the moment when the contact of the cold surfaces converts the vapour from the gaseous into the liquid state. We must therefore rank caloric among the constituent principles of steam. Caloric is obtained only by the combustion of wood, coal, &c. Steam therefore has a commercial value superior to that of the liquid, by the whole price of the combustible employed in the process of vaporization. If the difference of these two values be very great, it is to be attributed mainly to the latent caloric; the thermometric and sensible heat forms but a small portion of it.

I shall probably have occasion, in the sequel, to return to some of the other properties of steam. If I do not insist upon them at present, it assuredly is not because I attribute to this assembly the state of mind of certain students, who one day observed to their mathematical professor, "Why are you taking all this trouble to demonstrate these theorems? We repose entire confidence in you; give us only your *word of honour*, and that will suffice." But I feel anxious not to abuse your patience; and I ought also to remember that, by referring to particular treatises, you will readily supply the omissions which I shall find it impossible to avoid.

Let us now endeavour to assign the share of merit which is due to the several nations and individuals who should be enumerated in the history of the steam-engine, and trace the chronological series of improvements which this machine has undergone, from its first rude conceptions, now somewhat antiquated, down to the discoveries of Watt. I approach this inquiry with the firm determination of being impartial,—with the most earnest solicitude to bestow on every improver the credit which is his due,—and with the fullest conviction that I am a stranger to every consideration unworthy of the commission you have conferred upon me, or beneath the dignity of science, originating in national prejudices. I declare, on the other hand, that I esteem very lightly the innumerable decisions which have already emanated from such prejudiced sources; and that I care, if possible, still less for the bitter criticisms which undoubtedly await me, for the past is but the mirror of the future.

*A question well propounded is half answered.* If this sentiment, so full of truth, had always been kept in mind, the discussions concerning the invention of the steam-engine would assuredly never have presented that character of acrimony and violence which has hitherto been stamped upon them. By seeking to discover a single inventor, where it was necessary to recognise many, we have been "in endless mazes lost." The watchmaker, the most deeply versed in the history of his art, would remain dumb before the man who would ask him in general terms, who was the inventor of the watch? The question, on the contrary, would occasion him but little embarrassment, if directed separately to the spring, to the different forms of the escapement, to the balance-wheel, &c. So it is with the steam-engine: it now exhibits the realization of various capital but wholly distinct ideas, which could not have emanated from the same source, and of which it is now our duty to search carefully for the origin and the date.

If to have employed steam in any way whatever confers a right, as has been pretended, to figure in this history, we must cite the Arabians in the first rank, since, from time immemorial, their principal food, the pudding which they call *couscoussou*, is boiled by the action of steam in drainers placed upon their rude pots. Such a conclusion shews only the absurdity of the principle from which it is deduced.

Our compatriot Gerbert, who afterwards wore the triple crown under the name of Silvester II.,—had not he, it may be inquired, a superior claim, when, in the ninth century, he made the organ of the Rheims Cathedral resound by means of steam? I think not. For in the instrument of the future Pope, I see nothing more than a current of steam substituted for the common current of air, so producing the musical phenomena of the organ pipes, but without accomplishing any mechanical effect properly so called.

I find the first example of motion produced by steam in a toy much more ancient than the organ of Gerbert, viz. in the *Eolipyle* of Hero of Alexandria, the date of which ascends to 120 years before our era.* It will perhaps be difficult, with-

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* Hero the Elder, was the son of a Greek who had settled at Alexandria: he flourished in the reign of Ptolemy Philadelphus. "At an early age, the strong bent of his mind towards mechanical pursuits (says Stuart), attracted the notice of the celebrated Ctesibius; and the after friendship of that philosopher was the reward of his application and merit. Under his guidance, Hero aspired to celebrity as a follower of Democritus in philosophy; and some beautiful discoveries in mechanics recompensed the study of a long life, assiduously devoted to their cultivation.

"Tried by the high standard of even modern attainment, several of the machines described by Hero may be compared with the most useful, or the most ingenious, of those which have been appealed to as proud monuments, placing our own age at an immense distance beyond every other in mechanical invention. The fountain for raising water by the compression of air remains as he left it. The mode of out the help of figures, to give a clear conception of the mode in which this little piece of apparatus acts ; but I shall nevertheless make the attempt. When a gas escapes in a given direction from the vessel which contains it, this vessel has a tendency to move in a diametrically opposite direction, owing to the force of the reaction. The recoil of a musket when discharged is nothing more than this. The gas produced by the inflammation of the saltpetre, charcoal, and sulphur, issues

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forming a vacuum, by sucking the air from a vessel, and producing a blast by a fall of water, are to be found in his "Spiritalia;" and the construction of the fire-engine was first learned from his descriptions.

"In thirteen problems, Hero operates by the action of heat on air or water. In two, the doors of a temple are opened and shut by means of the rarefaction of air, produced by its coming into contact with the heated hearth of an altar; in another, water or wine is raised by the same means, and made to flow on the sacrifice, to assist in its combustion : this is combined with the hissing of a dragon in a fourth; and a rotatory motion is imparted to a small stage, on which automata are placed in a fifth. Hero was likewise the inventor of many toys, in which, as in the engine of the present day, the elasticity of steam of a low temperature was directly applied to produce motion. For drawings and descriptions of these, see the new edition of the Encyclopædia Britannica, article Steam.—N.

into the air in the direction of the barrel; that direction prolonged backwards, abuts at the shoulder of the person who has discharged it, and it is upon the shoulder therefore that the gunstock acts with violence. To change the direction of the recoil, all that is necessary is to change the direction in which the gas issues. If the barrel, closed at its extremity, were pierced by a lateral opening at right angles to its direction and horizontal, it would be laterally and horizontally that the gas of the powder would escape,—it would be at right angles that the barrel would produce its recoil,—and it would be upon the arm, and not upon the shoulder, that it would be felt. In the former instance, the recoil operates upon the individual who has fired the piece, from before backwards, with a tendency to throw him down; in this latter instance, it would have a tendency to make him whirl round upon himself. Were we then to attach the barrel, constantly and in a horizontal position, to a moveable vertical axis, at the moment of being discharged it would more or less change its direction, and would cause that axis to revolve upon itself. Still maintaining the same arrangement; suppose now, that the vertical rotative axis is hollow, but closed at its upper extremity, that it abuts at its lower extremity, like a sort of chimney in a boiler producing steam, and that, moreover, there exists a free lateral communication between the interior of the axis and the interior of the gun-barrel, so that the steam, after having filled the axis, penetrates into the barrel, and issues from it at the side by its horizontal opening,—then this steam, in escaping, will act, except in the degree of its intensity, in the same manner as the gas disengaged from the powder in the gun-barrel which was stopped at its extremity and pierced laterally; only that, in this instance, we shall not have a simple shock merely, as happens in the violent and instantaneous explosion of the musket, but, on the contrary, the rotatory motion will be uniform and continuous, as the cause which produces it: and finally, were we, instead of having a single musket, or rather a single horizontal pipe, to adapt a number of them to a rotatory vertical tube, then we should have before us, with some unessential differences, the ingenious apparatus of Hero of Alexandria.

Here, then, beyond doubt, is a machine in which steam produces motion, and may cause mechanical effects of some importance; in fact, it is a steam-engine. It is scarcely, however, necessary to add, that it has no real resemblance, either as regards form, or the mode of action of the moving force, to the engines which are now in use.* Were, however, the reaction of a current of steam ever to become practically useful, it would unquestionably be right to trace the idea back as far as Hero; at the present day, the rotatory Eolipyle can be introduced here, only as wood-engraving is mentioned in the history of printing.†

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* The engine of Avery the American, is, in its principle and mode of action, precisely like that of Hero, and is now in pretty general use in this country, a fact of which M. Arago does not seem to be aware. One of these engines, of six horses' power, may be seen at work on the farm of Pilton in the neighbourhood of Edinburgh.

† These remarks apply likewise to the project which Branca, an Italian architect, published at Rome in the year 1629, in a work entitled *The Machine*, and which consisted in producing a movement of rotation by directing the steam issuing from an eolipyle, under the form of a blast of wind, upon the winglets of a wheel. If, contrary to all probability, steam should ever be employed in the form of a direct blast, Branca, or the now unknown author from whom he borrowed this idea, would take the first place in the history of this new kind of machines. As it respects those at present in use, the claims of Branca are absolutely null.—N.

In the steam-engines of our manufactories, our steam-vessels, and railroads, the motion is the immediate result of the elasticity of the steam. Hence we must inquire where and how the idea of this power took its origin.

The Greeks and Romans were not ignorant that steam might acquire a prodigious mechanical power; for they explained, with the help of the sudden vaporization of a certain quantity of water, those frightful earthquakes which in a few moments force the ocean from its wonted bed, overturn to their foundations the most solid monuments of human industry, suddenly produce considerable islands in the midst of deep seas, and uplift high mountains in the centre of continents.

Though the contrary has been asserted, it does not appear that this theory of earthquakes presupposes that those who were its authors had engaged in any calculations, experiments, or exact measurements. Every one at the present day knows the fact, that if at the moment a boiling metal enters into the earthy or plaster moulds of the founder, but a few drops of liquid be enclosed in the moulds, the most dangerous explosions follow. Notwithstanding the progress of science, founders, even now-a-days, do not always escape these accidents; and we have no reason to suppose that the ancients were free from them. While casting, then, their innumerable statues, the splendid ornaments of their temples and public resorts, of their gardens and private mansions at Athens and at Rome, many accidents must have occurred; the artists themselves must have discovered the immediate cause; whilst the philosophers on their part, following that tendency to generalization which was the characteristic feature of their schools, would here behold in miniature a true image of the eruptions of Etna. Now, all this might be true without having the slightest relation to the history with which we are now engaged; and I would not even have insisted so much upon these slight traces of the science of the ancients regarding the power of steam, were it not that I might live at peace with the Daciers of both sexes, and with the Dutens of our own day.*

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* Influenced by the same motive, I can scarcely avoid mentioning here an anecdote, which, besides its romantic character, and its inconsistency with what we now know of the mode of the action of steam, shews us also the high idea which the ancients entertained of the power of this

Powers, whether natural or artificial, previous to becoming really useful to mankind, have almost always wrought wonders in support of superstition; and steam has been no exception to this general rule.

Chroniclers have informed us, that, upon the banks of the Weser, the god of the ancient Teutonic race manifested his displeasure by a kind of thunderbolt, to which, immediately afterwards, succeeded a cloud that filled the sacred enclosure. The image of the god *Busterich*, discovered, it is said, in some excavations, clearly demonstrates the mode in which this prodigy was produced. The god was made of metal. The hollow head contained water to the amount of an amphora; plugs of wood closed the mouth, and another opening situated under the fore-

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mechanical agent. It is stated that Anthemius, the architect of Justinian, had a dwelling contiguous to that of Zeno, and that, to annoy the orator, who was his declared foe, he placed beneath the ground-floor of his own house a number of great caldrons, which he filled with water; that from an opening made in the lid of each of these, proceeded a flexible tube, which was directed into the partition wall, under the beams that supported the ceilings of Zeno's mansion; and finally, that these ceilings actually shook as if from a violent earthquake, when fires were lit beneath the caldrons.

head, and combustibles suitably placed in a cavity of the cranium gradually heated the liquid. Speedily the steam generated caused the plugs to spring with a loud report, and then escaped with violence, forming a thick cloud between the god and his astonished worshippers. It appears also, that, in the middle ages, the monks found this to be a very valuable invention, and that the head of Busterich has performed before other assemblies besides those of the benighted Teutones.*

After these faint glimmerings of the Greek philosophers, we must pass over an interval of nearly twenty centuries, before we meet with

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* Hero of Alexandria attributed those sounds, the objects of so much controversy, which the statue of Memnon produced when the rays of the rising sun darted upon it, to the passage, through certain openings, of a current of steam, which the heat of the sun was thought to have produced, at the expense of the liquid, which the Egyptian priests placed, it was said, in the interior of the pedestal of the Colossus. Solomon de Caus, Kircher, and others, have gone so far as to investigate the particular arrangements by means of which the priestly fraud was palmed upon the credulous. It appears evident, however, that their explanations are erroneous, if, indeed, there existed any thing of the sort requiring explanation.

any useful notions concerning the properties of steam. From that time onwards, experiments, precise, conclusive, and irresistible, take the place of mere idle conjectures.

In the year 1605, Flurence Rivault, a gentleman of the bedchamber to Henri IV., and the preceptor of Louis XIII., discovered that an iron-ball, or bomb, with very thick walls, and filled with water, exploded sooner or later when thrown into the fire, if *its mouth were closed*, or, in other words, if you prevented the free escape of the steam as it was generated. The power of steam was here demonstrated by a precise proof, which, to a certain point, was susceptible of numerical appreciation,* whilst at the same

* If some antiquarian think that I have not gone back far enough because I commence with Flurence Rivault, and if, according to the statement of Alberti, who wrote in 1411, he should inform us that, in the beginning of the fifteenth century, lime-burners were much alarmed both for themselves and their kilns, on account of the explosions which were produced when the pieces of limestone had a cavity in their interior, I answer, that Alberti himself was ignorant of the real cause of these terrible explosions; that he attributed them to the transformation of the air they contained *into steam* by the agency of the flames. To this I add, that the explosion of a piece of limestone thus accidentally hol-

time it revealed itself as a dreadful means of destruction.

Enlightened minds were not stopped by this painful reflection. They knew well that mechanical powers, like human passions, will become useful or hurtful according as they receive a right or wrong direction. In the case of steam, it in fact requires only a very simple contrivance, to make available to productive labour, the formidable elastic power which, according to all appearance, shakes the earth to its centre, surrounds the art of the statuary with imminent danger, and breaks into a thousand pieces the strongest bombshell.

In what state do we find this projectile previous to its explosion? The lower part contains water at a very high temperature, *but still liquid*, and its remaining portion is filled with steam. This, according to the characteristic law of all gases, exercises its power equally in all directions; it presses with equal intensity upon the water, and the metallic sides which contain it. Let us now place a stopcock at the lower part of these

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low, supplied no means of that numerical calculation, of which the experiment of Rivault was evidently susceptible.

sides,—on opening it, the water, forced by the steam, will issue forth with extreme velocity. If the stopcock was placed upon a tube, which, after taking a bend round the outside of the bomb, were then directed vertically from below upwards, the water would ascend in the tube in the ratio of the elasticity of the steam; or rather, for it is the same thing in other words, the water would rise according to the degree of temperature; and this ascending movement would find its limits only in the strength of the apparatus.

For this bomb let us now substitute a strong close boiler of large dimensions, and then there is nothing to prevent our forcing great masses of liquid to indefinite heights by the sole action of steam; and we shall have constructed, in every sense of the word, a steam-engine which might serve the purpose of drainage.

And now you have been made acquainted with that invention for which France and England have contended, as formerly the seven cities of Greece respectively claimed the honour of being the birthplace of Homer. On the other side of the Channel they have unanimously ascribed the honour of it to the Marquis of Worcester, of the illustrious house of Somerset. On this side, again, we maintain that it belongs to an humble engineer, almost forgotten by our biographers, namely, Solomon de Caus, who was born at Dieppe, or in its neighbourhood. Let us now cast an impartial glance upon the several claims of these two competitors.

Worcester, deeply implicated in the intrigues of the last years of the reign of the Stuarts, was shut up in the Tower of London. One day, according to the tradition, the lid of the pot in which his dinner was preparing was suddenly elevated. In prison what can one do but think? Worcester pondered upon the strange phenomenon which he had witnessed. The idea then suggested itself, that the same force which had raised the cover, might become, under certain circumstances, a useful and convenient motive power. On recovering his liberty, he published, in the year 1663, in a work entitled *The Century of Inventions*, the means by which he proposed to realize his expectations. These means, in all essential particulars, so far at least as they can be comprehended, are, the bomb half filled with liquid, and the ascending vertical tube which we have just described.

This bomb and this same tube are described in "*La raison des forces mouvantes*," the work of Solomon de Caus. There the idea is brought out distinctly, simply, and without any pretensions. There was nothing romantic in its origin, nor had it any connection either with the events of a civil war, or with a celebrated State-prison, or even with the sudden elevation of the pot-lid of an unfortunate prisoner ; but, what is of far more importance in a question of priority, it is, according to the date of its publication, forty-eight years anterior to *The Century of Inventions*, and forty-one years before the imprisonment of Worcester.

Thus, brought to a comparison of dates, the controversy seems to be terminated ; for who can maintain that the year 1615 did not precede the year 1663 ? But those whose principal aim seems to have been to remove every French name from this important chapter in the history of science, suddenly changed their ground as soon as *La raison des forces mouvantes* was resuscitated from the dusty shelves in which it had been long entombed. They, without hesitation, broke their former idol ; the Marquis of Worcester was sacrificed to the desire of annihilating the claims of Solomon de Caus, and the bomb placed upon a burning furnace, with its ascending tube, ceased altogether to be the true germ of our present steam-engine ! *

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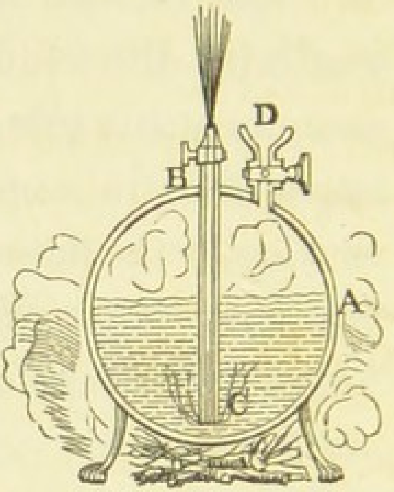
* De Caus's machine was a mere garden toy, and is a modification of one of Hero's. The figure exhibits it in section. A is a copper globe, into which are inserted two pipes, D and H. That at D is funnel-shaped, and merely enters the vessel, while that at H descends nearly to the bottom; both pipes are furnished with stopcocks.




The vessel having been about three parts filled with water through the funnel-shaped pipe D, and both of the stopcocks shut, is placed over a fire, and vapour is generated in the upper part of it. This elastic vapour, pressing on the surface of the water, will, upon the opening of the stopcock H, raise it in the ascending pipe, and force it out at its orifice in the form of a jet d'eau.

Let this be contrasted with the machine of the Marquis of Worcester, as described by himself in his celebrated Century of Inventions.

" An admirable and most forcible way to drive up water by fire, not by drawing or sucking it upward, for that must be as the philosopher calleth it, *infra sphærum 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, stopping and screwing up the

For my own part, I cannot allow that that individual accomplished nothing which was useful,

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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 found a way to make my vessels, so that they are strengthened by the force within them, and the one to fill after the other, have seen the water run like a constant fountain forty feet high; one vessel of water rarefied by fire driveth up forty of cold water; and a man that attends the work is but to turn two cocks, that, one vessel being consumed, another begins to force and refil with cold water and so on successively." And again,

"An engine so contrived that working the *primum mobile* forward or backward, upward or downward, circularly or cornerwise, *to* and *fro*, straight, upright or downright, yet the pretended operation continueth and advanceth, none of the motions above mentioned hindering, much less stopping the other; but unanimously and with harmony agreeing, they all augment and contribute strength unto the intended work and operation; and therefore I call this a *semi-omnipotent engine*, and do intend that a model thereof be buried with me." And again,

"How to make one pound weight to raise an hundred as high as one pound falleth, and yet the hundred pound descending, doth what nothing less than one hundred pounds can effect."

"Upon so potent a help as these two last-mentioned inventions, a water-work is, by many years' experience and labour, so advantageously by me contrived, that a child's force bringeth up an hundred foot high, an incredible quanwho, pondering upon the enormous power of steam, raised to a high temperature, was the first to perceive that it might serve to elevate great masses of water to all imaginable heights. I cannot admit that no gratitude is due to that engineer who was the first also to describe a machine which was capable of realizing such effects. It ought never to be forgotten, that we can only then correctly judge of an invention,

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tity of water, even two foot diameter, so naturally, that the work will not be heard into the next room; and with so great ease and geometrical symmetry, though it work day and night from one end of the year to the other, it will not require forty shillings' reparation to the whole engine, nor hinder one day's work; and I may boldly call it the *most stupendous work* in the whole world; and not onely with little charge to drain all sorts of mines, and furnish cities with water, though never so high seated, as well as to keep them sweet, running through several streets, and so performing the work of scavengers, as well as furnishing the inhabitants with sufficient water for their private occasions; but likewise supplying rivers with sufficient to maintaine and make them portable from towne to towne, and for the bettering of lands all the way it runs. With many more advantageous and yet greater effects of profits, admiration, and consequence; so that, deservedly, I deem this invention to crown my labours, to reward my expenses, and make my thoughts acquiesce in the way of further inventions."—N.

when we transport ourselves in thought to the time when it was proposed, and when we banish from our minds all the knowledge which has been accumulated during the ages posterior to its date. Let us suppose some ancient mechanist, Archimedes, for example, consulted upon the means of elevating water contained in a vast close metallic receiver. He would have suggested great levers, pulleys, simple and compound, the windlass, and probably his ingenious screw; but what would have been his surprise if, for the solution of the problem, some one had contented himself with a fagot and a match? Who, then, can refuse the title of an invention, to a contrivance at which the immortal author of the primary and true principles of statics and hydrostatics would have been astonished? This apparatus of Solomon de Caus, this close metallic vessel, in which is produced a moving power almost indefinite, by means simply of a fagot and match, will always maintain a distinguished place in the history of the steam-engine.*

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* It has been published to the world, that J. B. Porta in the year 1606, in his *Spiritali*, nine or ten years before the publication of Solomon de Caus's work, gave a description of a machine, the operation of which was intended to ele-

It is exceedingly doubtful whether either Solomon de Caus or Worcester ever constructed the apparatus they proposed.* This honour belongs

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vate water by means of the elastic power of steam. I have elsewhere demonstrated that the learned Neapolitan *did not speak, either directly or indirectly, of any machine,* in the passage alluded to; that his object—his only object—was to determine experimentally the relative volumes of water and steam; that in the small apparatus he employed for this purpose, the steam could not elevate the liquid, according to the author's own account, above a few inches; and that, in the whole description of the experiment, there is not a single word that conveys the idea that Porta was aware of the power of this agent, or of the possibility of applying it to the production of a useful working machine.

Again, are there those who think that I ought to have named Porta on account simply of his researches concerning the transformation of water into steam? I answer, that the phenomena had been previously studied with attention by Professor Besson of Orleans, about the middle of the sixteenth century, and that one of the works of this mechanician contains, in 1569, an essay expressly upon the determination of the relative volumes of steam and water.

* Against this doubt of M. Arago, let us put contemporaneous testimony. When Cosmo de Medicis, Grand Duke of Tuscany, accompanied by a number of men of letters and of artists, visited England in 1656, for the purpose of noting everything rare or useful which came under their observation, he beheld an engine of the Marquis of Worcester at work. In the English translation of the Journal

to an Englishman, to Captain Savery. I have no hesitation in associating the machine which this engineer constructed in the year 1698, with those of his two predecessors, although it must be added he introduced some important modifications; and among others that of generating the steam in a separate vessel. If it signify little as to principle, whether the motive steam be produced from the water which is to be raised, and in the interior of the same boiler in which it is about to act, or, whether it be produced in a distinct vessel, whence it is at will to be conveyed by means of a communicating pipe and a stopcock, to the surface of the liquid proposed to be raised, it is very different in a practical

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kept by his secretary, there is, under the date of 28th May 1699, the following entry:—"His Highness, that he might not lose the day uselessly, went again, after dinner, to the other side of the city, extending his excursion as far as Vauxhall, beyond the palace of the Archbishop of Canterbury, to see an hydraulic machine, invented by my Lord Somerset, Marquis of Worcester. It raises water more than *forty geometrical feet*, by the power of *one man only*; and in a very short space of time *will draw up four vessels of water, through a tube or channel not more than a span in width*; on which account it is considered to be of greater service to the public than the *other* machine near Somerset House."—N.

point of view. Another and a still more important change introduced by Captain Savery, will more appropriately find a place in the remarks we shall presently devote to the labours of Papin and Newcomen.

Savery entitled his work *The Miners' Friend*; but the miners seemed scarcely to appreciate the important compliment he paid them. With one solitary exception, none of them ordered his machines. They have only been employed in distributing water over the different parts of the palaces, of country houses, parks, and gardens, and they have not been used to raise water to a higher level than ten or fifteen yards. It ought also to be observed, that the danger of explosion would have been great, if the immense power had been employed, which their inventor contended might be reached.

Although the practical success of Savery was so far from being satisfactory, yet the name of this engineer should ever hold a very distinguished place in the history of the steam-engine. Individuals whose whole lives are devoted to labours of a speculative character, are little aware how vast is the interval between a plan, however ably and perfectly formed, and its realization.

Not that I allege with a celebrated German philosopher, that *Nature always exclaims No! No!* when we are about to raise any corner of the veil which covers her; but, prosecuting the metaphor, we may affirm, that the enterprise becomes so much the more difficult and delicate, and that its success is so much the more doubtful, in proportion as it requires both the concurrence of more numerous artists, and the employment of a greater number of material elements. In all these respects, and in reference to the epoch in which he lived, no one was placed in more unfavourable circumstances than was Savery.

