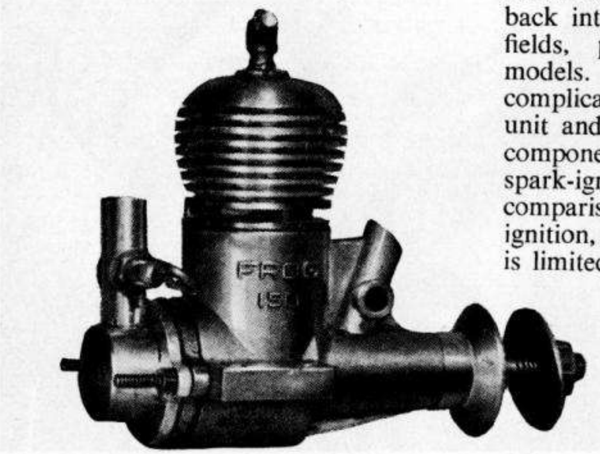
CHAPTER SIXTEEN

Engine Speed Controls

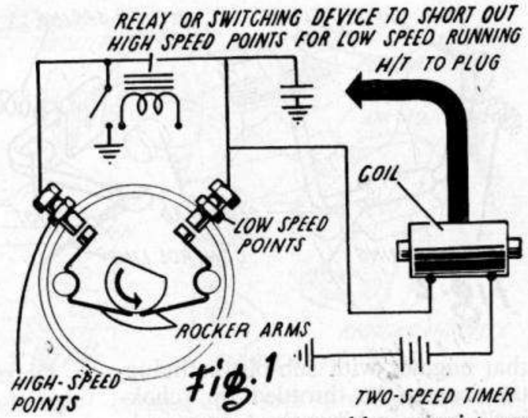
INHERENTLY the small two-stroke engine is less amenable to throttling by varying the amount of fuel fed to the cylinder than its full size counterparts, due both to an apparent "scale" effect with small volumetric sizes and, particularly, the method of carburettion employed. Thus throttles, as such, are absent from standard aero-engine designs. Running speed is then largely dependent on the load (*i.e.*, the size of propeller driven) with the mixture control (needle valve) adjusted for optimum performance. except in the case of spark-ignition engines. In the latter case, speed and any load can effectively be varied by adjusting the timing or the instant at which the plug sparks. *e.g.*, by rotating the contact breaker in the same direction as the direction of rotation to retard the spark and slow the engine; and against the direction of rotation to advance the spark to make the engine run faster.



NOT A CASE OF USING TWO carbs. for engine speed control, this experimental Frog 150 is actually a prototype of the latest 149 version using the vibra-matic induction system. A standard engine was employed with blanked main shaft.

This is a particularly positive form of speed control for with the spark retarded, for instance, it is not possible for the engine to speed up unless the contact breaker unit is rotated. Also the engine will continue to run steadily at this setting. Throttling a diesel or glow motor, on the other hand, *e.g.*, by running on a very rich mixture setting or reduced compression (diesel) *can* lead to the engine speeding up, or stopping during flight without any change in adjustment.

Although no spark-ignition areomotors are now produced in this country or the United States (the last was the spark-ignition version of the Frog "500" which was withdrawn in 1956) the type is coming back into favour in certain limited fields, particularly radio control models. Apart from the additional complication of the contact breaker unit and the weight of the ignition components to be carried, the spark-ignition motor suffers, by comparison with diesel, and glow ignition, in that its maximum speed is limited, and hence its power output per c.c. inferior. But where this can be tolerated its ready adaptability to speed control and its comparative cleanliness are still in its favour.



Dual Points for Spark-Ignition

To avoid the necessity of mechanical movement of the contact breaker assembly, electrical switching can be used for speed control by fitting a duplicate set of contact points—*Fig.* 1. The contact breaker unit is now fixed, the two set of contacts corresponding to "retard" and "advance" positions. (Fixed, here, is a relative term: the whole unit may still be movable for initial adjustment.) It is then possible to switch the ignition circuit from one set of contacts to the other, to change from "low" to "high" speed, or vice versa. Alternatively, the switching can be arranged to short out the high speed contacts for the low speed running, this being the more general arrangement.

Both diesel and glow motors can, however, be throttled quite effectively, although not always to the same positive degree. In both cases this is nearly always accomplished by supplying the engine with an excessively rich mixture for low speed running, although some diesels can equally well be throttled back by reducing compression. All diesels will reduce speed when compression is backed off from the running position, accompanied by "missing". It is very much an individual characteristic of the design, however, whether the engine will continue to run with reasonable consistency when this is done, or whether it will tend to stop. On a limited number of engines, the non-critical response to reducing compression may be such that the engine cannot be stopped by this means, *i.e.*, with the range of upward movement possible of the contra-piston, the compression ratio still remains high enough to continue to fire the mixture.

Altering the compression, however, is not a practical means of speed control, allied to light servo mechanisms which have to be contained on the model. Thus the rich mixture method is preferred as this can be accomplished with a simple clapper valve or similar device. There is one marked difference between diesels and glow motors when slowed by running on over-rich mixtures. Nearly all diesels have a tendency to die if run too slowly, whereas glow motors will generally keep going. The main objection to "throttling" by the use of a very rich mixture is the extremely messy running, a large proportion of solid fuel being ejected through the exhausts.

It must be remembered, however,

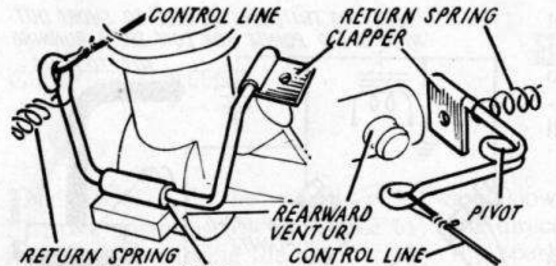
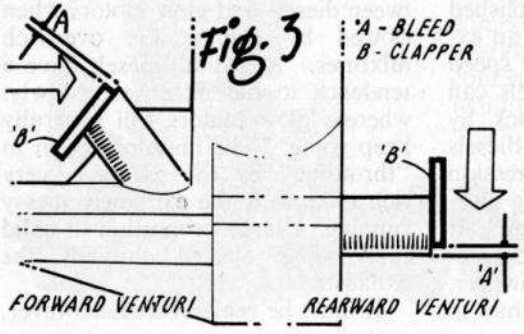


Fig. 2

that engines with sub-piston induction cannot be throttled by "choking" since whilst the air supply through the intake pipe is restricted by this method, additional air is drawn into the crankcase through the exhaust at the top of the stroke and hence the final mixture remains on the weak side. Some measure of speed control may be produced by choking, but seldom can a marked degree of speed difference be obtained for the slow running mixture can never be made rich enough if the needle is set for optimum lean mixture for normal running.

Simple Clappers

A simple clapper valve merely consists of a flat disc which can be lowered over the end of the intake tube—*Fig.* 2. The valve must seat reasonably well, but not completely seal off the air supply. Rather than rely on an indifferent seating to give the necessary air bleed it is better to make the clapper seat quite well and pierce it with a small bleed hole, *e.g.*, about $\frac{1}{32}$ in. diameter. The size of this hole can then be adjusted to produce consistent slow running with the clapper over the intake.



Depending on the individual design of engine again, it is possible to use a clapper valve to give a range of engine speeds, by varying the final position of the clapper offered up to the intake. In other words, the amount of air induction is modified by the proximity of the clapper. The clapper itself need not be pierced, the air bleed in the fully shut position being given by a slight clearance between the rim of the clapper and the induction pipe. Quite small movement of the clapper may then produce a marked variation in engine speed but the system is rather difficult to adapt to variable speed control by servo mechanisms. It would be more easily worked on the principle of sliding the clapper over the end of the intake, rather than lowering it in position—*Fig.* 3.

Throttles

Two proprietary throttles produced some years ago in America operated on the "choke" principle—the Drone throttle—*Fig.* 4*a*—designed specifically for the Drone diesel, and the Redwing speed control. The latter was designed for linkage to the

bellcrank on control line models so that a violent manoeuvre threw the control quadrant over to the "choked" position when it could be restored to normal running position by a sharp pull on the line—*Fig.* 4*b*. Operation is self-explanatory from the illustrations. The Drone control, however, was more useful as a motor cut-out since throttling could only be effected by screw adjustment of the plunger and thus required several turns either way to change from normal running to rich and back again.

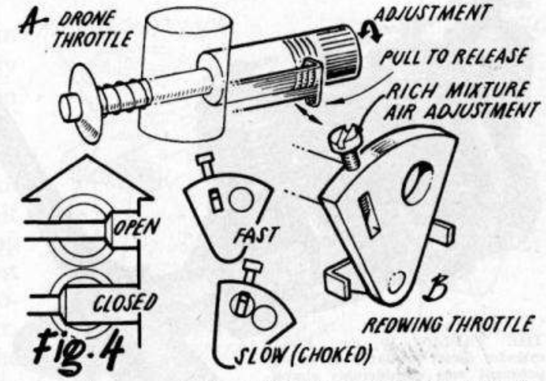


Fig. 4

A favourite American method of achieving two-speed engine control is to employ twin spraybars and needle valves, one, usually the top, being adjusted for a rich mixture and the other for optimum lean mixture. The fuel supply is then switched from one to the other spraybar, as required, to select the required speed. Provision can also be made to incorporate an air bleed in the switching system so that two engine speeds and "stop" are available as controls. A typical method of achieving this is shown in *Fig.* 6 which utilises a Bonner (American) escapement type valving switch, designed for radio control work.

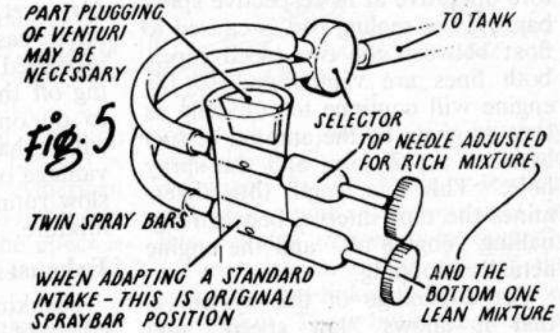


Fig. 5

Escapement Controls

In the Bonner motor control unit both spraybars are connected to the tank, but each has in it a "T" joint connecting to open-ended pipes on the contro unit. The escapement controls the position of

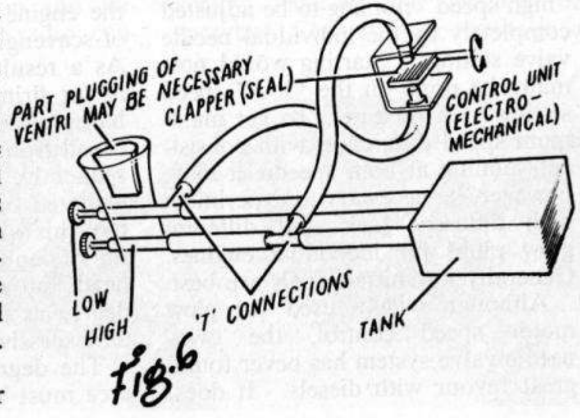
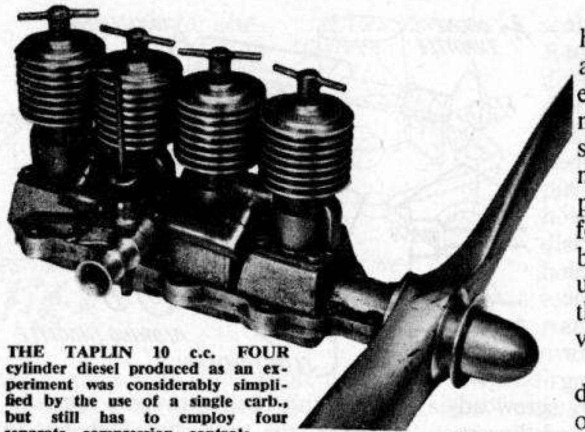


Fig. 6



THE TAPLIN 10 c.c. FOUR cylinder diesel produced as an experiment was considerably simplified by the use of a single carb., but still has to employ four separate compression controls.

a sealing pad which blanks off one or other of the bleed tubes. Whichever line is thus sealing off is therefore operative at its respective spray bar. If the sealing pad is caused to float between the two bleed pipes, both lines are vented and so the engine will continue to run only as long as given by the amount of fuel between the T joint and the spray hole. This line length thus determines the time interval between signalling "engine off" and the engine actually stopping.

