upon in the supply of engines of large capacity where the interest at stake are correspondingly great.

The methods employed in these tests are in general somewhat complex and delicate, and must be conducted with care and accuracy. The main items to be determined are the capacity of the engine to undertake the work guaranteed, the consumption of fuel under various loadings, and possibly also the efficiency of the governing where the engine is to be used in driving either electrical generators or textile machinery, in both of which cases "steady" running is essential.

The determination of the above factors may involve a consideration of the following:—

1. The actual brake horse power which the engine is capable of delivering at the fly wheel or driving pulley under various conditions.

2. The indicated horse power, that is, the power developed in the working cylinder.

3. Quality and quantity of gas supplied to the engine.

4. The conditions of the gas and air supply, that is, as to pressure and temperature.

5. The nature of the mixture fired in the cylinder.

6. The timing and method of ignition.

7. The exhaust conditions.

Each of these factors must be carefully considered, tests made wherever necessary, and care taken that correct deductions are drawn from each test result. Frequently indicator diagrams are misread in the absence of other test data. Brake tests, unless properly conducted, may be totally unreliable. It is clear, therefore, that whatever testing is to be done requires considerable experience and care, and the best of instruments. We will, in the following example, assume that a gas engine of moderate power is to be tested, thus the question of fuel consumption is of importance. And further, that the plant is one in which steady operation is absolutely essential. The test, therefore, must be elaborate and complete. The following data has to be determined:—The brake horse power under various conditions, the indicated horse power, quantity of gas used for certain duties, quality of the gas, its analysis and also both its calculated and its experimentally determined calorimetric value, the pressure and temperature of gas supply and exhaust, the efficiency of the governing, and the extent of the cyclical variations, and from the indicator and other diagrams, the timing of the ignition, and the explosion, compression and exhaust pressures.

The brake horse power may be measured either by direct application of a brake, or dynamometer, to absorb the energy delivered at the fly-wheel, or by measuring the power delivered by means of an electric generator, either direct or belt connected to the engine. In the latter case allowances have to be made for dynamo efficiencies and losses in belt transmission, if a belt is employed, the output being then readily recorded by suitable electrical measuring instruments. In such a case the power delivered by the generator is usually absorbed in a water resistance, and no further description of the methods, etc., is necessary, but where the brake is to be applied direct to the engine shaft some brief discussion may be of interest.

If the power to be absorbed is not very great, say up to 200 horse power at ordinary speeds, a brake band of cotton ropes may be applied direct to the rim of the fly wheel, or to that of a special pulley mounted on the engine shaft, as shown in Fig. 3, Plate XXIX. Wherever possible, it is always advisable to run a test extending over some hours, although a close approximation can sometimes be obtained on the result of a short run. As a general rule, the application of a brake to an ordinary fly wheel or pulley quickly raises the temperature of the wheel above the safe limit, generally within from 15 to 25 minutes, and the test has then to be stopped. For this reason, wherever practicable, arrangements should be made to cool the wheel during the run by fitting a rim with two water-tight sides, so that it becomes of channel section, into which water is fed as required, this water remaining in the rim by centrifugal force, so long as the engine is running. It is sometimes the custom to apply water to the outside of the rim, thereby wetting the brake, a practice which, if not carried out with the greatest of care, is extremely dangerous. The author has twice seen fatal accidents narrowly averted, when the wet ropes seized on the rim and flung the heavy dead weights through the iron roof of the building. And further than this, even if the brake should not be thrown over the wheel, the tendency of the wet ropes is to produce a violent surging of the load, thereby throwing altogether undue stress upon the engine, and making it extremely difficult to correctly record the brake readings. The only safeguard when using an externally cooled brake is to keep it thoroughly wet with a constant stream of water, but which, flying off the rim throughout the test, makes things very unpleasant for the operators.

Fig. 1, Plate XXX., shows modified methods of applying the load, in all the cases the brake horse power being determined by the well-known formula:—

Brake Horse Power equals lineal velocity of the rim in feet per second, multiplied by the nett load on the brake in pounds, divided by 33,000.

The nett load on the brake being the difference between the gross load on one end of the brake ropes and the tail reading at the other. The lineal velocity of rim is, of course, measured through the centre line of the rope. The various devices shown all operate in the same manner, but are varied to suit the different conditions, the type generally being determined by the clearance available between the fly-wheel and the engine foundations.

Another method of applying the load is by means of the "Alden" water friction brake, which is self-cooling, and capable of fine adjustment. It is shown in Fig. 2, Plate XXX. Two circular discs "A" and "B" attached to the shaft "C", which itself is coupled to the engine shaft revolve in the case "E" between fixed planes. The space between the discs and plane is supplied with running water which enters at "D", and escapes at the cocks "F", "G" and "H". The friction between the discs and the water absorbs the power, the braking effect being raised as required by increasing the depth of the ring of water.

