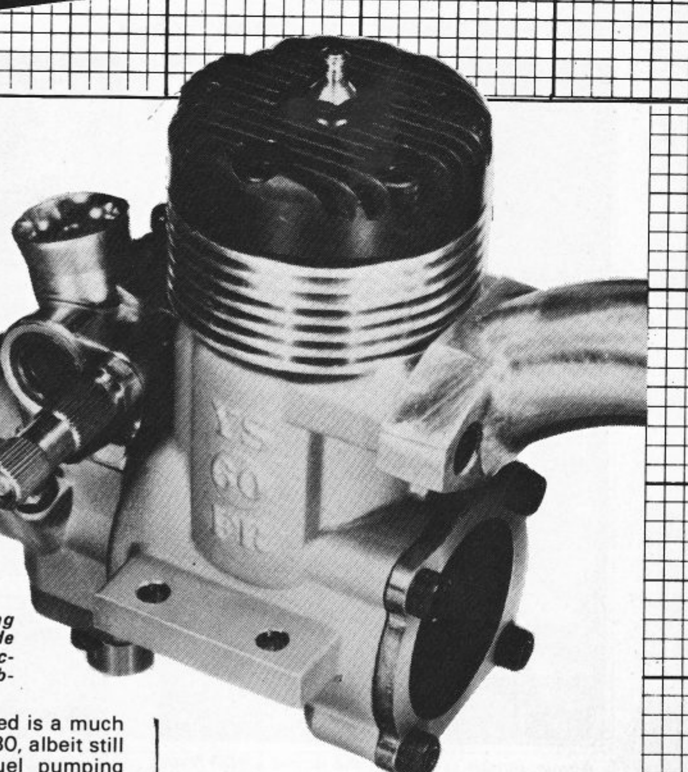
ENGINE TEST

No. 6

by Mike Billinton

YAMADA YS60



Right: immediate eye-catching characteristics of the YS60 include no-frills, extremely robust construction and physical size. Note, 'bomb-proof' exhaust manifold.

POPULARITY TRENDS in modelling equipment are notoriously slow to change once strongly established, and maybe that's as it should be — giving those manufacturers of good reliable products the 'reward' of an appreciative and faithful public consumer group. It tends to be self-perpetuating though when top competitors successfully use (and thus advertise) the product, which then influences others to make their purchases. It may be wise to stand back occasionally and surmise that the competitor did well maybe in spite of the equipment and not because of it. Lest this seems a criticism of those motors 'at the top' it must be said that engine quality in the R/C Aerobatic field is remarkably high and ever-rising!

Any new or less prominent manufacturer though, clearly has a large task in attempting to enter this field let alone gain large public acceptance.

The basic engine tester has a simpler more objective situation — seeing a line of engines pass beneath the gaze, and with all being submitted to similar testing procedures. Admittedly these rarely conform to the actual proposed usages out on the field (particularly change of motion situations), though much can be done to simulate some of the real conditions. But at least they have the merit of establishing some similar base lines against which to test each different make of engine.

When the Yamada 60 (rear Exhaust/ABC) first swam into this gaze it did appear a touch unprepossessing compared with some sleeker units in existence, though it did look particularly unbendable.

The writer has no first-hand knowledge of the original side-exhaust YS 60 released some years back; most comment seeming to concentrate on the complex bundle of trickery its pumper carb. represented. The rear exhaust version here tested is a much later machine appearing in 1980, albeit still with a crankcase charged fuel pumping system — though of changed design.

So, this new tuned-pipe motor was competitively faced both with the latest and best of the world products and the relatively low level of public awareness of the earlier motor.

It might be best to cut through further discourse and say that this test motor was the most powerful of the R/C aerobatic front induction 10cc units yet tested — in Open Exhaust format it finally breached the 2bhp mark. Achieved mainly through the high peak rpm reached, though even at the more normal 13-15 K it was definitely above previous best figures.

The interesting tuned pipe result is referred to later. There appears to be much unawareness of the potential of this latest Yamada 60; it certainly caught the writer off guard by its very strong and clearly reliable flow of high power, and equally he was taken aback by a list of results of 1981 Japanese F3A Trials. This showed Yamada in 2nd *to* 5th places plus being used by 20 out of 44 entrants. Enya and OS were the only others listed.