An advantage of this system is that it allows "low speed" and "high speed" running to be adjusted completely by the individual needle valve settings. Starting would normally be done on the "low" speed setting (rich mixture). To get maximum speed difference, with consistent running at both speeds, it may, however, be necessary to experiment with different fuels and different glow plugs for individual engines. Generally low nitrate fuels are best.

Although widely used for glow motor speed control, the twin-needle valve system has never found great favour with diesels. It does, however, work reasonably well on most diesels. Similarly, glow motors will normally respond to the "clapper" method of choking to produce a rich mixture for slow speed running, but this method is less used with glow engines than the twin needle valve set-up.

An objection with diesels to running on an over-rich mixture is the danger of getting too much solid fuel in the cylinder head leading to over-compression. Some diesels can tolerate running with the head very wet. Others cannot. In the latter case, speed control may be produced more effectively by blanking off the exhaust. This is easiest to do on engines which are fitted with exhaust stacks and has the advantage of being far less messy than slow running on an excessively rich mixture.

Exhaust Choke

Blanking off the exhaust has the effect of reducing the efficiency of the engine by reducing the amount of scavenging which can take place. As a result the fresh charge drawn in for firing is adulterated with exhaust gases which have not escaped from the previous cycle. Consequently, there will be less power gathered on the fire stroke. Again, too, this will lead to a similar build-up of unburnt (solid) fuel in the head, but not normally to the same degree as that given by running on an excessively rich mixture.

The degree to which the exhaust area must be blanked off to achieve

any appreciable drop in speed may be surprisingly high. Most exhaust areas on model engines are larger than necessary for complete scavenging to start with, in any case. Blanking off half the port area (*e.g.*, sealing off one of a pair of exhaust stacks) will normally produce no appreciable difference in running speed. The exhaust area may have to be cut almost completely off before a marked loss of speed is produced—*Fig.* 7. Also a good seal may be necessary on such a device. Depending on individual engine designs, however, this method can be effective for variable speed control, variable on the degree of blanking off. The exhaust choke method is mainly applicable to the American "35" size engines; but the noise can be deceptive, often the effect is more of silencing than speed control.

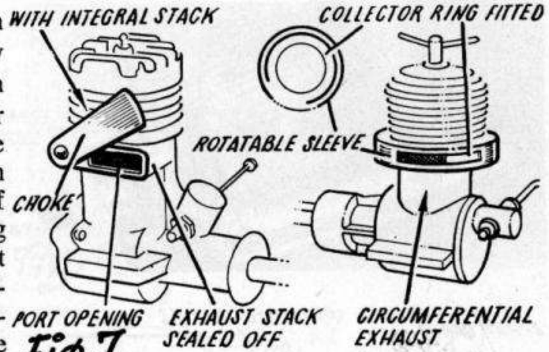


Fig. 7

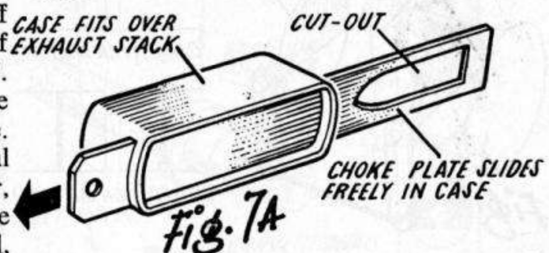
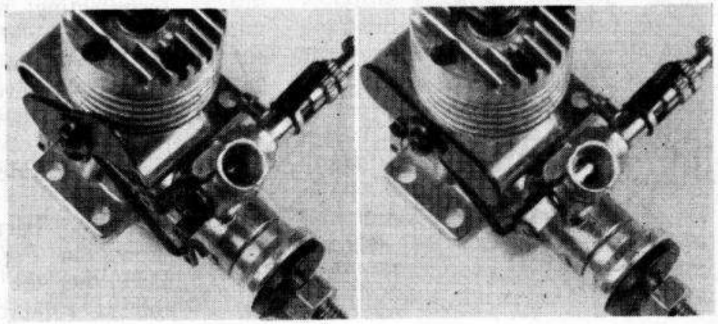
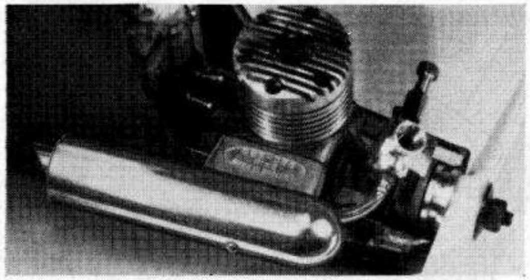


Fig. 7A

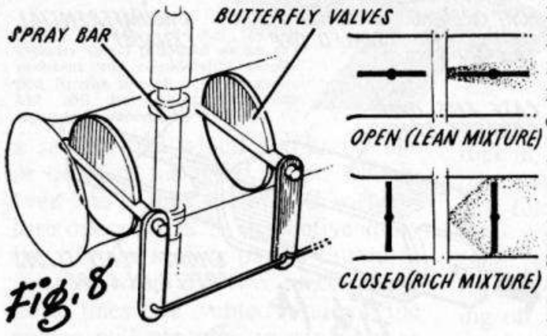
A method of speed control which has become popular on the larger diesels (mainly for radio control work) is the use of a butterfly valve in the intake tube. A scheme developed by G. Honnest-Redlich and Electronic Developments in this country utilises twin butterfly valves, one on either side of the spraybar, and linked to have parallel movement. These butterflies control airflow entering and leaving the spraybar. Closing them results in a

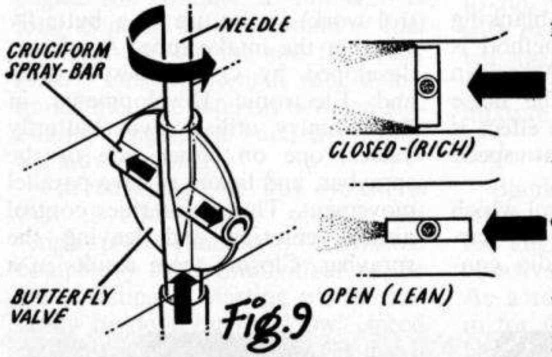
Open and shut positions of a Japanese O.S. coupled exhaust baffle and rotary intake barrel on an O.S. 10 R/C engine. This gives an excellent range of control.

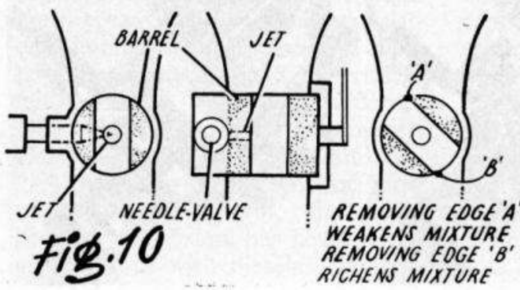




SOME SILENCERS GIVE AN improved fuel economy and better idling control. One of them is the Gee Dee Pike unit seen on a Merco 61 here (refer to page 182).





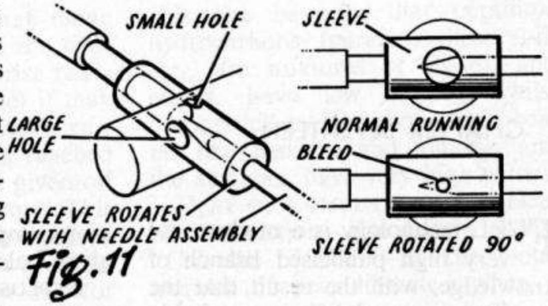


richening of the mixture, and vice versa. The butterflies must be quite snug fitting for maximum effect in the "closed" position and represent a certain difficulty in assemblage within the intake tube, but the external linkage necessary to operate them is simple, and power to move them low.

Much the same effect can be achieved with a single butterfly valve with a single "T"-shaped spraybar mounted on it—*Fig.* 9. Here the spraybar is rotated with the butterfly from fully closed (maximum rich) to fully open (maximum lean), the actual mixture being determined by the setting of the needle valve proper as controlling the fuel supply to the bar of the "T".

A valve of this type with the greatest possibilities is the barrel valve, although representing more of an "engineering" job in the matter of manufacture. In general, however, it is rather easier to make and fit a barrel-type valve than single-or double-butterfly units.

A true barrel valve is shown in *Fig.* 10. The barrel fits the choke tube and is rotatable, the re-

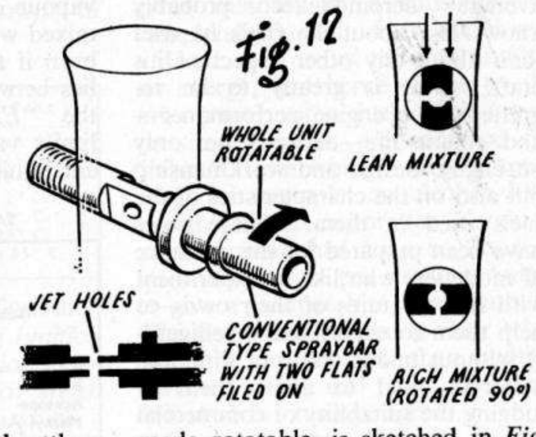


latively large hole drilled through it normal to its axis of mounting thus providing an adjustable air opening. The fuel jet opening terminates in the throat of the barrel opening, the mixture setting being controlled by a normal needle valve adjustment.

Quite accurate adjustment of the mixture can then be obtained by trimming the edges of the barrel. In the closed (slow running) position, removing metal from edge "A" weakens the mixture, whilst removing metal from edge "B" richens it. It is thus possible to arrive at an optimum mixture for slow running for a required needle valve setting (*i.e.,* for optimum "high speed" running mixture).

The proprietary Mills throttle—*Fig.* 11—works on a similar principle, the needle valve being surrounded with a rotatable sleeve. Actually, needle valve assembly and sleeve rotate as one unit, for convenience. The sleeve is then bored through with a large diameter hole (the same as the diameter of the venturi throat) to line up with the intake for normal running; but when rotated 90 degrees blanks off the intake except for a small bleed hole. In this position the air supply is considerably restricted and so the mixture is much richer for the same needle valve setting.

An adaption of the barrel valve principle, using in effect on ordinary spraybar, slightly modified and



made rotatable, is sketched in *Fig.* 12. Here the centre portion of the spraybar is formed into two flats to serve the same function as the hole through the barrel valve (except that the spraybar may not completely fill the intake tube and so some air passage is left on each side of it) Rotating the spraybar both "throttles" the air supply and also slightly affects the mixture due to the displacement of the jet holes relative to the intake axis giving, in effect, a variable mixture control between "open" and "shut" from fast (optimum lean mixture) to "slow" (maximum rich mixture). Like the barrel valve the final mixture for slow running can be finely adjusted by trimming the edges of the flats.

