ON
ASHTON AND STOREY'S STEAM-POWER METER
AND CONTINUOUS INDICATOR.

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In the employment of steam power it is a matter of great importance to be able readily and accurately to ascertain the exact amount of power developed in a given time; but hitherto approximate estimates founded upon the results of isolated tests and experiments, or calculations based upon indicator diagrams taken as averages of the whole work, have furnished the sole means for ascertaining the power developed by steam engines, in all cases where the power has been subject to variation. These indications have been taken at different intervals during a day, or generally during a much longer period; and have simply been registrations of the amount of power developed in the few strokes performed by the engine during the actual time of indication. The variations in the steam pressure, speed, or load upon the engine, which have occurred in the intervals between the indications, have been practically disregarded; and even from the indicator diagrams thus obtained, the power developed during the time of indication can only be ascertained with exactness by a tedious process of measurement and calculation.

The Steam-power Meter and Continuous Indicator forming the subject of the present paper, which is the invention of Mr. Ashton and the writer, possesses the advantages of not only measuring the power developed during a single stroke of the engine with as much exactness as the ordinary indicator, and also of registering this power as exactly as it is measured; but what is of much more consequence, this measurement and registration are effected continuously for the whole number of strokes made by the engine during the entire period of work, whatever variation may occur between the individual strokes. The instrument thus shows at all

times the measure of the power developed by the engine to which it is applied, and registers the aggregate of the power during any required period.

The continuous indicator is shown in Figs. 1 and 2, Plates 18 and 19; it consists of a small cylinder and piston A, like those of an ordinary indicator, but having each end of the cylinder connected by a separate pipe to the corresponding end of the engine cylinder. The piston-rod B is attached at top to an ordinary spiral indicator-spring C, which is compressed or extended when the piston is moved above or below its middle position in the cylinder. The rod also carries a long pinion D, turning loose upon it but held endwise between fixed collars E E; and this pinion gears into a toothed wheel F, which drives a train of wheel-work moving the index on the registering dial of the instrument. Fixed to the lower end of the loose pinion D on the piston-rod is a horizontal plain wheel G, 3 inches diameter, called the integrating wheel, Figs. 3 and 4, having a smooth rim with a rounded edge, which is in contact with the flat face of a vertical circular disc H, $3\frac{3}{4}$ inches diameter, mounted on a short shaft, the disc face being constantly pressed against the rim of the wheel by a light spiral spring J bearing against the end of the shaft; the pressure of this spring is adjusted by a set-screw, and is sufficient to cause any motion of rotation in the vertical disc H to be transmitted to the edge of the horizontal integrating wheel G without slipping. The movement of some reciprocating part of the engine is communicated to the disc shaft, causing the disc to rotate alternately in opposite directions; and the integrating wheel receives from the disc a rotary movement, the amount of which is proportionate to the distance of the point of contact of the wheel with the disc, above or below the centre of the disc. In Figs. 5 and 6, Plate 20, are shown the methods hitherto generally employed for driving the disc. In Fig. 5 a reciprocating iron bar L worked by the engine drives by friction a wheel M having an india-rubber rim, against which the bar is pressed by the lever and pressing pulley N; and the shaft of the india-rubber wheel M carries a pinion gearing into the pinion K upon the disc-shaft, Figs. 1 and 2. In Fig. 6 a cord or strap S from the engine crosshead passes round

a pulley P on the disc-shaft, being carried round guide-pulleys Q Q above and below. Other convenient modes of driving the disc are by means of a reciprocating rack R, Fig. 7, gearing into the pinion K on the disc-shaft; or by a spiral bar T, Fig. 8, carried in bearings at the ends, and rotated by the reciprocating movement of a slide-block U sliding along it.

