DOBBIE-McINNES

THE ENGINE INDICATOR

DIESEL :: STEAM

WITH

SPECIMEN DIAGRAMS

SHOWING

ENGINE FAULTS

DOBBIE McINNES LTD
191/3 BROOMLOAN ROAD, GLASGOW, S.W.1
and
LONDON · LIVERPOOL · SOUTH SHIELDS

"DOBBIE-McINNES" INDICATORS

MANY engineers will remember the "McInnes" Indicator, the immediate forerunner of the "McInnes-Dobbie" design, which in turn gave way to the modern "Dobbie-McInnes" type. This latest range, incorporating new patents, is available for the testing of reciprocating engines, pumps, compressors, refrigerators of all speeds ranging from those of the low speed steam engine to the high revolutions of aero- and automobile engines.

In this booklet, the advantages of continuous indicating are dealt with, and detailed suggestions are made for obtaining the best results from the mechanical type of 'Dobbie-McInnes' Indicator. Diagrams showing engine faults are also included. The "Dobbie-McInnes" 'Farnboro' Electric and other High-Speed Indicators, also Indicators and Pressure Recorders for special purposes, are dealt with in other booklets or catalogues, which will gladly be supplied on request.

Owing to the improvements continuously being made to our Indicators and to the introduction of new designs, we need hardly remind users to avoid indicators termed McInnes Pattern, Improved McInnes, McInnes-Dobbie Pattern, or bearing any names other than our trade designation **'DOBBIE-McINNES'** which, with our full name, **Dobbie McInnes Ltd.** appears on both instrument and box. In cases of doubt, enquiry to our Works at **191/3 Broomloan Road, Glasgow, S.W.1** will be welcomed.

THE VALUE OF INDICATOR DIAGRAMS

THE Indicator is a means of recording the pressure and rate of pressure change in an engine cylinder at all points of the cycle, and provides as well an important indication of the efficiency and working of details of the engine. With proper study of the diagrams, **maximum economy with a low fuel bill, small cost of repairs, greater output, an even speed, absence of breakdowns, minimum loss from depreciation** and consequently **longer life** can be attained. Therefore Indicator Diagrams should be taken frequently to enable recorded faults to be corrected immediately.

THE DIESEL ENGINE

Valve Adjustment—Frequent indicating of Diesel Engines is of special importance owing to the fineness of valve adjustment and because of the extent by which a small alteration or slight wear can affect engine conditions. Incorrect timing of the fuel valve may result in pre-ignition, loss of power and damage to the engine. Intake and exhaust valve setting errors may cause poor volumetric efficiency, increased pumping loss, and incomplete combustion. The indicator diagram besides showing the points of valve opening and closing, records incorrect cam-setting and roller clearance, also combustion time lag.

Combustion; Resistance—Correct combustion can only be obtained by ascertaining that the grade and viscosity of fuel, resistance of the spray valve, etc., are correct. Theoretically combustion should begin immediately the fuel enters the cylinder and end when the fuel valve closes. Resistance in the inlet and exhaust passages are shown on the light spring diagram by low intake and high exhaust lines resulting in a high pumping loss.

Mean Pressure ; Power—The Indicator Diagram is the only means of obtaining the **i.m.e.p.** (indicated mean effective pressure) and **i.h.p.** (indicated horse power) of an engine and from these its efficiency of operation is obtained. The area of the p-v diagram represents work done and shows if the engine is uneconomically over or under loaded.

Efficiency ; Fuel Consumption—The Indicator is used to determine power absorbed by the engine, power used to drive compressors, scavenge pumps, camshaft, etc., and the heat loss by radiation and conduction. It is also used in the computation of engine losses, mechanical, thermal and volumetric efficiencies, and the fuel consumption per i.h.p. hour.

Power Distribution—Many troubles in Diesel practice result from unequal power distribution between the cylinders, causing overloading or underloading of some of the cylinders. Comparison of the diagrams taken from all the cylinders indicates where the fuel supply is unbalanced.

Wear—Wear in the crosshead, crankpin, and crankshaft bearings, also leaky pistons and valves are shown by a loss of compression pressure. As a small amount of wear causes a noticeable reduction of compression pressure, the Indicator is a valuable guide in this respect.

