Note 137 The Indianapolis 500

The 500 mile race* on the circuit near the city of Indianapolis, first run in 1911, is the oldest and only race still held on a track unchanged in plan over its 103 runnings (109 years less 6 in Wartime).

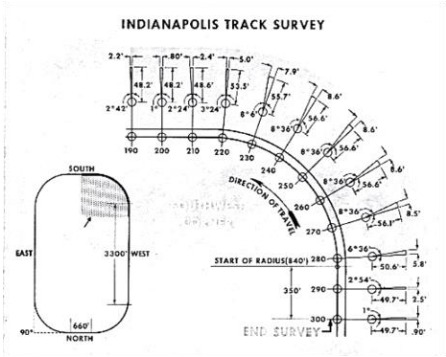
There are many sources of data on these events (see References below on P.6 for those used in this Note) but it seems the information has not been presented in chart form. This Note 137 provides that, plus some analysis for Power/Weight effect on Lap Speeds.

*There were 8 short races, see Appendix D on P.11.

The track

The plan of the Indianapolis circuit is as simple as it could be, short of a plain circle. It comprises 2 x 5/8 mile plus 2 x 1/8 mile straights joined by 4 x ¼ mile quarter-circle turns (radius 840 feet), total lap length 2 ½ miles, measured at the inner edge. The turns were banked at a nominal $9^0\,12'$ (but see below). The racing surface is 50 feet wide on the straights and 60 feet on the turns. It was built of brick initially, partly re-surfaced with tarmac in 1936 and wholly relaid in asphalt in 1961. Since then it has been relaid in asphalt several times.

When Ford, with Lotus, made a major effort to win the race in 1963 they surveyed the turns meticulously, with the result given on the diagram at the RHS. This shows how the bank angle is raised and lowered at entry and exit. At that date the actual maximum angle was $8^0\,36'$.

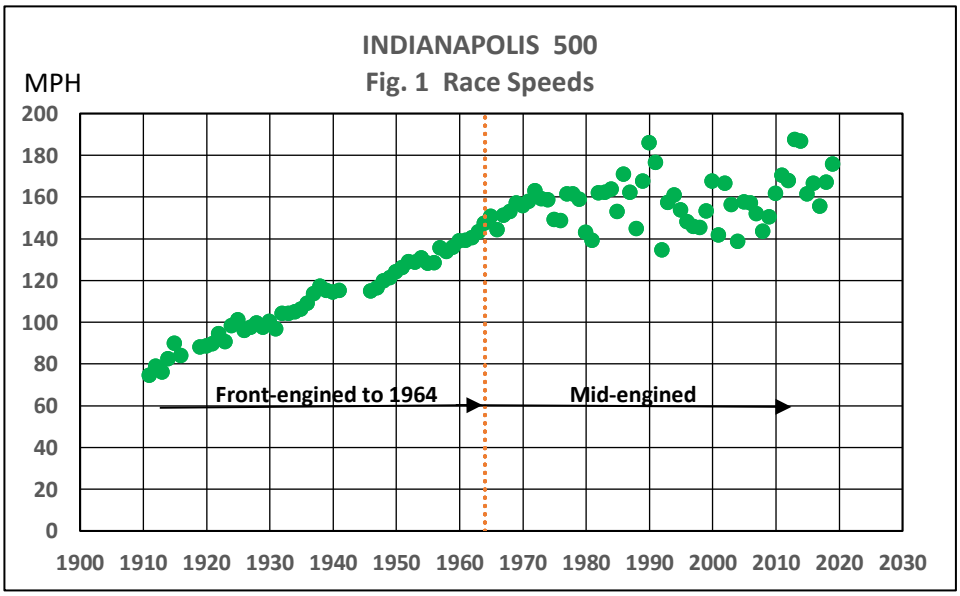


DASO 54

From being "open", corners were defined by kerbs (or "rumble strips") in 1993, but these were removed after 1995. Races are run anti-clockwise (800 left turns!).

Overall review of Race Speeds (Fig. 1)

This figure is shown with a division into two eras:- 1911 to 1964 all winners were front-engined; after the !963 Lotus-type 29-Ford showed the US racing establishment a better mid-engined "way-to-go"* all winners from 1965 -2019 adopted that configuration. This was one of Colin Chapman's major achievements. In return, the US racing teams showed him a better way to finance his Grand Prix racing, by bringing in non-automotive firms seeking advertisement by sponsorship (in 1968 his F1 cars were painted like a fag packet!).

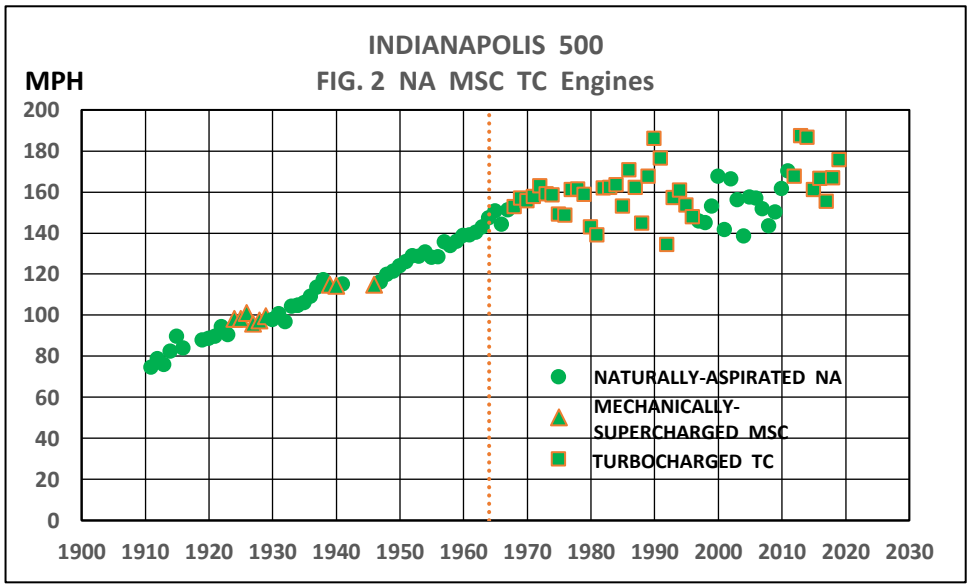


It is emphasised that, apart from the front/mid-engine configuration, no correlation with date of these speeds is possible .because race speeds over the 109 years included the time-based changes in materials and construction for engines and chassis; for materials, construction and pressure for tyres; for different suspension systems; plus the use of aero systems post-1972 to increase downforce. Notes on these effects have been given in "Progress over 64 years of Grand Prix racing".