When there is no pressure on the engine piston, and consequently none on the indicator piston, the height of the integrating wheel G on the piston-rod is so adjusted that its point of contact with the disc H is at the centre of the disc, as shown in Fig. 1, that being the zero point of the instrument; and in this position any rotation of the disc H which is geared with the engine may take place, without transmitting motion to the integrating wheel. But when the steam pressure comes upon the indicator piston, the integrating wheel traverses either upwards or downwards from the centre towards the circumference of the disc, through a distance proportionate to the pressure on the piston, which is measured by the compression or extension of the spiral spring C. Supposing the engine and with it the disc H be moving, the motion will be communicated by the disc to the integrating wheel G, Figs. 3 and 4, and through this to the index of the instrument. The extent of the motion so given to the index during any stroke of the engine is proportionate to the pressure of the steam on the indicator piston during that stroke, because the rate at which the integrating wheel is driven by the disc is directly proportionate to the distance that the integrating wheel is raised or lowered from the centre of the disc, and this distance is the same as the compression or extension of the indicator spring.

When the stroke is finished and the return stroke commences, the disc will rotate in the opposite direction, Fig. 4; and if the steam acting upon the piston were pressing in the same direction as before, the integrating wheel and index would necessarily go backwards. As however the steam acts on the opposite side of the piston when the piston's motion is reversed, the integrating wheel will be moved to the opposite side of the centre of the disc, so that the wheel will still be made to rotate in the same direction as before, Fig. 3; and the extent of forward motion given to the index during the return stroke

of the engine will again be proportionate to the pressure of the steam on the piston during the return stroke, and will be added to the movement of the index during the preceding stroke. By this means therefore the registering index is moved forwards during each stroke of the engine through a space proportionate to the sum of the moments of pressure exerted during that stroke; the total amount of power developed during the stroke is thus indicated, and is added on by the index to that of the preceding stroke. The indication upon the dial is accordingly continuous for the successive strokes of the engine; and the indicator piston being acted upon by the effective steam pressure in the engine cylinder, the power indicated is the net amount of power corresponding to the work actually done.

The following is the mode in which the graduation of the index and the measurement of power by the meter are effected. Assuming the indicator spring to be of such a strength as to yield one inch with a pressure of 25 lbs. per circular inch in the cylinder, the integrating wheel will be in contact with the driving disc at a distance of one inch from its centre when there is that pressure in the engine cylinder; and if the radius of the integrating wheel is one inch, one revolution of the disc will drive it one revolution. Then taking the circumference of the pulley where the motion of the engine is applied to be such that one revolution of the disc is made whilst the engine piston moves through one foot of its stroke, this movement of one revolution of the integrating wheel will represent a motion of one foot by the engine piston under a pressure of 25 lbs. per circular inch, or a moving power of 25 foot-pounds for each circular inch in the area of the piston. In the actual instrument the proportions of the moving parts and the gearing for reducing the motion down to the registering index are so arranged that each unit on the dial represents 1000 foot-pounds per circular inch of the engine piston.

The total work done by an engine in foot-pounds during any period is therefore measured at once by simply multiplying the number indicated on the dial during that period of work by 1000 and by the square of the diameter of the engine cylinder in inches. The

average horse power of the engine during the time is obtained by dividing this total amount of foot-pounds by the number of minutes during which the meter has been in action, and also by 33,000, the number of foot-pounds per minute forming a unit of horse power.* For convenience of reference, where the indicator is intended to be employed constantly for a particular size of engine, a separate index can be provided on the dial for showing at any time the load on the engine in horse power, by simply observing the movement recorded by the index during one minute. For this purpose it is only necessary that the index wheel should be proportioned to the square of the diameter of the engine cylinder, in order that the graduations on the "horse power" dial may represent the product of the whole amount of foot-pounds per circular inch of the engine piston, multiplied by the square of the diameter of the cylinder in inches and divided by 33,000.

