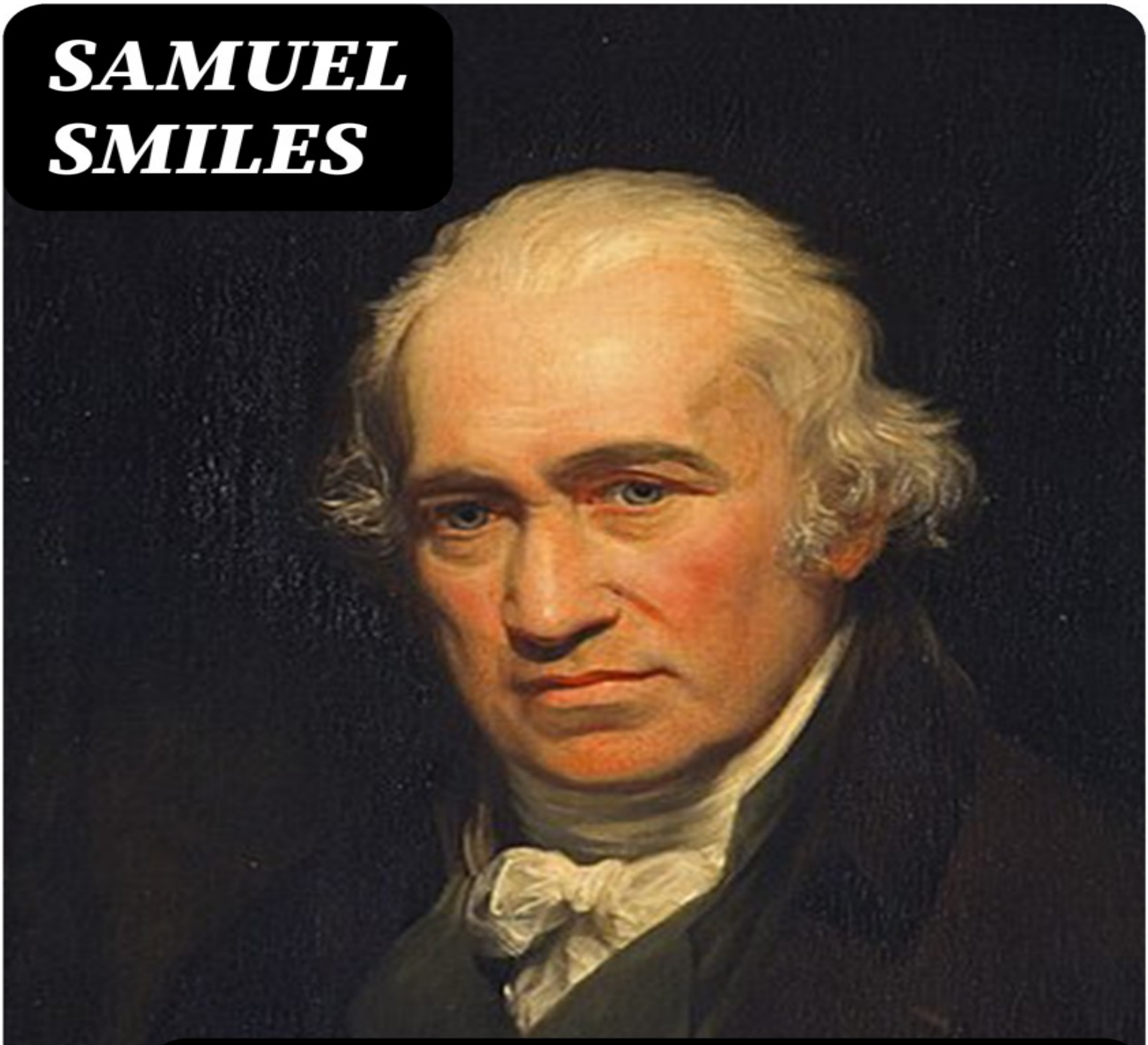
SAMUEL SMILES



LIVES OF BOULTON AND WATT. PRINCIPALLY FROM THE ORIGINAL SOHO MSS

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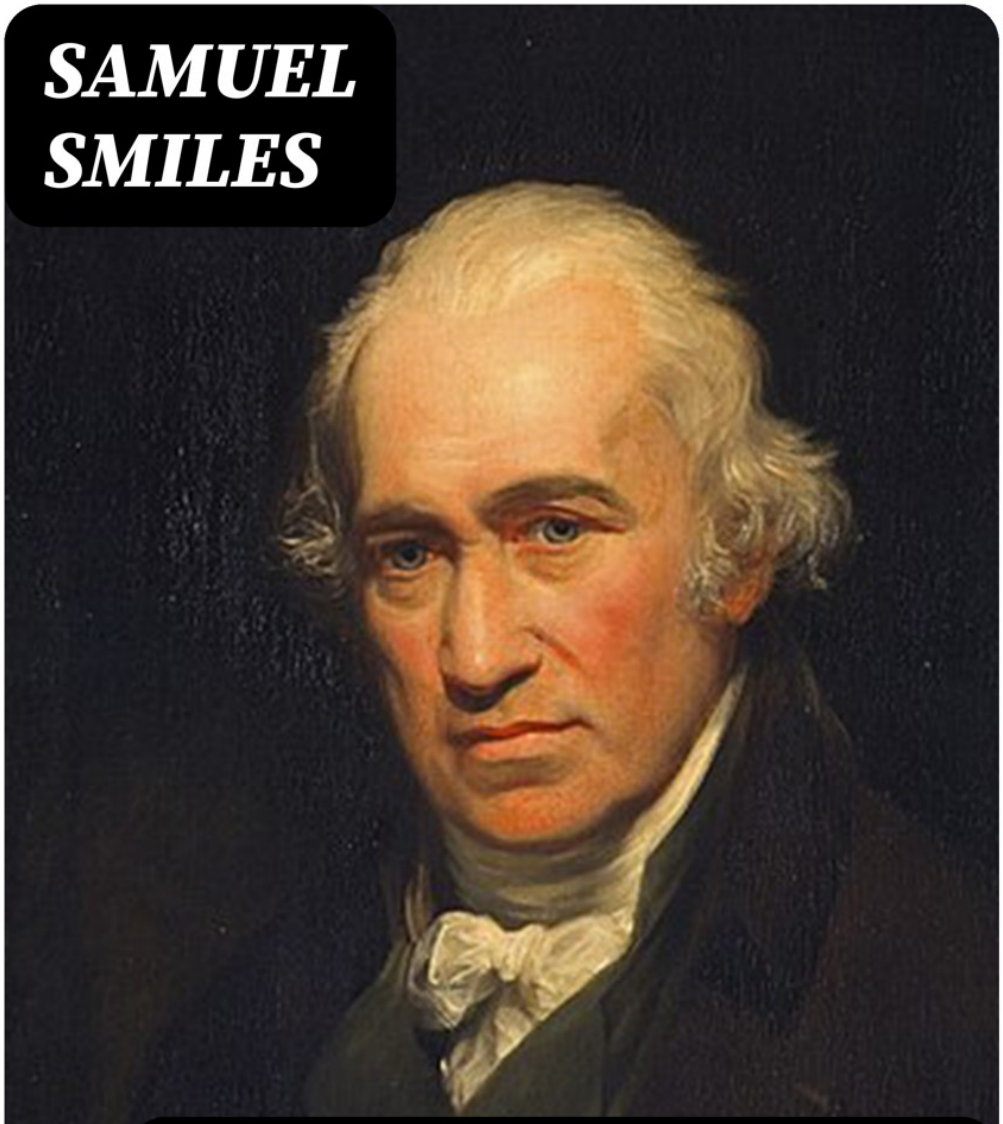

LIVES OF BOULTON AND WATT. PRINCIPALLY FROM THE ORIGINAL SOHO MSS

Samuel Smiles

Lives of Boulton and Watt. Principally from the Original Soho Mss

Comprising also a history of the invention and introduction of the steam engine

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PREFACE.

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THE present volume concludes the author's 'Lives of the Engineers.' Its preparation was begun many years since. The favourable reception given to the 'Life of George Stephenson,' the principal improver and introducer of the locomotive engine, encouraged the author to follow it by a Life of James Watt, the principal inventor and introducer of the condensing engine. On making inquiries, however, he found that the subject had already been taken in hand by J. P. Muirhead, Esq., the literary executor of the late Mr. Watt, of Aston Hall, near Birmingham. As Mr. Muirhead was in all respects entitled to precedence, and was, moreover, in possession of the best sources of information, the author's contemplated Life of Watt was abandoned, and he satisfied himself with embodying the substance of the materials he had collected in a review of Mr. Muirhead's work, which appeared in the 'Quarterly Review' for July, 1858.

Having recently, however, through the kindness of M. P. W. Boulton, Esq., of Tew Park, Oxon, been enabled to examine the extensive collection of documents brought from Soho, including the original correspondence between Watt and Small, between Watt and Boulton, and between the latter and his numerous intimate friends and business correspondents, it has appeared to the author that, notwithstanding the valuable publications of Mr. Muirhead, the story of the life of Watt is one that will well bear to be told again, in connexion with the life and labours of Matthew Boulton of Soho. The two men were so intimately related

during the most important period of their lives, and their biographies so closely intermingle, that it is almost impossible to separate them. They are therefore treated conjointly in the present volume, under the title of ‘Boulton and Watt,’ the name of the old Soho firm which so long enjoyed a world-wide reputation. But though the name of Boulton takes priority in the title, that of Watt will be found in many respects the most prominent in the narrative.