*Cooper at Indianapolis

While the major credit for the "Mid-engined revolution" at Indianapolis must be given to the effect of the Lotus 29 finishing (controversially) 2nd in 1963 and the Lotus 34 running 1st in 1964 before its Dunlop tyres let it down, there was a harbinger of this with Cooper. This company had just caused the "Mid-engined revolution" in F1 Grand Prix racing. In October 1960 Jack Brabham lapped Indy at 144.8 MPH with a T53-Climax 2.5 Litre. This was 96.8% of the then 1-lap Qualification (Q) record of 149.6 by a 4.2 L roadster on only 59.5% of the capacity. Encouraged by this, Cooper then built the T54 for 1961 with a Climax enlarged to 2.75 L. Brabham practised at 146.5, 97.9% of the still extant Q record. He finished 9th, slowed by the need to preserve his Dunlop tyres.

<u>Winners classed by Induction system (Fig. 2</u>



This chart shows the three types of induction system used at Indianapolis:-

- Naturally-Aspirated (NA);
- Pressure-Charged (PC),

either by:-

- Mechanical-Supercharging (MSC) – Centrifugal compressors 1924 – 1929 and 1946 (Sparks); Roots-type blowers 1939 – 1940 (Maserati 8CTF);

or

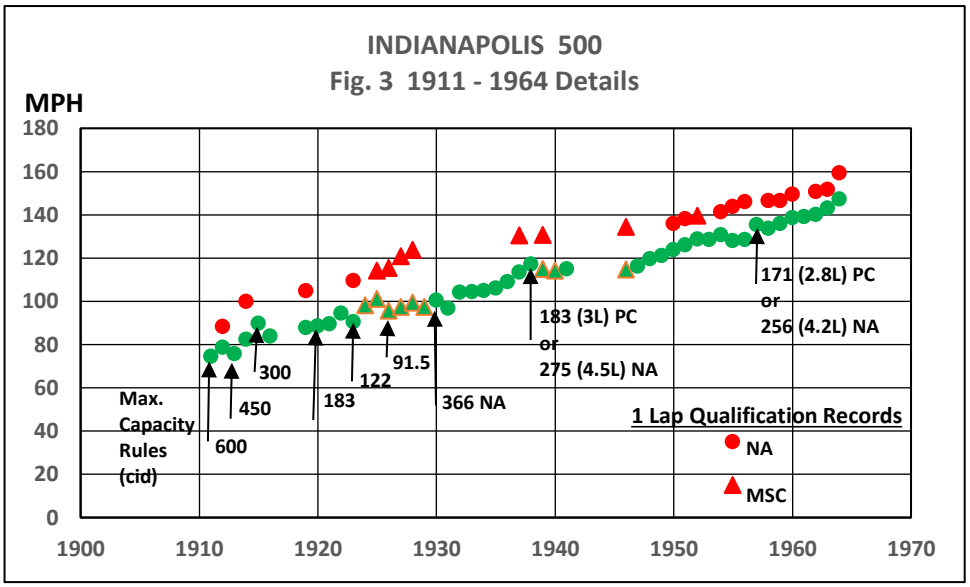
- TurboCharging – from 1968 to 1996 and from 2012 onward.

The system choice was sometimes because of effectivity and sometimes forced by the rules (which will be identified on the following charts.

Continued on P. 3.

Details 1911 – 1964 Fig. 3 The front-engined era

As well as the race winners this chart shows the 1-lap qualification records.



The first and the last front-engined cars

!911 Marmon

NA IL6 477.1 cid (7,820 cc)

Driven by Ray Harroun to win at 74.6 MPH.

tripadvisor.com

pinterest.com

1964 Watson./Offenhauser

NA IL4 251.9 cid (4,128 cc)

Winner A.J.Foyt at 147.4 MPH.

This was the 24th and last win powered by a Naturally-Aspirated (NA) "Offy", the 1st having been in 1934 (counting 3 wins labelled as "Miller"in DASO 1237.).

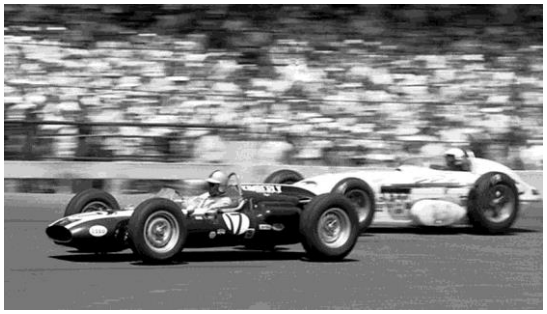
The cars which showed the mid-engined "Way-to-Go"

1961 Cooper T54/Climax

NA IL4 2,750 cc (167.8 cid)

Jack Brabham finished 9th.

Photo specially chosen to show the contrast in size to the typical US roadster.