The circulation of the water also keeps the appliance cool. This machine is capable of absorbing large power, and also of being run at extremely high speeds, even up to 20,000 revolutions per minute.

Another neat form of brake for small engines is shown in Fig. 3, Plate XXX. It is readily applied, simple in operation, and can frequently be used where there is no fly-wheel pit. Where large power units have to be tested, either an electrical load is applied, or else deductions are made from the indicated horse power at no load and at full load, in accordance with various standards arrived at by the careful testing of gas engines.

We come next to the indicated horse power. There is no class of data from gas engine tests which is so generally misleading as the indicator card. This must necessarily follow from the fact that the quality, and frequently also the quantity of the mixture admitted to the cylinder is continually varying from cycle to cycle, with the result that compression, explosion and exhaust pressures are ever changing, and in some cases even the general nature of the diagram is completely changed by variations in the rate of burning of the fired mixture. A few typical cards will make this clear.

Figs. 1, 2, Plate XXXI., show several diagrams under precisely the same loads, taken on consecutive cycles, yet varying to a very great degree. These were taken from a Premier four-cycle 350 horse power engine at full load, the engine being governed by a variation in the percentage of gas in the mixture.

If, in testing an engine, one obtains cards of this kind, it is almost impossible without other data to arrive at the true average indicated horse power. Some means has to be adopted to obtain average diagrams, and this may be done in three ways: By the use of Mathot Explosion Recorder, or a continuous diagram indicator, or by some form of optical indicator which gives a persisting image of the average diagram. The first is an instrument devised by Mr. Mathot, the well-known Continental gas engine expert. It consists of an auxiliary series of drums fitted to an ordinary gas engine indicator, and revolved by clock work at any desired speed. The indicator pencil traces on a paper, carried past it by these auxiliary drums, a continuous series of lines which represent the intensity of pressure attained on each fired stroke, and which also afford certain other indications of the happenings in the cylinder.

A typical diagram is shown by Fig. 1, Plate XXXII., taken recently by the author with this instrument on the same Premier engine previously referred to, and simultaneously with the last shown indicator diagram. This was taken on a Mathot Recorder fitted to a McInnes-Dobbie High Speed Indicator, a typical instrument of modern design, and illustrated in Fig. 2, Plate XXXII.

The next illustration, Fig. 3, Plate XXXII., is a Mathot Record from a 70 horse power Crossley Gas Engine working under similar conditions at about one-third of its horse power, and governing on the hit and miss principle. The missed explosions are clearly seen, the vertical lines in such cases only rising to the compression pressure. In obtaining this compression pressure for an engine governed in this way, the pressure shown on the explosion record should not be taken, since the compression thus shown (on the missed cycles) is that obtained with the admission of air only to the cylinder, and the maximum compression thus obtained is almost always below the true compression pressure reached on the fired cycles, and truly recorded on the indicated diagrams.

The next, Figure No. 1, Plate XXXIII., is taken from one of Mr. Mathot's own tests of a Tangye engine, and shows a record taken when the engine was developing the maximum catalogue brake horse power. The entire absence of missed cycles is to be noted, and whilst on this record it may be of interest to note the various terms used for horse power by the majority of gas engine builders. In a number of well-known engineering text and pocket books the term "Effective Horse Power" is used synonymously with the term "Brake Horse Power" as meaning the power developed in the engine cylinder. These terms then had special reference to steam engines and the effective or brake horse power was the power that the engine could continually develop from day to day and week to week, since the overload capacity of the ordinary steam engine is so great. These terms, particularly that of "Effective Horse Power," are now used in gas engine makers' catalogues, and lead to some confusion. The word "effective" still means the ordinary maximum horse power, but as the gas engine has such a low overload capacity, this "maximum" closely approximates to the actual possible maximum. Hence, as it is always desirable to instal plant capable of carrying a 10 per cent. to 15 per cent. overload for some hours if necessary, and further, that the faulty operation of a gas engine, or a drop in the quality of the gas, may seriously reduce the capacity of the machine, it is not expedient to set a gas engine to work under a steady continuous load equal to its catalogued effective horse power, since there is then practically no margin left for overload. Gas engine builders have recognised this, particularly in the case of suction gas plant, and now generally quote on two ratings:—First, the maximum, or effective horse power; and secondly, the continuous running horse power, which is generally from 10 per cent. to 15 per cent. below the other power. This is a very fair and proper method, but, unfortunately, the word "effective" in the makers' catalogue is frequently interpreted to mean the power actually available for continuous running, that is, the effective power of the engine, using the word in its ordinary sense. Hence, great confusion has existed in the past, and will still continue, unless the term is abandoned in gas engine practice, or its meaning more clearly defined. Recently the author heard the above meaning assigned to it by both technical and non-technical witnesses in a legal action, but a study of different gas engine catalogues and quotations would clearly show that it means the maximum horse power, and from the text books on steam engines one can readily see how the term "effective" has come to have this meaning.