The MS. papers which have been consulted for the purposes of the present volume are of an unusually complete and varied character. They consist of several thousand documents selected from the tons of business books and correspondence which had accumulated at Soho. The most important were selected and arranged by the late M. Robinson Boulton, Esq., who entertained the highest regard for his father's memory; and, from the character of the collection, the author inclines to the opinion that it must have been made with a view to the preparation and publication of a Life of Matthew Boulton,—which has not, however, until now been undertaken. Thus, among sundry papers endorsed “M. Boulton—Biographical Memoirs,” is found a MS. memoir in the handwriting of James Watt, entitled “Memorandum concerning Mr. Boulton, commencing with my first acquaintance with him,” and another of a similar character, by Mr. James Keir,—both written shortly after Mr. Boulton’s death. Another collection, endorsed “Familiarum Epistolæ et Selectæ, 1755 to 1808,” contains letters received from various distinguished personages in the course of Mr. Boulton’s long and interesting career. The number of original documents is

indeed so large, that, but for a rigid exclusion of non-essential matter, these Lives must have expanded into several volumes, instead of being compressed into one. But the author believes labour to be well bestowed in practising the art of condensation, and that the interest of biography gains much by judicious rejection. What Watt said to Murdock as to the production of a machine, holds equally true as to the production of a book,—“It is a great thing,” said Watt, “to know what to do without.”

Besides the memoirs of Boulton and Watt, which occupy the principal places in the following volume, it will also be found to contain memoirs of the other inventors who have at various times laboured at the invention and application of the steam-engine,—of the Marquis of Worcester, Dionysius Papin, Thomas Savery, and Thomas Newcomen. The author has also been enabled to gather from the Boulton papers a memoir of William Murdock, which probably contains all that is likely to be collected respecting that excellent and most ingenious mechanic.

In addition to the essential assistance received from M. P. W. Boulton, Esq., in preparing the present book, without which it would not have been undertaken, the author desires to record his acknowledgments to J. W. Gibson Watt, Esq., for information relative to James Watt;—to Charles Savery, Esq., Clifton, J. T. Savery, Esq., Modbury, Lieutenant-Colonel Yolland, R.E., and Quartermaster Connolly, R.E., for various facts as to the family history and professional career of Thomas Savery, inventor of the “Fire Engine;”—and to Thomas Pemberton, Esq., Heathfield; W. C. Aitkin, Esq., Coventry; George Williamson, Esq., Greenock; the late J.

Murdock, Esq., Handsworth; and the late Mr. William Buckle, of the Royal Mint, formerly of Soho,—for various information as to the lives and labours of Boulton and Watt.

In his treatment of the subject, it will be observed that the author has endeavoured, as much as possible, to avoid introducing technical details relating to the steam-engine. Those who desire further information on such points, are referred to the works of Farey, Tredgold, Bourne, Scott Russell, Muirhead (‘Mechanical Inventions of James Watt’), and other technical treatises on the subject, where they will find detailed particulars of the various inventions which are only incidentally referred to in the following pages.

London, October, 1865.

BEGINNINGS OF THE STEAM-ENGINE: THE EARLY INVENTORS.

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EDWARD, SECOND MARQUIS OF WORCESTER.

[By T. D. Scott after Vandyck.]

ANCIENT GREEK ÆOLIPILE.

BEGINNINGS OF THE STEAM-ENGINE: THE EARLY INVENTORS.

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CHAPTER I.

Dawnings of Steam Power—The Marquis of Worcester.

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When Matthew Boulton entered into partnership with James Watt, he gave up the ormolu business in which he had before been principally engaged. He had been accustomed to supply George III. with articles of this

manufacture, but ceased to wait upon the King for orders after embarking in his new enterprise. Some time after, he appeared at the Royal Levee and was at once recognised by the King. “Ha! Boulton,” said he, “it is long since we have seen you at Court. Pray, what business are you now engaged in?” “I am engaged, your Majesty, in the production of a commodity which is the desire of kings.” “And what is that? what is that?” asked the King. “POWER, your Majesty,” replied Boulton, who proceeded to give a description of the great uses to which the steam-engine was capable of being applied.

If the theory of James Mill[1] be true, that government is founded on the desire which exists among men to secure and enjoy the products of labour, by whatsoever means produced, probably the answer of Boulton to George III. was not far from correct. In the infancy of nations this desire manifested itself in the enforcement of labour by one class upon another, in the various forms of slavery and serfdom. To evade the more onerous and exhausting kinds of bodily toil, men were impelled to exercise their ingenuity in improving old tools and inventing new ones,—while, to increase production, they called the powers of nature to their aid. They tamed the horse, and made him their servant; they caught the winds as they blew, and the waters as they fell, and applied their powers to the driving of mills and machines of various kinds.