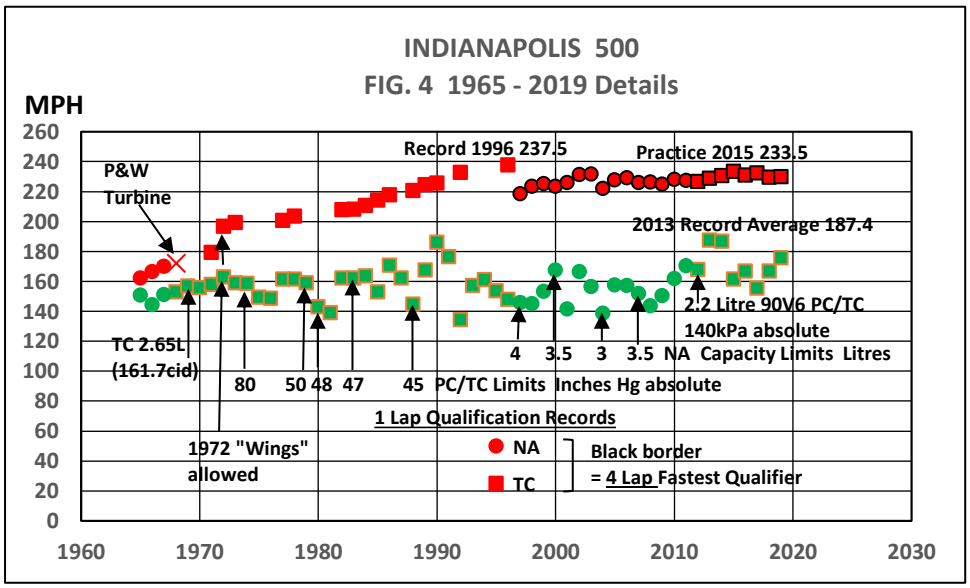
pinterest.com

Continued on P.4.

pinterest.com

1963 Lotus 29/Ford
NA 90V8 255.3 cid (4,178 cc)
Jimmy Clark finished 2nd.
PROHV engine
Colin Chapman, LHS in group.

Details 1965 – 2019 Fig. 4 The mid-engined era



The Clark/Lotus29/Ford effort in 1963 gained 2nd place in a race made controversial by oil leaking from the winner. A repeat with the Lotus 34, now fitted with the new 4 cam Ford engine, was frustrated by the Dunlop tyres failing while Clark was in the lead at 20% distance. In 1965 the Lotus 38, now on Firestone tyres (the make which had shod 89.6% of all the winners up to 1964) finally gained the victory.

TurboCharging entered the arena to win in 1968. Dale Drake had not despaired of the basic Offy, had reduced its capacity to 167 cid (2,737 cc) ,and fitted a Garrett TC (Note 89).

Ford countered by TurboCharging their 4 Cam engine with reduced stroke and powered another 3 wins, but left Indy racing in 1972. They sold the rights to A. J. Foyt and he won another race with the developed TC Ford engine in 1977 after another 5 TC Offy -powered wins.

Despite efforts to curb power from the TC engines with regulation “pop-off” inlet-system valves, Qualification (Q) speeds rose continually, partly because aero-downforce by “Wings” was officially-permitted in 1972 and exploited. In late 1995, when Q /R that year had reached 231.6 MPH/153.6 = 1.51, the authorities cried “Enough!”. They decreed that in 1997 engines must revert to Naturally-Aspirated (NA) and 4 Litres, with a Bore limit of 93 mm and a maximum permitted RPM of 10,500.

With varying capacities over the next 15 years (4 to 3 5 to 3 and back to 3.5 after a rule change to make 85% ethanol +15% gasoline fuel compulsory, in place of methanol), the Q/R ratio averaged about 1.47 (226.0 MPH/153.8). The team’s ability to enhance performance for the 4-lap Q runs had hardly altered – and, frankly, the way in which it was done is something of a mystery to this author, since so much was now limited! At least, the maximum speeds had been curbed.

Under pressure from the green lobby to make motor racing more efficient than NA, the rule-makers decided to return to TurboCharging for 2012, i.e. to make some use of exhaust energy otherwise wasted. The new formula, with a general intention to maintain racing speeds, was extremely prescriptive. The capacity chosen was 2.2 Litres with hosts of other factors laid down:- 90^0 V6; 95 mm max. Bore (B) (which, assuming a practical 2,195 cc meant a stroke (S) of 51.6 mm; B/S = 1.84); 1.38 ATA inlet charge pressure; 12,000 RPM max.; 4 valves/cylinder; coil valve springs; engine weight a minimum of 112.5 kg; specified make of ECU. All this in a specified chassis (Dallara IR12, later named DW12 in memory of the late Dan Wheldon) weighing 1590 lb. Teams *were* allowed to choose a package of aerodynamic body parts, within limits.

Still the Q/R ratio remained high, the 8 year average over 2012 to 2019 being 230.3 MPH/171 = 1.35. The fastest practice lap of that period, in 2015, was 233.5 MPH on about 600 BHP, only 2.4% less than the all-time 1996 figure of 239.3, made with a genuine 950 BHP.

Race speeds were actually higher than averaged over the 15 year NA formula, at 171 to 153.8, +11%.

Unlike the contemporaneous F1 formula there was no attempt to recover braking energy because it was only wasted at pit-stops.

<u>The 1st mid-engined winner</u>

1965 Lotus 38/Ford
NA 90V8 255.3 cid (4,178 cc)
Jimmy Clark won at 150.7 MPH.
4 cam engine.

pinterest.com

500legends

<u>The Official Lap Record holder</u>
1996 Reynolds 951/Cosworth XB
TC 90V8 161.7 cid (2,650 cc)
Arie Luyendyk at 237.5 MPH.
[He made a lap at 239.3 in practice:- a 2.5 mile lap in 37.6 seconds.]
It seems likely that this will be the all-time Lap Record, because of the rules demanding less-powerful engines.

