Note 125. Historical Mean Piston Speed (MPS) for reciprocating steam locomotives

Mean Piston Speed (MPS) has been much used in this review for the reason explained in Note 13 Part 1. It was thought that a historical look at this factor would be of interest to viewers.

It was recognised quite early in the development of reciprocating steam locomotive engines that MPS was important in the stressing of the piston and connecting rod. With these parts always in ferrous material, and so of the same density, their stress is proportional to (MPS)^2.

In standard steam engine design the piston, being double-acting, is supported by a cross-head outside the cylinder. Therefore it is not subjected to side loads and can be very short and just sufficient to carry sealing rings. In the 1907 GWR " *Star* " class (for which a drawing is available, thanks to GWR and " *Childrens' Encyclopedia* "!) the axial length was only 11% of the stroke.

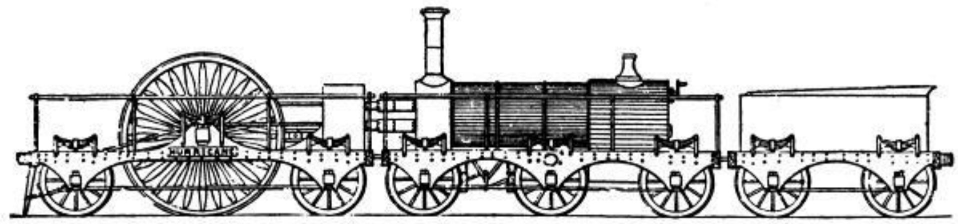
For locomotive steam engines travelling at V MPH on driving wheels of D feet in diameter and with a piston stroke of S feet the relation is

$$\text{MPS} = 56.02 \times (S/D) \times V \quad \text{ft/min.}$$

Examples

(1). In 1838 Isambard Brunel ordered a pair of locomotives from an outside builder for the GWR and specified that MPS should not exceed 280 ft/min (1.4 m/s) at 30 MPH (Ref. 1). This for cast iron pistons at something under 140C and with wrought iron connecting rods. Actually, Brunel's specification could only be met by having the cylinders carried on their own set of wheels, with the crank geared-up 2.3:1 to the driving pair, and with the boiler carried separately on another-truck (see Fig. 1 below). The result was described as " *More of a procession than an engine!* ". The locomotives were not a success. It must have been difficult to make steam-tight flexible joints in the connecting pipes. The adhesive weight was minimal. Judging by later values of MPS, Brunel seems to have been excessively cautious, rather surprising for such an innovator.

Fig. 1.

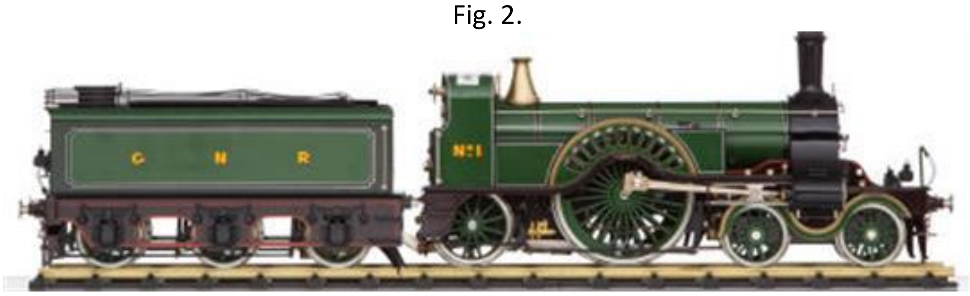


W FIG. 6. HARRISON'S "HURRICANE."

wikipedia

(2). To keep stresses within the available material limits at the design and manufacturing techniques of each age, as required speeds rose, the driving wheel diameters were increased. In 1870 the GNR Chief Engineer, Patrick Stirling, used 8 feet 1 inch single wheels to keep MPS to about 1,200 ft/min (6.2 m/s) at express speeds of 75 MPH (Ref. 1).

