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Indicating the High-Speed Multi-Cylinder Internal Combustion Engine

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ABSTRACT

An indicator claimed to be the only known device for certain and economical obtainment of composite indicator-diagrams depicting power, offset and lower-loop effects on high-speed multi-cylinder internal-combustion engines is described, the broad field of usefulness for such an instrument in furthering the development of high-speed engines by enabling accurate investigation of the processes within the engine cylinders having long been apparent, since the ordinary indicator fails at engine speeds above 300 r.p.m. due to inertia effects on its pencil mechanism and its drum. Because of the great need for obtaining accurate indicator-cards at high engine-speed, it was determined to construct a device that would produce diagrams having little or no inertia effect included, from the cylinders of an engine operating at any speed, and to make these diagrams available for analysis immediately, without recourse to photographic or other processes.

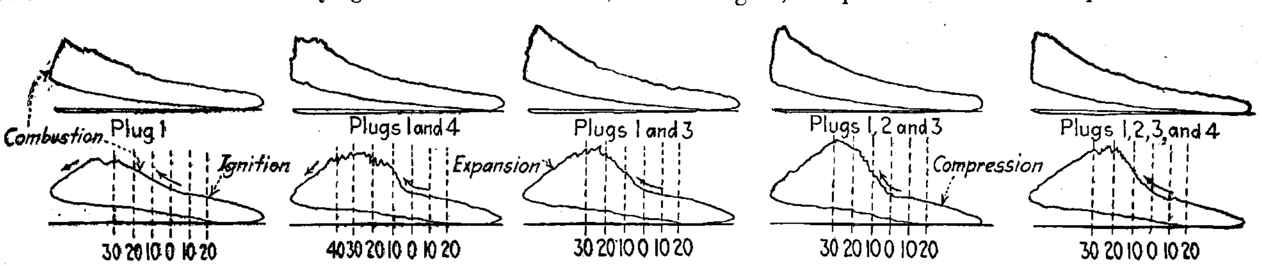
Briefly, a standard low-speed indicator having a drum 1½ inches in diameter is coupled directly by a standard union to the part of the device that has inside it a small poppet-valve which is opened for a very small interval of each cycle of the engine and which, when opened, completes communication between the manifold of the engine and the indicator. The indicator cylinder is filled with heavy lubricating-oil to provide a proper seal for the indicator piston and minimize gas transfer to or from the engine cylinder during each engine cycle.

Drum motion is controlled by a string threaded over a pulley and connected to a crosshead of the device which can be considered a replica of the engine piston but which moves through one stroke only for each 800 strokes of the engine piston and imparts a very slow back-and-forth movement to the indicator drum, thus nullifying inertia effects. The crosshead is controlled by a connecting-rod adjustable as to length and a graduated crank-disc, forming a train having exactly similar characteristics to those of the train that controls the engine piston. Since the connecting-rod can be varied in length, the ratio of the rod and its crank-disc can be made precisely the same as the ratio between the corresponding parts of the engine. The crosshead guide can be adjusted to simulate the offset of cylinders, if such offset exists, and the device can be made available for use on all types of internal-combustion engines and for connecting-rod to crank-throw ratios varying between 3¼ to 1 and 5½ to 1.

A shaft on the device passing vertically upward from another shaft driven at engine-speed turns at one-half engine-speed. The horizontal shaft carrying a hand crank is driven, when the clutch is engaged, at 1/40th engine-crankshaft speed. This horizontal shaft drives the vertical shaft to which the graduated crank-disc is attached through worm-gearing having a reduction of 20 to 1; so, with clutch engaged, this disc is driven by the engine at 1/800th of engine-speed and actuates the connecting-rod of the device. With the clutch disengaged, the graduated crank-disc can be operated by the hand crank in either direction.

Details and illustrations of the construction, application, procedure, and operation are included. This indicator has been in successful operation for more than 500 hours of testing and research work at Ohio State University. The composite indicator-diagram obtained over a great number of engine cycles which, individually, are generally not alike, is claimed to be a distinct gain over anything else yet tried, since the diagram is built-up before the eyes of the testing engineer.