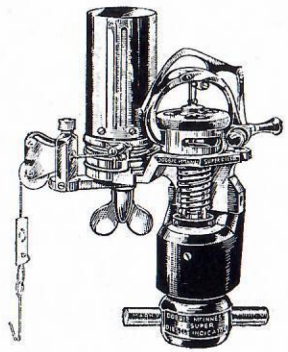
THE STEAM ENGINE

Valves ; Steam Passages—Derangement of valve gearing is revealed on the diagram by late admission or release, low initial pressure or high back pressure, or by absence of compression, all of which produce high steam consumption. The causes of the faults may be incorrect valve setting, faulty lap and lead, incorrect lengths of eccentric connecting rods. It should be remembered that although compression occasions a loss in the form of increased back pressure, this loss is compensated for by the reduction in clearance waste, in overcoming momentum of the reciprocating parts and by economy in steam consumption. The diagram also shows undue wire-drawing through insufficient size of inlet and exhaust passages.

Power—As the i.h.p. consists of the net power delivered plus that consumed in propelling the engine, the Indicator provides a means of estimating the power absorbed by machines to which the engine may be coupled. The engine is indicated with and without the machines coupled to it, the difference giving the required result. Over or under loading are also shown, attention to which makes for longer life of the engine.

Feed-Water Tests—The indicator is used for determining the steam consumption per i.h.p. hour giving a measure of the engine performance. A portion of the feed-water consumption may be found directly from the Indicator Diagram, but it should be remembered that leakage and cylinder condensation are not allowed for and that the computations are approximate.

Leakage ; Condensation—These losses are represented by that part of the feed-water consumption remaining after deducting the steam accounted for by the diagram. Cylinder condensation, being nearly constant for engines working under similar conditions, may be estimated. When the Indicator and feed-water test show more loss than should be produced by condensation, the excess represents the probable loss by leakage.



ERECTING INDICATOR ON ENGINE

INDICATOR REDUCING GEAR

IN order that the indicator drum movement shall be in direct proportion to the engine piston movement, accuracy in the reducing gear is essential. During recent trials of a Diesel Engine, 10 per cent. to 12 per cent. variation in the i.h.p. result was produced by only a $\frac{1}{2}$-degree error in the reducing gear cam setting on the cam-shaft. In general:—

(1) The indicator lead motion should always be proportional to that of the engine piston.

(2) The gear setting should prevent the indicator drum from reaching either stop.

(3) Play in the gear must be avoided.

(4) The indicator lead should be taut, as inelastic as possible, and free from kinks.

(5) Change-direction pulleys for the lead should be few, light, of reasonably large diameter, well-lubricated and not slack.

Lever Type Gears as used for steam engines are often incorrectly designed and give an inaccurate diagram because the lead motion is not proportional to that of the engine piston. Figs. 1 and 2 show correctly designed lever type gears.

Differential Pulley Gears—The "Dobbie-McInnes" 'Wade' Reducing Gear, consisting of a small pulley wound with the indicator drum cord, and on the same spindle a large wheel to take the lead from the engine crosshead, is an accurate type of differential gear. It is compact and fitted to the indicator itself.

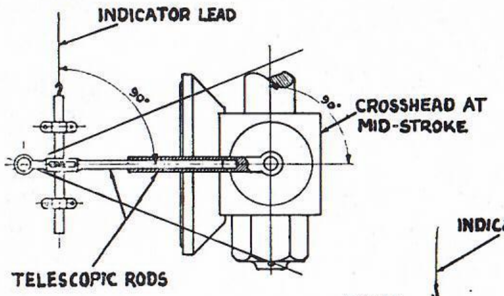


FIG. 1.

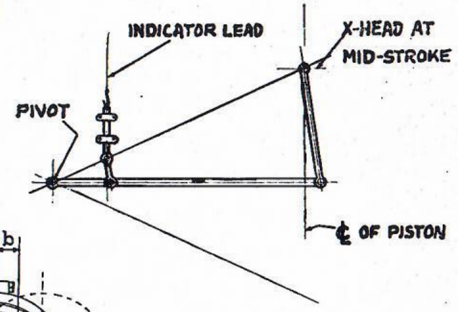


FIG. 2.