But there was a power greater by far than that of horses, wind, or water,—a power of which poets and philosophers had long dreamt,—capable of being applied alike to the turning of mills, the raising of water, the rowing of ships, the

driving of wheel-carriages, and the performance of labour in its severest forms. As early as the thirteenth century, Roger Bacon described this great new power in terms which, interpreted by the light of the present day, could only apply to the power of Steam. He anticipated that “chariots may be made so as to be moved with incalculable force, without any beast drawing them,” and that “engines of navigation might be made without oarsmen, so that the greatest river and sea ships, with only one man to steer them, may sail swifter than if they were fully manned.” But Bacon was a seer rather than an expounder, a philosophic poet rather than an inventor; and it was left to men of future times to find out the practical methods of applying the wonderful power which he had imagined and foretold.

The enormous power latent in water exposed to heat had long been known. Its discovery must have been almost contemporaneous with that of fire. The expansive force of steam would be obvious on setting the first partially-closed pipkin upon the fire. If closed, the lid would be blown off; and even if the vessel were of iron, it would soon burst with appalling force. Was it possible to render so furious and apparently unmanageable an agent, docile and tractable? Even in modern times, the explosive force of steam could only be compared to that of gunpowder; and it is a curious fact, that both De Hautefeuille and Papin proposed to employ gunpowder in preference to steam in driving a piston in a cylinder, considering it to be the more manageable power of the two.

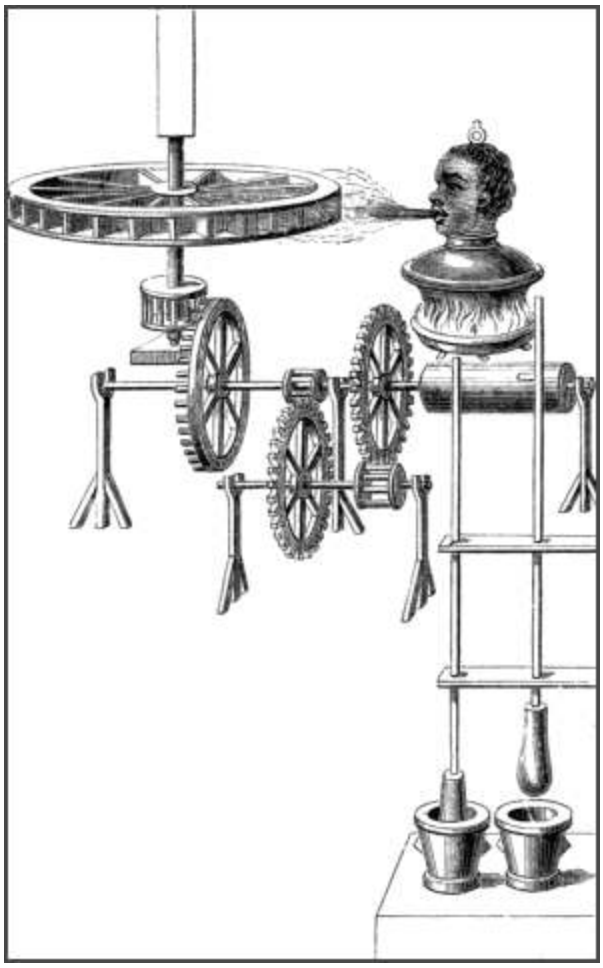
Although it appears from the writings of the Greek physician, Hero, who flourished at Alexandria more than a

century before Christ, that steam was well known to the ancients, it was employed by them merely as a toy, or as a means of exciting the wonder of the credulous. In his treatise on Pneumatics, Hero gives descriptions of various methods of employing steam or heated air for the purpose of producing apparently magical effects; from which we infer that the agency of heat was employed by the heathen priests in the performance of their rites. By one of the devices which he describes, water was apparently changed into wine; by another, the temple doors were opened by fire placed on the sacrificial altar; while by a third, the sacrificial vessel was so contrived as to flow only when the money of the votary was cast into it. Another ingenious device consisted in the method employed to pour out libations. Upon the altar-fire being kindled, the air in the interior became expanded and, pressing upon the surface of the liquid which it contained, forced it up a connecting-pipe, and so out of the sacrificial cup. The libation was made, and the people cried, “A miracle!” But Hero knew the trick, and explained the arrangement by which it was accomplished: it forms the subject of his eleventh theorem.

The most interesting of the other devices described by Hero is the whirling Æolipile, or ball of Æolus, which, though but a toy, possessed the properties of a true steam-engine, and was most probably the first ever invented. As Hero’s book professes to be, for the most part, but a collection of the devices handed down by former writers, and as he does not lay claim to its invention, it is probable the Æolipile may have been known long before his time. The machine consisted of a hollow globe of metal, moving on its axis, and

communicating with a caldron of water placed underneath. The globe was provided with one or more tubes projecting from it, closed at the ends, but open on one side. When a fire was lit under the caldron, and the steam was raised, it filled the globe, and, projecting itself against the air through the openings in the tubes, the reactive force thus produced caused the globe to spin round upon its axis “as if it were animated from within by a living spirit.”[2]

The mechanical means by which these various objects were accomplished, as explained by Hero, show that the ancients were acquainted with the ordinary expedients for communicating motion, such as the wheel and axle, spur-wheels, toothed pinions and sectors, the lever-beam, and other well-known expedients; while they also knew of the cylinder and piston, the three-way cock, slide-valves and valve-clacks,[3] and many other ingenious mechanical details which have been reinvented in modern times.