Hitherto we have spoken only of machines whose resemblance to the steam-engines of the present day may more or less be disputed. Now, however, we come to the consideration of the *Modern Steam-Engine*, which performs so important a part in our manufactories and steam-vessels, and is essential in almost every mining shaft. We shall see it commence, and enlarge, and develope itself, at one time under the inspiration of some celebrated genius, and at another, under the mere spur of necessity; for "necessity is the mother of invention."

The first name which we encounter in this new period is that of Denis Papin. It is to Papin that France owes the honourable rank she may claim in the history of the steam-engine. The high satisfaction which his success inspires is not however without its alloy. The claims of our countryman are to be found only in foreign archives; he published his greatest works on the other side of the Rhine; his liberty was threatened by the Revocation of the Edict of Nantes; and it was in melancholy exile that he for a time enjoyed that blessing of which studious men are the most jealous, namely, tranquillity. Let us throw a veil upon these deplorable results of our civil discords,—let us forget that fanaticism attacked the religious opinions of the philosopher of Blois, and let us turn again to mechanics, in respect of which, at least, the orthodoxy of Papin has never been disputed.

There are in every machine two things to be considered: These are, first, the moving power; and, secondly, the arrangement, more or less complicated, of the frame and moveable parts, by the aid of which the moving power transmits its action to the resistance. At the stage of perfection which mechanical science has now reached, the success of a machine intended to produce great effects, depends chiefly upon the nature of the moving power, on the manner of its application, and on the management of its force. Now, we find that it was to the production of an economical moving power, capable of effecting the unceasing and powerful strokes of the piston of a large cylinder, that Papin consecrated his life. The procuring afterwards from the strokes of the piston, the power requisite to turn the stones of a flour-mill, the rolls of a flatting-mill, the paddles of a steam-boat, the spindles of a cotton-mill; or to uplift the massy hammer, which, with oft-repeated stroke, thunders upon the enormous masses of red-hot iron just taken from the blast-furnace; to cut with great shears thick metal bars, as easily as you divide a riband with your scissors; these, I repeat, are problems of a very secondary order, and which would not embarrass the most common engineer. Hence, therefore, we may occupy ourselves exclusively with the methods by means of which Papin proposed to produce his oscillatory movement.

Conceive a wide vertical cylinder open above, and reposing at its base upon a metal table pierced with a hole which a stopcock can at will shut and open. Let us now introduce into this cylinder a piston, that is to say a large and moveable circular plate, which accurately fits it. The atmosphere will press with all its weight upon the upper side of this kind of diaphragm, and will tend to push it from above downwards. That part of the atmosphere again which fills the lower part of the cylinder, will tend, by its reaction, to produce the inverse movement. This second force will be equal to the former if the stopcock be open, for gases press equally in all directions. The piston will thus find itself operated on by two opposing forces, which will produce an equilibrium. It will nevertheless descend, but only in virtue of its own gravity. A slight counterpoise, somewhat heavier than the piston, will suffice to draw it contrariwise to the top of the cylinder, and to keep it there. Suppose the piston arrived at this point, we have now to seek for the means of making it *forcibly descend*, and then ascend again.

Suppose that, after having shut the lower stopcock, we should succeed in annihilating *suddenly* all the air contained in the cylinder,—in a word, in making a vacuum ; the piston receiving only the action of the external air, pressing from above, would *rapidly descend*. This movement accomplished, we might then open the stopcock, the air would then enter from beneath, and would counterbalance the pressure of the atmosphere above the piston. As at the commencement, the counterpoise would now raise the piston to the top of the cylinder, and every portion of the apparatus would be found in its original state. A second evacuation, or we may call it abstraction of the internal air, would make the piston again descend, and so on successively. The true moving power of this machine would here be the weight of the atmosphere. And let no one suppose that, because we walk and even run with facility through the air, the atmosphere must therefore be very feeble as a moving power. With a cylinder of two yards in diameter the pressure of the piston in descending—the weight it might raise throughout the whole height of the cylinder at each stroke, would be about 600 cwt. This enormous power, frequently repeated, may be obtained by means of a very simple apparatus, provided we could discover a method, at once prompt and economical, whereby we might produce and destroy at pleasure an atmospheric pressure in a metallic cylinder.

This problem Papin resolved. His beautiful and grand solution consists in the substitution of an atmosphere of steam for the common atmosphere,—in the replacement of this latter by a vapour which, at 212°, has precisely the same elastic force, but with this important advantage, of which the common atmosphere is destitute, viz., that the power of aqueous vapour is enfeebled very rapidly when the temperature is lowered, and that it almost wholly disappears, if the refrigeration be carried sufficiently far. I shall, therefore, adequately characterize the discovery of Papin, and in a few words, by saying, that he proposed to make a vacuum in large spaces by means of steam, and that his method is at once prompt and economical.*

The machine in which our illustrious countryman was thus the first to combine the elastic force of steam with the property which steam

* An English engineer, deceived, no doubt, by an incorrect translation, asserted, not long ago, that the idea of employing steam in one and the same machine, as an elastic force, and as a rapid means of producing a vacuum, belonged to Hero. I have, however, proved, beyond dispute, that the mechanist of Alexandria never dreamed of steam; and that in his apparatus the alternate movement could have resulted only from the dilatation and condensation of air proceeding from the intermittent action of the solar rays.

possesses of being annihilated by cold, he never executed on a large scale. His experiments were always made on mere models. The water which was intended to produce the steam did not even occupy a distinct vessel : enclosed in the cylinder, it reposed upon the metallic plate which closed it beneath. This plate Papin heated directly, to transform the water into steam ; and it was from the same plate he removed the fire when he wished to effect the condensation. Such a process, barely tolerable when experiment is intended to verify the accuracy of a principle, would evidently be altogether inadmissible, were the piston required to move with any degree of velocity. Papin remarked, that the end might be obtained " by different constructions which might readily be conceived," but left the constructions entirely unexplained. He devolved upon his successors both the merit of applying his pregnant conception, and that of discovering those details which alone can ensure the success of a machine.*

* If the object of the inventors of that day was the application of steam as an economic moving power, the question comes to be, Did Papin ever so apply it? He certainly did not; he never constructed a machine that did or could

In our earlier researches concerning the employment of steam, we have had occasion to cite the ancient philosophers of Greece and Rome; one of the most celebrated mechanists of the school of Alexandria; a Pope; a courtier of Henri IV.; and an engineer of Normandy, that province so productive of great men, and which has ornamented our national galaxy of talent, with a Malherbe and a Corneille, a Poussin and a Fontenelle, with Laplace and Fresnel: we have also had to quote an English nobleman; a British engineer: and finally a French physician who was a Member of the Royal Society of London,

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work; he left that, says M. Arago, to those who came after him. Yes! to the Saverys, the Newcomens, and the Watts; to the host of ingenious men whose scientific application of abstract philosophical truths to the business of life entitles them to the gratitude of the species. Papin was, in truth, in so far as regards the steam-engine, a mere schemer, who, when he approached the portal of discovery, lingered on the threshold and never crossed it; and however distinguished a rank he may hold in general science, he must here take his place among those experimenters whose labours serve to indicate the progress of invention, but have not power either to hasten or retard it. His claims to the notice of posterity for the useful application of steam, rest on the invention of the culinary digester, in which was first used the safety-valve.—N.

for we cannot but confess that Papin, almost always an exile, was nothing more than a corresponding member of our own Academy. Simple artisans and more humble workmen are now about to enter the lists; and so all classes of society will be found to have contributed their share to the production of a machine by which the whole world was to profit.

In the year 1705, fifteen years after the publication of Papin's first memoir in the Acts of Leipsic, Newcomen and Cawley, the one an ironmonger, and the other a glazier in Dartmouth, Devonshire, constructed (and mark, I do not say projected, which is a very different thing), I repeat, constructed a machine, which was meant to raise water from great depths, and in which there was a distinct vessel where the steam was generated. This machine, like the small model of Papin, consisted of a vertical metallic cylinder, shut at the bottom and open at the top, together with a piston, accurately fitted, and intended to traverse the whole length, both in ascending and descending. In the latter, as in the former apparatus also, when the steam was freely admitted into the lower part of the cylinder, so filling it, and counterbalancing the external atmospheric pressure, the ascending movement of the piston was effected by means of a counterpoise. Finally, in the English machine, in imitation of Papin's, so soon as the piston reached the limit of its ascending stroke, the steam which had impelled it was refrigerated ; a vacuum was thus produced throughout the whole space it had traversed, and the external atmosphere immediately forced it to descend.

To produce the necessary cooling, Papin, as we have already stated, did nothing more than remove the brasier which heated the bottom of his small metallic cylinder. Newcomen and Cawley introduced a process greatly preferable in every respect. They caused a large quantity of cold water to flow freely in an annular space formed between the external wall of the cylinder of their machine, and a second cylinder, somewhat larger, with which they surrounded it. The cold communicated itself by degrees to the whole thickness of the metal, and finally reached the steam itself.*

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* Savery had previously had recourse to a current of cold water which he threw upon the external surface of a metallic vessel, thereby condensing the steam which the vessel contained. This, in fact, was the origin of his connec-

Papin's machine, thus perfected, in so far as regarded the method of cooling the steam, or of condensing it, excited, in a high degree, the attention of mine proprietors. It was rapidly introduced into many counties of England, where it was of very considerable service. The want of rapidity in its movements, however—the necessary consequence of the slowness with which the vapour cooled and so lost its elasticity, was, at the same time, the subject of great complaint. Accident happily indicated a very simple means of overcoming this inconvenience.

At the commencement of the eighteenth century, the art of boring great metallic cylinders, and of closing them hermetically by means of moveable pistons, was as yet in its infancy. Thus, in the early machines of Newcomen, the piston was covered by a sheet of water, which was intended to fill the spaces included between the circular contour of this moveable portion and the internal surface of the cylinder. To the very great surprise of the makers, one of their ma-

tion with Newcomen and Cawley; but it ought not to be forgotten, that the patent of Savery, his machines, and the work in which they are described, are all many years later than the memoirs of Papin.

chines one day commenced working with most unwonted speed. After numerous observations, it was ascertained that, on that occasion, the piston had been pierced, that the cold water had found its way directly into the cylinder in small drops, and that these, in traversing the steam, had quickly condensed it. From this fortuitous observation is dated the complete suppression of the external refrigeration, and the adoption of an injection to *produce a shower of cold water* throughout the whole cylinder at the moment proper for the descent of the piston. The oscillations thus acquired all the velocity that could be desired.*

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* The subjoined figure is a representation of Newcomen's Engine in its second stage.

A represents a great boiler properly built in a furnace. At a small height above it is a cylinder CBBC of metal, bored very truly and smoothly. The boiler communicates with this cylinder by means of the throat or steam-pipe N. The lower aperture of this pipe is shut by the plate N, which is ground flat, so as to apply accurately to the whole circumference of the orifice. This plate is called the regulator or steam-cock, and it turns horizontally round an axis *b a*, which passes through the top of the boiler, and is nicely fitted to the socket by grinding. The upper end of this axis is furnished with a handle *b* T.

We have now to remark that, on a different occasion, an accidental circumstance seems to

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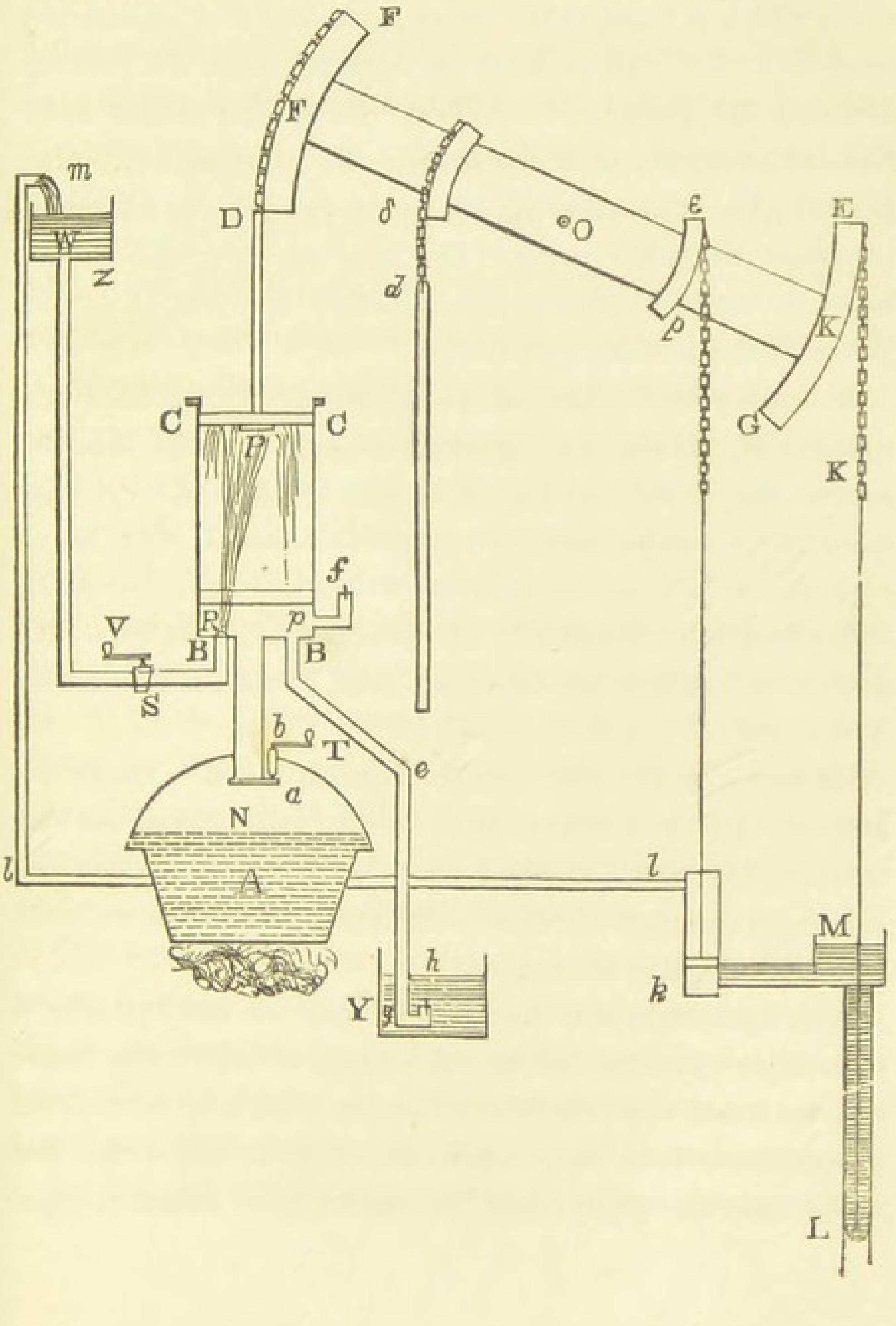
A piston P is suspended in this cylinder, and made air-tight by a packing of leather or soft rope, well filled with tallow;



have had a share in an improvement equally important. The first machine of Newcomen re-

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and, for greater security, a small quantity of water is kept above the piston. The piston-rod PD is suspended by a chain which is fixed to the upper extremity F of the arched head FD of the great lever or working beam FK, which turns on the gudgeon O. There is a similar arched head EG at the other end of the beam. To its upper extremity E is fixed a chain carrying the pump-rod KL, which raises the water from the mine. The load on this end of the beam is made to exceed considerably the weight of the piston P at the other extremity.

At some small height above the top of the cylinder is a cistern W, called the injection-cistern. From this descends the injection-pipe ZSR, which enters the cylinder through its bottom, and terminates in a small hole R, or sometimes in a nozzle pierced with many smaller holes diverging from a centre in all directions. This pipe has at S a cock called the injection-cock, fitted with a handle V.

At the opposite side of the cylinder, a little above its bottom, there is a lateral pipe, turning upwards at the extremity, and there covered by a clack-valve *f*, called the snifting-valve, which has a little dish round it to hold water for keeping it air-tight.

There proceeds also from the bottom of the cylinder a pipe *p e g h* (passing behind the boiler), of which the lower end is turned upwards, and is covered with a valve *h*. This part is immersed in a cistern of water Y, called the hot well, and the pipe itself is called the eduction-pipe.

quired the most unremitting attention on the part of the individual who unceasingly opened

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Lastly, the boiler is furnished with a safety-valve called the puppet-clack.

These are all the essential parts of the engine, and are here drawn in the most simple form. Let us now see how the machine is put in motion, and what is the nature of its work.

The piston being at the top of the cylinder, as shewn by our sketch, the water in the boiler being supposed to be in a state of strong ebullition, and the steam issuing by the safety-valve, the steam-cock is opened by turning the handle T of the regulator. The steam from the boiler will immediately rush into the cylinder, and mix with the air. Much of it will be condensed by the cold surface of the cylinder and piston, and the water produced from it will trickle down the sides, and run off by the eduction-pipe. This condensation will continue till the whole cylinder and piston, by abstracting caloric from the steam, become as hot as boiling water. When this happens, the steam will begin to open the snifting-valve *f*, and issue through the pipe; slowly at first, and very cloudy, being mixed with much air, but gradually becoming stronger and perfectly transparent.

When the blast of the snifting-valve is strong and steady, and the boiler fully supplied with steam of a proper strength, the steam-cock is shut, and the injection-cock S opened by by turning its handle V. The pressure of the column of water in the injection-pipe ZS immediately forces some water through the spout R. This, coming in contact with and closed certain stopcocks, first for the introduction of the steam into the cylinder, and then

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the pure vapour which now fills the cylinder, condenses it, and thus makes a partial void. What steam remains in the cylinder no longer balances the atmospherical pressure on the surface of the water in the injection-cistern, and therefore the water spouts rapidly through the hole R; at the same time, the snifting-valve *f*, and the eduction-valve *h*, are shut by the unbalanced pressure of the atmosphere. In a very short space of time, the condensation of the steam becomes universal, and the elasticity of what remains is almost nothing. The whole pressure of the atmosphere is exerted on the upper surface of the piston, while there is hardly any on its under side. Therefore, if the load on the outer end E of the working-beam is inferior to this pressure, it must yield to it. The piston P must descend, and the pump-piston L must ascend, bringing along with it the water of the mine, and the motion must continue till the great piston reaches the bottom of the cylinder. The injection-cock is now shut, and the steam-cock opened. The steam again rushes into the cylinder, and after suffering a partial condensation as before, soon by its elasticity forces the piston to the top, where it once more occupies the position seen in the sketch, and the operations already described have again to be repeated. Again the opening of the injection-cock is followed by the rapid condensation of the steam, the formation of a vacuum, the descent of the piston, and the end F of the working-beam, and the consequent raising of the piston of the liftingfor injecting the cold shower for its condensation. It happened on one occasion that the person so employed was a boy named Henry Potter. His young companions at their sports, uttered cries of delight, which vexed him beyond endurance. He was all impatience to join in their sport, but his required duties did not allow him half a minute's absence. His anxiety excited his ingenuity, and led him to observe relations he had never before thought of. Of the two stopcocks, the one required to be opened at the moment that the beam (which Newcomen first and so usefully introduced into his machines) terminated the descending oscillation, and required to be closed precisely at the termination of the opposite one. The management

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pump, bringing with it an additional load of water from the mine; and again is the piston forced up by the admission of steam; and thus the operations go on in regular succession. When the steam-cock is shut off, the steam acquires such additional elasticity as to blow strongly through the safety-valve of the boiler, but on the re-opening of the cock this is at once put an end to; and it has sometimes happened that the cold cylinder abstracts the steam from the boiler with such astonishing rapidity, that the pressure of the atmosphere has burst up the bottom of the boiler.—N.

of the other stopcock was precisely the reverse. The positions, then, of the beam, and of the stopcocks, had a necessary dependence upon each other. Potter seized upon this fact; he perceived that the beam might serve to impart to the other parts of the machine all the required movements; and on the spur of the moment he realized his conceptions. He attached a number of cords to the stopcocks; some to the one end of the handle, and some to the other, and these he attached to the most suitable parts of the beam, so that in ascending it pulled one set of the cords, and in descending the other, and so effectually, that all the work of his hand was entirely superseded. For the first time, the steam-engine went by itself; and now no other workman was seen near it but the fireman, who from time to time fed the furnace under the boiler.

For the cords of young Potter, the engineers soon substituted rigid vertical rods, which were fixed to the beam, and armed with small pegs which either pressed from above downwards, or from below upwards, as required; and thus turned the different stopcocks and valves. These rods themselves have since been replaced by other combinations; but, however humbling the avowal, all these expedients are nothing more than simple modifications of a contrivance suggested to a child by his desire to join in the gambols of his youthful companions.*

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* Among those engineers whose attention was directed to the improvement of the atmospheric engine of Newcomen, Mr Henry Beighton and Mr John Smeaton deserve especial notice. Beighton invented the hand-gear, which superseded the strings of the boy Potter. He also published a table of the proportion which the cylinders of the engines should bear to the pumps when used for drawing water at depths varying from 15 to 100 yards, and in quantities from 48 to 480 hogsheads per hour. This table was of the greatest importance, and was fully verified by practice.

Smeaton, whose engineering works remain proud monuments of his success every where throughout Britain, and whose Eddystone Lighthouse was raised amid difficulties which would have quite overwhelmed an ordinary mind, was early forced to turn his attention to remedy the imperfections of the atmospheric engine, and in his hands it assumed as perfect a form as it was perhaps capable of. He performed numerous experiments with a small engine made for the purpose, and from these deduced rules for proportioning the parts of his engines. The application of these rules to practice on the greatest scale was attended with perfect success. His Chace Water engine is a model of constructive skill. The elegant portable engine which he designed for the Earl of Egmont is represented in the annexed figure ; and although modified by the substitution

There exist in the museums of the curious, a considerable number of machines from which

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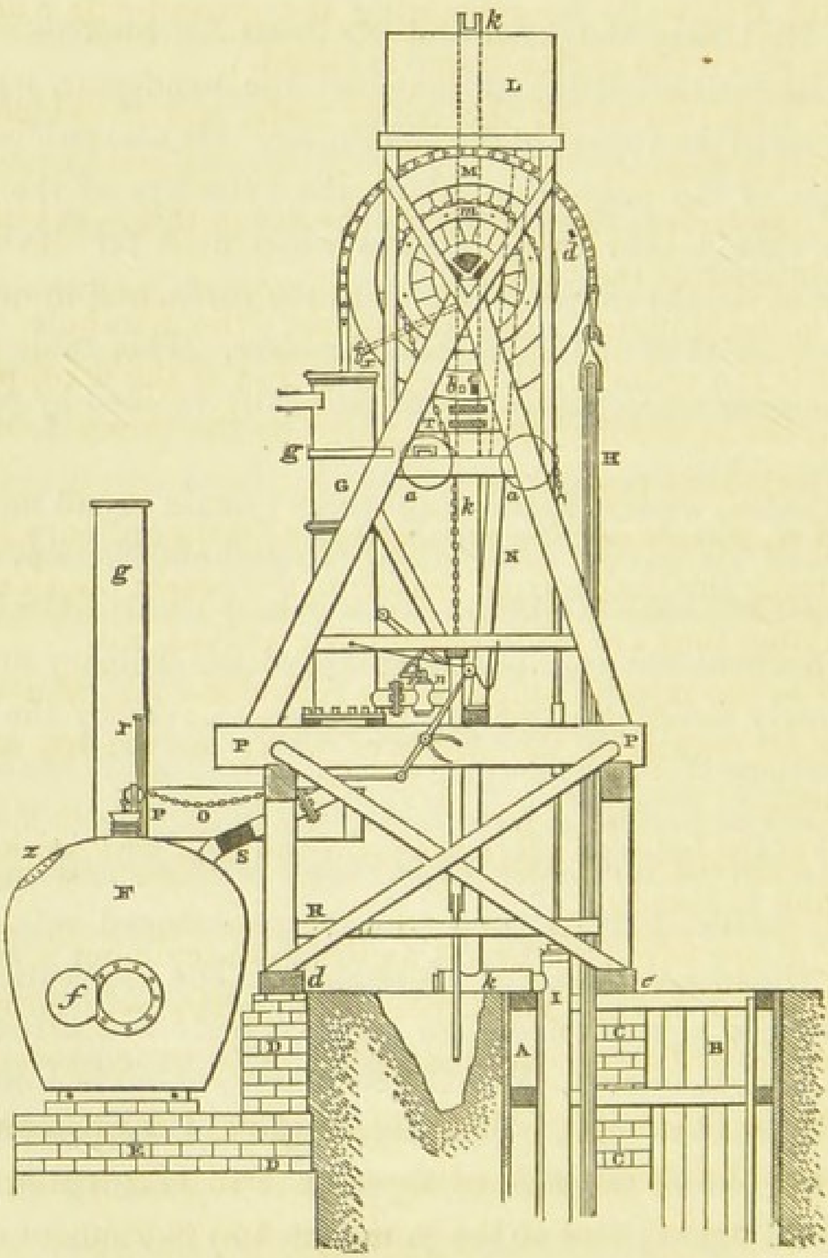
of a wheel for the working beam, it will serve as a specimen of the combination of his improvements with those of Beighton.



industry had anticipated great things, but which the expense of working and keeping them in order has rendered little more than mere objects of curiosity. Such, in all probability, would have

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AB is the pit or shaft.

