obtained by drawing in the boiler pressure line and prolonging the indicator card to meet it.

The indicated h.p. of gas and oil engines is defined by the Code of 1902 of the Committee on Standardizing Engine Tests, as the power developed in the engine cylinder (the algebraic sum of positive and negative works) minus the power indicated in the separate compression or feed cylinders, if there are any.

In a four-cycle engine, according to this definition, the indicated work is equal to the difference between the areas *c d e f* and *f a g b*, Fig. 2. If the area *e f b* be added

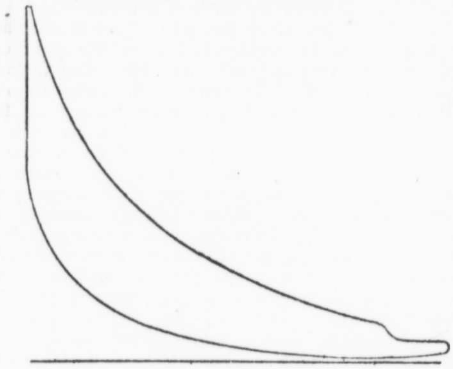

Fig. 3—Indicator Card of Two-cycle Gas Engine

to each of these, the indicated work is seen to be the difference between the areas *c d e b* and *e a g b*. The area *c d e b* is the total work done by gas; the area *a g b* is the work done in overcoming the resistances to the admission of gas, and the area *e a b* is the work done in overcoming the resistances to the exhaust of the gas; or in other words the area *e a g b* represents the work that has to be done to get the charge into and out of the cylinder. The indicated work of a four-cycle engine is consequently seen to be the difference between (1) the total work done by the gas, and (2) the work necessary to get the gas into and out of the cylinder.

In a two-cycle engine with separate air and gas pumps, or with preliminary compression of the charge in the crank case the indicated h.p., according to the definition, is the difference between (1) the main cylinder h.p., Fig. 3, and (2) the indicated h.p of the air and gas pumps, Fig. 4 and 5, or of the crank case, Fig. 6. In this engine the exhaust occurs only near the end of the stroke, so that the amount of work done by the main cylinder piston in overcoming the resistance to the escape of the gases is so small as to be practically negligible. The work represented by Fig. 3 is the total work done by the gas; while the work represented by Fig. 4, 5 and 6 is the work done in overcoming the resistance to the admission of the charge and consequently, in part, the work done in overcoming the resistance to the exhaust, since the incoming charge helps to force out the exhaust gases. The indicated h.p. of a two-cycle engine is seen to have practically the same meaning as the indicated h.p. of a four-cycle engine.

Considerations in Diesel Motor.

In a Diesel motor, the conditions are the same as in an ordinary four-cycle engine, with the addition that work is done in compressing the air used to spray the fuel. The indicated h.p. of the air compressor must, according to the definition, be subtracted from the indicated h.p. of the main cylinder in order to obtain the indicated h.p. of the engine. The difference between the areas *c d e b* and *e a g b*, Fig. 7, is the indicated work of the main cylinder, and, as with the four-cycle engine, Fig. 2, it is the difference between the work done by the gas in the cylinder and the negative work done in overcoming the admission and exhaust resistances. The compressor card however, Fig. 8, is different from the compressor cards for the two-cycle engine, Fig 4 and 5, for it represents not only the work required to overcome the frictional resistances of admission of the fuel spray to the cylinder, but also the work of compressing the air used for spraying up to the pressure existing in the cylinder during the admission of the charge. It is obvious that if a large percentage of the air used per cycle in a Diesel motor were compressed in the air compressor instead of in the main cylinder, there would be a serious error in regarding the work done in the compressor as part of the frictional resistance to the admission of the fuel. In actual engines, the indicated work of the compressor pump is generally at least 6 per cent of the indicated work of the main cylinder. It is easily possible by drawing the cylinder admission pressure line *c d* on Fig. 8 to separate the work done there into its two components; the work done in compressing the charge (area *b*) and the work done in overcoming discharge resistances (area *a*). The frictional resistance to the admission of air to the compressor is too small to be shown on the diagram. The total work done by the charge is then the algebraic sum of the positive area *c d e b*, Fig. 7, and the negative area *b*, Fig. 8, the work done in overcoming frictional resistances is the sum of the areas *e a g b*, Fig. 7, and *a*, Fig. 8. The indicated h.p. of a Diesel motor has the same meaning as the indicated h.p. of a four-cycle or a two-cycle engine; it is the difference between (1) the total work done by gas, and (2) the frictional resistances to the admission and exhaust of the gases.

Thermodynamic Efficiency and Net Efficiency.

In the analysis of the performance of a heat engine, there are two principal quantities that the engineer wants to know, namely (*a*) the thermodynamic efficiency of the engine, or the percentage of the total heat going to the engine that is actually converted into work, and (*b*) the net efficiency of the engine, or the percentage of the total heat going to the engine that is available for doing useful work. The difference between these two efficiencies is the percentage of the total heat going to the

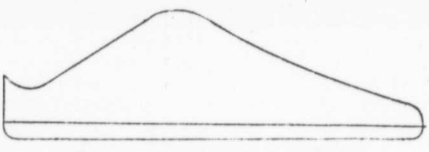

Fig. 4—Indicator Card of Air Pump

engine that has been used up in overcoming the various resistances which the engine itself offers to the carrying out of the cycle of operations.

It has been the practice in the past to calculate the thermodynamic efficiency by finding the ratio of the indicated work to the total heat supplied. But this does not really measure the percentage of the total heat that has been converted into work; it measures the percentage of the total heat that is available for doing work after certain engine resistances, viz.: those offered to the admission and exhaust of the working substances, have been overcome. The thermodynamic efficiency of an engine should have but one meaning and that is the efficiency of the engine in converting heat into work, irrespective of whether that work is used up, in part, in