WORK AND POWER AS MEASURED BY THE STEAM ENGINE INDICATOR.

(Continued from May Number.)

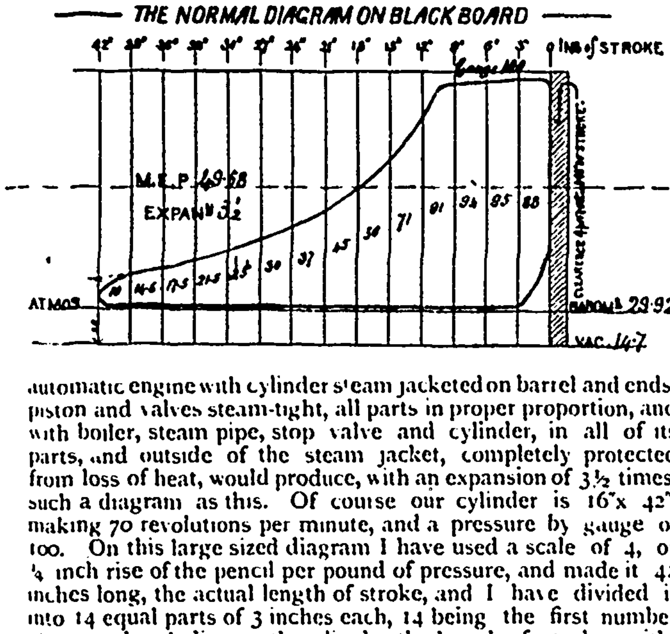
Of late years an instrument called the Planimeter has come into general use, for determining the M.E.P. of diagrams. In this form of it, it only gives the area of a diagram in square inches, and to the second decimal. Here its work ceases, and you must divide the area by the length—the quotient multiplied by the scale is the M.E.P. correct to the second decimal.

In Crosby's instrument, you set the instrument to the length of the diagram. After running the tracing point around the diagram, the reading of the wheel, if it began at 0, is the mean effective pressure to a scale of 40. If the scale is any other, then it is computed from 40. This instrument only goes to the first decimal.

The Coffin averager, has a moving pole. After going round the diagram and starting from the extreme right of the diagram, the tracing point is moved upward on a perpendicular line until the reading of the wheel is the same as at the beginning. The scale length from this point to the starting point, is the M.E.P. of the diagram. All of these instruments are expeditious in use and wonderfully correct, but their price puts them beyond the reach of a good many. I am acquainted with mechanical means for solving this same question, without making a figure or calculation of any kind mental or otherwise, that in quickness is away ahead of Amstler's Planimeter, and in accuracy superior I believe to the Coffin averager. If time permits, and you are not tired out before I get through, I will show you how it is done.

For illustrative purposes on this occasion a real diagram would be useless. You could not see it, and to overcome this I have laid out on the black board, an enlarged diagram, conforming in all respects, with the best performance of a first-class engine. There is no theory, guess, or dream about it. Any

THE NORMAL DIAGRAM ON BLACK BOARD



automatic engine with cylinder steam jacketed on barrel and ends, piston and valves steam-tight, all parts in proper proportion, and with boiler, steam pipe, stop valve and cylinder, in all of its parts, and outside of the steam jacket, completely protected from loss of heat, would produce, with an expansion of 3½ times, such a diagram as this. Of course our cylinder is 16"x 42", making 70 revolutions per minute, and a pressure by gauge of 100. On this large sized diagram I have used a scale of 4, or ¼ inch rise of the pencil per pound of pressure, and made it 42 inches long, the actual length of stroke, and I have divided it into 14 equal parts of 3 inches each, 14 being the first number above and including 10 that divides the length of stroke, without a fraction in the quotient. This makes it handy. By merely looking at the diagram, I can see that complete cut-off has taken place at 11 inches of the stroke, and that the exhaust port opened 3" previous to the end of stroke, and on the return stroke it closed at 3" previous to the end of the stroke, and followed by what is known as cushioning or compression.

On arrival at the end of the stroke the pressure due to compression has risen to 22 lbs. above atmospheric pressure, when it is evident that the steam valve has opened the passage, and the pressure jumps up to 98.

At this point the stroke from that end of the cylinder begins, the port is kept open, and in fact the opening is gradually increasing in area until in this case at 9½ inches of the stroke tripping or disengagement takes place, and at 11 inches of the stroke the valve has completely closed the communication with the boiler, and expansion of the steam then imprisoned in the cylinder follows. At the 39th inch of the strike, the exhaust port opens, a sudden drop of pressure takes place, and after the piston has finished the stroke, and is fairly started on its journey back, it sobers down to a uniform back or exhaust pressure of 1½ lbs. to the square inch, until cushioning is again set up—and so on, as long as the engine is working.