Figs. 2 and 3, Plate XXXIII., and Fig. 1, Plate XXXIV., show an interesting set of explosion records from Mathot's work, which may be new to some members.

Fig. 2, Plate XXXIV., shows an illustration of the indicator designed by Dr. Hopkinson. In this appliance the under side of the indicator piston "F" is in direct communication with the gas engine cylinder, and "F" rises and falls with the varying pressures operating against the flat bar spring "D." Mounted upon the horizontal spindle "I" is the flat mirror "H," and by means of the arm "M" and spring link "K" attached to the main indicator spring and piston at "L," this spindle "I," and with it the mirror "H" are rocked in the frame "J" about a horizontal axis, the amount of this oscillation being, of course, rigidly controlled by the spring and piston and, therefore, proportionate to the varying pressures in the engine cylinder. The top frame "B" carrying this mirror frame, etc., is capable of being rotated about the vertical axis concentric with the indicator piston, the spring and ball bearing races being clearly shown, these being applied to allow of free rotation without any slackness. The oscillation about the vertical axis is derived by suitable reducing gear direct from the gas engine piston or cross head. The mirror thus has two motions, one about the horizontal axis proportionate to the pressures in the engine cylinder, the other about the vertical axis in synchronism with the motion of the engine piston. A beam of light is projected upon this mirror, and reflected back again through suitable optical apparatus, either directly on to a ground glass screen, upon which the motions can be seen, or upon a photographic plate where the record can be taken. Just as in the ordinary indicator card, horizontal measurements represent piston position, and vertical ordinates the pressures in the cylinder. The whole appliance can be clearly seen by an inspection of the indicator here, which the author shall be glad to explain later to anyone interested.

Fig. 3, Plate XXXIV., is a typical diagram taken by Dr. Hopkinson with this indicator and photographically reproduced. This is an average diagram for 12 consecutive cycles. In this case the greatest care was taken to obtain uniform cycles as regards pressures, etc. But even with the ordinary varying diagrams a very fairly close determination of the average diagram can be made by carefully watching the path of the beam of light upon the ground glass screen which is provided with fine horizontal and vertical lines graduations to facilitate the reading of the pressures, etc.

Fig. 1, Plate XXXV., shows Mr. Dugald Clerk's optical indicator fitted to a gas engine. This apparatus is somewhat similar to the instrument manufactured by the Cambridge Scientific Instrument Company, of which there is an example here to be explained later, if desired.

Fig. 2, Plate XXXV., shows six diagrams from a four-cycle engine, illustrating the effect of varying the point of ignition, that is, the point at which the compressed charge of gas and air is fired in the cylinder. It is usual, when running at full speed, to ignite the charge at a point in the piston travel from 5 per cent. to 7 per cent. before it reaches the end of the compression stroke. In the diagram shown the ignition is varied from 25 per cent. early to 10 per cent. late, and the resultant effects are very marked. But the development of a diagram closely resembling some of those of this series may not necessarily be due to early or late ignition, as shown in this next illustration, in which diagrams from several consecutive cycles are reproduced.

Gas engines are usually governed in one of four ways:—

(a) The hit and miss principle in which the whole gas supply is cut off by the governor for one or more consecutive cycles, there being, therefore, no explosion during those cycles.

(b) By quality regulation, that is where the governor varies the quantity of gas admitted to the mixing valve, thus varying the quality of the mixture, which, as the load decreases, becomes weaker and weaker. In this system constant compression is maintained, but the combustion efficiency of the mixture at light loads is generally somewhat impaired. In Fig 1, XXXVI. will be seen the effects of poverty of the mixture, the rate of combustion through the charge being at light loads extremely slow, thus producing the result shown. In the Premier engine it may be mentioned that the governing is affected by a combination of these two methods "a" and "b" in that, at very low loads the governing operates on the hit and miss principle, and cuts out the gas supply altogether, thus somewhat avoiding the disadvantage of operating at light loads with very weak mixtures and resultant inefficient combustion. In this last diagram we have seen typical cards obtained at light loads with this system.

(c) The next system of governing is by quantity regulation, in which both air and gas are reduced by the governor as the load diminishes. This gives a uniformly efficient mixture at all loads, but greatly diminishes compression pressures as the loads fall, since the actual amount of gas and air to be compressed is steadily reduced.

This is clearly shown in Fig. 2, Plate XXXVI., a diagram due to Junge. This is a system largely in use in large European and American four-cycle machines, and has also been adopted by Messrs. Tangye Limited, of Birmingham, in their latest engines.