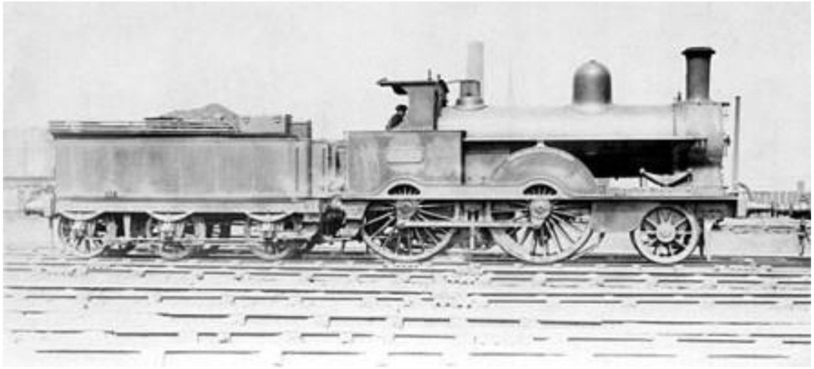
Fig. 2.



thesaleroom

(3). By 1875, during the last " Race to the North ", the LNWR locomotive " Hardwicke ", designed by Francis Webb, reached 88 MPH at about 1,400 ft/min (7.1 m/s) (Ref.1).

Fig. 3.



Wikipedia

(4). In 1904 the GWR locomotive " *City of Truro* ", designed by William Dean with George Churchward's assistance, was timed unofficially (but by an experienced observer) to reach 100 MPH (<u>down a 1/90 slope</u>) (Ref. Wikipedia). This was 1,809 ft/min (9.2 m/s).

Fig. 4.

modelrailforum

(5). An officially timed dynamometer run in 1934 by the LNER " *Flying Scotsman* ", designed by Nigel Gresley, recorded 100 MPH (probably down Stoke Bank, 1/200). This was 1821 ft/min (9.2 m/s). The engine had Ni,Cr-alloy con. rods (Ref. 3).

Fig. 5.

Wikipedia

This shows the corridor connection on the tender, which enabled crews to change on non-stop London to Edinburgh runs.

(6). In 1935, about a century after Brunels' specification, AlCo built 4-4-2 locomotives to haul the " *Hiawatha* " express between Chicago and Minneapolis on the Chicago, Milwaukee, St Paul and Pacific Railroad at a regular 100 MPH (Ref.2). This was an MPS of 1,900 ft/min (9.6 m/s). These engines had 300 psi steam pressure, instead of the then-usual 275, especially to keep down the diameter and mass of the forged-steel pistons, working at a superheated steam temperature of 370C. The con. rods were Ni-alloy steel.

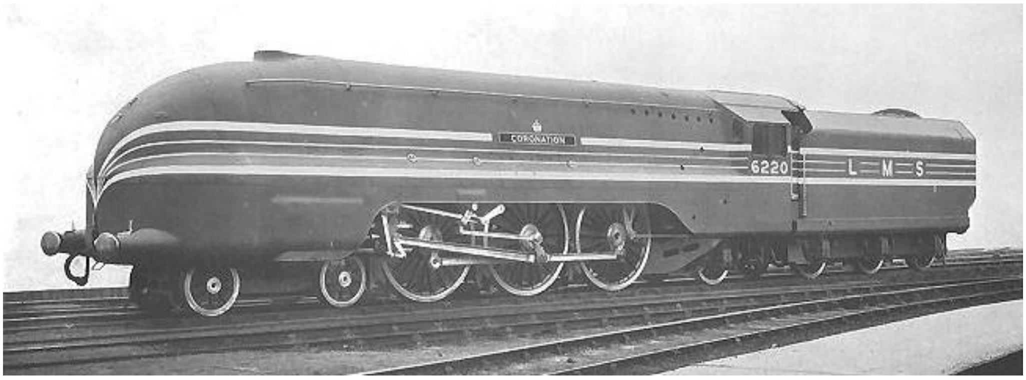
See Fig. 6 on P.3

Fig. 6.