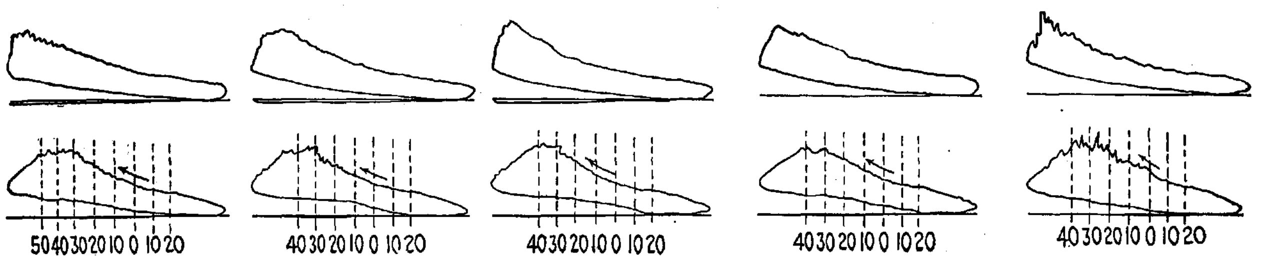
NEED for obtaining indicator diagrams from the cylinders of engines operating at more than 300 r.p.m. has been existent since the internal-combustion engine first came into use, because of the difficulties due to inertia effects when using the conventional, thoroughly logical and simple indicator such as that used ordinarily on air compressors and steam and gas engines operating at the higher speeds. Pencil-motion inertia is usually the most apparent, although that existing in the drum is often present. Attempts have been made to use some means of deflecting a beam of light and thus obtain a photographic record but, although this method has shown many things and has been invaluable in many investigations, its greatest objections are the danger of distortion of the record in development or printing and the great length of time ordinarily required, in addition to the cost, to make the record available for analysis in test or research work. So, the first two parts of the problem are to (*a*) provide a device for obtaining diagrams having few or no inertia effects from the cylinder of an engine operating at any speed and (*b*) produce a device that will draw diagrams which are available for analysis immediately without recourse to photographic or other processes. Further, if we wish to use such a device on a multi-cylinder engine, the problem is more complicated.



Run No.	347	346	345	344	343
Card Area, sq. in.	1.035	1.026	1.052	1.067	1.097
Card Length, in.	2.840	2.850	2.840	2.846	2.850
Mean-Effective Pressure, lb. per sq. in.	58.300	57.700	60.300	60.100	61.500
Air-Fuel Ratio	15.150	14.960	15.560	15.450	15.450
Engine-Speed, r.p.m.	1,060	1,060	1,060	1,060	1,060
Spring Scale, lb. per in.	160	160	160	160	160

Fig. 1—Typical JR Indicator-Diagrams

Five Pairs of Diagrams Taken on a 2½ x 5-In. Single Cylinder Air-Cooled Engine Having a Volumetric Compression-Ratio of about 3.63 to 1.00 Are Shown, the Upper Diagram of Each Pair Being the Power Diagram. The Lower Diaphragm of Each Pair Is Called an "Offset" Diagram Because the Crank that Operates the Indicator Drum Is Offset 90 Deg. from the Position Used When Making the Power Diagram. Ignition Occurred at 20 Deg. before Dead-Center in All Five Runs. The Purpose of the Tests from Which These Diagrams Were Selected Was To Show the Effects of Multiple Ignition



Run No.	358	357	348	347	425
Card Area, sq. in.	1.050	1.070	1.073	1.035	0.990
Card Length, in.	2.870	2.850	2.850	2.840	2.880
Mean-Effective Pressure, lb. per sq. in.	58.400	60.000	60.200	38.300	33.000
Air-Fuel Ratio	10.860	12.220	13.210	13.150	18.150
Engine-Speed, r.p.m.	1,060	1,060	1,060	1,060	1,060
Spring Scale, lb. per in.	160	160	160	160	160

Fig. 2—Other Typical Diagrams

These Are Similar to Those in Fig. 1, Except That They Show the Effects of Changing the Air-to-Fuel Ratio When Spark-Plug No. 1 Is Firing in All Cases. The Diagrams for the 12.22 to 1.00 and the 13.21 to 1.00 Air-to-Fuel Ratio Show the Greatest Mean-Effective Pressure, Which is To Be Expected

It is desirable also to arrange to obtain an average record over a considerable period, so as to secure results that are useful and comparable, since a spot-diagram, that is, a diagram of one single cycle, may or may not be representative of average conditions. Generally, such a diagram is not representative even on a slow-speed internal combustion engine using a gas as fuel, as is well known to anyone having experience. With liquid fuels, the problem is complicated further by the introduction of other variables.