BRANCA’S MACHINE.

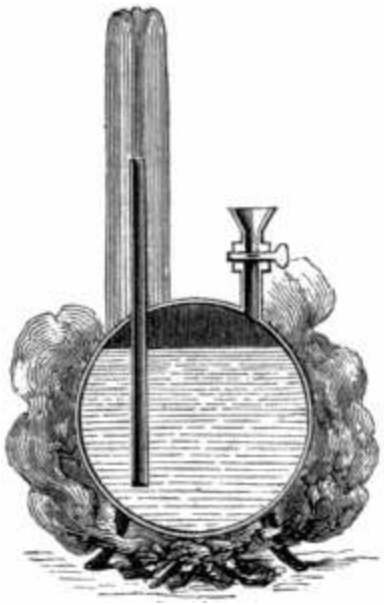
Hero’s book lay hidden in manuscript and buried in libraries, until the revival of learning in Italy in the sixteenth century, when a translation of it appeared at Bologna in 1547. By that time printing had been invented; and the multiplication of copies being thereby rendered easy, the book was soon brought under the notice of inquiring men throughout Europe. The work must, indeed, have excited an extraordinary degree of interest; in proof of which it may be mentioned that eight different editions, in different languages, were published within a century. The minds of the curious and the scientific were thus directed to the subject of steam as a motive power. But for a long time they

never got beyond the idea of Hero's Æolipile, though they endeavoured to apply the rotary motion produced by it in different ways. Thus, a German writer suggested that it should be used to turn spits, instead of turnspit dogs; and Branca, the Italian architect, used the steam jet projected from a brazen head to drive an apparatus contrived by him for pounding drugs. The jet forced round the vanes of a wheel, so as to produce a rotary motion, and this, being communicated to other wheels, set in motion a rod and stamper, after the manner shown in the preceding cut.

Solomon de Caus was another of the speculative inquirers whose attention was drawn to the subject of steam by the publication of Hero's book. De Caus was a native of Normandy, and for some time studied the profession of an architect in Italy; from whence he returned to France early in the seventeenth century. Religious persecution was then raging, and, being a Protestant, he was glad to take refuge from it in England. He entered the service of the Prince of Wales, by whom he was for a time employed in designing grottoes, fountains, and hydraulic ornaments for the Palace Gardens at Richmond. While occupied in that capacity he gave lessons in design to the Princess Elizabeth; and on her marriage to the Elector Palatine he accompanied her to Heidelberg, to take charge of the Castle gardens there. It was while residing at Heidelberg that De Caus wrote his well-known book on hydraulics, which was published at Frankfort in 1615.[4]

One of De Caus's expedients for raising water consisted of an apparatus in which he proposed to employ the expansive power of steam for the purpose. In Hero's book it

is shown how a column of water may be thrown up by means of compressed air; and De Caus merely proposed to employ steam instead of air. His apparatus was very simple. It consisted of a spherical vessel fitted with two pipes, one of them provided with a cock and funnel; the other, which reached down to near the bottom of the vessel, being open at the top to the external air. When the vessel was filled with water and a fire lit underneath, the water was forced up the open tube in a jet, greater or less in proportion to the elasticity of the steam. When both tubes were tightly closed, so that neither steam nor water could escape, the heat, says De Caus, would shortly cause a compression from within so violent that “the ball will burst in pieces, with a noise like a petard.”



DE CAUS’S STEAM APPARATUS.

It will be observed that there was little mechanical contrivance, and no practical use in this apparatus; it merely furnished an illustration of the extraordinary force of pent-up steam, and that was all. Though De Caus made

many experiments with his steam-vessel, he never succeeded in making—if, indeed, he ever attempted to make—a working steam-engine of any kind. It is not improbable that he was dismayed, as others were, by the apparent violence of the imprisoned monster; and it needed a more ingenious head than his to contrive a method of rendering him docile, and making him go quietly in harness. [5]

It is probable that the first contriver of a working steam-engine was Edward, second Marquis of Worcester, one of the first and most illustrious of a long line of unfortunate inventors. The career of that nobleman—born though he was to high rank and great estate—was chequered and sad in no ordinary degree. Edward Somerset was the eldest son of Henry Lord Herbert, afterwards Earl of Worcester, and consequently heir to that title. He was born in London in 1601. His early years were principally spent at Raglan Castle, his father’s country seat, where his education was carefully attended to. In the course of his pupilage he made occasional visits to the continent, accompanied by his tutor, for the purpose of acquiring that degree of polish and culture considered necessary for a person of his social position. On the accession of his father to the Earldom of Worcester, in 1627, Edward became Lord Herbert by courtesy; and in the following year he married, and went to reside at Raglan Castle.