<u>The Record Winning Race Average holder (up to 2020)</u>

2013 Dallara DW12/Chevrolet
TC 90V6 134.2 cid (2,195 cc)
Tony Kanaan at 187.4 MPH.
This race was a record for fewest caution laps (21).

Note the yard-wide strip of original bricks at the Start/Finish line.

r

Indianapolis Star

The 2nd near-miss by a Turbine-powered car

1968 Lotus 56/United Aircraft of Canada (Pratt & Whitney) ST6N-76
Specially-developed for Indianapolis from the PT6 aero engine, with Intake Area 16 sq. in. (reduced from 24 in 1967).
Driven by Joe Leonard, stopped when leading at 188/200 distance. A caution period caused engine temperature to rise which triggered a "fail-safe-stop" feature (DASO 854).

barrett-jackson

The 2019 winner

2019 Dallara UAK18/Chevrolet
90V6 134.2 cid (2,195 cc)
Engine designed and developed by Ilmor Engineering.
Team Penske.
Driven by Simon Pagenaud
to win at 175.8 MPH.

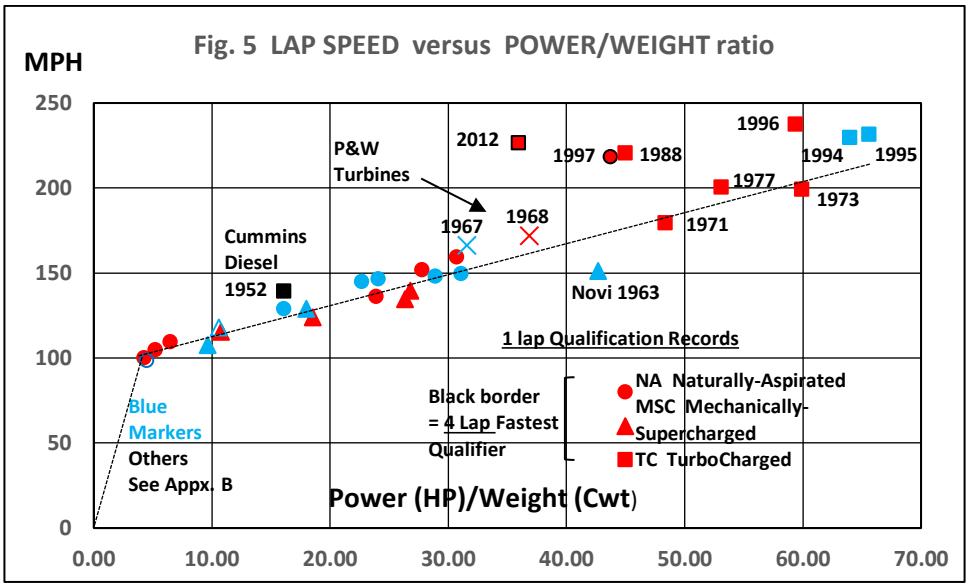
racer.com

References DASO
4 THE GRAND PRIX CAR Revised Ed. Vol. 1.
5 Profile No. 73.
6 GOLDEN AGE OF AMERICAN RACING CAR.
27 MASERATI.
39 Profile No. 18.
54 SAE818A.
55 SAE S397.
468 MERCEDES-BENZ QUICKSIVER CENTURY
854 STORY OF LOTUS 1961-1971.
926 McLAREN.
938 COMPLETE HISTORY OF GP MOTOR RACING.
1035 FABULOUS NOVI STORY.
1046 OFFENHAUSER.
1237 Indianapolis 500 winners
1238 List_of_Indianapolis_500_pole-sitters.
1239 Indianapolis_Motor_Speedway_race_results.
1239B Indy 500 Recaps: the Short Chute Edition
1240 indi500/history-stats/race-stats...Qualifying Records
1241 f1.technical
1242 8w.forix.com/indy96
1243 conceptcarz/s20359/penske-pc-17
1244 chevrolet_indy_v6.
1245 dallara dw12.

Fig. 5 on P.7.

Lap Speed versus car Power/Weight ratio

The Fig.5 below shows the Qualification Lap Speed Records (MPH) versus Power/Weight (HP/Cwt) [although out-of-date the Hundredweight (Cwt = 112 lb).is a very handy measure for this purpose.]. The blue markers are for other Qualifiers. Appendix D explains the black marker and blue cross.



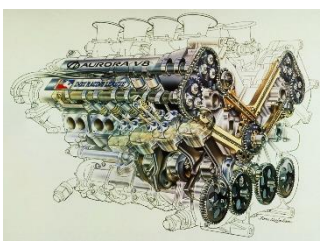
Data Appendix A for red markers is on P.8.
Data Appendix B for blue markers is on P.9.

Discussion of Fig.5*

As mentioned above, Fig.5 cannot be regarded as attempting a correlation because of all the time-related factors (and driver skill and weather, although *not* rain) influencing lap speed, as well as Power/Weight ratio. Nevertheless, the influence of the latter was clearly very important up to the late '70s. Then, it seems, tyre and aero factors took off in a big way. The former was affected by a battle between Firestone and Goodyear which began in 1965 and lasted until Goodyear retired after 1999:- tread compounds, carcase construction (radials superseding cross-ply in 1987), and aspect ratio all changed and the friction co-efficient doubled from 1 to 2 (which alone increased cornering speeds by 40%). After some minimal attempts to get aero downforce from body parts, "Upside-down-wings" as bolt-on additions to give real downforce and higher grip were permitted in 1972. They promptly gave an increase of 17 MPH in Q speed – nearly 10%! Later under-body effects would add yet more grip and cornering speed. Changes were not always consistent as rules were changed.

