STEAM ENGINE OPERATION COURSE

LESSON No. 10

THE INDICATOR—INDICATOR DIAGRAMS—ENGINE—HORSE POWER

Synopsis:

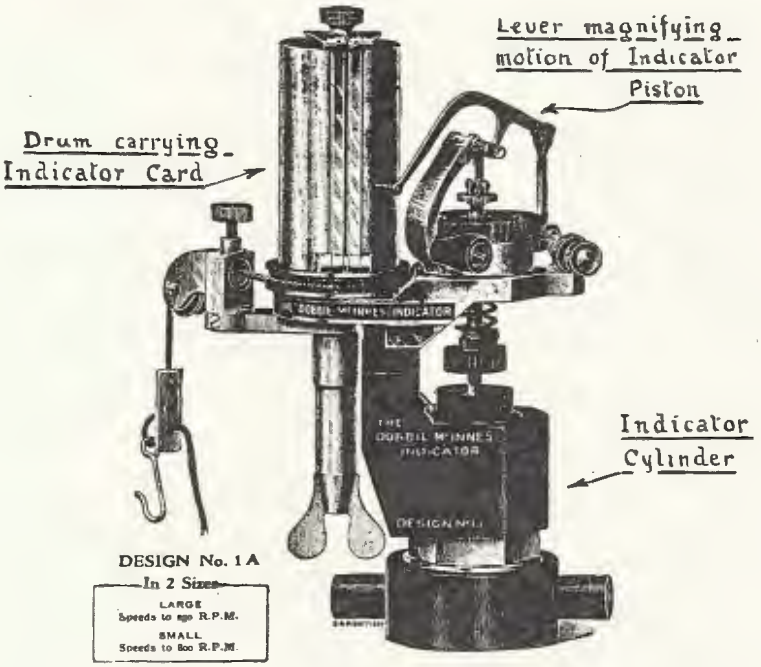
10.1. The Indicator.
10.2. How to take an Indicator Diagram.
10.3. The Indicator Diagram.
10.4. Characteristic Diagrams.
10.5. Finding the M.E.P. from an Indicator Diagram.
10.6 Calculating the I.H.P.
10.7. Brake Horse Power and Mechanical Efficiency.
10.8. Certification of Engine-drivers.

10.1. THE INDICATOR

The importance of the indicator as a means of testing an engine's performance under various conditions cannot be too strongly stressed and the fact that the instrument is not made as much use of as it should be, in the efficient and economical running of steam engines, is to be deplored.

In Lesson No. 1, Para. 1.12, it was shown, briefly, that the indicator diagram gives a graphical picture of exactly what is going on in the engine cylinder and from the diagram the Mean Effective Pressure in the cylinder can be calculated, thus enabling the I.H.P. of the engine to be determined.

The indicator is defined as an instrument used for the purpose of recording the pressure of the steam in the cylinder, at all points of the stroke, as the piston moves to and fro. The record is made on a piece of specially prepared paper, secured to a rotating drum, by a steel point on the arm attached to the indicator piston.



ENGINE INDICATOR.

FIG. 10·1·2

The indicator is said to have been invented by James Watt, but it was at first vastly inferior in finish and accuracy to the improved forms now in use; these are all substantially of the same construction and act upon the same principle.

The indicator consists of a small cylinder accurately bored out and fitted with a piston capable of working in the cylinder with little or no friction and yet practically steam tight; the piston rod is attached to a pair of light levers at the end of one of which is carried a pencil designed to move on a parallel line to the axis of the drum.

The motion of the piston is controlled by a spring of known tension, several of which are supplied with each instrument; each spring is marked to show at what steam pressure it is to be used. The elasticity of the spring is such that each pound pressure on the piston causes the pencil to move a certain fractional part of an inch.

Attached to the instrument is a drum which has a diameter of about two inches, and around which is placed the paper, the ends passing underneath a clip, so fitted that the paper can be firmly held.

The drum is capable of a semi-rotative motion on its axis to an extent that permits of the extreme length of the diagram being about five inches; motion is imparted to this drum by a cord attached to suitable reducing gear driven from the engine cross head; thus the drum is made to reciprocate synchronously with the engine piston as shown in Fig. 10.1.2. Fig. 10.1.1 illustrates a complete instrument of the outside-spring type, that is, the spring is external, whereas, the spring is within the cylinder in the inside spring type.

