The MIKE BILLINTON Test

YS60FS

Mike Billinton reviews the Yamada YS 60 Heli.

YS engines emanating from Aichi, Japan occupy an unusual position in Aeromodelling, being orientated towards the needs of that numerically small but significant group of R/C Aerobatic competitors in the International FAI classes F3A (fixed wing) and F3C Helicopter (rotary wing).

A large majority of model engine manufacturers worldwide do, of course, offer 'top-of-the-range' competitive engines for serious competitors in these classes — but only as one part of their often very large range of other engines. Among those who make suitable 2-stroke 10 cc and/or 20 cc 4-stroke units are O.S., Enya, OPS, Picco, Saito, Webra, S. Tigre, Rossi, etc. More recently a few of these famous names have now begun to make available high-pressure fuel pump versions of their engines — which is some sort of recognition, both of a demand from fliers for stable engine performance under high-G aerobatic manoeuvres and of the example set in this area some years ago by the first Yamada 60.

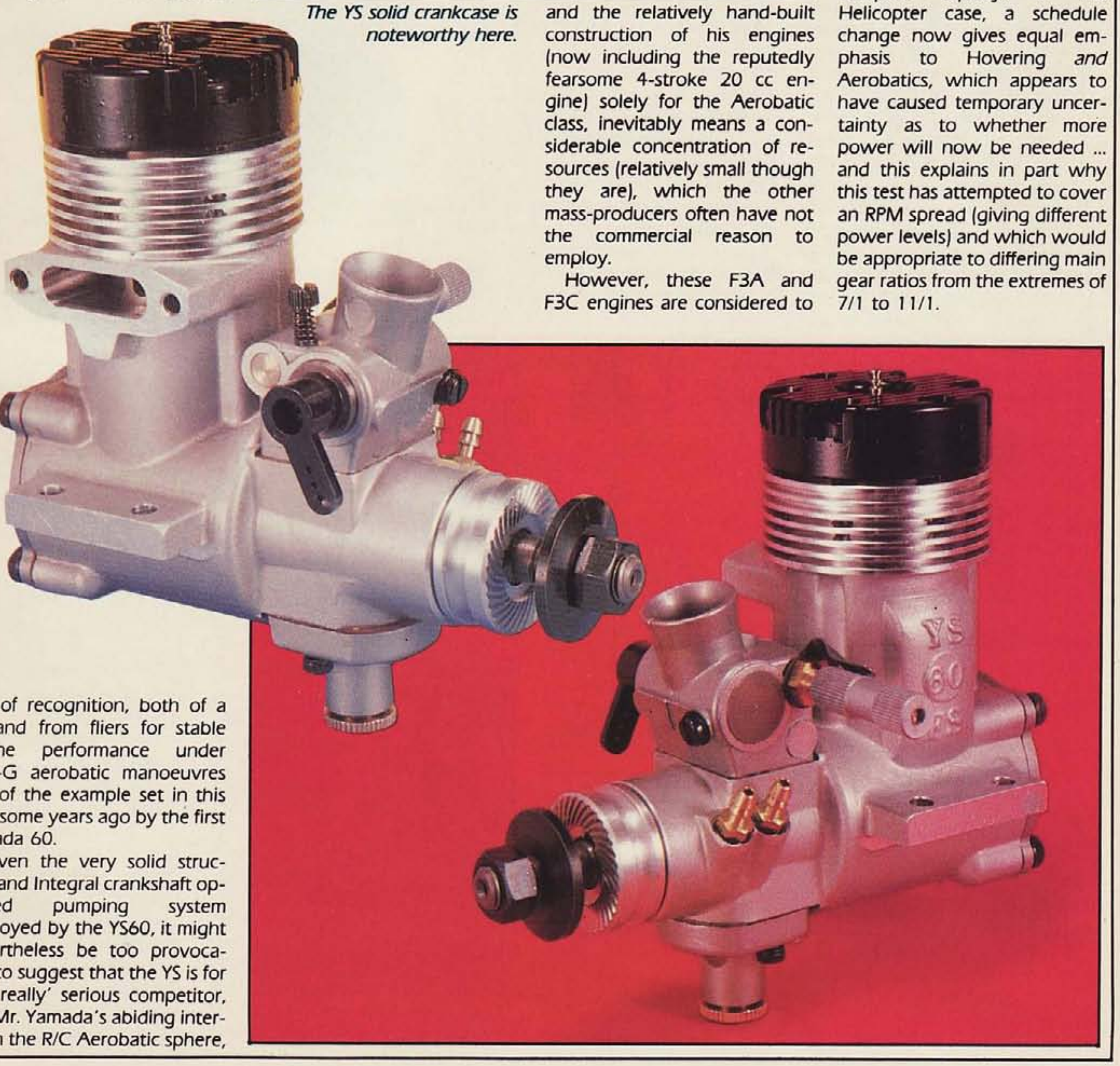
Given the very solid structure and Integral crankshaft operated pumping system employed by the YS60, it might nevertheless be too provocative to suggest that the YS is for the 'really' serious competitor, but Mr. Yamada's abiding interest in the R/C Aerobatic sphere, and the relatively hand-built construction of his engines (now including the reputedly fearsome 4-stroke 20 cc engine) solely for the Aerobatic class, inevitably means a considerable concentration of resources (relatively small though they are), which the other mass-producers often have not the commercial reason to employ.

However, these F3A and F3C engines are considered to be the 'flagships' of each manufacturers production line, and so they continue to provide widespread competitive stimulus. It certainly will not be the first time though that the small but intensive producer meets the more diverse mass-producer in equal competition in the Internal combustion engine world and the results are frequently instructive ... and entertaining.

Some general Heli engine points

As with the F3A (fixed wing) class, F3C has recently seen certain changes. In the case of the fixed wing craft, a relative constriction of flying space within which to judge the various maneouvres has caused some slowing of flying speeds and therefore another chance for the slower rpm, 4-stroke to compete equally. In the Helicopter case, a schedule change now gives equal emphasis to Hovering *and* Aerobatics, which appears to have caused temporary uncertainty as to whether more power will now be needed ... and this explains in part why this test has attempted to cover an RPM spread (giving different power levels) and which would be appropriate to differing main gear ratios from the extremes of 7/1 to 11/1.

The YS solid crankcase is noteworthy here.



