Note 119

Opel 1992 Formula 3 Eg SO28

As an early stepping-stone for drivers aspiring to join a Grand Prix team, Formula 3 is designed to be both relatively cheap and not too powerful. Therefore the F3 regulations current in 1992 specified (mainly):-

- A 4-stroke 4 cylinder 2 litre production petrol engine base, retaining the original block and head;
- Natural aspiration (NA) with breathing restricted through a 24 mm diameter, 3 mm long, orifice.

Grand Prix engines have never been breathing-restricted, although it is a common rule in top-level sports car racing and also for NASCAR races on super-speedways. However, the method has interesting aspects which were thought worth examining on this site.

Comprehensive data on the Opel 1992 F3 engine, which powered the German F3 series Champion of that year – Pedro Lamy in a Reynard 923 chassis – were published in Motortechnische Zeitschrift 54 (1993) (DASO 1119). This has been provided to the author recently by the courtesy of Bosse Skånhed. The Opel engine was developed in conjunction with the German tuning firm of Siegfried Spiess, which had previously produced a successful Volkswagen-based F3 engine.

Opel base engine

Opel chose a basic production engine in sporting tune which had the following specification:-

DOHC; 4 v/c @ VIA = 46^0; cast iron block; Al-alloy head;

This engine had been developed with input from Cosworth on the head for Vauxhall (see Appendix 1 Eg SO23 and also Significant Other SO23). It had Barrel Turbulence (aka Tumble Swirl).

IL4 Bore (B) 86 mm Stroke (S) 86 mm B/S = 1 Swept Volume (V) = 1,998 cc.

R = 10.5 so ASE = 0.61

PP = 110 kW = 147 BHP

@ NP = 6,000 RPM

BMPP = 11.06 Bar

MPSP = 17.20 m/s

ECOM = 47.7%

Obviously, the life between overhauls of this series production engine was measured in years, helped by its low Load Factor in typical road service.

Opel F3 engine

The breathing restriction

The inlet restriction of 24 mm diameter means that an efficient 2 litre 4-stroke piston engine can induce enough airflow to “choke” the orifice. That is to say, at a certain RPM the accelerated flow of air reaches sonic velocity in the orifice. After that, at fixed ambient temperature and pressure, there cannot be any increase in velocity or air mass flow.

The choked flow condition is given by:-

- $\left(V/\sqrt{T}\right) = 59.5$;
- $\left(\frac{M \times \sqrt{T}}{A \times P}\right) = 0.394$

where V = Velocity in the orifice ft/sec;
T = Absolute Ambient Temperature before acceleration ^{0}K
M = air Mass Flow lb/sec;
A = Area of the orifice sq. in.;
P = Ambient Total-head Pressure before acceleration psi.

(Data from DASO 429 *The Compressible Flow of Fluids in Ducts*
R. Jamison & D. Mordell, Rolls-Royce Ltd, 1944).

At ambient Standard Temperature and Pressure (STP) of 288^{0}K and 14.7 psi (1013 milliBar) and A = 0.7 sq. in. (4.52 sq. cm.) for a 24 mm orifice:-

- V = 1010 ft/sec = 308 m/s;
- M = 0.24 lb/sec = 0.11 kg/sec.

These figures assume negligible friction loss up to the orifice which, with a well-shaped bell entry, is near enough true. What is essential is that the throat velocity is diffused back to a low value, recovering as much as possible of the static pressure, before entry into the engine. The geometry used in the Opel engine is shown on Figs. SO28A & B below (from DASO 1119).

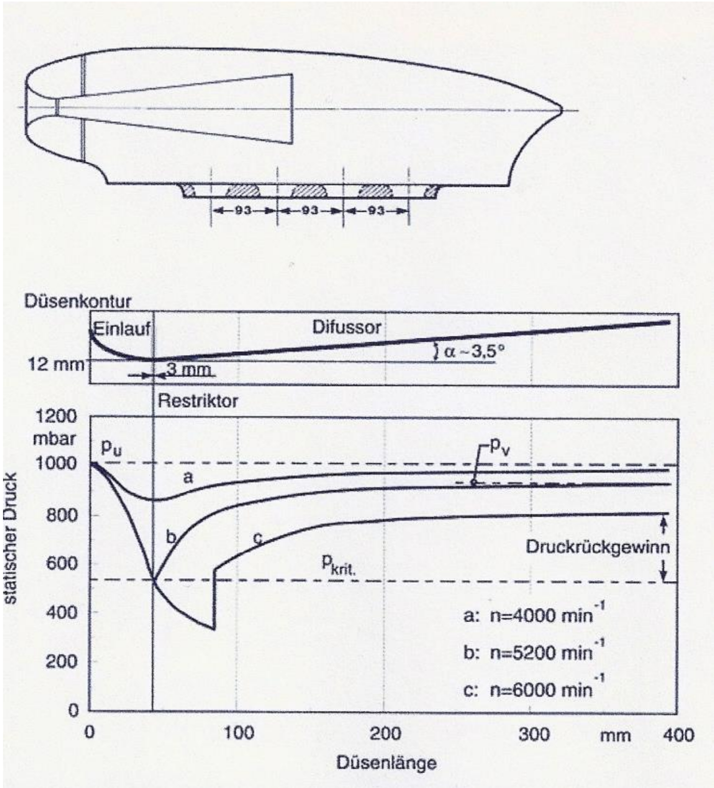

Fig. SO28A
The airbox containing the regulation orifice is mounted externally on the side of the engine cowling and is streamlined to reduce drag.