From an early period of his life Lord Herbert took especial pleasure in mechanical studies, and in the course of his foreign tours he visited and examined the famous works of construction abroad; for as yet there were none such in

England. On settling down at Raglan, he proceeded to set up a laboratory, or workshop, wherein to indulge his mechanical tastes, and perhaps to while away the tedium of a country life. To assist him in his labours, he engaged a clever foreign mechanic, named Caspar Kaltoff, who remained in his service for many years, and materially helped him in his various contrivances. Among the works executed by Lord Herbert and his assistant at Raglan, was the hydraulic apparatus by means of which the castle was supplied with water. From an incidental reference to the "water-works" by a contemporary writer, we learn that they consisted of a series of engines and wheels, by means of which water was raised through pipes to a cistern placed on the summit of the central tower.[6] It is probable that the planning and construction of these works induced Lord Herbert to prosecute the study of hydraulics, and to enter upon that series of experiments as to the power of steam which eventually led to the contrivance of his "Water-commanding Engine."

In pursuits and studies such as these, Lord Herbert spent about seven years at Raglan Castle. But his wife dying in 1635, the place became connected in his mind with too painful associations, and he shortly after left it to reside in London. On his arrival there, he proceeded to put to the practical test a plan of perpetual motion which he had long studied, and now thought he had brought to perfection. He accordingly had his self-moving wheel[7] set up in the Tower; but though it moved, its motion did not prove perpetual, and it shortly dropped out of sight, to be no more heard of.

After the lapse of four years, Lord Herbert again married, taking to wife the Lady Margaret, second daughter of the Earl of Thomond. In the year after his second marriage, the celebrated Long Parliament began its sittings. Questions of great public import were agitating the minds of thinking men, and the nation was gradually becoming divided into two hostile parties, soon to be arrayed against each other in deadly strife. A Royalist and a Roman Catholic like his father, Lord Herbert at once ranged himself on the side of the King. On the outbreak of the Civil War, we find both father and son actively employed in mustering forces, and preparing to hold the western counties against the Parliament. Raglan Castle was strongly garrisoned, and fortifications were thrown up around it, so as to render it secure against assault. The Earl, now Marquis of Worcester, was appointed Generalissimo of the Western Forces, while his son, Lord Herbert, was made General of South Wales. From this office he was shortly after called by the King, who, creating him Earl of Glamorgan, despatched him on a mission to Ireland, with the object of stirring up the loyalists of that kingdom, and inducing them to come to his help. This delicate office he is said to have performed with more zeal than discretion. Indeed, the studious habits of his early life must in a measure have unfitted him for the conduct of so important an affair; and the bungle he made of it was such that the King felt himself under the necessity of repudiating the acts which the Earl had done in his name.

It is unnecessary that we should follow the fortunes of the house of Raglan in the course of the civil war. Suffice it to say that the King’s cause was utterly lost; that Raglan

Castle was besieged, taken, and dismantled; that the Marquis of Worcester, having advanced to the King at different times as much as 122,500*l.*, had completely impoverished himself; and that when the Earl succeeded to his father's title, and became second Marquis of Worcester, in 1646, he inherited an exhausted exchequer, a confiscated estate, and a ruined home. The services he had rendered to the King were remembered against him; and to escape the vengeance of his political enemies he took refuge in France. There he lived in poverty and in exile for a period of about five years. At length, drawn to England by the powerful attractions of wife and family, and probably also commissioned to perform a service for the exiled Charles II., the Marquis secretly visited London in 1655, where he was shortly after detected, apprehended, and imprisoned in the Tower. He sought and found solace, during his confinement, in study and contemplation, reverting to his early experiments in mechanics; and he occupied the long and weary hours in committing to paper descriptions of his many ingenious devices, which he afterwards published in his 'Century of Inventions.' The Marquis's old and skilled mechanic, Caspar Kaltoff, continued faithful to him in his adversity, and was permitted to hold free communication with him; from which we infer that his imprisonment was not of a very rigid character.

After lying in the Tower for about two years, the Marquis was liberated on bail, in October, 1654, when he proceeded to take steps to erect his long-contemplated Water-commanding Engine. Even while a prisoner, we find him negotiating with the then owner of Vauxhall for its purchase,

with a view to the establishment there of a school of skilled industry; thus anticipating by nearly two centuries the School of Mines and Manufactures at South Kensington. In the month preceding his enlargement we find Hartlib writing to the Hon. Robert Boyle,—"The Earl of Worcester is buying Fauxhall from Mr. Trenchard, to bestow the use of that house upon Caspar Calchoff and his son as long as they shall live, for he intends to make it a College of Artizans."[8] His main difficulty, however, consisted in raising the necessary means for carrying his excellent project into effect. He was, indeed, so reduced in his circumstances as to be under the necessity of petitioning his political enemies for the bare means of living; and we find Cromwell, in the course of the year following his liberation from prison, issuing a warrant for the payment to him of three pounds a week "for his better maintenance." The Marquis also tried the experiment of levying contributions from his friends; but they were, for the most part, as poor as himself. He next tried the wealthy men of the Parliamentary party, and succeeded in obtaining several advances of money from Colonel Copley, who took an active interest in the prosecution of various industrial undertakings.[9] The following letter from the Marquis to Copley shows the straits to which he was reduced:—