If it is possible also to arrange the apparatus so that we can obtain not only the conventional power-diagram but also offset diagrams that will show the combustion-line in greater detail, and lower-loop diagrams by which we will be able to study the effects of changes in the induction or the exhaust systems, we then will have a device by which we can make a complete analysis of the cylinder action. Finally, if the device can be arranged to take all the foregoing diagrams from each of the cylinders of a multi-cylinder engine on but one indicator of the conventional type, the investment in testing apparatus is reduced and all diagrams that are obtained are made easily comparable to all other diagrams of the same type.

Work on this rather complicated problem was begun about two and one-half years ago by C. P. Roberts and myself, and the result of this work is presented in the JR indicating-device herein described. It seems logical to present first a discussion of some diagrams obtained by using this device before describing the device itself.

Power and Offset Diagrams

Fig. 1 shows five pairs of typical diagrams taken on a 2½x5-in. single-cylinder air-cooled Delco-Light engine having a volumetric compression-ratio of about 3.63 to 1.00. The upper diagram of each pair is easily recognizable as being the power diagram. The lower diagram is called an "offset" diagram because the crank operating the indicator drum is offset 90 deg. from the position used when making the power diagram. Ignition occurred at 20 deg. before dead-center position in all five runs. The offset diagrams were made so that the compression stroke is shown at the right end with ignition occurring at the line marked 20, which means 20 deg. before dead-center. The vertical line marked 0 is then the dead-center position for the engine.

Thus, in run No. 347, combustion began at 20 deg. before dead-center and the pressure in the cylinder became greatest at about 30 deg. past dead-center. It is apparent that, knowing the engine-speed, it is easily possible to arrive at a time-rate of pressure increase within the cylinder at dead-center, constant volume, by measuring the slope of the combustion-line at its intersection with 0-deg. line.

The purpose of the tests from which these diagrams are selected was to show the effects of multiple ignition. Therefore, the cylinder-head of this very small engine was fitted with four spark-plugs identified as Nos. 1, 2, 3 and 4. Spark-plug No. 1 was the plug as ordinarily fitted in this engine's cylinder-head; No. 2 was placed at 90 deg. from No. 1 and under the inlet-pipe; No. 3 was located opposite to No. 1; and No. 4 was set below the exhaust-valve. The four plugs were thus spaced 90 deg. apart and all were pointing horizontally into the cylinder. The diagrams in Fig. 1 were selected so that the air-to-fuel ratios for each were closely alike. Upon examination it is seen that, with spark-plugs Nos. 1 and 3 placed opposite, the cylinder gives about as good results as can be expected without too great expense for ignition apparatus. The differences in operating conditions are readily apparent from the power diagrams, and the offset diagrams show very clearly the details of the combustion-line for each combination of spark-plugs.

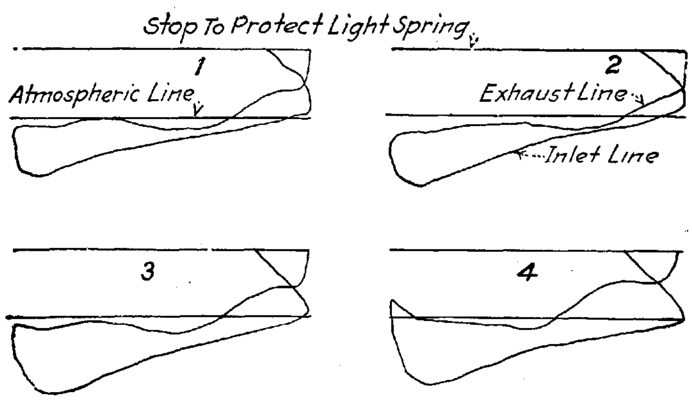


Diagram No.	1	2	3	4
Inlet-Valve Clearance in.	0.008	0.037	0.037	0.037
Exhaust-Valve Clearance, in.	0.010	0.010	0.021	0.037
Engine-Speed, r.p.m.	1,170	1,180	1,190	1,120
Spring Scale, lb. per in.	8	8	8	8