Another point is probably already apparent to Helicopter enthusiasts out there; that is, the writer's considerable inexperience in Heli matters ... operation and testing of engines is more my area.

Advice and help has therefore been gratefully received from committed operators, Martin Briggs and Jim Davey. There was some agreement on the difficulty of providing meaningful information likely to be of specific value to Helicopter pilots. The actual HP curves at different pipe lengths (together with Fuel consumption) are naturally of some help in sorting out where to operate the particular engine.

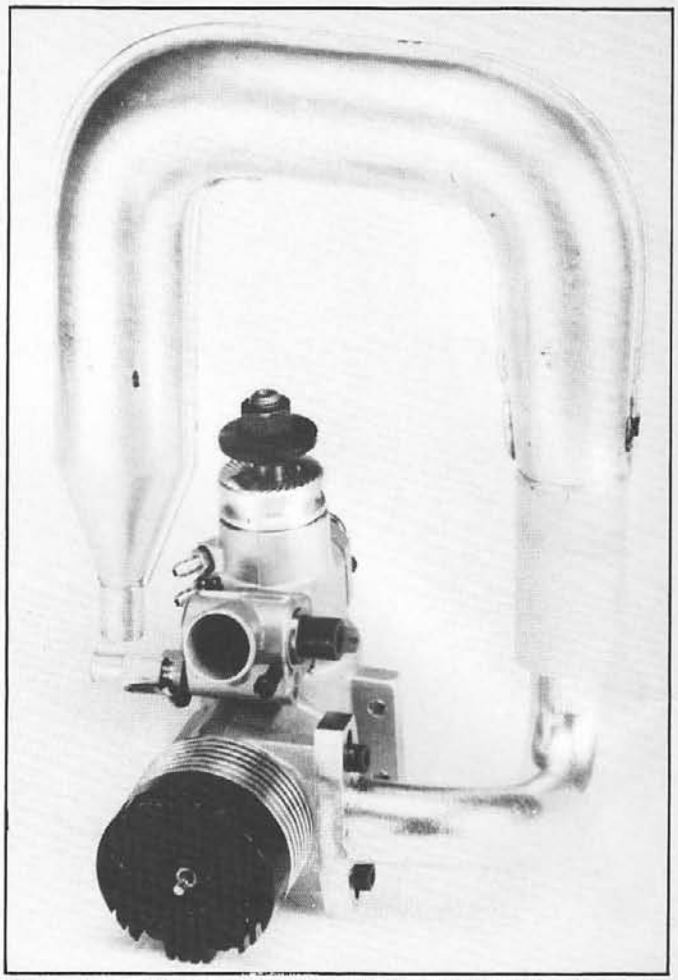
However, with the relatively fixed relationship between throttle opening and 'Rotor pitch (having the intention of varying HP into the head *without* the Rotor changing speed) being an almost unique aspect of the Helicopter, the engine's behaviour in response to varying throttle openings (whilst *its* RPM remains unchanged) is a critical point — particularly so where a 'narrow-band' tuned pipe is fitted, and where the consequence of 'coming off resonance' due to undesireable shifts in mixture strength, would be a dangerously large loss of HP. As has become apparent to this writer, this behaviour is a matter of some importance to the Helicopter.

It is hoped that as further tests unfold, further input from Heli operators will give guidance as to what further information would be of value. Best to say now though, that the idea of loading up a specific engine with a Helicopter's rotor and placing the lot on a dynamometer designed for horizontal engine operation does not immediately appeal and in any event may not give much further information!

In pursuance then of a major concern expressed by Jim Davey, that of carburettor 'sublety', some Torque and Fuel readings at one fixed RPM point were obtained at differing throttle openings by change to Air beam loads, and these are shown as 'spot' readings on the graph. Further info. is detailed under Test 3 later in this report.

YS Pressure System

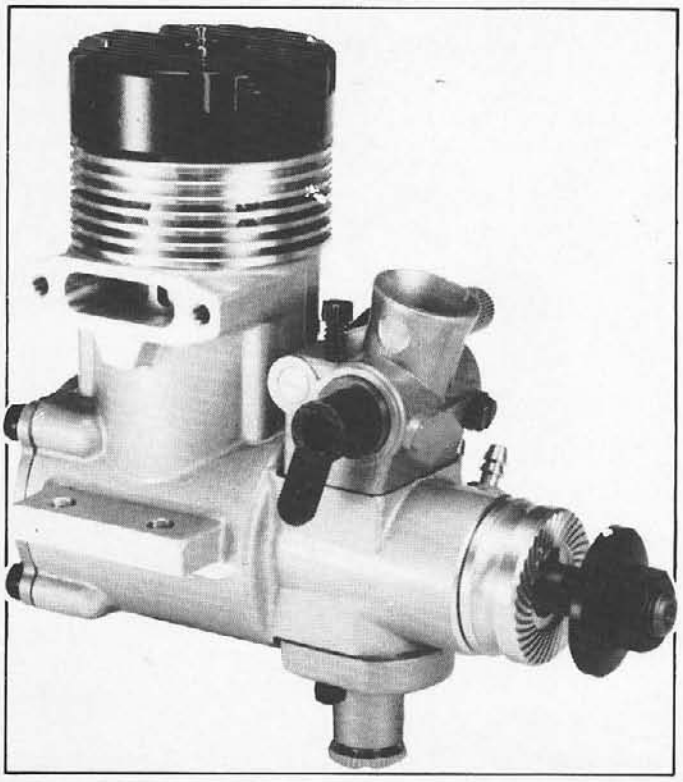
This is essentially a variant of normal timed crankcase pressure systems which normally generate around 4½ PSI to pressurise fuel tank. The difference here is that the offset narrow slot in crank ahead of the normal Induction opening enables a more effective part of the descending piston's pressure to be reached. Also, this pressure is used to operate an adjustable diagraphm under front housing to variably control amount of fuel reaching carburettor. Maximum pressure varies with throttle opening and RPM, so the fuel amount entering is automatically varied broadly in keeping with the engine's demand — and the adjuster effectively allows a 'finer-tuning' of this process.