Fig. SO28B
The upper diagram shows the critical figures for the diffuser:-
Total included angle 7^0;
Area ratio = Exit/Orifice = 7
The lower diagram shows the Static Pressure through the system.
Dusen = Nozzle; *Druck* = Pressure; *Druckruckgewinn* = Pressure recovery.

Line b @ 5,200 RPM is the pressure when the orifice is just choked, when the pressure lost is (p_u - p_v). (NB. The entry pressure should show 1013 mBar).

Line c @ 6,000 RPM shows how the further suction from the engine accelerates the flow from the orifice at a velocity increasing from sonic and then goes through a shock wave of pressure rise to subsonic and steady diffusion thereafter. The air mass flow is unaltered from the value at 5,000 RPM and the pressure loss is greater so power is reduced (see the Power Curve on P. 5).

An engine cross-section is given on P.3

Fig SO28C
Opel F3 engine
The exhaust system, not shown, was 4-into-1. A silencer was fitted to meet a rule noise limit of 106 dBa at 4,000 RPM.

DASO 1119

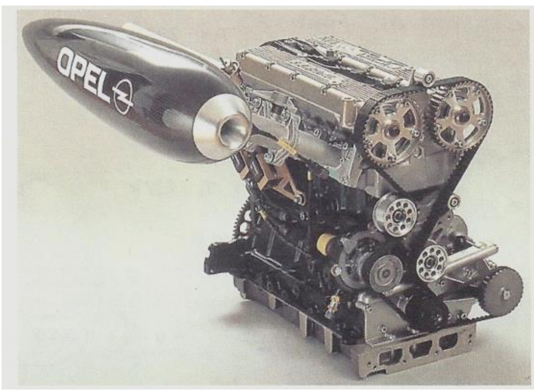

Fig. SO28D

1992 Opel Formula 3

IL4 86/86 =1 1,998 cc

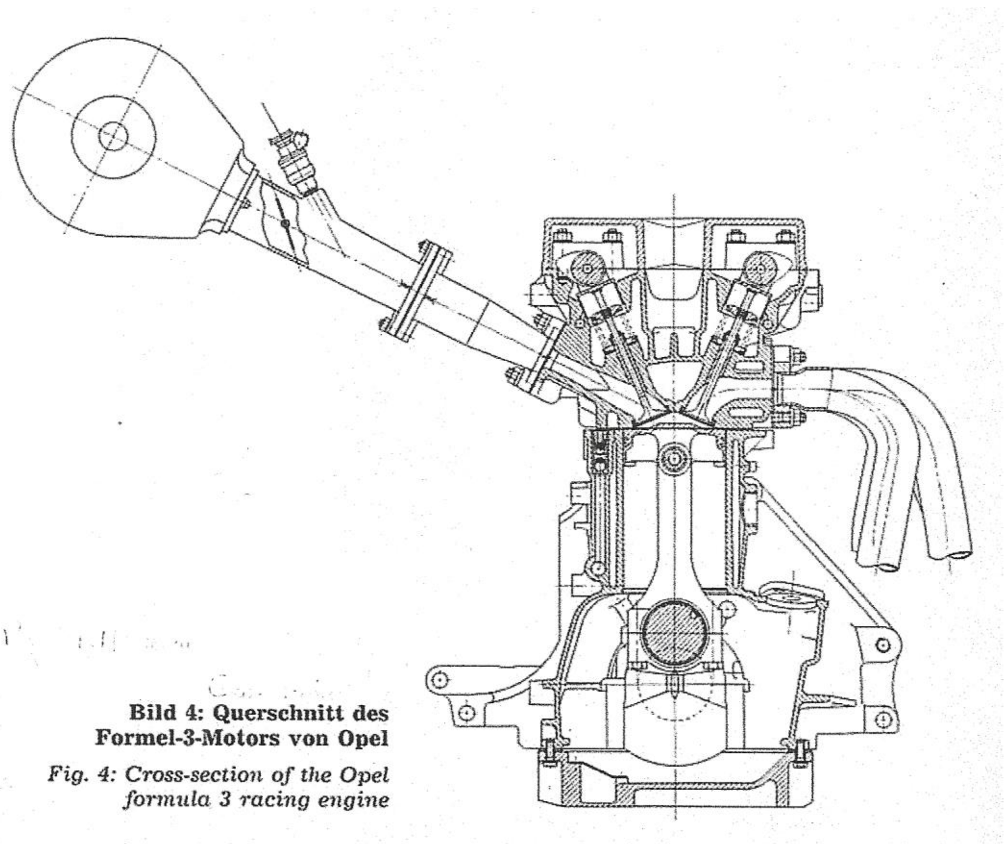

Bild 4: Querschnitt des Formel-3-Motors von Opel

Fig. 4: Cross-section of the Opel formula 3 racing engine

DASO 1119

Performance modifications to basis engine

Long individual inlet tracts were required to tune them to the relatively low speed of the breathing-restricted F3 engine. At 400 mm their length (LIN) corresponded to a resonance at 6,500 RPM on simple theory (see Note 27). This was well above the operating range, with 6,000 maximum, but the airbox probably affected the result. [In 1993 variable length adjustment was fitted, which raised BMEP by 5% at 4,200 RPM].