Fig. 3—Lower-Loop Diagrams Illustrating the Great Sensitiveness of the Device

Diagram No. 1 Shows the Effects of the Long Pipes for the Inlet and for the Exhaust; for Diagram No. 2, the Clearance of the Inlet-Valve Was Changed; for Diagrams Nos. 3 and 4, Changes Were Made in the Clearance of the Exhaust-Valve Alone. These Changes Are Apparent in the Raising of the Exhaust-Line

I have been asked whether the device will produce time-pressure diagrams. It should be apparent now that, if such diagrams are necessary, they can be constructed rather easily from the power and the offset diagrams; however, with these two diagrams available, the observer will hardly need a true time-pressure diagram. The question as to how the vertical lines are located on the offset diagram may arise. A dummy from which these lines can be traced easily is made by drawing a circle of a diameter equal to the diagram or card length and laying off the piston travel for each 10 deg. of

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crankpin travel, using a connecting-rod length exactly proportional to the length of the connecting-rod used in the engine.

Fig. 2 shows diagrams similar to those in Fig. 1, except that they show the effects of changing the air-to-fuel ratio when spark-plug No. 1 is firing in all cases. The diagrams for the 12.22 to 1.00 and the 13.21 to 1.00 air-to-fuel ratios show the greatest mean-effective-pressure which is to be expected. The slow-burning rich-mixture and the slow irregular-burning lean-mixtures are readily apparent from these diagrams.

Lower-Loop Diagrams

The lower-loop diagrams shown in Fig. 3 are very interesting in that they show how sensitive the device is in operation. Owing to the necessity for measuring the air going to the engine and the location of the main exhaust-header in the laboratory, both the inlet and the exhaust pipes were between 8 and 10 feet in length. The effects of the pipes being long are apparent in diagram No. 1 in Fig. 3, wherein the exhaust-line shows pressures below atmospheric for the greater part of the stroke and in which the pressure within the cylinder at the beginning of the compression stroke is above atmospheric. For diagram No. 2, the clearance of the inlet-valve was changed. The increased suction necessary in the early part of the inlet stroke is very apparent in this and in the succeeding diagrams. For diagrams Nos. 3 and 4, changes were made in the clearance of the exhaust-valve alone. These changes are apparent in the raising of the exhaust-line. In the multi-cylinder engine all lower-loop diagrams from each of the cylinders should be exactly the same in shape and of the same area below the intersection of the exhaust and the compression-lines to make certain that each cylinder is getting its fair share of the mixture.

While I have not had occasion to try the following procedure, it seems that, by using a 40 or 50-lb. spring with a stop for its protection as in the case of the diagrams of Fig. 3, it easily would be possible to make studies as to the valve action by utilizing the conventional lower-loop diagram and also an offset lower-loop diagram. Possibly, small changes in valve-seat angle, cam contour and the like can be studied to the betterment of our knowledge of these matters. It certainly is logical that lower-loop diagrams will afford considerable information as to the effects of changes in diameter, length and the contour of both inlet and exhaust-manifolds.

It should be apparent from the diagrams that they are not spot-diagrams. Each small irregularity in these diagrams shows that consecutive cycles were not exactly the same, since but a small part of each diagram is