(d) In the fourth system a combination of the quality and quantity regulation is affected by reducing the quantity of gas admitted as the load decreases, thereby reducing the quality of the mixture, but at the same time increasing the air supply, making the total charge of gas and air greater, and thus increasing compression pressures. This system has not yet been adopted to any great extent, being only in use, as far as I am aware, upon one make of engine, but excellent results are claimed for it.

A further illustration, Fig. 3, Plate XXXVI., shows a group of curves from a two-cycle machine taken during serious pre-ignition troubles due to a baffled exhaust, and consequent incomplete expulsion of the burnt gases. This resulted in a baffling of the incoming charge of air, which thus allowed the following live charge of gas and air to come into contact with the incompletely expelled burnt gases from the last charge, thereby becoming ignited, with the result shown on this set of diagrams. It may be mentioned that this is not peculiar to two-cycle engines, but is common to all gas engines should anything interfere seriously with the expulsion of the burnt gases, such, for instance, as might occur, and did occur, in the case in question, when the stones or bricks, etc., in the exhaust silencer or pit settle too closely together, and unduly obstruct the passage of the exhaust gases.

Fig. 1, Plate XXXVII., shows a diagram, taken from the same engine, of an interesting example of pre-ignition. Two complete cycles are shown, one in which the charge was properly fired, shown in dotted lines, the other, in which the pre-ignition took place immediately after the admission of the inlet charge to the cylinder, that is, practically at the beginning of the compression stroke, the mixture, igniting at this point with resultant increase in volume, is thus compressed to a very high pressure, as shown, the subsequent lines on the diagram falling below the compression lines; the useful work done being thus negative.

Owing to the high pressures evolved in the ordinary gas engine cylinder it is necessary in indicating them to use very stiff indicator springs. This allows for the high explosion pressures, but provides little record of any value of the pressures during the exhaust and suction strokes. For this reason it is always advisable to take special cards with very light springs, the undue rise of the indicator pistons following the explosion being prevented by a suitable spring buffer in the indicator. These light springs or air cards, as they are sometimes called, give valuable data as to the state of the inlet and exhaust passages, whether there is undue baffling of either the incoming air or gas, or of the outgoing burnt gases.

Fig. 2, Plate XXXVII., shows a card from a two-cycle Korting engine tested by the writer, in each case the clear definition of exhaust and suction pressures is to be noted.

We next consider the determination of the speed and the efficiency of the governing devices. In the simplest of tests, speed must be recorded and is generally counted over frequent intervals by at least two observers. But it is undoubtedly of value to fit a special counter to the engine to record the revolutions, or cycles, for the whole test period, and also a second counter to count the number of fired cycles when testing engines governed on the hit and miss system. There are various types of counters in use, most of which are suitable, and probably familiar to all of you. A useful adjunct is the ordinary engine Tachometer, such as is fitted to nearly all high speed steam engines to record the actual speed at any instant.

In testing an engine in which uniformity of speed is essential, that is, one in which the cyclical variations must be a minimum, it is usual to demonstrate the co-efficient of regulation by means of Dr. Horn's Tachograph, an extremely neat instrument, of which, through the kindness of Professor Barraclough, there is an example here. This instrument primarily consists of a centrifugal governor driven from the engine shaft and operating a pencil mechanism which records the instantaneous speed upon a continuous roll of paper. This paper is travelled at any predetermined speed, and is marked electrically with a series of perforation points in its travelling, corresponding with engine crank positions.

Fig. 3, Plate XXXVII., shows a typical diagram taken at full load with the Tachograph by Guldner from a four-cycle 100 horse power engine governed on the hit and miss system. The diagram is divided off into four cycles, and the speed fluctuations on each stroke of the cycle are clearly to be seen. It is to be noted that the cyclical variations were in this case excessive.

Fig. 1, Plate XXXVIII., shows a tachogram from the same engine under very light load, the rapid acceleration of the ignition stroke is very marked.

We have yet to consider the means adopted for determining the quality and quantity of gas supplied, and this for want of time the writer can but deal with in the briefest manner. The quantity of gas used for any given period is determined by a suitable gas meter, of which there are many varieties on the market. The quality of the gas is arrived at by analysis, generally in special portable apparatus, from which the estimated calorimetric value can be computed, and sometimes also it it advisably supplemented by an experimental determination of the calorimetric value in a Junker's, or other form of gas calorimeter. The gas analysis is usually obtained by means of the Orsat apparatus, of which one is on view, kindly lent by Mr. A. H. Stewart, of the Technical College.

The Orsat apparatus, as modified by Lunge, is shown in Fig. 2, Plate XXXVIII. It consists of a measuring tube "A" of 100 c.c. capacity, surrounded by a water jacket to ensure even temperature conditions. The bottom of the burette "A" is connected by a level tube to a level bottle "X," which is filled two-thirds with water. The top is connected to a capillary tube "Y," which is bent at right angles, and ends with three-way cock "K." On this glass tube are