> "Dear Friend,—I knowe not with what face to desire a curtesie from you, since I have not yet payed you the five powndes, and the mayne businesse soe long protracted, whereby my reality and kindnesse should with thankfullnesse appeare; for though the least I intende you is to make up the somme already promised to a thousand powndes yearly, or a share

ammounting to four more, which, to nominate before the perfection of the woorke, were but an *individuum vagum*, and, therefore, I deferre it, and upon noe other score. Yet in this interim, my disappointments are soe great, as that I am forced to begge, if you could possible, eyther to helpe me with tenne powndes to this bearer, or to make use of the coache, and to goe to Mr. Clerke, and if he could this day help me to fifty powndes, then to paye your selfe the five powndes I owe you out of them. The Alderman has taken three days' time to consider of it. Pardon the great trouble I give you, which I doubt not but in time to deserve, by really appearing

"Your most thankfull friend,

"WORCESTER.

"*28th March, 1656.*

"To my honoured friend, Collonel CHRISTOPHER COPPLEY, these."

The original of this letter is endorsed "My Lord of Worcester's letter about my share in his engine," from which it would appear that the Marquis induced his friends to advance him money on the promise of a certain proportion of shares in the undertaking. He also pressed his invention upon the notice of Government, representing that he was in a position to do his Highness the Protector "more service than any one subject of his three nations." But neither the Protector nor his Ministers took any further notice of the Marquis or his project. It is probable that they regarded him as a bore, and his water-commanding engine as the mere dream of a projector.

The Marquis himself continued to be as confident as ever of the ultimate success of his scheme. He believed that it would yet realise him an immense fortune. Writing of the engine to the Earl of Lotherdale, he described it as “the greatest invention for profit that I ever yet heard of vouchsafed to a man, especially so unworthy and ignorant as I am.” But the Marquis was not so humble as he affected to be, believing in his heart that he had invented, without exception, the most wonderful machine of the age. Still it remained a mere project. Without the means of erecting an engine, it promised to remain such; and all his efforts to raise the necessary funds had thus far proved unavailing.

The Restoration of Charles II., in 1660, revived his hopes. Now that the King enjoyed his own again, the Marquis believed that he, too, would come into possession of the means for carrying out his project. For thirteen years he had lived in exile, in prison, and in poverty: but brighter days had dawned at last; and he indulged in the hope that compensation would at length be made to him for his sufferings in the cause of the Stuarts, and that he would now bask in the sunshine of Royal favour. He made all haste to represent his case to the king, and to claim restitution for his heavy losses in the late war. But there were thousands of like suppliants all over the kingdom, and redress came slowly. The Marquis was, however, shortly put in possession of such parts of his estates as had not been sold by the Protector; but he found them for the most part cleared of their timber, and comparatively valueless. The castle at Raglan was in ruins. He himself was heavily burdened with debt, and his creditors were becoming increasingly

importunate for money. It was thus long before he could shake himself clear of his embarrassments, and devote himself to the great object of his life, the prosecution of his water-commanding engine.

One of his first cares, on the partial recovery of his property, was to obtain a legal protection for his inventions; and in the year following the Restoration we find him taking out a patent for four of his schemes,—a watch or clock, guns or pistols, an engine to give security to a coach, and a boat to sail against wind and tide. In the session of Parliament, 1662–3, he obtained an Act securing to himself the profits of the water-commanding engine. About the same time he gave to the world his famous 'Century,'[10] which contains his own account of his various inventions. In the second dedication of the book to the members of both Houses of Parliament he states that he had already expended the large sum of 10,000*l.* on experiments; but he professed that he esteemed himself sufficiently rewarded by the passing of "the Act of the Water-commanding Engine," and, his debts once paid, he intended to devote the rest of his life to the service of his King and country. The 'Century' is a mere summary of things alleged to have been tried and perfected, conveyed in vague and mysterious language, and calculated rather to excite wonder than to furnish information. The descriptions were unaccompanied by plans or drawings, so that we can only surmise the means by which he proposed to carry his schemes into effect. It is possible that he purposely left the descriptions of his inventions vague, in order that he might not be anticipated in their application; for it is certain that at the time the book

was written the Marquis had not taken out his first patent, nor obtained the Act securing to him the profits of his engine.