Valve sizes were restricted by rule to the same sizes as the basis:-

IVD = 33 mm, so IVA/PA = 0.294; EVD = 29 mm.

Camshaft alterations were permitted, so lift was increased:-

IVL = EVL = 11.15 mm (+ 17.4% above basis);

so IVL/IVD = 0.338; EVL/EVD = 0.384.

Valve timing was extended:-

Inlet		Exhaust		
Opens	Closes	Opens	Closes	Rel. to basis
33^0	53^0	58^0	28^0	
early	late	early	late	
IOD = 266^0		EOD = 266^0		$+14^0$ inlet; $+6^0$ exhaust
	OL = 61^0			$+9^0$

These relatively modest timing also reflect the low F3 RPM.

Compression ratio (R) was raised to 12.8 for the unleaded 98RON petrol of the German F3 rules (104RON was allowed in other F3 series), so ASE = 0.639. [In 1993 knock-sensors and ignition adjustment were fitted].

Performance

	Rel. To basis
PP = 129 kW = 173 BHP	+17.3%
@ NP = 5,000 RPM	-1,000 RPM
BMPP = 15.50 Bar	+ 40.1%
@ MPSP = 14.33 m/s	
ECOM = 63.8%	+16.1%points
TP = 256 Nm = 189 lb.ft.	
@ NT = 4,600 RPM	
BMTP = 16.12 Bar	+30.8%
@ MPST = 13.19 m/s	
$\left(\frac{NP - NT}{NP}\right)$ = F = 8%	-12%points

Opel claimed at the time that the value of BMTP at 16.1 was the best known for a Naturally-Aspirated engine. It would have been helped by lower friction losses at the low RPM.

Thermal Efficiency

The Specific Fuel Consumption (SFC) at Peak Power was:-

271 g/kW.Hr (0.446 lb/BHP.Hr)

On petrol this was equivalent to Brake Thermal Efficiency (BThE) = 29.8%.

Volumetric Efficiency

With the given data and by the method described in Note 37 Volumetric Efficiency (EV) is calculated as EV = 1.37.

Other non-critical data

MGVP = 48.66 m/s

This suggests that, being so far below an optimum of around 70 m/s, the performance could have been improved by fitting smaller valves, but this probably was not allowed by the rules.

MVSP = 2.52 m/s

CRL/S = 1.72; MPDP = 1,551 g

The con. rods were 5 mm longer than in the basis engine as a shorter, slipper, piston was fitted (PH/B = 0.42). Rod section was changed from the usual –**I-** section to a proprietary **–H-,** for no obvious reason**.**

All these factors were very moderate because of the low speed.

MJ = 58 mm; CP = 49 mm; GP = 18 mm (reduced from 21 with lighter piston).

Weight

W = 96 kg; PP/W = 1.80 HP/kg.

Weight had been reduced by 34 kg from the basis engine, mostly by discarding un-needed accessories e.g. the generator, but also by certain specification changes (kg):-
4.53 with a lighter flywheel of greatly reduced inertia; 4.23 lighter crank with reduced counter-weighting; 2.2 by cutting off unwanted block mountings; 0.64 lighter (Mg-alloy) camshaft cover; 0.564 lighter rods (total); 0.472 lighter pistons & pins (total); altogether saving 12.6 kg.

Comparison with Basic and Racing-Touring Performance

The Opel 1992 F3 breathing-restricted engine was 17.3% more powerful than its basis engine (173 to 147 HP) but 41.4% less powerful than the same engine modified (as a Vauxhall) for the 1995 British Racing Touring class (173 to 295 HP with an 8,500 RPM max rule limit) (see Appendix 1 SO23 and Significant Other SO23).

Life between overhauls (LBO)

It is believed that the LBO was 1000 racing km.

POWER CURVES

Eg.	SO28
DASO	1119
YEAR	1992
Make	Opel
Model	F3
Vcc	1998
Ind. System	NA
Confign.	IL4
Bmm	86
Smm	86

N	P	MPS	BMEP
kRPM	HP	m/s	Bar
4	137	11.47	15.34
4.18	143.4	11.98	15.37
4.5	159.5	12.90	15.88
4.6	165.6	13.19	16.12
5	173	14.33	15.50
5.2	171.5	14.91	14.77
5.5	167.5	15.77	13.64
5.8	166	16.63	12.82
6	163	17.20	12.17
6.2	165	17.77	11.92

Powers as published were kW and have been multiplied by 1.3403 to convert to BHP