

II.—*The Place of Sadi Carnot in the History of Thermotics.*

BY PROF. R. H. THURSTON.

Read April 5th, 1880.

M. Hirsch, in his Introduction to his translation of the writer's History of the Steam Engine,* publishes a new fact relating to Carnot and the history of the mechanical theory of heat, as revealed in recently discovered documents, which had only come to his knowledge at the time of writing.

The documents referred to, were presented to the President of the Academy of Sciences by M. H. Carnot, November 30th, 1878. They show clearly, that if the doctrine of the equivalence of heat and mechanical energy was not recognized by Sadi Carnot when, in 1824, he published his now celebrated work, "*Reflexions-sur la Puissance Motive du Feu*," the idea of the identity of the two forms of energy soon did become recognized by him and observable in the course of his work.

The following are extracts from the manuscript notes left by Carnot :—

"La Chaleur n'est autre que la puissance motive, ou plutôt, que le mouvement qui a changé de forme. C'est un mouvement dans les particules des corps. Partout où il y a destruction de puissance motive, il y a, en même temps, production de chaleur en quantité précisément proportionnelle à la quantité de puissance motive détruite. Réciproquement, partout où il y a destruction de chaleur, il y a production de puissance motive."

"On peut donc poser en thèse générale que la puissance motive est en quantité invariable dans la nature, qu'elle n'est jamais, à proprement parler, détruite. A la vérité, elle change de forme, c'est-à-dire qu'elle produit tantôt un genre de mouvement, tantôt un autre; mais jamais elle n'est anéantie."

[Heat is nothing else than motive power (energy), or rather, a motion which has changed its form. It is a motion of the molecules of bodies. Whenever motive power is destroyed, there is, at the same time, a production of heat in quantity precisely proportional to the quantity of power destroyed. Reciprocally,

* *Histoire de la Machine à Vapeur*, par R. H. Thurston, Prof. of Mechanical Engineering at the Stevens Institute of Technology. Revised, annotated and enlarged by J. Hirsch, Prof. of the Steam Engine at "Ecole des Ponts et Chaussées de Paris;"—Vol. I, p. XV, foot note.

wherever there is destruction of heat, there is production of power of motion.

We may then state as a general law, that energy is, in nature, invariable in amount; that is, is never, properly speaking, either created or destroyed. In fact, it changes form; that is, it causes sometimes one kind of motion, sometimes another; but it is never destroyed.]

Again:

• • • • D'après quelques idées que je me suis formé sur la théorie de la chaleur, la production d'une unité de puissance motive nécessite la destruction de 2.70 unités de la chaleur (chaque unité de puissance motive, ou dynamique, représentant le poids de 1 mètre cube d'eau élevé à 1 mètre de hauteur."

[• • • • According to my ideas of the theory of heat, the production of a unit of energy demands the destruction of 2.70 units of heat (each unit of energy, or *dynamie*, representing the raising of the weight of one cubic meter of water one meter high.)

This estimate gives for the value of the "mechanical equivalent of heat," $\frac{1000}{2.70} = 370$, roughly approximating 424, the metric equivalent of 772 foot-pounds, the British unit of heat-equivalence.

M. Hirsch remarks upon the precision with which Carnot states the law of equivalence of heat and work, as well as the more general law of the "conservation of energy." The considerations which lead him to this last-named law are of the extreme simplicity.

Still more: Carnot lays out a complete programme of experiments on heat and energy—the very experiments since made by Joule, Thompson, Hirn, Regnault, and others.

Hitherto, Carnot has been credited with the invention of the standard method of examination of the relations between heat and work, and it has been assumed that he was, to the last, a believer in the materiality of heat. His idea that we can only infer this relation after studying processes of such nature as present a complete cycle of changes resulting in the perfect restoration of the primitive physical conditions observed in the working substances, and his proposition that the reversible engine is the perfect engine, have admittedly formed the basis

of modern thermodynamic investigation. Prof. Tait justly asserts* that, without this basis, the dynamical theory of heat could never have obtained, in so brief a period, the wonderful development witnessed during the past half-century. Carnot's imperfect enunciation and demonstration of these points, remained unfruitful until, a quarter of a century later, Thompson and Rankine commenced their work in this field. The former then called attention to the work of Carnot,† and adapted his conception to the dynamical theory and perfected the typical cycle.

Carnot's original work contains no evidence that he accepted the dynamical theory of heat, and it has only now become evident that, if not then aware of the falsity of the material hypothesis, he soon became conscious of it, and fully accepted the true theory.

His value (370) for the dynamical equivalent, is not nearly as close an approximation as that obtained by earlier investigators. Rumford, especially, not only accepted, and in 1798 published in the *Philosophical Transactions*, a complete and definite statement of the equivalence of heat and work, but gave data, as shown by the writer,‡ giving the value 783.8 foot-pounds, or within 1.5 per cent. of the now accepted value. This fact, however, while creditable to Rumford as the first correct expounder and the experimental discoverer, does not detract from the honor due Carnot as the propounder of his method.

It is certainly unfortunate that the manuscript notes left by Carnot could not have been published by him; and still more unfortunate is it that he had not earlier announced his belief and incorporated the dynamical theory of heat in his great work. His already great reputation, as it is, will be heightened by their tardy publication; but had he made the "Reflexions" the vehicle of their presentation, Carnot would indisputably have earned the position, which is now sometimes denied him, of the founder of the modern science of heat-dynamics.

* *Recent Advances in Physical Science.*

† See Tait's *History of Thermodynamics*.—also, *Phil. Mag.*, 1872.

‡ *Trans. American Society of Civil Engineers*, 1873.