By closing the cock connecting one end of the indicator cylinder with the corresponding end of the engine cylinder, and opening a small drip cock to admit air freely to the disconnected end of the indicator cylinder, the indicator is rendered single-acting, and will show the manner of working and the amount of work done by one end of the engine cylinder alone. By opening the closed cock, and closing the open one the action is reversed, and similar information is obtained respecting the other end of the engine cylinder. The connecting pipes from the indicator cylinder to the engine cylinder are made as short and direct as possible; and for convenience of repairs, as well as for cleaning the inside of the indicator cylinder and the piston, the bottom connection is made by a brass plug V, Fig. 2, of the full diameter of the cylinder. This plug is inserted

*The two calculations may be represented in a concise form by the following expressions for the total work done and the average indicated horse power during any period:—

$$1000 (N-n) d^2 = \text{total work done in ft.-lbs.}$$

$$\frac{1000 (N-n) d^2}{33,000 m} = \frac{(N-n) d^2}{33 m} = \text{average indicated horse power;}$$

where d is the diameter of the engine cylinder in inches, n the reading of the index at the commencement of the period, N the reading at the end of the period, and m the number of minutes elapsed between the times of reading.

through the casing of the instrument into the bottom of the cylinder, and can be readily taken out at any time ; and the piston-rod being detached from the spring C at the top, and from the two collars E E upon it, can then be drawn out with the piston through the bottom of the casing, thus affording an easy means of also changing the integrating wheel G if required.

The effect of early closing of the exhaust in producing "cushioning," or compression of the exhaust steam in front of the piston, is shown at the end of each stroke by the integrating wheel turning backwards through a distance proportionate to the loss of power by the cushioning. In the case of a non-condensing engine, with the indicator connected to one end only of the engine cylinder, the integrating wheel would not come back to the centre of the rotating disc during the return stroke of the engine, by a distance proportionate to the back pressure opposing the motion of the engine piston ; and the effect would therefore be that during the return stroke the integrating wheel and index would be wound backwards through a distance proportionate to the loss of power by back pressure.

The instrument can be so constructed that ordinary indicator diagrams may be taken by it, for indicating the action of the steam in each end of the engine cylinder separately, or in both ends conjointly. The rotating barrel W, Fig. 1, for taking diagrams on paper, is carried on a bracket, which slides into a groove in the side of the indicator box at X, the driving cord being actuated by some reciprocating part of the engine, while the tracing point is carried by the upper collar E on the piston-rod. After taking a diagram by this means, the barrel on its bracket can be removed from the box and replenished with a blank sheet of paper, and another diagram can then be taken as before.

In cases where engine power is supplied to tenants, this continuous indicator furnishes the only means whereby the power supplied may be accurately measured, on account of the impracticability of obtaining from any isolated strokes of the engine a correct average of the whole. Also in the case of marine

engines in a rough sea, it is the only instrument that can give reliable information respecting the power exerted by the engines, as it is frequently impossible during a whole voyage to obtain consistent diagrams from the ordinary indicator. The instrument is also applicable to the air cylinder of a blowing engine, for the purpose of indicating the weight of blast supplied by the engine in a given time, whatever variation there may be in the pressure of blast or speed of engine during that time. In a slightly modified form it is also useful for determining the power given out by a turbine water-wheel, during any length of time and under all conditions of variable pressure and velocity. Another valuable use of the instrument has been found to be for testing the amount of power required in rolling mills for the manufacture of rolled iron bars and plates, copper and brass tubes and sheets, &c.: no means having hitherto been available for obtaining any reliable information on these points. Two of the first instruments made were applied, one to the engine of an iron-rolling mill in South Wales, and the other to that of a copper and brass tube and sheet manufactory, near Manchester; and during the period of more than twelve months that they have now been in use they have given very valuable information, showing the exceedingly variable nature of the work, and the great difference in the power required for the different classes of work. By recording the aggregate power during any period, the continuous indicator supplies the means for forming a correct judgment as to whether the engine power has been duly maintained during the whole period, and whether at any time there has been a want of due economy in fuel; and the comparative merits of different kinds of fuel or lubricants may thereby be tested definitely.