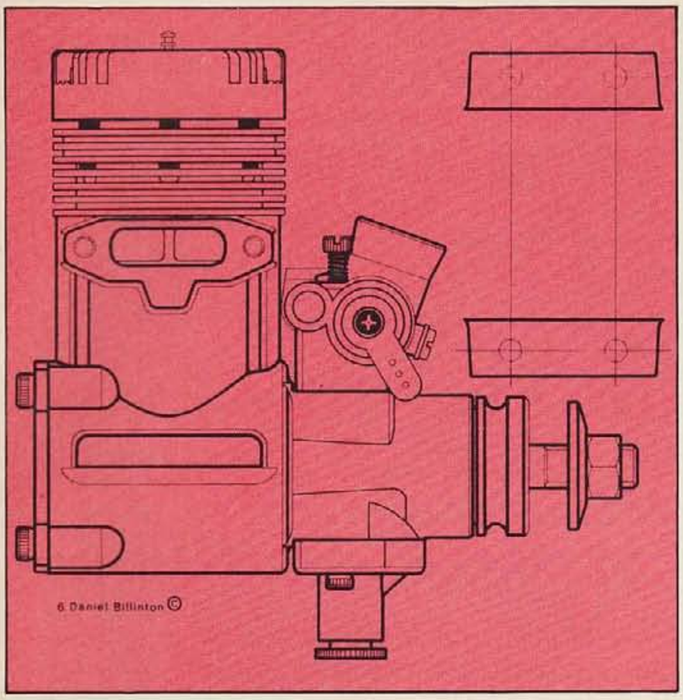


Curves in manifold and pipe plus the internal baffles might have led to slight power loss.

Actual pressure gauge readings tapped off the YS pressure line (rearmost nipple on front housing), were 6½ PSI at WOT (wide open throttle) above around 10,000 RPM. With movement to smaller throttle openings this figure instantly moved in linear fashion to lower values, ie. at ⅕ throttle this reduced to 2½ PSI. There was no drift whatever in PSI readings which stabilised as rapidly as the throttle could be moved. In future tests similar note will be taken of the linearity and speed of responce of the various fuel pressure systems employed. Good reports of the Enya 60 XF GP pump system have been heard, but it will have to be exemplary indeed to better the YS 60's very crisp and instant responsiveness. There is a price however, in that the YS system is more complex and susceptible to lack of cleanliness. During this test (and on an earlier test of the 'fixed-wing' YS60 — RCME Dec 1982) lack of adequate pressure was eventually traced to an unclean one-way valve in the pressure line, whilst continual richening-up of mixture strength at reduced throttle settings, together with a more alarming and persistent total flooding of carburettor when engine stopped, to the point that crankcase could fill with fuel, was eventually traced to an incorrectly assembled brass plunger which operates the silicon fuel diagraphm underneath front housing. Hasten to say this was not a manufacturer problem, but that of the writer's obsessive pursuit of cleanliness which led to a stripdown of this part and apparently then a faulty assembly.

The Enya and OS gear type pumps operating off rear of engine are simpler and less likely to suffer in same way. As commented on before, the YS pumper carb operating off the high point of internal crankcase pressure is an ingenious device, with many small fuel and air passages, and these, together with the operating parts — diaphragm, plunger and one-





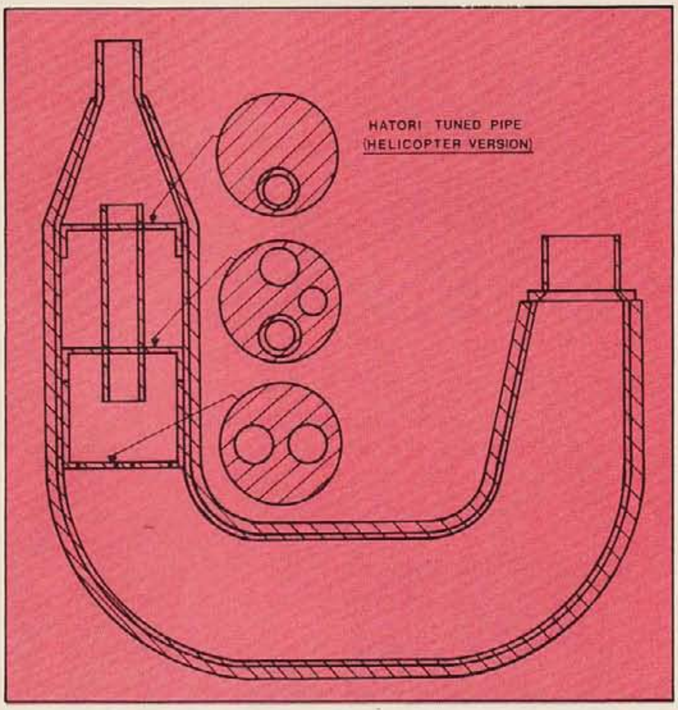
way valve — all need to be in clean condition to ensure perfect trouble free working. So, clean hands, filters in fuel line (maybe even in the air line), and careful clean assembly of all lines etc., is a wise move. Following which, if not continually tampered with, the system can be left to function efficiently for long periods.

Mechanical Points:

The YS 60 has a satisfyingly solid one-piece sandcase crank*case/front housing* combined. Normal twin Schnuerle transfers and single Boost passages are incorporated. The Nitrided 17 mm *crankshaft* differs from an earlier 'fixed-wing' 1982 engine in that the milled slot used to time the high pressure period as piston descends has been extended from the earlier 55° period to now a total 120°(pressure line now opens 44° ATDC and closes 16°BBDC). Actual Induction opening is nominally similar at 196° total. *Piston/Liner* combination is still non-ferrous combination ABN.

It was thought that an Iron liner version was to be provided for this test, but it is uncertain that such exists anyway. Port timings shown in spec sheet are those taken from 'top-of-piston' position. More realistic dynamically, is to read them from 'top-of-piston ring' in this particular engine in which case, add 8° to all cylinder timings.

The liner material here is Brass as usual but is plated using a Nickel process having Silicon inclusions to give added hardness (first though to have been used in Model engines by OS).



Piston in this Helicopter engine is still high percentage silicon aluminium alloy, but fitted at generous .002 inch skirt clearance and .006 inch crown clearance. This is quite loose for such a low-expansion type piston, and is probably so in order to cope with the generally higher temperatures reached on occasion in Helicopter setups.

Such a clearance of course necessitates a Piston ring — Cast Iron in this case and the net result of all this is a static piston seal of much less severity than that of the typical lapped piston engine, and so is more easily started in the restricted helicopter environment, apart from which the helicopter engine occasionally lacks much meaningful flywheel effect to overcome fierce compression seals.