Perhaps the overall *net* gain over the last 44 years, *apart* from P/W effect, can best be seen by comparing the 1968 (1 lap) Q record with first (4 lap) Q of the 2012 formula:- with quite similar weight and power (see Appendix A) the 2012 car lapped nearly 1/3rd faster (226.5 to 172).

*The low point for the 1963 Novi, with reliable data (DASO 1035), probably shows how 734 HP could not be utilised at Indianapolis at that date.



aurorah.proboards.com

(LHS) 1997 Oldsmobile
90V8 4L NA
93 mm max. bore
(=73.6 approx stroke)
B/S = 1.26

2012 Chevrolet
90V6 2.2L TC
95 mm max. bore
(=51.6 approx stroke)
B/S = 1.84

newatlas.com

Appendix A

Indianapolis 1 Lap Qualification Speeds

General note: For Q weight a nominal 200 or 250 lb, as shown, has been added to Empty Dry weight to allow for Oil, Water and driver. D = Data Source (DASO) F = Front-engined M = Mid-engined NA = Naturally-Aspirated MSC = Mechanically-Supercharged TC = TurboCharged.

LAP SPEED MPH	YEAR	DRIVER	CAR ENGINE D	CHASSIS D	V cc	POWER (P) HP	WEIGHT MT Dry Lb	WEIGHT (W) Q Cwt	**P/W** HP/Cwt
All Speed are Data Source DASO 1240									
99.9	1914	G. Boillot	Peugeot F 5	L56 5	5655 NA	115		27	**4.26**
104.8	1919	R. Thomas	Ballot F 938	938	4817 NA	140	2747 +250	26.8	**5.23**
109.5	1923	T. Milton	Miller F 938	938	1980 NA	120	1874 +200	18.5	**6.49**
115.5	1926	F. Lockhart	Miller F 6	6	1478 MSC	154	1400 +200	14.3	**10.78**
124	1928	L. Duray	Miller F 6	6	1478 MSC	265	1400 +200	14.3	**18.55**
134.5	1946	R. Hepburn	Novi F 1035	1035	2976 MSC	510	1919 +250	19.4	**26.33**
136	1950	W. Faulkner	Offy F 1046	K. Kraft 1035	4425 NA +NM	400 (+16%)	1623 +250	16.7	**23.92**
139.6	1952	C. Miller	Novi F 1035	Kurtis 1035	2969 MSC	550	2050 +250	20.5	**26.78**
151.8	1963	P. Jones	Offy F 1046 +54	Watson	4128 NA +NM	464 (+16%)	*1623* +250	*16.7*	**27.78**
159.4	1964	J. Clark	Ford M 854	Lotus 34 854	4185 NA +NM	425 +?	1350 +200	13.8	**30.71**
172	1968	J. Leonard	P&W M 854	Lotus 56 854	GAS TURBINE	510	1350 +200	13.8	**36.85**
179.4	1971	P. Revson	Offy M 926	McLaren M16A 926	2613 TC	700	1370 +250	14.5	**48.40**
199.1	1973	J. Rutherford	Offy M 1241	McLaren M16C	2613 TC	959		Say 16	**59.94**
200.5	1977	T. Sneva	Cosworth DFX M See Appx 5 Col. BH	McLaren M24	2643 TC	850		Say 16	**53.13**
220.5	1988	R. Mears	Chevy 265 M 1243	Penske PC-17 1243	2647 TC	720	1550 +250	16	**45.00**
237.5	1996	A. Luyendyk*	Cosworth XB M 1242	Reynard 951	2650 ? TC	950		Say 16	**59.38**

*Luyendyk practiced at 239.3 (DASO 1242).

4 Lap Fastest qualifiers

First 500 of the 1997 NA Formula

218.3	1997	A. Luyendyk	Oldsmobile M mecum.com	G-Force	3994? NA	700	1550 +250	16	**43.75**

First 500 of the 2012 TC formula

226.5	2012	R. Briscoe	Chevrolet M 1244	Dallara DW12 1245	2195? TC	575	1590 +200	16	**35.94**

See Appendix C for Engine details available on the website via Links

Appendix B
Indianapolis: Other Qualification Speeds
Notes as for Appendix A

LAP SPEED MPH	YEAR	DRIVER	CAR ENGINE D	CHASSIS D	V cc	POWER (P) HP	WEIGHT MT Dry Lb	WEIGHT (W) Q Cwt	P/W HP/Cwt
In Lap Speed order									
98.6	1915	R. DePalma	Mercedes F	Mercedes			2385		
4			M93654	1914 GP		106	+250	23.5	**4.51**
			468	468	4483 NA				
107.6	1929	L. Chiron	Delage F	Delage			1770		
1239				15-S-8		170	+200	17.6	**9.66**
			39	39	1488 MSC				
118	1938	M. Rose	Maserati F	Maserati			1433		
27		1239B		6CM		155	+200	14.6	**10.6**
			27	Wikipedia	1493 MSC				
128.8	1947	W. Holland	Offy F	Deidt				Say	
1239				Blue Crown		274		17	**16.1**
			1035		4425 NA				
129	1939	W. Shaw	Maserati F	Maserati			1918		
27			8CTF		2991 MSC	350	+250	19.4	**18.0**
			27	27					
144.8	1960	J. Brabham	C .Climax M	Cooper			1000		
Autocar 12 May 1961			FPF	T53		243	+200	10.7	**22.7**
			A'car	1035-*A'car*					
					2496 NA				
146.6	1961	J. Brabham	C. Climax M	Cooper			1050		
1035			FPF Special	T54		270	+200	11.2	**24.1**
			55	1035					
					2751 NA				
147.9	1962	D. Gurney	Buick M	Thompson			1080		
1035			1035	1035		330	+200	11.4	**28.9**
					4194 NA				
149.3	1963	D.Gurney*	Ford M	Lotus L29					
1035			854	*Motor* 27March 1963		370	1130		
					4185 NA		+200	11.9	**31.1**
151.3	1963	J. Hurtubise	Novi F	Kurtis ?			1680		
1035					2751 MSC	734	+250	17.2	**42.7**
			1035	1035					
229.5	1994	A. Unser Jr**	Mercedes M	Penske PC-23			1550		
468			(Ilmor) 500I		3429 TC	1024	+250	16	**64**
			468	468					
231.6	1995	S. Brayton	Menard M	Lola T9500				Say	
1239		***	(Buick V6)		3429 TC	1050		16	**65.6**
			1242						

*Gurney practiced at 153 (DASO 1035). **E. Fittipaldi practiced at 230.5 (DASO 468).