CHAPTER SEVENTEEN

Fuels

FUEL technology is a modest, not very high publicised branch of knowledge, with the result that the average aeromodeller probably knows less about the fuels he uses than about any other aspect of his craft. This is greatly to be regretted since engine performance—and engine life—depends not only on engine design and workmanship but also on the characteristics of the fuels used in them. These notes have been prepared for the guidance of modellers who like to experiment with fuel mixtures of their own—to help them to experiment intelligently without undue waste of time and materials—and to assist them in judging the suitability of commercial brands of fuel for whatever purpose they may have in mind. No attempt has been made to write a "Formulary" or to review existing commercial fuels. What has been attempted is a concise and simplified account of the properties and functions of the major fuel ingredients, and an outline of the basic scientific principles to be followed in working out the design of a fuel for any particular purpose.

Before it is possible to proceed to the formulation of a satisfactory "Diesel" or "Glo" fuel it is necessary to be familiar with certain fundamental properties of fuel components such as *"Flash Point"*, *"Heat of Combustion"*, *"S.I.T."*, etc., and a short explanation of the more important of these terms is given below.

EXPLOSIVE LIMITS. When the vapour of an inflammable liquid is mixed with air the mixture will only burn if the concentration of vapour lies between certain limits known as the *"Explosive Limits"*. These limits vary considerably for different liquids, as shown in Table 1.

TABLE I.—EXPLOSIVE LIMITS.

Substance	Explosive Limits per cent of vapour in the air	
	Lower	Upper
Benzine	1.35	8
Acetone	3	13
Methyl Alcohol (Methanol)	5.5	21
Ethyl Alcohol ... (ordinary alcohol)	2.8	9.5
Ethyl Ether	1.7	48
Paraffin Hydrocarbons	about 1	about 3.5

Taking Methanol as an example it can be seen that if the concentration of methanol vapour in the air is less than 5½ per cent the mixture will be too weak to fire, whilst if it exceeds 21 per cent the mixture will be too rich.

FLASH POINT. *"Flash Point"* is a measure of the inflammability of a liquid. If a little inflammable liquid is placed in the bottom of a small metal cup it will give off vapour into the air space above it. If this concentration reaches the lower explosive limit the mixture of air and

vapour will "flash" if a small flame or spark is brought above the cup. If the liquid does not vaporise readily (paraffin oil for example) it may be necessary to warm it until a certain critical temperature is reached at which enough vapour is given off to form the explosive mixture. This temperature, below which ignition will not take place, is known as the *"Flash Point"*, and varies widely for different liquids, as shown in Table 2.

TABLE II.—FLASH POINTS.

Liquid	Flash Point
Ethyl Ether	—41° C.
Benzene	—21° C.
Acetone	—17° C.
Toluene	— 2° C.
Methanol	0° C.
Butyl Acetate	25° C.
Paraffin and Diesel Oil ...	about 65° C.

SPONTANEOUS IGNITION TEMPERATURE. Also known as *"Self Ignition Temperature"*, *"Auto-Ignition Temperature"*, and *"S.I.T."* for short. This is the temperature at which a mixture of inflammable vapour and air will ignite *without* the application of a flame or spark. S.I.T. is totally unrelated to the Flash Point, and should not be confused with it. Table 3 gives some typical values.

TABLE III.—SPONTANEOUS IGNITION TEMPERATURES.

Substance	Self-Ignition Temperature
Acetone	630° C.
Benzene	580° C.
Toluene	553° C.
Ethyl Acetate	484° C.
Methanol	475° C.
Ethyl Alcohol	421° C.
Amyl Acetate	379° C.
*" Petrol "	280° C.
Coml. Diesel Oil ...	240° to 260° C.
Paraffin	about 250° C.
High Cetane Val. Gas Oil	220° to 240° C.
Ethyl Ether	188° C.

It can be seen that paraffinic hydrocarbons (paraffin, diesel oil, etc., are mixtures of these), and ethers, have low S.I.T.'s whilst "aromatic" hydrocarbons from coal tar like benzene and toluene, and the alcohols, have very high values.

HEAT OF COMBUSTION. The Heat of Combustion—also known as the *"Calorific Value"*—is the total amount of heat liberated when a given quantity of a substance is completely burned. It is, therefore, a direct measure of the total intrinsic energy, and hence of the available power, of a fuel. Some approximate values are recorded in Table 4, from which it can be seen why, for example, an alcohol fuel requires larger carburettor jets than petrol; more fuel must be flooded into the cylinders per stroke in order to give a comparable power output. The figures also make it clear why alcohols run "cooler" than hydrocarbon fuels, and are therefore favoured for racing engines.

OCTANE VALUE. Pure Iso-Octane is a very good anti-knock fuel for spark ignition engines, since it has a high S.I.T., whilst Pentane, with a very low S.I.T. is a bad fuel. Other fuels are compared as regards performance with mixtures of iso-octane and pentane and thereby given an "Octane" rating. If the fuel is as good as iso-octane its Octane Value is 100, whilst if it is only as good as a mixture of equal parts iso-octane and pentane its Octane Value is 50.

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* This refers to a straight-run petroleum fraction of low Octane Value, before "leading" or admixture with benzene, etc.

A good commercial petrol will be higher than 280°, and an aviation spirit higher still.

CETANE VALUE. This is a method of assessing the values of diesel fuels by comparing their performance in a test engine with mixtures of different proportions of the excellent diesel fuel cetane and the very poor diesel fuel methylnaphthalene. Cetane and Cetene Values may also be calculated indirectly from the specific gravity and Aniline Point of the fuel, but this method is not applicable if "dopes" are present. A high Cetane Value means a low Octane Value, and vice versa.

IGNITION LAG. When a mixture of a diesel fuel vapour and air is raised to the Self Ignition Temperature, there may be a considerable delay before the explosion actually takes place. This time interval is known as the "Ignition Lag" and for smooth running should be small. The running characteristics of a poor fuel may be enormously improved by reducing the ignition lag by making small additions of certain "dopes". This must not be overdone since *too* short an ignition lag causes detonation, etc.

LIQUID FUELS for internal combustion engines are of two fundamentally different types, namely those to be fired by spark or hot-wire ignition and those designed to ignite under the heat of compression alone, without the application of a spark or other local hot-spot. The former fuels, of which petrol is the commonest example, should contain a low-boiling fraction (the "light ends") of low Flash Point to ensure starting from cold, but must have a *high* S.I.T. to prevent firing taking place under compression alone before the spark passes. The second type of fuel, for use in Diesel engines, need not possess a low Flash Point but *must* have a low S.I.T. It follows that a good petrol will be a bad diesel fuel—and vice versa.

Miniature Diesel Fuels

The diesel fuels used in road transport vehicles are fairly high-boiling fractions from natural petroleum consisting mainly of certain types of "paraffinic" hydrocarbons. Such a "gas oil" has a Spontaneous Ignition Temperature around 250° C. and when forced into the cylinders in finely atomised form will fire satisfactorily under the high-temperature conditions prevailing in these very high-compression full-scale engines. But they will not ignite in a model "Diesel" unless it is hot, and to enable miniature compression-ignition two-stroke engines to be started it is customary to add a proportion of Ethyl Ether, which combines the phenomenally low S.I.T. of 188° C. with very wide Explosive Limits. Since the miniature "Diesel" is a two-stroke engine, lubricant must also be incorporated in the fuel. Finally, to ensure smooth even running it is often advantageous to include a small proportion of a further component, the "dope". It is worth while to study in some detail the functions and properties of these *four vital components*.

(1) *The Paraffinic Base-Fuel.*

This is the main ingredient of the fuel. Its function is to provide most of the energy of the fuel, and it should therefore possess high Calorific Value and low S.I.T. Reference to Table 3 will show that, with the exception of certain ethers, the only readily available substances with relatively low S.I.T.'s are the

paraffin hydrocarbons—which fortunately also possess very high Calorific Values. Ruling out individual pure hydrocarbons like pentane, hexane, heptane, etc., on the grounds of expense, this virtually narrows down our choice of base fuel to paraffin oil, commercial diesel oil and special high cetane gas oil fractions, if available. There is little to choose between paraffin and diesel oil, the latter having its higher viscosity and greater "oiliness" to recommend it. It can be seen, partly by reference to Table 3, that the addition of petrol, benzene, toluene, naphthalene, turpentine, white spirit, or in fact any of the fantastic materials that have from time to time been recommended, must of necessity make the fuel worse, because of the high S.I.T.'s of these substances.

TABLE IV.—CALORIFIC VALUES.

Substance		Heat of Combustion (calories)
HYDRO-CARBONS:	Paraffin Oil ...	11,000
	Diesel Oil ...	10,900
	Petrol ...	10,000
	Benzene ...	9,960
ETHERS:	Ethyl Ether ...	8,800
	Methylal ...	7,900
KETONES:	Acetone ...	7,300
ESTERS:	Ethyl Acetate	6,100
ALCOHOLS:	Ethyl Alcohol	7,080
	Methanol ...	5,330
NITRO HYDRO-CARBONS:	Nitrobenzene	6,030
	Nitromethane	5,370
	Nitroethane	4,300
	Nitropropane	2,790
ETHYL NITRITE		4,450
ETHYL NITRATE		3,560

Their use to "deaden down" the detonation of the ether is a case of two wrongs failing to make a right: a fuel that needs deadening down has got far too much ether in it.

(2) *The Lubricant.*

The lubricating component of the fuel may be any good quality lubricating oil, either mineral or vegetable. The only limitation imposed by vegetable oils like Castor Oil is that alone, they will not blend with paraffin base fuels; castor oil can be used only in a fuel ready-mixed with ether, which will keep all the components in solution. There is scope for experimenting with different grades and qualities of oil.

With regard to the *quantity* of oil to incorporate in the fuel, this again is a matter for experiment. Many miniature engine fuels are grossly over-lubricated, with the result that they are unnecessarily messy in use, and also require more ether than they otherwise would. In designing a diesel fuel it should be borne in mind that the oil has one function only—to provide adequate lubrication—and that it should not be expected to burn, to moderate the explosive tendencies of excess ether, or to do anything else. A two-stroke motor-cycle engine runs on the road for long periods at a time under much greater (and varying) loads than any model engine, and with considerably greater bearing and piston speeds, yet seldom does the percentage of lubricant in the fuel exceed $7\frac{1}{2}$ per cent. It is desirable in formulating a model diesel fuel to increase this proportion for the following reasons: (1) a new engine may have tight spots and require excessive lubrication till it is run-in; (2) in a very old, or badly made engine, the piston may be a poor fit in the bore, so that a fairly thick viscuous fuel is needed in order to seal the compression, and (3) the manufacturer must allow a reasonable safety factor. Point 2 normally affects only the ease of starting: once the engine has been started it will usually continue to run perfectly satisfactorily even on a very thin fuel. With old engines starting can usually be facilitated by injecting a drop or two of lubricating oil through the ports.

For a normal fuel for use in a run-in engine in good condition, oil percentages in the region 30 per cent to 50 per cent are unnecessarily high. If the aeromodeller experiments with proportions of oil in the range 12 per cent to 20 per cent for racing blends and 20 per cent to 30 per cent for general-purpose and running-in fuels, he will not go far wrong. Diesel oil based fuels tend to require rather less than those blended with paraffin.

(3) *Ether*.

Apart from its low S.I.T., which enables it to start easily, and its wide Explosive Limits which ensure that throttle settings are not critical, *ether is a bad diesel fuel*. It has a considerably lower Calorific Value than the paraffinic base-fuel and it detonates or "knocks" badly. Excess of ether means correspondingly less base-fuel in the formulation, and hence a fuel of lower calorific value than need be, whilst its detonating propensities when present in excess cause diesel knock and impose undue strains on the con-rod. Ether should, therefore, be added to a diesel fuel for one purpose only, namely to make the engine start. Just enough for this purpose should be added—*and no more*. Thirty per cent to 35 per cent is excessive, and modellers are recommended to experiment in the range 20 per cent to 30 per cent. It cannot be overstressed that the function of the ether is solely to bring about easy starting; it should not be expected to usurp the function of the base-fuel.

