How Powerful is Powerful?

By Jeremy Clarke

This is a question posed by Dr W. A. Tuplin, a well-known mid-20th century commentator on and critic of locomotive working, in an article appearing in the July 1956 edition of The Railway Magazine.

He asks it particularly in the light of yet another question; can one find a yardstick of power in relation to size? This has little if anything to do with that deceptive formula, tractive effort. The obvious answer is that a good, big engine will always beat a good, little engine, something Bluebell Railway loco crews will certainly be aware of.

But Tuplin takes it a step or two further, and by doing so poses further questions on the nature of "power." The widely-used Johanson formula goes some way to providing a pretty accurate reply, but Tuplin then goes on to ask, "what should be taken as the measure of the size of a locomotive?" Furthermore, he provides a series of measures for finding a possible answer.

Now, such erudite matters may be of little interest to the enthusiast, still less to the layman, but they could well intrigue and, indeed, enlighten a scholar of steam locomotive matters or a footplate practitioner. So, if your interest lies outside this particular sphere may I suggest you curtail your reading here and search out something more to your taste?!

Still with me? Good! To continue then: power in a steam engine comes from burning coal: QED! However, the limiting factor is not how much coal a fireman can shovel in through the firehole door but the area of the grate on to which it is being fed and thus the loco's ability to burn it.

Too much will give any engine, no matter how efficient its draughting arrangements, the locomotive equivalent of indigestion. Tuplin contends, after some intensive arithmetical calculations—which, thankfully, he refrains from including—that published records of locomotive performance in the *Railway Magazine* and other similar publications indicate the drawbar horsepower per square foot of grate to be remarkably consistent, irrespective of the size and type of engine involved.

There are obviously variations depending on the duration of the effort. The steam engine is a very tractable beast and can, for a short time, exert power way beyond its theoretical sustainable maximum—hence the unreliability of assessing power on the basis of tractive effort!—by "mortgaging the boiler," with the intent of rebuilding the fire, stabilising water level and regaining mean steam production as soon as circumstances allow.

Tuplin also asserts high power output becomes less attainable the further into a journey the loco travels. In the main this is due to the effect of clinkering on the grate, the rate at which that happens being primarily dependent on the type of coal being burned, as well as the design of the grate itself. In addition there will be a build-up of ash in the ashpan that possibly restricts the volume of air drawn through the fire.

Also coming into the equation, which eventually appears as an algebraic by which Tuplin claims to assess “power” more accurately, is the heating surface of the firebox in relation to the size of the grate. The advantage gained by a high ratio, as with a deep firebox for example, may not be great but advantage there certainly is.

Plotting relevant information from published data—average speed, duration and tonnage hauled, as well as the areas of the grate and firebox heating surface—use of the algebraic provides an extrapolated curve showing drawbar horsepower per square foot of grate. It corresponds to approximately 110 dhp per sq ft for a few seconds, about 74 for a minute, 49 for five minutes, 38 for half an hour and so on.

The truth of two facts noted earlier will be seen: that really high power outputs can be sustained for a very short time only and that performance tails off the longer the time progression though the rate of tailing itself tails off. The longest period to which the curve appears relevant is 210 minutes, by which time the dhp per sq ft of grate is down to around 30, thus illustrating the last point very well.

Another point Tuplin makes is that any formula is plagued by uncertainties: train resistance formulae themselves contain uncertainties as they take little account of the effects of wind or other weather conditions or the mechanical condition of the vehicles and track. Such influences have to be assessed by the observer and adjustments made to account for them. Nevertheless, Tuplin has taken the best published examples he can find of “hard running” by 40 different classes of engine and, using the algebraic, reduced the effort required by each to a whole number. The number 20 is taken as the “high-class” standard, while other numbers represent so many twentieths of it. For example a number 18 represents a figure between 17.5 and 18.5/20ths of the high-class figure for the duration concerned.

To illustrate the method Tuplin takes at random a figure of 36dhp per sq ft sustained for 60 minutes, which, using the algebraic, equals the high-class standard and is therefore marked 20. If such an effort were to be sustained for 210 minutes, for which the high-class standard is 30, the continuing output figure of 36 would be graded as (36/30) x 20 = 24. He points out the rationality of the method by showing how many classes—quite dissimilar in design, dimensions, and proportions—have produced much the same figures and are often known to have sustained power output in and around a high class figure of 23. Incidentally, and *apropos* this, he makes no claim that the examples are the best ever, only the best he can find recorded and published up to this time.

