thermodynamic point of view, is weil shown by comparing their consumption of fuel. In the steam-engine we find in good engines of large size a consumption of 2 K) or 13/4 lb of coal per I.H.P. per hour, and by triple expansion this is reduced in large marine engines to about 11/3 lb. On the other hand, in small-power engines the consumption is at least 21/2 lb, and is generally 3 lb or more. When Mr Dowson’s cheap gas,@@1 which is produced by passing a mixture of superheated steam and air through red-hot anthracite, is used to drive an Otto engine, the consump­tion of coal has been found to be only 1·1 lb per I.H.P. per hour, or less than half the amount used by a steam- engine of similar size. What gives this comparison additional interest is the fact that the gas-producer for a 40 or 50 H.P. engine need not take up more space than the boiler of a steam-engine of the same power.

263. In another sense the gas-engine is much less perfect than the steam-engine. The actual efficiency of the latter is about half the ideal efficiency which a perfect engine would show when working through the same range of temperature. In the gas-engine the actual is less than one-fourth of the ideal efficiency. Taking the highest temperature as 1900° C.—a value reached in some of Mr Clerk’s experiments—and the lowest temperature as 15° C., the efficiency of a perfect engine would be 0·87, while that of the actual engine is 0·2. This only means that the gas-engine has all the greater margin for future improvement.

264. At present the main causes of waste in gas-engines are the action of the sides of the cylinder and the water-

jacket, and the high temperature of the exhaust gases. The water-jacket absorbs about half the whole heat, only to keep the cylinder cool enough to permit of lubrication. The waste gases are discharged at a temperature of about 420° C., and so carry away a large amount of heat which might in part be saved by having a greater ratio of expan­sion, or by the use of a regenerator. Another source of thermodynamic imperfection is the after-burning, which gives heat to the working substance at a temperature lower than the maximum.

In an engine constructed by the late Sir William Siemens it was attempted to do away with or reduce the two main causes of loss—(1) by using a separate combustion-chamber, distinct from the cylinder in which the piston worked, and (2) by passing the exhaust gases through a regenerator, which afterwards gave up heat to the incoming air and gas.@@2 The late Prof. Fleeming Jenkin endeavoured to attain the same ends by adapting the Stirling type of engine to inter­nal combustion, a mixture of gas and air being exploded under a displacer like that of fig. 141. Practical difficulties have hitherto prevented regenerative internal-combustion engines from coming into use, but it can scarcely be doubted that their development is only a question of time. With regard to the probable future of heat-engines, it is important to notice that the internal-combustion engine using gaseous fuel, though already much more efficient than the steam- engine, is crude and full of defects which further inven­tion ought to remove, while the steam-engine has been improved so far that little increase in its efficiency can be expected, and more than a little is impossible. (j. a. e.)

@@@1 *Min. Proc. Inst. C.E.,* vol. lxxiii. p. 311.

@@@2 Siemens, “Discussion on the Theory of the Gas-Engine,” *Min. Proc. Inst. C.E.,* 1882.