CC, DD, walls for supporting the ground-sills *c* and *d*, upon which the engine-frame is raised.

E, a wall on which the boiler rests, and in which the ash-pit is formed.

F, the boiler; *f* the fire-door, the fire in this case being in the interior of the boiler.

*g* is the chimney, *s* the steam-pipe, *z* the man-hole.

G is the cylinder, H the spear or rod of the main-pump.

L, the injection-cistern, supplied by the pump I, called the jack-head pump.

M *m*, wheels serving as substitutes for the ordinary beam. To bring the chains from these into the proper positions for working, they are made to pass over pullies, *a a*.

N is the injection-pipe, *n* the injection-cock, and *x* the cock for regulating the supply of water on the top of the piston.

O is the hot-well; R, a stage for the man who works the engine to stand on.

P P are two main beams on which the cylinder is seated and bolted down. The action of the engine will be understood from the previous description of Newcomen's.—N.

About this time, too, Leupold, a native of Saxony, and author of the *Theatrum Machinarum*, a man of great modesty and ingenuity, gave to the world the first rude model of the high-pressure engine.—N.

been the fate of Newcomen's machines, at least in those districts which were not rich in fuel, had not the labours of Watt, which I must now proceed to analyze, succeeded in conferring upon them an unlooked-for perfection. This perfection must not be considered as the result of some fortuitous observation, or of any single inspiration of genius: the author effected it by means of most assiduous labour, and by innumerable well conceived and very delicate experiments. We may well say that Watt took for his guide this celebrated maxim of Bacon, "To write, speak, meditate, or act, when we are not provided with *facts* to direct our thoughts, is to navigate a coast full of dangers without a pilot, and to launch into the immensity of the ocean without either rudder or compass."

There was in the museum of the University of Glasgow, a small model of one of Newcomen's steam-engines, which could scarcely ever be made to work satisfactorily. Dr Anderson, the Professor of Natural Philosophy, requested Mr Watt to repair it, and under the able hand of the artist all the defects of its construction disappeared, and from that time the apparatus annually performed its task in the class-room, to the astonishment of the admiring pupils. With this degree of success most men would have been satisfied. Not so Watt; who, according to custom, here beheld an occasion for the gravest study. His researches were successively directed to all the points which seemed capable of explaining the theory of the machine. He determined the extent to which the water dilated in passing from its liquid state into that of steam; he calculated the quantity of water which a given weight of coal could vaporize,—the quantity of steam, in weight, which each stroke of one of Newcomen's machine of known dimensions expended,—the quantity of cold water which required to be injected into the cylinder to give the descending stroke of the piston a certain force; and finally, the elasticity of steam at different temperatures. All these investigations would have occupied the lifetime of a laborious philosopher, whilst Watt brought all his numerous and difficult researches to a conclusion, without allowing them to interfere with the labours of his workshop. Dr Cleland wishing, not long ago, to shew me the house, near the harbour of Glasgow, whither our associate retired, after quitting the shop, to follow out his experiments, we found it pulled down. Our disappointment was great, but happily of short continuance, for, within the site on which it had stood, we found ten or a dozen vigorous workmen, who seemed occupied in doing all honour to the cradle of modern steam-engines; they were at work on boilers whose united dimensions certainly equalled those of the humble dwelling which there stood no more. In such a spot, and in such circumstances, the most elegant mansion, the most superb monument, or the most perfect statue, could not have so much awakened the most interesting associations as did these colossal caldrons!

If the properties of steam be still present in your recollection, you will at once perceive that the economical play of Newcomen's machine seemed to require two irreconcilable conditions. When the piston descends, the cylinder must be cold; if this be not the case, it encounters steam still highly elastic, which much retards its progress, and diminishes the effect of the atmospheric pressure. When, afterwards, steam at the temperature of 212° rushes into the same cylinder, if the parietes be cold, this steam in heating them is partially liquefied, and until the moment that their temperature likewise rises to 212°, the elasticity of the steam is decidedly diminished;

hence slowness of movement must be the result; for the counterpoise does not raise the piston till there exist within the cylinder a force which is capable of counterbalancing the action of the atmosphere; and hence also increased expense; steam being very dear, as I have already explained. No doubt will be entertained of the great importance of this economical consideration, when I state that the Glasgow model at each stroke used a volume of steam many times greater than that of the cylinder. The expense of the steam, or, what comes to the same thing, the expense of the combustible, or, in other words, the pecuniary cost indispensable for maintaining the action of the machine, would be many times less if we could succeed in doing away with the successive heatings and coolings, the inconveniences of which have just been described.

Watt in a very simple way resolved this apparently insolvable problem. All he did was to add to the machine, as previously constructed, a vessel perfectly distinct from the cylinder, and communicating with it only by means of a narrow tube, supplied with a stopcock. This vessel, known by the name of *the condenser*, is the chief of Watt's inventions; and, in spite of all my desire to be short, I cannot but explain its mode of action.

If there exist a free communication between a cylinder filled with steam, and a vessel void of steam and air, the steam of the cylinder will pass in part and very rapidly into the vessel, and the current will not stop till the elasticity be the same throughout. Suppose, then, that with the help of an abundant and continual injection of water, the vessel be kept constantly cold throughout its whole capacity, the steam will be condensed there so soon as it enters;—the whole of the steam with which the cylinder was originally filled will come to be successively annihilated;—the cylinder will thus be freed of its steam without its sides being in the slightest degree cooled;—and the new steam with which we may fill it, will lose nothing of its elasticity.

The *condenser* entirely absorbs the steam of the cylinder, on the one hand, because it contains cold water; and on the other, because the rest of its capacity contains no elastic fluid. But so soon as the first condensation of the steam is effected, these two conditions of its efficiency have disappeared; the condensing water is heated by absorbing the latent caloric of the steam, and some vapour is formed from this hot water; the cold water also contained atmospheric air, which, of course, was disengaged in the process of heating. If, then, after every act of condensation, this hot water, and vapour, and air, which the condenser contains, were not removed, it would become inefficient. Watt accomplished this triple evacuation by means of a common air-pump, where a piston was conveniently attached to the beam, and so was worked. The force required to keep the air-pump in action, diminishes by so much the power of the machine; but this forms but a small loss compared with what was sustained by the old method of condensing the steam, through the refrigerated sides of the cylinder.

One word more, and the advantages of another invention of Watt will become manifest to all. When the piston descends in Newcomen's machine, it is the atmosphere which pushes it. That atmosphere is cold, and must cool down the parietes of the metallic cylinder, open at top, along which it successively moves throughout their whole extent. These sides of the cylinder can recover from this refrigeration, during the ascending course of the piston, only at the expense of a certain quantity of steam. There exists no loss, however, of this sort, in the *modified engines* of Watt; the atmospheric action is wholly eliminated, and in the following manner. The cylinder is closed at the top by a metallic cover, which has an opening nicely fitted with greased tow, so that the cylindrical piston-rod moves freely in it, without allowing the slightest passage to air or steam. The piston thus divides the cylinder into two chambers which are distinct from each other and perfectly closed; when it is about to descend, the steam from the boiler readily reaches the upper chamber through a tube properly placed, and forces it downwards, as did the atmosphere in the machine of Newcomen. This movement meets with no obstacle, provided that, during the period of its execution, the lower part of the cylinder alone be in communication with the condenser, whither all the lower steam rushes and is liquefied. So soon as the piston has quite descended, the simple turning of a stop-cock makes the two parts of the cylinder situated above and below the piston communicate,*—

* The communication with the condenser must at the same time be cut off.—Edit.

these two spaces are filled with steam of the same degree of elasticity, the piston is then put in equilibrium, and reascends to the top of the cylinder, as in Newcomen's atmospheric machine, by the mere action of a counterpoise.*

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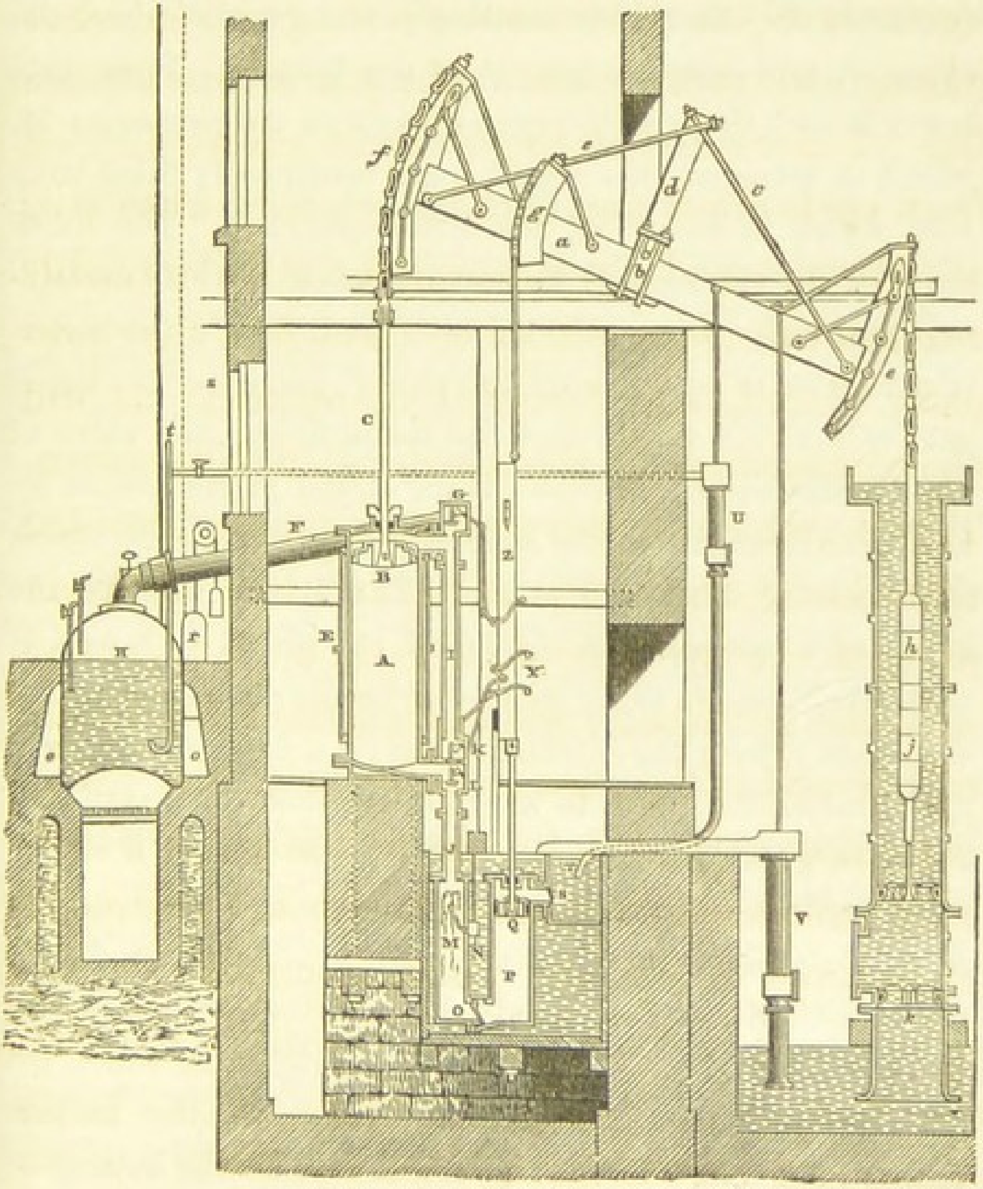
* In the figure is represented one of Watt's single-acting engines. H is the boiler; surrounded by the flues *o o*,



In prosecuting his researches as to the means of economizing steam, Watt reduced almost to

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forming a passage which the flames and heated air traverse before their escape into the chimney; *r* is the damper for regulating the draught. From the boiler, the steam-pipe F conducts the steam to the cylinder; this pipe, upon arriving at G, divides into two branches, one entering the cylinder there, the other, I, descending parallel to the side of the cylinder, and opening into it at the bottom. From this lower branch the eduction-pipe J leads to the condenser M, which is situated in a vessel kept continually filled with cold water by means of the lifting-pump V. The other parts of the engine will be better explained while describing its action. Steam having been generated in the boiler, is permitted to pass through the pipe F, and enter the upper part of the cylinder through the steam-nozzle and valve at G; the descending branch I being closed at the bottom by the equilibrium valve and nozzle at K, prevents the steam from getting below the piston. The elastic force of the steam now operating on the top of the piston B, causes it to descend, and it being connected by the piston-rod C and the chain *f*, with the working beam *f b e*, depresses the end *f*, and raises the end *e*, to which is attached the piston-rod, *h j*, of a great lifting-pump. While the piston B of the steam-cylinder A was descending, so was also the piston Q of the air-pump P, which is connected by its piston-rod with the arch-head *g* of the beam; to this piston-rod is attached the plug-tree ZY, carrying the projecting studs which act upon the spanners of the valves GKL. By the descent of this plug-tree, when the piston B reaches the bottom of nothing, the loss which resulted from the cooling down of the outside of the cylinder in which the piston played. For effecting this object, he enclosed the metallic cylinder in a wooden one somewhat larger, and filled the space between them with steam.

Thus, then, was the steam-engine completed. The improvements it received from Watt are evident, and of their immense utility there can-

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the cylinder, the disposition of the valves is altered. The valve G is depressed, and shuts off the communication between the boiler and the cylinder,—the valve K is opened, and permits the steam in the upper part of the cylinder to flow into the condenser, where it is annihilated by a jet of water which enters through the injection-cock N. A vacuum being thus formed in the upper part of the cylinder, there is nothing to balance the weight of the atmosphere, which is resting on the piston of the lifting-pump at the opposite end of the beam, and it accordingly descends and replaces the piston B in the position shewn on the drawing; while, by the action of the piston Q of the air-pump P, the injection water, condensed steam and air, is withdrawn from the condenser M, by the blow-valve O, and is emptied into the hot well S; from which a small pump UT again withdraws it for the supply of the boiler. By the drawing up of the plug-tree ZY, the valves are restored to their original position, and the communication between the boiler and the upper part of the cylinder is again opened.

not be a doubt. You will, therefore, anticipate, that it would immediately displace, as a draining apparatus, the comparatively ruinously expensive machines of Newcomen. This, however, was far from being the case. The author of a discovery has always to contend with those whose interests may be affected, with the obstinate partisans of whatever is ancient, and finally, with those who are jealous,—and these three classes united form (must we confess it ?) the great majority of the public. Yet, to avoid a paradoxical result, I leave out of my calculation all those who had double motives. It is time alone that can disunite and scatter this phalanx of opponents. Nor will time alone do it. They must be energetically and unceasingly attacked ; and the means used must be varied, as is done by the chemist, whom experience has taught that the complete solution of certain compounds requires the successive employment of several acids. The strength of character and firmness of purpose, which, in the long run, defeat the most wily intrigues, are seldom united with an inventive genius. Watt, were it necessary, might be quoted as a convincing proof of the fact. His grand invention and most felicitous conception, that steam might be condensed in a vessel quite separated from the cylinder in which the mechanical action is going forward, was completed in the year 1765 ; and in two years, scarcely any progress was made to try its applicability upon the great scale. At length, however, his friends put him in communication with Dr Roebuck, the founder of the great establishment at Carron, so celebrated even at the present time. The engineer and the projector now associated themselves together, Watt yielding to him two-thirds of his patent. A machine was speedily constructed upon the new principles; it confirmed all the anticipations of theory; its success was complete, although, in the mean time, Dr Roebuck's fortune was injured. The invention of Watt would, without doubt, have repaired it; all that was required, was to apply to money-lenders; but our brother associate thought it more simple to renounce his discovery, and to change his career. In the year 1767, when Mr Smeaton was executing the surveys and levellings between the rivers Forth and Clyde, preparatory to those gigantic works which were about to be executed in that part of Scotland, we find Watt conducting analogous operations along a rival line. Still later, he furnished a plan for the Monkland Canal, and executed it. Many projects of a similar kind, continued to occupy the attention of our associate till the close of the year 1773. Among these, we may mention the Crinan Canal, which was subsequently formed by Mr Rennie; also improvements in the harbours of Ayr, Port-Glasgow, and Greenock;* the building of bridges at Hamilton and Rutherglen; and the surveying the district of the celebrated Caledonian Canal, upon which he made a report, with plans and sections, subsequently referred to by Mr Telford. Without depreciating the importance of these labours I may still be permitted to add, that their interest was only of a local character; and that for their conception, superintendence, and conduct, there was no need of calling in the assistance of James Watt.

Were I now for an instant to forget my duties as the organ of the Academy, and to aim at producing a smile rather than insisting upon import-

* We may also mention the deepening the river Clyde; the improving the navigation of the Forth and Devon and the Water of Leven; the making a canal from Machrihanish Bay to Campbeltown, and another between the grand canal and the harbour of Borrowstownness.—Edit.

ant truths, the fact before us would supply the materials of a striking contrast. I might adduce not a few authors, who, at our weekly meetings, are wont to demand, with all their heart and might, leave to communicate the solitary remark, the trifling reflection, the hasty note which was conceived and written the previous evening. I might represent them cursing their destiny, when our laws, or the priority of another's communication, postponed their paper for a week; although they have the guarantee of the *paquet cacheté* being deposited in our archives. On the other hand, we see the great inventor of a machine destined to constitute an epoch in the annals of the world, submit, without a murmur, to the stupid neglect of capitalists, and apply his superior genius for eight years, to the preparation of plans, to the making of surveys, to troublesome calculations of levelling, and to measurements of masonry. How strikingly does this exhibit the serene character, the subdued ambition, and the true modesty of Watt. But, indifference such as this, however noble its causes, was not devoid of blame. It is not without reason that society stamps with its reprobation, those who withdraw from circulation the gold hoarded in their coffers. And is that individual less culpable who deprives his country, his fellow-citizens, and the age in which he lives, of the treasures a thousand-fold more valuable, which are the products of the mind; who retains for himself alone those immortal discoveries, the sources of the noblest and purest delights of the soul; and who does not bestow on the artisan, mechanical contrivances which may indefinitely multiply the products of industry, which may diminish, to the profit of civilization and humanity, the effects of the inequalities of our lot, and which may ere long afford us the satisfaction of visiting the humblest dwellings, without discovering the heart-rending spectacle of fathers of families, and wretched children of both sexes, assimilated to the brutes, and hurrying prematurely to the grave?

Towards the commencement of the year 1774 (after what we must call the indifference of Watt was overcome), he formed a connection with Mr Boulton of Soho, near Birmingham, a gentleman equally distinguished by his knowledge of the arts and his enterprising spirit.* The two friends

* In the note with which he accompanied the last edition of Professor Robison's Essay on the Steam-Engine, Watt

applied to Parliament for prolongation of the privilege, for Mr Watt's patent was dated in

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expressed himself in the following terms concerning Mr Boulton. "Our friendship continued undiminished to the close of his life. As a memorial due to that friendship, I avail myself of this, probably my last, opportunity of stating, that to his friendly encouragement, his partiality for scientific improvements, and his ready application of them to the processes of art, to his intimate knowledge of business and manufactures, and to his extended views and liberal spirit of enterprise, must, in great measure, be ascribed whatever success has attended my exertions."

Mr Boulton's manufactory at Soho had existed for several years previous to the association spoken of in the text. This establishment, the first upon so great a scale which sprung up in England, is still quoted for its elegance. There were here manufactured all kinds of first-rate articles in steel, plate-metal, silver, and or-molu, as also astronomical clocks, and painted glass. During the last twenty years of his life, Mr Boulton was occupied with improvements in the fabrication of the coinage. By the combination of some processes, which originated in France, with new presses, and an ingenious application of the steam-engine, he united an extraordinary rapidity with perfection of execution. Hence Mr Boulton, at the order of the English Government, recast all the copper-money of the United Kingdom. The economy and distinctness of this prodigious undertaking, rendered counterfeits almost impossible. The numerous executions with which the towns of London and Birmingham used annually to be distressed ceased. It was the year 1769, and had only a few years to run. The introduction of the bill gave rise to an animated discussion. The celebrated mechanist thus writes to his aged father, in a letter, dated London, May 8. 1775 :—"After a series of violent and various opposition, I have at last got an act of Parliament. The affair has been attended with great expense and anxiety, and, without many friends of great interest, I should never have been able to have carried it through, as many of the most powerful people in the House of Commons opposed it." I was curious to learn to what class of society those members of Parliament belonged, to whom Mr Watt alludes, and who refused to the man of genius a small fraction of that wealth which he was about to create. Conceive my surprise, when I learned that at their head stood the celebrated Burke! Is it then the fact, that a man may be given to profound thought, may possess extensive knowledge and sterling honesty, be pre-eminently en-

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on this occasion that Dr Darwin exclaimed in his "*Botanic Garden*," if a civic crown was given in Rome for preserving the life of one citizen, Mr Boulton should be covered with garlands of oak." Mr Boulton died in the year 1809, at the age of 81.

dowed with oratorical talents to move and carry along with him political assemblies, and yet be wanting in plain common sense ? Since the important and wise improvements which Lord Brougham has introduced into the law of patents, inventors will not be subjected to that long series of annoyances to which Mr Watt was exposed.

So soon as Parliament renewed Mr Watt's patent for a period of twenty-five years, he and Mr Boulton together, commenced at Soho those establishments which have proved the most useful school of practical mechanics for the whole of England. They speedily undertook the construction of draining pumps of the largest dimensions ; and repeated experiments demonstrated, that, in the production of equál effects, there was a reduction of three-fourths of the expense of the fuel consumed by those of Newcomen. From that moment the new engines spread over all the mining districts, and especially Cornwall. Boulton and Watt received, as remuneration, the third part of the value of the coal which was saved by the use of each of their machines ; and we may judge of the commercial importance of the invention by the fact, that, in the single mine of Chacewater, where three pumps were employed, the proprietors thought it worth their while to purchase the rights of the inventors, at the price of L.2500 per annum for each engine. Thus, in a single establishment, the substitution of the *condenser*, effected in fuel alone, a reduction in expense of more than L.7500 per annum.

Men willingly consent to pay the rent of their dwelling or their farm ; but this compliancy abandons them when they have to do with an idea, however great the profit or advantage it may have procured. Ideas ! they exclaim, surely they cost no labour and no trouble. Who, besides, they add, can prove that in a very short time they would not have occurred to all the world ? According to this reasoning, neither days nor months, nor years of priority, should confer the slightest privilege. These opinions, which there is now no occasion for my criticising here, had, from mere repetition, acquired a sort of prescriptive establishment. Men of genius, and the *manufacturers of ideas*, it seemed, ought to remain strangers to any thing like material enjoyments ; and their history, forsooth, should continue to resemble the legends of the martyrs.

Whatever may be thought of notions like these, it is certain that the Cornish miners continued, with augmenting repugnance, to pay from year to year the gratuity they owed to the Soho engineers. They availed themselves of the first pretences which plagiarism afforded, to insist that their engagements were dissolved. The dispute was a serious one; it might have compromised Mr Watt's social position; and he therefore devoted much of his attention to it, and became quite a lawyer. The circumstances of the long and expensive processes which Boulton and Watt had to carry on, and which they ultimately gained, do not merit particular remark; but as we have just cited Burke among the opponents of the great mechanist, it seems just, on the other hand, to state that Roy, Mylne, Herschel, Deluc, Ramsden, Robison, Murdoch, Rennie, Cumming, More, and Southern, publicly and powerfully defended the rights of persecuted genius. It may not be useless to add, as a curious trait in the history of the human mind, that the advocates, who are sometimes accused of superfluity of words, reproached Watt, against whom they were leagued in great numbers, that he had invented nothing but ideas. This sentiment drew upon them, in open court, that chastisement of Rous, "Go, gentlemen! approach these untangible combinations, as you call Mr Watt's machines; but know that these pretended abstract ideas could crush you like so many flies, and leave no trace of your existence."

The persecutions to which a man of sensibility is exposed, where the strictest justice would lead him to expect the unanimous expression of gratitude, rarely fail to discourage and sour his temper; and the amiability of Watt did not withstand the trial. Seven long years of litigation excited a feeling of vexation which sometimes manifested itself in bitter terms. "We have been so beset with plagiaries," he remarks, "that if I had not a very distinct recollection of my doing it, their impudent assertions would lead me to doubt whether I was the author of any improvement on the steam-engine; and the ill-will of those we have most essentially served, leads them to canvass whether such improvements have not been highly prejudicial to the commonwealth."

But, though much irritated, Watt did not suffer himself to be discouraged. At first, his machines, like those of Newcomen, were nothing more than simple pumps, in other words, simple means of raising water. In a few years, however, he transformed them into machines capable of producing all kinds of movements, and of indefinite power. His first step in this new career was the construction of the *double-acting engine.* To understand the principle of this engine, we must refer to the *modified machine,* already explained (p. 82). In it, as we have seen, the cylinder is closed; the external air is excluded ; it is the pressure of the steam, and not that of the atmosphere, which produces the descent of the piston; and finally, it is a simple counterpoise which produces the ascending movement, for at the moment the movement is effected, the steam being allowed to circulate freely between the upper and lower portions of the cylinder, presses the piston equally in the two opposite directions. Hence, it will be clearly perceived, that the *modified machine,* like that of Newcomen, has no real force except during the descending stroke of the piston.

