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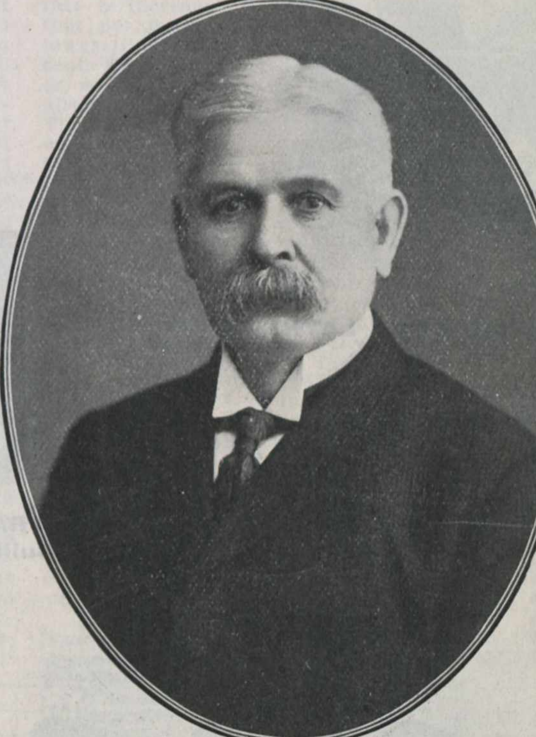
Fuel Economy on Testing Plants and Railways.

By H. H. Vaughan, Assistant to Vice President, Canadian Pacific Ry.

Most of us have at one time or other been confronted with the statement that there was a terrific waste in the operation of a steam engine, something like 5% of the heat developed by the coal burned under the boiler, being all that was transformed into useful work. That such a statement is true is easily shown by comparing the coal consumption of an ordinary engine, taking say 4 lbs. of coal per h.p. hour, and the work that is the equivalent of the heat in the coal. A horse power is 33,000 foot pounds of work per minute, so that a horse power hour is 1,980,000, or very nearly two million foot pounds of work. Four pounds of coal will develop about 60,000 b.t.u. of heat and as the mechanical equivalent of heat is 778 foot pounds per b.t.u., the total work that is the equivalent of the heat contained in the four pounds of coal is about 46,000,000 foot pounds. As only 2,000,000 or under one-twentieth of this is developed useful work, the statement that 95% is wasted is entirely true and cannot well be denied. As is well known, the larger part of this 95% is not waste at all in the proper sense of the word, but is the necessary result of the natural laws governing the action of heat engines. We are very much in the position of trying to utilize sea water, pumped into a tower at Winnipeg, for power purposes. If the tower were 200 ft. high and the discharge were into the river at a height of 750 ft. above sea level, the best possible efficiency that could be obtained would be by using 200 ft. out of the total head of 950 ft. available, or about 21%. The 79% that was lost on account of the impossibility of utilizing the total down to sea level would not be waste, but power rendered unavailable on account of the conditions under which it was supplied. While not by any means an exact simile, such a case does to a certain extent resemble the conditions under which heat can be used in the heat engine. The heat that can possibly be utilized depends on the proportion of the range of temperature through which the engine works to the initial temperature, and the initial temperature, like the height of the water tower, is not measured from the level at which we can use it, but from the absolute zero of temperature, about 465 degrees below zero Fahrenheit. The most perfect form of heat engine therefore working between a temperature of 390 degrees, or that of steam at 200 lbs. pressure, and 60 degrees, the temperature of the atmosphere, could then only have an efficiency of 330/855 or 38%. It is needless to say that nothing approaching this could practically be realized, not only because such extreme efficiency would be more expensive than the results would justify, but also because any such engine would have to be of a totally different type to the existing steam engine, which cannot work under the conditions demanded for the most economical heat engine. In order, therefore, to afford a practical working comparison, the definition of an ideal steam engine has been adopted, as follows:—

"A perfect engine receiving steam at its upper limit of pressure equal to that measured close to, but on the boiler side of the engine stop valve, and continuing this pressure and temperature up to cut-off. Beyond cut-off the steam is assumed to expand adiabatically in the cylinder down to a pressure equal to the back pressure against which the engine is working. The steam is then exhausted from the cylinder at constant pressure corresponding to the lower limit of temperature."



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This definition, while it may appear rather complicated, really specifies a perfect steam engine, working as a steam engine does, with steam at boiler pressure and an exhaust pressure determined by conditions, but with perfect expansion and an entire absence of all the losses due to the cylinder condensation, compression, and the various other causes which prevent an actual engine from obtaining the greatest possible economy. Such losses are however, more or less avoidable, and it is the aim of the steam engineer to reduce them by compounding, superheating, and other means, so that the ideal engine thus set up may be fairly taken as a standard which may be approached, although never equalled, by an actual steam engine.

It is interesting to examine the degree to which the steam locomotive has so far approximated this ideal engine, and for the information in connection with steam locomotives we can use the results obtained in the tests conducted on the testing plant at the St. Louis Exposition in 1906. The conditions under which these engines worked may be taken as a boiler pressure of 200 lbs. and an exhaust pressure of 6 lbs., and with these limits the ideal engine would require about 250 b.t.u. per h.p. per minute, or 12.8 lbs. of steam per hour at boiler pressure. The simple locomotives tested required from 23.6 to 28.9 lbs., while the compounds required from 19.0 to 27.0 lbs., so that compared to an ideal steam engine under the same conditions, the efficiency of the simples was 54 to 44%, and of the compounds 67 to 47%.

The ideal engine taking 250 b.t.u. per h.p. per minute, or 15,000 b.t.u. per hour has an efficiency of 17%. This is obtained by multiplying 15,000 by 778, which gives the work that is the equivalent of that amount of heat, 11,670,000 foot pounds, and dividing this by 1,980,000, the foot pounds equal to the work of one h.p. hour. As the engines on the testing plant may be said to have had an efficiency of about 50% for the simples, and 60% for the compounds, we see that the actual heat efficiency was from 8½ to 10% based on the total heat delivered to them in the steam, so that even in the case of these particular engines there is 90 to 91½% of the heat in the coal that cannot be used, that the fireman cannot be blamed for.

The efficiency of the engine is however, only one of the factors determining the proportion of the heat in the coal that can be developed as useful work. The boiler, while not limited by the same conditions as the engine, is still unable to deliver in the steam the full amount of heat that is generated by the coal