Note 134

2019 Grand Prix Pole Speeds related to Circuit Geometry

Introduction

It was thought that visitors to this website might be interested in a way of improving a bald list of 2019 Grand Prix Pole Speeds by showing the figures in a way related to each circuit's geometric characteristics.

In the section of this site entitled "Progress over 64 years of Grand Prix racing" the idea of a Track Factor (TF) for racing circuits was explored which would determine the Lap Speed (LS) achievable for a particular type of car. It was desired to keep the TF simple, calculated with data available to the ordinary enthusiast, although the *full* list of the elements involved was truly daunting – as shown on the Table repeated here as P.2. However, the referenced article confined itself to the input of only 2 elements:-

- Lap length (L) metres;
- Total Turning per lap (T) degrees.

The value of T is measured directly from the circuit diagram (official FIA). By identifying Right and Left turns a check can be made on the accuracy of the measurement from their difference, which must be 360^0 except where the track crosses over itself, as at Suzuka, where the difference is 0.

It was quickly found necessary to distinguish between "Tracks"* with flat kerbs and wide run-offs and "Streets" with hard edges (and often poor quality surfaces). The lack of easy run-off is a powerful incentive to a driver to keep something in hand to avoid damage to the car and himself.

*Including rebuilt road circuits such as Spa from 1983.

In this examination it was also necessary to separate the speeds achieved on circuits at altitudes substantially above the average:- a 500 metre cut-off was used.

2019 Grand Prix cars

For the record, the 2019 season was raced to the tightly-prescribed basic formula introduced in 2014:- 90^0 V6 1.6 Litre; 80 mm maximum Bore diameter; Pressure-Charged by single centrifugal compressor; maximum fuel flow rate 100 kg/hour at 10,500 RPM of fuel containing a minimum 10% ethanol; dynamotor recovering braking energy to a battery and permitting extra output of 120 kW (161 BHP) for 33.3 seconds (4 MegaJoules energy expenditure limit). Fuel ration of 110 kg for the race (revised upward from original 100 kg/hour).

By 2018 Mercedes-Benz were claiming that their PU106 Internal Combustion Engine was developing over 700 PS (690 BHP) (see Note 129). With the additional boost from the battery the total was around 850 BHP. This was in a car of rule minimum, including water, oil and driver, weighing for a Pole-setting lap little more than 750 kg. The resultant Power/Weight ratio was about 1150 BHP per Ton in a car pressed onto the surface by additional aero forces several times its weight.

2019 Mercedes-Benz W10
(Built in England)
Constructors' Champion car
and mount of
Drivers' Champion
Lewis Hamilton.

autosport.com

Continued on P.3

TABLE 1

FACTORS WHICH FIX LAP SPEEDS THROUGH A RACING SEASON

- VEHICLE SPECIFICATION
  - Car } As originally designed and with original range of
  - Tyres } adjustments and alternatives
  - Set-Up particular to a circuit, covering choice of original adjustments or alternatives to :-
    - Engine variables (egs. Valve and Ignition timing, Fuel/Air ratio)
    - Gear Ratios (Final drive and Intermediates)
    - Chassis variables (Aerodynamics, Suspension, Steering, Braking)
    - Fuel
    - Tyre type for each wheel
  - Modifications during the season, beyond the original ranges, for all elements of Specification

- FUEL LOAD

- DRIVER
  - Inherent driving ability and courage
  - Rapport with the car and ability to describe its qualitative performance to the Engineer (nowadays telemetry gives the quantitative data)
  - Knowledge of each circuit
  - Form on-the-day and on-the-lap

- CONSUMPTION FACTORS
  The Engineer and Driver can maximise lap speed at the expense of the life of :-
  - Engine, Tyres, Brake-pads, Fuel
  - Driver's Physical and Nervous Energy

