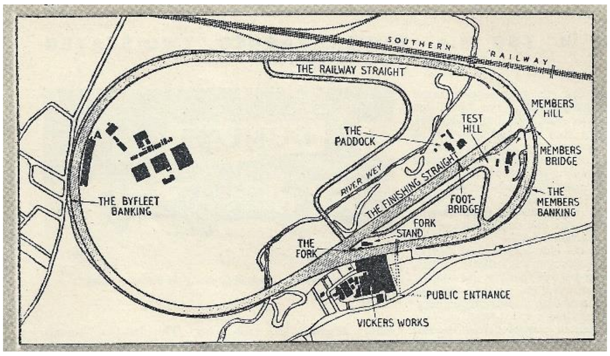
Note 104B
Brooklands Outer Circuit Lap Speeds

While seeking data on the power of the famous Freddy Dixon modified NA 2 Litre Riley, which he never bench-tested, a look was taken of its speed on the Brooklands Outer Circuit in comparison with other cars. This led to a correlation of speeds and powers on that track and it is thought that this might be of interest to others.

The circuit

Brooklands was built in 1907, the first dedicated motor-racing track in the world. Fig 1 shows its plan.

Fig. 1



DASO 331

The Outer Circuit, lapped anti-clockwise, comprised a reinforced-concrete uniform 100 feet wide track in the following sections:-

- The Home (or "Members") Banking with an inner radius of 1,000 feet turning through 165^0, rising from level to banking whose cross-section increased smoothly in a curve to a top quarter at 30^0 to the horizontal, the banking then decreasing to level at the Railway Straight;
- A 9^0 curve entering the Railway Straight;
- The level Railway Straight;
- The Byfleet Banking with an inner radius of 1,500 feet turning through 213^0 and a top angle of 20^0, with the same type of transition sections at entrance and exit;
- A level section with the Fork curve 27^0 to the right, where a Finishing Straight continued straight on (feature never copied on any other motor-racing track)..

The total turning of 360^0 was therefore made up of:_ 165^0 LH + 9^0 LH + 213^0 LH – 27^0 RH
The track was 2 miles 1,350 yards long on the centreline (2.767 miles; 4.453 km).

It was reported to have been designed for 120 MPH (article in *M. Sport* March 1925 by A.W.Phillips). This is discussed in an Appendix, regarding the assumed Coefficient of Friction on the banking.

Lap Speeds

Lap Speeds(LS) from 1910 to 1938 are given in Appendix 10. These are all open-wheeled cars, mostly nominal 2-seater* except where shown as narrow 1-seaters. The Peak Powers (PP) and Laden Weights (W) are given (W is in Hundredweights (cwt), as originally measured; 1 cwt = 112 lb = 50.8 kg). The Laden weight is the quoted empty weight plus a nominal amount to include fluids and driver.

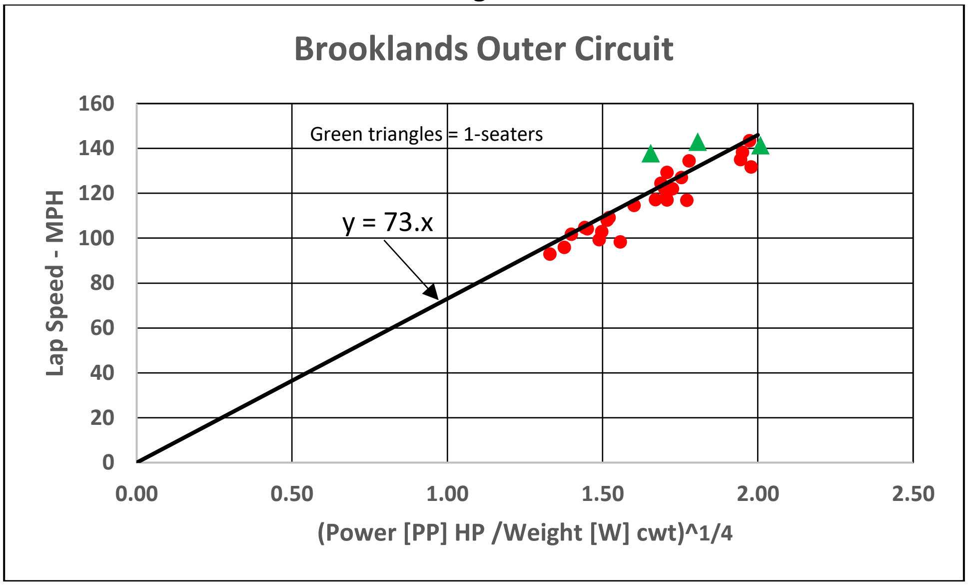
*The Napier-Railton all-time record holder is classed as a "Nominal 2-seater" because of its body width.

