## WORK AND POWER AS MEASURED BY THE STEAM ENGINE INDICATOR.

THE following paper on the above subject was read by the author, Capt. Wright, at a meeting of Montreal Branch No. 1, C. A. S. E. Introductory to the paper, as printed below, the author gave a brief history of the invention and improvement of the indicator.

I will now proceed to an investigation of the revelations of the indicator diagram. First, it is simply a record of the pressures against one face of the piston during a complete revolution of the crank pin. It goes no further; the rest we must do ourselves. I am aware that there are able engineers, men fit for any position, intelligent and reading men, who yet consider the whole thing a humbug, and look at indicating an engine as mere playing with a toy. To do them justice I will defend them. They have never given the subject a serious thought, and during their education as engineers, the instrument was not in use. I have often told them that if James Watt, Wm. McNaught and Dan Gooch found it necessary to invent instruments to tell them what was going on in their cylinders, perhaps it would do us no harm to follow their example.

I am aware that the standing of the indicator has been injured by quacks and prodigies men who will practically tell you, that what they don't know is not worth knowing. It is plain that they have not learned the first lesson in indicator practice, that we know very little about steam doing work in a cylinder, and it is advisable to be modest. But it is said that nothing was made in vain, and so the indicator quack performs the important mission of bringing the instrument to the notice of the public. The mechanical terms, "Work," "Power," "Energy," which must be used in our present enquiry, had better be defined. These words have a technical meaning in engineering which cannot be found in our common dictionaries. "Work" is motion against resistance. A resistance is overcome, motion takes place, work is done. "Power," as understood by the modern engineer is simply the rate at which work is done; thus, the hammer of a pile driver weighs 3,000 lbs. and it is lifted 30 feet high; here a certain amount of work is done, viz., 3,000 lbs. lifted 30 feet, or its equivalent in foot pounds, 9,000 lbs. lifted 1 foot high. So far we can say no more. But when I say that 3000 lbs. is lifted 30 feet high in half a minute, a rate of work is named. And these three factors, namely, amount of resistance, distance moved, with the rate or time it was done in, is the "power" which is generally expressed in units of 33,000 lbs. lifted 1 foot high in a minute called a horse power. But it must be remembered that this so called h. p. is only a convenient unit. It would be absurd for the Grand Trunk or C. P. R. to express distances between stations in inches. The figures would become so large, that we could not compare or comprehend them. In consequence a unit of 63,360 inches is used, called a mile. It is just so in our business. The units of work done by engines pile up so fast, that a unit of 33,000 foot pound per minute is used, which brings the amount within our comprehension.

The engineering "Energy" is the ability to do or the capacity for performing work. We now wonder how the old engineers, managed to express their ideas without this word, for its use by engineers is quite modern. They were in the habit of coining some word from Latin or Greek, with the result that they confused themselves, and other people could not find out what they meant. Go to the Bonaventure station at 4.30 in the afternoon, and you will see several locomotives, standing in front of trains. They look quiet and peacable they are doing no work. Look in the cab, you may see the finger of the gauge pointing to 100. We have the idea there is something about her quite different from what would be, if the finger stood at 0 on the gauge. In the state she is in, she is possessed of energy; she is capable of doing work, and the amount can be determined. In this case energy exists, but for the time being is not used, it is at rest. I imagine the train going along at 40 miles per hour; steam is suddenly shut off; she keeps on going; there is now no force drawing her along; it is the energy stored in the train by the work previously done by the engine. In this form it is energy in motion, and in proof that it is capable of doing work, look at the destruction caused by a collision.

The mechanical idea of work covers every case of resistance overcome, whether it be the sawing out of a board in a mill, or the breaking of it up in a collision. And so in the case of a fly wheel, energy is stored in the early part of the stroke, and restored in the latter part. Build a dam across a river—the impounded water is a store of energy; work is capable of being done there. A boiler under steam is a store of energy; no work is done by the boiler except in case of an explosion. The small matters of every day have their examples. I wind up my clock at night; in doing so I have done work; by raising ten weights I have stored energy in the weight. It is capable of doing work in driving the clock for the next 24 or 30 hours. In all the cases mentioned, the amount of work that can be done is in proportion to the stored energy, either at rest or in motion, and it can be computed. From this standpoint an indicator diagram is a diagram of energy. Give me the scale of the spring with which it was taken, the diameter of the piston and the length of stroke, and I can compute the work done per stroke. Give me the number of revolutions per minute and I can compute the power, or the rate at which work is done.

There are many distinct classes of engines slide valve, with lap or without it, with a governor and without; some have cut off valves on the back, some cut off outside of the steam chest. Then there are automatic engines, condensing and non-condensing, compound engines with two, three and four cylinders. Each class of engine, if in good working order, makes a diagram with characteristics of the class to which it belongs. A glance is generally sufficient to tell the family it came from.

In the multiplicity of peculiarities and forms observed in diagrams, it would be impossible to take notice of all, I think one is enough, and I have selected one of the Corliss class: it may be a Brown or a Green, or any other of the automatic family, with a cylinder 16" diameter and 42" stroke, making 70 revolutions per minute, a piston speed of 490 feet per minute. This engine is a common size, neither very large nor very small, with a fair speed of piston. Another reason why I selected this size cylinder and speed of piston is to avoid fractions, which if any, required constants, are so small in this case that they can be neglected without any sensible error.

In determining the performance and efficiency of an engine by means of an indicator, it is usual to calculate certain quantites, called "constants," which save a great deal of after time and trouble. A constant is a reality, it is the result of a calculation carried out to a certain point, which point is common to all engines of that size piston, and speed of piston. A power constant, for our selected engine may take this form. What is the power of a 16"x42" engine, with a piston speed of 490 feet per minute and 1 lb. M. E. P.? Work this out in the usual way - multiply the piston area by the M. E. P. and by the piston speed, divide the product by 33,000. The quotient is 3, which is the h. p. with one pound M. E. P. This is the power constant in this particular case. Look seriously at this for a few moments, and you will perceive that if the M. E. P. was doubled, you would have double the power; if the M. E. P. was trippled, you would have three times the power; of course all other factors remain the same. If you have doubts of this, work it out, and you will find it is true.

It is then established that the M. E. P. multiplied by 3 is the h. p. of any diagram taken from a 16" cylinder having a piston speed of 490 feet per minute. It is sometimes best to know exactly what we are doing. If anyone here works out this constant, he will find that the real constant is a three-hundredth part less than 3, which I have dropped as insignificant and of no consequence. An extra piston speed of 20 inches per minute would bring the constant up to 3. Looking at the thing from a money point of view, a tenant rents 1 h.p. from our 16" engine at the rate of $75 per year. In working up the h.p. of the engine the constant 3 was used, our tenant is paying one-twelfth of a cent too much per day—an amount of no consequence in such a bargain.

Another constant much used and a powerful weapon in the hands of the engineer, is known as "piston displacement," or the volume swept by the piston while making one stroke, or one revolution, or during one minute or one hour—or for that matter, one day if you wish, but for good reasons it is customary to count it by the hour. A moment's thought will convince any engineer that at work the cylinder and piston of an engine are actually performing the functions of a meter. She discharges every stroke a certain volume and weight of steam. The volume is constant, but the weight varies according to the pressure