Help towards easier starting is also afforded by reduction of effective Compression ratio to 7.46/1 (compared with the 'fixed wing's' YS60 — 1982 of 9.46/1). However the main reason for this reduction appears to be pursuit of extra reliability — which can be a more necessary component of the helicopter scene — with engine 'death' being a greater hazard (even with the auto-rotation facility) than that of the fixed-wing's aircraft's ability to glide considerable distances power-off. Alternatively this lower C/R would allow effective use of high percentages of Nitromethane for the more desperate competitor ...

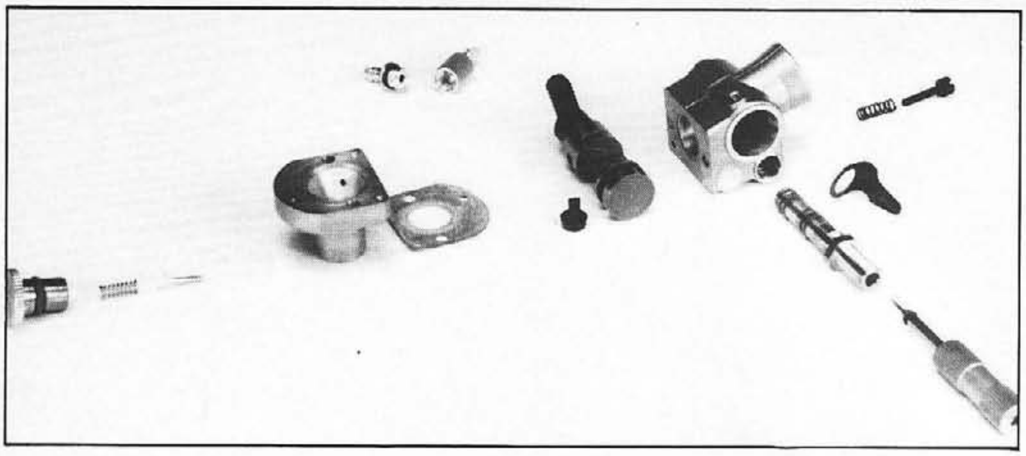
Connecting rod is still a substantial milling from aluminium alloy, with phosphor bronze bushings at each end.

Gudgeon Pin continues with the unusual shrink-fit into piston bosses, and single circlip fitting with reduced diameter at crankshaft side of piston.

Carburettor retains its unusual (in model terms) butterfly throttle valve style — a feature now seen in the OS type 8H carburettor of 12 mm bore. In the YS helicopter engine though, this butterfly plate is no longer symetrically disposed across carburettor throat when open, but is offset approximately ⅗ of the bore. Comment from YS has been hard to come by, and with all instructions printed solely in Japanese, the correct reason for this offset (and for the widening of that crankshaft pressure slot) is for this writer a matter of surmise. Certainly the offset ensures that from ⅓ throttle to Idle position any air entering carburettor must do so on one side only of the flat butterfly valve — that is, the lower downstream side which is the side nearest to where fuel issues to carburettor throat just below the valve. The result at reduced throttle is a wholly concentrated stream of air passing nearest to the fuel exit point (and thus maybe more consistent mixing?) and is a situation which does not apply to the symetrically disposed valve having air streams split down either side of valve at all throttle settings. Unfortunately this could all imply that throttle response at small throttle openings is less precise in the 'fixed-wing' engine and/or that superior transition is needed for the helicopter engine? Carburettor airflow speeds differences between the two engine types probably hold the clue, because the helicopter engine is unusual in operating at relatively constant RPM over a range of throttle settings and thus sees a marked increase in carburettor air velocity as throttle closes, whereas the 'fixed-wing' engine having a (usually) fixed pitch propellor, sees a reduction in RPM's as throttle closes, and thus a constant or reduced velocity air-stream through carburettor.

Any actual helicopter operator will have a distinct edge over the writers because in dyno. tests of both engine types, it has only been possible (because of the fixed loads used) to see RPM's rise and fall with throttle movement, so strictly the test falls some way behind in assessing the potential qualities of the asymetric valve in its transitions from medium to low settings whilst RPM remains constant.

It is possible that this test engine will see service in helicop-



Pressure line one-way valve is shown at top centre. Between the two halves is the small silicon rubber valve which must be kept clean.

Diaphragm and brass plunger is shown at left centre.

ter flight, and so the point could — as normal — be more sensibly assessed in real variable load conditions.

Power Tests

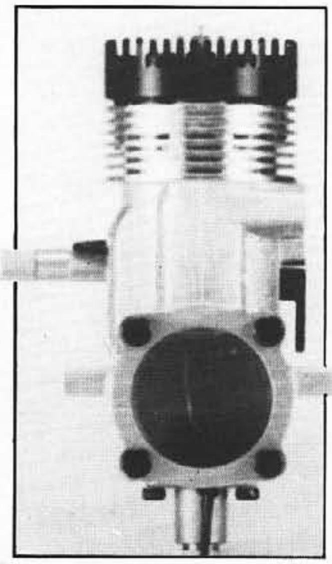
1. *Open exhaust,* 5% Nitro. with 10% Castor and 5% ML70. OPS 250 glowplug.

Taken together with RPM checks on some standard 'fixed wing' propellors, this Open exhaust test was mainly a familiarisation and then initial running-in exercise, though as the engine was not an 'Iron liner' version, little running was needed before the ring — the main beneficiary in this case — became well bedded down and compression improved. Fuel consumption was monitored throughout all tests, using of course a sealed fuel system capable of withstanding the maximum operating pressure of 6½ PSI. It will be noted in open exhaust format how profligate is the consumption. By comparison it is a frequent finding that Tuned pipe consumption fugures, even when generating higher power levels, are more modest.