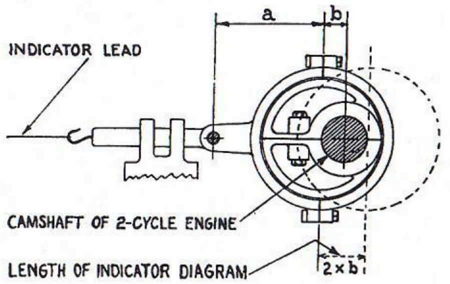
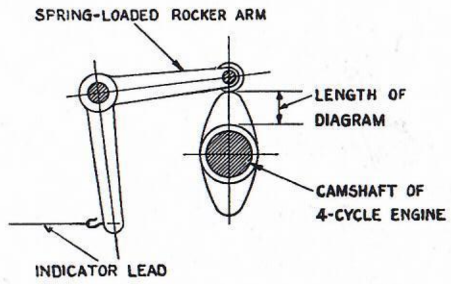


FIG. 3.

FIG. 4.



INDICATOR REDUCING GEAR FOR DIESEL AND STEAM ENGINES

Crank Gears—The "Dobbie-McInnes" Crank-type Gear, used for their higher speed indicators, provides a diagram 2 ins. long. It may be adjusted for various crank connecting rod ratios and runs in an oil bath.

Eccentric and Cam Gears—Most Marine Diesel Engines drive the indicators from the camshaft which is generally near the indicating points. Fig. 3 illustrates an eccentric type gear for 2-cycle engines; it is a small reproduction of the connecting rod and crank and therefore a/b must equal the connecting rod to crank ratio. Fig. 4 shows a double profile cam gear as used on 4-cycle engines; in this type it is important that the profiles are designed to allow for eccentricity of the connecting rod.

(For additional information, see *British Standard Specification* No. 412-1935.)

CONNECTING THE INDICATOR

The **tail pipe** from engine cylinder to indicator should be as free from bends as possible (especially in the case of Diesel Engines) and such that the ratio of its length to its bore is small. The indicator cock is screwed in position preferably with a grummet ring and red lead under the lock-nut to prevent leakage. For Diesel Engines the **"Dobbie-McInnes" Valve** should be used as it is heat-resisting and specially designed for high pressures.

A lead consisting of indicator cord, steel tape or wire is stretched between the reducing gear hook and a spring anchored to the engine casing, the spring keeping the lead taut and relieving the drum spring. The lead is taken close to the indicator, the spring being beyond it, and a loop is made for the drum cord hook.

Change Over Cock—To enable the top and bottom of a Steam Engine cylinder to be indicated with one instrument, two copper pipes are led to a change-over cock to which the indicator cock is screwed; the "top" diagram may then be obtained on the same card as the "bottom" and immediately after it. The fitting may be obtained with the instrument if desired.

MANNER OF TAKING DIAGRAMS

A BLANK card is stretched on the drum and the cord hook is attached and adjusted so that the drum is clear of the stop at each end of its travel. For the **split-ring type hook :**

(1) With hook held in position shown, thread end of drum cord through eye.

(2) Pull sufficient cord through eye for desired position of hook; pass end **under** lead from drum and continue **over** shank of hook.

(3) Pull tight between coils of eye. The hook now grips cord positively.

(4) If necessary, or to ensure no slip during indicating, repeat (3) but carry end **over** lead and **over** shank, again pulling tight.

To adjust position of hook on cord, reverse (4) and (3), move hook to new position and repeat (3) and (4), retaining hold of end of cord throughout.

After cleaning and oiling piston and cylinder, a suitable pressure spring is fitted and, on re-assembly, the pencil pressure regulating screw is adjusted for a fine trace with minimum pressure. For a Steam Engine the cock is opened for a few seconds to warm the indicator and remove condensation. In Diesel practice, as flame may reach the indicator, the tail-pipe should be cleaned before mounting the instrument.

When the required engine conditions are reached, the drum cord is hooked to the lead, the cock is opened and the pencil put in contact with the paper for one cycle only. On closing the cock, the atmospheric line is drawn. For a Diesel cylinder the diagram will probably be representative, but for a Steam Engine it is advisable to average a series of cards.

