Note 27

Tuning of individual inlet and exhaust systems

Naturally, single-cylinder engine makers were those who developed most intensively the art and science of tuning individual inlet and exhaust tracts for frequency and inertia effects in the air/mixture/gas flows so as to create a higher-than-normal density in a Naturally Aspirated (NA) piston engine cylinder at the moment the inlet valve closed, so raising Volumetric Efficiency (EV) and therefore BMEP. This was not actually 'free supercharge' because the gain at the tuned RPM had to be 'paid for' in a loss of EV at some other speeds - until variable length or variable capacity systems were introduced when the 'payment' was in terms of extra complexity and weight.

Pre-WW2 the British motor-cycle racing singles, especially Norton and Velocette, were the beneficiaries of the art, carried to the 'super tuning' level with diffusers ('megaphones ') on the exhaust to lower the pressure at the valve and help induce more charge. The 1938 Senior TT -winning Norton had an area ratio of about 8 from exhaust port to megaphone exit and the latter had an included cone angle of 13°. In this way Joe Craig, Norton's engineering/racing manager, obtained BMPP = 13 Bar at R = 11 on 50/50 petrol/Benzole fuel at MPSP = 21.2 m/s ((12B) and SO12). For comparison, the 1938 Delahaye GP Type 145 60V12 4.5L had BMPP = 9.4 Bar at R = 8.5, probably on similar fuel with three two-choke carburettors, at MPSP = 14.1 m/s (485). However, the Norton would not run smoothly below 60% of peak speed and the clutch had to be slipped at the start and on hairpin corners.

Continental motor-cycle racers in the mid '30s had gone instead of super-tuning for the allowed option of mechanical supercharging but Moto-Guzzi and Benelli had developed the NA tuning method.

Car engine tuning - the 1922 Miller 183

In car engines, inlet tuning had been pioneered by Harry Miller who, in 1922, had fitted his 183 cu. inch (3L) IL8 with individual tracts breathing through four two-choke own-design up draught carburettors. However, this engine was very limited in RPM, short of power peak, by having only a three-bearing crank. Its BMEP = 9.4 Bar on R = 8, probably petrol, at MPS = 13.6 m/s ((6) and S07))*. It is speculated by Griffith Borgeson that Eduardo Weber was inspired to produce his later famous two-choke carburettors by seeing the Miller units (on a 2L car) at Monza in 1923 (6).

As Miller, in company with all other front-rank car racing engine makers, moved on to mechanical supercharging in 1924, his NA work came to a halt. Later NA engines from the Offenhauser/Meyer-Drake successors to Miller did not resume individual and tuned inlets until the development of Hilborn indirect fuel injection in 1950.

Car engine tuning - the Dixon Rileys 1930-1935

Freddy Dixon, a very experienced and successful motor-cycle racer, following up a works Riley initiative in fitting four Amal motor-cycle carburettors to an IL4 1100cc sports car engine in 1930, became the great exponent in the mid '30s of individual tuned inlet and exhaust systems on NA Rileys from the 1l00cc to the lL6 2L. With the latter in a low nominal- two-seater, long-tail chassis he achieved a lap of the Brooklands Outer Circuit (BOC) banked track at 134.4 mph (216.3 kph) in 1935. This may be compared with the all-time BOC record of 143.4 mph made by a 500 HP machine and is believed to represent a genuine 150 HP from 2L NA (BMPP = 11.3 Bar at R = 10.8 on alcohol/toluol fuel, MPSP about 21 m/s) (141) (Dixon never bench-tested his engines). Percy Maclure and Hector Dobbs built similar Riley-based engines.

*See the note at the end concerning the tuning of the Miller 183.

1950 developments, British and Italian

Ferrari, racing V12 F2 2L NA engines in 1950, was impressed by the performance on twisty circuits of the IL4 cars of Amadee Gordini and John Heath, the latter named HWM and fitted with Geoffrey Taylor-built Alta engines. Both raced with only two carburettors. The Alta was tested originally with four Amal carburettors and four individual, tuned-length exhaust pipes and as such carried on and improved upon the pre- WW2 Dixon layout - but the Amals did not give adequate starting or acceleration characteristics and were not raced, while breakages of the long separate exhausts soon forced a change to a manifold and single pipe; power dropped 13% after these two alterations (147).

Connaught at the end of 1950 had introduced an F2 car with four tuned inlets using Amals applied to an IL4 1.8L modified Lea-Francis engine (originally aimed at US Midget racing) very similar in head design to Dixon's Rileys. The exhaust system had cylinders 1,4 and 2,3 flowing into a separate pair of tail pipes. This car had not raced abroad.

When Aurelio Lampredi designed the Ferrari Type 500 IL4 F2 2L NA engine in late 1950, as his response to the Gordini and HWM performances, it is considered that, because of the time, space and culture gaps from the earlier work on tuned, individual inlet and exhaust systems, he made his own decisions in the matter of such tuning. Weber apparently produced a suitable two-choke/one-float-chamber horizontal carburettor (Type DCO) especially for the new Ferrari engine at the appropriate bore (50mm) and port spacing.

With a bore of 38mm the DCO was sold simultaneously to HWM for their 1951 single-seaters. On their 2L Alta engine these Weber units became part of a tuned individual inlet and stub-exhaust system which was actually the first to race internationally post-WW2, 29 years after Miller's pioneering engine (it recovered the 13% lost from the early 1950 tests, back to 130 HP) (147). The Ferrari IL4 engine, in 2.5L form, first raced in early September 1951.

Simple inlet-tuning theory

In the simple organ-pipe theory, as given in (282), the Mean Piston Speed (MPS) at which resonance occurs can be estimated from.-

$$\text{MPS} = 88.25 \times (\text{S/LIN}) \text{ m/s}$$

where LIN = Inlet system length to back of valve, in same units as S = Stroke.

Consequently, the following applies:

LIN/S	3	3.53	4	5	6	7
Resonant MPS m/s	29.4	25	22.1	17.7	14.7	12.6

The Ferrari Type 500 in 1953 (Eg 31) had LIN/S = 330/78 = 4.23 and would have resonated theoretically at 20.9 m/s; the peak speed was actually 19.5 m/s.

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* Miller 183

Ref (6) shows that this engine had LIN/S = 600/101.6 = 5.9 and the simple formula gives resonant MPS = about 15 m/s, versus the rated maximum of 13.6 m/s. The optimum length was found by varying the pipe lengths and timing the car round the Beverly Hills banked board track.