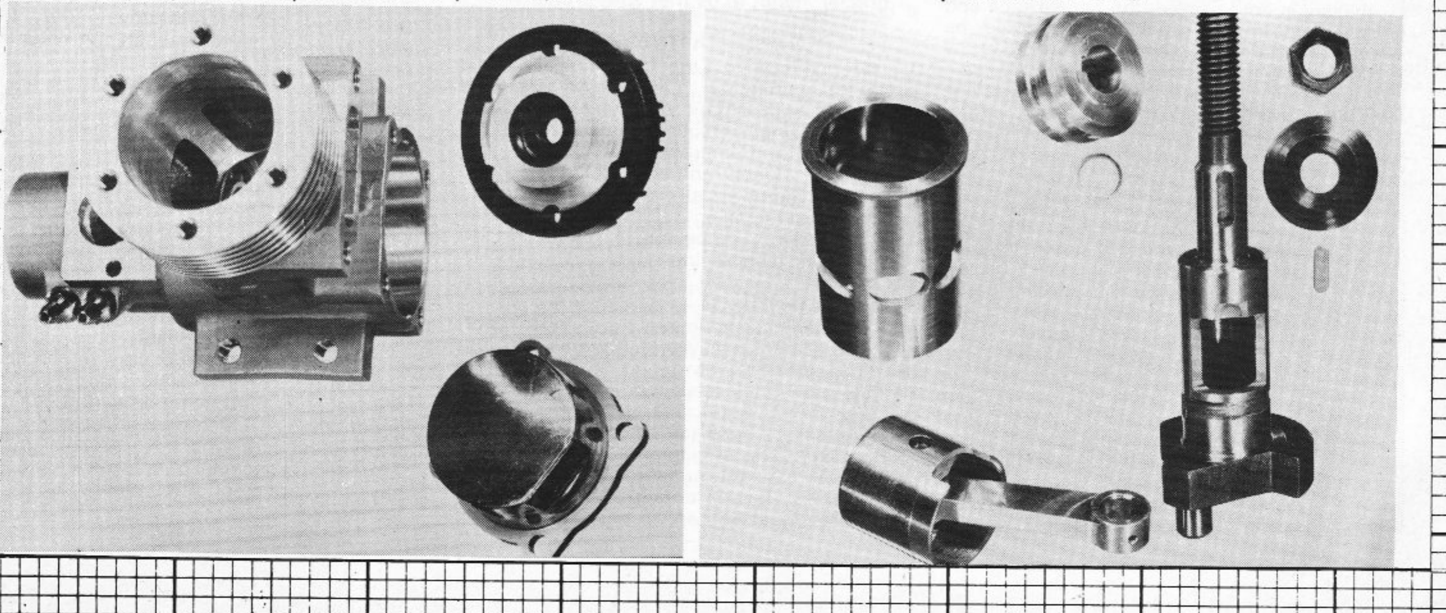
A majority were using the Japanese MK vari-pitch propeller (at diameters between 10½in. and 11¾in. and with pitch range zero to 13in.), and whatever were the initial reasons for using variable pitch, its continued use reflects more than one advantage which sufficiently skilled pilots can exploit:

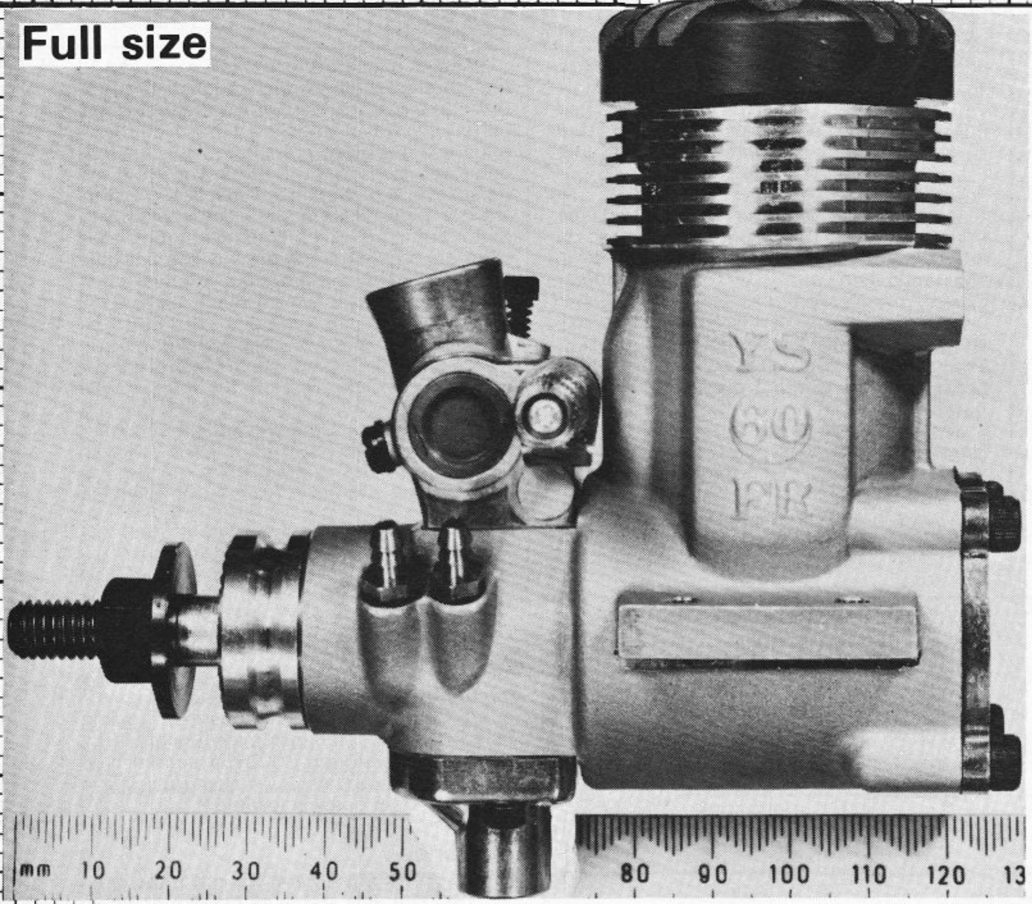
1. Superior model speed control through manoeuvres (e.g. in downward leg of square loop very low or zero pitch can act as a brake to ease transition to level flight at bottom of loop and, with suitable pitch to give swift model acceleration on upward side, the aircraft exhibits to the judges an almost constant and controlled motion around the loop which is more likely to be truly 'square'.

2. The changeable load of the variable pitch prop can enable pilots to keep engine rpm at any desired point thus ensuring a measure of controlled use of the fairly sharp power peaks and associated troughs common with tuned pipes.

3. Not so desirable is the 'negative' of the above — the use of high pitch on the ground running phase keeps motor *well short* of the maximum power peak and thus evades any normal attempt at effective sound monitoring. Yet another example of the complication to be dealt with if following the 'DB route' to noise nuisance problems. It seems to the writer that the contest procedures necessary to cope with the various international *aircraft* classes are likely to be an ever present problem for the FAI unless some simple 'linear measurement' or 'reward system' is instituted.

Below left: YS60 crankcase details, including twin transfer and single boost Schneurle passages. Below right: ABC piston and liner plus nitrided crankshaft.





Test motor — mechanical details

This arrived for test from USA distributors in Pennsylvania, together with the recommended quiet tuned pipe and manifold. At a nominal 22mm stroke the YS 60 is really a 61, and actually skirted dangerously near to maximum cylinder capacity at 9.995cc (.6099cu. in.).

Crankcase is a particularly solid sand-casting with unusually rigid crankshaft housing partly due to extra metal needed for carb mounting and its various jet holes. Usual twin transfer and single boost Schnuerle passages. Crankcase bore is honed to accommodate liner which ensures intimate contact for good heat transfer.

ABC Liner/Piston has precise taper fit (1 thou tight at top of stroke). Chromed brass liner is honed to a matt finish, which should give better boundary layer lubrication situation compared with high-gloss chrome with surface honing.

