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A System of Mechanical Philosophy

After a brief career at sea, during which he tested Harrison's chronometer for the Board of Longitude, John Robison (1739–1805) became lecturer in chemistry at the University of Glasgow. In 1774, having spent a period teaching mathematics in Russia, he returned to Scotland as professor of natural philosophy at Edinburgh. Despite his busy schedule, he contributed major articles on the sciences to the *Encyclopaedia Britannica*, giving an overview of contemporary scientific knowledge for the educated layperson. After his death, these and other pieces of his scientific writing were edited by his former pupil David Brewster (1781–1868) and were finally published in four volumes in 1822, with a separate volume of illustrative plates. This reissue incorporates those plates in the relevant volumes of text. Volume 2 contains Robison's articles on the steam engine (revised and expanded by his friend James Watt), on other machinery, and on fluid flows.

A System of Mechanical Philosophy

VOLUME 2

JOHN ROBISON
EDITED BY DAVID BREWSTER

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A

SYSTEM

OF

MECHANICAL PHILOSOPHY.

By JOHN ROBISON, LL. D.

LATE PROFESSOR OF NATURAL PHILOSOPHY IN THE UNIVERSITY OF EDINBURGH.

WITH NOTES,

By DAVID BREWSTER, LL. D.

FELLOW OF THE ROYAL SOCIETY OF LONDON, AND SECRETARY TO THE ROYAL SOCIETY OF EDINBURGH.

IN FOUR VOLUMES,

AND A VOLUME OF PLATES

VOL. II.

EDINBURGH:

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1822.

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OF

VOLUME SECOND.

THE

ARTICLES

STEAM AND STEAM-ENGINES,

WRITTEN FOR THE ENCYCLOPÆDIA BRITANNICA,

BY

JOHN ROBISON, LL.D. F.R.S.E. &c.

LATE PROFESSOR OF NATURAL PHILOSOPHY IN THE UNIVERSITY OF EDINBURGH, &c.

WITH NOTES AND ADDITIONS,

BY

JAMES WATT, LL.D. F.R.S. L. & E.

MEMBER OF THE NATIONAL INSTITUTE OF FRANCE, AND OF THE BATAVIAN SOCIETY OF ROTTERDAM.

AND

A LETTER ON SOME PROPERTIES OF STEAM,

BY THE LATE JOHN SOUTHERN, Esq.

LETTER

TO

DR BREWSTER FROM MR WATT.

DEAR SIR,

AT your request, I have carefully perused my late excellent friend Dr ROBISON's articles "Steam" and "Steam-Engines," in the Encyclopædia Britannica, and have made remarks upon them in such places where, either from the want of proper information, or from too great a reliance on the powers of his extraordinary memory, at a period when it probably had been weakened by a long state of acute pain, and by the remedies to which he was obliged to have recourse, he had been led into mistakes in regard to facts, and also in some places where his deductions have appeared to me to be erroneous.

There had been but very little interchange of letters between us for some years previous to his writing those articles, and our opportunities of meeting had been rare, and of short duration, and not occupied by philosophical

discussions. Had I been apprised of his design, I might at least have prevented the errors respecting the facts in which I was concerned; but, upon the whole, it is more surprising to me that his recollection should have served him so well in narrating transactions of 30 years standing, than that it should sometimes have led him astray. If I had not retained some memorandums made at the time of, or soon after, their occurrence, I should myself have felt great difficulty in recalling to mind the particulars at the period when I first perused those articles, which was some time after their publication. I had about that period an opportunity of personally stating to Dr Robison some remarks upon them, of which he availed himself to a small extent in the Supplement to the Encyclopædia Britannica, and probably would have done so still more, had he been called upon to remould these articles.

I have endeavoured to throw most of my corrections into the form of notes; but in some places I judged it necessary to alter the text; which alterations I have marked to be printed in Italics, that they may be readily distinguished from the original. In a few places I have cancelled part of the text without any substitution, none appearing to me to be required. In others I have left part of the reasoning unaltered which I did not concur in; as in mere matters of opinion, where no manifest error was involved, I did not conceive it proper to introduce my own speculations.