A very simple change will remedy this serious defect, and present us with the *double-acting engine.* In the engine known under this name, as in that which we designated the Modified Engine, the steam of the boiler, when required, passes in freely above the piston, and depresses it without encountering any obstacle, because, at the moment, the lower part of the cylinder is in direct communication with the condenser. This movement once accomplished, and a certain stopcock being opened, the steam issuing from the boiler now rushes underneath the piston only, and elevates it, whilst the upper steam which had produced the descending movement, passes off to be liquefied in the condenser, with which it is now, in its turn, in free communication. The contrary movement of the stopcocks replaces all the different parts in their first state, so soon as the piston is at the summit of its elevation; and the same changes can be repeated indefinitely. The moving power here, it will be observed, is the steam exclusively; and the machine, with an exception dependent upon the inequality of the weight of the piston, has the same power whether the piston ascends or descends. Hence, from its first invention, it was justly designated the *Double-acting Engine.*

That he might render his new motive power of ready and convenient application, Mr Watt had to overcome additional difficulties. He had first to discover the means of establishing a *rigid communication* between the inflexible piston-rod, whose stroke was perpendicular, and the beam whose movement was circular. The solution which he gave of this important problem, is probably his most ingenious discovery.

Those who have seen a steam-engine at work, have probably been struck by the presence of a certain jointed parallelogram. At each double oscillation it opens and closes with the smoothness, and I had almost said the gracefulness, which so much charms us in the movements of a consummate actor. Follow attentively with your eye the progress of these different transformations, and you will find them subjected to the most curious geometrical conditions. You will perceive that *three* of the angles of the parallelogram describe in space certain arcs of circles, whilst *the fourth*—the angle which raises and depresses the piston-rod,—moves very nearly in a straight line. The vast utility of this result, astonishes mechanicians still less, than the simplicity of the means by which Mr Watt obtained it.*

* The following are the terms in which Mr Watt gave

Power, however, it should be observed, is not the only element of success in the labours of industry. Regularity of action is of scarcely less importance; and what degree of regularity is to be expected from a moving power which is procured from the fire, under the influence of the poker and shovel, and supplied by coals of

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an account of his first trial of this jointed parallelogram:—"I have myself been much surprised with the regularity of its action. When I saw it in movement for the first time, it afforded me all the pleasure of a novelty, and I had quite the feeling as if I had been examining *the invention of another.*" Mr Smeaton, who was a great admirer of Mr Watt's inventive powers, did not think nevertheless that, practically, it would become a usual and economical means of conferring *directly* a rotatory movement on the axes. He maintained also, that steam-engines would never drain so effectually as by directly pumping out the water: he believed that this liquid thus raised to the necessary height should then be thrown into the troughs, or poured upon the boards of common hydraulic wheels. The anticipations of Mr Smeaton have not in these respects been confirmed. Nevertheless, I saw, in the year 1834, in Mr Boulton's establishment at Soho, an old steam-engine, which is still employed in raising water from a large pond, and then throwing it upon the buckets of a large water-wheel, which was used when, in particularly dry seasons, the usual supply was not sufficient.

very different qualities, under the influence, too, of workmen often far from intelligent, and almost always inattentive? We should expect that the propelling steam would be sometimes superabundant; that hence it would rush into the cylinder with the greater rapidity, so making the piston work more rapidly according as the fire was more powerful; and from such causes great inequalities of movement appear almost inevitable. But for all irregularities of this sort the genius of Watt provided a remedy. The valves through which the steam proceeds from the boiler to enter into the cylinder, have a variable area. When the speed of the machine is accelerated, these valves partially close, hence the steam enters less freely, and the acceleration is arrested; and, on the contrary, when the movement relaxes, then the apertures of the valves are increased. The mechanism which is necessary for effecting these different changes, connects the valves with an apparatus whose principle Mr Watt met with in the regulator of certain wind-mills, and which he denominated the *governor*, but which is now commonly called the *regulator by centrifugal force*. Its efficacy is such, that a few years since there was to be seen at Manchester, in the cotton-mill of Mr Lee, a mechanist of great talent, a clock, which was set in motion by the steam-engine of the establishment, and which kept time, without any marked inferiority, with an ordinary clock of the common construction.*

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* The figure shews the Double-acting Engine made by Watt for the Albion flour-mills. In this engine his elegant invention of the sun and planet wheels for changing a rectilinear into a rotatory motion was used; and in it are also seen the governor (W in the figure), and the parallel motion (*c d e f b*).

The action of the engine may be thus described:—The steam-pipe conveys steam from the boiler to the cross-pipe, or upper steam-nozzle G, and by the perpendicular steam-pipe J, to the lower steam-nozzle K. In the nozzle G is a valve, which, when open, admits steam into the cylinder *above* the piston through the horizontal square pipe at its top; and in the *lower* steam-nozzle L there is another valve, which, when open, admits steam into the cylinder *below* the piston. In the upper exhaustion-nozzle H is a valve, which, when open, admits steam to pass from the cylinder *above* the piston into the exhaustion-pipe J, which conveys it to the condensing-vessel M, where it meets the jet of the injection from the cock N, and is reduced to water; and in the *lower* exhaustion-nozzle L, there is also a valve, which, when open, admits steam to pass out of the cylinder *below* the piston, by the eduction-pipe, into the condenser M.

The regulator of Watt, and a skilful employment of fly-wheels, constitute the secret, the

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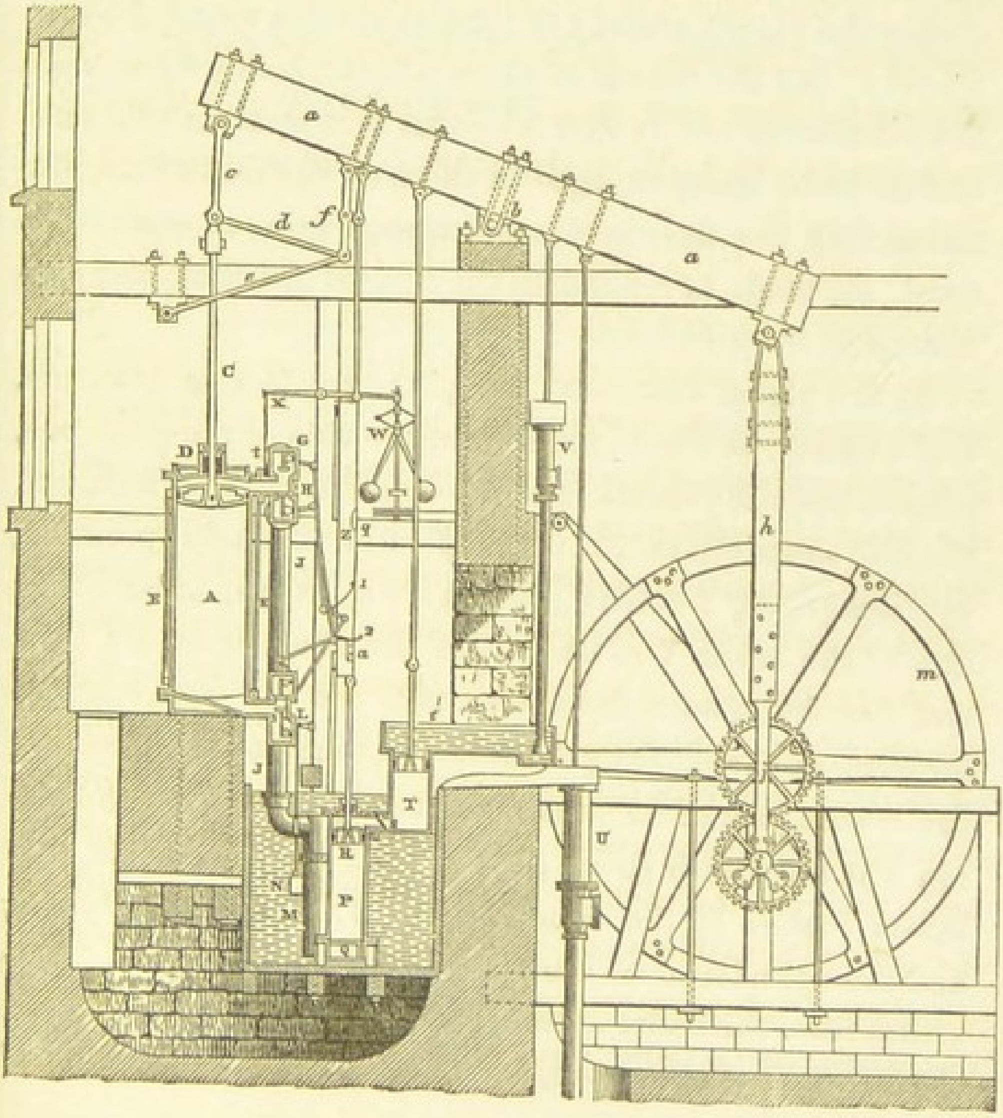
The piston being at the top of its stroke, the valves G and L are to be opened, and the fly-wheel *m* turned by hand about one-eighth of a revolution, or more, in the direction in which it is intended to move; the steam which is then in the cylinder will pass by L into the condenser, when, meeting the jet of water from the injection-cock, it will be



true secret, of the astonishing perfection of the manufactures of our epoch. It is this which now-

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converted into water, and the cylinder thus becoming exhausted, the steam, entering the cylinder by the valve G, will press upon the piston and cause it to descend, while, by its action upon the working-beam through the piston-rod, &c., it pulls down the cylinder-end of the beam, and raises up the outer-end and the connecting rod *h*, which, causes the planet-wheel *i* to tend to revolve round the sun-wheel *j*; but the former of these wheels, being fixed upon the connecting rod so that it cannot turn upon its own axis, and its teeth being engaged in those of the sun-wheel, the latter, and the fly-wheel, upon whose axle or shaft it is fixed, are made to revolve in the desired direction, and give motion to the mill-work.

As the piston descends, the plug-tree Z also descends, and a clamp, or slider, fixed upon the side of the plug-tree, presses upon the handle 1 of the upper Y shaft, or axis, and thereby shuts the valves G and L, and the same operation, by disengaging a detent, permits a weight suspended to the arm of the lower Y shaft to turn the shaft upon its axis, and thereby to open the valves at L and H. The moment previous to the opening these valves, the piston had reached the lowest part of its stroke, and the cylinder *above* the piston was filled with steam; but as soon as H is opened, that steam rushes by the eduction-pipe J, into the condenser, and the cylinder *above* the piston becomes exhausted. The steam from the boiler entering by the lower valve, acts upon the *lower* side of the piston, and forces it to return to the top of a-days confers on the steam-engine a working movement which is wholly free from irregularity; hence it can as easily embroider muslin as forge anchors,—can weave the most delicate fabrics, as well as communicate a rapid movement to the ponderous stones of a flour-mill. This also explains how Mr Watt said, without fearing the reproach of exaggeration, that to avoid the intrusion of domestics, we might employ steam, and in cases of sickness could supply medicines through its silent agency. I am not ignorant that in popular estimation this gentleness of movement is supposed to be obtained at the ex-

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the cylinder. When the piston is very near the upper termination of its stroke, another slider *a* raises the handle 2, and, in so doing, disengages the catch which permits the upper Y-shaft to revolve upon its own axis, and open the valves G and L, and the downward stroke recommences as has been related.

When the piston descends, the buckets R, T, of the air-pump P, and hot-water pump T, also descend. The water which is contained in these pumps passes through the valves of their buckets, and is drawn up and discharged by them through the lander or trough *t*, by the next descending-stroke of the piston. Part of this water is raised up by the pump V, for the supply of the boiler, and the rest runs to waste.—N.

pense of power. But this is an error, and a gross one; and the apophthegm "Much noise and little work," is not only true in the moral world,—it is also an axiom in mechanics.

A few words more, and we reach the termination of these technical details. Within these few years great advantage has been derived from not allowing a free communication between the boiler and cylinder, throughout the whole continuance of each stroke of the machine. This communication is accordingly interrupted when the piston has traversed, we shall say, a third of its course. The two remaining thirds of the stroke are thus accomplished in virtue of the preacquired velocity, and especially by the expansion of the steam. Mr Watt had already indicated this procedure.* Excellent judges place it, in point of economical importance, on a level

* The principle of the expansion of steam, clearly indicated in a letter of Mr Watt's to Dr Small, dated in May 1769 (see the letter in Farey's Steam-Engine, vol. i. p. 339), was put in practice in the year 1776 at Soho, and in 1778 at the *Shadwell Water-Works*, from economical considerations. The invention, and the advantages which were expected from it, are fully described in the patent of 1782.

with the condenser. It appears certain, that since its adoption the Cornish machines have yielded unlooked-for results; and that, with a bushel of coal, they realize the work of twenty men working for ten hours. Let us remember, that in the coal districts a bushel of coal often does not cost *ninepence*, and it will be seen that Watt has brought it about, that over a great part of England, a man's hard day's work—ten work hours to the day—may be done for less than a halfpenny.*

Such numerical valuations so strikingly prove

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* At a time when so many people are occupied with projects of rotatory steam-engines, it would be unpardonable were I not to state that Watt had not only thought of them (of which we find proof in his patents), but had actually constructed them. Mr Watt subsequently abandoned them, not because they did not work, but because they appeared to him decidedly inferior, in an economical point of view, to machines of double powers and rectilineal oscillations.

There are, in fact, few inventions, great or small, among those so admirably combined in our present steam-engines, which are not the development of some of the original ideas of Watt. Examine his labours, and in addition to the principal points minutely enumerated in the text, you will find he proposed machines without condensation, in which, after having acted, the steam is dispersed in the air, and which the importance of the inventions of our learned associate, that I cannot resist the temptation of giving two other illustrations, both of which I borrow from Sir John Herschel, one of the most distinguished correspondents of the Academy. The ascent of Mont Blanc, starting from the val-

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were intended for localities where large quantities of cold water could not readily be procured. The operation of the principle of expansion in machines with several cylinders, was also one of the projects of the Soho engineer. He suggested the idea of pistons, which should be perfectly steam-tight, although composed exclusively of metal. It was Watt also who first had recourse to mercurial manometers for measuring the elasticity of the steam in the boiler and the condenser, who conceived the idea of a simple and permanent gauge by whose assistance might always be ascertained, with a glance of the eye, the level of the water in the boiler, and who, to prevent this level ever varying injuriously, connected the movements of the feeding pump with those of a float; and who, when required, placed in an opening in the cover of the principal cylinder of the machine the *indicator*, a small apparatus so constructed that it accurately exhibits the state of the steam, in relation to the position of the piston, &c. &c. Did time permit, I could shew that Watt was not less skilful and happy in his attempts to improve the boilers, to diminish the loss of heat, and to consume those torrents of black smoke which issue from common chimneys, however elevated they may be.

ley of Chamouni, is very justly considered as one of the hardest tasks which it is possible for a man to execute in the course of two days. Thus the maximum of the labour which we are capable of undergoing in twice twenty-four hours, may be measured by the transport of the weight of our body to the height of Mont Blanc. This labour, or an equivalent to it, is executed by a steam-engine with the consumpt of two pounds of coals. It has thus been established by Watt, that the daily power of man does not exceed that which is contained in a pound of coal. Again, Herodotus informs us, that the construction of the Grand Pyramid of Egypt employed one hundred thousand men during the space of twenty years. The pyramid is formed of limestone ; its volume can easily be calculated ; and hence it is deduced that its weight is about thirteen millions of millions of pounds. To elevate this weight to the height of one hundred and twenty-five feet English, which is the height of the centre of gravity of the pyramid, it would be necessary to consume under the boiler of a steam-engine 630 chaldrons of coal ; and I could name a foundery in Britain which consumes a greater quantity every week.

*Copying Press—Heating by Steam—The Composition of Water—Bleaching by means of Chlorine—Experiments upon the Physiological Effects resulting from the Respiration of various Gases.*

Birmingham, when Mr Watt went to establish himself at Soho, reckoned among the inhabitants of the neighbourhood, Priestley, whose name is universally known; Darwin, the celebrated author of the Zoonomia, and of a poem, "The loves of the Plants;" Withering, a physician and distinguished botanist; Keir, a chemist well known by the notes appended to his translation of Macquer, and by an interesting memoir on the Crystallization of Glass; Galton, to whom we are indebted for an elementary treatise on Ornithology; and Edgeworth, the author of several esteemed works, and father of the celebrated Maria Edgeworth. These scientific and literary men speedily became the friends of the distinguished mechanist, and most of them united in forming with him and Mr Boulton an association under the name of "*The Lunar Society.*" This fantastic title has given rise to various mistakes; but it imported nothing more than that the night of meeting was that of the full moon, a time selected, in order that the members might comfortably reach their several homes.

Every meeting of the Lunar Society gave fresh occasion to remark the uncommon fertility of invention with which Watt was endowed. "I have thought," observed Dr Darwin one evening, "of a kind of double pen, a pen with two points, by which one might write the same thing twice over at the same time, and thus supply himself at once with the original and with a copy." "I hope," replied Watt, almost immediately, "to discover a better method for accomplishing the same object. I will mature my ideas to-night, and communicate them to you to-morrow." The *Copying Press* was invented the next day; and even a small model was prepared, ready to shew its powers. This most useful instrument, now so generally adopted in all the offices and counting-rooms in England, has recently received some slight modifications, of which various artists have assumed the credit to themselves; but I can truly affirm, that the present form was described and delineated as early as the year 1780, in the patent of our associate.

*Heating by means of Steam* was an invention three years later in time, which Mr Watt introduced into his own dwelling in 1783. We have no wish here to conceal, that this ingenious method was previously described by Colonel Cooke, in the Philosophical Transactions for 1745;* but there it long lay overlooked and neglected. Mr Watt, however, had the sole merit of reviving it. He was the first to apply it; and it was his calculations upon the extent of surface necessary to be heated in rooms and edifices of different sizes, which served at the first as the basis of the plans of most English engineers.

Had Watt, during his long career, done nothing more than introduced the separate condenser, the working steam expansively, and the

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* By the work of Mr Robert Stuart, I find that Sir Hugh Platte, previous to Colonel Cooke, had foreseen the possibility of applying steam to the heating of apartments. In the *Garden of Eden* of this author, published in the year 1660, we find mention made of something of an analogous kind for preserving plants during winter in greenhouses. Sir Hugh Platte proposed to place covers of tin, or of some other metal, upon the vessels that were used for cooking, and thus to connect pipes to openings in the covers of these vessels, by which the heated vapour might be carried whereever it was desired.

jointed parallelogram, he would have occupied one of the first places among the small number of individuals whose life constitutes an epoch in the annals of the world. It appears to me, however, that his name is also connected in a distinguished manner with the greatest and most prolific discovery of modern chemistry, namely, the *discovery of the composition of water*. My assertion to many may appear rash, inasmuch as, in the numerous works which have professedly treated upon this capital point in the history of the sciences, Watt has been forgotten. I trust, notwithstanding, that you will be ready to follow my discussion without prejudice; that you will not be diverted from the inquiry by authorities who have taken the other side of the question, and who, after all, are less numerous than is generally supposed; that you will remember how few authors now-a-days go direct to the original sources, how little disposed they are to encounter the musty dust of our libraries, and, on the contrary, how much easier it seems to them to live upon the erudition of another, reducing the composition of a book to the simple labour of compilation. The warrant which I hold for your confidence seems to me more serious; I have examined numerous published memoirs, and the whole of a very voluminous authentic correspondence still in manuscript; and if I now come, after a lapse of fifty years, to claim for James Watt an honour which was too readily conceded to one of his most illustrious countrymen, it is because I consider it useful to demonstrate, that, within the walls of our scientific associations, truth is sooner or later brought to light, and that, in the matter of discovery at least, there is no prescription.

The four pretended elements of fire, air, earth, and water, whose various combinations were supposed to produce all known bodies, constitute one of the legacies of a brilliant philosophy, which dazzled and misled the most noble intelligences. Van Helmont was the first who shook, though but slightly, one of the principles of this ancient theory, by calling the attention of chemists to several permanent elastic fluids or *airs*, which he called *gases*, whose properties differed from those of common air, or elemental air. The observations of Boyle and of Hooke created still graver difficulties, for they established that the common air, necessary to respiration and combustion, undergoes very remarkable changes in the course of these processes, and such changes in its properties, as to imply that it is a compound body. The numerous observations of Hales; the successive discoveries of carbonic acid gas by Black, and of Hydrogen by Cavendish; of nitrous acid, of oxygen, of muriatic and sulphurous acids, and of Ammonia by Priestley, gave the finishing blow to the antiquated notion that air was simple and elemental, and dismissed it as one of the rash and almost always false conceptions, which proceed from those who have the hardihood to consider themselves called not to discover, but to divine, the footsteps of Nature.

In the midst of these remarkable discoveries, water had always maintained its character of an element. The year 1776, however, was distinguished by one of those observations which necessarily led to the overturn of this general belief; whilst, at the same time, we must avow, that from the same period are to be dated those strange attempts which chemists for a long time made to resist the consequences which naturally flowed from their experiments. The observation to which I here particularly allude, was one of Macquer's. This judicious chemist having placed a white porcelain saucer over the flame of some hydrogen gas, which burned steadily as it issued from a bottle's mouth, observed that the flame was not accompanied by any smoke properly so called, and that it deposited no soot. The portion of the saucer upon which the flame struck—or, to use his own words, which it *lapped*—was soon covered with very conspicuous drops of a liquid similar to water, and which, upon trial, was found to be pure water. Here, assuredly, was a singular result, well worthy of attention: it was in the midst of flame, in that portion of the saucer, as Macquer said, lapped by the flame, that watery drops were deposited! This chemist, however, did not seize upon the fact;—he was in no degree astonished at what was so wonderful; he simply states it, without the slightest comment; and failed to perceive that he had touched upon the very threshold of a grand discovery.

In the sciences of observation, then, is genius to be reduced to the mere capability of saying at the fitting moment,—*Why?*

In the physical world, we consider as volcanos, mountains which never have had more than a single eruption; and in the intellectual world, in like manner, there are men who, after one flash of genius, for ever disappear from the history of science. Such an one was Warltire, whose truly remarkable experiments fall here in chronological order to be cited. At the beginning of the year 1781, this philosopher conceived that an electric spark could not traverse certain gaseous mixtures without inducing a change in them. An idea so novel, which no previous analogy could have suggested, and of which such wondrous applications have since been made, in my apprehension, requires that all the historians of the science should render due honour to its author. Warltire was deceived regarding the true nature of the changes caused by electricity. Happily for himself, he foresaw that an explosion would be a necessary consequence; and hence he made his first experiment in a metallic vessel in which he had put a mixture of common air and hydrogen.

Cavendish speedily repeated the experiments of Warltire. The *certain date* (and by this term I mean such an one as results from a paper having been given in, a communication having been read in a scientific society, or a treatise having been printed), the *certain date*, I repeat, of this investigation is previous to the month of April 1783; because Priestley quotes the observations of Cavendish in a memoir dated the 21st of that month.

The citation, it should be noted, informs us only of a single particular, viz. that Cavendish had obtained *water* by the detonation of a mixture of oxygen and hydrogen, a result which Warltire had previously obtained.

In his memoir of the month of April, Priestley added an important circumstance to those resulting from the experiments of his predecessors: he proved that the weight of the water which is deposited upon the sides of the vessel, at the instant of the detonation of the oxygen and hydrogen, is precisely the same as the weights of the two gases.

Watt, to whom Priestley communicated this important result, immediately perceived, with the penetration of a superior man, that a proof was here afforded that water was not a simple body. "What," he writes to his illustrious friend, "are the products of your experiment? They are *water*, *light*, and *heat*. Are we not, thence, authorized to conclude that water is a compound of the two gases, oxygen and hydrogen, deprived of a portion of their latent or elementary heat; that oxygen is water deprived of its hydrogen, but still united to its latent heat and light? If light be only a modification of heat, or a simple circumstance of its manifestation, or a component part of hydrogen, oxygen gas will be water deprived of its hydrogen, but combined with latent heat."

This passage, so clear, so precise, and logical, is taken from a letter of Watt's, dated 26th April 1783. The letter was communicated by Priestley to several of the scientific men in London, and was transmitted immediately afterwards to Sir Joseph Banks, the President of the Royal Society, to be read at one of the meetings of that learned body. Circumstances, which I suppress as being foreign to the present discussion, retarded the reading of the letter for about a year, but it remained the while in the archives of the Society. It appears in the 74th volume of the Transactions, with its true date, April 26th, 1783. It is there to be found embodied in a letter from Watt to Deluc, bearing date 26th of November 1783, and is distinguished by inverted commas, supplied by the secretary of the Royal Society. I ask not indulgence for this profusion of details, because it is clear that the minute comparison of dates can alone bring the truth to light concerning a discovery which confers the highest honour upon the human intellect.

Among those who put in their claims to be the authors of this most pregnant discovery, we shall now see appearing the two greatest chemists, of whom France and England can boast. As every one will anticipate, I speak of Lavoisier and Cavendish. The date of the public reading of the memoir in which Lavoisier gives an account of his experiments, whereby he explained his views upon the production of water by the combustion of oxygen and hydrogen, is later by two months than the deposit of Watt's letter already alluded to, in the archives of the Royal Society of London.