Pinterest

(7). When the LMS 4-6-2 engine “ *Coronation* ”, designed by William Stanier, reached 114 MPH in June 1937 (down a 1/269 slope) the level of MPS was 2,200 ft/min (11.2 m/s) (Ref.3). The superheated steam temperature was 312C.

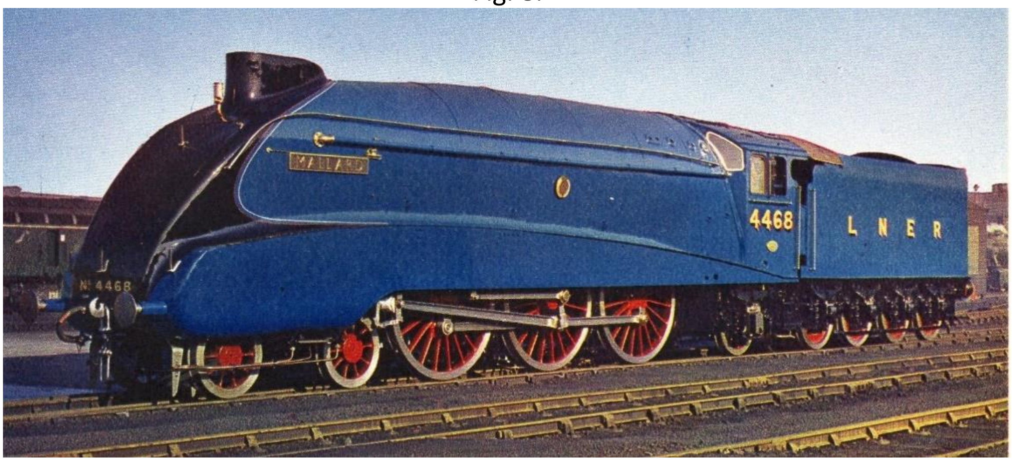
Fig. 7.



railalbum.co.uk

(8). In July 1938 the LNER A4-class 4-6-2 “ *Mallard* ”, designed by Nigel Gresley, set an all-time steam record of 126 MPH (down the 1/200 Stoke bank). MPS was 2,300 ft/min(11.6 m/s). This was at the cost of a failed middle big-end bearing (a well-known A4 fault caused by wear in the gear operating the central cylinder valves from the outside cylinders, so that this cylinder was over-loaded). (Ref. 3).

Fig. 8.



pinterest

(9). Post-WW2 a Norfolk & Western J-class 4-8-4 locomotive, running on a " race-track " section of the Pennsylvania, achieved 110 MPH. This was an MPS of 2,818 ft/min (14.3 m/s). The stress would have been 50% higher than " *Mallard* ". The con. rods were " lightweight ". All bearings were roller. The boiler was mechanically stoked. (Ref. 4).

Fig. 9.

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(10). As a tailpiece, not part of the rising MPS series above, a BR class 9F 2-10-0, designed by R Riddles for heavy freight service, was timed unofficially at 90 MPH while descending the 1/200 Stoke Bank in 1958 on a passenger train (Ref. worldrailfans.info). MPS = 2,353 ft/min (12 m/s), i.e ,slightly more than " *Mallard* ". The bearings were plain and, to avoid excessive wear to these, such high speeds were banned later..

Fig. 10.

traintalktv

This engine was not named while in BR service.

<u>Conclusion</u>

The increase in reciprocating parts stresses, proportional to (MPS)^2, over the period 1870 to 1904 was [9.2 m/s/6.2 m/s]^2 = 2.2. From 1904 to 1950 it was [14.3/9.2]^2 = 2.4. This was with locomotives designed for normal use, although no doubt carefully prepared, not " racing " engines. The changes in materials were, egs. pistons improving from cast iron to forged steel, and con. rods from wrought iron to plain steel to Ni,Cr-alloy steel.

<u>Sources</u>

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B. Hollingsworth. Salamander. 1982
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(3). British Pacific Locomotives. C. Allen. Ian Allan. 1971.
(4). Loco Profile No. 20. The American 4-8-4. B. Reed. Profile Publications. 1972.