THE INDICATOR AND DYNAMOMETER, WITH THEIR PRACTICAL APPLICATIONS TO THE STEAM-ENGINE; PP. 8-64

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by Thomas J. Main & Thomas Brown

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PRACTICAL APPLICATIONS TO THE STEAM-ENGINE.

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being intended to fit into an orifice in some part of the engine (generally the top or bottom of the cylinder) by means of the screw *a a*; *b* is a stop-cock, by which, when the instrument is attached, we can, at will, make or cut off a communication with the internal parts of the engine. Within the hollow cylinder *A* is a piston *mn*, packed and fitting steam-tight.[1] Let us suppose, for perspicuity, the instrument to be in communication with the *top* of the steam-cylinder. Then, when a vacuum is formed above the steam-piston, the atmospheric pressure will force down the piston of the Indicator, and it will remain at its lowest position till fresh steam enters; but it would immediately (unless prevented), on receiving a new impulse, be blown out of the open top *HE*. To prevent this, and at the same time to enable us to measure the force of the steam, a spiral spring presses with its lower extremity against the surface of the piston, while its upper end rests against the fixed cross-piece *c*. By this arrangement, the place of the piston will always vary as the pressure of the steam varies; for it is a mechanical fact, that the tension of a spring varies as the extension. Hence the greater the pressure of the steam, the more the spring is compressed; and, on the contrary, as the steam loses its elastic force, the spring expands, and the piston descends. So that, to get a clear idea of the instrument, conceive the piston to be acted on by opposing forces: on the lower surface by the pressure of the steam (continually varying), and on the upper surface by two forces, viz. the pressure of the atmosphere (constant) and the force of the spring (varying so as to balance the steam-pressure). Now, as the steam-force is perpetually varying, it follows that the

[1] In practice this piston must not be packed *overtight*, for fear of increasing the friction and preventing the free motion of the pencil; but the defect, if any, must be remedied by keeping melted tallow or oil on the upper surface.

piston-tube (*de*) will be continually rising or falling. If a pencil (*p*) be attached to the upper end of this tube (*de*) in which the spring works, it will describe a vertical straight line on a piece of paper brought into contact with it. This, however, is not sufficient for our purpose. This line would, after it was traced, tell us the maximum and minimum pressure during the stroke; but the pressure *at any particular portion of the stroke* would still be undetermined. We must, therefore, have some plan similar to that adopted in other cases where the vertical motion of a pencil under particular circumstances is to be *registered*. In all such instances, the paper on which the variation is to be laid down is drawn horizontally at a certain rate. If, for instance, we were desirous of recording how the pressure varies with the *time*, the paper must be drawn *uniformly*, by connecting it with clock-work, or some other apparatus for giving a *uniform* motion. But this, however, is not usually the desideratum in the steam-engine. Our object is here to have, represented before our eyes, the variation of the pressure for every portion of the stroke of the piston; and this is contrived as follows: the paper is wrapped round a cylindrical barrel *C*, which is brought back against a stop, by a strong watch-spring contained in the box *EF*. A string passes round the pulley *D*, and is led away through a fair-leader *G*, to some part of the engine having a similar motion to the piston cross-head, only much reduced; by which means the watch-spring and the string are always opposing each other. As the piston rises, the barrel will be pulled from left to right; and, on the contrary, as the piston descends, the string having a tendency to slacken, the barrel will, by the force of the spring, be brought back from right to left. At *p* is the pencil attached to the upper end of the tube (*dg*), and rising and falling with the Indicator-piston; and this can be brought into contact with the

paper on the barrel *C*, or removed from it, at will, by means of the joint at *g*. The rod *xz*, and another one on the opposite side of the cylinder, serve as guides to the piston.

The Indicator-scale.

The paper is kept on the barrel by means of the strip of metal *hi*, on which are divisions representing the pressure of the steam. It will be seen that it is graduated throughout its whole length, beginning from zero, and proceeding upwards and downwards. Now this zero is the level at which the pencil stands when the instrument is unconnected with the steam-engine, and therefore acted on by the atmospheric pressure above and below the piston. The pencil will be seen at this level in the figure. If the barrel be made to revolve under these circumstances, a horizontal line will be traced out. This is called the atmospheric or zero line. And, therefore, the pencil will also be at this level whenever the steam, taking the place of the atmosphere *below* the piston, exerts the same pressure: and, consequently, wherever the diagram cuts this horizontal line, the pressure of the steam is 15lbs. on the inch;[1] when on the level of the marks 1, 2, 3, &c. above this zero, the pressure is 16, 17, 18, &c.; and when on the level of the marks 1, 2, 3, &c. below this, the pressure is 14, 13, 12, &c.

To graduate the Indicator-scale.