Nitrided crankshaft as large as they come at 17mm main journal diameter, and with one-piece crankpin, generates much confidence. Twinned with the very solid crankcase it forms the essential central base for the high power figures reached. It has two unusual features: one is a milled groove around main journal just ahead of rear ball race which ensures positive lubrication of plain bearing section of front housing (between rear race position and induction opening) thus ensuring improved long-term seal at this point for good crankcase compression. The other is a small milled slot ahead of and connecting with induction cutaway. The purpose of this is to ensure that only the high peak of crankcase pressure is tapped for fuel tank pressurisation, rather than the more usual (slightly lower) timed pressure peak given if using the whole induction slot. Untimed average crankcase pressure is of course *much* lower still and is not considered suitable for constant engine runs in high-G aerobatic situations. The YS crank pressure slot provides high pressure from 105° ATDC to 160° ATDC, thus its 55° opening period compares with around 110° if whole induction slot were to utilised to generate pressure — as is normal.

Propeller drive is by Woodruff key.

Cylinder-head is very dark grey aluminium alloy anodised. Has normal squish band width but raised to 7°. 'Top hat' combustion chamber used at highish 9.24/1 effective compression ratio and so is quite effective on low or no nitro fuels.

Connecting-rod is generously large from solid aluminium alloy. Thankfully this part is receiving more adequate treatment these days; though it is certain that they will get more substantial yet because the need to keep reciprocating weight down seems less important that it once was. Modern pistons in very high-revving ABC motors are often heavier than their counterparts from a previous decade, though this is mainly to resist high-nitro fuels.

So for the lower revving R/C aerobatic motor an extremely substantial rod is a very useable option. Meantime the YS rod goes some way further along this road. It is phosphor-bronze bushed at both ends with lube holes.

Gudgeon pin's main interest is the heat-shrink fit in piston bosses, and the tight cold fit in little-end of con-rod. The latter eases when warm and ensures good slack-free fit when motor is running. Pin is reduced in diameter on boost side of piston to prevent ejection through boost port, plus giving accurate endwise positioning during heat fitment of pin to piston. The set-up in this area is the tightest the writer has come across in model use, and mirrors much full-size engine practice. It certainly assists in maintaining geometrical accuracy during running though presents assembly problems.

Carburettor is an intriguing butterfly device, and is a sensible structural compromise having the advantages both of the normal full-size car engine butterfly style and the modeller's normal rotating barrel type. Very accurately machined in steel it's nevertheless lighter than the barrel unit. It should offer better transition from full to half power because it lacks the barrel style's sudden change of air flow pattern on leaving wide open throttle position. On the other hand of course w.o.t. still sees the butterfly as a turbulating restriction, for which some allowance though can be made by a larger overall bore. This YS carb happens to be a massive 11mm choke diameter giving a very large area of 79sq. mm.

The main fuel needle is a misnomer because this part is a solid brass spring-loaded plunger ($^{3}/_{16}$in. dia.) with taper at one end. Idle control is by variation of diaphragm pressure in control unit located under crankcase/shaft housing.

Combining this little lot with a number of fine drilled passages inter-connecting carb, crankcase and pressure regulator means that the whole system represents for some users a new and slightly scary bundle of bits to deal with compared with the by now very familiar standard needle and barrel carbs with their easy to understand operating mechanism. Well, it may be that if fault develops then the user may be undecided as to the remedy. In practice just as in a full-size car the most complicated of carbs respond well to cleanliness, which prevents many problems from even appearing. The modeller has more of a problem in that he can mishandle much of the equipment or environment around the engine, so at the very least adequate filtering of fuel at the latest possible point in the fuel supply line is a very necessary point with this YS carburettor, i.e. a good line filter in the fuel line just prior to crankcase fuel nipple.

Filtering earlier than this increases chances of dirt entering carb and there to block one of the fine drilled passages. Next in order of importance is good cleanliness in the engine bay section of model. Lastly the general environment around the model during ground running and take-off is worthy of consideration, though here this is not always in the control of the operator.

Some time was spent trying to fathom out this fuel/pressure system. The main difference from a normal timed crankcase high-pressure set-up is that each single pressure pulse not only charges fuel tank above atmospheric pressure (as is normal), but it also causes diaphragm and one-way valve movement which releases a given amount of fuel through to the needle valve once per pressure pulse.