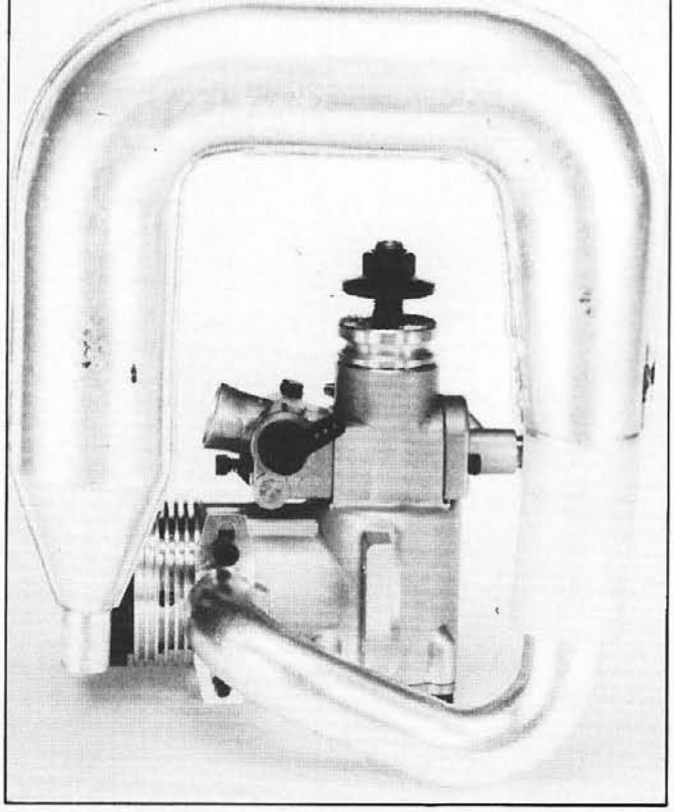
Compared with the higher C/R 'fixed-wing' engine's Open exhaust 2.12 HP, this helicopter engine was slightly down to 1.92 HP at 17,500.

Because the earlier engine peaked at the higher RPM of 19,500 and, with all port timings nominally similar, the lowered C/R of this helicopter engine appears to be the only reason for its reluctance to go higher in RPM and where the extra HP would be found. Maximum Torque itself was virtually unchanged at 126 oz ins. in both engines in the 11,500 RPM area.

2. *Hattori helicopter tuned silencer,* set at standard full length with curved exhaust manifold. Fuel and plug as Test 1.



This combination can be considered the normal 'out-of-the-box' set-up, with tuned length being approximately 16 in. from glow-plug round all the curves to the flat exhaust pulse reflector disc. Design changes in this area continue and the Hattori pipe, first seen by writer in 1981 is now not the only pipe to have quietly abandoned the rear convergent cone of the classic tuned pipe design. Drawings show the early 1980 straight pipe design, and the later curved helicopter pipe design used on this test. Changes are evident — the long parallel section aft of first taper but before first reflector disc is now apparent — and is a feature usually thought to improve 'band-width'. This later pipe has the first reflector disc with 2 holes in it — of sufficient a diameter to lead to the thought that the exhaust pulse might equally reflect back off the next disc in line, some 1 in. further along ... another intriguing thought from son Daniel (he who prepares the engine drawings), is that with a curved pipe, the 'outside' of that curve represents a longer path for the acoustic wave than does the 'inner' path, and thus a greater band-width!? Prefer not to get too involved in this ... suffice to say that although band-width as revealed on Torque tests here was wider than for a normal twin-cone tuned pipe, it was no wider than that of the straight Hattori pipe shown here and tested back in 1982.

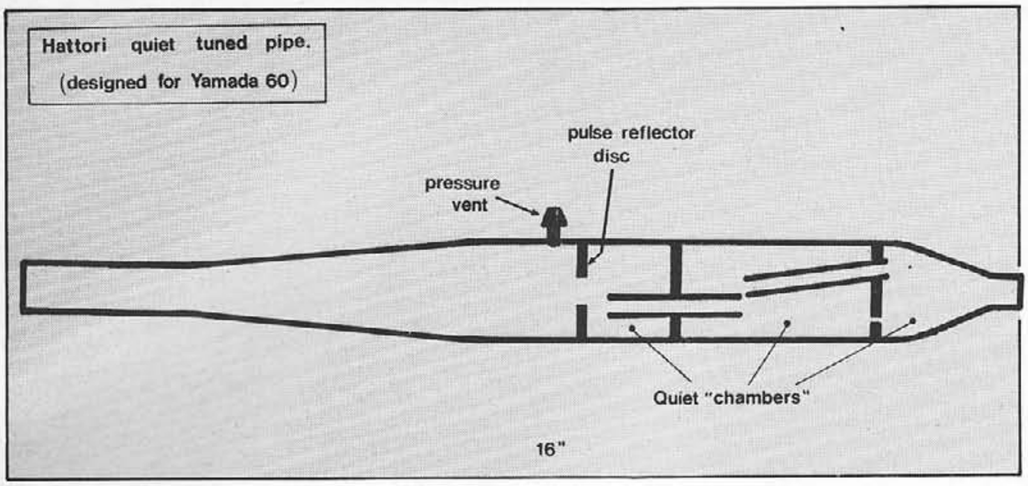


For this test the rear exit hole of the curved Hattori pipe was sleeved down to the standard 5 mm, it previously having been drilled out to 8.3 mm (same size as the internal pipes) in pursuit of hoped-for extra power.

In fact, removal of the sleeve 'on the run' caused no measureable change to Torque or RPM. Although not checked it is possible though that gradual rise in temperatures might occur with the smaller restrictor hole, depending on the particular cooling provision.

As can be seen, the band-width of useable power is quite wide — almost unnecessarily so it might appear for the relatively fixed RPM of the helicopter. However, such flexibility is rarely other than a blessing — unless attained at the cost of considerable power.

As with the Open exhaust result, the comparison with the higher compression 1982 'fixed-wing' engine shows a small reduction in overall power — this helicopter engine is 1.97 HP at 15,600 RPM, as against the earlier 2.12 HP at 15,100 RPM. Admittedly though, the Hattori helicopter pipe used here is not precisely the same layout, plus being potentially more constrictive due to the 4 right-angled bends



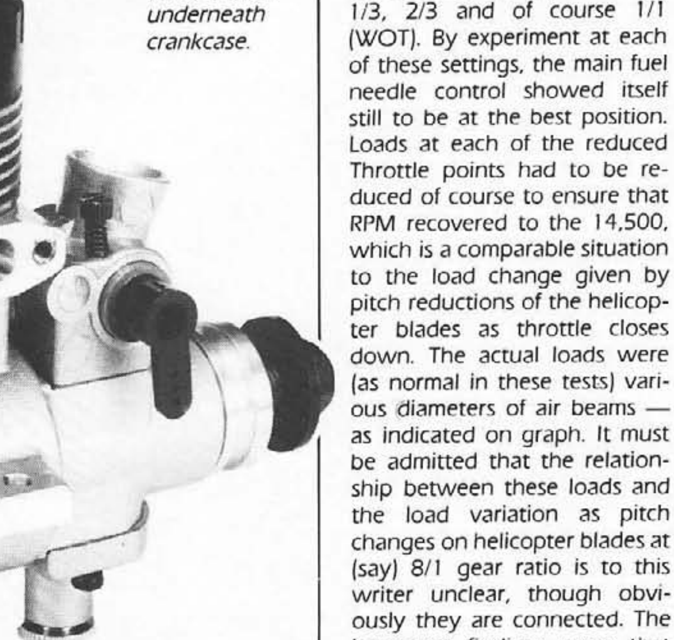
Hattori quiet tuned pipe.
(designed for Yamada 60)

Brass adjuster is shown underneath crankcase.

now being part of the helicopter package.