Mark the point where the pencil touches the scale when the atmosphere is acting freely on both sides of the Indicator-piston; then, having previously found the area of the piston in square inches, multiply the result by 15, and apply it as a weight in lbs. to the under side of the piston. This will cause the pencil to descend through a space corre-

[1] More strictly, 14·75lbs., or a quantity differing from this slightly, according to the state of the weather.

sponding to a decrease in pressure of 15lbs. Make another mark at the point where the pencil is standing, and divide the intervening space into 15 equal parts, each of which will correspond to 1lb. pressure. This scale can be continued above the highest division as far as requisite. As an example, let us suppose the diameter of the piston to be $1\frac{5}{8}$ inch, the corresponding area is 5·1051 square inches, and the weight to be attached $15 \times 5{\cdot}1051$, or 76·5lbs.

When the atmospheric line is to be traced.

The atmospheric line should not be taken till after the rest of the diagram has been completed; because, as the parts become warm by the steam, slight variations occur in its position, depending principally on the alteration in the force of the spring; and since this line serves as the origin from which the pressures are dated, it is necessary to have it laid down as correctly as possible.

The use of the small hole (m) in the side of the stop-cock (mb).

It serves to let the air into the cylinder (*A*) when the steam is cut off by the stop-cock, and thus enables us to take the atmospheric line; the stop-cock performs the office of a three-way cock; for by turning it in one direction we allow the steam to enter, and exclude the external air; and by turning it in the opposite direction we admit the air, and exclude the steam.

Method of taking a diagram.

First, look out for some part of the engine whose motion is proportioned to that of the steam-piston;[1] taking care that the space moved through at that part shall be

[1] That is to say, when you are wishing to find how the *pressure* varies with the *stroke* of the engine.

somewhat less than the circumference of the traversing barrel:[1] that is to say, whatever be the diameter of the traversing barrel, let the movement of the part you are looking for be not greater than *three* times this diameter. Fasten a string firmly to this point, and have a traversing loop in the loose end of the string; it must be of such a length that it may be connected with the string passing round the pulley of the Indicator. Then close the stop-cock of the Indicator, and fix it by the screw (*aa*) to some orifice previously prepared in the top or bottom of the cylinder.[2] Insert the pencil you intend to use in the small hole (*p*) made for its reception, and clamp it there. The pencil should be hard, and have a fine point, to give as clear and distinct a line as possible. Those used for drawing-instruments, and marked HHH, are probably the best. Have some pieces of clean writing-paper provided, long enough to be brought round the traversing barrel, and overlap about an inch. Paper previously ruled is useful for this purpose, the ruled lines being placed lengthways on the cylinder. Wrap a piece smoothly round the barrel, and fix it by means of the clasp (*ih*) on which the scale is marked. Then tear away all the surplus paper, and examine what

[1] In some engines there is no point except the cross-head of the piston to which the string could be attached. The motion must, in these cases, be reduced by pulleys; the circumference of one pulley being equal to the stroke of the engine, and that of the other to the motion of the Indicator, or they should be to each other in these proportions.

[2] If the top of the cylinder be chosen, the orifice for the grease-cup will generally answer the purpose. In most cases, however, a pipe leads from the top to the bottom of the steam-cylinder, and the Indicator is attached to this pipe. It is provided with stop-cocks, so that when once fixed, the arrangement is very convenient for taking two diagrams almost simultaneously from the upper and lower part of the cylinder. The only objection to it seems to consist in the tendency of the steam to condense in the pipe. For this reason it is advisable to have the Indicator as close to the cylinder as possible.

remains, to see if it be quite smooth; for if there be any ridges, the curve will have an irregular appearance, which might lead us to suppose some of the gear for working the slides had become loose, or much worn. Next wind the Indicator-string round the pulley of the barrel *D;* and connect the hook at its extremity with the loop of the string attached to the engine. Adjust the string by means of the running loop, till you are satisfied of the motion of the barrel; allowing it to make nearly a whole revolution, but examining it most carefully to see whether it becomes slack, or overtaut. The stop-cock (*b*) may now be opened wide, and the Indicator-piston will immediately start into motion: the piston must be well lubricated, to reduce the friction as much as possible, and at the same time to prevent leakage. Let the instrument work for a few seconds, to allow it to become thoroughly heated; and when it has arrived at the same temperature as the steam-cylinder, it is in a fit state to trace its diagram. When satisfied of the working of the machine, take hold of the pencil when it comes to the *bottom* of its stroke, as it is longer stationary at this part, and bring it gently into contact with the paper. This part of the operation requires some practice; for if the pencil be allowed to come forward too rapidly, the spring at *g*, by which it is pressed against the barrel, will break the point; and again, if held too long, the force of the steam, suddenly acting on the machine, will force it out of the hand, or break the holder. When left to itself, it will trace out a curve on the paper. As soon as it has made a complete circuit, let the pencil be withdrawn from the paper (being careful not to take hold of it until at the *bottom* of its stroke). In order to have the line distinct, the pencil should not go over the same ground twice. Shut off the stop-cock, and the piston will become stationary, both sides being acted on by the pressure of the atmo-