Diagram paper printed for inclusion of test particulars—date, engine conditions, etc.—is supplied by us to order.

In view of the important information provided by the Indicator, diagrams should preferably be taken every three days.

SPECIAL INSTRUCTIONS

Lubrication—An oil of moderately low viscosity which should not gum at the temperatures encountered nor deposit abrasive solids, should be used for the piston. "Dobbie-McInnes" Special Indicator Oil is recommended and it should be applied on cleaning the piston before and after use and at frequent intervals during tests: for Steam say every half-dozen diagrams and for Diesel even more often. Poor lubrication results in a stepped, not wavy, diagram or in piston seizure.

Pencil Point and Pressure—The pencil should be sharpened so that it traces a fine line without tearing the paper, and the adjusting screw should be set to prevent excessive pencil friction.

Pressure Springs—For slow speed engines, the lightest spring that will accommodate the maximum pressure is best, but for the higher speeds, a heavier spring should be employed to restrict the travel of the piston and to prevent a wavy expansion line. Before indicating, ensure all screwed connections of spring, piston rod and covers are tight. When removing spring, first unscrew the milled head between piston and parallel motion.

Drum Spring—The drum spring torque should be sufficient to keep the cord taut; for the higher speeds the torque should be increased. The drum spring is intended to return the drum and cord only and not the reducing gear as well ; see under "Connecting the Indicator" (page 7)

Drum Travel—Like piston travel, this should also be reduced for high speeds. For slow speed Steam Engines a diagram length of 4 to $4\frac{1}{2}$ in. is usual ; for Marine Diesel Engines $3\frac{1}{2}$ in., and for the higher speeds 2 in. to $1\frac{1}{2}$ in.

Absolute Pressure—During Steam Engine tests, the barometric height should always be noted for calibration of the atmospheric pressure line.

MEASUREMENT OF I.M.E.P. AND I.H.P.

MID-Ordinate Method—Two lines perpendicular to the atmospheric line are drawn at each end of the diagram and the intervening space is divided into ten equal parts, which are in turn equally sub-divided by mid-ordinates. The average length of the mid-ordinates bounded by the diagram outline is divided by ten and the result in inches is multiplied by the spring strength to give the i.m.e.p. With "Dobbie-McInnes" Indicators, a **Radial Divider** is supplied for plotting the mid-ordinates instantaneously.

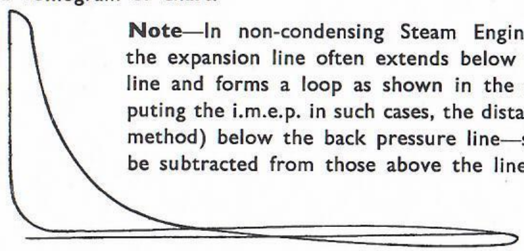
Planimeter Method—This is theoretically more accurate than the above method as the planimeter takes into account all peculiarities of the diagram outline. "Dobbie-McInnes" Planimeters are specially designed for indicator diagrams.

I.H.P.—The horse-power is obtained from the i.m.e.p. by a simple calculation:—

If p_m = i.m.e.p. in lb./sq. in.,
l = piston stroke in feet,
a = cylinder area in sq. in.,
n = number of working strokes (not revolutions) per min.,

Then $\text{i.h.p.} = \dfrac{p_m.l.a.n}{33{,}000}$ per cylinder.

This calculation may however be avoided and the i.h.p. read directly from a nomogram or chart.



Note—In non-condensing Steam Engines on light load, the expansion line often extends below the back pressure line and forms a loop as shown in the diagram. In computing the i.m.e.p. in such cases, the distances (mid-ordinate method) below the back pressure line—see page 19—must be subtracted from those above the line.