***A. Luyendyk practiced at 234.9 in the same type of car (DASO1239). High humidity reduced Pole power and speed by 3 MPH (DASO1242).

See Appendix C for Engine details available on the website via Links

Appendix C

Engine details available on the website via Links

Entry	Engine on Website	Details ref.	Text ref
1913 Winner	= 1912 Peugeot L76	Bore reduced from 110 mm to 108 to meet 450 cid rule.	
		Appendix 1 Eg. 4	1st Naturally-Aspirated Era P.3
1914 Q Record	= 1913 Peugeot L56	" Eg. 5	" " " P. 6
1915 Winner	=1914 Mercedes GP	" Eg 6	" " " P. 8
		Also Illustrations for Appendix 5 Part 1 P.1	
1919 Q Record	4.9L Ballot	This can be represented by the	
	1920 3L Ballot	Appendix 1 Eg. SO6	Significant Other Fig. SO6A
		and CORRECTIONS & ADDITIONS: PART 2 at P.1	
		Also see 1st Naturally-Aspirated Era P.12	
1920 Winner	Frontenac	Appendix 5 Col. P	
			Illustrations for Appendix 5 Part 1 P.2
1922 Winner	Miller 183	Appendix 1 Eg. SO7	Significant Other Fig. SO7A
1927 Q Record	Can be represented by Lockhart's specially-tuned engine		
		Appendix 1 Eg. SO9	Significant Other Fig. SO9A
1939 Winner	Maserati 8CTF	Appendix 5 Col. AE	
			Illustrations for Appendix 5 Part 1 P.6
1962 Q Record	Meyer-Drake-Offenhauser		
		Appendix 1 Eg. SO16	
			Significant Other Fig. SO16A
1963 2nd Place	Ford Indy PROHV	Appendix 5 Col. AX	
			Illustrations for Appendix 5 Part 2 P.16
1964 Q Record	Ford 4OHC	Appendix 1 SO17	Significant Other Fig. SO17A

Typical TurboCharger section:- Review of Salient Design Features P.6

1978 Winner	Cosworth DFX	Appendix 5 Col. BH	
			Illustrations for Appendix 5 Part 2 P.21
1992 Winner	Chevrolet/Ilmor 265B	Appendix 5 Col. BO	
			Illustrations for Appendix 5 Part 2 P.23
1994 Winner	Mercedes 500I/Ilmor		
		Appendix 5 Col.BQ	
			Illustrations for Appendix 5 Part 2 P.24

TurboCharged Offy
1969 IL4
102.4 mm/79.4 = 1.29
2616 cc

f1technical.net

TurboCharged Ford 4-Cam
1969 90V8
95 mm/46.5 = 2.04
2637 cc

canamcarsltd.com

Appendix D

Short races (8)

A race of 300 miles was scheduled in 1916.

The other 7 short races were stopped because of rain (Indy has never raced in the wet):-
1926 (400 miles); 1950 (345); 1973 (333); 1975 (435); 1976 (255); 2004 (450); 2007 (415).

Other rule limits

The author has not researched fully the other limits applying at Indy apart from capacity and pressure-charging, e.g. ½ seats; fuel/oil allowances and type; weight minima; RPM; exhaust aero assistance permitted/banned. He would be glad to hear from any visitor familiar with such limits who believes they had a significant effect on the races, via "Enquiries".

Three technical surprises at Indy – within the rules!

In the post-WW2 years the "establishment" at Indianapolis received three technical surprises, all of which were prepared in secret but entirely within the rules as they existed at the time. These were:-

- The 1952 Cummins Diesel;
- The 1967 STP-Paxton Turbocar;
- The 1994 Penske PC-23.

These will be described in detail below.

The 1952 Cummins Diesel (see www.official.bankspower.com/1952cumminsdiesel)

Cummins, a Diesel manufacturer, had entered its engines in the 500 in 1931, 1934 and 1950. The first entry had run non-stop, burning 33 US gallons of fuel oil, and finished 13th. One of the pair of 1934 had achieved 12th place, the highest result for a Diesel even to date.

Since 1949 the Indy rules had offered a special concession to a Diesel entry at a permitted 6.6L size, expecting it to be pressure-charged, where other-fuel engines were limited to 2.8L when supercharged.

Cummins, still in search of publicity for their products, made another entry for 1952. They did not say much about it. A standard IL6 engine of 401 cid (6,571 cc) was much lightened by using Al-alloy for the block and head and Mg-alloy for the crankcase. As a 1st for the company-- and Indianapolis – a Turbocharger was fitted to give an inlet charge pressure of 50'' Hg absolute (1.67 ATA) to deliver 400 HP @ 4,000 RPM. A chassis was commissioned from Frank Kurtis, an early version of his "roadster" design with the driveshaft from the front engine running alongside the driver. To minimise the tall engine's C of G it was "laid-over" at 5^{0} from the track (see illustration below). This also reduced the frontal area.