The following instance of the application of one of these steam power meters to a large pumping engine in the neighbourhood of Manchester may be referred to as an illustration of the important practical utility of the information afforded by the instrument as to the conditions under which an engine is performing its work. The engine in this case is employed in raising water from a river into a reservoir about 16 feet higher, and the piston-rod of the steam cylinder is attached direct to the pump-rod. The pump is a large

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ram of about 44 inches diameter with a stroke of 9 feet, and by the action of the steam below the piston together with a vacuum above it the ram is raised, and the water from the river is drawn up by it into the pump-barrel below the ram; a portion of the steam is then allowed to pass round from the under to the upper side of the piston by means of an equilibrium valve; and the piston, piston-rod, pump-rod, and ram descending by their own weight force the water out through the upper portion of the pump-barrel into the reservoir. On attaching the power meter to the engine it was found that 25 double strokes were usually required to move the index of the instrument one unit on the dial, which in this case represented 2000 foot-pounds per circular inch in the area of the engine cylinder. The index was of course observed to move forwards during each upstroke of the engine, thereby showing work done; but during the downstroke it was seen to go backwards through a portion of the space over which it had advanced during the preceding upstroke; thereby showing work undone, in consequence of a portion of the steam that had been employed in the upstroke being uselessly confined under the piston in the downstroke to arrest the descent of the ram. The instrument thus clearly pointed out that the moving parts were too heavy, their excessive weight requiring more steam to raise them than was equivalent to the work done in the water lifted; and the amount of the excess was shown by the backward movement of the index. By comparing the number of revolutions of the integrating wheel during its backward movement with the number of those during the forward movement, the relative loss of effect is obtained; and this was found to be in the proportion of 3 to 10, showing that 3-10ths of the steam power employed was exerted uselessly in first raising an unnecessary weight and afterwards restraining its descent, the remaining 7-10ths alone being usefully expended in raising the water and overcoming the friction of the engine.

As 25 double strokes of the engine were required for a total work of 2000 foot-pounds per circular inch, the work done per stroke was 80 foot-pounds per inch; and the length of stroke being 9 feet, the average effective pressure on the piston was 8.9 lbs. per circular inch. As the effective pressure was only 7-10ths of the total pressure, the

latter amounted to 12.7 lbs. per inch, and the pressure lost was the difference or 3.8 lbs. per inch. The total pressure would be equivalent to the load of water lifted, together with the dead weight of pump-rods &c., *plus* the friction of the engine; while the pressure lost would be equivalent to the dead weight of pump-rods *minus* the friction of the engine. The height of lift of the water being 16 feet, the load of water was 5.4 lbs. per circular inch; and it follows from the amount of the total pressure, that the dead weight of pump-rods &c. amounted to 5.6 lbs. per circular inch, and the friction of the engine to 1.7 lbs. per inch. The steam piston being 44 inches diameter or 1936 circular inches area, the amount of pressure lost, 3.8 lbs. per inch, showed an excess in dead weight of 7357 lbs. or $3\frac{1}{4}$ tons that required counterbalancing.

While the power meter was attached to this engine, numerous indicator diagrams were repeatedly taken from both ends of the cylinder simultaneously, from which the work performed by the engine was computed in the ordinary way; and the results when compared with those shown by the power meter for the same time were found to be closely coincident, sometimes one being slightly in excess, and sometimes the other. Each varying circumstance in the action of the steam in the cylinder was distinctly exhibited by the meter, and the "cushioning" of the steam at the termination of the stroke was shown by a sudden backward rotation of the integrating wheel, which was reversed again at the beginning of the return stroke of the engine. Instead of 25 strokes of the engine being required to move the index of the meter through one unit on the dial, from 28 up to even 34 strokes were sometimes required for registering one unit. The cause of these discrepancies in the readings was found to be the different heights of the water in the river owing to freshets at the different times of observation. So faithful a recorder of the power exerted was the meter found to be, that from its readings the depth of the water in the pump-well could at any time be ascertained.

The extended use of the steam power meter on ocean steamers and other large engines has fully established confidence in the

accuracy of its records, and also in the solidity and durability of its construction. The regularity of its working is illustrated by the following results from the continuous indication of one of the engine cylinders in the Cunard steamship "Siberia" during two voyages from Liverpool to New York and back, the time being nine days in each case; the engine has two 62 inch cylinders with 3 ft. 6 ins. stroke.