ENGINE EFFICIENCY

MECHANICAL Efficiency depends upon the power lost in driving the engine itself. It has been greatly improved by recent changes in design notably by the introduction of airless injection. It should be less in the case of 2-cycle than of 4-cycle Diesel Engines since the latter are not fitted with scavenge pumps. From the Indicator Diagram:—

$$\text{Mechanical Efficiency } (\eta_m) = \frac{\text{brake mean pressure}}{\text{i.m.e.p.}} \text{ or } \frac{\text{b.h.p.}}{\text{i.h.p.}}$$

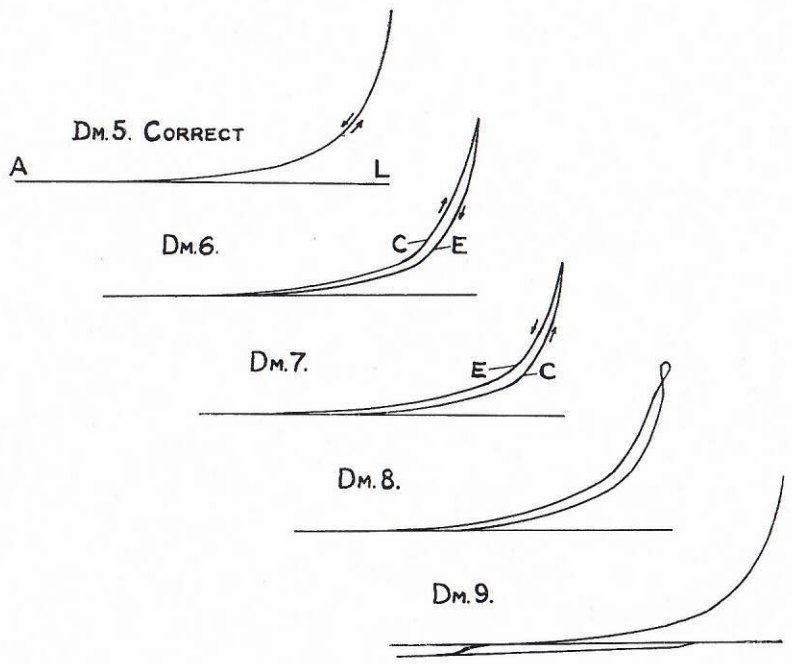
Thermal Efficiency is governed by the heat lost to the cooling water and exhaust gas (Diesel) and by radiation and conduction, and is found from the i.h.p. converted to heat units:—

$$\text{Thermal Efficiency } (\eta_\theta) = \frac{\text{i.h.p. in B.Th.U. per min.}}{\text{heat from fuel in B.Th.U. per min.}}$$

Overall Efficiency$= \eta_m \times \eta_\theta$

Fuel or Steam Consumption—Diesel Engine performance is also measured by the Fuel Consumption per i.h.p. hour, diagrams being taken over a period while the Fuel consumed is weighed. The Steam Engine Equivalent is the Feed Water Test.

Volumetric Efficiency is important when considering Diesel output, and is the ratio of the volume of air at normal temperature and pressure drawn into the cylinder during intake to the piston-swept volume. Air intake resistance, faulty valve timing and small valve lift cause low volumetric efficiency. For comparative purposes only, it can be measured approximately from the indicator light spring diagram by dividing the distance between the toe of the diagram and the point where the compression line cuts the atmospheric line by the total diagram length (see, however, Diagram 18—supercharged engine).



COMPRESSION DIAGRAMS

DIESEL ENGINE INDICATOR DIAGRAMS

COMPRESSION Diagram—Before taking power diagrams, possible faults in the Reducing Gear or Indicator should be tested by a Compression Diagram. For pressure-volume cards, the compression and expansion lines on no fuel should appear coincident.

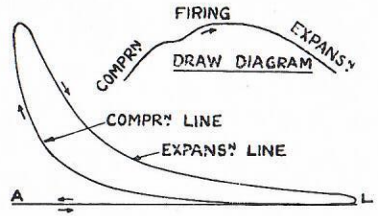
Diagram 5—Correct Compression Diagram. AL=atmospheric line.

Diagram 6—Expansion line (E) below compression line (C); correct height of diagram. Fault: play in the reducing gear.

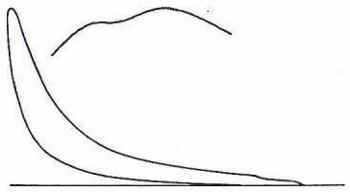
Diagram 7—Expansion line (E) above compression line (C); peak of diagram low. Fault: indicator valve and tail pipe require cleaning.