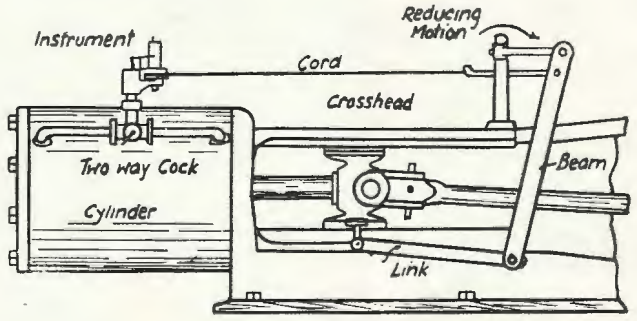


FIG.10·1·2

The working principle of the indicator is illustrated in Fig. 10.1.3.

A small cylinder A is screwed into the cylinder communicating with the clearance space B.

The small piston C works within A against the steam pressure in B by means of the spring D.

E is a horizontal arm attached to the piston C, and carrying on its outer end a pencil point F.

The carrier bar G carries a sliding board H to which a sheet of paper it attached; this is moved back and forth in step with the movement of the piston J by means of the spring R and the Lever L, which is attached to the crosshead M.

To follow the operation, assume the piston J to be at its inner dead centre and the clearance space B empty, or at the atmospheric pressure; the small piston C will be down and the pencil point at F.

Now, as steam is admitted to B the increasing pressure will force the piston C to rise, against the spring, carrying the pencil F vertically to the point N until the steam pressure is sufficient to move the piston J.

If this pressure is kept constant while the piston J travels from O to P, the pencil will draw the horizontal line from N to R as the board moves in the direction of the arrow. As the pressure is not kept constant, cut-off occurring at some part of the forward stroke of J, the pressure begins to fall and falls rapidly as the piston J completes its stroke.

As the pressure falls the small piston C comes down under the influence of the spring and as the board is moving in unison with the piston J as a curve is drawn by the pencil from R to S.

The return of the piston J moves the board in the opposite direction and the pencil traces a horizontal line from S to F, thus completing the diagram, the area of which graphically represents the work done in the cylinder.

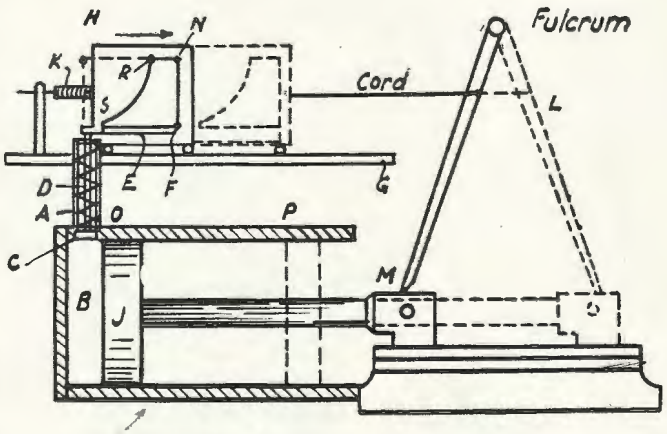
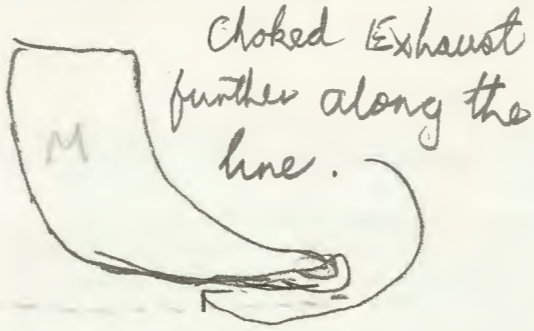
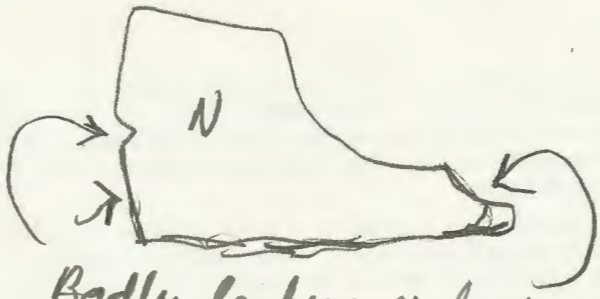