The dry weight of 2,500 lb + the usual allowance in this review for oil, water and driver at 275 lb, rather than 250 lb for a normal large car, to allow for the large engine's higher capacities, gives a Qualification (Q) weight of 24.8 Cwt. Power/Weight was therefore 16.1 HP/Cwt.
At "The Brickyard" the team and the driver, Freddie Agabashian, made sure in practice that no-one could evaluate the car's potential for fear that some last-minute rule change should negate it. On Pole Day (when the fastest 4-lap (Q) average secures the prime position, regardless of higher speeds later in Q week) the Indianapolis "establishment" was *stunned* by a 1st lap at 139.1 MPH! See Fig. 5 (black marker). It was a superior performance, possibly due to the lay-down feature. Q average was 138. As the run was carefully timed just before the track closed the Cummins obtained that No. 1 position.

In the race the car was slow away because of its weight, cruised at a speed to prevent excessive tyre wear for the same reason, but had TC trouble. A low inlet for that pioneer unit picked up track debris, particularly rubber "marbles" [this calls to mind the similar failure of the pioneer pressure-charged FIAT in the 1923 French GP, although that was gravel ingestion]. Retirement was forced at 71 laps (35% distance).

However, Cummins had achieved their publicity objective. The car never raced again. Three years later the Indy rules concession was cut to 5.5L. No Diesel has since raced there.

[Perhaps stimulated by the "lay-down" 1952 Cummins an Offy 250 cid-engined roadster was built like that by George Salih which won the 1957 500. It won again in 1958. There were several other lay-down copies, but none won a race. It may be that the Salih car just had a very-good engine. The upright-engined, high-C of G, roadsters with large LH mounting-bias remained the winners from 1959 up to 1964, possibly because under lateral 'g' in cornering the four wheel weights and therefore grips were even and optimum. Fore-and aft weight transfers would also come into it during acceleration and braking. A very detailed review of the pros-and-cons of the "lay-down" v. the "upright" configurations can be found in:-
www.indyroadsters.webs.com/apps/blog/show/2487525].
[A snag to LH bias for cornering was that if some situation called for a sharp right turn, such as a car spinning ahead, there could be a loss of control and the car might join the wreck!.]
[The vogue for lay-down cars came and went, rather like that for front-wheel-drive. This was popular before WW2 and scored the famous triple victory for the Blue Crown specials in 1947,1948 and 1949, but none won after that last race.]

The 1967 STP-Paxton Turbocar (Wikipedia for some details)

In the '50s and '60s many firms experimented with automotive gas turbines (GT). Chrysler went so far as to field-test 50 GT-powered cars over 1963-1966. Poor fuel economy and acceleration lag led to discontinuance of the programme.

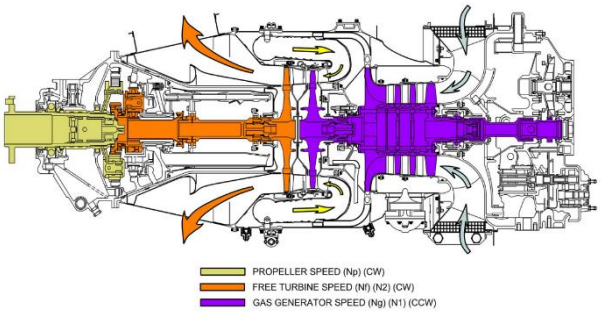
Indianapolis opened a class for GT cars in 1951, without specifying size. This rule continued until 1965 but then an intake area maximum of 24 sq. inches was added.

Andy Granatelli, boss of the oil treatment company STP, accepted a 1965 proposal by Ken Wallis to build a GT car for the 500. Granatelli had tried for many years to win the race with V8 supercharged Novi engines in various chassis, including in 1964-65 Ferguson 4WD systems from the English company. He added that system and mid-mounting to the GT project. The GT selected was the ST6B turboshaft version of the quite-newly Certificated PT6 aero engine built by the Canadian subsidiary

of the famous Pratt & Whitney company. It was rated at 550 HP. A diagram of the type is shown below.

PT6

The important feature for automotive use was the free power turbine, (shown orange) not connected mechanically to the gas-generator (purple).



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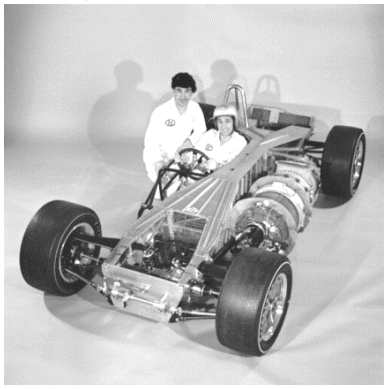
In complete secrecy the Paxton division of STP built the car, with an Al-alloy backbone having the ST6B mounted amidships on the LHS and the cockpit on the right. See the illustration below.

The weight was 1750 lb, so allowing 200 lb for load (no water and little oil) the Q weight was 17.4 Cwt. P/W was therefore 31.6.



historicmotorsportcentral.com

What the driver thought about having a 40,000 RPM core next to him is not recorded, but he did have the knowledge that the engine was rated safe for passenger-carrying!

Because of damage during construction the car was not ready for the 1966 500 and only first appeared for the 1967 race. Parnelli Jones, 1963 winner, drove the car and qualified at 166.1 MPH, only 6th. The Pole was 169. It is very probable that Jones was keeping speed in hand. Jones' speed is plotted on Fig. 5 (blue cross). The superior performance will be a consequence of no cooling drag.

Jones took the lead easily and led to within 8 miles of the finish. A bearing costing allegedly $5 then failed in the transmission.

After this surprise and fright, the authorities promptly reduced the permitted inlet area of GT to 16 sq. inches! This was despite their own rule of 2 years' notice for major changes. It did not prevent another effort by a GT car. Granatelli backed the Lotus type 56 with a suitably-choked inlet for the 1968 500 and it too dominated the race until a "Fail-safe" feature (which Lotus had wanted to disable but on which P&W insisted) brought the car to a standstill at 94% distance when leading (see P.6 above and also Fig. 5).