- TRACK SPECIFICATION
  - Number and Lengths of Straights
  - Number and Radii of Corners and their Turning Angles
  - Sequence of Straights and Corners
  - Changes of direction between successive Corners
  - Width
  - Surface Grip, Bumpiness and Cleanliness
  - Camber and Banking
  - Hills
  - Average Atmospheric conditions (Temperature, Pressure, Humidity) for circuit geographic location (Latitude, Longitude, and Altitude) and seasonal race date
  - Run-off Margins and Safety Features generally

- WEATHER
  - Dry or Wet
  - Atmospheric conditions on-the-lap, as variables from the circuit average
  - Wind Speed, Direction and Gustiness

- RACING TRAFFIC ON-THE-LAP

Continued from P.1

Modified Total Turning

In Note 131B an attempt was made to improve Track Factor by introducing a Factor of Difficulty (FOD) for each corner of a circuit to produce a Modified Turning Angle (TM). To introduce this subjective judgement in addition to pure objective angles in a controlled way it was necessary to write some rules. Those settled on were as follows:-

Method for determining Modified Turning Angle (TM)

Given the basic details measured for total turning (T), with Left and Right angles identified and with the difference checked as 360^0 , the Modified Turning Angles are determined as follows, by multiplying each angle by a Factor of Difficulty (FOD).

. Measured Turning Angle — FOD multiplication

- **40^0 or less** — Measured angle **x 0** Treated as "Non-friction-limited", by the car path radiused within the road width.
- **Between 80^0 and 100^0**

  Sharp corner meaning that the car path is radiused only in road width:- Measured angle **x 2**

  Radiused corner — Take angle **as measured**
- **Beteen 150^0 and 180^0**

  Sharp Hairpin (as above) — Measured angle **x 3**

  Radiused — Take angle **as measured**
- **Chicane** — Measured angles **x 1.5**

This approach, as shown in Note 133B, gave very good results when applied to the pre-WW2 B-type ERA, particularly when related to one driver ('B. Bira').

It was therefore thought worthwhile to apply the TM idea with the above rules to 2019 results. It must be admitted that this was more difficult to judge on most current circuits, where there are no very-sharp corners compared to the typical pre-WW2 sort.

Data

The resultant figures for L and TM are recorded on P.6. In 2019 all Pole Speeds (LS) obtained in Qualification period 3 (Q3LS) were in dry weather and usable for this analysis. Of the 21 races, 13 were classed as on Tracks (T), 5 as Streets (S) and 3 at altitudes above 500 metres on Tracks.

Track Factor

A Multi-variable Regression Analysis (MRA) was carried out with L and TM as the variables affecting Q3LS on the 13 Tracks. It became clear that the Pole Speed at Silverstone was far above what could be expected from the other 12 in the sample. There was no apparent reason for this, if the "Rules" for FOD were followed honestly. The only way of progressing the situation was to put it aside and do the MRA on the 12. No distinction was made for make or driver, as figures were so close in Qualification. The result was:-

Q3LS = 63.064 x (L metres)^0.266/(TM degrees)^0.128 kph

with R^2 = 0.85.

