overcoming engine resistances or remains entirely available for useful applications. That is the plain meaning of the term and the only meaning which will permit a direct comparison of the efficiencies of the processes actually occ rring in the cylinders of different engines. If the indic: ted work is used in calculating the thermodynamic efficiencies, such a comparison does not necessarily throw any light on the actual processes at all, since the frictional resistances resulting from a poor design of compression pumps, valves, ports, etc., may more than offset the gain from the use of a more efficient cycle.

It is, moreover, important that the thermodynamic efficiency should have the suggested meaning in order to permit a fair comparison with the ideal cycle. The state that the thermodynamic efficiency of a gas engine is 60 per cent. of the thermodynamic efficiency of the ideal gas engine working under the same external conditions, is

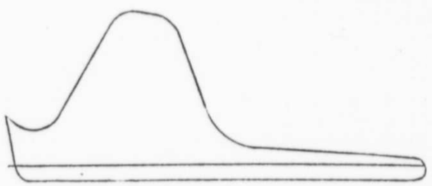

Fig. 5—Indicator Card of Gas Pump

entirely misleading, if the gas friction resistances to admission and exhaust have been subtracted from the total work done by the gas. In some engines, the gas friction resistances may amount to 15 or 20 per cent. of the total work, and if that were the case, an actual ratio of efficiencies of 70 per cent. would appear to be but 60 per cent., that is, the apparent possibility of improvement of the purely thermodynamic processes would be reduced from 40 per cent. to 30 per cent. If the gas friction is taken into account in calculating thermodynamic efficiencies, there does not seem any sufficient reason why the machine friction should not similarly be taken into account. The process of getting a charge into and out of the cylinder is purely mechanical—it is not part of the thermodynamic cycle.

Total Work of Dynamic Horse Power.

The writer believes that for gas and oil engines, the power of the engine can be most usefully expressed as the total work done by the working substance—this might be called the total h.p., or, since it measures the amount of heat converted into work, the thermo dynamic h.p. The total work for a four-cycle engine is the area *c d e b*, Fig. 2; for a two-cycle engine, the area of Fig. 3; and for a Diesel engine, the area *c d e b*, Fig. 7, minus the work represented by the area *b*, Fig. 8, of the air compressor card. As measured in this manner, the total work is not entirely independent of the design of exhaust valves and passages since the occurrence of release before the end of the stroke (which is necessitated by the resistance of the exhaust) reduces the total work area. It is only in the case of the comparatively early exhaust of the two-cycle engine that the actual work might be considered as being affected in an appreciable manner by the release before the end of the stroke. It is, however, proper to regard the work of this cycle as being finished when the exhaust opens—the toe of the diagram being the equivalent of the negative area of the four-cycle diagram. Since the area of the toe of the diagram is always extremely small, its inclusion in the total work area introduces no appreciable error.

The total work done by the working substance is used up in three ways.

a. In overcoming the resistances to the admission and exhaust of the charge; this may be called gas friction work.

b. In overcoming engine friction; this may be called machine friction work, and

c In doing useful work.

The indicated h.p. is then the total h.p. minus the gas friction h.p. and it retains the meaning it has always had.

What Gas Engine Tests Show.

An ordinary gas engine test permits the determination of the total h.p., the gas friction h.p., the machine friction h.p. and the useful or brake h.p. The value of finding these separate h.p.'s will be apparent if, for example, a comparison is to be made between two-cycle and four-cycle gas engines. It is urged against the two-cycle engine that it obtains its very great advantage of nearly doubled power per cubic foot of piston displacement, at a cost of considerable loss in efficiency. This loss in efficiency is said to be (1) thermodynamic, resulting from (*a*) the loss of some of the charge to the exhaust during admission, or (*b*) the retaining of too much of the burnt gases in the cylinders; (2) gas friction loss resulting from the separate compression of the gas and air and the consequent extra valve and pipe resistance, and (3) machine friction losses resulting from the actual mechanical arrangements. The statement of the separate h.p.'s will throw light at once upon all these points, and will show also wherein any particular engine fails to come up to the standard of its class.

From the commercial point of view, there is no advantage in retaining the indicated h.p., since it is the brake h.p. that the engine user wants. From the scientific point of view, the indicated h.p. can be of use only for the comparative study of engines and if it is not the best measure of power for that purpose, it should not be permitted to retain its present position.

If the total h.p., gas friction h.p., machine friction h.p.

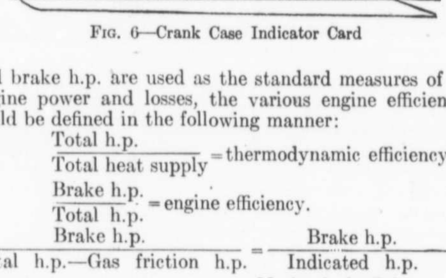

Fig. 6—Crank Case Indicator Card

and brake h.p. are used as the standard measures of the engine power and losses, the various engine efficiencies could be defined in the following manner:

$$\frac{\text{Total h.p.}}{\text{Total heat supply}} = \text{thermodynamic efficiency.}$$

$$\frac{\text{Brake h.p.}}{\text{Total h.p.}} = \text{engine efficiency.}$$

$$\frac{\text{Brake h.p.}}{\text{Total h.p.—Gas friction h.p.}} = \frac{\text{Brake h.p.}}{\text{Indicated h.p.}} = \text{Mechanical efficiency}$$

$$\frac{\text{Brake h.p.}}{\text{Total heat supply}} = \text{net efficiency.}$$

Thermodynamic efficiency $\times$ engine efficiency $=$ net efficiency.

These definitions retain for indicated h.p. and mechanical efficiency their usual meanings.

The thermodynamic efficiency is the actual efficiency of the process of converting heat into work; the engine efficiency is the true measure of all the frictional losses of the actual mechanism, not only the friction of bearings