3. *All equipment as Test 2.*

Strictly this was the only test which had a specific helicopter purpose behind it, and was a set of figures obtained at reduced fixed throttle settings. The object being to asses both whether the main fuel control needle setting (1-5/8 turns open) and pressure regulator setting (2-1/3 turns open) could in fact be left at their previously found best positions for WOT running without need of re-adjustment at lesser throttle openings. In view of the wide band of adequate power (pipe on good resonance from 11,000 to 16,000 RPM) an arbitrary RPM point just past maximum Torque but slightly before maximum HP at 14,500 RPM was chosen for this exercise. The spot points shown on graph indicate Torque, HP and Fuel consumption at fixed Throttle settings approximately 1/3, 2/3 and of course 1/1 (WOT). By experiment at each of these settings, the main fuel needle control showed itself still to be at the best position. Loads at each of the reduced Throttle points had to be reduced of course to ensure that RPM recovered to the 14,500, which is a comparable situation to the load change given by pitch reductions of the helicopter blades as throttle closes down. The actual loads were (as normal in these tests) various diameters of air beams — as indicated on graph. It must be admitted that the relationship between these loads and the load variation as pitch changes on helicopter blades at (say) 8/1 gear ratio is to this writer unclear, though obviously they are connected. The important findings were that the pipe remained correctly on resonance, and that the engine did not drift towards over-rich or over-lean fuel settings when the throttle was closed to each new fixed position. Omitted from graph is a small throttle setting (approximately 1/5 open) and which, at 14,500 RPM, gave Torque to 40 oz in./ .58 HP/7 cc/min. fuel consumption using beam deameter of 5.0 ins.



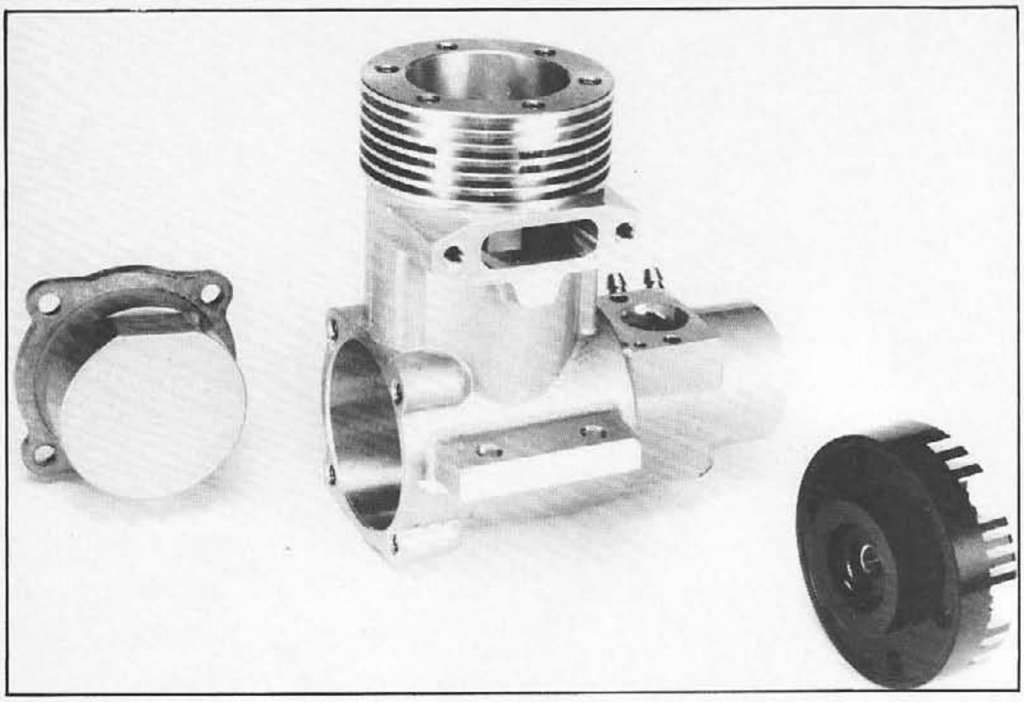
4. *Hattori pipe reduced in length by 2½ in.* (taken off manifold). Other equipment still as Test 2.

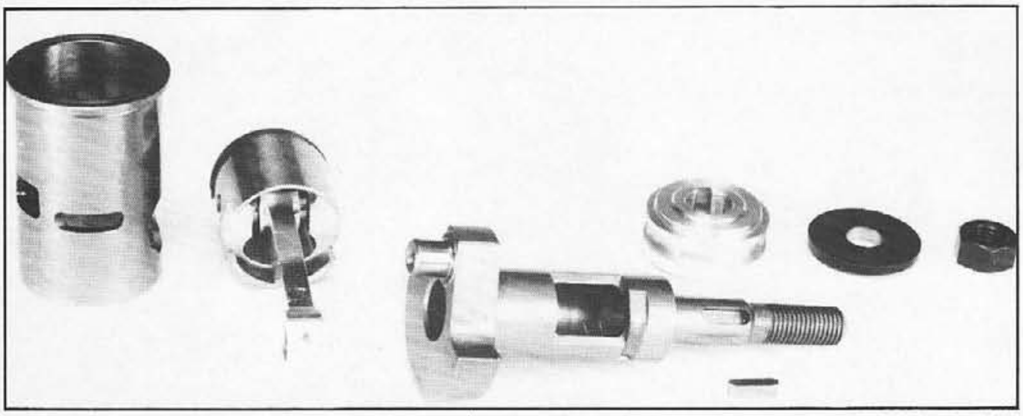
Attempting to move peak power point up the RPM scale in this usual manner was sucessful, but at the cost of some band-width of useful power, whilst in general the engine's response and fuel settings became a little more critical, though still manageable. HP of 2.12 at 18.053 RPM was recorded in this set-up.