The Track Factor TF5 is therefore (L)^0.266/(TM)^0.128

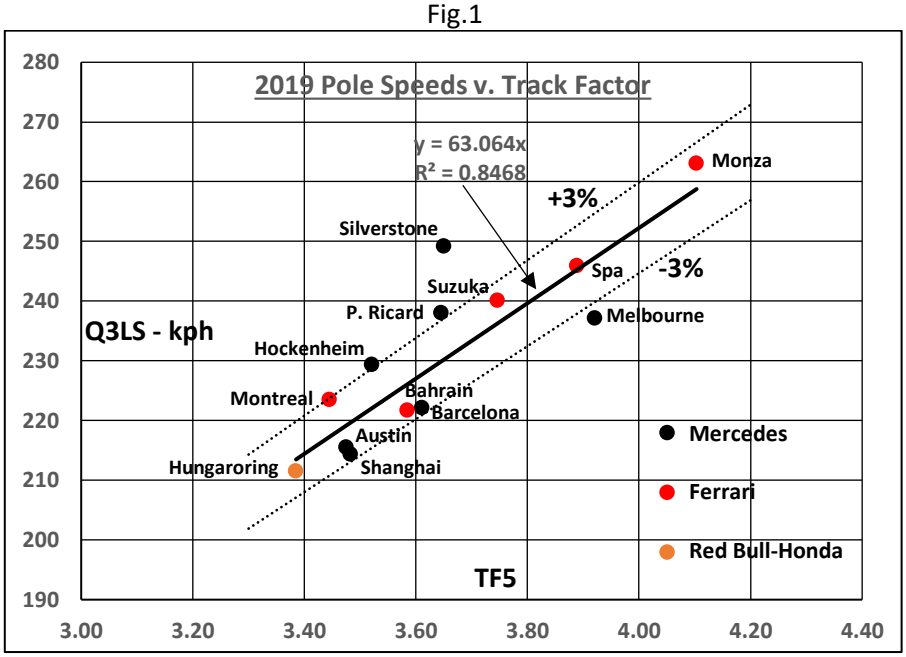
This is not a very good correlation, but yields a result on the 12 race sample that

average error (Actual-Trend)/Trend = 2.2%.

[Silverstone, segregated from the other 12 in the MRA, was 8.3%.]

The figures are charted as Fig.1 on P.4 below. Makes are there identified by colour.

Fig.1



Comments applying to this chart are:-

- Q3LS in the MRA were taken as achieved, without distinguishing between makes, since it is certain that the difference was generally far below the likely scatter on this simple correlation. However, it *may* be significant that those by Ferrari after mid-season (Montreal, Spa, Monza, and Suzuka) average 1.6% above trend. During this period it has been alleged that Ferrari were, in some way, obtaining a higher fuel flow rate than prescribed. The FIA post-season seemed to acknowledge this.
- The Melbourne error of -4% is believed to be because the circuit is used by normal city traffic on 362 days and so the surface grip is degraded by oil droppings
- Comparing the indices of L and TM in TF5 with those of TF4 obtained from the pre-WW2 ERA B-type, they are:-

  TF5 (L)^0.266/(TM)^0.128 versus TF4 (L)^0.22/(TM)^0.26.

  The significant difference in the TM indices is probably because the 2019 car was much less slowed by corners by reason of vastly greater braking power and surface grip.

Street circuits

The results for Street Circuits are shown on Fig.2 on P.5.