Once again the Indy rule-makers acted; they reduced the permissible GT inlet area to 12 square inches. That *did* kill any further attempt to race GT-power at the "Brickyard".

The 1994 Penske PC-23 (DASO 468 by Karl Ludvigsen)

Since 1930 the Indy authorities have tried several times to interest production car manufacturers in re-entering the 500, partly for a general reason of returning it to its original purpose of improving the automobile and partly to ensure the desired field of 33 cars. In 1930 the then-President of the Speedway, Eddie Rickenbacker, produced a 366 cid rule to encourage "stock" cars. They had to be un-supercharged (Naturally-Aspirated, NA) and only 2 valves per cylinder (2v/c). The Indy establishment nicknamed it the "Junk" formula. Many firms entered but none won over the next 8 years until the European GP rules were adopted. The specialist racing machines of Miller and then the Miller-based designs produced by his former foreman, Fred Offenhauser, still took all the victories.

Post-WW2, a few engines based on stock units appeared. A good example was the modified Al-alloy V8 Buick in a 1962 mid-engined Thompson Special (see Appendix B, Q speed 149.3 MPH). Driven by Dan Gurney it ran well until an oil leak ruined the gearbox at 47% distance.

In the mid-'80s, when entries for the 500 fell below the historic 33 car field, the authorities once again sought to encourage " stock block" developments up to 8 cylinders by allowing them 3,430 cc (209.3 cid)with TC. The 2 v/c had to be push-rod operated from a single crankcase-camshaft (PROHV) and use a steel coil-spring valve-return system (CVRS). For Indianapolis an inlet charge pressure of 55''Hg absolute could be used. These rules therefore gave an advantage in capacity of 3430/2650 = 1.294 and inlet pressure of 55/45 = 1.22, product x1.58 over pure overhead-camshaft engines. A good proportion of that could be turned into HP advantage.

In the late '80s and early '90s GM Buick built engines to these rules in some numbers but obtained no wins. They argued that the "stock block" requirement hampered them. The rule-makers accepted this and that was removed from the formula in 1992. The author is uncertain, but it appears that Buick still cast their reinforced blocks in iron. At Ilmor Mario Illien then saw an opportunity to do a pure racing engine with an Al-alloy block. In 1993, just after the 500 had been won by an Ilmor engine (badged as Chevrolet) supplied to the Penske team and with the agreement of his equal 1/4th share partners in the firm, Paul Morgan and Roger Penske (the other 1/4th partner, Chevrolet, was seeking to leave and their share would soon be bought by Mercedes-Benz) he began the design of such an engine. It was intended for 1994, less than a year away. Complete secrecy was maintained for most of that period, because the result was certainly against the *spirit* of the regulations, although entirely within the rules. The specifics can be read in Appendix 5 on this site.

autosport

Over 1,000 HP was quickly obtained in January 1994. No further power was sought, but mechanical reliability. This was obtained " just-in-time" for Qualification. Three PC-23 cars were entered. Emerson Fittipaldi practiced one at 230.5 MPH. Al Unser Junior secured Pole at 228, with a 4th of the 4 laps at 229.5, which is plotted on Fig.5 (see also Appendix B).

The official 1 lap Record at that date was held by a 1992 Buick-engined Lola driven by Roberto Guerrero at 232.6 (who tried to warm his tyres on a cold race day by spinning them on his Pole-holding parade lap - and crashed!). That V6 3.4L engine (see illustration at RHS) was Buick's wholly-in-the-spirit version of the "Stock" rules.

pinterest

Although it took the survivor of 3 cars to win the 1994 500, with the English-built Ilmor engine now Mercedes-Benz-badged in the English-built Penske PC-23 chassis, win it did! One car retired at 100 laps with a TC damaged by debris. Fittipaldi led 145 laps but crashed. Al Unser Jr then inherited the victory.

It is almost needless to write that the Indy rule-makers immediately reduced the "Stock" concession to 52''Hg absolute and then to 48''! After Ilmor tested at the lower boost, Penske decided not to proceed with the project, although many other teams were ready to buy.

For Illien to design a PROHV engine, completely novel to him, whose most critical feature required for success was a CVRS Mean Valve Speed (MVS) of over 5 m/s while TurboCharged at 55'' Hg (1.83 ATA) and for Ilmor to build it and win 1st time out inside a year was an amazing *tour-de-force.* It ranks with Keith Duckworth's and Cosworth's feat with the 1967 DFV.

DASO 468 points out that no other PROHV engine won the 500. After the1912 failure at 98.5% of the distance of Ralph de Palma with a modified Mercedes 37/90 PROHV, the nearest to winning was the Ford engine in the 1963 Lotus 29 at 2nd place (after Jimmy Clark was slowed by oil on the track about which the stewards did nothing). As so many tried with that type from production-car bases, up to 1996 for the Menard-Buick, it has to be concluded that all the built-in subtle little details which secure success over 500 miles can only come from solid racing engineering experience. Cost is also a factor. Starting with an engine in which even *cents* count is not the best way to succeed in an arena which calls for tool-room precision and expense. However, the NASCAR engine scene shows that decades of more experience *can* now produce NA units with PROHV, 2v/c CVRS with Ti-alloy valves, which *will* run MVS over 6 m/s for long distances (see Note 135 at PS A1).

P.S.

On PP4-5 the reason why the Qualification/Race speed ratio (Q/R) was so different when so much is now controlled was queried – the 8 year average 2012 to 2019 being 1.35.

Perhaps this is because of relative acceptable tyre wear between 4 laps at Q speed to 200 laps race distance/6 pit stops for fuel and tyres (2019 figures) = about 33laps (subject to caution periods).

The author would be pleased to hear about this from those familiar with Indianapolis.