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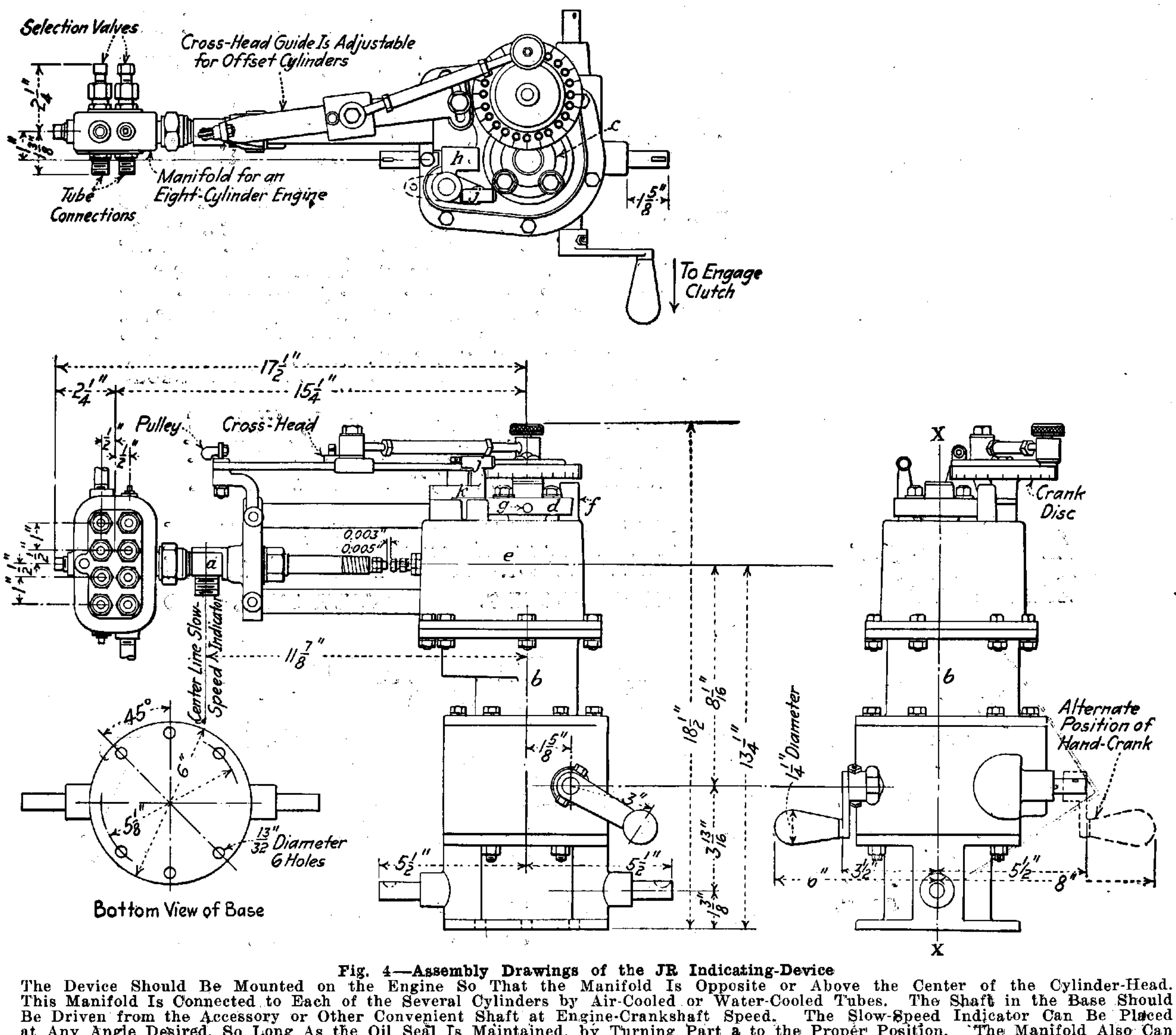

Fig. 4—Assembly Drawings of the JR Indicating-Device

The Device Should Be Mounted on the Engine So That the Manifold Is Opposite or Above the Center of the Cylinder-Head. This Manifold Is Connected to Each of the Several Cylinders by Air-Cooled or Water-Cooled Tubes. The Shaft in the Base Should Be Driven from the Accessory or Other Convenient Shaft at Engine-Crankshaft Speed. The Slow-Speed Indicator Can Be Placed at Any Angle Desired, So Long As the Oil Seal Is Maintained, by Turning Part a to the Proper Position. The Manifold Also Can Be Turned to Any Desired Position; in Fact, the Tube Connections and the Selection Valves Can Be Reversed if Necessary

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taken from any one individual cycle of events. The diagrams are built-up, part-by-part, on the card, the whole forming a composite diagram of the conditions within the cylinder. The larger irregularities, such as after-burning waves, are repeated again and again on successive diagrams, there being cases in which as many as six diagrams were as near alike as the proverbial two peas. These composite diagrams have been construed as average diagrams by almost everyone who has seen them made. While I feel sure that the diagrams do represent average conditions, I prefer to call them "composite" diagrams since they are built-up from many cycles of the engine.