As the subjects of Steam, and Steam-Engines, had been almost dismissed from my mind for many years previous to my undertaking this revision, I have called in the aid of my friend Mr John Southern, and of my son, whose daily avocations in the manufacture of steam-engines, render them more conversant with some points, to direct my attention to them; and of the former, to examine such of the algebraic formulæ as appeared essential, an office for

which he is much better qualified than myself; and he has accordingly marked those formulæ with his initials.

I have not attempted to render Dr Robison's memoir a complete history of the Steam-Engine; nor have I even given a *detailed* account of my own improvements upon it. The former would have been an undertaking beyond my present powers, and the latter must much have exceeded the limits of a commentary upon my friend's work. I have therefore confined myself to correcting such parts as appeared necessary, and to adding such matter as he had not an opportunity of knowing.

Here it was my intention to have closed this letter; but the representations of friends, whose opinions I highly value, induce me to avail myself of this opportunity of noticing an error into which not only Dr Robison, but apparently also Dr Black, has fallen, in relation to *the origin* of my improvements upon the Steam-Engine, and which not having been publicly controverted by me, has, I am informed, been adopted by almost every subsequent writer upon the subject of Latent Heat.

Dr Robison, in the article Steam-Engine, after passing an encomium upon me, dictated by the partiality of friendship, qualifies me as the "*pupil* and intimate friend of Dr Black;" a description which, not being there accompanied with any inference, did not particularly strike me at the time of its first perusal. He afterwards, in the dedication to me of his edition of Dr Black's Lectures upon Chemistry, goes the length of supposing me to have professed to owe my improvements upon the Steam-Engine to the instructions and information I had received from that gentleman, which certainly was a misapprehension, as, though I have always felt and acknowledged my obligations to him for the information I had received from his conversation, and particularly for the knowledge of the doctrine of Latent Heat, I never did, nor *could*, con-

sider my improvements as originating in those communications. He is also mistaken in his assertion, p. 8 of the Preface to the above work, that "I had attended two "courses of the Doctor's Lectures;"* for, unfortunately for me, the necessary avocations of my business prevented me from attending his or any other lectures at College; and as Dr ROBISON was himself absent from Scotland for four years at the period referred to, he must have been misled by erroneous information. In page 184 of the Lectures, Dr BLACK says, "I have the pleasure of think-"ing that the knowledge we have acquired concerning "the nature of elastic vapours, in consequence of my for-"tunate observation of what happens in its formation and "condensation, has contributed in no inconsiderable de-"gree to the public good, by *suggesting* to my friend Mr "WATT of Birmingham, then of Glasgow, his improve-"ment on this useful engine," (meaning the steam-engine, of which he is then speaking). There can be no doubt, from what follows in his description of the engine, and from the very honourable mention which he has made of me in various parts of his Lectures, that he did not mean to lessen any merit that might attach to me as an inventor; but, on the contrary, he always was disposed to give me fully as much praise as I deserved. And were that otherwise doubtful, it would, I think, be evident from the following quotation from a letter of his to me, dated 13th February, 1783, where, speaking of an intended publication by a friend of mine on subjects connected with the history of steam, he says, "I think it is very proper for "you to give him a short account of your discoveries and "speculations, and *particularly to assert clearly and fully*

* Repeated more in detail, with the same erroneous inferences, in his note, vol. I. p. 504.

"*your sole right to the honour of the improvements of the* "*Steam-Engine;*" and in a written testimonial which he very kindly gave on the occasion of a trial at law against a piracy of my invention in 1796–7, after giving a short account of the invention, he adds, "*Mr Watt was the sole* "*inventor of the capital improvement and contrivance above* "*mentioned.*"

Under this conviction of his candour and friendship, it is very painful to me to controvert any assertion or opinion of my revered friend; yet in the present case I find it necessary to say, that he appears to me to have fallen into an error, and I hope, in addition to my assertion, to make that appear by the short history I have given of my invention in my notes upon Dr Robison's essay, as well as by the following account of the state of my knowledge previous to my receiving any explanation of the doctrine of Latent Heat, and also from that of the facts which principally guided me in the invention.