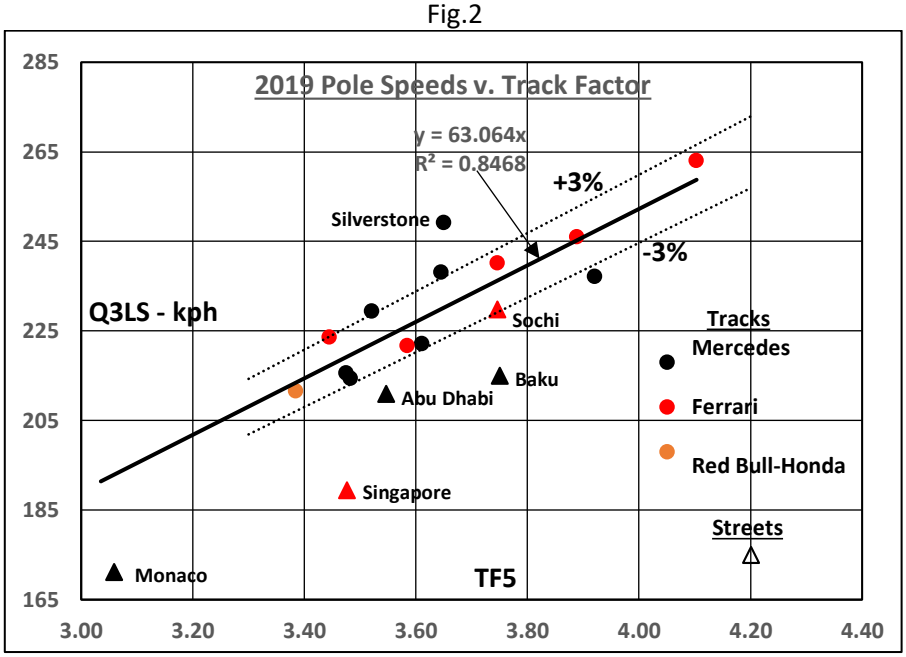
2019 Ferrari SF90

wikipedia.org

2019 Red Bull-Honda RB15

grandprix247.com

Fig.2

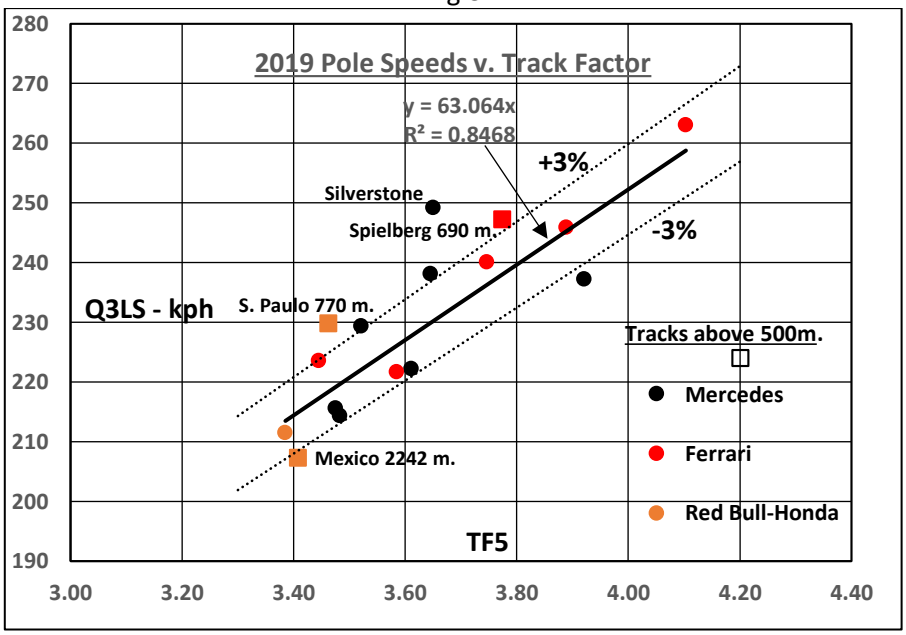


- Comment on Fig.2 is that the Ferrari Pole at Sochi was in the "questionable period", and so was Singapore.

Circuits over 500 metre altitude

The Poles at these circuits are shown on Fig. 3

Fig.3



- With a prescribed Fuel Flow Rate the power at altitude can be restored to Sea Level output by increasing the compressor pressure ratio. It is then a question of whether the *reduced aero drag* is offset by *reduced grip in the corners*. It appears that the former wins up to 700 metres but the latter at the extreme Mexican atmosphere.

Conclusions

It is hope that these "pictures" will be of interest to visitors, although the relation is not good enough to bet on!

Silverstone remains a puzzle which someone else may be able to solve.

Date 17 March 2020

Title Circuit Speed Analysis

YEAR 2019

Tyres:- Pirelli only;