FIG.10·1·3

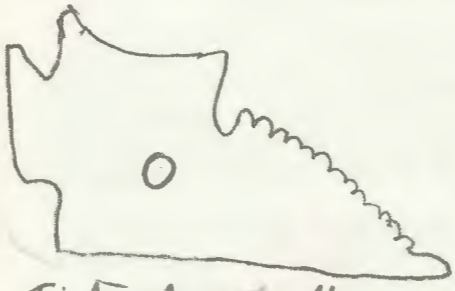
In an actual indicator the pencil arm E is not fixed in a horizontal position but is attached to the piston C by a system of levers, which multiplies the motion of the piston, also the movable board H is replaced by a rotatable drum which carries the paper. A spiral spring in the interior of the drum rotates it in a direction opposite to that of the forward stroke of the engine piston, the spring being put into a state of tension, when the drum is rotated in the opposite direction, by means of a cord attached to the reducing gear operated by the engine. It must be understood that this description of the operation of the elementary indicator as shown in Fig. 10.1.3 is given to make the operation of the instrument perfectly clear.



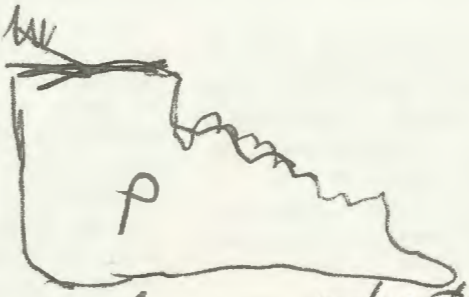
Choked Exhaust further along the line.



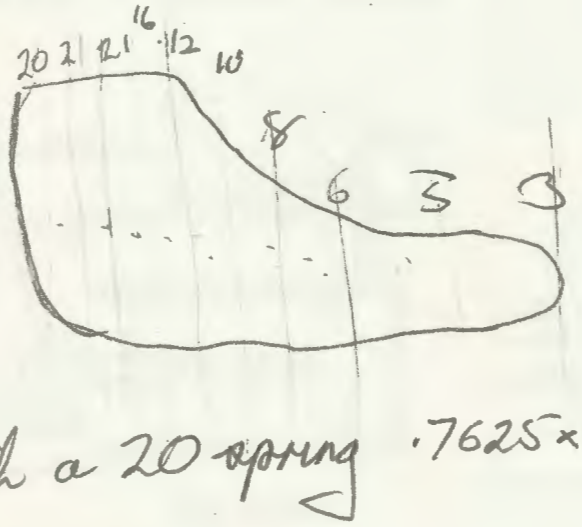
Badly leaking valves



Indicator Fault
inertia of indicator



Sticking in indicator



10 ordinates all in 1/16"

Sum = 7.625"

Mean = $\frac{7.625}{10}$ = 0.7623

With a 20 spring .7625 × 20 = 15.25 lbs/sq inch

↑ Mean Effective Pres.

PLAN

33,000

5" Bore × 6" Stroke
500 RPM

$$= \frac{15.25 \times 6/12 \times \pi/4 \times 5^2 \times 500}{33000}$$

= 2.27 (× 2 = 4.54 HP)

RETURN PAPER TO:
Officer in Charge
Correspondence Teaching Division,
45-47 Broadway,
SYDNEY.

Student's Name .....

Postal Address .....

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STEAM ENGINE OPERATION COURSE

Lesson No. 10

ASSESSMENT QUESTION PAPER

All questions to be attempted. Maximum Marks—100

Marks. Teacher's Comment

1. Q. What is an indicator?

   A. ....
   ....
   ..... 5 .....

2. Q. Which is the most important part of an indicator?

   A. ..... 5 .....

3. Q. To what does the number marked on the springs used in an indicator refer?

   A. ..... 5 .....

4. Q. What is the reducing motion?

   A. ....
   ....
   ..... 5 .....

5. Q. When the engine piston is at the inner end of the cylinder and steam is shut off, where would the indicator pencil be on the diagram?

   A. ..... 5 .....

6. Q. When steam is admitted and the indicator cock is open, in what direction would the indicator pencil move and which line would it trace?

