Note 19

Other Mechanical and Thermal Limits

In addition to the Mechanical limits already listed in Note 13, other limits were (and are):-

Instantaneous in destructive effect :-

Valve motion out-of-control

With OHV engines, (excluding Desmodromic valve gear, see below) as Compression Ratio (R) was raised and Valve-Opening-Periods extended, there was created the certainty that, above a critical RPM, an exhaust valve would fail to follow the cam home and it would be overtaken by the rising piston. The actual critical RPM would depend on the type of valve gear and the quality of the cam contour.

At the least the valve would be bent and so power lost; at the worst a valve head would be broken off and/or a piston holed and the engine could be destroyed

For many years the only safeguard was a "Red Line" on the tachometer and a trust in the driver to obey it – which often was ignored in the heat of battle (see also Sub-Note A). In 1938 Mercedes-Benz experimented with an automatic rev-limiter but did not find it sufficiently reliable to use in races (468)(see also Note 82). For the Cosworth DFV in 1967 a reasonably-reliable rev-limiter was available and this, gradually improved, became a standard for Grand Prix engines (see also the descriptions of DFV development in "The Unique Cosworth Story". It protected the engine against missed upward gear changes or deliberate over-speeding but could not guard it from premature downward changes when the car's speed would over-rev the engine.

With the arrival in 1989 of electronic engine management systems linked to semi-automatic gear-change-cum-clutch operation mechanisms,initially by Ferrari, the over-revving problem was solved completely (see Sub-Note B).

Desmodromic valve gear – mechanically-controlled valve motion –could also solve the problem, of course, but the cost of doing this successfully was only tolerable by Mercedes-Benz in the 1954-1955 M196. No other CoY engine in this review used it.

Time-related in destructive effect:-

Crankshaft torsional vibrations

See the description of the Mercedes-Benz M196 (Eg. 32) (2NA page 4).

Camshaft-drive vibrations

See the descriptions of the Cosworth DFV development "The Unique Cosworth Story" and also of the Coventry Climax 4 valve per cylinder engine (Eg. 44)(2 NA page9).

Thermal limit to RPM

An example of an instantaneous *Thermal* limit to RPM is given in Sub-Note C.

Sub-Note A

Avoiding over-revving

Ricardo limited the 1922 3 L TT Vauxhall engine to R = 5.8 so that valve-piston clash could not occur if a valve stuck open or if the engine was over-revved until the valve left its cam (4). The Bugatti vertical-valve engines (i.e. those preceding the 1931 type 50 et seq "Miller-head" engines) could run very high R (up to 13.5 in a type 37A (308)) without risking a valve-piston collision. Although not run that way for GPs it made them very popular with British tuners for sprint races and hill climbs.

On the other hand, the 1922 FIAT 2-valve/cyl. head with VIA = 102^0 was probably the first engine at risk if over-revved. The normal practice in later years as R was raised was to provide cut-outs in the piston crown to reduce the likelihood of contact. The Mercedes-Benz 4-valve/cyl. engines of the 1934 – 1939 period were given raised "buttons" on the piston cut-outs, on the valve centre-line, in the hope that any contact would not bend the valve.

Certainly *some* over-revving past the normal race-life limit was possible in these Mercedes if needed for a last-lap overtaking opportunity against the Auto Union 1934 – 1937 V16s, whose push-rod actuation of the exhaust valves could not accept emergency over-rev without failure (607).

Von Brauchitsch of the pre-WW2 Mercedes team was a notorious frequent over-revver and the works sought to control him by an over-stated tachometer dial. These experiences were part of the reason for adopting mechanically-closed valves for the 1954 – 1955 M196 engines (468).

Another way of trying to control drivers had been tried on the 1927 Delage by having coloured segments on the very-large tacho dial – green from 6,000 to 7,500 RPM, then yellow to 8,000 and red from 8,000 to 9,000. Another simple practical step was to mount the tacho with the max. recommended RPM at the top so that a quick glance at a vertical needle was re-assuring. On the Delage the dial-top number was 7,500 RPM (1075). The 1936 Auto Union, with its noted sensitivity to over-revving, had a red sector on the tacho from 3,500 to 5,000 RPM (381).

It is interesting to note that the first piece of "stored-data-readout" from a GP engine was the max.-RPM-reading non-return needle on the tachometer, introduced post-WW2. Now this has been long-superseded by multi-channel recorders radioing data back to the pits.

Sub-Note B

In the 2003 Cosworth CR5 V10 3 L, taking advantage of the electronic RPM control, the clearance between the valves and pistons was so small that no carbon formed on the piston crown between those parts (883).

Sub-Note C
Thermal limit

Apart from time-related thermal limits to the life of pistons, described in Note 14, a case is known of an instantaneous thermal limit to RPM of the 1936 MG type Q/Ex127 IL4 750 cc record engine. On the test-bed this highly-mechanically-supercharged engine ran into a backfire problem. Sydney Enever determined that this was pre-ignition from over-heated exhaust valves, which were solid KE965. He lengthened the valve guides to improve heat flow out of the valve stems by cutting the bronze guides and inserting extra cast-iron sections machined from available bar stock. This solved the problem (139). However, the engine (at 7,500 RPM) was still "Rated" below its 'natural' peak power.

An *apparently* similar problem in 1953 with the developed BRM T15 V16 1.5 L – backfiring on the test-bed at 11,500 RPM – was in that case put down by Tony Rudd to the back-pressure from inadequate rig silencers (40). In the car the engine could rev to 12,000 – an inversion of the usual situation for all power plants where the installed performance does not reach the test-bed figure!

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