Variable friction coefficients through the season

CIRCUIT	M'bourne	Bahrain	S'hai	Barcelona	M'real	P. Ricard	H'heim	Hng'ring
Car:- Polesitter; ; M = Mercedes. F = Ferrari. RB = Red Bull	M	F	M	M	F	M	M	RB
Driver:- ; H = Hamilton. B = Bottas. LeC = Leclerc. V = Vettel. Vn = Verstappen.	H	LeC	B	B	V	H	H	Vn
Altitude - Metres	11	15	4	123	8	426	111	232
Temp. degrees K	297	308	288	292	292	300	296	303
Type - T = Track; S = Street	T	T	T	T	T	T	T	T
Pole Speed Q3LS - kph	237.2	221.7	214.4	222.2	223.5	238.1	229.4	211.5
Geometry								
L = Length - metres	5303	5412	5451	4655	4361	5842	4574	4381
T = Turning - Degrees	1290	1372	1820	1550	1080	1658	1230	1508
TM = deltaT multiplied by Factor of Difficulty (FOD) - Degrees	1274	2669	3399	1849	2326	2751	2169	2693
TF5 = (L)^0.266/(TM)^0.128	3.92	3.59	3.48	3.61	3.45	3.64	3.52	3.39
Speed Error % :-(Actual-Trend)*100/Trend	-4.04	-1.94	-2.38	-2.40	2.87	3.59	3.33	-0.93

CIRCUIT	Spa	Monza	Suzuka	Austin	S'stone
Car:- Polesitter; ; M = Mercedes. F = Ferrari. RB = Red Bull	F	F	F	M	M
Driver:- ; H = Hamilton. B = Bottas. LeC = Leclerc. V = Vettel. Vn = Verstappen.	LeC	LeC	V	B	B
Altitude - Metres	414	185	36	155	149
Temp. degrees K	289	303	297	295	289
Type - T = Track; S = Street	T	T	T	T	T
Pole Speed Q3LS - kph	245.9	263	240.1	215.6	249.2
Geometry					
L = Length - metres	7004	5793	5807	5513	5891
T = Turning - Degrees	1592	918	1622	1780	1642
TM = deltaT multiplied by Factor of Difficulty (FOD) - Degrees	2416	1071	2188	3542	2768
TF5 = (L)^0.266/(TM)^0.128	3.89	4.10	3.75	3.47	3.65
Speed Error % :-(Actual-Trend)*100/Trend	0.27	1.64	1.61	-1.61	8.27

STREETS

CIRCUIT	Baku	Monaco	S'pore	Sochi	Abu Dhabi
Car:- Polesitter; ; M = Mercedes. F = Ferrari. RB = Red Bull	M	M	F	F	M
Driver:- ; H = Hamilton. B = Bottas. LeC = Leclerc. V = Vettel. Vn = Verstappen.	B	H	LeC	LeC	H
Altitude - Metres	-17	2	10	10	0
Temp. degrees K	285	297	301	293	298
Type - T = Track; S = Street	S	S	S	S	S
Pole Speed Q3LS - kph	215	171.2	189.4	229.8	211
Geometry					
L = Length - metres	6003	3340	5065	5853	5554
T = Turning - Degrees	1696	1856	1786	1470	1746
TM = deltaT multiplied by Factor of Difficulty (FOD) - Degrees	2332	3382	2956	2225	3064
TF5 = (L)^0.266/(TM)^0.128	3.75	3.06	3.48	3.75	3.55
Speed Error % :-(Actual-Trend)*100/Trend	-9.08	-11.26	-13.62	-2.75	-5.66

*Vn was demoted from pole

OVER 500 Metres

CIRCUIT	S'berg	Mexico	S.Paulo
Car:- Polesitter; ; M = Mercedes. F = Ferrari. RB = Red Bull	F	RB	RB
Driver:- ; H = Hamilton. B = Bottas. LeC = Leclerc. V = Vettel. Vn = Verstappen.	LeC	Vn*	Vn
Altitude - Metres	690	2242	770
Temp. degrees K	290	297	293
Type - T = Track; S = Street	T	T	T
Pole Speed Q3LS - kph	247.2	207.3	229.8
Geometry			
L = Length - metres	4326	4304	4309
T = Turning - Degrees	894	1430	1398
TM = deltaT multiplied by Factor of Difficulty (FOD) - Degrees	1121	2460	2180
TF5 = (L)^0.266/(TM)^0.128	3.77	3.41	3.46
Speed Error % :-(Actual-Trend)*100/Trend	3.85	-3.56	5.23