The J-R Indicating Device

Three views of the JR indicating-device are shown in Fig. 4, which is an assembly drawing. The device should be mounted on the engine being tested so that the manifold is opposite or above the center of the cylinder-head. This manifold is connected to each of the several cylinders by air-cooled or water-cooled tubes, all tubes being of the same length to obtain exactly comparable results. These tubes generally will be connected into the holes used ordinarily for priming cups.

The ⅝-inch shaft projecting both ways from the base should be driven from the accessory or other convenient shaft at engine-crankshaft speed.

A slow-speed indicator, such as the Crosby, the Trill or some other make, having a drum 1½ inch in diameter is then mounted directly on the part *a*, which is machined to take the particular union furnished by the indicator manufacturer. This indicator should always have its pencil motion pointed downward, since its cylinder must be well filled with 600-W or other fairly heavy lubricating oil. This oil serves a two-fold purpose; first, it produces a very good seal around the indicator piston, thus reducing the rate of leakage very materially and, second, it reduces the clearance in the indicator cylinder to such an extent that the volume of gas transferred to or from the engine cylinder then being tested is confined to an infinitesimal volume from the individual cycle.

Drum Motion Is Slow

The motion of the drum of the slow-speed indicator is controlled by a string threaded over the small pulley shown above the part *a* and connected to the small grooved-pin on the crosshead. This crosshead can be taken as a replica of the engine piston, but it is moved at a very slow speed in comparison with that of the engine piston; therefore, the drum of the slow-speed indicator is moved back and forth very slowly and, in fact, the engine piston makes 800 strokes to 1 stroke of the crosshead. This slow motion nullifies all the inertia troubles that enter if it is attempted to move the indicator drum in unison with the movement of the engine-piston.

The crosshead is controlled by a connecting-rod-and-crank mechanism. The connecting-rod is made adjustable as to length, so that the motion of the drum of the indicator can then be controlled by a crank-and-connecting-rod train that has exactly the same characteristics as the crank-and-connecting-rod train controlling the motion of the piston of the engine being tested. The throw of the crank is 1⅝ in. and it is not adjustable;

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but, since the length of the connecting-rod can be changed by the differential screw-adjustment, the ratio between the two easily can be made exactly the same af the ratio between the corresponding parts of the engine. Futher, as shown in Fig. 4, the crosshead guide can be adjusted to stimulate the offset of the cylinders of the engine, should the engine have offset cylinders. The device is thus made available for use on all types of engine, whether they have offset cylinders or not, and for connecting-rod to crank-throw ratios varying between 3¼ to 1 and 5½ to 1.

Relative Speed of Crank-Disc and Engine

The shaft passing vertically upward from the ⅝-in. shaft driven at engine-speed is operated at one-half engine-speed. The horizontal shaft, which carries the hand crank, is driven at 1/40th engine-crankshaft speed when a clutch is engaged. This horizontal shaft drives the vertical shaft to which the graduated crank-disc is attached, through worm-gears having a reduction of 20 to 1; therefore, with the clutch engaged, the graduated crank-disc is driven by the engine at 1/800th of engine-speed. With the clutch disengaged, the crank-disc can be operated in either direction by the hand crank.

The Valve

A small poppet-valve is installed inside of part *a*, and constitutes the heart of the mechanism. This valve is opened for a very small interval of each cycle of the engine being tested. The valve head is located to the left of the part *a* so that, when opened, it completes communication between the manifold and the indicator attached to part *a*. The valve is made carefully so that no packing is required on its stem to prevent leakage from the indicator cylinder from cycle to cycle of the engine.