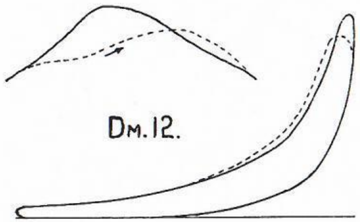
Diagram 8—Diagram looped. Fault: defective reducing gear due to oscillating lead, use of bad pulleys, or incorrectly profiled cam.

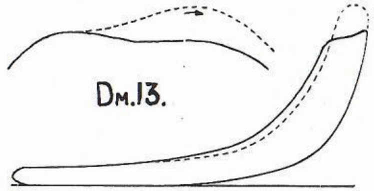
Diagram 9—Part of diagram below atmospheric line. Fault: Indicator motion pivots slack through wear.

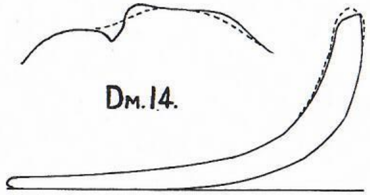


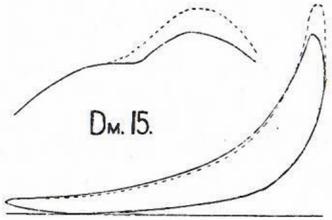
Dm. 10. 4-Cycle – Correct.

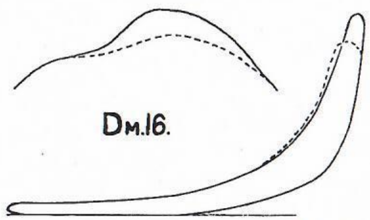

Dm. 11. 2-Cycle – Correct.

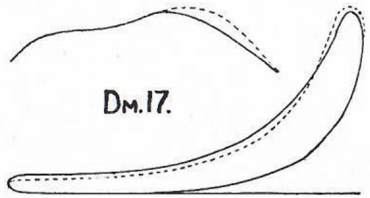

Dm. 12.


Dm. 13.


Dm. 14.


Dm. 15.


Dm. 16.


Dm. 17.

POWER DIAGRAMS

P-V **Power Diagram and Draw Card**—The compression card having checked the reducing gear setting, power diagrams are obtained and it is advisable to take a draw card on the same paper with an out-of-phase gear or by pulling the drum cord by hand. The dotted lines on the following diagrams show the effect of the required adjustments (4-cycle engine).

Diagram 10—Correct 4-cycle Power Diagram with Draw Card, taken with "Dobbie-McInnes" Mark V Indicator (see its latest development—page 22).

Diagram 11—Correct 2-cycle Power Diagram with Draw Card also from Mark V Indicator.

Diagram 12—Injection too early, resulting in high maximum pressure, low exhaust temperature, knocking, probably normal fuel injection pressure and greater economy but greater danger to white metal bearings, etc. due to overstressing.

Diagram 13—Injection too late, causing loss of power (pressure rise should start at top centre), reduced economy and poor combustion with smoky exhaust.

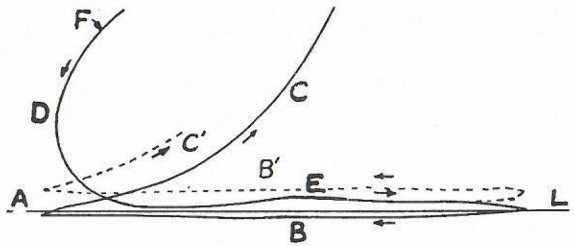
Diagram 14—Late injection and small resistance in atomiser showing fuel cam retarded and too few atomiser rings or insufficient staggering of holes (air injection engine).

Diagram 15—Restricted spray valve nozzle giving very high injection pressure and severe knocking, also delayed combustion and smoky high-temperature exhaust (supercharged engine).

Diagram 16—Insufficient nozzle resistance and valve lift ; valve timing correct.

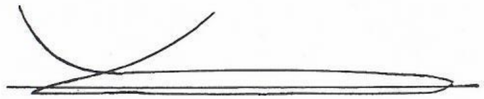
Diagram 17—After-burning causing bad combustion, high fuel consumption and high exhaust temperature. If fuel valve setting correct, fault may be resistance to exhaust and insufficient clean air in the cylinder.

