Locomotive Power and Performance

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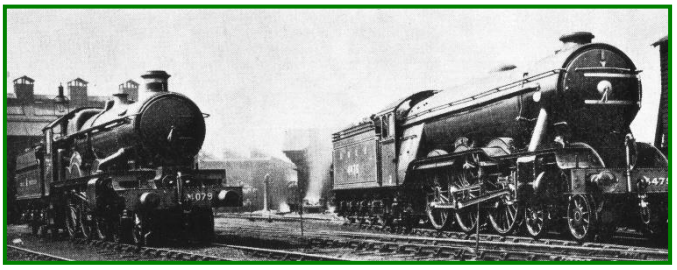
Locomotive power and Performance

It seems as though there are more and more events in the miniature locomotive world that involve measuring performance. Terms like drawbar effort, power and efficiency are casually thrown around but I sometimes wonder if we really understand what they mean.

There is almost a conspiracy to confuse the unwary with lots of techno-speak and even that pillar of respectability, the Great Western Railway Company, had a go at mis-information in 1924. Most of us are aware of the locomotive contest of that time between GWR "Castles" (in the dark green corner) and LNER A1 Pacifics (light green corner!) This arose due to the northern company showing off No. 4472 "Flying Scotsman" at the Empire Exhibition but having the bad luck to have as its neighbour GWR No. 4073 "Caerphilly Castle" - complete with a notice to the effect that it was "Britain's most powerful passenger locomotive". Since the pacific was quite visibly a larger lump of metal than the Castle this must have been a bit confusing for the average visitor, and even more confusing for the directors of the LNER who naturally turned to Mr Gresley for an explanation. In fact, it was the Tractive Effort of No. 4073 that was greater than that of No. 4472, but the GW passed it off as Power. Of course, Swindon knew the difference so we must conclude that the western men must have had the intention of pulling the wool over the eyes of Joe Public. The upshot was that Kings Cross got irritated and foolishly arranged a locomotive exchange with Paddington in which the big pacifics were shown up in a rather poor light.



Let us distinguish between the terms "Tractive Effort", "Drawbar Effort" and "Power". Start with Drawbar Effort (DBE) as it is quite easy to explain: the train is hooked on to the back of the locomotive (to the tender if not a tank engine) and as the engine proceeds it has to pull the train to make it move, the pull is a force just like that needed to lift a pound of apples. As kids we had our own unit for this force, the skin of rice puddings, as in the expression "a Midland 2P couldn't pull the skin off a rice pudding", but the force to raise a pound of apples is 1 lbf (the "f" means force), for a whole train it is several thousand pounds (a few tons). It roughly equates with our concept of strength: the heavier the train the greater the DBE needed, so a stronger engine will be required. DBE is a bit difficult to assess as you have to put a spring balance between engine and train to measure the pull and in fact this is exactly what a dynamometer car does both in full size and at IMLEC. OK, then what is Tractive Effort (TE)? It is a theoretical calculated figure invented by locomotive engineers in an attempt to quantify the strength of a locomotive, i.e. how hard it can pull. Open your Ian Allen ABC (Western Region) and go to Castle class, below all the small print about weight, cylinders, etc you will see "T.E. 31,625 lb"- yes, the Castle is supposed to be able to pull with a force of around 14 tons. The heck it can! TE is of very little use as far as real output is concerned but it has its place as a comparative unit of pull, in other words don't expect to achieve the TE but the pulling strength of different locomotives can be compared by using their TE figures.

As a matter of interest, the TE for the original LNER A1 class was 26,900 lbf, quite a bit less than the Castle which had the advantage of more cylinders working at a higher pressure, so the A1 was definitely outclassed in pull, but as we shall see that does not necessarily make it less powerful. So, picture a scene at Paddington, a long train from the west has just arrived pulled by a "Castle", a heavy train with a strong engine. The train

engine is uncoupled and the coaches are pulled back to the sidings by a small saddle tank engine, the forerunner of the Panniers. The typical GWR shunting 0-6-0T had a TE of around 18,000 lbf, (say 8 tons), just over half the Castle's, yet it has no difficulty in pulling the same train, which only requires about 2 tons DBE anyway.

Tractive effort is a figure calculated from the size of the cylinders, the steam pressure and the diameter of the coupled wheels. If the engine moved slowly in full gear with wide open regulator the force at the wheel rim would be about the TE figure. The TE goes up with higher pressure and bigger cylinders and down with bigger wheels due to the extra leverage off the crankshaft. So, the shunting tank gets quite an advantage in the rice pudding department from its small coupled wheels that offset the smaller cylinders. So why bother to build expensive 4-6-0's if a value-for-money 0-6-0T can pull the train, even to Bristol if required? The difference is in the speed at which the big engine can pull at 2 tons: this leads us to Power.

Although we tend to think of power as strength, a sort of pull thing, in reality it is defined as the Rate of Doing Work and measured in Horsepower, that is, equivalent to so many Gee-gees, surprisingly it is so well established that it was absorbed into the metric system as a "parallel unit" and is still alive, just.

The term horsepower and its definition are due to none other than James Watt. Being in the business of selling stationary engines to industry Messrs Boulton & Watt needed some way of indicating the work that a particular model would do. Work was measured as foot-pounds (ft-lbf), if you lift a pound of apples one foot you will have done 1 ft-lbf of work, two pounds through three feet is 6 ft-lbf and so on. If it takes you a second to lift 2 lb through 3 feet your rate of working is 6 ft-lbf per sec, but if you are getting on a bit and it takes you 2 seconds to put the bag on the table your rate of working is only 3 ft-lbf per sec. Clearly the work done is the same but the output per second is different in each case so one action requires twice the power of the other. Thousands of ft-lbf/sec are a bit difficult to visualise but if you were told that the engine could do the work of 10 gee-gees you would get a better idea, more so 200 years ago when most work was actually done by horses. After a bit of observation and measurement Watt decided that the average gee-gee produced 550 ft-lbf of work per second which he then called a Horsepower. Later observations showed this figure to be somewhat high (perhaps he was looking at the winner of the Derby) so mill owners were pleasantly surprised to find that their new acquisitions replaced more gee-gees than expected. If we hang 400 tons of train behind a Castle on Brunel's billiard table the pull on the hook is about 2 tons. Where have we seen this figure before? Oh yes, Churchward set himself the design target of 2 tons DBE at 70 mph. This DBE is 4480 lbf which when moving through 6160 ft in a minute works out at 836 HP and this was effectively the target for the Star class. The Castles were enlarged Stars with cylinders capable of producing 1200 HP at the drawbar and they were equipped with a really good boiler that could supply them with steam to maintain this rate. The shunting engine has sufficient TE to pull 2 tons, but it will be a bit late arriving at Temple Meads as cylinders and boiler are not big enough to run at anything like 70 mph: it just isn't as powerful as the Castle.

So forgetting the GWR red herring, was the Castle really more powerful than the A1? To the embarrassment of Gresley & Co, yes it was. Due to its larger cylinder volume and higher pressure the work output per rev of the Castle was about 18% greater than the pacific's. This alone was not enough unless the boiler could keep up with them, but again Swindon was on a winner because their engine was significantly more efficient than the Doncaster product so that the smaller boiler was more than sufficient to provide the HP. Drawbar Effort moves heavy loads, but Horsepower shifts them quicker.