		Total Indication of Meter per day.*			Indicated Horse Power.		
		Lowest.	Highest.	Average.	Lowest.	Highest.	Average
First Voyage..	Out ...	3520	3795	3667	567	612	588
	Home	3378	3751	3595	555	628	601
Second Voyage	Out ...	3548	3722	3678	566	592	585
	Home	3400	3610	3510	500	608	574

* The intervals between the readings of the meter were not exactly a day, but within one hour variation from 24 hours in each case.

In cases where the united action of two steam cylinders is employed to propel the same machinery, if a continuous record of extreme accuracy be required it will of course be necessary to have a meter attached to each cylinder. But the expense of a second meter may be avoided and very valuable results may be obtained, sufficiently accurate in practice for most purposes, by the simple expedient of connecting the cylinder of a single meter to each cylinder of the steam engine by junction pipes and taps, so that communication may be made with either cylinder at pleasure, and the amount of work done by either through any given time can then be ascertained, although but one meter is used. Of the whole work done by both cylinders in combination it is to be considered that a certain definite proportion is done by each, and that this proportion is invariable so long as the degree of expansion and the working condition of each engine remain the same. In order to determine this constant proportion between the two engines, the power of each is measured separately during two successive periods, at some time when the load on the engines is uniform and not subject to any material variation during the trial. The total power of the two

engines can then be ascertained at any other time, by measuring the power of one engine by the meter, and adding to it the corresponding proportionate power of the other.

Mr. ASHTON exhibited specimens of the power meter, one of them driven in the ordinary manner hitherto employed, by means of a plain iron bar driving by frictional contact a wheel with an india-rubber rim; and the other meter showed the more recent mode of driving by a rack and pinion.

The PRESIDENT asked what was found to be the durability of the integrating wheel, upon which the accuracy of the indication depended; and what material the wheel was made of.

Mr. ASHTON said the rounded rim of the integrating wheel was the part most exposed to wear in the instrument, and he showed one of the first wheels made, which was of ordinary gun-metal and had been in constant use for fifteen months, working most of the time both night and day; it had now become worn flat in the middle of the rounded rim, the amount of wear being somewhat less than 1-300th inch, which on the original radius of $1\frac{1}{2}$ inches was less than 1-450th part of the whole, and the error thereby occasioned in the indication would consequently be less than $\frac{1}{4}$ per cent., requiring 1 horse power to be deducted from every 450 indicated. The wheel could readily be taken out at any time, and replaced in a few minutes, whenever it was considered to be worn down too much for continuing at work. Steel, cast-iron, and wrought-iron had also been tried for the discs working against the integrating wheels; but they were now made, as well as the integrating wheels, of the very hardest bell-metal, considerably harder than the worn specimen exhibited, and so hard that it could only just be worked with the tool. There was no lubrication between the integrating wheel and the disc face, which were

perfectly clean and dry when put to work; and being completely enclosed within the case of the instrument, they were thoroughly protected from risk of any grease or oil getting upon them and interfering with the requisite adhesion between them.

The PRESIDENT enquired what amount of pressure was put upon the disc by the spring at the end of the disc-shaft, for keeping the integrating wheel and the disc always in contact.

Mr. ASHTON said the pressure exerted by the spring was very slight, only just enough to keep the disc in contact with the edge of the integrating wheel, and he did not think it exceeded $\frac{1}{4}$ lb. The external set-screw afforded the means of adjusting the spring to the degree of pressure that was found sufficient for the purpose.

Mr. J. ROBINSON asked whether any error was occasioned in the indications of the instrument by variation in the elasticity of the main spiral spring at different parts of its range; or whether it was found that the degree of extension or compression under equal additions of force was the same throughout the whole extent of movement. In such springs he thought the resistance to equal additions of force was less at the commencement than in the higher parts of the scale.