The celebrated memoir of Cavendish, entitled "Experiments upon Air," is still later, being read on the 15th of January 1784. It could not fail to be a matter of astonishment, that facts so well authenticated should become the subject of an animated controversy, were I not immediately to bring under notice a circumstance to which I have not hitherto alluded. Lavoisier distinctly states, in precise terms, that Mr Blagden, secretary of the Royal Society of London, was present at his first experiments on the 24th June 1783; and "that he told him that Cavendish, having previously endeavoured, in London, to burn hydrogen in close vessels, had obtained a sensible quantity of water." Cavendish, also, in his own memoir, alludes to the communication made by Blagden to Lavoisier. According to him, it was more ample than the French chemist avows; and he states that the confidential communication embraced the conclusions to which the experiments led; in other words, the theory of the composition of water. Blagden also took part in the controversy; and in Crell's Journal, in the year 1786, did what he could to confirm the assertion of Cavendish. According to him, the experiments of the Parisian academician were only a simple verification of those of the English chemist; and he assures us, that he announced to Lavoisier, that the water produced in London was of a weight precisely equal to that of the two consumed gases. Finally, Blagden adds: *Lavoisier has said the truth, but not the whole truth.* This reproach is severe; but, if it was deserved, shall I not materially diminish its severity, if I prove that, with the exception of Watt, all those whose names appear in this piece of history were more or less exposed to it?

Priestley reports in detail, and as his own, the experiments from which it results that the water produced by the detonation of a mixture of oxygen and hydrogen, is of a weight precisely equal to that of the two consumed gases. Cavendish, some time after, claims this conclusion as his property, and insinuates, that he had communicated it verbally to the chemist of Birmingham.

From this equality of weights, Cavendish deduces the consequence that water is not a simple body. In the first instance, he makes no mention whatever of a memoir deposited in the archives of the Royal Society, and in which Watt developed the same theory. It is true that, when Cavendish's paper was printed, Watt's name is not omitted ; but it is not in the archives that the account of the labours of the celebrated engineer had been found; it is stated that the information was obtained from a paper recently read at a public meeting. It is, however, now clearly established, that the paper referred to, was read many months subsequent to the memoir in which Cavendish alludes to it.

Appearing upon this field of controversy, Blagden announces his firm determination to clear up and settle every thing. He does not flinch from any accusation, or from the citation of any date, so long as his object is to insure for his protector and friend Cavendish, the priority in reference to the French chemist. So soon, however, as he takes up the question as between his own two countrymen, his explanations become altogether vague and obscure. "During the spring," he remarks, "of the year 1783, Mr Cavendish shewed us that he had necessarily deduced from his experiments, the conclusion, that oxygen is nothing else than water deprived of its phlogiston (that is to say, its hydrogen). *About the same time*, the news reached London, that Mr Watt of Birmingham had been led by some observations to a similar opinion." The expression, *About the same time*, to adopt Mr Blagden's own phrase, was not *the whole truth. About the same time decides nothing.* Questions of priority may depend upon months, weeks, days, or even minutes. To be clear and precise, as he had promised, he ought to have told us if the verbal communication made by Cavendish to several members of the Royal Society, preceded, or followed, the reception of the news of Watt's opinion. Is it conceivable that Blagden would have failed to be explicit upon a fact of such importance, if he could have cited an authentic date in favour of his friend?

To make the confusion complete, even the compositors, printers, and correctors of the press of the Philosophical Transactions would appear to have taken part in the dispute. Many of the dates are there inaccurately given. In the separate copies of his memoir, which Cavendish himself distributed, I perceive a mistake of a whole year. By a sad fatality, for it is a real misfortune involuntarily to give occasion to grievous and unmerited suspicions, not one of these typographical errors was favourable to Watt! Let it not be supposed that, by these remarks, I mean to inculpate the literary honesty of the celebrated men whose names I have mentioned; they prove merely, that where matters of discovery are concerned, the narrowest justice is all that one can expect from a rival or competitor, however high may have been his previous reputation. Cavendish would scarcely listen to his men of business, when they came to consult him concerning the disposal of his prodigious wealth; but we may perceive, he had not the same indifference concerning his scientific property. We ought to insist, therefore, in demanding, after the example of the judges in courts of law, that the historians of science should never receive, as valid titles of property, any other than written, I should perhaps add published titles. It is then, and then only, that an end will be put to those constantly recurring disputes which are usually agitated at the expense of national vanity; and it is then only that the name of Watt will assume that distinguished place in the history of chemistry to which it is justly entitled.

The solution of a question of priority, where, as in the present instance, it is grounded upon the most attentive examination of printed memoirs, and a minute comparison of dates, possesses all the characters of a complete demonstration. Nevertheless, it may not be superfluous to notice slightly, various difficulties to which respectable individuals have seemed to me to attach some importance.

How, it has been said, can it be admitted that, amidst the immense turmoil of commercial business,—engaged with a multitude of law-suits, and obliged to provide, by the ingenuity of every passing day, for the difficulties of an infant discovery, Watt could have found time to follow, step by step, the progress of chemistry, to originate experiments, and propose explanations which even the masters of the science had not foreseen? To this difficulty, I make a very short and conclusive answer. I have now in my possession the copy of an active correspondence, relating principally to chemistry, which Watt maintained during the years 1782–3, and 4, with Priestley, Black, Deluc, the engineer Smeaton, Gilbert Hamilton of Glasgow, and Fry of Bristol.

Another objection, proceeding from a profound knowledge of the human heart, appears more specious. Since the discovery of the composition of water is one that ranks at least as high as the admirable inventions combined in the steam-engine, can it supposed that Watt consented with satisfaction, or without even testifying his displeasure, to see himself despoiled of the honour which it would for ever have conferred upon his name? The only defect of this reasoning is, that it has not the shadow of foundation. Watt never renounced the part which legitimately belonged to him in the discovery of the composition of water. He caused his paper to be printed with scrupulous accuracy in the Philosophical Transactions. A detailed note determined authoritatively the dates when the several parts of this paper were presented. What more could, or ought, a philosopher of Mr Watt's character to have done, except to wait patiently for the time when justice would be awarded.

Besides, the imprudence of Deluc had almost forced our associate from his usual equanimity. The Genevese philosopher, after having informed the celebrated engineer of the inexplicable omission of his name in the first impression of Cavendish's memoir; and, after having characterized this neglect in terms which the celebrity of the parties does not permit me to repeat, writes to his friend: "I would almost counsel you, in your circumstances, to extract from your discoveries, practical results which will improve your fortune. You must avoid causing people to be jealous." These words wounded Watt's noble mind. "As to what you say," he replies, "about making for myself *des jaloux*, that would weigh little with me, for were I convinced I had had foul play, if I did not assert my right, it would be from a contempt for the modicum of reputation which would result from such a theory, from a conviction of my own mind I was their superior, or from an indolence that makes it more easy for me to suffer wrongs, than to seek redress. In point of interest, so far as connected with money, that would be no bar, for, though I am dependent on the favour of the public, I am not on Mr Cavendish or his friends."

Few, I apprehend, will consider that I have attached too much importance to the theory which Watt suggested in explanation of Priestley's experiments. Those who refuse to pay a just tribute to this theory, because it now appears to be nothing more than the inevitable consequence of the facts, forget that the most beautiful discoveries of the human intellect have been the most distinguished for their simplicity. What did Newton himself, when, repeating an experiment which had been known for fifteen centuries, he discovered the composition of white light? He attached to that experiment an interpretation so natural, that now-a-days, it seems impossible to find any other. All that you obtain, says he, with the help of any process whatsoever, from a pencil of white light, was contained therein in its state of mixture. The glass prism has no creative power. If the parallel and infinitely slender pencil of solar light which strikes upon the one face, issues from the other divergingly, and with increased breadth, it is because the glass separates that which, in the white ray, was, by its nature, unequally refrangible. These words are nothing more than a literal interpretation of the well known experiment of the prismatic solar spectrum, an interpretation, however, which had escaped the penetration of Aristotle, Descartes, and Robert Hooke.

But, without departing from our present subject, let us come to arguments which bear still more directly on this point. The theory conceived by Watt concerning the composition of water reaches London. If, according to the apprehension of the time, it was as simple and as evident as it now appears to be, the Council of the Royal Society would not have failed to adopt it. But it was far from doing so; its *strangeness* made them even doubt the truth of Priestley's experiments: *they even laughed at it*, says Deluc, *as at the explanation of the dent d'or.* Again, a theory, the conception of which was attended with no difficulty, would certainly have been disdained by Cavendish; and yet, with what pertinacity, under the influence of that man of genius, did Blagden claim priority of discovery in opposition to Lavoisier. Priestley, upon whom a considerable share of the honour attached to the discovery of Watt must naturally fall, and whose affectionate regard for the celebrated engineer cannot be questioned, wrote to him, under date of 29th April 1783: "You will examine with surprise and indignation the sketch of an apparatus with which *I have undermined, to its very basis, your beautiful hypothesis.*"

Upon the whole, then, a theory which was ridiculed at the Royal Society,—which forced Cavendish out of his habitual reserve,—and which Priestley, regardless of the fresh honour it brought him, set himself deliberately to overturn,—deserves to be recorded in the history of science as a great discovery, whatever notion our present intimacy with the subject might lead us to adopt concerning it.*

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* Lord Brougham was present at the public meeting of the Institute, when, in the name of the Academy of Sciences, I paid this tribute of gratitude and admiration to the memory of Watt. On his return to England, he collected some valuable documents, and studied anew the historical question to which I have devoted so much space in this memoir. He investigated the subject, in his usual masterly style, and with that scrupulous care, in some degree judicial, which might be expected from the former Lord Chancellor of Great Britain. I owe it to an act of kindness which I duly appreciate, that I am able to present to the public the result of the labours of my illustrious fellow member.

*Bleaching by means of Chlorine*, the beautiful invention of Berthollet, was introduced into Britain by James Watt, soon after having paid a visit to Paris, towards the end of the year 1786.* He constructed all the necessary apparatus, directed their suitable arrangement, superintended the first trials, and then confided to his father-in-law Mr Macgregor, the general introduction of the valuable improvement. In spite of all the urgent solicitations of the illustrious engineer, our celebrated countryman obstinately refused (however extraordinary it may appear in the age in which we live) to be associated in an undertaking which, to him, was free from risk, and of which, it appeared, the profits must be very great.

No sooner, in the latter half of the last century, were the numerous gases discovered, and the important agency they exerted in the explanation of chemical phenomena, than the question

* This journey was undertaken with Mr Boulton, at the instance of the French Ministry, to advise them respecting the substitution of steam for water, as the moving power in the water-works at Marly. The state of the finances, and the approaching revolution, put an end to the plan at the time.—Edit.

of their employment as powerful medicines was convassed and advocated. Dr Beddoes especially prosecuted this subject with sagacity and perseverance. With the help of private subscriptions, he was enabled to establish at Clifton, near Bristol, an institution, known under the name of the *Pneumatic Institution*, where the remedial properties of the gases generally might be carefully studied. This establishment, for a time, was more immediately superintended by Humphry Davy, then a young man just beginning his brilliant career. It was also honoured with the name of Watt as one of its founders; and the celebrated engineeer did more, for he planned, described, and constructed, in the manufactory of Soho, the apparatus which was employed in preparing the different gases, and in administering them to the patients. I find that many editions of his Directions were required, and were published in the years 1794, 1795, and 1796.

The thoughts of our associate were directed to this interesting subject, from the circumstance that many of his connections and friends were cut down in early life, by diseases of the chest; and he imagined that it was in this class of complaints that the specific properties of the new gases would be most strikingly manifested. He also anticipated that some benefit would be derived from the iron and zinc, which hydrogen contains in impalpable molecules, when prepared by certain processes. I shall add, in conclusion, that among the numerous notes supplied by physicians, and published by Dr Beddoes, announcing results more or less favourable, there is one, signed John Carmichael, respecting the complete cure of one of his servants, named Richard Newberry, to whom Watt had himself administered, from time to time, by way of respiration, a mixture of steam and carbonic acid. Though perfectly aware of my incapacity to come to any satisfactory conclusion on a matter of this sort, I must take the liberty of expressing my regret that a plan of treatment which numbered Watt and Jenner among its adherents, should be at present entirely abandoned, and this without there being adduced any connected series of experiments in manifest opposition to those of *the Clifton Pneumatic Institution.**

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* Twenty years previous to the existence of the Pneumatic Institution, Watt had applied his chemical and mineralogical knowledge to the improvement of a pottery,

*Watt in Retirement—Details respecting his Life and Character—His Death—The numerous Statues erected to his Memory—Reflections.*

In the year 1764, Mr Watt had married his cousin Miss Miller. She was an accomplished person; and her talents, imperturbable sweetness, and cheerfulness of disposition, speedily rescued the celebrated engineer from an oppression of lassitude, discouragement, and misanthropy, which a nervous attack, and the injustice which he experienced, had well nigh rendered fatal. Without the cheering influence of his wife, Watt perhaps would never have published to the world his beautiful inventions. Of this marriage were born four children, two sons and two daughters. At an after period Mrs Watt expired in child-bed, and her infant did not survive her. Her husband at the time was absent, engaged in the north of Scotland, with the plans of the Caledonian Canal. I shall here take the liberty of transcribing, in all their native simplicity, a few lines from the journal in which he was in the

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which, along with some friends, he had established at Glasgow, and of which he continued a partner to the close of his life.

habit of recording daily his most private thoughts, his fears and his hopes. " I did what I could to force grief from my mind ; but feared to come home where I had lost my kind welcomer. In her I lost the comfort of my life, a dear friend, and a faithful wife." Here is a striking picture of heartfelt sorrow, which may serve to shake the confidence of those system-makers, who, despite of innumerable instances to the contrary, deny the free and kindly play of the feelings to every one whose intellect finds its nourishment in the sublime and imperishable truths of the exact sciences. After several years of widowhood, Mr Watt had the happiness to find in Miss Macgregor, a companion, rendered worthy of him, by the variety of her talents, the soundness of her judgment, and the strength of her character.*

On the expiration of the term to which his patent had been extended by Parliament, viz. in the beginning of the year 1800, Mr Watt withdrew himself entirely from business. His two sons succeeded him; and, under the enlightened direction of the younger Mr Boulton, and the

* This lady deceased in the year 1832, at a very advanced age. She had the misfortune of surviving the only two children she ever had.

young Messrs Watt, the establishment at Soho continued to prosper, and became more extended than ever. Even to the present day, it occupies the first rank among the English manufactories of great and powerful machines. Mr Watt's second son, Gregory Watt, had distinguished himself at an early period of his short career, both by his literary labours, and by some geological investigations; but he was cut off, by a disease of the chest, in the year 1804, at the age of twenty-seven. This afflictive event overwhelmed the illustrious engineer, and it required the most anxious attentions of his family and friends to supply some balm to a heart that was well nigh broken. This deep grief has been assigned as the reason of the almost total silence which Mr Watt maintained during the latter years of his life; and I am far from denying it had its share in the result. There is not, however, any occasion for resorting to extraordinary causes, when we reflect upon what were the inherent inclinations of his mind. So far back as the year 1783, we find him stating in a letter to his friend Dr Black, " I wish you to be quite aware that I have no desire to occupy the public with the experiments I have made;" and elsewhere we find these somewhat extraordinary words in the mouth of a man who has filled the world with his renown, " I know but two pleasures—idleness and sleep." That sleep, however, was light; and the slightest excitement roused him from his favourite indolence. Every object presented to his notice, gradually received, in the machinery of his mind, changes of form, of construction, and of nature, which rendered them susceptible of important applications; and when no occasion offered of realizing these conceptions, they were lost to the world. An anecdote will explain my meaning.

A water-company in Glasgow had established, on the right bank of the river Clyde, great buildings, and powerful machines, for the purpose of conveying water into every house in the town. When the works were completed, it was discovered that on the other side of the river there was a spring, or rather a kind of natural filter, which abundantly supplied water of a very superior quality. To remove the works was now out of the question; but a question arose as to the practicability of drawing the water from wells on the left bank, by means of the pumping-engines then existing on the right bank, and through a main-pipe to be carried by some means across the river. In this emergency Watt was consulted; and he was ready with a solution of the difficulty; pointing to a lobster on the table, he shewed in what manner a mechanist might, with iron, construct a jointed tube which would be endowed with all the mobility of the tail of the crustacea; he accordingly proposed a complete jointed conduit-pipe, capable of bending and applying itself to all the inflections, present and future, of the bed of a great river;—in fact, a lobster-tail of iron, two feet in diameter, and a thousand feet in length. He soon after furnished plans in detail, and drawings; and the design was executed for the Glasgow Water Company, with the most complete success.*

Those who were favoured with the personal acquaintance of our honoured associate, have not hesitated to declare, that in him the invaluable qualities of the heart were even superior to those

* We have thought it necessary to alter somewhat the version of this account given in the original, as M. Arago seems to have misapprehended the facts which were stated to him regarding the Glasgow Water Company. A full account of the flexible Water-Main, by Sir John Robison, together with an illustrative plate, will be found in the *Edinburgh Philosophical Journal*, vol. iii. p. 60.—EDIT.

of his head. His singular candour, his child-like simplicity of manners, his most scrupulous love of justice, and his inexhaustible benevolence, have left in Scotland, and throughout Britain, recollections which will never be effaced. But with all this disposition, so moderate and gentle, Mr Watt writhed when he heard an invention ascribed to any other than the true author, and especially when some base flatterer would attempt to enrich him, at the expense of another. In his eyes, scientific discoveries were property of the highest order; and whole hours of discussion he considered well spent, if he succeeded in doing justice to modest men, whose inventions had been filched from them by plagiarists, or who were merely overlooked by an ungrateful public.

The memory of Watt might be cited as prodigious, even in comparison of all the wonders which have been narrated of this faculty as possessed by a few privileged individuals. Its extent, however, was its least merit; for while it made him master of every thing that was of real value, it wholly rejected, and almost instinctively, whatever was superfluous, and not worth the keeping.

The variety of the knowledge of our associate, would have been absolutely incredible, were it not attested by many eminent men. Lord Jeffrey, in his eloquent notice, very happily characterizes the understanding of his friend, at once strong and subtile, by comparing it to the proboscis of the elephant, which serves with equal facility to lift a straw, or uproot the oak.*

The following are the terms in which Sir Walter Scott speaks of his illustrious countryman in the preface to The Monastery. "It was only once my fortune to meet Watt, when there were assembled about half a score of our northern lights.† Amidst this company stood Mr Watt, the man whose genius discovered the means of multiplying our national resources to a degree, perhaps, even beyond his own stupendous powers of calculation and combination; bringing the treasures of the abyss to the summit of the earth,—giving to the feeble arm of man the momentum of an Afrite,—commanding manufactures to arise,—affording means of dispensing with that time and tide which wait for no man,—and of

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* See extract from the Encyclopædia Britannica, LIFE OF WATT, appended to this publication. The discrepancy in regard to the application of Lord Jeffrey's comparison, occurs in the original of M. Arago.

† At the table of one of the Commissioners of Northern Lighthouses.—EDIT.

sailing without that wind which defied the commands and threats of Xerxes himself. This potent commander of the elements,—this abridger of time and space,—this magician, whose cloudy machinery has produced a change in the world, the effects of which, extraordinary as they are, are perhaps only beginning to be felt,—was not only the most profound man of science, the most successful combiner of powers, and calculator of numbers, as adapted to practical purposes,—was not only one of the most generally well-informed, but one of the best and kindest of human beings. There he stood, surrounded by the little band of northern literati. Methinks I yet see and hear what I shall never see or hear again. In his eighty-first year, the alert, kind, benevolent old man, had his attention at every one's question, his information at every one's command. His talents and fancy overflowed on every subject. One gentleman was a deep philologist,—he talked with him on the origin of the alphabet, as if he had been coeval with Cadmus; another a celebrated critic,—you would have said that the old man had studied political economy and belles-lettres all his life;—of science it is unnecessary to speak, it was his own distinguished walk. And yet when he spoke with your countryman, you would have supposed he had been coeval with Clavers and Burley,—with the persecutors and persecuted; and could number every shot that the dragoons had fired at the fugitive Covenanters."

Had our associate been at all solicitous, he might easily have acquired a name among the writers of Romance. In the circle of his more intimate acquaintances, he seldom failed to improve upon the anecdotes, whether frightful, affecting, or amusing, which he heard narrated. The minute details of his recitals, the proper names with which he interspersed them, the technical descriptions of castles and country houses, of forests and caves, to which the scene was successively transported, gave to these *improvisations* so complete an air of truth, that one could scarcely retain the slightest sentiment of disbelief. On one occasion, however, Watt experienced considerable embarrassment in extricating his characters from the labyrinth in which he had somewhat imprudently involved them. One of his friends, perceiving his difficulty, from the unwonted frequency with which he applied to his snuff-box, as if to explain his pauses, and gain time for reflection, said to him, "Are you, at random, recounting a tale of your own invention?" "Your inquiry," replied the old man, "astonishes me; during the twenty years I have been so happily spending my evenings with you, I have done nothing else. Surely you did not wish to make me the rival of Robertson and Hume, when the utmost of my pretensions was to follow, at a humble distance, in the footsteps of the Princess Scheherazade of '*The Thousand and One Nights*.'"

Every year, during a very short visit to London, and sometimes to towns not so remote from Birmingham, Mr Watt made a minute examination of every thing new which had appeared since his previous journey. I do not except the industrious fleas, and the puppet theatricals; for the illustrious engineer visited them with all the enthusiasm and joy of a schoolboy. In following, even now, the itinerary of these annual progresses, we should find, in many places, brilliant traces of Mr Watt's visits. At Manchester, for example, we may see the Hydraulic Ram, at the suggestion of our associate, helping to raise the water of condensation of a steam-engine to the feeding reservoir of the boiler.

Watt usually resided at his country-seat near Soho, called Heathfield, which he bought about the year 1790. The respectful veneration which my friend Mr James Watt cherishes for every thing that recalls the memory of his father, procured for me the satisfaction of examining, in the year 1834, the library and furniture at Heathfield, in the precise state in which the illustrious engineer left them. A second property, on the picturesque banks of the Wye in Wales, furnishes to travellers multiplied proofs of the refined taste of Mr Watt and his son, for the improvement of roads, plantations, and all kinds of agricultural operations.

The health of Mr Watt had improved with his years; and his intellectual faculties retained all their vigour to the last. At one time our associate imagined that they were declining, and, in keeping with the seal he had adopted (an eye surrounded with the word *observare*), he determined to satisfy his doubts by making observations on himself; and accordingly, when upwards of seventy years of age, he determined to select some kind of study on which he might try his powers, and for a time was in despair, because he could find no subject that was new to him. At length he thought of the Anglo-Saxon tongue, which is a difficult language ; and immediately it became the subject of the desired experiment, when the facility with which he mastered it, soon convinced him there was no ground for his apprehensions.

During the last few months of his life, Mr Watt was engaged in the construction of a machine intended to copy rapidly, and with mathematical precision, pieces of statuary and sculpture of all dimensions. This machine, of which it is tobe hoped that the arts will not be deprived, must have been nearly completed. Many of its productions, upon the whole very satisfactory, are now to be seen in various private collections, both of Scotland and England. The illustrious engineer presented them to amateurs somewhat facetiously, as the first attempts of a young artist entering upon the eighty-third year of his age.

Of that eighty-third year, our associate was not permitted to see the end. In the commencement of the spring of the year 1819, alarming symptoms appeared, which defied all the powers of medicine. Mr Watt was himself perfectly aware of his situation, and often remarked to the numerous friends who visited him, that he was deeply affected with the strong attachment they manifested towards him, and that he was the more anxious to thank them, because he had arrived at his last illness. His son appeared to him not sufficiently resigned ; and every day he sought some new occasion to point out to him with gentleness, kindness, and tenderness, the many causes of consolation which the circumstances of the inevitable event still presented. That mournful event happened on the 25th of August 1819.

Watt was interred in the burying-ground of the parish church of Handsworth, near Birmingham, in Staffordshire. Mr James Watt, whose distinguished talents and noble sentiments, for nearly twenty-five years, enhanced the happiness of his father's life, has erected to him a splendid Gothic monument which makes the church of Handsworth extremely remarkable. In the centre of the structure, there is an admirable statue, in marble, by Chantrey, which is a very faithful representation of the noble features of the original.

A second statue, likewise in marble, from the hand of the same master, has also, by filial affection, been placed in one of the halls of the celebrated university, where, in his youth, the artist, yet unknown, and exposed to the persecution of the corporations, received encouragement so flattering, and so well merited. Nor has the town of Greenock forgotten that it can boast of being the birthplace of Watt. Its inhabitants have ordered, at their own expense, a marble statue to the illustrious mechanist. It is to be placed in a beautiful library, built on a site presented gratuitously by the late Sir Michael Shaw Stewart, and in which will be united the books of the public library, and the Collection of Works of Science which Watt had presented to the establishment during his lifetime. This building has already (in 1834) cost L.3500, to which Mr James Watt has liberally contributed. A fine colossal statue in bronze, placed upon a beautiful pedestal of granite in George's Square, Glasgow, demonstrates to every one how proud this capital of Scottish industry is of having been the cradle of Watt's discoveries. Finally, the portals of Westminster Abbey have been opened at the voice of an imposing union of subscribers; and there stands a colossal statue of WATT in Carrara marble, the chef-d'œuvre of CHANTREY (bearing an inscription by Lord BROUGHAM,* and one of the principal ornaments of the English Pantheon. There is unquestionably some *coquetterie* in thus uniting the illustrious names of Watt, Chantrey, and Brougham, upon the same monument. But far be it from me to make this a ground of blame.