A one-way check valve in pressure line from engine to fuel tank prevents pressure from returning to engine via that line, which would otherwise lead to the pressure systems normal vice — that of fuel filling up carb when engine is stopped after a run — and which leads to very difficult starting next time, or possible hydraulicing and motor damage if mechanical starting is used.

The other difference is the ability to control more effectively the hi-pressure of the tank at idle speed. Normal crankcase high-pressure systems lead to over-richness at idle speeds.

In the Yamada 60 the spring-loaded plunger can be adjusted to give correct mixture at idle (when overall pressure has dropped somewhat below the 5psi max.), but then this spring loading is overcome to allow full flow when engine rpm rises (and crankcase pressure rises to its maximum.)

Two points worth noting: one, that both idle and full flow mixtures follow same path through carb to the issuance point just upstream of butterfly. The other, that due to the overall higher pressures reached by the YS charging principle, the fuel tank is more highly stressed. So take care with plumbing — use stronger than average fuel tanks or use strapping around your normal plastic tanks.

Tuned Pipe is purpose made for Yamada by Japanese manufacturers Hattori. This aluminium pipe is yet another which has departed from the twin-cone style with quiet rear cone addition. As with OS pipes the rear cone has been demoted in importance such that it is no longer the major pulse reflector. The Hattori pipe uses a flat annular reflector disc set at right-angles to pipe axis and some 1½in. back from end of first cone. This disc has a central hole .6in. dia. to allow egress of exhaust through to 'quiet' chamber and thence to atmosphere. The rear cone seems adornment only, as it cannot contribute any meaningful pulse back to engine via a tortuous silencer route.

In practice this tuned pipe was effective as a quietening device so not surprisingly the power uplift from its use was not as high as with some pipe designs — but which suffer from higher noise levels. It was however quite flexible, non-critical in use, except when used at the shortest length tried (11in. glowplug to pipe pressure nipple position) and then only when above 20K rpm.

The associated exhaust manifold is machined from massive ⅜in. sheet aluminium alloy — a real no-nonsense affair to which is strongly welded the curved exhaust pipe stack.

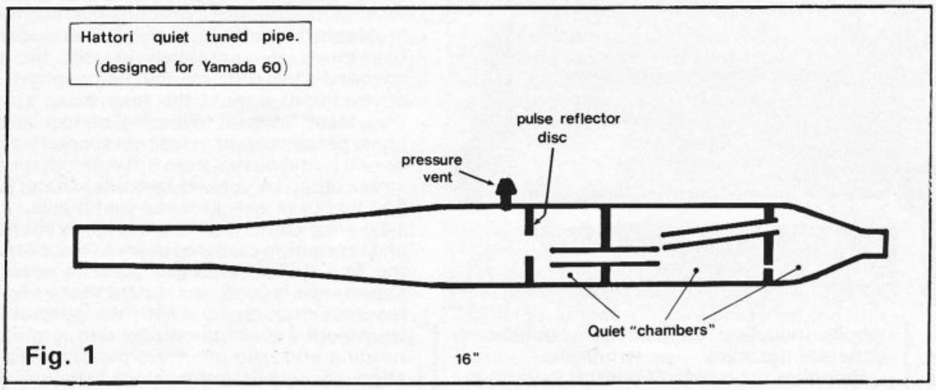


Fig. 1

Power tests

Test 1.

First runs (including the short running-in period) used open exhaust, OPS 300 plug, 5% nitro, with oil being a mix of 8% castor and 10% synthetic (UK ML70). Pressure feed for fuel supply was rigged up as per instructions.

RPM checks on several Zinger props immediately put the YS in a high-power category. Starting was easy, provided motor was rotated several hand turns to pressurise fuel tank prior to starting. Going up the rpm range, the torque figures produced were high. More surprising was that the expected decline around 16-18 K did not occur. Instead, more like a racing engine, it carried on producing high torque figures and good handling right up to the 22,500rpm finally reached.

Just over 2bhp was still being achieved at that point, with the peak of 2.12 being passed a little way back at 19.5K.

Certainly the high-rpm aspect of this YS is a part consequence of the large choke size made possible by the pressure fuel system, and no doubt the torque figures also reflect this to a degree. The highly individual nature of the YS carb system make a direct comparison with other engines a difficult matter so it was not possible to test run any smaller diameter carb on this engine but from previous results and observations it is unlikely that the YS's power advantage over other competitive engines has been achieved solely by use of the larger carb.