I will now measure this diagram in order to find the mean effective pressure. I have already done it with my foot rule, in order to save your time, in sitting looking at me while doing it, and the number of ¼ in. in the mean height of each 3" division, I found as follows: 88, 95, 94, 91, 71, 56, 45, 37, 30, 25, 21½, 17½, 14½ and 10. These amounts added together, give a total of 695½, which divided by 14 (the number of equal parts that the diagram is divided into), gives a quotient, 49.68, of which is the M.E.P. in pounds per square inch of this particular diagram on a scale of 4, and here our power constant of 3 comes in. This M.E.P. of 49.68 multiplied by 3 gives us 149 HP. being the rate of work done by our 16" x 42" engine under conditions as per diagram.

As we all know, this means that a constant pressure of 49.68 lbs. per square inch, acting on the face of the piston during the whole stroke, would do the same amount of work done by the varying pressures in the diagram.

At this point an important question arises that I have often heard asked by young engineers and by old ones too for that part, and likely the same query has arisen in some form or another in the mind of nearly every person present.

The work done by the varying pressures in that diagram ranging from 95 to 10 is equivalent to a uniform pressure during the whole stroke, of 49.68, or say 50 in round numbers—why would it not be as effective and economical to use a plain slide valve engine, without lap, and carry a uniform pressure of 50 lbs. during the whole stroke, and do away with all the whim whams and gimcracks of dashpots, springs, weights, trip gear, multiplicity of valves, and so on?

This is an honest straightforward question, and is entitled to a direct answer. In conjunction with the diagram, we are indebted to a Frenchman, Henry Victor Regnault for a direct, easy and true solution of this very important question. Between 1845 and 1850 he was instructed by the French government to make investigations and establish numerical data bearing on calculations connected with the working of steam engines. Regnault was well adapted for such work. He was a professional chemist and experimentalist, and had the mechanical ability for contriving means for the solution of such questions. After several years close application he finished the work; and the French Government with that liberality so characteristic of it in scientific affairs, gave the results to the world free.

As I stated before, the piston and cylinder of an engine at work, in reality perform the functions of a meter. Every stroke she discharges a uniform volume of steam, which volume is equal to the piston displacement during a stroke, and the pressure at which discharge or exhaust takes place is measured on the diagram, and in all cases must be measured from a perfect vacuum, which by common consent is 14¾ lbs. below the atmospheric line on the diagram. If great accuracy is required then the true position of the vacuum line is obtained from the height of the barometer when the diagram was taken.

And now when these preliminaries are through with, I will answer the previous question. By a former calculation I found that the piston displacement or displacement constant of our 16 x 42 inch engine, making 70 revs. per min. was 41050 cubic feet per hour, and this is also the volume of steam discharged in that time. Next I measure the terminal pressure of the expansion or automatic diagram, and find it to be 28 lbs. I next refer to Regnault's tables, and find that 14.37 cubic feet of steam at a total pressure of 28 lbs. per square inch weighs one pound. Here is what we are looking for. The total volume of steam per hour, 41050 cubic feet, divided by 14.37 the number of cubic feet in a pound, gives for answer 2856 pounds of water in the form of steam as having passed through the cylinder in one hour as accounted for by the indicator. But our engine has worked during that time at the rate of 149 HP. Dividing 2856 by 149, we get 19.15 pounds of steam accounted for by diagram, per HP. per hour. So far I have paid no attention to cylinder clearance; it is down on the diagram as 4 per cent. or 1.25 part of the stroke. Leaving cushioning out of the question this will have the effect of adding 1.25 or 4 per cent. to 19.15, bringing it very close to 20, which amount I accept as the water equivalent of our diagram per HP. per hour.

We will now take up the case of the M.E.P. being carried the whole stroke, and see what the results are, the piston displacement being the same. The terminal pressure must be measured from a vacuum, and in this case it is 49.68 x 14.7, or a little over 64 lbs. according to Regnault's tables 6.6 cubic feet of steam at a total pressure of 64 lbs. weigh one pound. As before dividing the constant 41050 by 6.6 we get for answer 6220 pounds of steam passing through the cylinder per hour, and delivering 149 H.P., the same rate as in the expansion engine. Dividing 6220 by 149 as before, we get a rate of 41.7 lbs of steam per HP., per hour, accounted for by the indicator, to which we add as in the first case 4 per cent. for clearance, we finally get 43 lbs. which is the water equivalent of our non-expansive engine, per H.P. per hour. For every 20 lbs. of steam discharged by the automatic engine 43 is discharged by the non-expansive engine in delivering 149 HP., with the necessary consequence that more than twice as much fuel is burnt on the grate to generate 43. lbs of steam, than it takes to generate 20.

It is in this manner that the economical performance of engines are compared—slide valve, automatic, condensing, non-condensing or compound, are all subject to one general principle rule or law, that the lower the terminal pressure of a diagram is, relative to the M.E.P., the greater is the economy of the engine. This is a truth common to all engines, yet it has a limit, steam obeys laws in expansion, and if the pressure falls below the amount due to that grade of expansion, it is proof of loss, either by condensation or leakage. A performance in

* Paper read at a recent meeting of Montreal Branch No. 1, C. A. S. E.