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* We subjoin the inscription :—

Not to perpetuate a name
which must endure while the peaceful arts flourish,
but to shew
that mankind have learnt to honour those
who best deserve their gratitude,
the King,
his Ministers, and many of the Nobles
and Commoners of the Realm,
raised this Monument to
JAMES WATT,
who, directing the force of an original genius,
early exercised in philosophical research,
to the improvement of
the Steam Engine,
enlarged the resources of his country,
increased the power of man,
and rose to an eminent place
among the illustrious followers of Science,
and the real benefactors of the world.
Born at Greenock MDCCXXXVI.
Died at Heathfield in Staffordshire, MDCCCXIX.

Happy rather that people who thus avail themselves of opportunities to honour their illustrious dead.

We have thus given an account of five grand statues which have been erected in a short time to the memory of Watt. And must we now confess, that these tributes of filial love, and public gratitude, have excited the disapprobation of some narrow-minded beings, who, remaining stationary themselves, fancy they thereby arrest the advance of ages. According to them, warriors, and magistrates, and statesmen (though I venture to assert they will surely not include all of this latter class), have alone a right to statues. I do not know if Homer and Aristotle, if Descartes and Newton, would appear in the eyes of these new Aristarcuses worthy of a simple bust; but assuredly they would refuse even a modest medal to our Papins and Vaucansons, our Watts and Arkwrights, and to other mechanists, unknown, perhaps, in a certain circle, but whose renown will go on augmenting from age to age with the progress of knowledge. Since such heresies as these are openly avowed, we must not disdain to combat them. It is not without reason that public opinion has been styled a sponge for prejudices. But prejudices are like hurtful plants: the slightest effort suffices to eradicate them, if they be at once attended to; on the contrary, they grow with time, become inveterate, extend far and near, and their numerous ramifications seize upon every thing that comes within their reach.

If this discussion offend the self-love of some, I must remark it has been provoked. The men of science of our day are not those who have complained that they saw not the great authors, whose inheritance they cultivate, figure in the long ranges of colossal statues, which the authorities proudly elevate on our parapets, and places of public resort; for well they know that these monuments are fragile, that hurricanes shake and overturn them, and that the very vicissitudes of the seasons suffice to destroy their contours, and to reduce them to shapeless blocks. But they too have their statuary and their painting in the printing-press. Thanks to this admirable invention, when the works of science and imagination possess real value, they may defy time and political revolutions. Neither fiscal regulations, nor commotions, nor all the terrors of despots, can hinder such productions from crossing the most carefully guarded frontiers. A thousand vessels transport them, under a variety of forms, from hemisphere to hemisphere. They are studied at one and the same time in Iceland and Van Diemen's Land; they are read in the little circle of the humblest cottage, and in the most brilliant saloons of palaces. The author, the artist, and the engineer, are recognised and appreciated throughout the world by all that is most noble and elevated in man—by judgment, mind, and intelligence. That individual would be foolish indeed, who, occupying such a commanding position, should ever wish that his lineaments, traced in marble or in bronze, even by the chisel of David, should ever be exposed to the gaze of idle loungers. Such honours as these, I repeat, a man of scientific or literary celebrity, or an artist, cannot envy, although he can never admit that he is unworthy of them. Such, at all events, is the decision suggested to my mind by the discussion I am about to submit to your attention.

It is a circumstance passing strange, that our opponents have been led to advance such haughty pretensions, precisely on the occasion of the erection of five statues, which have not withdrawn a single farthing from the public treasury. It is far, however, from being my intention to avail myself of this indiscretion. I prefer considering the question in the abstract, namely, as already stated, the alleged superiority of arms over literature, science, and the arts. And here we must not be deceived; for, if magistrates and governors be associated with military men, it is only that they may be a passport to them.

The extreme shortness of the time I can now devote to this discussion, impresses upon me the necessity of being concise and methodical. That there may be no mistake, then, as to my opinions, I very explicitly declare that independence and national liberty are, in my estimation, the first of human blessings,—that to defend them against foreign and intestine foes is the first of duties, and that to have maintained them—at the price of one's blood—establishes the first claim to public gratitude. Raise, then, splendid monuments to the brave men who fell on the glorious ramparts of Mayence, on the immortal fields of Zurich, and of Marengo, and assuredly my offering will be readily paid; but, at the same time, do not require that I shall do violence to my reason, and to those sentiments which nature has planted in every bosom, nor expect that I shall ever agree to place all military service on the same distinguished level. What Frenchman, possessed of a spark of feeling, even of the times of Louis XIV., would willingly have sought an example of courage, either in the cruel scenes of the Dragonnades, or in the flaming whirlwind which consumed the towns and villages, and rich domains of the Palatinate? Not long since, after a thousand prodigies of patience, ability, and bravery, our valiant soldiers forced Saragossa, already more than half in ruins, and reached the portals of a church, where a priest was heard to exclaim, in the ears of the devoted crowds, these sublime words:—"Spaniards! here I celebrate your obsequies!" I do not know but that, at this moment, the true friends of our national glory, balancing the several merits of the conqueror and the conquered, would gladly have seen them exchange places!

Let morality, if you choose, be put entirely out of the question. Bring to the bar of conscientious criticism the personal claims of certain gainers of battles, and believe that, after having assigned a just share to accident (an ally this of which little is said, because it is dumb), there will be but few heroes who will appear worthy of this high-sounding name.

Were it at all necessary, I should not decline entering into an examination of details, few as have been the opportunities which my purely academical occupations have supplied for collecting accurate documents on the point. I might, for example, cite from our own annals a modern battle,—a battle gained too, the official accounts of which described all as foreseen and anticipated, planned after reflection, and executed with consummate ability, but which, in truth, was gained by the spontaneous movements of the soldiery, without orders from the general upon whom the honours were heaped, and who neither gained the day, nor knew how it was won.

That I may escape the common reproach of incompetency, I shall summon to my help, in support of the philosophical thesis I maintain, no others than warriors themselves. We shall then see how much they valued intellectual labours, and how enthusiastically they appreciated them; and we shall find, that, in their real opinions, works of genius never occupied the second rank. Confined within narrow limits, I shall endeavour, for number and novelty, to substitute celebrity, and shall only cite the opinions of Alexander and Pompey, of Cæsar and Napoleon.

The admiration of the Macedonian conqueror for Homer is an historical fact. Aristotle, at his command, undertook the revision of the text of the Iliad. This corrected copy became his favourite and most esteemed book; and when, in the centre of Asia, amidst the spoils of Darius, a magnificent coffer, of gold, pearls, and precious stones, appeared to excite the cupidity of his lieutenants,—"Let it be reserved for me," exclaimed the conqueror of Arbela, "that I may put my Homer in it. It is the best and most faithful of my counsellors during my military operations; and it is, moreover, just, that the richest production of the arts should be used for the preservation of the most precious production of the human mind." The sack of Thebes had previously demonstrated more clearly still, the unlimited respect and admiration Alexander entertained for literature. One single family alone, of this populous town, escaped death and slavery, and it was the family of Pindar. A solitary mansion remained erect amidst the ruins of temples, palaces, and private dwellings, and it was the house where Pindar—not that where Epaminondas—was born!

After the termination of the Mithridatic war, when Pompey went to visit the celebrated philosopher Posidonius, he prohibited the lictors from knocking at his door with their rods, according to their practice. Thus bowed, adds Pliny, before the humble dwelling of a sage, the fasces of him who had beheld the east and the west prostrate at his feet.

Cæsar, whom literature may well claim as her son, has clearly, and in many passages of his immortal Commentaries, indicated the relative places which the various kinds of faculties—so largely possessed by himself—held in his estimation. How brief and rapid his accounts of combats and battles! On the contrary, he considers no detail superfluous he can lavish upon the description of the famous bridge along which his army so unexpectedly crossed the Rhine. And why? Because here success depended upon conception alone; and the designs were all his own. The preference which Cæsar assigned to certain events of war, has been pointed out by others;

what he chiefly boasted of was a moral influence. "*Cæsar harangued his army,*" is almost always the first clause of his description of a battle won. "Cæsar did not arrive in *time to address his soldiers, and to exhort them to good conduct,*" is the habitual accompaniment of the recital of a surprise, or of a temporary defeat. The general invariably disappears before the orator, *and truly*, remarks the judicious Montaigne, *his tongue often did him wondrous service.*

And now, without transition, and without even dwelling upon the well-known exclamation of the great Frederick—"I had rather have written Voltaire's *Siècle de Louis XIV.* than gained a hundred battles;"—I come to Napoleon. I must be brief, not even alluding to the celebrated proclamation, written under the shade of the Pyramids, by a *member of the Institute*, and General-in-Chief of the Army of the East; nor to the treaties of peace, in which the monuments of art and of science were the ransom-price of the vanquished; nor to the high esteem in which the General, now become Emperor, ever held Lagrange, Laplace, Monge, and Berthollet, and the riches and honours with which he loaded them.

An anecdote which is little known, will conduct us more directly to the point.

Most people know something of the decennial prizes. The four classes of the Institute had drawn up rapid analyses of the progress of science, literature, and the arts; and the Presidents and Secretaries were to be called upon to read these documents to Napoleon, before the Dignitaries of the Empire and the Council of State. The 27th of February 1808 was the day appointed for the assembling of the *Académie Française;* and, as may be supposed, the meeting was more numerous than usual, for who does not suppose himself a sufficient judge in matters of taste? M. Chénier was the appointed orator. He was listened to with religious silence; but on a sudden the Emperor interrupted him, and with his hand upon his heart, and his body inclined, his voice trembling with manifest emotion, he exclaimed, "This is too much, gentlemen, too much; you overwhelm me; I cannot find words to express my gratitude."

I will leave it to yourselves to conceive the deep surprise of the crowd of courtiers who were the witnesses of this scene; those very individuals who, from step to step, had gone so far in their adulation as to tell their master, and apparently without exciting his astonishment or rebuke, that " When God had created Napoleon, he felt need of repose !"

What, then, were the words which went so straight—so pointedly to the heart of Napoleon? They were the following: " In our camp, where, far from the calamities of the interior, the national glory was preserved unsullied, there sprung up another kind of eloquence till then unknown in modern times. Concerning it there can be no dispute. When, in ancient authors, we read the harangues of the most renowned captains, we are usually called to admire only the genius of the historian. But here the heart-stirring addresses still exist, and may be collected without trouble. These beautiful proclamations emanated from the army of Italy; where the conqueror of Lodi and Arcole, whilst creating a new art of war, gave existence also to military eloquence, of which he will ever remain the model." On the 28th of February, the day subsequent to the celebrated meeting, the particulars of which I have now traced, the *Moniteur* with its *accustomed fidelity*, published the Emperor's answer to the discourse of Chénier. It was cold, formal, and insignificant, and had, in short, all the characters, others might say all the qualities, of an official document. It made no allusion to the incident I have related;—miserable concession to predominating opinion, and to the susceptibilities of the Staff.

The master of the world, to avail myself of Pliny's expression, yielding for a moment to his real feelings, lowered his fasces before the literary compliment paid to him by the Academy.

These reflections upon the comparative merit of the philosopher or author, and the warrior, although they have been suggested to me chiefly by what is said, and what passes, around us, will not be wholly inapplicable to the native country of Watt. I lately travelled extensively throughout both England and Scotland. The kindness I received authorized me to ask questions, so searching, distinct, and direct, that, in other circumstances, they would have been excusable only in the President of a board of inquiry. Being even then deeply preoccupied with the obligation under which I lay, to deliver, on my return, a judgment concerning the celebrated mechanist; and already somewhat anxious at the thought of the solemnity of that assembly to which I now address myself, I had prepared this inquiry, "What is your opinion of the influence which Watt exercised upon the wealth, the power, and the prosperity of England?" I do not exaggerate when I say that I have addressed this question to more than a hundred people, belonging to all classes of society, and to all shades of political opinion, from the most restless radical to the most determined conservative; and the response has always been the same. Each placed the services of our associate above all comparison; and almost every one quoted the speeches, made at the meeting which agreed to the erection of the statue in Westminster Abbey, as the faithful and unanimous expression of the sentiments of the British nation. What, then, was the tone of these speeches?

Lord Liverpool, the first minister of the crown, designated Watt as one of the most extraordinary men to whom England had given birth, and one of the greatest benefactors of the human race. He declared that his improvements had increased to an incalculable degree the resources of his country, and even those of the whole world. Then, looking at the question in a political point of view, "I have lived," said he, "in times, when the success of a campaign, or even of a war, has depended upon the possibility of dispatching our squadrons from port, and when contrary winds prevailed for whole months, and completely disappointed the anxious wishes of Government. Thanks to the steam-engine, such vexatious difficulties are now for ever at an end."

"Again," exclaimed Sir Humphry Davy, "cast your eye upon the metropolis of this mighty empire, upon our towns and villages, our arsenals and manufactories,—examine the subterranean excavations and the works that are executed on the surface of the earth,—contemplate our rivers, our canals, and the ocean which surrounds our shore, every where will you find tokens of the enduring beneficial labours of this great man." "The genius," added the illustrious President of the Royal Society, "which Watt has displayed in his admirable inventions, has contributed more to demonstrate the practical utility of science, to aggrandize the power of man over the material world, and to multiply and spread wide the conveniences of life, than the labours of any other individual in modern times." Davy, in fact, did not hesitate to place Watt in a more elevated position even than Archimedes.

Mr Huskisson likewise, the President of the Board of Trade, proclaimed, that, regarded in reference to the prosperity of the human race, the inventions of Watt appeared to him to merit *the highest possible admiration.* He explained in what way the economy of labour, the indefinite multiplication and the extreme cheapness of the productions of industry, contributed to advance knowledge, and promote its wide extension. " The steam-engine," he remarked, " in the hands of man is not only the most powerful instrument he can employ in changing the appearance of the physical world, it also acts as a moral and irresistible lever in pushing forward the grand cause of civilization." In this point of view Watt appeared to him distinguished among the chief benefactors of mankind. And, as an Englishman, he did not hesitate to say, that without the inventions of Watt, the British nation could never have sustained the immense expense of its last war with France.

The same idea occurs in the speech of another member of Parliament, who expresses his sentiments in no less decided terms. I allude to Sir

James Mackintosh. "It is the discoveries of Watt which have enabled England to sustain the most arduous and dangerous conflict in which she has ever been engaged. All things considered, I declare, without hesitation, that no one had ever more urgent claims than Watt to the homage of his country, or to the veneration and respect of future ages."

We shall now turn to the results of numbers and figures, which, as it appears to me, are still more eloquent than the various passages we have just been perusing. The younger Mr Boulton informs us, that, in the year 1819, the establishment at Soho alone, had manufactured of Watt's machines, a number whose steady labour would have required not fewer than one hundred thousand horses; and that the saving resulting from the substitution of these machines for animal labour, amounted annually to more than L.3,000,000 Sterling. Throughout England and Scotland at the same date, the number of these machines exceeded ten thousand. They effected the work of 500,000 horses, or of three or four millions of men, with an annual saving of from L.12,000,000 to L.16,000,000 Sterling. These results must, by this time, be more than doubled.

See here, then, in a scanty abridgment, what was said of Watt by statesmen, philosophers, and manufacturers, the most capable of appreciating his merits. Gentlemen, this creator of six or eight millions of labourers,—of assiduous and indefatigable labourers, among whom authority is never required to repress either coalition or commotion, and who labour for a halfpenny a-day ;—this man, who, by his brilliant discoveries, afforded England the means of supporting a most furious struggle, during which her very nationality was at stake ;—this second Archimedes, the benefactor of his race, whose memory future generations will for ever bless,—what, I inquire, was done for him during his lifetime ?

The peerage is in England the first of dignities, the highest of rewards ; and you will naturally suppose that Watt was created a Peer. So far was this from being the case, that it was never even thought of ! Were we to speak the truth, we should say, so much the worse for the Peerage. Such a neglect, however, in a nation so justly proud of its illustrious men, could not but greatly astonish me. When I inquired into the cause of this neglect, what think you was the response ? Those dignities of which you speak, I was told, are reserved for naval and military officers, for influential members of the House of Commons, and for members of the aristocracy. "*It is not the custom,*" it was said, and I quote the very phrase, "to grant these honours to scientific and literary men, to artists or engineers!" I well knew it was not the custom in the reign of Queen Anne, because Newton was never a Peer of England. But after a century and a half of progress in science and philosophy, when all of us, within the short span of life, have seen monarchs banished, forsaken, proscribed, and replaced upon their thrones by mere soldiers of fortune, who have hewn out their renown by their swords, surely I might be permitted to hope that the time had passed when it would be attempted to divide men into exclusive classes; that, at all events, it would not be declared openly, and in the style of the inflexible code of the Pharaohs, Whatever may be your services, your virtues, or your acquirements, not one of you shall ever rise above the level of your caste; in a word, that such a senseless custom (since custom it is) should no longer be permitted to disfigure the institutions of a great people.

Let us hope better things of the future. The time will come when the science of destruction shall decline before the arts of peace ; when the genius which multiplies our powers, which creates new products, and dispenses comfort throughout immense masses of our population, shall occupy, in general esteem, the place which reason and sound sense have even now assigned to it.

Watt will then appear before the grand jury of the population of the two hemispheres. They will see him, assisted by his steam-engine, penetrating in a few weeks into the bowels of the earth, to depths, which, before his time, could only have been reached after an age of the most difficult labour ; he will there clear out spacious galleries, and free them, in a few minutes, from the vast volumes of water which daily overflow them, and thus will he procure from the virgin earth those inexhaustible mineral riches which nature has there deposited. Uniting delicacy to power, Watt will be seen twisting with the same success, the huge folds of the colossal cable by means of which the stately vessel rides secure amid raging seas, and the microscopic filaments of those laces and airy gauzes, upon which fashion ever so much depends in the preparation of her light but fascinating adornments. A few strokes of the same machine will drain vast marshes, and give them up to husbandry; and districts already fertile will by it be freed from the periodic influence of those deadly miasmata produced by the scorching heat of the summer sun. Those great mechanical powers, which are only to be found in mountainous regions, at the foot of rapid cascades, will now, thanks to the ingenuity of Watt, be reared at will, without difficulty and without incumbrance, in the centre of towns, and in every story of a building. The intensity of these powers will be regulated by the mechanic's will, and will not depend, as heretofore, upon the most unsteady of natural causes, —atmospheric influence. The different branches of each manufacture may be united in a common enclosure, and even under the same roof. The productions of industry, whilst they are thus improved in quality, will be diminished in price. Population, well fed, well clad, and comfortably lodged, will increase with rapidity,—it will cover with elegant dwellings every region, even those districts which have been justly styled the Steppes of Europe, and which the barrenness of ages seems for ever to have condemned to remain the exclusive domain of the *feræ naturæ*. In a few years insignificant hamlets will become important cities; and, in a short while, such towns as Birmingham, where, a few years since, one could scarcely count thirty streets, will take their place among the largest, most beautiful, and richest towns of a powerful kingdom.

Transferred to our ships, the steam-engine will replace an hundredfold, the efforts of the triple and quadruple banks of rowers, from whom our ancestors required an extent and kind of labour, ranked among the punishments of the greatest criminals. With the help of a few bushels of coals Man will overcome the elements, and will make light of calms, contrary winds, and even storms. Transport will become much more rapid,—the time of the arrival of the steam-vessel will be as regular as that of our public coaches: and we shall no longer have occasion to remain on the coast for weeks, or even months, the heart a prey to cruel anxiety, watching, with anxious eye on the distant horizon, for the uncertain traces of the vessel which is to restore to us a father or a mother, a brother or a friend. In fine, the steam-engine, conveying in its train thousands of travellers, will run, upon railroads, more swiftly than the best race-horse, loaded only with its diminutive jockey.

This, gentlemen, is a very abridged sketch of the benefits bequeathed to the world by the machine of which Papin supplied the germ in his writings, and which, after so many ingenious exertions, Watt carried to such admirable perfection. Posterity will assuredly not degrade them to the level of other labours which have been too much commended, and whose real influence, weighed by the tribunal of reason, will for ever remain circumscribed within the confined circle of a few individuals and a limited space of time.

We have long been in the habit of talking of the age of Augustus, and of the age of Louis XIV. Eminent individuals amongst us have likewise held that we might with propriety speak of the age of Voltaire, of Rousseau, and of Montesquieu. I do not hesitate to declare my conviction, that, when the immense services already rendered by the steam-engine shall be added to all the marvels it holds out to promise, a grateful population will then familiarly talk of the ages of Papin and of Watt!

A biography of Watt intended to form a part of our collection of memoirs, would certainly be incomplete, did it not contain an enumeration of the academic titles with which the illustrious engineer was invested. The list will, moreover, occupy but a few lines. Watt became a member of the Royal Society of Edinburgh in the year 1784; of the Royal Society of London in 1785; of the Batavian Society in 1787; a correspondent of the Institute in the year 1808; and in 1814, *L'Academie des Sciences* of the Institute, conferred upon Watt the highest honour it can bestow, by naming him *one of its eight* foreign associates. By a spontaneous and unanimous vote, the Senate of the University of Glasgow conferred on Watt, in the year 1806, the honorary degree of LL.D.

# ON MACHINERY

CONSIDERED IN RELATION TO THE

## PROSPERITY OF THE WORKING CLASSES.*

### BY M. ARAGO.

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Many individuals, without questioning the genius of Watt, regard the improvements on account of which the world is his debtor, and the

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* In writing the following chapter, I thought that I might avail myself without scruple of the numerous documents I have collected, whether in my occasional intercourse with my illustrious friend Lord Brougham, or in those works which his Lordship has published, or which have appeared under his patronage. Were I to believe the criticisms which various persons have published since the reading of this eloge, I have, in endeavouring to combat the opinion that Machinery is injurious to the working classes, been attacking a worn-out prejudice which has no

great impulse they have given to the labours of industry, as a social calamity. Were we to believe them, the adoption of every new machine inevitably increases the inconveniences, and adds to the miseries of our artisans. All those wonderful mechanical combinations which we are in the custom of admiring for the regularity and harmony of their movements, and for the energy and delicacy of their effects, are, in their opinion, only instruments of evil, which the legislator ought to proscribe with a just and implacable severity.

Conscientious opinions, and especially when associated with feelings of philanthropy, should

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longer any real existence. Could I believe this to be the case, I would willingly suppress all my reasonings, good or bad. But unfortunately, the letters which worthy workmen frequently address to me, whether as Academician or Deputy, and still more the dissertations *ex professo,* and quite recent, of several political economists, leave me no doubt as to the necessity of affirming now, and of repeating upon every becoming occasion, that machinery has never been the real cause of the sufferings of one of the most numerous and interesting classes of society; that its destruction would only aggravate suffering; and that it is not in this quarter we shall find the remedy for evils, which I regret from the bottom of my heart.

ever have a claim to attentive examination. Nay, I will add, that from me such an examination is an imperative duty. I should, in fact, neglect that aspect of the labours of our illustrious associate which is most worthy of public admiration, were I not, far from subscribing to the criticisms of prejudice, to hold up such labours to the attention of men of property, as the means the most powerful, the most direct, and the most efficacious for relieving the operatives of their hardest sufferings, and for making them participate in all the blessings which appeared to be the peculiar inheritance of the rich.

When we have to make a choice between two propositions which are diametrically opposed to each other—when the one being true, the other must necessarily be false, and when nothing, at the first glance, seems to indicate a rational choice between them, geometricians are in the habit of taking up these contrary propositions, of following them out minutely through their several ramifications, and so arriving at their ultimate logical results; and the proposition which is incorrect, and it alone, seldom fails by this process to lead to consequences which a correctly constituted mind cannot admit. Let us employ for a moment this method of examination, of which Euclid so often availed himself, and which is so justly termed the *reductio ad absurdum.*

The opponents of machinery would annihilate it, or at least would greatly restrict its employment, to preserve, they say, more work for the labouring classes. Let us for a moment adopt this view, and we shall find that the anathema extends far beyond machines properly so called.

And we must begin by taxing our ancestors with the greatest improvidence. If, instead of founding the city of Paris, and continuing to extend it on both banks of the Seine, they had built it upon the plain of Villejuif, then, for ages, the corporation of water-carriers would of all others have been the best employed, the most necessary, and the most numerous. The political economists, therefore, with whom we are now contending, should consult the interest of these water-carriers. To divert the Seine from its course is by no means an impossibility; they should, therefore, propose the accomplishment of this great work—they should open a subscription to divert the river from Paris; and the general laugh would then teach them that the method of the *reductio ad absurdum* is not without its use even in political economy; and the workmen themselves, in their right senses, would tell them that it is the river which has created that immense Capital where they find so many sources of occupation, and that without it, Paris would probably still have been only another Villejuif.