There seems to be some confusion regarding the grades of ether suitable for use in fuels. Ether is manufactured from ordinary ethyl alcohol, two molecules of which join together, with the elimination of water, thus:—

$$C_2H_5–O–H + H–O–C_2H_5$$

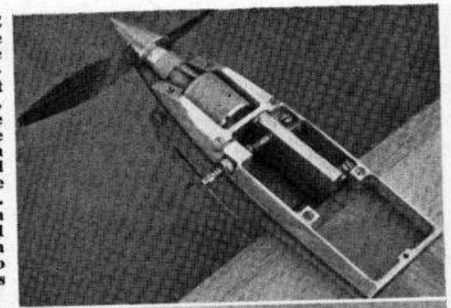
2 Ethyl Alcohol

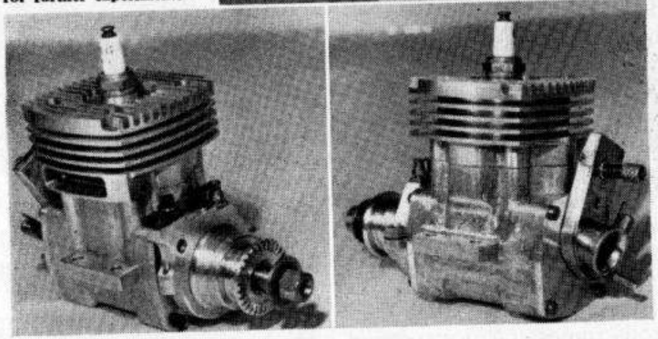
$$\rightarrow C_2H_5–O–C–{}_2H_5 + H_2O$$

1 Ethyl Ether Water

The process is usually carried out by heating the alcohol with concentrated sulphuric acid, which absorbs the water formed—which is why the product is sometimes called "sulphuric ether". The ether which distils over is washed free from acid, purified, dried and re-distilled. It therefore contains no acid whether it is sold as "Anaesthetic Ether" "Ether .720", "Ether B.S.S. 759". "Sulphuric Ether", or "Ether Meth.". All these materials are, effectively, the same thing; and if properly manufactured are all harmless to model engines. The .720 refers to the specific gravity of the product and shows the substantial absence of water; B.S.S. 579 refers to the appropriate British Standards Specification laying down the standard of purity; "Ether Meths." indicates that the ether was not manufactured from pure ethyl alcohol but from methylated spirits, which contain a few per cent of

ENGINES WHICH ARE specially fuel sensitive are the high performance types used for team racing and speed. At right is Drazek's M.V.V.S. diesel in "Orion". Note the neat mount and the slim 10 c.c. tank with fuel filler valve supported in the mount. Below are two views of the R. Kinnersly 10 c.c. ultra short stroke engine tested on petrol/ignition with slide throttle control to establish a true basis for further experiment.





methanol—this will give traces of methyl-ethyl and di-methyl ethers in the product, which are not harmful. Anaesthetic ether is made from pure alcohol and usually contains a proportion of deliberately added alcohol, and sometimes other additives, to prevent peroxide formation on storage. It is more expensive than other grades and, if anything, is slightly less suitable for fuel work.

The di-ether, Methylal, with the chemical formula $CH_3–O–CH_2–O–CH_3$, may be used partly or wholly to replace ethyl ether in certain specialised fuel formulations. The higher ethers Amyl Ether and Butyl Ether are too high boiling to be valuable alone, but may be used mixed with ethyl ether. Isopropyl Ether, unlike the straight-chain ethers above, has a very high S.I.T. and is not suitable for use in diesel fuels. It is a possible ingredient of glo-fuels.

(4) *Dopes*.

There are a number of well recognised "dopes" which may be added to diesel fuels, best known of which are

- Ethyl and Amyl Nitrites
- Ethyl and Amyl Nitrates
- 3–Chloro-ethyl Nitrate
- Paraldehyde
- Various organic peroxides like Tertiary Butyl Hydro-Peroxide, Di-Tertiary Butyl Peroxide, etc.

The choice of dope is usually determined by price and availability.

The function of the dope is to reduce "Ignition Lag" and thereby give smooth, powerful running. Very little dope is needed for this purpose, the precise amount depending on the particular fuel formulation, and is a matter for experiment in each case. Seldom is more than 3 per cent required, and modellers would be well advised to start with about 1 per cent of dope and gradually increase, by not more than $\frac{1}{2}$ per cent at a time up to a maximum of about $2\frac{1}{2}$ per cent, until smooth even running is obtained—and then to *stop*. This is a case of "a little of what you fancy does you good"—but a little bit more can play hell. Dopes should be used *solely* for the purpose described above and should under no circumstances be used in excess to assist starting. They do, indeed, lower S.I.T. somewhat, but their effect in this direction is most marked with the first few per cent and then falls off very rapidly. It should be remembered that nitrate dopes are, in effect, high explosives and that when they burn they generate nitrous fumes. An overdoped fuel requires the compression setting of the engine to be drastically reduced as the engine warms up, it sets up unnecessary strains in the engine, and it is corrosive.

A proprietary brand of fuel will be a carefully balanced blend of ingredients with the correct amount of dope; no attempt should be made to "improve" it by further dope additions.

Following the basic principles discussed above, and bearing in mind that each component of the mixture has its own specialised part to play in the performance of the final fuel, it is now possible to set about designing a good diesel fuel for a particular engine or for a specific purpose. A good running-in fuel for new engines and for general purpose flying would look something like this:

Paraffinic Base Fuel	45-60%
Lubricant	20-30%
Dope	1-$2\frac{1}{2}$%
Ether	20-25%

whilst a Racing or Competition fuel might well be:

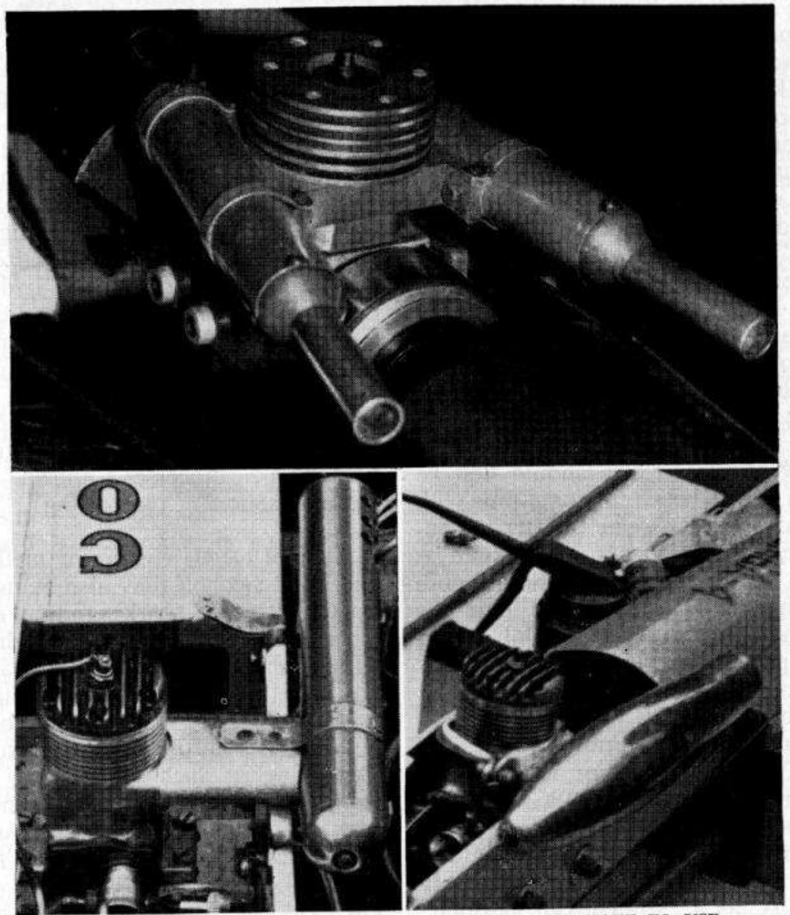
Paraffinic Base Fuel	55-65%
Lubricant	$12\frac{1}{2}$-20%
Dope	1-3%
Ether	20%

If the fuel is of the ready-mixed variety all the ingredients are mixed together, and the lubricant may be castor oil. But if the fuel is to have its ether added immediately before use, only the first three components are mixed in each case; in which event mineral lubricant must be employed.

Starting with either of the above basic formulations as a guide, the ideal fuel for a particular purpose and individual engine can readily be worked out on the test bench by modifying the components of the appropriate formula a very few per cent at a time until optimum performance is obtained. It should be borne in mind that the perfect fuel for one engine may not be ideal for another with totally different design characteristics, and the really scientific flying enthusiast will study the individual fuel requirements of all the more important engines in his "armoury". It should also, of course, be appreciated that different fuels may require different starting and running settings—and the careful experimenter has to develop a considerable amount of patience.

Running-in: Engine Temperature

It follows from the increased proportion of base-fuel and the reduced proportion of ether that a "racing" fuel will run hotter than a running-



HYDROPLANE ENTHUSIASTS WERE THE FIRST TO HAVE TO USE the silencer. These three units are typical of those engineered to fit special, and McCoy engines.

in or general-purpose fuel, because of its higher Calorific Value. This relatively high-temperature running has been known to worry some modellers, who sometimes attribute it to frictional heat arising from under-lubrication. Any well-formulated racing fuel is, by its very nature, bound to run hot—and it is advantageous that it should do. The efficiency of operation of the internal combustion engine increases, within reasonable limits, with increase in temperature of running, hence the modern practice of cooling full-scale aero engines with ethylene glycol (b.p. 198° C.) instead of water (b.p. 100° C.).

If the modeller is anxious, it is suggested that he feel, not the cylinder head where combustion of powerful fuel is taking place, but the crankcase main-bearing. If this remains moderately cool he need have no fear of a seizure.

WARNING. In fairness to the manufacturer, as well as in his own interests, the modeller should, of course, be careful only to use a fuel for the purpose for which it is intended. A "Competition" or "Racing" mixture is, as its name implies, intended for high-speed work, and the manufacturer assumes his customer will not be expecting to develop maximum power and revs. with a new engine straight out of its box. A "Standard" or "Running-in" fuel should always be used with new engines, which should first be run on the bench for some time with an oversize propeller. After the engine has loosened up it should be run for another half hour or more with a standard prop., still on the same type of fuel. Only after proper running-in, and after a fair amount of work should peak output with racing fuels be attempted.

Spark Ignition Fuels

The usual fuel for an ordinary spark plug engine is "Petrol". A motor spirit which is a simple "cut" from the distillation of natural petroleum—what is known in U.S.A. as a "straight-run gasoline" —consists mainly of paraffinic and naphthenic hydrocarbons boiling over the range 40°–190° C. Because of its high paraffinic content it has a fairly low S.I.T. and tends to "knock" or "pink" badly in a modern high-compression automobile engine. Its low Octane Value is raised by either of two methods. The first is to incorporate a small amount of a dope having precisely the opposite effect of a diesel dope, in order to *suppress* pre-ignition, *i.e.,* to *raise* the S.I.T. Lead Tetra-Ethyl is pre-eminent for this purpose, although when used alone it has the disadvantage of giving hard deposits of lead oxide inside the engine. Modern "Ethyl Fluid" contains ethylene dibromide to minimise this trouble. The second method is to enrich the straight-run fuel by additions of benzene (benzole), toluene, other hydrocarbons of high Octane Value (high S.I.T.), or alcohols. The high octane hydrocarbons may be obtained from coal-tar distillation or from the gasoline itself by various high - pressure, high - temperature "cracking" processes known as "aromatisation", "preforming", "alkylation", etc.