   A. ....
   ....
   ..... 5 .....

7. Q. When the steam pressure moves the engine piston, what takes place on the indicator diagram?

   A. ....
   ..... 5 .....

8. Q. When does the pencil cease to draw the steam line on an indicator diagram?

   A. ..... 5 .....

Marks. Teacher's Comment

9. Q. When cut-off has taken place, what occurs on the indicator diagram as the engine piston moves to the end of its stroke?

A. ....

....

....

..... 5 .....

10. Q. When the exhaust is perfectly clear and the engine piston is on the return stroke, what takes place on the indicator?

A. ....

....

....

..... 5 .....

11. Q. If the exhaust line on an indicator diagram is above the atmospheric line, what does it denote?

A. ..... 5 .....

12. Q. Why is it essential to have the indicator cord of the correct length, and taut?

A. ....

..... 5 .....

13. Q. If a 20 spring is used in an indicator, what steam pressure would be required to move the indicator pencil one inch?

A. ..... 5 .....

14. Q. If an engine is running condensing, where would the exhaust line show on an indicator diagram?

A. ..... 5 .....

15. Q. If the vacuum gauge reading is 24 inches, what would the back pressure be?

A. ..... 5 .....

16. Q. If the pressure gauge reading is 95 lb., what would the absolute pressure be?

A. ..... 5 .....

17. Q. How would you make sure that an indicator is working freely?

A. ..... 5 .....

18. Q. If an indicator piston does not work freely, what may be the result?

A. ..... 5 .....

19. Q. If the steam line on an indicator diagram shows a sudden drop then a gradual rise without a well-defined cut-off point, to what would you attribute the cause?

A. ..... 5 .....

20. Q. If the admission line on an indicator diagram sloped backwards instead of being perpendicular, what do you consider the most likely cause?

A. ..... 5 .....

Total Marks .. ..

STEAM ENGINE OPERATION COURSE

Lesson No. 10

SELF-TESTING QUESTION PAPER

(All questions to be answered in a few words)

1. Q. What is the mechanical efficiency of an engine if the I.H.P. is 90 and the B.H.P. is 81?

   A. .....

2. Q. How is the I.H.P. of an engine obtained?

   A. .....

   .....

   .....

3. Q. What is the area of a piston 5 inches in diameter?

   A. .....

4. Q. Assume the ordinates of the card shown in Figure 10.5 are 19, 20, 20, 15, 11, 9, 7, 5, 4, 2 1/16 inches respectively and a 20 spring was used; what is the M.E.P.?

   A. .....

5. Q. What is the I.H.P. of an engine of 5-inch bore, 6-inch stroke, with a M.E.P. of 40 lb. and running at 500 r.p.m.?

   A. .....

6. Q. A brake such as shown in Fig. 10.7.3 is applied to an engine shaft, the radius of the lever is 4 feet, the weight is 12 lb. and the revolutions are 500 r.p.m.; what is the B.H.P. of the engine?

   A. .....

7. Q. How is the drum of an indicator rotated?

   A. .....

   .....

8. Q. Why is it necessary to open the indicator cocks to atmosphere before attaching the indicator?

   A. .....

   .....

9. Q. Why is it necessary to feel the working of the indicator mechanism before taking a diagram?

   A. .....

   .....

10. Q. Why should the atmospheric line be traced after the diagram has been taken instead of before?

    A. .....

    .....

    .....

11. Q. How is a late cut-off shown on an indicator diagram?

A. .....

12. Q. If the admission line of an indicator diagram slants forward, what does it denote?

A. .....

13. Q. How is a choked exhaust shown on an indicator diagram?

A. .....

.....

14. Q. What does a loop in the admission line on an indicator diagram denote?

A. .....

15. Q. If a body of 100 lb. weight is lifted 700 feet vertically from the ground, how many foot-pounds of work will be done per minute, if it takes five minutes to raise the body?

A. .....

16. Q. If a force of 80 lb. is applied to a 3-ft. lever what is the torque?

A. .....

17. Q. Define Inertia.

A. .....

.....

.....

18. Q. What is Power?

A. .....

19. Q. What does the expansion curve on an indicator diagram represent?

A. .....

.....

20. Q. Where is the terminal pressure shown on an indicator diagram?

A. .....

Instructions as per No. 1 apply to this paper.

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