A NEW THEORY OF THE STEAM ENGINE, AND THE MODE OF CALCULATION BY MEANS OF IT, OF THE EFFECTIVE POWER, &C. OF EVERY KIND OF STEAM ENGINE, STATIONARY OR LOCOMOTIVE

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BY

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A NEW THEORY

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In our Treatise on Locomotive Engines, the first edition of which appeared in the beginning of 1835, was published the basis of a new theory of the steam-engine. We then limited ourselves to showing its application to locomotives, merely announcing that it was no less indispensable for calculating with exactitude both the effects and the proportions of stationary steam-engines of every kind. The memoir of which we now offer an analysis, and which was read by parts at the *Institute Royale* of France, from February till the close of the year, 1837, has for its object to give a further developement of that theory, and to extend it to the various systems of steam-engines in use. It consists of three parts, namely :—

Part I.—Proofs of the inexactitude of the ordinary methods of calculation, used to determine the effects or the proportions of steam-engines; and a succinct exposition of the method proposed.

Part II.—General formulæ for the calculation of the effects, &c. of rotative, stationary or locomotive, high or low pressure, expansive or unexpansive, condensing or uncondensing steam-engines, according to the proposed theory.

Part III.—Special application of these formulæ to the divers systems of steam-engines in use.

PART I.

PROOFS OF THE INEXACTITUDE OF THE ORDINARY METHODS, AND EXPOSITION OF THE ONE PROPOSED.

§ 1. *Mode of calculation hitherto in use.*—All the problems in the application of steam-engines merge into these three—

The velocity of the motion being given, to find the load the engine will move at that velocity.

The load being given, to find the velocity at which the engine will move that load;

And, the load and the velocity being given, to find the vaporization necessary, and consequently the area of heating surface requisite for the boiler, in order that the given load be set in motion at the given velocity.

The problem, which consists in determining the useful effect to be expected from an engine of which the number of strokes of the piston per minute is counted, that is, whose velocity is known, evidently amounts to determining the effective load corresponding to that velocity; for that load being once known, by multiplying it by the velocity we have the useful effect required.

According to the mode of calculation hitherto admitted, when it is wanted to know the useful effect an engine will produce at a given velocity, or, in other words, the effective load that it will set in motion at that velocity, the area of the cylinder is multiplied by the velocity of the piston, and that product by the pressure of steam in the boiler; this gives, in the first place, what is called the theoretical effect of the engine. Then, as experience has shown that steam-engines can never completely produce this theoretical effect, it is reduced in a certain proportion, indicated by a constant number, which is the result of a comparison between the theoretical and practical effects of some engines previously put to trial; and thus is obtained the number which is regarded as the practical effect of the engine, or the work it really ought to execute.

A mode perfectly similar is followed, for determining the vaporization which an engine ought to produce in order to produce a desired effect; that is to say, for resolving the third of the problems which we have presented above. As to the second of these problems, that which consists in determining the velocity the engine will assume under a given load, no solution of it has been proposed in this way, and we shall expose, farther on, some fruitless essays that have been made to resolve it in another way.

As in the above-mentioned calculation no account is taken of friction, nor of some other circumstances which appear likely to diminish the power of the engine, the difference observed between the theoretical and the practical result excites no surprise, and is readily attributed to the circumstances neglected in the calculation.

§ 2. *First objection against this method of calculation.*—This mode of calculation is liable to many objections, but for the sake of brevity we limit ourselves to the following :—

The coefficient adopted to represent the ratio of the practical effects to the theoretical, varies from $\frac{1}{3}$ to $\frac{2}{3}$, according to the various systems of steam-engines; that is to say, that from $\frac{2}{3}$ to $\frac{1}{3}$ of the power exerted by the machine is considered to be absorbed by friction and divers losses. Not that this friction and these losses have been measured and found to be so much, but merely because the calculation that had been made, and which might have been inexact in principle, wanted so much of coinciding with experience.

Now it is easy to demonstrate, that the friction and losses which take place in a steam-engine can never amount to $\frac{2}{3}$, nor to $\frac{1}{3}$ of the total force it developes. It will suffice to cast an eye on the explanation attempted, on this point, by Tredgold, who follows this method in his Treatise on Steam-Engines.* He says (art. 367), that, for high pressure engines, a deduction

* The author here refers to the first edition of 'Tredgold on the Steam-Engine:' in the new edition just published the algebraic parts are transformed by the editor into easy practical rules, accompanied by examples familiarly explained for the working engineer.

of $\frac{4}{10}$ must be made from the *total* pressure of the steam, which amounts to a deduction of $\frac{5}{10}$ on the ordinary *effective* pressure of such engines; and to justify this deduction, which however is still not enough to harmonize the theoretical and practical results in many circumstances, he is obliged to estimate the friction of the piston, with the losses or waste, at $\frac{2}{10}$ of the power, and the force requisite for opening the valves and overcoming the friction of the parts of the machine, at $\frac{6}{100}$ of that power. Reflecting that these numbers express fractions of the gross power of the engine, we must readily be convinced that they cannot be correct; for, in supposing the engine had a useful effect of 100 horses, which, from the reduction or coefficient employed, supposes a gross effect of 200 horses, 12 would be necessary to move the machinery, 40 to draw the piston, &c.! The exaggeration is evident.

Besides, in applying this evaluation of the friction to a locomotive engine, which is also a high pressure steam-engine, and supposing it to have 2 cylinders of 12 inches diameter, and to work at 75 lbs. total pressure, which amounts to 60 lbs. effective pressure, per square inch, we find that from the preceding estimate, the force necessary to draw the piston would be 5650 lbs., whereas our own experiments on the locomotive engine, the *Atlas*, which is of these dimensions, and works at that pressure, demonstrate that the force necessary to move, not only the two pistons, but all the rest of the machinery, including the waste, &c., is but 48 lbs. applied to the wheel, or 283 lbs. applied on the piston.

It is then impossible to admit, that in steam-engines the friction and losses can absorb the half, nor the third, much less the $\frac{2}{3}$ of the total power developed; and yet there do occur cases wherein, to reconcile the practical effects with the theoretical ones thus calculated, it would be necessary to reduce the latter to the fourth part, and even to less; and what is more, it often happens, that the same engine which in one case requires a reduction of $\frac{3}{4}$, will not in other cases need a reduction of more than about $\frac{1}{6}$. This is observed in calculating the effects of locomotive engines at very great velocities, and afterwards at very small ones.

There is no doubt, then, that the difference observed between the theoretical effect of an engine and the work which it really performs, does not arise from so considerable a part of the applied force being absorbed by friction and losses, but rather from the error of calculating in this manner the theoretical effect of the machine. In effect, this calculation supposes that the motive force, that is, the pressure of the steam *against the piston or in the cylinder*, is the same as the pressure of the steam in the boiler; whereas we shall presently see, that the pressure in the cylinder may be sometimes equal to that of the boiler, sometimes not the half nor even the third of it, and that it depends on the resistance overcome by the engine.

§ 3. *Formulæ proposed by divers authors to determine the velocity of the piston under a given load, and proofs of their inexactitude.*—We have said that this problem was not resolved by the foregoing method.