Continued on P.2

Relation between LS and PP/W

Power/Weight (PP/W) ratio is a meaningful parameter in relation to Lap Speed (LS) because it has the physical dimensions of ***Speed x Acceleration***. Fig. 2 shows **LS** related to **(PP/W)^$^{1/4}$**.

Fig. 2



Inevitably there is a scatter of data because of:- less-than-scientific accuracy of figures available over 27 years; weather variations, particularly of wind speed, direction and turbulence, especially at the Fork curve after the erection there of large sheds close to the track; and, of course, the driver skill, experience and the determination to cope with the notorious bumps which quite quickly appeared due to settlement.

concerning the latter, it is relevant to quote something written by Tim Birkin, shortly after setting a record of nearly 138 MPH in 1932:-
"I think that it is, without exception, the most out-of-date, inadequate and dangerous track in the world. Brooklands was built for speeds no greater than 120 MPH and for anyone to go over 130 without knowing the track better than his own self is to court disaster. The surface is abominable. There are bumps which jolt the driver up and down in his seat and make the car leave the road and travel through the air." (Quoted in Bonham's literature for the auction of Birkin's record-breaking Bentley UU5871 in 2012.)

The most notorious bump was where the track crossed over the River Wey, towards the end of the Home banking. Here the track had settled on either side of the bridge, which had not settled (as described by H.N.Charles in DASO 331). The resultant effect on fast cars is shown in Fig. 3.

Fig. 3

John Cobb driving his Napier-Railton over the R. Wey bump

With all four wheels off the track there must have been previously a correction to straight line travel to prevent a sideways displacement.

pinterest

Given the mentioned effects on LS, a "Maximum" line for nominal 2-seaters has been drawn on the chart, passing through the all-time record of 143.4 MPH set by John Cobb in 1935, at:-

LS = 73 x (PP/W)^$^{1/4}$ (rounded-up)

Clearly, 2 out of the three 1-seater cars beat the 2-seater "Maximum" by a substantial amount, due to lower drag. This and other good and bad figures are discussed on P.3.

Variations from "Maximum" line

1926 2 Litre 1922 Sunbeam

Below the line by 13%. With due respect to the driver, J. Spencer, he was a private owner and did not figure much in Brookland's annals with a 4 year old car.

1927 Mercedes 1924 GP

About 10% low. One of Ferdinand Porsche's "Hard to drive" designs, with a low polar moment of inertia and very stiff suspension. Two out of 3 built crashed. Mays recorded the comments of Segrave on his run at Brooklands:-"*Ray, you're damn lucky to be alive, and if you take my advice you will never drive that car again!*" (DASO 446). Enough said.

1930 Delage 1927 GP

Very close to the line, but noted because it was *assumed* that this run was at the much-publicised 170 HP. Note 5 discusses in detail the reasons why this could not have been the *sustainable GP-race-long* output because it would require RPM in the piston-ring flutter region. However, the rings *could* have lasted for a few laps of Brooklands.

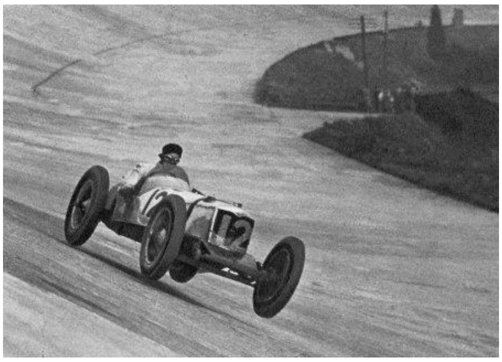
1935 MG Q-type

Below the line by 3%. The power output is the unsustainable short-run level quoted by H.N. Charles in DASO 331. He also commented about the lap speed, by a private owner "*The lightness of touch and degree of anticipation necessary to do this would be possessed by very few people. His driving on that occasion was better than the car he drove.*" Charles' own earlier experience with the Q-type prototype at Brooklands led him to design the all-independently-sprung R-type.

1935 Dixon-Riley

This is 3½% better than the line. It was a car with very low lines for its type, as can be seen in Fig.4.

Fig. 4



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Freddy Dixon driving his 2 Litre Riley Special over the R. Wey bump.

It was concluded that the 150 HP conservatively estimated by the car's 1995 owner, Mark Gillies, was a reliable figure. (DASO 141). This was a very remarkable power for a Naturally-Aspirated IL6 2 Litre engine in 1935. It is discussed further in "Significant Other" at SO11.

1937 Talbot t150C

Nearly 4% above the line. This was one of only 2 cars in the data to have independent front suspension (IFS; the Multi-Union was the other). All other cars listed had rigid axles with leaf springs all round. The T150C rear axle was rigid. This IFS *could* have been an advantage over the Brooklands bumpy surface. It would have depended on whether the resultant low-front-to-high-rear roll axis, the relative front/rear roll stiffnesses and the weight distribution, gave a balanced car or not. Over or understeer would be definite handicaps on the banking. Presumably the T150C was sufficiently balanced.