5. *OS Quiet pipe (straight),* set at 19 in. from glow-plug to end plate (or 10 in. plug to first maximum dia.). Other equipment as Test 2.

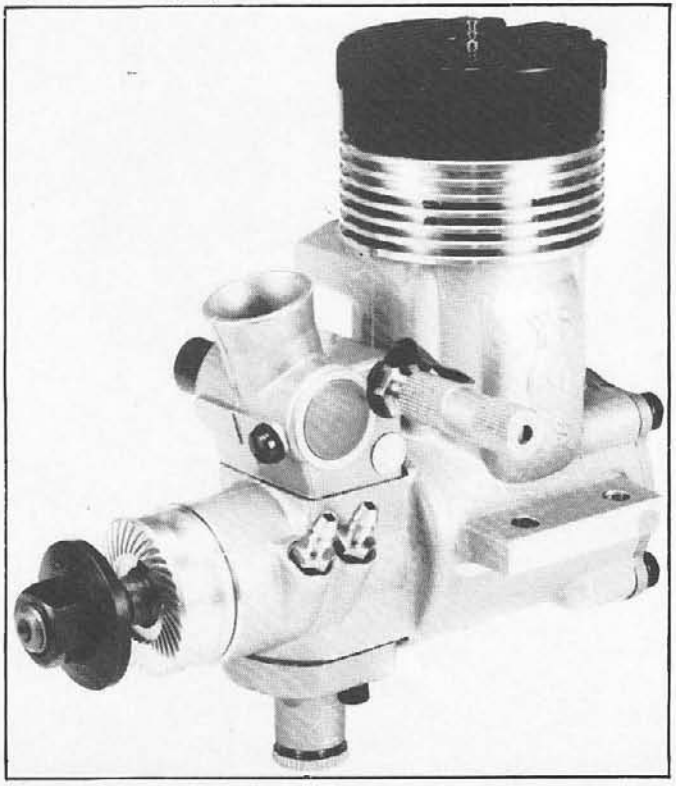
This test was a classic negative proof of not changing more than one thing at a time ... but nevertheless the outcome cannot be denied. Use of the writer's OS straight Quiet pipe was financially a more viable and swifter exercise than obtaining a straight version of the Hattori pipe. The internals of the OS pipe are thought to be on similar lines acoustic design principles — but, it is a different pipe, the pipe is straight, and it was set up with minimum direction changes (ie. sticking straight out sideways from the YS side exhaust position), it does have a 10 mm outlet which was not sleeved down to assess effect of restriction down to the same 5 mm outlet size of the Hattori pipe. The actual length arbitrarily chosen did lead to a peak resonance point that turned out to be at higher RPM than those for the Hattori pipe.

So, all in all, quite a different animal, and so which of the various differences explain the extra HP gained must wait for a more orderly back-to-back test regime. Fortunately the finding is maybe of limited value only (say to straight line speed helicopter runs) because its unsurprising narrow band would be more difficult to control than that of the wide Hattori's wide power band.





Very solid connecting rod and crankshaft is clear in this view. Note keyway drive to prop. driver.



YS needle-valve is solid and well sealed with small 'O' ring. Reasuringly predictable on test.

The addition throughout of Nitromethane, up to 40% would certainly raise power levels — the OS pipe result for instance would likely reach 3.0 HP without much trouble, though with extra heat. Of interest here is that the final use of the OS pipe saw the one OPS 250 glowplug which had survived all tests thus far, finally disintegrate at the maximum resonance RPM of 19,430 whilst Torque reading was 130 oz ins.

Heat Sink

The YS60 helicopter engine uses the standard head from the 'fixed-wing' engine, and so in the helicopter format installation is expected to fit into existent model structure-based heat-sinks. In fact when using 5% Nitro. the engine runs quite cooly and would seem to need little extra in the way of head material. As usual it is the pipe which cause problems with engine failing to remain on best resonance point or even failing to get onto that point in the first place. It is instructive that pipe and header water cooling is a very important feature of Marine competition engines though admittedly they also have head cooling.

Summary

The YS60 helicopter engine ended the test session of 60 separately recorded runs and approximately 3 hours running time in fine conditions, and with very little apparent wear. Its very solid rigid construction increases the chance of quite extended life at high power levels. On its inception in 1980 the YS60 rear exhaust engine (fixed-wing) was considered a specialist high-quality product setting new high standards and broadly this picture has not changed. However, since that time, other major manufacturers have increasingly improved their products, whilst the YS has remained largely unchanged. So, as these various helicopter engine tests unfold there could well be much of interest to record.