Alcohol blends containing methyl and ethyl alcohols may also be used satisfactorily in spark ignition engines. They perform best in engines with high compression ratios and are therefore most suited to motorcycles and racing cars, where their high S.I.T.'s ensure immunity from "knocking". Such blends are, of course, eminently suited to miniature spark-ignition engines, castor oil lubricant being incorporated for two-stroke engines. The relatively low calorific values of alcohol blends, and their higher price, makes their use for ordinary purposes uneconomic if hydrocarbon fuels are available. But the increased volume of fuel that has to be flooded into the cylinders in order to obtain comparable power output tends to keep the engine moderately cool at high speeds, an important consideration with racing engines. The calorific value of methanol blends may be increased by replacement of part of the methanol by Methylal, the di-ether already referred to above, which is not prohibitive in cost for specialised fuels. Methylal can be used alone as a motor fuel.

The higher the compression ratio of an engine the higher must be the Octane Value of its fuel. But the spark-ignition engine possesses a certain measure of tolerance for poor fuels resulting from the ability to vary the ignition timing—retarding for starting and with fuels of low rating, and advancing for high speeds and with high octane fuels. This flexibility is lacking with glo-plug motors.

Glo-Plug Motor Fuels

The glo-plug engine is without ignition control, and fuel formulation might therefore be expected to be more critical than for spark ignition engines. For maximum racing performance this is undoubtedly true, yet it is surprising on how many weird and wonderful concoctions the average glo-motor will run passably well. A good general-purpose fuel on which any glo-plug engine will run is a simple mixture of

Castor Oil	... ...	30%
Methanol	... ...	70%

but performance may not be outstanding. The castor oil proportion may with advantage be increased for some engines for the preliminary running-in ; it should seldom be reduced below 20 per cent even with well seasoned engines. Methanol does not have the natural inherent oiliness of diesel oil, and glo-fuels must have a higher oil content than diesel fuels. In order to develop the high revs. of which it is capable the glo-engine must be fairly "sloppy", and to ensure adequate compression for starting a fairly oily viscous fuel is needed. Castor oil, and not a blended lubricant like Castrol "R", is to be preferred since it does not contain additives insoluble in methanol and therefore yields a clear fuel without sediment.

A very large number of substances have been suggested from time to time as useful additives to simple Castor Oil/Methanol blends in order to give increased performance. This list includes Amyl Acetate, Ethyl and Amyl Nitrates, Acetone, various cellulose solvents, Nitrobenzene, and many more. Extensive experiments with a host of other materials have led to the conclusion that whilst one or two may have a slight effect in glo-plug engines of early type, most of them are valueless in a modern glo-engine. In work with, for example, the latest type McCoy, replacement of part of the methanol in a methanol/castor oil blend by

Ethyl Nitrate
Amyl Nitrate and Nitrite
Amyl, Butyl, Ethyl and Isopropyl Ethers
Ethyl and Amyl Acetates
Paraldehyde
Acetaldehyde
Nitrobenzene

and many other solvents was found to have *little or no useful effect,* even when added in quite substantial quantities. It is true that in some instances the engine developed a very satisfying staccato note suggestive of increased revs., a very potent exhaust flavour, or both, but in no case was any significant speed improvement recorded by the instruments.

An approach to the problem of improving simple methanol blends can be made by replacing part of the methanol by a fuel of higher calorific value such as benzene, toluene, acetone, ethyl alcohol or methylal. In some cases these materials effect a slight improvement, but usually more in the direction of improved fuel consumption than in increased speed. In any case there is a limit to the proportion of such substances that can be added since, without exception, they have narrower Explosive Limits than methanol; after quite a small percentage has been added the throttle setting may become too critical for reasonably easy control. Furthermore, excess of some of these compounds of high calorific value can cause an engine to run very hot indeed and to eject showers of red sparks, so that risk of seizure becomes very real. Acetone was invariably found to give erratic running, which is surprising.

METHANOL. Some straight methanol castor oil blends have been found to run more smoothly than others. Modellers would be well advised to purchase only the purest methanol. Methyl and Ethyl alcohols come on the market in various "Proof" strengths, *i.e.*, containing varying proportions of water and for best results only 74° over-proof methanol should be used (this contains over 99 per cent of methanol).

METHANOL/CASTOR OIL RATIO. Unlike diesel fuels, the speed is not greatly influenced by variation in the base-fuel/oil/ratio. If a particular engine is adequately lubricated by, say, 20 per cent of oil and 80 per cent of methanol, there is no significant loss of speed when the ratio is altered to 30 : 70. On the other hand, if the former mixture is somewhat under-lubricating the engine, there may be a substantial increase in r.p.m. when the oil ratio is raised.

Nitroparaffins

Whilst most of the substances so far discussed are without any profound effect on the speed of a glo-engine, this is certainly not true of the nitroparaffins. Replacement of part of the methanol in a Methanol/castor oil blend by Nitromethane, Nitroethane or Nitropropane may increase engine speed by between 1,000 and 2,000 r.p.m. In this respect the nitroparaffins appear to be unique—and are indispensable for really high speed work. Unfortunately, they have not been readily available and they have been fantastically expensive, and except in carefully balanced fuel formulation they involve high fuel consumption. Supplies of Nitromethane are not stocked by the model traders and should be ordered through a dispensing chemist or direct from an organisation such as British Drug Houses.

Just why nitroparaffins are so effective is not clear. They have very low energy contents, as reference to their Calorific Values in Table 4 will show. Nitromethane, for example, has only half the Calorific Value of Methanol and a nitromethane fuel might more logically, in fact, be described as a "cool" fuel than a "hot" fuel. Their effectiveness would seem to lie not in their intrinsic energy contents (which are very low) but rather in the extreme rapidity with which this energy and oxygen content can be liberated. In effectiveness, Nitromethane and the Nitropropanes are closely similar on the test-bench, nitropropane possibly giving a slightly more stable mixture under flight conditions. They would appear to be interchangeable in glo-fuel formulations, the choice depending mainly on price and availability. Nitroparaffin blends require a slightly wider throttle setting than non-nitrated blends, and are hence a little less economical in use.

With regard to the *amount* of nitromethane or nitropropane to include in a glo-fuel formulation, it is the considered opinion of many that the proportions sometimes advocated are excessive. A fuel with 25 per cent to 40 per cent of nitromethane, apart from its exhorbitant cost, usually seems to kill off glo-plugs with fair rapidity. Secondly, careful speed tests on a number of engines have shown that at first there is a considerable speed increase when nitromethane is added, but that the effect gets progressively less with each further addition until it becomes insignificant. The experimenter is recommended to start off with a fairly small percentage of nitroparaffin in his fuel mixture and to carry out several speed determinations on his engine. Another mixture should then be prepared with the same base-fuel/oil ratio, but with a few per cent more nitromethane, and further speed readings taken. This process should be repeated with small nitroparaffin increases until there is no further speed increase measurable. In this way the most effective, and at the same time most economical, fuel will be worked out with the minimum waste of expensive materials. It will often be found by trials of this sort that 20 per cent of nitromethane is just as useful as 30 per cent.

The response of an engine to changes in fuel composition depends to a very considerable extent on the design of the engine, particularly as regards timing, porting and compression ratio. One engine may be found on test to be very much faster on a nitroparaffin blend than on a straight castor oil/methanol, whilst the performance of another engine may be found to be almost identical on either fuel. The moral is, clearly, do not run on expensive nitroparaffine blends if a non-nitrated racing methanol blend will give as good results. And equally, a commercial fuel should not be condemned because it does not improve the performance of *your* engine; it may be giving your friend another 1,000 revs. on his engine of identical make. Engine manufacturers are constantly experimenting and incorporating minor design changes so that two apparently similar engines may, in fact, differ noticeably in compression ratio, timing, or both.

Finally, there is ample scope for studying the effect of combining nitroparaffins with other additives like amyl acetate, etc., which are ineffective by themselves. The guiding principle in all such work always being to make only one change at a time, and to make the changes small gradual ones.

Fuel Testing

Smoothness of running, the absence of "missing", etc., can be tested fairly well with a critical ear —although an electronic stroboscope is better if you can borrow one. Adequacy of lubrication can be checked by feeling the crankshaft bearing (not the head!) by holding a plate behind the engine when it is running and noting how much oil is

TABLE V.—ADVISED FUELS FOR AMERICAN RACING GLOW ENGINES.

Engine	Prop.	U.S. Commercial Fuel	Standard Blends (per cent)	Glow Plugs
Thermal Hopper	4 x 6 4½ x 5	Thimble-Drome Racing	30 N.M. 20 C.O. 50 A.	Thimble-Drome Racing Plug
McCoy 19	6 x 9	Supersonic 1,000 This Is It	35 N.M. 30 C.O. 10 N.B. 25 A.	McCoy Hotpoint O & R Racing
Torpedo 19	6 x 10	Supersonic 1,000 This Is It	50 N.M. 25 C.O. 25 A.	O & R Racing McCoy Hotpoint O.K. Long
Fox 19	6 x 10½ 6 x ½ x 10	This Is It	50 N.M. 25-30 C.O. 20-25 A.	O & R Racing McCoy Hotpoint O.K. Long
McCoy 29	7 x 10	O & P No. 4 This Is It	35 N.M. 30 C.O. 10 N.B. 25 A.	McCoy Hotpoint Champion VG-2
Dooling 29*	7 x 9*	This Is It*	40 N.M. 25 C.O. 35 A.	O & R Racing McCoy Hotpoint O.K. Long
McCoy 60	9 x 12	OBR No. 4 This Is It Stardust H.	30-40 N.M. 25-30 C.O. 20-35 A. 10 N.B.	O.K. Long Champion VG-2
Dooling 61	8 x 11 9 x 11	This Is It (with added Nitro)	50 N.M. 25 C.O. 10 N.B. 15 A.	O & R Racing McCoy Hotpoint

* As used by winner Bob Lutker, Texas, U.S.A., at 1954 World Speed Championships, The Hague.
Standard Blends Code : N.M.=Nitro Methane N.B.=Nitro Benzine C.O.=Castor Oil A=Alcohol.

TABLE VI.—ADVISED FUELS FOR BRITISH DIESEL ENGINES.

Manufacturer	Ether per cent	Paraffin per cent	DERV per cent	Tvo per cent	Castor per cent	Redex per cent	Mineral Oil per cent	Amyl Nitrate per cent	A. Nitrite per cent
Oliver ...	30	50			20			3	
E.D. ...	33	33			33				
Allen-Mercury	32.5	40			25			2.5	
Davies-Charlton (Allbon)	30		45		5		25		2.5
Sugden ...	27		55		15				3
Buskell ...	35		30		35				3
Redex Racing Fuel	30			40		25	5 Esso/ Racer TFD 46		
Fixed Head Fuel	70					30			1

ejected, by noting whether the engine slows of its own accord when hot even with correct throttle and compression settings, and by seeing whether the engine runs any better when a few per cent more oil is added to the fuel.