Up to the present time, the Parisians have always been congratulated upon their proximity to those inexhaustible quarries, whence, for many generations, have been procured the materials employed in the construction of their temples, their palaces, and their private dwellings. But all this is mere illusion! The new political economy will prove to us, that it would have been eminently advantageous had all our stone and lime been found no nearer than Bourges, a distance of nearly 150 miles. In this case, count upon your fingers, if you can, the number of workmen, whose employment would have been necessary, to convey to the stone-yards of the capital, the stones which the builders have required for five centuries, and you will obtain a prodigious result; and however little satisfied you may be with these novel ideas, yet you may rejoice to your heart's content upon the delight which such a state of things would create among the day-labourers !

The capital of a powerful kingdom, not very distant from France, is traversed by a majestic river, which even ships of war ascend in full sail. Innumerable canals in all directions intersect the surrounding country, and transport, at little expense, packages of the largest bulk. A complete net-work of excellent roads, most admirably kept, leads to the most distant parts of the country. In addition to these great gifts of nature and of art, the said capital enjoys *an advantage* of which Paris is deprived, for the stone-quarries essential to building are not in its vicinity, but are found only at a distance. Here, then, is the Utopia of the new economists realized. They may now calculate the hundreds of thousands, nay, the millions of quarrymen, boatmen, carters, and stone-cutters, who must unceasingly be occupied in raising, transporting, and preparing all the variety of stones which are required in the construction of the immense number of buildings, which are every year added to this great metropolis. But stop ! they may spare their pains, for it happens that in this city —as it would happen in Paris, deprived of its rich quarries—that stone being very expensive, is not used, and brick is everywhere substituted in its place.

Thousands of workmen every day execute at the surface and in the bowels of the earth prodigious labours, which it would be necessary totally to abandon, if certain machines were relinquished. One or two examples will suffice to make this truth sufficiently apparent. The daily removal of the water which rises in the galleries of the Cornish mines requires a power of fifty thousand horses, or of three hundred thousand men. I ask if the wages of three hundred thousand workmen would not absorb all the profits which the mining operations might produce? But the question of wages and profits may touch a tender point; and therefore I turn to other considerations, which, however, lead to the same conclusion. A single copper-mine in Cornwall, one of those known as the *Consolidated mines*, requires a steam-engine of the power of more than three hundred horses constantly at work, and thus every twenty-four hours realizes the labour of one thousand horses. Concerning this, the assertion cannot be doubted, that no means could possibly be found beneficially and simultaneously to apply the strength of three hundred horses, or two or three thousand men, around the mouth of the shaft of the mine. To proscribe, therefore, the action of the steam-engine of the *Consolidated mines*, would be to reduce to a state of inactivity a great number of workmen whose labours are now rendered available; it would be to declare that the copper and tin mines of Cornwall must for ever remain buried under a mass of soil, rock, and liquid, many hundred yards deep. The proposition, brought to this form, could certainly have few defenders; but the form is nothing, whilst the substance remains the same.

If, from operations which require the greatest development of power, we turn to the examination of different products of industry whose delicacy of parts and regularity of form have ranked them among the wonders of art, the insufficiency, and even the inferiority of our organs, compared with the ingenious combinations of machinery, are equally striking to all. Where, for example, is the expert spinner who, from a single pound of raw cotton, could produce a thread one hundred and fifty miles long, as can the mule-jenny?

I am not ignorant of what certain moralists have said about the uselessness of muslins, laces, and tulles, which these slender threads are employed to manufacture; but I need only remark, that the most perfect *mule-jennies* require the continued superintendence of a great number of workmen; that the only object with them, is to manufacture productions which will sell; and that, finally, if luxury be an evil, a vice, or even a crime, it should be ascribed to the buyers, and not to the poor workers, whose means of existence, I believe, would be hazarded, if they employed their strength in making for the ladies, coarse stuffs, instead of fashionable tulles.

Let us now, however, leave these details, and come to the essential merits of the question. "We must not," said Marcus Aurelius, "receive the opinions of our fathers, as do mere infants, for the simple reason that our parents held them." This assuredly just maxim should not at the same time prevent us from thinking, or, at all events, from presuming, that those opinions, concerning which no objection has been raised since the origin of society, are conformable both to reason and general interest. Well, then, upon the opinion so much debated concerning the utility of machinery, what were the unanimous sentiments of antiquity? Its ingenious mythology will inform us. The founders of empires, the first of legislators, the conquerors of those tyrants who oppressed their country, received the qualified title of demi-gods; but it was among the gods themselves that the inventors of the spade, the sickle, and the plough, were placed.

But instantly, I hear some of our adversaries declaiming about the extreme simplicity of the instruments I have cited,—refusing them the name of machines,—designating them mere tools, and obstinately entrenching themselves behind this distinction. To this we might reply, that such a distinction is puerile; and that it is impossible to say with precision where the tool ends, and the machine begins. It is of more importance, however, to remark, that the murmurers against machines have never said one word of their greater or less degree of complication. If they reject them, it is because, by their means, one workman performs the labour of many; and will they venture to maintain that a knife, a gimlet, a file, or a saw, does not give a marvellous facility of action to the man who uses them ; and that his hand, so supplied, can do the work of many hands armed only with their nails ?

Those labourers were not arrested by this sophistical distinction between tools and machinery, who, seduced by the execrable theories of some of their pretended friends, ran through some counties of England, in the year 1830, vociferating *Death to machinery!* Rigorous logicians, they broke the sickle in the farm-yard, destined for reaping, the flail employed in thrashing, and the sieve with which the grain was cleaned. Who can deny, that the sickle, the flail, and the sieve are, in truth, means for abridging labour ? Not even the spade, pick-axe, plough, and driller, found favour with this blind herd ; and, if one thing in the history of this mania astonished me more than another, it was, that they spared the horses, which, in reality, are a kind of machines, kept up comparatively at a cheap rate, each of which daily executes the work of six or seven labourers.

Political economy has now happily taken its place among the sciences of observation. The experiment of the substitution of machinery for manual labour has now so frequently been resorted to, that we can draw general results, though not, perhaps, quite free from accidental irregularities. These results are as follows :—

By saving the labour of man, machinery effects a reduction in price. The effect of this reduction is increased demand ; and to such an extent, so great being our desire to improve our condition, that, in spite of the almost inconceivable reduction of price, the pecuniary value of the total merchandize produced, every year surpasses what it was previous to the introduction of these improvements, and the number of workmen which these employments require, *increases* with the introduction of the means of more rapid fabrication. This last result is precisely the opposite of that which the adversaries of machinery predict. At first sight, the fact appears paradoxical ; but notwithstanding, it is demonstrated beyond dispute, by an examination of the most satisfactorily determined results.

When, three centuries and a half ago, the printing-press was invented, copyists supplied books to the very small number of the wealthy who could afford this very expensive gratification. A single individual of these copyists, by means of the new invention, being able to accomplish the work of two hundred, people did not fail at the time to characterize it as an *infernal* invention, which, in a certain class of society, would reduce to beggary nine hundred and nine-five persons out of every thousand. Let us compare the actual results, with this sinister prediction.

Manuscript books were little in demand; printed books, on the contrary, on account of their very low price, were sought after with the greatest avidity. The great works of the principal Greek and Roman authors required to be reproduced unceasingly. New ideas and new opinions gave rise to a multitude of works, some of an enduring interest, whilst others were called into existence by passing events ; so that, it has been calculated that, in London, previous to the invention of printing, the trade in books afforded occupation to about two hundred individuals, whereas, now, there are, *engaged in it*, *tens of thousands.* And what would be the result, if, laying aside the restricted, and, so to speak, the *material* view of the subject, we regard printing in its moral and intellectual aspects ; if we examined its influence upon public manners, upon the diffusion of knowledge, and the progress of the human mind ; if we could count the number of volumes for which we are indebted to it, which the copyists would certainly have despised, but from which genius daily draws forth the elements of its best and most pregnant conceptions ? However, I must not forget that the question before us, only regards the number of workmen employed in the different branches of industry.

The manufacture of cotton presents us with results still more remarkable than those of printing. At the time when an ingenious barber at Preston, by name Arkwright, who left a fortune of about one hundred thousand pounds a-year to his children, rendered the substitution of turning rollers for the spinners' fingers, useful and profitable, the annual product of the cotton manufacture of England did not amount to more than L.2,000,000, now it exceeds L.37,000,000. In the county of Lancaster alone, there is delivered, every year, to the manufacturers, a quantity of cotton thread, which twenty-one millions of expert spinners could not prepare by means of the spindle and distaff. Now, although, in the art of preparing this thread, mechanical means have been carried to their extreme limits, a million and a half of workmen find daily employment, where, previous to the inventions of Arkwright and Watt, there were not fifty thousand employed.*

A certain philosopher has exclaimed, Nothing new is now published, unless that which has been long forgotten be called such. If he intended his remark to apply only to old errors and prejudices, there would be some point in it; for all ages have been so fertile in this way, that no one can now have the advantage of priority. For instance, the pretended philanthropists of our day have not even the merit (if merit there be) of having invented the system I am now examining. For behold poor William Lea exhibiting the first stocking-frame in the presence of King James I. The mechanism appeared admirable; why then reject it? Simply from the pretext, that the working classes would suffer.

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* Mr Edward Baines, the author of an esteemed work upon the history of the cotton manufacture in Britain, has had the singular curiosity to calculate the length of the thread which is annually employed in the fabrication of cotton goods, and has found that the total length equals fifty-one times the distance of the sun from the earth (fifty-one times thirty-nine millions of leagues), or about two thousand millions of leagues.

Nor was France a whit wiser than England. Lea found no encouragement there, and he died in an hospital, like so many other men of genius who have had the misfortune to advance beyond their age.

It should here be observed, that a person would very much deceive himself if he supposed that the stocking-knitters, of whom William Lea thus became the victim, were a numerous body. In the year 1583, none but individuals of high rank and large fortune wore stockings. The middle classes, instead of this part of our clothing, wore tight bandages of various stuffs. The rest of the population, that is to say, nine hundred and ninety-nine out of every thousand, went bare-legged. Now, on the contrary, out of a thousand individuals, there is not perhaps more than one who is not able, owing to their extreme cheapness, to provide a pair of stockings. And hence, an immense number of workmen in all countries, are engaged in this kind of manufacture.

Were it at all necessary, I might add, that, at Stockport, the substitution of steam for the labour of the hands in the manufacture of lace, has increased the number of workmen engaged in this branch of manufacture, and this to the extent of one-third, in a very few years.

We must now, finally, drive our adversaries from their last retreat, for they must not be allowed to say, that we have adduced our proofs solely from antiquated subjects of human industry. We accordingly remark, that their lugubrious anticipations respecting the recent engraving on steel, were not a whit less wide of the mark. A copper-plate, they observed, cannot produce more than two thousand impressions. A steel-plate, which can supply a hundred thousand, without wearing, will supplant fifty copper-plates. The plainest arithmetic, therefore, they contended, demonstrates that the majority of engravers (forty-nine out of the fifty), will be forced to leave their benches,—to throw away their graver for the trowel and the pick-axe, or to implore charity on the public ways. For the twentieth time we beseech you, anticipators of evil, to remember the principal element of the problem ye pretend to solve !—consider the insatiable desire of wellbeing which Nature has implanted in the heart of man ;—think that the gratification of one want whets the appetite for the satisfaction of another,—that our desires increase with the cheapness of the supply which supports them, and to such an extent as to defy the creative energies of the most powerful machines.

But to return to engravings. The great majority of the public never thought of them when they were dear, and when cheap, they are in universal demand. They have already become the ornaments of our best books, and they confer on second-rate works the best prospect of sale. Even in our almanacs, the antique and hideous representations of Nostradamus and Mathieu Laensberg have given place to picturesque views, which in a few seconds transport our immoveable citizens from the banks of the Ganges to those of the Amazon,—from the Himalayas to the Cordilleras,—from Pekin to New York. Behold too, the poor engravers whose ruin was so piteously foretold. They were never so numerous —never so well employed.

All these are unanswerable facts; and from them one consequence most assuredly does *not* follow; viz. That in the world we live in, among its inmates, such at least as nature has created them, the employment of machinery diminishes the number of workmen required in the several branches of industry. With other habits, manners, and passions, a different conclusion *might* be reached; but the probabilities on this supposition may be left to be wrought out by those who speculate upon the domestic economy of the inhabitants of the Moon, Jupiter, or Saturn.

Confined within much narrower limits, I inquire,—If, after having thus sapped the very foundation of the system of the opponents of machinery, it be at all necessary to glance at some minor points, which have been mixed up with the consideration of the subject? The Poor Law of England is the most important of these: but, from this bleeding wound, the nation has suffered since the days of Queen Elizabeth; and surely it is absurd to ascribe to the abuse of machinery, an evil which took its origin, and luxuriated for ages, before the labours of Arkwright and Watt were ever heard of. But you must concede, it will be answered, that the steam-engine, and the mule-jenny, and the carding-machine, and the printing-press, &c., these objects of general predilection, have at all events aggravated and extended the evils of pauperism? Far from it. For what are the facts? First of all, machinery has never been represented as a universal panacea. It has never been alleged that it possessed the unheard of power of dispelling error and passion from political assemblies; that it could direct the counsellors of princes in the paths of moderation, wisdom, and humanity; that it could have prevented Pitt from unceasingly intermeddling with the affairs of other countries—from every year resuscitating, in all quarters of Europe, the enemies of France,—from subsidising them with immense sums, and thus overwhelming England with a debt of hundreds of millions. This is the cause why the poor-law tax has so rapidly and so prodigiously increased. Machinery has not, and could not produce the evil. On the other hand, it has done much to moderate it,—an assertion which may be proved in few words. Lancashire is the most manufacturing county of England. In it are situated the towns of Manchester, Preston, Bolton, Warrington, and Liverpool. Here, we say, machinery has been most rapidly and most generally introduced; and with what effect? If we compare the total annual amount of the poor-law tax in Lancashire, with the amount of that raised throughout the country, and ascertain the share of each individual, we find that in this county it amounts to only one-third of the mean paid in the other counties! These ciphers, then, give no quarter to the allegations of system-makers.

Nor should the high-sounding words, so often used by certain declaimers about the poor-laws, induce us to suppose that the labouring classes among our neighbours are wholly deprived of forethought and resources. A publication of very recent date has shewn that, in England alone (Scotland and Ireland being omitted), the capital belonging to operatives in the Savings-Banks now amounts to about sixteen millions Sterling! And the results observed in the principal towns are not less instructive.

There is one principle which has remained uncontroverted, amidst the animated controversies to which the science of political economy has given birth, viz. that population increases with general prosperity, and rapidly diminishes in times of wretchedness.* Now, let us place facts in juxtaposition with the principle. Whilst the mean population of England, during the last

* To this general rule Ireland is an exception; the cause of this, however, is well known.

thirty years, has augmented in the ratio of 50 per cent., Nottingham and Birmingham, two of the most manufacturing towns, exhibit increments of 75 and 90 per cent. Finally, Manchester and Glasgow, which occupy the first rank in the British Empire for the number, size, and importance of the machines they employ, in the same period of thirty years, have seen their population augment 150 and 160 per cent.; an amount three or four times greater than in the agricultural counties, and in those towns which are not manufacturing. These figures speak for themselves, and there is no sophistry, or false philanthropy, or eloquence, that can resist them.

One chief objection brought against machinery I cannot disregard. At the moment that new improvements are introduced, and when by their means manual operations are very extensively superseded, certain classes of workmen suffer from the change;—their honourable and laborious industry is annihilated at a blow; and those who, according to the previous method, were the most expert and deserving, being deficient of the qualifications which the new plan requires, are thrown out of employment, and can but rarely find other means of subsistence.

These reflections are just, and I may add, that the melancholy consequences to which they refer, must frequently occur, for the mere caprices of fashion often in this way produce extensive wretchedness. If, then, I do not hence conclude that the world should remain stationary, but still desire advancement in the general interests of society, I am far from maintaining that we should be indifferent to the individual sufferings, of which this advancement is the momentary cause. The authorities, always watching for new inventions, seldom fail to reach them with their fiscal regulations. Would it be too much to ask, that the first contributions levied on the successful exercise of genius, should be appropriated to the opening of spacious workshops, in which the workmen deprived of employment might for a time find occupation suitable to their powers and intelligence? This course has sometimes been followed with success, and why should it not be generalized? Humanity demands it as a duty; sound policy dictates it; and, were other inducements necessary, sad events, whose history is not yet forgotten, strongly recommend it on economical grounds.

To the objections of the theorists, who apprehended that the progress of machinery would reduce the working classes to a state of total inactivity, have succeeded difficulties of quite a different character, on which it seems indispensable we should for a few moments dwell.

By superseding, in our manufactories, every exertion of great masculine strength, machinery permits the introduction of a great number of children of both sexes; and the cupidity of their parents has a tendency to abuse the opportunity. The hours of labour are made to surpass all bounds; and, for the daily bait of a few pence, minds, which education would enlighten, are sacrificed to enduring brutalization, whilst the bodily frame is blighted for want of that development which the enjoyment of the air and sun rarely fails to bring along with it. Under these circumstances, to insist that the Legislature should put a stop to this shameful oppression—to urge forward measures calculated to contend with the demoralization which is the usual consequence of numerous meetings of the young persons employed—to endeavour to introduce, and multiply in our cottages, various implements, by which, according to the season, the labours of agriculture might be associated with those of the artisan,—this would be patriotism and humanity, this would be to understand and supply the real wants of the working classes. But, on the other hand, to persist that the vast labour, which machinery can effect in a moment and cheaply, shall be performed, at a great price, by the toil of man's hand and the sweat of his brow—to assimilate the workman to the brute—daily to require from him exertions which ruin his health, and which science can obtain to the extent of a hundredfold, by means of wind, and water, and steam, this would be to recede from the grand object we have in view. It would be to abandon the poor to nakedness; to reserve a thousand enjoyments exclusively for the rich which are now common to all. It would be, in short, to return again to the ages of ignorance, barbarity, and wretchedness.

But I must now quit this subject, though it is far from being exhausted. Nor must I boast too much of having triumphed over a host of inveterate and systematic prejudices. One result, however, I may count upon; it is, that I will carry along with me the whole crowd of those in easy circumstances in our capital, who occupy no small share of their time in making the love of enjoyment harmonize with the exigencies of their delicate health. In a few years, thanks to the discoveries of Watt, all these Sybarites, by means of steam-carriages on railroads, may rapidly visit every part of the kingdom. In the same day they may examine the preparations of our squadron at Toulon—may breakfast on juicy *Rougets* at Marseilles—may bathe at midday their relaxed limbs in the mineral waters of Bagnères—and return in the evening, by way of Bordeaux, to attend a ball in the Opera-House. This expedition requires only a rate of twenty-six leagues an hour; and, whilst steam-carriages have already realised fifteen, Mr Stephenson, the celebrated engineer of Newcastle, offers to construct others to go two and a half times more rapidly—carriages which shall accomplish forty leagues an hour!

# EULOGIUM

OF

# JAMES WATT.

BY LORD JEFFREY.

[FROM THE ENCYCLOPÆDIA BRITANNICA.]

Mr James Watt, the great improver of the steam-engine, died on the 25th of August 1819, at his seat of Heathfield, near Birmingham, in the 84th year of his age.

This name fortunately needs no commemoration of ours; for he that bore it survived to see it crowned with undisputed and unenvied honours; and many generations will probably pass away before it shall have "gathered all its fame." We have said that Mr Watt was the great *improver* of the steam-engine; but, in truth, as to all that is admirable in its structure, or vast in its utility, he should rather be described as its *inventor*. It was by his inventions that its action was so regulated as to make it capable of being applied to the finest and most delicate manufactures, and its power so increased as to set weight and solidity at defiance. By his admirable contrivances, it has become a thing stupendous alike for its force and its flexibility,—for the prodigious power which it can exert, and the ease, and precision, and ductility, with which it can be varied, distributed, and applied. The trunk of an elephant that can pick up a pin or rend an oak is as nothing to it. It can engrave a seal, and crush masses of obdurate metal like wax before it,—draw out, without breaking, a thread as fine as gossamer, and lift a ship of war like a bauble in the air. It can embroider muslin and forge anchors, —cut steel into ribbands, and impel loaded vessels against the fury of the winds and waves.

It would be difficult to estimate the value of the benefits which these inventions have conferred upon the country. There is no branch of industry that has not been indebted to them; and in all the most material, they have not only widened most magnificently the field of its exertions, but multiplied a thousandfold the amount of its productions. It is our improved steam-engine that has fought the battles of Europe, and exalted and sustained, through the late tremendous contest, the political greatness of our land. It is the same great power which now enables us to pay the interest of our debt, and to maintain the arduous struggle in which we are still engaged, with the skill and capital of countries less oppressed with taxation. But these are poor and narrow views of its importance. It has increased indefinitely the mass of human comforts and enjoyments, and rendered cheap and accessible all over the world the materials of wealth and prosperity. It has armed the feeble hand of man, in short, with a power to which no limits can be assigned, completed the dominion of mind over the most refractory qualities of matter, and laid a sure foundation for all those future miracles of mechanic power which are to aid and reward the labours of after generations. It is to the genius of one man, too, that all this is mainly owing; and certainly no man ever before bestowed such a gift on his kind. The blessing is not only universal, but unbounded; and the fabled inventors of the plough and the loom, who were deified by the erring gratitude of their rude contemporaries, conferred less important benefits on mankind than the inventor of our present steam-engine.

This will be the fame of Watt with future generations; and it is sufficient for his race and his country. But to those to whom he more immediately belonged, who lived in his society, and enjoyed his conversation, it is not perhaps the character in which he will be most frequently recalled—most deeply lamented—or even most highly admired. Independently of his great attainments in mechanics, Mr Watt was an extraordinary, and in many respects a wonderful man. Perhaps no individual in his age possessed so much and such varied and exact information,—had read so much, or remembered what he had read so accurately and well. He had infinite quickness of apprehension, a prodigious memory, and a certain rectifying and methodising power of understanding, which extracted something precious out of all that was presented to it. His stores of miscellaneous knowledge were immense,—and yet less astonishing than the command he had at all times over them. It seemed as if every subject that was casually started in conversation with him, had been that which he had been last occupied in studying and exhausting; such was the copiousness, the precision, and the admirable clearness of the information which he poured out upon it without effort or hesitation. Nor was this promptitude and compass of knowledge confined in any degree to the studies connected with his ordinary pursuits. That he should have been minutely and extensively skilled in chemistry and the arts, and in most of the branches of physical science, might, perhaps, have been conjectured; but it could not have been inferred from his usual occupations, and probably is not generally known, that he was curiously learned in many branches of antiquity, metaphysics, medicine, and etymology, and perfectly at home in all the details of architecture, music, and law. He was well acquainted, too, with most of the modern languages—and familiar with their most recent literature. Nor was it at all extraordinary to hear the great mechanician and engineer detailing and expounding, for hours together, the metaphysical theories of the German logicians, or criticising the measures or the matter of the German poetry.

His astonishing memory was aided, no doubt, in a great measure, by a still higher and rarer faculty—by his power of digesting and arranging in its proper place all the information he received, and of casting aside and rejecting, as it were instinctively, whatever was worthless or immaterial. Every conception that was suggested to his mind seemed instantly to take its place among its other rich furniture, and to be condensed into the smallest and most convenient form. He never appeared, therefore, to be at all encumbered or perplexed with the *verbiage* of the dull books he perused, or the idle talk to which he listened; but to have at once extracted, by a kind of intellectual alchemy, all that was worthy of attention, and to have reduced it for his own use, to its true value, and to its simplest form. And thus it often happened that a great deal more was learned from his brief and vigorous account of the theories and arguments of tedious writers, than an ordinary student could ever have derived from the most faithful study of the originals,—and that errors and absurdities became manifest from the mere clearness and plainness of his statement of them, which might have deluded and perplexed most of his hearers without that invaluable assistance.

It is needless to say, that, with those vast resources, his conversation was at all times rich and instructive in no ordinary degree; but it was, if possible, still more pleasing than wise, and had all the charms of familiarity, with all the substantial treasures of knowledge. No man could be more social in his spirit, less assuming or fastidious in his manners, or more kind and indulgent towards all who approached him. He rather liked to talk,—at least in his later years; but though he took a considerable share of the conversation, he rarely suggested the topics on which it was to turn, but readily and quietly took up whatever was presented by those around him, and astonished the idle and barren propounders of an ordinary theme, by the treasures which he drew from the mine they had unconsciously opened. He generally seemed, indeed, to have no choice or predilection for one subject of discourse rather than another; but allowed his mind, like a great cyclopædia, to be opened at any letter his associates might choose to turn up, and only endeavoured to select from his inexhaustible stores what might be best adapted to the taste of his present hearers. As to their capacity he gave himself no trouble; and, indeed, such was his singular talent for making all things plain, clear, and intelligible, that scarcely any one could be aware of such a deficiency in his presence. His talk, too, though overflowing with information, had no resemblance to lecturing or solemn discoursing, but, on the contrary, was full of colloquial spirit and pleasantry. He had a certain quiet and grave humour, which ran through most of his conversation, and a vein of temperate jocularity, which gave infinite zest and effect to the condensed and inexhaustible information, which formed its main staple and characteristic. There was a little air of affected testiness, and a tone of pretended rebuke and contradiction, with which he used to address his younger friends, that was always felt by them as an endearing mark of his kindness and familiarity,—and prized accordingly, far beyond all the solemn compliments that ever proceeded from the lips of authority. His voice was deep and powerful,—though he commonly spoke in a low and somewhat monotonous tone, which harmonized admirably with the weight and brevity of his observations, and set off to the greatest advantage the pleasant anecdotes which he delivered with the same grave brow and the same calm smile playing soberly on his lips. There was nothing of effort, indeed, or impatience, any more than of pride or levity, in his demeanour; and there was a finer expression of reposing strength, and mild self-possession in his manner, than we ever recollect to have met with in any other person. He had in his character the utmost abhorrence for all sorts of forwardness, parade, and pretension; and, indeed, never failed to put all such impostors out of countenance, by the manly plainness and honest intrepidity of his language and deportment.