Now, all this is a rather drawn-out introduction to the figures attained by the five classes of Southern engine that feature in the table. These are:

Class	Number	Route	Ave. MPH	Duration (Mins)	Tons	DHP	Date
School 4-4-0	932	Wimbledon-Worting Jct.	58.7	44	510	1,130	10/39
Nelson 4-6-0	865	Eastleigh-Litchfield	53.2	19.5	495	1,360	10/39
Arthur 4-6-0	768	Salisbury-Honiton Tnl (W)	57.2	73	460	950	5/35
MN 4-6-2	21C4	Wilton-mp113	61.3	46	575	1,380	3/49
WC 4-6-2	34006	Aylesbury-mp31.5	35.6	11	395	1,110	1948

It is only the "School" that gets into the 20+ bracket with a 'score' of 21 as calculated on the curve produced by the algebraic. That may seem astonishing until one thinks about it in terms particularly of the various sizes of the grates.

For those unfamiliar with them all the routes are, in general and not surprisingly, against the engine. From Wimbledon "Blundells" had an undulating road to Byfleet and New Haw, a distance of 13 miles with no serious gradients, but then faced the 11-mile climb to mp31 and another long one from mp38 to Worting Junction (mp50¼). Incidentally, note the load being hauled!

Apart from a slight easing at Winchester the Southampton line facing "Sir John Hawkins" climbs at a relentless 1 in 252 for the 18 miles between Eastleigh and the summit tunnel at Litchfield. In later steam days, timings usually called for an average of around 43mph from departure at Southampton to passing Worting Junction, and there was generally enough "fat" in the following point-to-point stages for any time lost to be regained without breaking the line's overall speed limit.

The 70 miles between Salisbury and the west end of Honiton tunnel are a very different proposition from the previous two routes. In the main this is because the line either follows or crosses river valleys, though the engineer Joseph Locke surveyed it in such a way that there were no speed restrictions anywhere, so full advantage could be taken of the downhill stretches to get a run at the following climb.

But to begin with "Sir Balin"—a personal favourite incidentally from its days at Stew Lane in the 1950s—began with a 14-mile slog from Wilton uphill through the Nadder valley to a summit at Semley. There follows a sharp four-mile fall to cross the Dorset Stour at Gillingham and an equally sharp rise to Buckhorn Weston tunnel. And so it goes on, uphill and down dale, frequently in the 1 in 80/100 range, until a summit at mp 133¼ to the west of Crewkerne. Then comes the 13-mile dash down the valley of the River Axe. If 100mph were to be reached anywhere on the journey to the south west from Salisbury, it was at or close to Axminster. But this glorious racing ground is followed immediately by the debilitating 7-mile climb, almost all of it at 1 in 80, to and through Honiton tunnel.

"Cunard White Star's" contribution was taken over a portion of this same route, covering five climbs and four falls of various lengths and steepness while "Yeovil's" exploits over the ex-Great Central route during the 1948 exchange trials are well documented, both officially and unofficially. This particular segment covers a climb of just 6½ miles from a standing start and is up a constant gradient of 1 in 117, apart from slight easings through Stoke Mandeville and Wendover stations. Cecil J. Allen waxed lyrical about this run as "one of the most startling exhibitions that I recorded … I know of no parallel with any ex-LNER locomotive similarly loaded over this route."

So, let's put a little meat on the bones. The "School" is a relatively small engine but an outstandingly good small engine. How else, in its earlier days, could it have successfully tackled loads of up to and sometimes more than 500 tons on the Bournemouth road? But let's make some comparisons: "Blundells" had a grate area of 28.3 sq ft against the 21C4's 48.5 sq ft, which also boasted a firebox heating surface of 275 sq ft, over a third greater than that of the "School."

Here is a stark illustration of Tuplin's point, the "MN," by virtue of its generous dimensions actually falling into the "16" category on the recorded performance. "Sir Balin" scores relatively highly at 18 because its firebox and grate dimensions are little different from those of the School while the "Nelson" is a place higher at 19. Despite CJA's championing 'Yeovil' could not manage anything higher than '14'. Once again the relatively generous grate area and firebox heating surface brought its score down.

