about 10 feet; for which reason I have employed in the synopsis A, now forwarded, the same values as before, correcting only the obvious errors to which I have drawn attention in the second paragraph of this letter; at the same time I have endeavoured to put within the reach of those who interest themselves in the problem of the figure of our planet, all the data at my command, and if any fresh light should hereafter be thrown on the subject, shall be very happy to communicate it.

GEORGE EVEREST.

IV. "On the Thermodynamic Theory of Steam-engines with dry saturated Steam, and its application to practice." By W. J. MACQUORN RANKINE, C.E., LL.D., F.R.S.S.L. & E., Pres. Inst. Eng. Scot., Regius Professor of Civil Engineering and Mechanics in the University and College of Glasgow. Received December 27, 1858.

(Abstract.)

In 1849 it was demonstrated, contemporaneously and independently, by Professor Clausius and the author of this paper, from the laws of thermodynamics, that when steam or other saturated vapour in expanding performs work, and receives no heat from without, a portion of it must be liquefied.

That theoretical conclusion has since been confirmed by practical experience.

The principal effect of the "steam-jacket" invented by Watt is to prevent that liquefaction.

The presence of liquid water in any considerable quantity in the cylinder of a steam-engine acts injuriously, by taking heat from the steam while it is being admitted, and giving out that heat to the steam which is about to be discharged. Most of the heat so transferred is wasted.

The only *exact thermodynamic* formulæ for the work of steam hitherto published (by the author in the Phil. Trans. 1854, and by Professor Clausius in Poggendorff's 'Annalen,' 1856), are adapted to steam which receives no heat in expanding.

The present paper, after recapitulating the general equation of thermodynamics, and the special formulæ for the pressure, volume,

and latent heat of steam, proceeds to the investigation of the exact formulæ for the work of steam which is supplied during its expansion with just enough of heat to prevent any appreciable portion of it from condensing, for the expenditure of heat in producing and using that steam, and for its efficiency in producing motive power.

There is explained a convenient approximation to the exact formulæ, founded on the facts, that for initial pressures of steam of from 30 to 120 lbs. on the square inch (*including* atmospheric pressure), and for ratios of expansion up to *sixteen*, the pressure of saturated steam varies nearly as the *seventeenth power* of the *sixteenth root* of its density, and that the expenditure of heat in an engine in which dry saturated steam is used, expressed in units of energy, is nearly equal to *fifteen-and-a-half* times the product of the initial pressure and volume of the steam expended.

Lastly, there are given examples of the application of the formulæ to the engines of three steam-vessels lately experimented on by the author. The displacements of those ships are from 700 to 1100 tons; the indicated horse-power of their engines from 226 to 1180; the initial absolute pressures of steam in their cylinders range from 32 to $108\frac{1}{2}$ lb. on the square inch, and the ratios of expansion from 4 to 16. In each case the difference between the results of calculation and experiment is within the limits of error of observation, and ranges from $\frac{1}{80}$ to $\frac{1}{200}$ of the actual work of the steam.

The author has computed Tables of the results of the formulæ, exact and approximate, which are now in the course of being printed.

Summary of Formulæ.—*Notation and Constants.*

t, absolute temperature in degrees of Fahrenheit, = temperature measured from the ordinary zero $+ 461^{\circ}\cdot 2$.

p, pressure in pounds on the *square foot*.

v, volume of one pound of steam in cubic feet.

t_1, p_1, v_1, refer to the admission of steam into the cylinder.

t_2, p_2, v_2, to the end of the expansion.

$r = v_2 \div v_1$, ratio of expansion.

p_3 = pressure of exhaustion.

t_4, absolute temperature of feed-water.

J, "Joule's equivalent," or specific heat of one pound of liquid water, = 772 foot-pounds per degree of Fahrenheit.

W, work of one pound of steam.

$\mathfrak{H}$, expenditure of heat per pound of steam in foot-pounds.

$a=1109550$ foot-pounds.

$b=540{\cdot}4$ foot-pounds per degree Fahrenheit.

Efficiency of steam, $W \div \mathfrak{H}$.

Exact Formulæ.

$$W = a \text{ hyp. log } \frac{t_1}{t_2} - b(t_1 - t_2) + v_2(p_2 - p_3).$$

$$\mathfrak{H} = a\left(1 + \text{hyp. log } \frac{t_1}{t_2}\right) - bt_1 + J(t_2 - t_4).$$

Approximate Formulæ.

$$W \div v_2 = p_1(17r^{-1} - 16r^{-\frac{17}{16}}) - p_3.$$

$$\mathfrak{H} \div v_2 = \frac{15\frac{1}{2}p_1}{r}.$$

In applying the exact formulæ, the relations between p, v, and t may be found by means of known formulæ or Tables.

February 3, 1859.

Sir BENJAMIN C. BRODIE, Bart., President, in the Chair.

The following communications were read:—

I. "On Platinized Graphite Batteries." By C. V. Walker, Esq., F.R.S., F.R.A.S., &c. Received January 4, 1859.

In a short note communicated to the Royal Society on March 9th, 1857, and which was read on March 19th, reference was made to the voltaic combination that I had adopted for certain telegraphic purposes; namely, zinc-graphite. Graphite in its crude state had for some years been of great service to me, especially for batteries whose resting time is great in proportion to their working time. Since the date of that notice, I have considerably increased the value of graphite for electrical purposes by platinizing it according to the process first described by Mr. Smee, whose platinized silver battery has been long known and much used. The material to which I refer by the term "Graphite," is the crust or corrosion that is collected from the interior of iron gas retorts that have been long in use.