But *speed* cannot be checked by ear—*use instruments*. An electronic stroboscope, if available, is the ideal instrument since it puts no load on the engine and since it shows *variations* in speed from second to second as well as overall average speed. Failing this, use a good Revolution Counter and watch, or Tachometer. The vibrating reed type of Revolution Indicator, if properly calibrated and carefully used, is capable of detecting reasonable variations in r.p.m. at the slower speeds, but is not capable of showing up small speed differences. It is suitable, therefore, for the preliminary experiments with diesel fuels, but is too insensitive at the higher revs. to be of much value in glo-fuel development. In all cases the engine should be reasonably solidly mounted ; a well balanced engine fitted with a properly balanced prop., if firmly clamped in a vice, seldom gives an early reading on a reed indicator: but vibration can kill r.p.m.

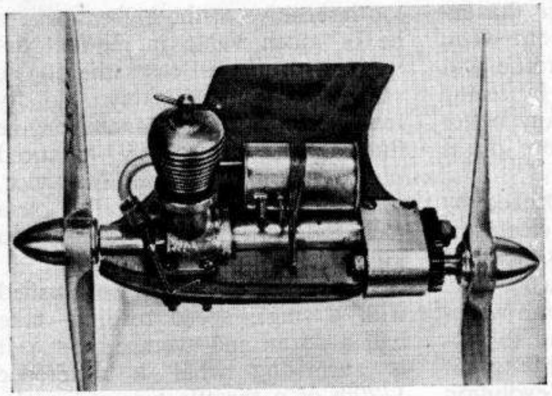
In conclusion, do not be satisfied with a single speed reading—take half a dozen and average them. It is surprising what a difference 1/20th of a throttle turn can make to a precision engine running near its flat-out maximum speed. And check back from time to time the values of your earlier fuel mixtures—the apparent increases in speed you have been getting with the later mixtures may be due to the engine loosening up with prolonged running. Elementary, but it happens every day.

CHAPTER EIGHTEEN

Choosing the Right Propeller

SELECTING the best propeller for a particular engine to go with a particular model can be a very complicated business, if you take into account all the theoretical aspects involved—or just a simple case of "cut and try", using a number of different propellers until you find one which gives the best results. Neither method on its own, however, guarantees that you will get the best possible results. Whatever propeller size may be worked out as being the best possible for a particular design case still has to be proved in practice, and there are so many factors which can affect the result that the finer details can only be worked out by practical tests.

Fortunately, this does not apply to the majority of power models. For everyday or "sports" flying, in fact, the modern engine is far more powerful than it need to be for the job, so if the propeller efficiency is low it does not matter. It may



TWIN PROPS ON THE GERMAN WAF-1 experiment with an extension rear shaft. Rear prop. has higher pitch, working in the slipstream, and contra-rotation eliminates torque troubles.

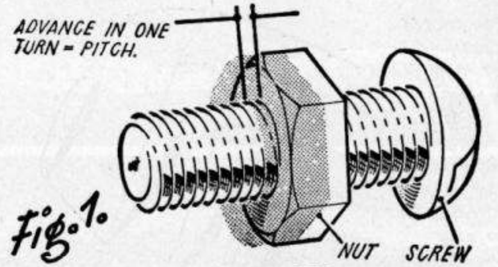
even be a good thing in that it makes the model that much more docile to handle. But for power duration flying and control line work, the right propeller for the job can make all the difference. In control line speed, ultimately it is the best engine-propeller combination which counts (with the propeller size limited to a certain extent by the model characteristics) since performance here is truly an expression of the amount of power the engine is capable of delivering and the efficiency with which it is turned into useful work.

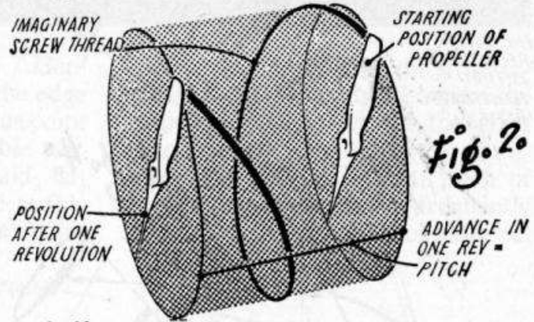
Since practical results are what we are after we do not propose to go into the theory of propeller design and performance but only touch on those aspects, important for an understanding of how to compare and select different propeller sizes. For those interested in the theoretical side we recommend a study of the books and more technical articles previously published on the subject. We would emphasise, however, that full size propeller theory does not hold good in model sizes, particularly where small diameter propellers are concerned. Propeller efficiency appears to drop alarmingly once propeller diameter is reduced to about 6 in. and below. It appears, in practice, that much of this loss of efficiency can be recovered by increasing the pitch of a small diameter propeller. This would appear to indicate that, in the smaller propellers at least much of the useful work in producing thrust is done by the *back* of the blade rather than the front or upper surface of the blade (aerofoil) section. Hence blade section seems to become less important as propeller size diminishes, except for the general rule that the greater the thickness of the blade section the more drag it has and thus the more power it requires to rotate it.

The pitch of a propeller, as quoted, is more often than not an arbitary figure. Pitch is measured on the assumption that a propeller acts like a screw. Rotate a screw in a matching nut or screw thread and it will advance into (or out of) the thread a distance equal to the *pitch* of the thread in one revolution. In this case there can be no slipping between the threads, unless they are stripped, and so the pitch is clearly defined. It is equally clearly seen that pitch can be measured as the distance between two similar points on adjacent threads on the screw—*Fig.* 1.

The pitch of a propeller is defined on similar lines, assuming that

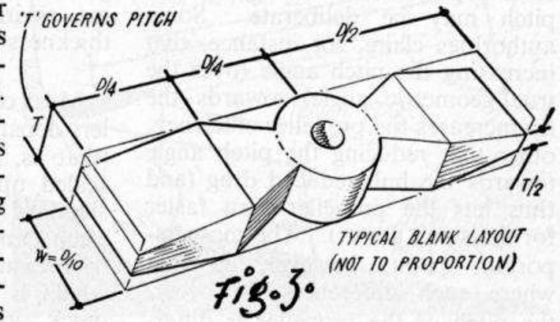
it is screwing itself through some medium where it cannot slip. If easier to visualise, you can consider it as an element of a large imaginary screw thread screwing into a matching thread tapped in "solid" air—*Fig.* 2.



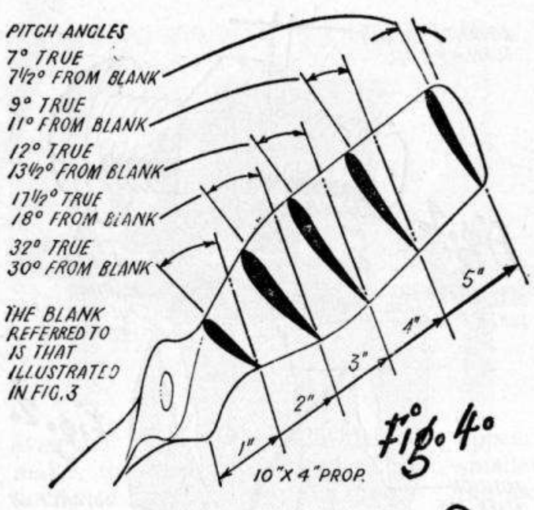


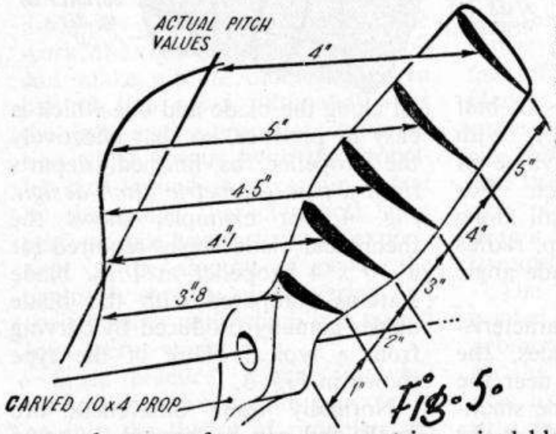
Since the propeller is only an element of the complete screw thread, however, its pitch can only be measured as the theoretical geometric advance per revolution. Mathematically this can be calculated as 44/7 *times* the radius *times* the tangent of the angle of the blade at the radius (*i.e.*, Pitch $= 2\pi R \tan \emptyset$). The possible radii dimensions vary from zero (at the hub centre) to half the diameter (at the tip), with a corresponding different value of the blade angle (∅) for each. For the pitch to be the same all along the blade from centre to tip, radius *times* the tangent of the blade angle must be the same.

This accounts for the characteristic twist of propeller blades, the greatest blade angle being near the root (where the radius is the smallest) and the least blade angle at the tip. In a carved propeller this necessary "twist" is arranged for in the shaping of the blank—see *Fig.* 3. In machine cut propellers, the necessary twist is incorporated in the movement of the cutters along the blade. But most practical propellers are compromises between a propeller with true pitch angles all along the blade and one which is easy to produce, so that effectively the propeller, as finished, departs from a *true geometric pitch design. Fig.* 4, for example, shows the theoretical blade angles required for a 10 x 4 propeller at 1 in. blade stations compared with the blade angles actually produced by carving from a typical blank of the type shown in *Fig.* 3.



Normally these differences are small, and can be ignored. In some





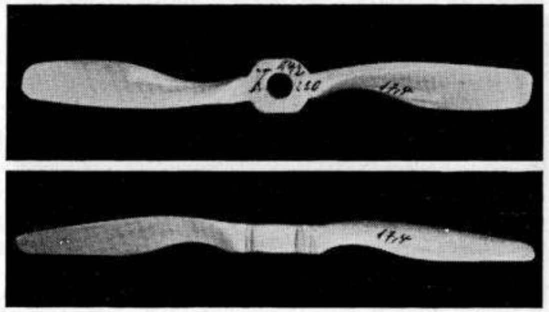
cases departure from true geometric pitch may be deliberate. Some authorities claim, for instance, that increasing the pitch angle (over the true geometric angle) towards the tip increases the propeller efficiency; other that reducing the pitch angle towards the hub reduced drag (and thus lets the propeller turn faster for the same power). The most important point, however, is that where such differences do occur, the pitch of the propeller is different along the blade length and so which pitch figure is quoted as being *the* pitch of the propeller, for selection of comparison purposes, will depend on which point this pitch is measured or calculated from. *Fig.* 5, for instance, shows actual pitch of carved propeller of the previous example at different blade stations.

Various "standard" methods of measuring pitch quote .5, .6 and .75 of the full radius (half diameter) as the station at which the propeller pitch should be measured. Measurement at half radius is generally best for model work, since most propeller blanks are laid out on this basis. On power model propellers, too, the depth of the blank, and thus the thickness of the propeller, is left constant from the centre to the half radius and so the thickness of the hub becomes a suitable measure of pitch for any given family of propellers. If the width of the original blank is measured at half radius, as in *Fig.* 6 and also the hub thickness

$$\text{Pitch} = \frac{11 \times \text{dia.} \times T}{7 \times W}$$

Most commercial wooden propellers depart from a true family layout (that is, the blank layout is not scaled up or down exactly from a standard shape) and so nominal pitch cannot be determined simply by measuring the hub thickness (T) which is a more useful method of quick identification with a true

SPEED PROPS., MARKED FOR dia., pitch and r.p.m., used by Czech expert J. Sladky. Note how the root area is trimmed away for speed.