In any case this will be verified at a later date when it is intended to use an 11mm carb on one of the competitor engines.

Results should be interesting!

This particular test could have been continued further up the rpm band, but conservation of the engine had to be ensured, whilst maximum possible rpm in any case is largely academic in the R/C aerobatic motor — if only because of the rpm limiting tuned pipe normally fitted.

At this stage it was apparent that the YS 60 performance was considerably more aggressive than its publicity bandwagon — which appears to reflect the relatively limited number of engines produced, incorporating as they do a fair degree of hand work and assembly.

Test 2.

Moving on to use of the Hattori tuned pipe — this was set at 14in. length from glow-plug to pressure nipple on pipe. (This nipple is positioned ¼in. ahead of the flat reflector disc mentioned earlier.)

In accordance with the instructions this should give a peak power point around 14K. The pressure on the pipe is not in fact required because of the YS crank pressure system — but it's there if needed for other engine styles. In this and next test it was blocked off. Nitro content was kept at 5% — Yamada suggestion is that no more than 10% should be used. This probably has more to do with reliability of glow-plug elements, because it is felt that the motor itself is surely capable of using and resisting much larger percentages of nitro.

The recommended length proved accurate as higher torque figures were now reached near to 14K. Maximum bhp however was almost identical to that of open exhaust due to fact of sharp decline in torque after 17K caused by pipe's reflections getting out of phase wth engine rpm at this point. so in this case the pipe was forcing production of best yet bhp figures at much lower rpm than was natural for the motor, and with the bonus of lower sound levels and ability to turn larger, more suitable propellers.

Nevertheless the matter of that very high open exhaust peak and its relationship to tuned pipe use still rankled. Whether or not it would be possible to use a higher rpm placement because of propeller problems or noise levels is subject to field testing, but as this was an engine test and not an R/C aerobatic model test, so then it seemed right to verify the motor's capabilities at least, so that users could then decide whether to operate the motor in a different manner to release the higher power possibilities.

Test 3.

Therefore the pipe was now shortened by a significantly large 3in. by cutting both exhaust manifold and tuned pipe itself.

At this new length of 11in., and using same equipment as before, the torque figures below 14K were now quite poor (and well below both open exhaust and long pipe readings). At the 15K mark however things started to improve with correct pipe resonance giving good torque figures from 16 to 20 K — (as opposed to the 11 to 16 K of the longer pipe.) The resultant in bhp terms was the highest figure yet reached in this series of tests for this style of motor and equipment configuration; i.e. 2.39 at an rpm area close to open exhaust best point. Seeming to add further proof to the idea that tuning of pipe length to give maximum resonance near to open exhaust best figures usually provides the maximum possible power on pipe.

The cost of operating in this fashion can be high though: there is much reduced torque at those low rpm through which the motor has perforce to travel, and it may thus be difficult to persuade a given propeller to get past that point and up into the high power area; the noise level is higher; in the post 20K area this shorter pipe causes critical operation with motor cutting out if fuel mixture setting goes even slightly lean; additionally the possible use of an 11in. dia. prop (but at lower pitch than 7in. to allow rpm to reach up to 21K) would place tip velocity of 690mph dangerously near to speed of sound (approximately 750mph) and which is known to be a limiting factor for our fragile propellers.

These amongst other reasons may inhibit exploitation of the YS full potential, though *some* shortening of pipe (to say 12½in.) to give a peak around 17K may be a viable proposition.

RPM Points

Yamada's recommended prop sizes are 11 × 7 or 11 × 6. Judging by this test motor, these sizes are only just large enough if pipe length is cut down to 14in. or slightly shorter.

If pipe is left at 'out of box' length then a larger size may be preferable — say 11½ × 7 or 11 × 8. For fixed pitch props the principle being that maximum ground rpm should be not more than around 1,000 rpm short of best resonance rpm in the air (i.e. hopefully where maximum bhp point is located.)

Idle speed

Using 11 × 8 prop and 5% nitro, the open exhaust idle was stable at 3,000rpm; whilst on quiet pipe at 14in. length a slower speed of 2,900 was achievable provided idle regulator adjuster was screwed in one turn compared with best open exhaust position.