Variable Valve-Opening During the Cycle

The vertical shaft on the center-line X-X is in two parts, the upper part being driven from the lower part through a conventional differential-mechanism. Attached to the upper shaft is the small disc *c*, the purpose of which will be explained later. Disc *d* has a hollow extension that encloses the upper shaft and carries a cam within the housing at point *e*. This cam operates the small poppet-valve through a suitable rocker-lever, also enclosed in the housing, and an adjustable tappet, the end of which is shown. The clearance should be made from 0.003 to 0.005 in. between the valve-tappet and the valve-stem.

The movement of the differential carrier and, therefore, that of the satellite gears, is controlled by suitable gears between the crank-disc shaft and the differential carrier. By moving the differential carrier, the discs *c* and *d* when clamped together as shown can be moved faster or slower than the lower vertical-shaft as the case may be. This means that the cam can be advanced or retarded with reference to some particular point in the engine cycle. The gears between the crank-disc shaft and the differential carrier are proportioned so that the cam is advanced or retarded one full turn for two turns of the crank-disc. Since the crank-disc shaft rotates very slowly, the cam is only moved very slightly from cycle to cycle. Thus, the pressure within the engine cylinder forces a small volume of gas into or from the indicator cylinder at a certain point in the cycle. While the engine crankshaft makes the next two turns, the crank-disc moves a very small distance, thus moving the indicator drum through the connecting-rod, the crosshead

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and the cord, and the cam is moved slightly forward or backward so that the valve is opened in the next cycle at a slightly different point. Hence, but a small segment of the final diagram is obtained from an individual cycle of the engine.

Crank-Disc Use on Multi-Cylinder Engines

The crank-disc is made regularly with 24 drilled and reamed holes spaced equally on the circumference of a circle of 1⅝-inch radius as shown in Fig. 4. The stroke of the crosshead is then 3¼ inches. A movable crank-arm is mounted on this crank-disc. This crank-arm is held in position by the point of the knurled screw that fits into any selected hole in the crank-disc. This crank-disc can be considered as the crankshaft of the engine, operating at a very low speed. The hole marked 0-360 deg. can be considered as the crank for cylinders Nos. 1 and 4 of a four-cylinder engine. In this case, the hole marked 180 deg. would be the hole used in obtaining power diagrams from cylinders Nos. 2 and 3. In the case of a six-cylinder engine, hole 0-360 deg. might be used for cylinders Nos. 1 and 6. Hole 120 deg. would then be used for either cylinders Nos. 2 and 5 or Nos. 3 and 4, and hole 240 deg. would be used for cylinders Nos. 3 and 4 or Nos. 2 and 5 according to the firing order of the engine. In the case of an eight-cylinder engine with equal firing intervals, the 0, 90, 180, and 270-deg. holes would be used. This standard crank-disc can be used on anv engine for which the firing intervals are in multiples of 15 deg. Hence, it can be used on a 30, 45, 60, or 90 deg. V-type engine. If it should become necessary to test a 42-deg. V-type engine, it is possible to replace this crank-disc with another having its holes specially located.

In the case of the four-cylinder engine already mentioned, the offset diagrams are made by using the hole at 270 deg. for cylinders Nos. 1 and 4 and the hole at 90 deg. for cylinders Nos. 2 and 3. In like manner, a hole at 90 deg. from the hole used to obtain a power diagram can be used in all cases for obtaining offset diagrams.

In obtaining lower-loop diagrams, the same holes in the crank-disc are needed as when obtaining the power diagrams. It is necessary to provide a rather light spring for use in the indicator, and also a stop on the piston of the indicator to protect the indicator spring from distortion and damage.