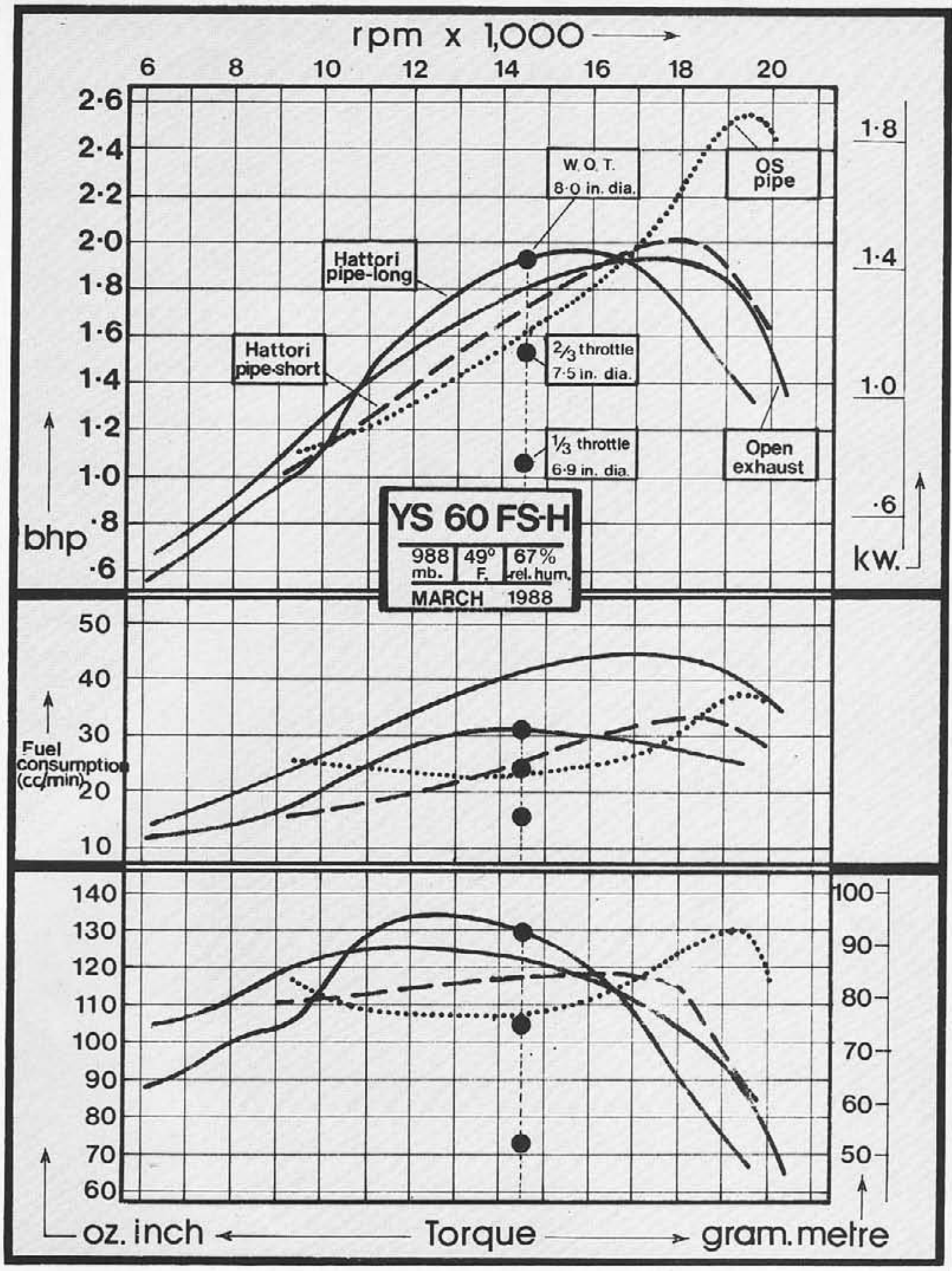
An omission in these tests is any assessment of individual part life at extended duration of running time. This is mentioned because of reports that there are differences appearing between engine makes on the matter of rear main bearing life, for example. Now this has some importance, though in the last analysis it is only one of many factors to consider, and may well be one price to pay for what may be in other areas, a fine useable and precise engine. In any case there may be user problems or chemical attack reasons to explain a particular failure quite separate from a possible structural incapacity in the engine. Having said that, the writer would be the first to admit that a 3 hour running period — as this test is short indeed compared with the many hours operation needed to fine-hone a pilot's aerobatic skills. In the meantime, keep those engines clean ... occasionally (preferably always) flushed through with petrol or a preferred cleaner, after use ... and then re-oiled. Some 'structural' problems may thereby be prevented in the first place.

Capacity — .6067 cu in (9.94 cc).
Bore — .945 in (24.01 mm).
Stroke — .865 in (21.97 mm).
Stroke/Bore ratio — .915/1.
Timing Periods:
  Exhaust — 156°.
  Transfer — 116°.
  Boost — 114°
  Front Induction:
    Opens — 37° ABDC.
    Closes — 53° ATDC.
    Total period — 196°.
    Blowdown — 20°.
Combustion volume — 1.05 cc.
Compression ratios:
  Geometric — 10.46/1.
  Effective — 7.46/1.
Exhaust port height — .275 in. (7 mm nominal).
Cylinder head squish — .018 in. (.46 mm).
Cylinder head squish angle — 7°.
Squist band width — .169 in. (4.31 mm).
Carburettor bore — 10.86 mm.
Crankshaft dia. — .669 in. (17 mm).
Crankshaft bore — .432 in. (11 mm).
Crankpin dia. — .275 in. (7 mm).
Crankshaft nose thread — 8 mm x 1 mm.
Gudgeon pin dia. — .236 in. (6 mm).
Connecting rod centres — 39 mm.
Engine Height — 3.91 in. (9.9 mm).
Width — 2.4 in. (61 mm).
Length — 3.7 in. (94 mm).
Width between bearers — 1.58 in. (40.1 mm).
Mounting hole dimensions — 20 x 52 mm with 4.5 mm holes.
Ex. manifold bolt spacing — .32 mm.
Frontal area — 6.85 sq in.
Weight — 19.1 oz (542 g) without manifold or silencer.
Crankshaft weight — 3.4 oz (97 g).
Piston weight — .75 oz (21 g).

Performance:

Max BHP:

2.56 @ 19,430 RPM (OS pipe/5% Nitro.).
2.12 @ 18,053 RPM (Hattori pipe shortened/5% Nitro.).
1.92 @ 17,500 RPM (Open exhaust /5% Nitro.).



Max Torque:
134 oz in. @ 12,918 RPM (Hattori pipe standard).
130 oz in. @ 19,430 RPM (OS pipe).
126 oz in. @ 11,400 RPM (Open exhaust).

RPM on Standard (fixed-wing) propellors.

	Open ex.	Hattori pipe (long)	OS pipe
13 x 6 MK glass	11,220	11,105	—
12 x 7 Mastro	11,220	11,366	—
10 x 8.3 Graupner 3-bl	12,818	—	—
10.5 x 7.5 Weller"	13,287	13,849	—
11 x 7.5 Airflow	13,373	13,753	—
11 x 6 Graupner	14,210	14,765	—
10 x 6 MK glass	15,502	—	14,586
9 x 6 Master	—	—	19,490
9 x 4 Zinger	—	—	20,843

Performance Equivalents:

BHP/cu in. — 4.22
BHP/cc — .257
Oz in./cu in. — 221
Oz in./cc — 13.5
G metre/cc — 9.66
BHP/lb — 2.14
BHP/kilo — 4.72
BHP/sq in. Frontal area — .373

Manufacturer:

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

UK Distribution

Sprengbrook.