In his temper and dispositions he was not only kind and affectionate, but generous, and considerate of the feelings of all around him, and gave the most liberal assistance and encouragement to all young persons who shewed any indications of talent, or applied to him for patronage or advice. His health, which was delicate from his youth upwards, seemed to become firmer as he advanced in years ; and he preserved, up almost to the last moment of his existence, not only the full command of his extraordinary intellect, but all the alacrity of spirit and the social gaiety which had illuminated his happiest days. His friends in this part of the country never saw him more full of intellectual vigour and colloquial animation,—never more delightful or more instructive, than in his last visit to Scotland in autumn 1817. Indeed, it was after that time that he applied himself, with all the ardour of early life, to the invention of a machine for mechanically copying all sorts of sculpture and statuary, —and distributed among his friends some of its earliest performances, as the productions of a young artist just entering on his 83d year.

This happy and useful life came at last to a gentle close. He had suffered some inconvenience through the summer ; but was not seriously indisposed till within a few weeks from his death. He then became perfectly aware of the event which was approaching ; and with his usual tranquillity and benevolence of nature, seemed only anxious to point out to the friends around him the many sources of consolation which were afforded by the circumstances under which it was about to take place. He expressed his sincere gratitude to Providence for the length of days with which he had been blessed, and his exemption from most of the infirmities of age, as well as for the calm and cheerful evening of life that he had been permitted to enjoy, after the honourable labours of the day had been concluded. And thus, full of years and honours, in all calmness and tranquillity, he yielded up his soul, without pang or struggle,—and passed from the bosom of his family to that of his God.

He was twice married, but has left no issue but one son, long associated with him in his business and studies, and two grandchildren by a daughter who predeceased him. He was a Fellow of the Royal Societies both of London and Edinburgh, and one of the few Englishmen who were elected members of the National Institute of France. All men of learning and science were his cordial friends; and such was the influence of his mild character and perfect fairness and liberality, even upon the pretenders to these accomplishments, that he lived to disarm even envy itself, and died, we verily believe, without a single enemy.

# HISTORICAL ACCOUNT

OF THE

# DISCOVERY OF THE COMPOSITION OF WATER.

BY THE

RIGHT HON. HENRY LORD BROUGHAM,

F.R.S., AND MEMBER OF THE NATIONAL INSTITUTE OF FRANCE.

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THERE can be no doubt whatever that the experiment of Mr Warltire,* related in Dr Priestley's 5th volume, gave rise to this inquiry, at least in England: Mr Cavendish expressly refers to it, as having set him upon

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* Mr Warltire's letter is dated Birmingham, 18th April 1781, and was published by Dr Priestley in the Appendix to the 2d Vol. of his " Experiments and Observations relating to various branches of Natural Philosophy; with a continuation of the Observations on Air;"—forming in fact the 5th volume of his " Experiments and Observations on different kinds of Air," printed at Birmingham in 1781.

Mr Warltire's first experiments were made in a copper ball or flask, which held three wine pints, the weight 14 oz.; and his object was to determine " whether heat is heavy or not." After stating his mode of mixing the airs, and of adjusting the balance, he says he " always accurately balanced the flask of common air, then found the difference of weight after the inflammable air was introduced, that he might be certain he had confined the proper proportion of each. The electric spark making his experiments.—(Phil. Trans. 1784, p. 126.) The experiment of Mr Warltire consisted in firing by electricity a mixture of inflammable and common air in a close vessel, and two things were said to be observed; *first,* A sensible loss of weight; *second,* A dewy deposit on the sides of the vessel.

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having passed through them, the flask became hot, and was cooled by exposing it to the common air of the room: it was then hung up again to the balance, and a loss of weight was always found, but not constantly the same; upon an average, it was two grains."

He goes on to say, "I have fired air in glass vessels, since I saw you (Dr Priestley) venture to do it, and I have observed, *as you did*, that, though the glass was clean and dry before, yet, after firing the air, it became dewy, and was lined with a sooty substance."

As you are upon a nice balancing of claims, ought not Dr Priestley to have the credit of first noticing the dew?

In some remarks which follow by Dr Priestley, he confirms the loss of weight, and adds, "I do not think, however, that so very bold an opinion, as that of the latent heat of bodies contributing to their weight, should be received without more experiments, and made upon a still larger scale. If it be confirmed, it will no doubt be thought to be a fact of a very remarkable nature, and will do the greatest honour to the sagacity of Mr Warltire. I must add, that the moment he saw the moisture on the inside of the close glass vessel in which I afterwards fired the inflammable air, he said, that it confirmed an opinion he had long entertained, viz. that common air deposits its moisture when it is dephlogisticated."

It seems evident, that neither Mr Warltire, nor Dr Priestley, attributed the dew to any thing else than a mechanical deposit of the moisture suspended in common air.—(Note by Mr James Watt.)

Mr Watt, in a note to p. 332 of his paper, Phil. Trans. 1784, inadvertently states, that the dewy deposit was first observed by Mr Cavendish ; but Mr Cavendish himself, p. 127, expressly states Mr Warltire to have observed it, and cites Dr Priestley's 5th volume.

Mr Cavendish himself could find no loss of weight, and he says that Dr Priestley had also tried the experiment, and found none.* But Mr Cavendish found there was always a dewy deposit, without any sooty matter. The result of many trials was, that common air and inflammable air being burnt together, in the proportion of 1000 measures of the former to 423 of the latter, " about one-fifth of the common air, and nearly all the inflammable air, lose their elasticity, and *are condensed into the dew* which lines the glass." He examined the dew, and found it to be pure water. He therefore concludes, that " almost all the inflammable air, and about one-sixth of the common air, are turned into pure water."

Mr Cavendish then burned in the same way dephlogisticated and inflammable airs (oxygen and hydrogen gases), and the deposit was always more or less acidulous, accordingly as the air burnt with the inflammable air was more or less phlogisticated. The acid was found to be nitrous. Mr Cavendish states, that " almost the whole of the inflammable and dephlogisticated air *is converted into pure water*." And, again, that " if these airs could be obtained perfectly pure, the whole would be condensed." And he accounts for common air and

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* Mr Cavendish's note, p. 127, would seem to imply this ; but I have not found in any of Dr Priestley's papers that he has said so.—(NOTE BY MR JAMES WATT.)

inflammable air when burnt together not producing acid, by supposing that the heat produced is not sufficient. He then says that these experiments, with the exception of what relates to the acid, were made in the summer of 1781, and mentioned to Dr Priestley, and adds, that "a friend of his (Mr Cavendish's) last summer (that is 1783) gave some account of them to Mr Lavoisier, as well as of the conclusion drawn from them, that dephlogisticated air is only water deprived of its phlogiston; but at that time so far was Mr Lavoisier from thinking any such opinion warranted, that, till he was prevailed upon to repeat the experiment himself, he found some difficulty in believing that nearly the whole of the two airs could be converted into water." The friend is known to have been Dr, afterwards Sir Charles Blagden; and it is a remarkable circumstance, that this passage of Mr Cavendish's paper appears not to have been in it when originally presented to the Royal Society, for the paper is apparently in Mr Cavendish's hand, and the paragraph p. 134, 135, is not found in it, but is added to it, and directed to be inserted in that place. It is moreover not in Mr Cavendish's hand but in Sir Charles Blagden's, and indeed the latter must have given him the information as to Mr Lavoisier, with whom it is not said that Mr Cavendish had any correspondence. The paper itself was read 15th January 1784. The volume was published about six months afterwards.

Mr Lavoisier's memoir (in the vol. de l'Académie des Sciences for 1781) had been read partly in November and December 1783, and additions were afterwards made to it. It was published in 1784. It contained Mr Lavoisier's account of his experiments in June 1783, at which, he says, Sir Charles Blagden was present; and it states that he told Mr Lavoisier of Mr Cavendish having "already burnt inflammable air in close vessels, and obtained a very sensible quantity of water." But he, Mr Lavoisier, says nothing of Sir Charles Blagden having also mentioned Mr Cavendish's conclusion from the experiment. He expressly states, that the weight of the water was equal to that of the two airs burnt, unless the heat and light which escape are ponderable, which he holds them not to be. His account, therefore, is not reconcilable with Sir Charles Blagden's, and the latter was most probably written as a contradiction of it, after Mr Cavendish's paper had been read, and when the Mémoires of the Académie were received in this country. These Mémoires were published in 1784, and could not certainly have arrived when Mr Cavendish's paper was written, nor when it was read to the Royal Society.

But it is further to be remarked, that the passage of Mr Cavendish's paper in Sir Charles Blagden's handwriting, only mentions the experiments having been communicated to Dr Priestley; they were made, says the passage, in 1781, and communicated to Dr Priestley, it is not said when, nor is it said that "the conclusions drawn from them," and which Sir Charles Blagden says he communicated to Mr Lavoisier in summer 1783, were ever communicated to Dr Priestley; and Dr Priestley in his paper (referred to in Mr Cavendish's), which was read June 1783, and written before April of that year, says nothing of Mr Cavendish's theory, though he mentions his experiment.

Several propositions then are proved by this statement.

*First,* That Mr Cavendish in his paper, read 15th January 1784, relates the capital experiment of burning oxygen and hydrogen gases in a close vessel, and finding pure water to be the produce of the combustion.

*Secondly,* That, in the same paper, he drew from this experiment the conclusion, that the two gases were converted or turned into water.

*Thirdly,* That Sir Charles Blagden inserted in the same paper, with Mr Cavendish's consent, a statement that the experiment had first been made by Mr Cavendish, in summer 1781, and mentioned to Dr Priestley, though it is not said when, nor is it said that any conclusion was mentioned to Dr Priestley; nor is it said at what time Mr Cavendish first drew that conclusion. *A most material omission.*

*Fourthly,* That, in the addition made to the paper by Sir Charles Blagden, the conclusion of Mr Cavendish is stated to be, that oxygen gas is water deprived of phlogiston; this addition having been made after Mr Lavoisier's memoir arrived in England.

It may further be observed, that in another addition to the paper, which is in Mr Cavendish's handwriting, and which was certainly made after Mr Lavoisier's memoir had arrived, Mr Cavendish for the first time distinctly states, as upon Mr Lavoisier's hypothesis, that water consists of hydrogen united to oxygen gas. There is no substantial difference perhaps between this and the conclusion stated to have been drawn by Mr Cavendish himself, that oxygen gas is water deprived of phlogiston, supposing phlogiston to be synonymous with hydrogen; but the former proposition is certainly the more distinct and unequivocal of the two: and it is to be observed that Mr Cavendish, in the original part of the paper, *i. e.* the part read January 1784, before the arrival of Lavoisier's, considers it more just to hold inflammable air to be phlogisticated water than pure phlogiston, (p. 140).

We are now to see what Mr Watt did, and the dates here become very material. It appears that he wrote a letter to Dr Priestley on 26th April 1783, in which he reasons on the experiment of burning the two gases in a close vessel, and draws the conclusion, "that water is composed of dephlogisticated air and phlogiston deprived of part of their latent heat." * The letter was received by Dr Priestley, and delivered to Sir Joseph Banks, with a request that it might be read to the Royal Society; but Mr Watt afterwards desired this to be delayed, in order that he might examine some new experiments of Dr Priestley, so that it was not read until the 22d April 1784. In the interval between the delivery of this letter to Dr Priestley and the reading of it, Mr Watt had addressed another letter to Mr Deluc,

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* It may with certainty be concluded from Mr Watt's private and unpublished letters, of which the copies taken by his copying-machine then recently invented, are preserved, that his theory of the composition of water was already formed in December 1782, and probably much earlier. Dr Priestley, in his paper of 21st April 1783, p. 416, states, that Mr Watt, prior to his (the Doctor's) experiments, had entertained the idea of the possibility of the conversion of water or steam into permanent air. And Mr Watt himself, in his paper, Phil. Trans. p. 335, asserts, that, for many years he had entertained the opinion that air was a modification of water, and he enters at some length into the facts and reasoning upon which that deduction was founded.—(NOTE BY MR JAMES WATT.)

dated 26th November 1783,* with many further observations and reasonings, but almost the whole of the original letter is preserved in this, and is distinguished by inverted commas. One of the passages thus marked is that which has the important conclusion above mentioned; and that letter is stated in the subsequent one to have been communicated to several members of the

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* The letter was addressed to Mr J. A. Deluc, the well known Genevese philosopher, then a Fellow of the Royal Society and Reader to Queen Charlotte. He was the friend of Mr Watt, who did not then belong to the Society. Mr Deluc, following the motions of the Court, was not always in London, and seldom attended the meetings of the Royal Society. He was not present when Mr Cavendish's paper of 15th January 1784 was read; but, hearing of it from Dr Blagden, he obtained a loan of it from Mr Cavendish, and writes to Mr Watt on the 1st March following, to apprise him of it, adding that he has perused it, and promising an analysis. In the postscript he states, "In short, they expound and prove your system word for word, and say nothing of you." The promised analysis is given in another letter of the 4th of the same month. Mr Watt replies on the 6th, with all the feelings which a conviction he had been ill treated was calculated to inspire, and makes use of those vivid expressions which M. Arago has quoted; he states his intention of being in London in the ensuing week, and his opinion, that the reading of his letter to the Royal Society will be the proper step to be taken. He accordingly went there, waited upon the President of the Royal Society, Sir Joseph Banks, was received with all the courtesy and just feeling which distinguished that most honourable man, and it was settled that both the letter to Dr Priestley of 26th April 1783, and that to Mr De Luc of 26th November 1783, should be successively read. The former was done on the 22d, and the latter on the 29th April 1784.—(Note by Mr James Watt.)

Royal Society at the time of its reaching Dr Priestley, viz. April 1783.

In Mr Cavendish's paper as at first read, no allusion is to be found to Mr Watt's theory. But in an addition made in Mr Cavendish's own hand, after Mr Watt's paper had been read, there is a reference to that theory (Phil. Trans. 1784, p. 140), and Mr Cavendish's reasons are given for not encumbering his theory with that part of Mr Watt's which regards the evolution of latent heat. It is thus left somewhat doubtful, whether Mr Cavendish had ever seen the letter of April 1783, or whether he had only seen the paper (of 26th November 1783) of which that letter formed a part, and which was read 29th April 1784. That the first letter was for some time (two months, as appears from the papers of Mr Watt) in the hands of Sir Joseph Banks and other members of the Society during the preceding spring, is certain, from the statements in the Note to p. 330; and that Sir Charles Blagden, the Secretary, should not have seen it seems impossible, for Sir Joseph Banks must have delivered it to him at the time when it was intended to be read at one of the Society's meetings (Phil. Trans. p. 330, Note), and as the letter itself remains among the Society's Records in the same volume with the paper into which the greater part of it was introduced, it must have been in the custody of Sir C. Blagden. It is equally difficult to suppose, that the person who wrote the remarkable passage already referred to, respecting Mr Cavendish's conclusions having been communicated to Mr Lavoisier in the summer of 1783 (that is, in June), should not have mentioned to Mr Cavendish that Mr Watt had drawn the same conclusion in the spring of 1783 (that is, in April at the latest). For the conclusions are identical, with the single difference, that Mr Cavendish calls dephlogisticated air, water deprived of its phlogiston, and Mr Watt says, that water is composed of dephlogisticated air and phlogiston.

We may remark, there is the same uncertainty or vagueness introduced into Mr Watt's theory which we before observed in Mr Cavendish's, by the use of the term Phlogiston, without exactly defining it.* Mr Cavendish leaves it uncertain, whether or not he meant by Phlogiston simply inflammable air, and he inclines rather to call inflammable air, water united to phlogiston. Mr Watt says expressly, even in his later paper (of November 1783), and in a passage not to be found in the letter of April 1783, that he thinks that inflammable air contains a small quantity of water and much elementary heat. It must be admitted that such expressions as these on the part of both of those great men, betoken a certain hesitation respecting the theory of the composition of water. If they had ever formed to themselves the idea, that water is a compound of the two gases deprived of their latent heat,—that is, of the two gases, with the same distinctiveness which marks Mr Lavoisier's statement of the theory such obscurity and uncertainty would have been avoided.†

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* Mr Watt, in a note to his paper of 26th November 1783, p. 331, observes, "previous to Dr Priestley's making these experiments, Mr Kirwan had proved by very ingenious deductions from other facts, that inflammable air was, in all probability, the real phlogiston in an aerial form. These arguments were perfectly convincing to me, but it seems proper to rest that part of the argument on direct experiment."—(Note by Mr James Watt.)

† Mr Watt, in his letter of 26th April 1783, thus expresses

Several further propositions may now be stated, as the result of the facts regarding Mr Watt.

*First,* That there is no evidence of any person hav-

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his theory and conclusions (Phil. Trans. p. 333): "Let us now consider what obviously happens in the case of the deflagration of the inflammable and dephlogisticated air. These two kinds of air unite with violence, they become red hot, and, upon cooling, totally disappear. When the vessel is cooled, a quantity of water is found in it, equal to the weight of the air employed. This water is then the only remaining product of the process, and *water*, *light*, and *heat*, are all the products" (unless, he adds in the paper of November, there be some other matter set free, which escapes our senses). *Are we not then authorized to conclude that water is composed of dephlogisticated air and phlogiston, deprived of their latent or elementary heat; that dephlogisticated or pure air is composed of water deprived of its phlogiston, and united to elementary heat and light; that the latter are contained in it in a latent state, so as not to be sensible to the thermometer or to the eye; and if light be only a modification of heat or a circumstance attending it, or a component part of the inflammable air, then pure or dephlogisticated air is composed of water deprived of its phlogiston and united to elementary heat?*"

Is this not as clear, precise, and intelligible, as the conclusions of Mr Lavoisier?—(NOTE BY MR JAMES WATT.)

The obscurity with which Lord Brougham charges the theoretical conceptions of Watt and Cavendish does not appear to me well founded. In 1784, the preparation of two permanent and very dissimilar gases was known. Some called these gases, pure air and inflammable air; others, dephlogisticated air and phlogiston; and lastly, others, oxygen and hydrogen. By combining dephlogisticated air and phlogiston, water was produced equal in weight to that of the two gases. Water thenceforward was no longer a simple body, but a compound of dephlogisticated air and of phlogiston. The chemist who drew that conclusion, might have erroneous ideas as to the intimate nature ing reduced the theory of composition to writing, in a shape which now remains, so early as Mr Watt.

*Secondly,* That he states the theory, both in April and November 1783, in language somewhat more distinctly referring to composition, than Mr Cavendish does in 1784, and that his reference to the evolution of latent heat renders it more distinct than Mr Cavendish's.

*Thirdly,* That there is no proof, nor even any assertion, of Mr Cavendish's theory (what Sir C. Blagden calls his conclusion) having been communicated to Dr Priestley before Mr Watt stated his theory in 1783, still less of Mr Watt having heard of it, while his whole letter shews that he never had been aware of it, either from Dr Priestley, or from any other quarter.

*Fourthly,* That Mr Watt's theory was well known among the members of the Society some months before Mr Cavendish's statement appears to have been reduced into writing, and eight months before it was presented to the Society. We may, indeed, go farther, and affirm, as another deduction from the facts and dates, that, as far as the evidence goes, there is proof of Mr Watt having first drawn the conclusion, at least that no proof exists of any one having drawn it so early as he is proved to have done.

*Lastly,* That a reluctance to give up the doctrine of Phlogiston, a kind of timidity on the score of that long-

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of phlogiston, without throwing any uncertainty upon the merit of his first discovery. Even at this day, have we *mathematically demonstrated,* that hydrogen (or phlogiston) is an elementary body ; or that it is not, as Watt and Cavendish supposed at the time, the combination of a radical and of a little water ?—(NOTE BY M. ARAGO.)

established and deeply-rooted opinion, prevented both Mr Watt and Mr Cavendish from doing full justice to their own theory, while Mr Lavoisier, who had entirely shaken off these trammels, first presented the new doctrine in its entire perfection or consistency.*

All three may have made the important step nearly at the same time, and unknown to each other; the step, namely, of concluding from the experiment, that the two gases entered into combination, and that water was the result; for this, with more or less of distinctness, is the inference which all three drew.

But there is the statement of Sir Charles Blagden to shew that Mr Lavoisier had heard of Mr Cavendish's drawing this inference before his (Mr Lavoisier's) capital experiment was made;† and it appears that Mr

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* It could scarcely be expected that Mr Watt, writing and publishing for the first time, amid the distractions of a large manufacturing concern, and of extensive commercial affairs, could compete with the eloquent and practised pen of so great a writer as Lavoisier; but it seems to me, who am certainly no impartial judge, that the summing up of his theory (p. 333 of his paper), here quoted, p. 321, is equally luminous and well expressed as are the conclusions of the illustrious French chemist.—(NOTE BY MR JAMES WATT.)

† In the letter which Sir Charles Blagden addressed to Professor Crell, and which appeared in Crell's *Annalen* for 1786, professing to give a detailed history of the discovery, he says expressly, that he had communicated to Lavoisier the conclusions both of Cavendish *and Watt*. This last name appears in that letter for the first time in the recital of the verbal communications of the Secretary of the Royal Society, and is never mentioned by Lavoisier.—(NOTE BY MR JAMES WATT).

Lavoisier, after Sir C. Blagden's statement had been embodied in Mr Cavendish's paper and made public, never gave any contradiction to it in any of his subsequent memoirs which are to be found in the Mémoires de l'Académie, though his own account of that experiment, and of what then passed, is inconsistent with Sir Charles Blagden's statement.*

But, there is not any assertion at all even from Sir C. Blagden, zealous for Mr Cavendish's priority as he was, that Mr Watt had ever heard of Mr Cavendish's theory before he formed his own.

Whether or not Mr Cavendish had heard of Mr Watt's theory previous to drawing his conclusions, appears more doubtful. The supposition that he had so heard, rests on the improbability of his (Sir Charles Blagden's), and many others knowing what Mr Watt had done, and not communicating it to Mr Cavendish, and on the omission of any assertion in Mr Cavendish's paper, even in the part written by Sir C. Blagden with the view of claiming priority as against Mr Lavoisier, that Mr Cavendish had drawn his conclusion before April 1783, although, in one of the additions to that paper, reference is made to Mr Watt's theory.

As great obscurity hangs over the material question, at what time Mr Cavendish first drew the conclusion from his experiment, it may be as well to examine what that great man's habit was in communicating his discoveries to the Royal Society.

A Committee of the Royal Society, with Mr Gilpin the clerk, made a series of experiments on the formation

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* Could Blagden's letter to Crell also have escaped Lavoisier's notice ?—(NOTE BY MR JAMES WATT.)

of nitrous acid, under Mr Cavendish's direction, and to satisfy those who had doubted his theory of its composition, first given accidentally in the paper of January 1784, and afterwards more fully in another paper, June 1785. Those experiments occupied from the 6th December 1787 to 19th March 1788, and Mr Cavendish's paper upon them was read 17th April 1788. It was therefore written and printed within a month of the experiment being concluded.

Mr Kirwan answered Mr Cavendish's paper (of 15th January 1784) on water, in one which was read 5th February 1784, and Mr Cavendish replied in a paper read 4th March 1784.

Mr Cavendish's experiments on the density of the earth, were made from the 5th August 1797 to the 27th May 1798. The paper upon that subject was read 27th June 1798.

The account of the eudiometer was communicated at apparently a greater interval; at least the only time mentioned in the account of the experiments is the latter half of 1781, and the paper was read January 1783. It is, however, probable from the nature of the subject, that he made further trials during the year 1782.

That Mr Watt formed this theory during the few months or weeks immediately preceding April 1783 seems probable.* It is certain that he considered the theory as his own, and makes no reference to any previous communication from any one upon the subject,

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* That the idea existed in his mind previously, is proved by his declarations to Dr Priestley, cited by the latter; by his own assertions, p. 335 of his paper, and by the existing copies of his letters in 1782.—(Note by Mr James Watt.)

nor of having ever heard of Mr Cavendish drawing the same conclusion.

The improbability must also be admitted to be extreme, of Sir Charles Blagden ever having heard of Mr Cavendish's theory prior to the date of Mr Watt's letter, and not mentioning that circumstance in the insertions which he made in Mr Cavendish's paper.

It deserves to be farther mentioned, that Mr Watt left the correction of the press, and everything relating to the publishing of his paper, to Sir Charles Blagden. A letter remains from him to that effect written to Sir Charles Blagden, and Mr Watt never saw the paper until it was printed.*

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* The notes of Mr James Watt formed part of the manuscript transmitted to me by Lord Brougham, and it is at the express desire of our illustrious fellow-member, that I have printed them as a useful commentary upon his essay.—(Note by M. Arago.)

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