Mr. ASHTON replied that in testing the springs within the range at which they worked in the indicator the resistance both to extension and compression was found equal, and was uniformly proportionate to the amount of displacement of the spring. The lengthening or shortening of a spiral spring being due to a torsional rather than an extensional or compressional strain on the material, there was no reason why it should require more force to twist it one way than the other, within moderate limits; and the amount of yielding was accordingly in direct proportion to the total pressure exerted.

Mr. E. A. COWPER observed that the spiral spring in the power meter now described would be as true as an ordinary indicator spring, and he did not think any error would be involved in that portion of the instrument.

Mr. F. J. BRAMWELL thought it would be well if the continuous indicator were in general use for all classes of steam engines, and

especially for marine engines, as it was very important that the actual horse power expended during a voyage should be correctly known. The total consumption of coal could then be divided by the indicated horse power really obtained from the engines during the whole run, instead of by some abnormal horse power given out in a special trial at a measured mile and assumed as an average of the power developed in ordinary working; the true degree of economy with which the engines were working would thus be ascertained. He thought that when the present instrument had become better known it would be very extensively adopted.

Mr. J. B. FENBY suggested that it would be an improvement if it were practicable for the whole amount of the power developed to be shown by the continuous indicator, with a separate registration of the power lost or work undone, which in the present arrangement of the instrument could only be ascertained by constantly watching the movement of the index or of the integrating wheel, and noting by observation the extent of any backward movements. Without such attention, an engine might be considered to be performing no more than the work shown by the indicator, whilst it might really be exerting a greater amount of power, but at the same time also undoing a portion of its own work.

Mr. ASHTON said the object of the indicator was to record the absolute work done by the engine, and any power that was exerted without producing a corresponding useful effect did not get recorded by the index. In all non-condensing engines there was of course a certain amount of loss of power by back pressure of the exhaust steam; and in these or any other cases of loss of power the extent of the loss could be detected with the continuous indicator by trying each end of the engine cylinder separately, disconnecting the indicator first from one end and then from the other; the backward movement of the integrating wheel during the return stroke would then be seen, and the amount could be noted for each end of the cylinder. With both ends of the cylinder connected to the indicator, the effect of the back pressure was deducted in the instrument itself from that of the driving pressure, and the movements of the indicator piston corresponded therefore with the effective pressure in the cylinder,

and thus caused the index to show the net amount of the effective work done by the engine.

Mr. G. D. HUGHES considered the indicator was an important and valuable invention, and one which would supply a great desideratum in connection with the working of steam engines, if it answered its purpose as efficiently as appeared to be the case. The only point which appeared to him to allow room for doubt respecting the certainty of its action was the adhesion between the disc-wheel and the rim of the integrating wheel; and if any lubrication ever got on the face of the disc, or if there were any uncertainty in the pressure with which the disc was held against the integrating wheel, it occurred to him that the wheel might slip and fail to indicate the full amount of power. He enquired whether any diagrams had been taken simultaneously by an ordinary indicator, and compared with those taken by means of the barrel attached to the instrument now described; and whether they were found to coincide, after the continuous indicator had been at work for a length of time.

Mr. ASHTON said it was a necessary condition for the correct working of the continuous indicator that the face of the disc-wheel should be kept scrupulously clean, free from oil or anything which might cause the integrating wheel to slip upon it; and with regard to the pressure of the disc against the wheel, no nicety of adjustment was needed, and it was only necessary to tighten up the external set-screw at the end of the disc-shaft, until the spring exerted the slight amount of pressure that was found sufficient to ensure the disc keeping in contact with the integrating wheel, so as to drive it without slipping. In reference to the diagrams taken with this indicator, the first instrument made had recently been tested in the manner suggested, after many months' working, by comparing the diagrams with others taken simultaneously by a Richards indicator; the latter had a spring yielding 1 inch for every 24 lbs. pressure per square inch, while in the continuous indicator the spring had the same extent of motion for every 25 lbs. pressure per circular inch; and when these differences in the graduation were allowed for, the diagrams from the two instruments were found to be perfectly identical.