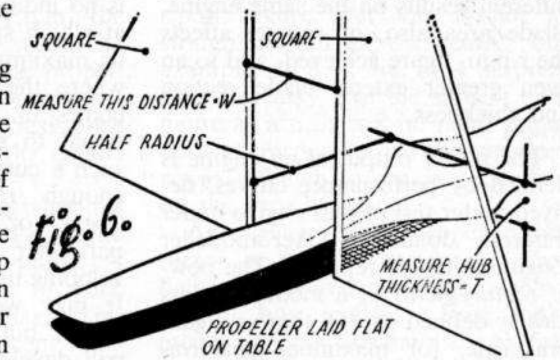


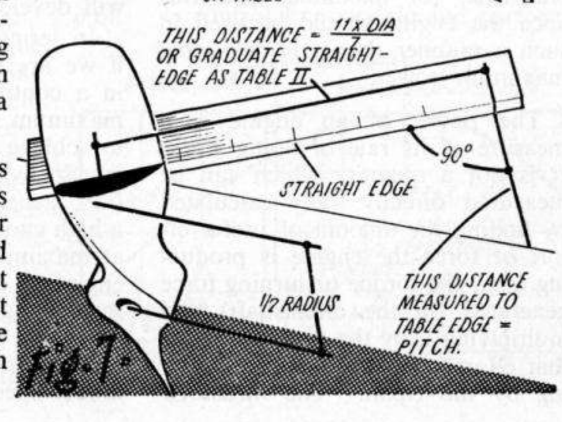
family of propellers, *e.g.*, laid out like *Fig.* 3.

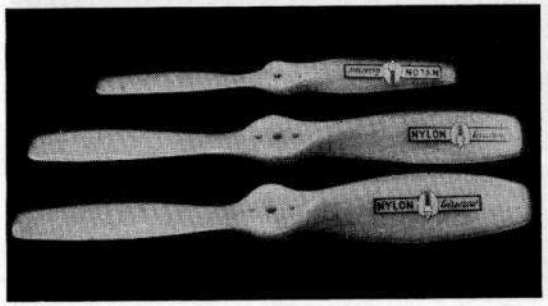
Commercial propellers can be checked for pitch by the method shown in *Fig.* 6 or by the direct method of measuring the blade angle as shown in *Fig.* 7 Here the propeller is held against the edge of a table so that the half radius point comes just level with the table top. A straight edge is then laid flat against the back of the blade at this station. Measuring from a point $\frac{11 \times \text{prop. dia.}}{7}$ from the centre of the blade along the straight edge, and then at right angles out to the table edge gives a measurement of the pitch of the propeller. To save calculation each time the straight edge, *e.g.*, a strip of 1 in. x ⅛ in. balsa, can be "calibrated" ready for use by marking out as in Table 2 for different propeller diameters, leaving only the pitch dimension to measure direct with a ruler.

One limitation of this method is that the backs of commercial propeller blades are seldom flat and judging the true tangent position of the straight edge can sometimes be difficult, especially with moulded plastic props.

We have dealt with pitch determination in some detail since the propeller pitch is one of the chief factors affecting propeller performance, and since the actual pitch of commercial propellers frequently differs from their stated or nominal







FROG FAMILY OF NYLON moulded airscrews, good for general purpose flying and frequently the subject of thinning experiments by free-flight exponents.

pitch, a method of checking for comparative purposes is strictly necessary. It is this difference between nominal and actual pitch which often accounts for why two commercial propellers of the same stated size (pitch and diameter) give different results on the same engine. Blade area also, of course, affects the r.p.m. figure achieved, and to an even greater extent, blade section and thickness.

The power output of an engine is defined by performance curves, derived under test of that engine under different loads—of Aeromodeller Engine Analysis reports. The power *requirements* of a model are less clearly defined except, that as a general rule, for maximum performance the engine should be used in such a manner that it is delivering maximum power.

The power of an engine is a measure of its rate of doing work It is not a quantity which can be measured directly, only calculated by finding the amount of useful effort or force the engine is producing (*e.g.*, the torque or turning force generated on the crankshaft) and multiplying it by the speed at which that effort is applied, *i.e.*, multiplying by the r.p.m. The *measured* performance of torque curves of an engine is thus in many ways more useful data than the power (B.H.P.) curve.

The torque output of an engine varies with speed. As the r.p.m. increase the torque tends to fall off (largely because more torque is being absorbed *inside* the engine in overcoming the increased friction of the faster moving parts). But there is no indication on the torque curve at which speed the engine is giving its maximum performance. That is where the power or B.H.P. curve comes in. Horsepower is proportional to torque *times* r.p.m., and such a curve, if plotted over a wide enough range, always shows a "peak" or maximum value. At this particular speed, the engine is developing its *maximum power output*. It may well be capable of going faster, but at any higher speed it will develop less power.

In terms of a practical example, if we are using a particular engine in a control line speed model, the maximum speed which we can hope to achieve is that particular propeller size which both suits the model (*i.e.*, generates enough thrust with a high enough pitch to fly the model at maximum speed) and allows the engine to operate at the r.p.m. corresponding to peak power. Trimming that propeller to make the *engine* go faster will then *reduce* the model speed. On the other hand. a propeller which does not let the motor reach peak r.p.m. in flight will again result in loss of speed.

That is the chief significance of the power curve, for any particular engine. We can use it to determine at what *speed* we should operate the engine for maximum performance. For instance, taking the top half or power curve of a typical Aeromodeller Engine Analysis graph—*Fig.* 8—we can see the operating speed of that engine for maximum performance.

Actually we cannot use this figure directly. It refers to the required engine r.p.m. *in flight*. If we used a propeller of the right size to give this speed on the ground, *e.g.*, static running, where we can conveniently measure the r.p.m., the engine speed in the air would be higher because in flight the propeller is "unloaded" to a certain extent, therefore, offers less resistance to being rotated and so the engine r.p.m. increases.

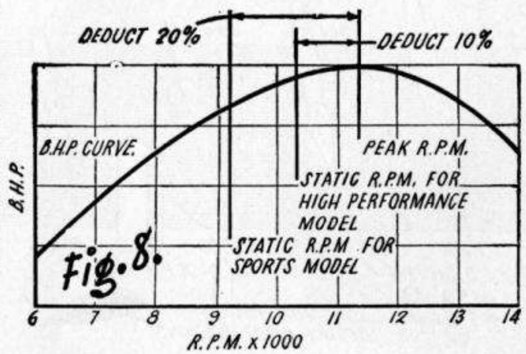
We can only guesstimate what this increase in speed is between static running and "in flight" running. A fair estimate, which seems to work out well in practice, is that r.p.m. goes up by some 10 per cent. To arrive at the required *static r.p.m.* figure for peak r.p.m. in the air we shall not be far wrong if we take this as 10 per cent *less* than the graph figure—see *Fig.* 8 again. This is a general rule for models aiming at maximum performance with a particular engine. For sports models it is generally better to work at a lower r.p.m. figure—say taking 20 per cent off the peak r.p.m. as given on the graph.

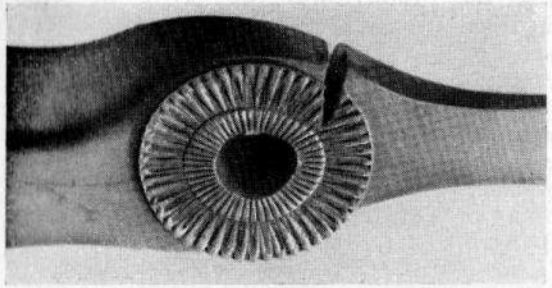
Either way we arrive at what is the required operating r.p.m of the engine, and the next job is to select the propeller size to suit.

It can be pointed out that the peak r.p.m. figure arrived at by test is usually typical for other engines of the same type, although there may well be some variations. The peak may well be altered by using different fuels, however, particularly "doped" fuels which enhance performance. But for average selection purposes, test figures are usually an accurate enough guide.

The obvious way of finding the right propeller size is then to try different propellers until we find one which gives the required static r.p.m. figure, but this is not as straightforward as it appears. For example, an 8 in. dia. by 4 in. pitch propeller may give the same r.p.m. figure as a 6 in. x 8 in. pitch prop., both corresponding to the required r.p.m. Which to use is dependent on the type of model.

As a general rule, propeller *diameter* is most important on free flight models and propeller *pitch* on control line models. Free flight models do not normally fly as fast as control line models and perform



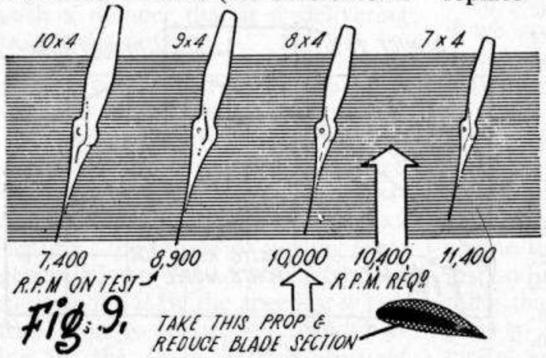


WARNING.—THIS IS WHAT happens to a plastic acetate prop. if over-revved. The blade would shear on the next run. Nylon mouldings rarely exhibit this fault.

better with large diameter small pitch propellers. Control line models, on the other hand—particularly speed models—will not be able to attain the necessary speed unless the propeller pitch is high, which means trimming down the diameter to enable the engine to drive the propeller at the required r.p.m.

Suppose we want to match the engine whose power curve is given in *Fig.* 8 for maximum free flight performance. The required static speed is 10,400 r.p.m. so we try it out on a series of commercial propellers, 10 x 4, 9 x 4, 8 x 4, and 7 x 4, with the results shown in *Fig.* 9. The required propeller size in this case is obviously something between an 8 x 4 and a 7 x 4. Try an 8 x 3½, for instance, if available, or an 8 x 4 of another make (the difference in nominal pitch may make it "faster" or "slower" for the same size).

The other method is to trim the propeller which is the next size too large, *i.e.*, the 8 x 4. Nearly all commercial propellers can be increased in efficiency by thinning down the blades, making sure the underside is flat (not convex) and generally working to a lower drag aerofoil section with sharper edges. Such modifications will increase the r.p.m. achieved with the same propeller quite considerably—perhaps even to the extent where it is overdone. In that case start again with the next largest propeller (9 x 4 in this case, and treat similarly). Then any final trimming for speed, if necessary, can be done by reducing the diameter a little at a time.



This method is tedious, but it will give the best results. It means, however, that if you break a propeller you have to re-work another one to replace it. Most people—except the contest experts—prefer to work with the nearest available stock size of propeller and leave it at that. Contest propellers are commonly reworked from standard commercial varieties, or carved individually (when the best material, for a long-lasting propeller, is probably red fibre). An approximate propeller size may be arrived at using stock commercial sizes, the pitch measured and checked and the final propeller laid out from these days for trimming down to final size by practical tests.

Usually a 3 to 4 in. pitch gives best results on free flight models with propellers from 5 to 12 in. diameter. There are exceptions. Some contest modellers prefer to work with higher pitches and reasonably large diameters and trim blade *area* down to arrive at the required r.p.m. figure, giving the "toothpick" type of propeller more usually seen on a control line model.

Lack of pitch on a control line model propeller means that the model cannot fly fast enough—perhaps not even fast enough to keep the lines taut. To fly at 60 m.p.h for instance, with an engine giving 12,000 r.p.m., requires a propeller pitch of at least 6 in. (allowing for

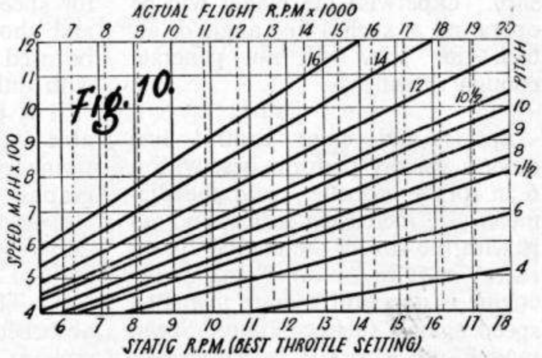


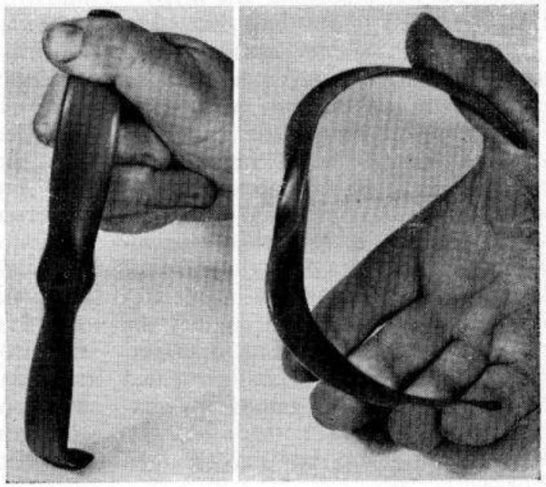
TABLE I.—PITCH AS A FUNCTION OF PROPELLER.
Hub thickness for blade layout as Fig. 3.