It was known very long before my time, that steam was condensed by coming into contact with cold bodies, and that it communicated heat to them. Witness the common still, &c. &c.

It was known by some experiments of Dr Cullen, and others, that water and other liquids boiled in vacuo at very low heats; water below 100°.

It was known to some philosophers, that the capacity or equilibrium of heat, as we then called it, was much smaller in mercury and tin than in water.

It was also known, that evaporation caused the cooling of the evaporating liquid, and bodies in contact with it.

I had myself made experiments to determine the following facts.

1*st*, The capacities for heat of iron, copper, and some sorts of wood, comparatively with water. Similar experiments had also subsequently been made by Dr Irvine, on these and other metals.

2*d*, The bulk of steam was compared with that of water.

3*d*, The quantity of water which could be evaporated in a certain boiler by a pound of coals.

4*th*, The elasticities of steam at various temperatures greater than that of boiling water, and an approximation to the law which it followed at other temperatures.

5*th*, How much water, in the form of steam, was required every stroke by a small NEWCOMEN's engine, with a wooden cylinder six inches diameter, and twelve inches long in the stroke.

6*th*, I had measured the quantity of cold water required in every stroke to condense the steam in that cylinder, so as to give it a working power of about 7 lb. on the inch.

Here I was at a loss to understand how so much cold water could be heated so much by so small a quantity in the form of steam, and applied to Dr BLACK, as is related in the short history, p. 116, Note, and then first understood what was called Latent Heat.

But this theory, though useful in determining the quantity of injection necessary where the quantity of water evaporated by the boiler, and used by the cylinder, was known, and in determining, by the quantity and heat of the hot water emitted by NEWCOMEN's engines, the quantity of steam required to work them, did not lead to the improvements I afterwards made in the engine. These improvements proceeded upon the old-established fact, that steam was condensed by the contact of cold bodies, and the later known one, that water boiled in vacuo at heats below 100°, and consequently that a vacuum could not be obtained unless the cylinder and its contents were cooled every stroke to below that heat.

These, and the degree of knowledge I possessed of the elasticities of steam at various heats, were the principal things it was *necessary* for me to consider in contriving the new engine. They pointed out that, to avoid useless con-

densation, the vessel in which the steam acted upon the piston ought always to be as hot as the steam itself; that to obtain a proper degree of exhaustion, the steam must be condensed in a separate vessel, which might be cooled to as low a degree as was necessary, without affecting the cylinder; and that as the air and condensed water could not be blown out by the steam as in NEWCOMEN's, they must be extracted by a pump, or some other contrivance; that, in order to prevent the necessity of using water to keep the piston air-tight, and also to prevent the air from cooling the cylinder during the descent of the piston, it was necessary to employ steam to act upon the piston in place of the atmosphere. Lastly, to prevent the cylinder from being cooled by the external air, it was proper to inclose it in a case containing steam, and again to inclose that in a case of wood, or of some other substance which transmitted heat slowly.

Although Dr Black's theory of latent heat did not *suggest* my improvements on the steam-engine, yet the knowledge upon various subjects which he was pleased to communicate to me, and the correct modes of reasoning, and of making experiments of which he set me the example, certainly conduced very much to facilitate the progress of my inventions; and I still remember with respect and gratitude the notice he was pleased to take of me when I very little merited it, and which continued throughout his life.

To Dr ROBISON I am also bound to acknowledge my obligations for very much information and occasional assistance in my pursuits, and above all, for his friendship, which ended only with his life; a friendship which induced him, when I was beset with an host of foes, to come to London in the depth of winter, and appear as a witness for me in a court of justice, whilst labouring under an excessively painful disorder, which ultimately deprived him of life. To the remembrance of that friendship is principally owing my

taking upon myself the office of his commentator at my advanced age.

May I request, sir, that you and the public will permit that age to be my excuse for any errors I may have committed, and for any deficiencies in the performance of an office which at no period would have been congenial to my habits; and allow me to remain, with esteem,

DEAR SIR,

Your most obedient humble servant,

JAMES WATT.

HEATHFIELD, May 1814.