Timing the Indicating-Device

It is necessary to time the device so that true and accurate diagrams can be obtained. The procedure is to set three parts and to clamp but two parts together, after arranging a positive drive from the engine for the lower horizoltal-shaft and connecting the tubes from the manifold to the several cylinders. Let it now be assumed that the engine has four cylinders and that it is desired to use holes 0 and 180 deg. in obtaining the power and the lower-loop diagrams. First, the engine must be set so that pistons Nos. 1 and 4 are on their upper dead-center. Second, turn the movable crank so that the knurled pin can be placed in hole 0 deg. of the crank-disc. Then turn the crank-disc until the crosshead is in its upper dead-center position, where it can be held by a timing-pin, not shown in Fig 4, dropped through another of the holes into a hole in boss *f*. Third, it is necessary to arrange to have the valve open at this time. This is done by loosening the cap-screws holding parts *c* and *d* together, so that part *d* can be rotated to have the hole *g* opposite a corresponding hole in boss *h* on the housing. Another timing-pin is then put through boss *h* into hole *g* to hold part *d* in position while the cap-screws that make a unit of parts *c* and *d* are being tightened. The engine is now on dead-center for pistons Nos. 1 and 4, the crosshead is in its corresponding dead-center position, the cam it in position to hold the valve open and the timing clutch *cd* is tightened. The timing-pins in the crank-disc, and in the cam-disc *d*, should now be removed.

Operation on the Engine

All selection valves should be closed and the cooling-water should be circulated around the tubes and through the manifold before starting the engine. A suitable spring is placed in the indicator and its cylinder is filled with heavy oil before attaching the indicator at part *a* and connecting the cord with the drum to the crosshead. With the engine warmed-up, it is now necessary to open the selection valve to cylinder No. 1, to have the crank-pin in hole 0 deg., and to engage the clutch whereby the entire mechanism is operated by the engine. This clutch, which is a jaw-type clutch, is engaged by pulling the hand crank axially as indicated in Fig. 4. The diagram for cylinder No. 1 will then be built-up part-by-part, 1600 revolutions of the engine crankshaft being required to complete it. The mechanism can then be stopped by moving the hand crank axially to disengage the clutch. A new card can then be placed on the indicator drum, the selection valve to cylinder No. 1 closed and that to No. 4 cylinder opened. A diagram can then be obtained from cylinder No. 4. To obtain diagrams from cylinders Nos. 2 and 3, it is not only necessary to open the proper selection-valve but also to change the crankpin to hole 180 deg. in the crank-disc. A similar procedure is necessary on six and on eight-cylinder engines, care being taken to select the proper holes in the crank-disc and to open the proper selection-valves.

The Cam Throw-Out and the Atmospheric Line

At times, it is advisable to operate the engine without operating the valve in part *a*. Provision is made to do this by lifting the pin *j* and moving the lever *k* into the position shown in dotted lines in the top view. This moves the cam follower away from the cam by means of an eccentric inside the housing.

The atmospheric line can be obtained when testing a four or a six-cylinder engine by opening one of the extra selection-valves and pulling the cord by hand while the valve in part *a* is operating. On an eight-cylinder engine, a small relief-cock can be fitted into one of the small plugged-holes in the manifold and operated for this same purpose.

Advantages in Test Work

The advantages of this type of indicating-device are many, even now, although the field for it has not been investigated extensively. The composite diagram, built-up over a great number of cycles which, individually, are not generally alike, is a distinct gain over anything else that has been tried before. The diagram is built-up part-by-part before the eyes of the test engineer; so, he always has a check on operating conditions from the viewpoint of the engine portion of the testing equipment. The diagram is then available for study and analysis as soon as drawn, without recourse to photographic or other processes.

By means of the crank-discs any part of the cycle, such as the combustion-line, can be extended over a large part of the diagram, thus enabling a more minute study to be made. Offset diagrams easily can be made to show the valve action in greater detail than is indicated in the lower-loop diagrams shown in Fig. 3. The device enables rapid and accurate work to be done when investigating the fluid processes of multi-cylinder engines, which to date, can be accomplished only by expending a great amount of time and money. In fact, such investigations have not yet been made, although the need certainly exists. Variations in valve timing, valve lift, ignition timing, and other things affecting individual cylinders become apparent immediately and can be corrected.

The Field for the Device

To date, one of these indicating-devices has been used for at least 500 hr. of test and research work in the engineering experiment station at Ohio State University, and has given entire satisfaction as to performance and results. The device easily can be used in routine or line test-work in manufacturing. If small and inexpensive provisions are made on engines in production, the device can be used in service-stations to check valve fits, ring fits, ignition setting, carburetor adjustments, and other things that, at best, are now done only by guesswork.