Mr. E. B. MARTEN said he had lately applied the continuous indicator to an ordinary forge engine at a rolling mill in the neighbourhood of Stourbridge, where it acted very satisfactorily; and it afforded information respecting the working of the engine which he had not been able previously to obtain with equal accuracy. It had been found by this means that the actual power developed by the engine was less than had been estimated by the ordinary plan of taking indicator diagrams and calculating the power from them. It was indeed very difficult to ascertain the absolute horse power of a rolling-mill engine in any other way than by some plan of continuous indication, on account of the constantly changing load on the engine. In a trial of 30 minutes' duration with the continuous indicator, the mean power actually developed by the engine was found to be 115 horse power, while the indicator diagrams taken at intervals during the same period with an ordinary indicator gave an average of as much as 163 horse power. In a second trial of the same duration the continuous indicator showed 124 horse power actually developed, while the highest indicator diagram gave 325 horse power and the lowest 89 horse power, the mean being therefore 207 horse power, which was again much in excess of the actual power developed. In such cases therefore diagrams taken with an ordinary indicator, which measured only the power developed in a single stroke of the engine, were quite unreliable as an indication of the average power; and he considered the continuous indicator would be found to be exceedingly valuable for all kinds of work where the load on the engine varied at all. There had been no difficulty in attaching the instrument to the engine, and it was worked by a strap from the radius rod, passing round a pulley on the disc-shaft of the indicator, with a weight hung on the other end of the strap to keep it stretched tight and pull it back in the return stroke. This had been found the most convenient method of working in that case, and he was not then aware of the other modes of driving that had been subsequently proposed.

Mr. E. A. COWPER mentioned that an early application of the principle of an integrating wheel and disc for affording continuous indication had been made by Professor Moseley in a steam-power

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indicator which had been employed for measuring the power of the Cornish pumping engine at the East London Water Works.

Mr. ASHTON said the integrating wheel and disc had long been known; but he believed the integrating wheel had not previously been made to cross the centre of the disc, working alternately above and below the centre, as was the case in the power meter now described, whereby a continuous indication was now obtained from both ends of the engine cylinder, showing the total effective power developed.

Mr. A. ALEXANDER concurred in believing that in the previous use of the integrating wheel and disc, which had been referred to, the wheel did not travel backwards and forwards across the centre of the disc, but continued always on the same side of the centre. An integrating wheel had been originally employed he believed by Morin, in the construction of his registering dynamometer.

Mr. E. A. COWPER asked what was the cost of one of the continuous indicators, as that would be an important consideration in relation to its general adoption.

Mr. ASHTON replied that the cost of the instrument was about £20, without the addition of the indicator barrel for taking diagrams, which would be about £3 extra. There were now about thirty of the indicators in operation.

The PRESIDENT observed that questions of priority of invention did not come within the scope of the Institution, and it was always quite possible that other minds might have been on the same track previously; at all events in the present instance it did not appear that the results of former attempts had been to bring forward a practical arrangement in such a shape as should commend itself for general use. This merit however he thought was possessed by the instrument now described; and the only objections raised against it were of a refined and theoretical nature, and in practice did not amount to anything of importance. The wear of the integrating wheel, for instance, was shown to be practically inappreciable; and the same was the case with regard to any slight difference that might perhaps occur in the strength of the indicator spring when considerably compressed or elongated, the diameter of a spiral

spring, and consequently the leverage of the load upon it, being of course increased slightly by compressing the spring, and diminished by elongating it. This continuous indicator appeared to him therefore to be theoretically almost perfect, and in practice quite so; and he considered it a very valuable instrument. He proposed a vote of thanks to Mr. Storey and Mr. Ashton for the paper, which was passed.

The following paper was then read :—

Fig. 1.
Front View.

Fig. 2. Back View.

Fig. 3.
Plan of
Integrating Wheel
and Disc.

Fig. 4. Elevation.

Methods of driving the Disc-wheel.

Fig. 5. *Friction Bar.*

Fig. 6. *Cord.*

Fig. 7. *Rack.*

Fig. 8. *Spiral Bar.*