If the placings of the Bullied engines are considered disappointing, it should be noted the best recorded LNER "V2" was also categorised as 14 and the BR "Britannia" representative is only on 15. "Sir Balin" very creditably shares the 18 spot with "Flying Scotsman'" in original "A1" form as well as the LMS 5XP 4-6-0 no. 5660, "Rooke," whose fireworks under test over the Settle & Carlisle raised eyebrows in 1937. The "Nelson" also comes out very creditably for an engine considered by many not to have lived up to expectations. True, "Sir John" is in the condition as modified by Bulleid with multiple jet blastpipe and improved steam passages, but it still shares its 19 placing with the LMS "Princess Elizabeth" and the LNER "A3" as well as the same company's mighty "Mikado" of class "P2," "Cock o' the North." The "School" is up with the ubiquitous "Black 5" and the "Royal Scot" in its original condition. (The rebuilt version got a class 23 rating alongside "Star" and "King" classes.)

The most highly rated UK engine is "A4" "Pacific" no. 4901, "Capercaillie," which, in the late-summer of 1940, hauled the enormous load of 730 tons over the 25.5 miles from Otterington to Poppleton Junction at an average speed of 75.2mph, thus producing a dhp of 2,120 for a period of 20 minutes. This put the engine in at a rating of 26. Be it noted the "A4" grate is comparable in size to that of a Bullied "Light Pacific."

And the highest noted rating of all? That was 29 and over the Channel with one of Andre Chapelon's superb Paris-Orleans Railway "Mountain" 4-8-0 rebuilds. The engine covered the 102 miles between Calais and Amiens at an average of 72 mph, producing a dhp of 2,200 in hauling its 635-ton train.

One last 'hurrah' for Team GB! In July 1961 one of the most experienced and widely travelled observers of locomotive performance, Baron Vuillet, footplated "9F" 2-10-0 no. 92000 hauling the

“Pines Express” between Bath and Bournemouth. The load was given as 450 tons, which, as it exceeded the 410 ton limit for these engines to take unassisted over the Mendips to Evercreech Junction, would normally have required a pilot. However, the Bath shedmaster, Mr. Harold Morris, acceded to the request of the engine crew, the legendary driver Donald Beale and fireman Peter Smith, that they go it alone. The Baron later wrote to his friend O. S. Nock that this trip was one of the most remarkable he had ever made on a steam engine, and he included some details of the hill climbing which Nock subsequently published in the October 1961 edition of the *Railway Magazine*.

The gradient on the first four miles of the seven-mile climb from Radstock to Masbury was calculated by the Baron, with compensation for curvature, to be 1 in 52. Over this section, covered in 8m 40s, (average speed 27.7mph), he estimated the average dhp to be 2,000 with a cylinder hp at 2,240.

The remaining three miles are on slightly easier grades in the 1 in 60/73 range, but Vuillet still estimated the average dhp for the whole climb, completed in 14m 7s at an average of 29.8mph, as 1840. The finish to the run was just as remarkable: for a mile beyond Poole the line is level but then follows the sharp two-mile long rise to Branksome West Junction, much of it at 1 in 60, the Baron calculating this climb at an average 1 in 64. Speed attained in that first level mile was 47 mph but it had fallen only to 41 mph at the summit. Not to put too fine a point on it the engine was thrashed to achieve this, being driven over the last mile on full regulator and 52% cut off.

This latter section illustrates “power” in its rawest sense with an output well beyond the theoretical maximum. Vuillet calculated that for one minute the cylinder horsepower of the “9” at close to 3,000. This indicates a dhp in excess of 2,600. Though higher than that on the climb over the Mendips, the latter is put into a higher grading because of its longer duration.

There is also the point that the firebox of the “9F” is relatively shallow as it sits above the 5-feet driving wheels rather than above carrying wheels as in a “Pacific.” This, of course, comes into the equation, but the performances generally put this quite magnificent class well into the “high” grading. What is more, by using the algebraic, the power output on Parkstone Bank for that duration of one minute works out exactly to the 74 dhp per sq ft of grate as predicted.

Perhaps Tuplin had something relevant to say after all, even if he did have a penchant for all things GWR over anything else.