There can, however, be no doubt that, vague and mysterious though the ‘Scantlings’ be, they indicate a knowledge of mechanical principles considerably in advance of the age, as well as a high degree of mechanical ingenuity. The hundred Articles into which the book is divided contain suggestions, in shorthand descriptions, of things so various as ship-destroying machines, telegraphs, combination and escutcheon locks,[11] improvements in fire-arms, universal alphabets, seals and watches, various kinds of cipher, a boat rowing against wind and tide, automata, and mechanical appliances of different kinds, including the “stupendious and semi-omnipotent” engine. Some of them read like descriptions of conjuring tricks, such as the artificial bird, the hour water-ball, the flying man, the brazen head, the dicing-box, and various automata. Others are full of prophetic insight, and contain anticipations of mechanical marvels, which, however wonderful they may at that time have appeared, have since been fully realised. The style in which the treatise was written, however, presented so remarkable a contrast to the contemporary writings of Newton, Boyle, Pascal, Guericke, and others, that it is not improbable it had the effect of prejudicing the minds of scientific men against the writer, and led them to regard his schemes as those of a wild projector, and hence to treat his propositions with neglect, if not with contumely.

So soon as the Marquis had become possessed of the requisite funds, he proceeded to erect an engine at Vauxhall

to illustrate the uses of his principal invention. He was assisted, as before, by his old workman, Caspar Kaltoff. It is probable that the engine was erected by the beginning of 1663; for in the course of that year M. Sorbière paid his visit to England, and found the Marquis's "hydraulic machine" at work. He describes it as capable of raising, by the strength of one man only, within a minute of time, four large buckets of water to a height of forty feet, through a pipe eight inches in diameter. He proceeds to compare it with another machine at Somerset House, worked by one or two horses, which he considers the more effective machine of the two. [12] This account of the Marquis's invention is confirmed by another brief description of it, which occurs in the narrative of the travels of Cosmo, Grand Duke of Tuscany, in England, some years later. Count Magalotti, the narrator, says, "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 at Somerset House." It will thus be observed that the Duke's secretary entertained a different opinion from that expressed by M. Sorbière as to the comparative merits of the two engines spoken of.

It is worthy of remark that the incidental accounts of these two foreigners contain almost the only contemporary information we possess as to the character of the Marquis's invention. English writers of the time are almost entirely silent about it; and when Dr. Hooke, the learned Secretary of the Royal Society, refers to the contrivance, it is in a tone of

ridicule rather than of praise. Writing to Mr. Boyle, in 1667, he characterises the definition or description of the water-commanding engine as “so purely romantic that it would serve one rarely to fill up half a dozen pages in the ‘History of Fortunatus his Wishing Cap.’” ... “I was,” he adds, “since my return to London to see this engine, when I found Caltrop [Kaltoff], his chief engineer, to laugh at it; and as far as I was able to see it, it seemed one of the perpetual-motion fallacies; of which kind Caltrop himself, and two or three others that I know, are labouring at this time in vain to make, but after several ways; and nothing but costly experience will make them desist.”[13]

It is difficult to gather from the statements of Sorbière and Cosmo de Medici what was the precise nature of the Marquis’s hydraulic apparatus. There is no mention whatever of steam, either in their accounts or in that of Dr. Hooke; but the latter does not seem to have been allowed to examine the details of the machine. From the mention by Sorbière of the “four large buckets of water,” and by Cosmo’s secretary, of “four vessels of water,” it might possibly have been only an improved hydraulic apparatus, worked by a man instead of a horse. In order, therefore, to obtain a clue to the real nature of the machine we find it necessary to resort to the Marquis’s ‘Scantlings’ for his own account of its action, and we find it in article No. 68, which runs as follows:—

> “68. An admirable and most forcible way to drive up water by fire, not by drawing or sucking it upwards, for that must be as the Philosopher calleth it, *Intra sphæram activitatis*, which is but at such a

> distance. But this way hath no Bounder, if the Vessels be strong enough; for I have taken a piece of a whole Cannon, whereof the end was burst, and filled it three-quarters full of water, stopping and scruing up the broken end; as also the Touch-hole; and making a constant fire under it, within twenty-four hours it burst and made a great crack: So that having a way to make my Vessels, so that they are strengthened by the force within them, and the one to fill after the other, I have seen the water run like a constant Fountaine-stream forty foot high; one Vessel of water rarified by fire driveth up forty of cold water. And a man that tends the work is but to turn two Cocks, that one Vessel of water being consumed, another begins to force and refill with cold water, and so successively, the fire being tended and kept constant, which the self-same Person may likewise abundantly perform in the interim between the necessity of turning the said Cocks.”

From this account we gather that the Marquis had contrived a plan for raising water by the expansive force of steam, after the manner of De Caus, but with important modifications and improvements. It had obviously occurred to him, that by generating the steam in a separate vessel, and conveying it by means of a suitable pipe to a second closed vessel, he could thereby make it expel the water which the latter contained by pressing upon its surface, as in De Caus’s apparatus. The admission of the steam could easily be regulated by the turning of two cocks; one to admit the steam from the boiler, and the other to allow the