Using the quiet tuned pipe the engine unhesitatingly stormed from idle to maximum rpm and back even with very swift throttle movement.

Summary

Used in the recommended manner the Yamada 60 produced a fine set of figures, and it is a matter of personal regret that this 10cc motor is not available in full racing format.

Although there are still to be tested two or three latest 'states of the art' R/C aerobatic motors, they will have to be strong indeed to better this particular test unit.

As high-pressure fuel systems are designed for the purpose of overcoming the dynamic effects of high G forces, it is likely that the motor's performance 'on the move' will not differ from that found on the bench here.

Carburettor response in test was vivid, with no 'loading up' at idle.

The only slight problem to occur (and this was not a motor fault in any way) was that on two occasions from the 70 separate runs undertaken, the check valve in pressure line failed to 'seal off' and this allowed fuel tank pressure to activate diaphragm which caused carb to fill with fuel. Experimentally altering attitude of this valve had no effect on its operation, so it's felt that very light spring loading of this small silicon plunger valve would prevent even this area occurrence.

The relatively limited production runs of this very strong motor will undoubtedly restrict its overall exposure and thus popularity — but wherever R/C aerobatic competitors foregather it is likely to be the subject of some discussion and interest . . . a case of improving the breed.

Sadly this test motor is now winging its way back to the USA having shown itself to be one of those motors which grow on one from quiet beginnings. Some motors could better it visually, but one awaits its superior — dynamically speaking.

Yamada YS.60.FR (rear exhaust)

Dimensions & Weights

Capacity — .6099cu. in. (9.99cc).
Bore — .947in. (24.05mm).
Stroke — .866in. (21.99mm).
S/B Ratio — .914/1.
Timing periods — Exhaust 157°.
Transfer 119°.
Boost 112°.
Induction — Opens 33° ABDC
Closes 54° ATDC
Total — 201°
Combustion volume — .05cu. in. (.82cc).
Compression ratios — Theoretical 13.18/1.
Effective 9.24/1.
Exhaust port height — .28in.
Cylinder head squish — .015in.
Squish band width — .160in.
Squish angle — 7°.
Carburettor bore — 11mm.
Carburettor cross section — 79sq. mm.
Crankshaft diameter — .669in. (17mm).
Crankshaft bore — .433in. (11mm).
Crankpin diameter — .275in. (7mm).
Gudgeon pin diameter — .236in. (6mm).
Prop shaft diameter — .312in. (nominal 8mm) × 20tpi.
Con rod dimensions — Centres 39mm/.191in. thickness.
.32in. to .35in. width.
Engine height — 3.8in.
Engine width — 2.4in.
Engine length — 3.75in.
Bare weight (less pipe and manifold) 18.75oz. (.53 Kilo).
Overall weight (with pipe and manifold) 25oz. (.708 Kilo).
Mounting hole dimensions — 20 × 52 mm with 4.5mm holes.
Engine frontal area — 5.8sq. in.

Performance:

Max. bhp — 2.39 at 19,200rpm (Quiet pipe/5% nitro).
2.12 at 19,500rpm (Open exhaust/5% nitro).
Max. torque: 141oz. in. at 13,870rpm (Quiet pipe/5% nitro).
126oz. in. at 11,800rpm (Open exhaust/5% nitro).

RPM Standard Propellers:	*Open ex./5% nitro*	*Quiet pipe at 14"/ 5% nitro*
14 × 6 Zinger	7,860	7,550
13 × 6 Topflite M	11,380	11,530
11 × 8 Zinger	12,440	13,330
12 × 6 Zinger	12,500	12,740
11 × 7 Zinger	13,700	14,470
10 × 6 (From 12× 6 Zinger)	14,930	15,420

Performance equivalents:

BHP/cu. in. — 3.92.
BHP/cc. — .239
Oz. in./cu. in. — 231.
Oz. in./cc — 14.1.
Gm metre/cc. — 10.0.
BHP/lb. — 2.04.
BHP/Kilo — 4.51.
BHP/sq. in. frontal area — .412.

Manufacturer:

Yamada Mfg. Co. Ltd., Inuyama, Aichi, Japan.