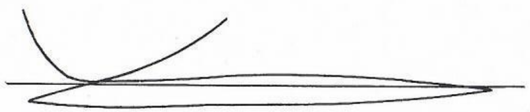
At high speeds or with some engines at normal speeds, a wavy expansion line may be produced. If it is inconvenient to use a stronger spring or a higher speed indicator, it should be remembered that a mean line drawn through the waves will give the correct diagram outline.



DM.18.
CORRECT.

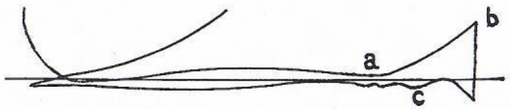
DM.19.





DM.20.

DM.21.



LIGHT SPRING DIAGRAMS

Light Spring Diagram—Examination of the Intake and Exhaust Lines of a 4-cycle P-V Power Diagram is possible if a light spring is substituted for the heavy pressure spring, the lower part thus being magnified. The shape of the Light Spring Diagram varies slightly with the make of the engine and even with the cylinders of the same engine. A diagram showing a square toe for instance may be due to one of the other cylinders exhausting while the piston of the cylinder in question is near top centre. In double-acting engines a pressure of 4 lb./sq. in. is often registered at the toe of the diagram through this cause. The loop of the diagram represents pumping loss, but can be neglected when measuring i.m.e.p.

Diagram 18—Normal 4-cycle Light Spring Diagram.

B—Intake Line	E—Exhaust Line
C—Compression Line	F—Exhaust Opens
D—Expansion Line	AL—Atmospheric Line

Note—Light Spring Diagrams from supercharged engines may take the form shown by the dotted line (B above E and AL).

Diagram 19—Exhaust obstructed, causing high exhaust line and increased pumping loss.

Diagram 20—Intake pipe slots obstructed, causing low intake line, large pumping loss and low volumetric efficiency.

Diagram 21—Early exhaust valve closing at **a,** causing pressure rise until inlet valve opens at **b.** Wavy line at **c** is produced by resulting indicator spring oscillation. Poor combustion and increased pumping loss result from this fault.

The light spring should not be too light, 16 to 30 lb./sq. in. per inch being the usual strengths employed.

TECHNICAL PRESS

The following books can be recommended for additional information:—

1 **"ELEMENTARY INTERNAL COMBUSTION ENGINES,"**
By J. W. Kershaw, M.Sc.
Published by Longmans, Green & Co., Ltd., 43 Albert Rd., London, S.W.19.

2 **"MARINE ENGINE INDICATOR CARDS,"**
By J. W. M. Sothern, M.I.E.S., M.I.Mar.E.
Published by Crosby, Lockwood & Son, Ltd., 20 Tudor Street, London.

3 **"INDICATOR DIAGRAMS FOR MARINE ENGINEERS,"**
By W. C. MacGibbon, M.I.Mech.E.
Published by James Munro & Co., Ltd., 16 Carrick Street, Glasgow, C.2.

4 **"THE RUNNING AND MAINTENANCE OF THE MARINE DIESEL ENGINE,"**
By John Lamb, M.I.Mar.E.
Published by Charles Griffin & Co., Ltd., 43 Drury Lane, London, W.C.2.

5 **"THE TESTING OF HIGH SPEED INTERNAL COMBUSTION ENGINES,"**
By Arthur W. Judge.
Published by Chapman and Hall, Ltd., 37-39 Essex Street, London, W.C.2.

6 **"MARINE DIESEL OIL ENGINES—A Manual of Marine Oil Engine Practice,"**
By J. W. M. Sothern, M.I.E.S., M.I.Mar.E.
Published by Crosby, Lockwood & Son, Ltd., 20 Tudor Street, London.

THE STEAM ENGINE INDICATOR DIAGRAM

THE outline depends largely on the type of engine ; that shown in Fig. 6 is a representative diagram showing the essential features.