1938 Multi-Union

Although a 1-seater with a streamlined body and IFS, the Multi-Union lapped 3½% *below* the line officially (*unofficially* it came within 1/10 second of the record, 143.2 MPH, according to DASO 286). Considering that the other 1-seaters lapped so much faster than the line – the Bentley special driven by Tim Birkin +14% in 1932 and the Oliver Bertram-driven Barnato-Hassan + 8½% in 1938, it is not clear why Chris Staniland did not achieve more with the Multi-Union. The question of balance for a car with IFS but a rigid rear axle has been mentioned under the Talbot T150C above. Maybe the Multi-Union in its final configuration did not have the required stability. Very few people in 1938 knew how to provide a car with steering appropriate to the circuits on which it was raced. Continued on P.4.

1938 Multi-Union, continued.

There is another possible explanation for the relatively disappointing Multi-Union speed as a 1-seater – *insufficient weight*. Brooklands surface was in a very poor condition from quite early in its history, as Tim Birkin described (see above). A heavy car would be able to keep its wheels on the ground better than a lighter one. The 1-seaters which were well above the line were 31/32 cwt; the Multi-Union, derived from an original 750kg (14.8 cwt without wheels and tyres) formula car was only about 20 cwt. The Napier-Railton was 33 cwt. The three other 2-seaters with $(PP/W)^{1/4}$ around 2, the same as the Napier-Railton, which were 3 to 9% below the line were around 20 cwt.

The all-time record

The all-time Brooklands Outer Circuit record was set by John Cobb in his Napier-Railton at 143.44 MPH in October 1935. If, for simplicity, it is assumed that this was also the speed on the Home banking*, Appendix A shows that this was consistent with a Coefficient of Friction of about 0.4. Profile 28 records that the surface was "damp". The calculation for the Byfleet banking is similar. This is twice the track design assumption. The tyres lasted just two laps!

As we now know, although very few people would have known in the mid-'30s, a pneumatic tyre in order to develop lateral force must run distorted at a "slip angle" to the car's axis. The car travels at this angle to the vehicle centre-line, which the driver allows for automatically with the steering (until the angle goes beyond a limit set by the tyre's construction and materials). An observer of Cobb's first stab at the record in Easter 1934, placed where he could see a semi-plan view of the car on the Byfleet banking, wrote in *M. Sport* May 1934:-

"*On the Byfleet the Napier-Railton seemed to be in a steady slide, the tail a little higher on the banking than the front*". The car was not actually sliding but the observer very accurately described the effect of slip angle.

With rigid axles at each end - i.e. a horizontal roll axis - and equal spring bases fore and aft (Profile 28 plan), the car presumably was stable – more by Reid Railton's intuition than by calculation it is suspected (perhaps only Maurice Olley could have done the calculation at that date).

The record lap was described by Cobb as "*Like seeing how far you can lean out of an upper-storey window of a tall building without falling out!*".

*The car would have been faster along the Railway Straight – 160 MPH was mentioned – but slower while negotiating the Fork curve with its wind turbulence.

Appendix
Theory and practice of cars on a banked track

The theory for this is available on the internet (HyperPhysics):-

where the radius of the curve is **r ft;**
gravitational acceleration is **g = 32.17 ft/sec^2 ;**
the angle of the banking is $\boldsymbol{\theta}$ $\boldsymbol{degrees}$**;**
the Coefficient of Friction is $\boldsymbol{\mu}$**;**

then $$V_{max} = \sqrt{\frac{r.g.(\sin\theta + \mu.\cos\theta)}{\cos\theta - \mu.\sin\theta}}$$

in **Ft/Sec (x 60/88 = MPH)**

For the Brooklands Home banking the maximum safe radius for the car Centre of Gravity is, say, 10 ft in from the lip
at:- r = 1,090 ft; and $\theta = 30\ degrees$:-
then

for $\mu =$	0	0.2	0.4	
V =	97	120	144	MPH

For the Brooklands Byfleet banking
At r = 1,590 ft; and $\theta = 20\ degrees: -$
then

for $\mu =$	0	0.2	0.4	
V =	93	120	146	MPH

The Brooklands track designer, to arrive at the reported design speed of 120 MPH, seems to have assumed a Coefficient of Friction of 0.2. This appears as exceedingly pessimistic, but there would have been little or no data on the friction of narrow, high-pressure pneumatic tyres at that date. The greater radius of the Byfleet banking allowed a reduction of bank angle to 20^0 for the same speed (which would have saved a lot of earthwork).

The practice resulted in a final Lap Record of 143.4 MPH by John Cobb in 1935 in his Napier-Railton. This corresponds to a Coefficient of Friction of 0.4 (this is assuming for simplicity that the lap speed corresponded to the banking speed).

Not surprisingly, the fastest cars did not race when the track was wet.