Steam is admitted at A and the pressure rises to B, the piston being on top centre. This drives the piston to C, with steam still entering. Here the slide valve begins to close until at D the steam is completely cut off. From D, the steam expands driving the piston before it until at E the slide valve opens and the steam exhausts. The piston returning from bottom centre drives the remaining steam through the exhaust port until the slide valve closes at H. From H to A, what steam is left in the cylinder is compressed to the pressure at A.

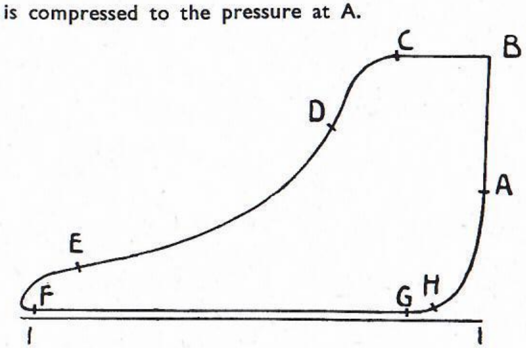


Fig. 6

The names of the various points and lines of the steam diagram are:—

AB—Admission Line
BC—Steam Line
D—Point of Cut Off
DE—Expansion Line
E—Point of Release
FG—Exhaust or Back-pressure Line
H—Point of Compression
HA—Compression Line
I J—Atmospheric Line

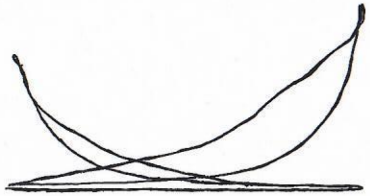
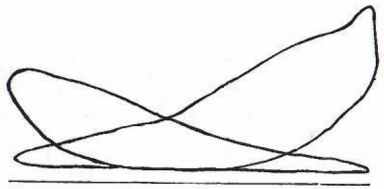


Diagram No. 22
From Locomotive
Valves set by sound.
Speed, 208 revolutions per minute
Scale 80 1st Notch

Diagram No. 23
From Locomotive
Valves set by sound.
Speed, 210 revolutions per minute
Scale 80 3rd Notch



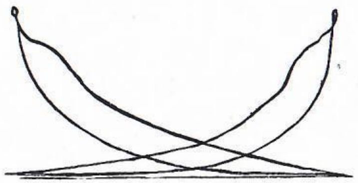
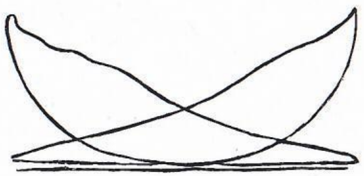


Diagram No. 24
From Locomotive
Correct Adjustment
Speed, 204 revolutions per minute
Scale 100 1st Notch

Diagram No. 25
From Locomotive
Correct Adjustment
Speed, 198 revolutions per minute
Scale 100
Between 2nd and 3rd Notches



THE USE OF THE INDICATOR ON LOCOMOTIVES

SINCE locomotives consume a large quantity of fuel, it is importan that indicator diagrams should be taken frequently. Some time ago the following figures were obtained to show the saving in fuel costs that might follow from indicating the engines of a railway company. The company operated 200 miles of road and used 1,200 tons of coal daily at an annual expenditure of £175,000. If the application of the indicator had resulted in a fuel saving of only 5 per cent., the coal bill would have been reduced by £8,750 per annum.

To illustrate the benefit derived from indicating locomotives, diagrams are appended that were taken on a road not hitherto employing the indicator.

Diagrams Nos. 22 and 23 are from an engine that had received the usual valve adjustment in the shop. When on the road the engineer thought from the sound of the steam that the exhausts were uneven and adjustment was made until the desired uniformity was secured. The diagrams were then taken as shown, the reversing lever being in the first notch for the first set and the third notch for the second set, and they showed an obviously poor balance of steam admission, a large difference between admission pressures, and a considerable waste of steam.

Diagrams Nos. 24 and 25 were obtained from an engine with more accurate adjustments and show a marked improvement as a result of indicating.

With a guard to protect the operator, diagrams may be obtained from a moving locomotive with ease and at the rate of one set per minute per cylinder. The **"Dobbie-McInnes" 'Cipollina' Indicator** which is automatic in action and obtains simultaneous and continuous diagrams is frequently used for locomotive work and is strongly recommended.