Pitch	Hub Thickness
4	.25
5	.32
6	.38
7	.45
8	.51
9	.57
10	.64
11	.70
12	.76
14	.89

All dimensions in inches.

TABLE II.—LAYOUT DIMENSIONS FOR STRAIGHTEDGE.
(For direct propeller pitch measurement —See Fig. 7.)

Propeller Diameter (inches)	5	6	7	8	9
Scale Dimension (inches)	7.85	9.42	11.0	12.57	14.14
Propeller Diameter (inches)	10	11	12	13	14
Scale Dimension (inches)	15.71	17.28	18.85	20.42	22.00



COMPARISON OF FLEXIBILITY. At left, a Frog Acetate type, and at right, an American coloured Nylon Perm-a-prop by Windsor Eng., both 10 x 6 in. size.

slip). Otherwise the blades will be operating at such a fine angle of attack that they will not generate enough thrust.

Sports and stunt control line models usually perform best with a 6 in. pitch propeller, with the diameter size increasing correspondingly with the size of the engine. Team racers require up to 9 in. if the engine is powerful enough to match speed against fuel economy. Speed models use 9 to $10\frac{1}{2}$ in. pitch propellers, as a general rule. Your cut and try selections can therefore be made with available propeller sizes within these recommended ranges. The graph reproduced in *Fig.* 10, incidentally, gives quite good results for speed model propeller selection and shows the pitches which must be used to achieve different speeds with different engine r.p.m.

It is possible to save a considerable amount of time and trouble in trying out propellers by using the graphs published in the AERO-MODELLER of torque absorption curves for families of different commercial propellers (see Appendix VI). These graphs show the torque absorbed by individual propeller sizes at different speeds. Superimposed over a motor torque curve, speeds at which that particular engine will drive each propeller are given by the intersection of the engine torque curve with the propeller torque absorption curves.

CHAPTER NINETEEN

Equipment and Its Influence on Design

Making Your Own Diesel Engine

HOW many of you have longed to make the perfect model diesel engine, designed to meet exactly your own requirements and incorporating your own ideas, but have cast the thought aside, thinking that the construction of model engines can only be accomplished by skilled experts? This is not so, for although Dave Sugden, designer of the engine which follows in this section, has made several engines, he is not a skilled machine operator. The information to be presented has simply been gained by experience.

For those who have access to a reasonable lathe may I say that this work is no more difficult than aeromodelling and only demands the same qualities of ingenuity and patience. The less fortunate ones who have no machining facilities will probably find interest in the processes involved, whilst some of the information derives from, and is applicable to, aeromodelling. Earlier chapters have told us the basic design features of production engines, now we can try to fabricate our own miniature two-stroke.

Equipment

The most important machine tool required is a reasonable centre

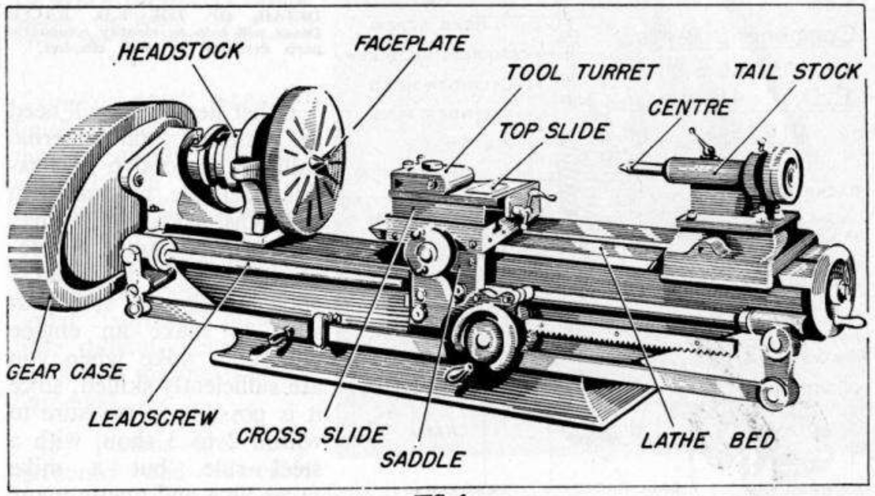


FIG. 1.

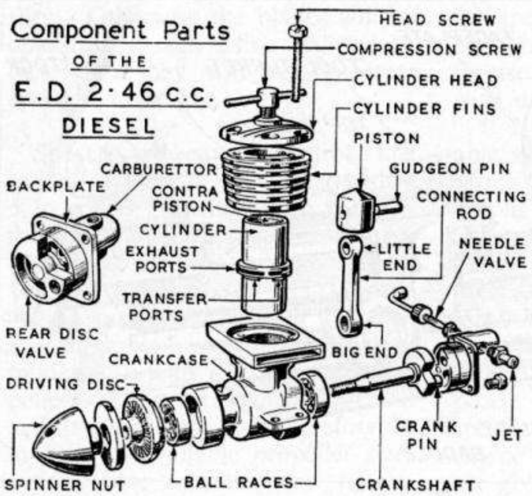
lathe. Without one, making an engine would be almost impossible and the project would become a nightmare. The use of other tools, whilst making certain operations easier is not vital; for a lathe suitably set up is capable of handling all the operations.

The most convenient size is a $3\frac{1}{2}$ in. centre lathe, having the centres set $3\frac{1}{2}$ in. above the bed. Anything much smaller will present serious clearance problems when turning such parts as an engine crankcase of the $2\frac{1}{2}$ c.c. size. The $3\frac{1}{2}$ in. lathe possesses the advantages of being capable of removing excess metal at a higher rate and are less prone to chatter with work of our size. *Fig.* 1 shows the various parts. Lathes of the watchmaker pattern and those not having feed along and across the bed are of little use for our sort of work.

Although a lathe is capable of doing all the jobs required certain other equipment is also necessary. A grinding wheel is almost essential and one with a hard wheel should be obtained. The cheap soft wheels will be found to be useless on high quality high speed steel tools.

A milling machine is also a useful piece of equipment as it can do jobs easily which take a great deal of setting up on a lathe, but a vertical slide as supplied by Myfords for use with their lathes is more useful still, since angular motion in two directions as well as vertical and transverse motion is available.

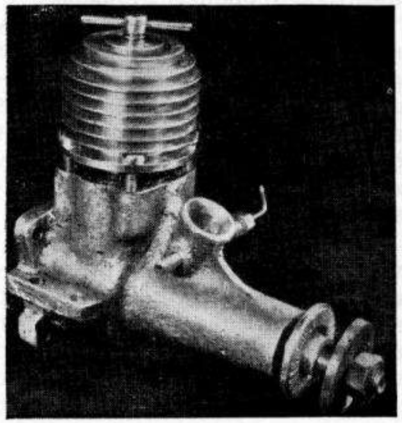
Grinding equipment is a luxury not essential for making engines provided that your ability to produce a respectable turned finish is reasonable. Finishing of cylinder bores, pistons, etc., is facilitated by a small internal grinding and attachment which can be easily made. The largest size of grinding wheel which will fit into the bore is procured from a good engineering shop and mounted either directly on to an electric motor, or a spindle geared to run at about 20,000 r.p.m. The grinding attachment is mounted in



DETAIL OF THE E.D. RACER Diesel will help to identify component parts described in these chapters.

the tool holder and used to remove turning marks prior to lapping.

Certain minor jobs such as drilling carburettor spraybar holes, jets, and exhaust parts are facilitated with a drilling machine or Wolf type drill stand. The drill holder which comes as part of the latter equipment is useful as a means of providing a mounting for the drill on the lathe saddle or vertical slide, for milling operations.



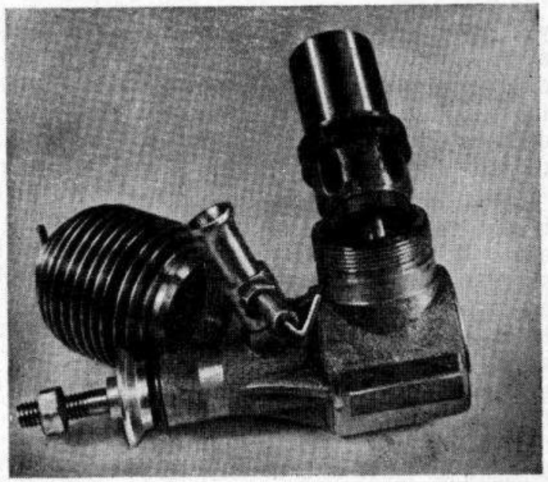
Other items you will need are internal and external callipers, a good 6 in. flexible steel rule, graduated in 1/100ths. and 1/64ths., some sort of square, a scriber, centre pop, files and a good micrometer. It is possible to make an engine without a mike when you are sufficiently skilled, since it is possible to measure to within 2 to 3 thou. with a steel rule, but a mike saves time and averts many mistakes. A depth gauge is useful but not vital.

Influence of Available Equipment Upon Motor Design

You may find that because of lack of equipment or skill, certain operations such as milling cannot be carried out. These need not be major stumbling blocks. We shall consider the various machines or operations, the jobs they accomplish and the means of achieving the same object, or even avoiding it, by modification of design. GRINDING is a means of producing a good finish after ordinary turning and is often intermediary between turning and lapping or honing. Its advantage is felt on parts which are case hardened, when applying a good finish by other means becomes tedious. Parts usually ground are (*a*) Cylinder bores; (*b*) pistons; (*c*) crankshaft and (*d*) crankpins.

THE SUGDEN 2.5 SPECIAL DIESEL IS THE feature item of these chapters on "making your own" engine. It can be made by anyone with lathe facilities.

AN EARLY SUGDEN 2.5 DIESEL showing the drilled and grooved transfer passages referred to below.



(*a*) A good reamered finish is nearly equal to that of grinding so that whether the cylinder is hardened or not it is not too difficult to go from the reamered finish directly to the lapped one. A good bored surface presents little difficulty either, especially if the metal is not hardened.

(*b*) Pistons are never hardened and therefore are easily lapped to fit from plain turning, in fact probably more easily lapped because the volume of metal being removed may be less due to the rough surface.

(*c*) An equivalent finish is easily obtained by careful use of fine files and emery cloth, it being not advisable to case harden crankshafts.

(*d*) Even if grinding were possible it would hardly be convenient to grind this item and a finish is obtained as in (*c*).
does not affect design.

Thus lack of grinding facilities

MILLING is usually carried out in transfer passages, or ports, pistons for lightening, glo-motor cylinder head finning, etc. Lack of a milling machine is no handicap; a lathe will be found to be capable of doing most jobs (to be covered later).

The chief point to watch is that the design is such that the milling cutter can get in to do the operation. On a side port design an Eta type transfer passage cannot be milled out since a suitable cutter will not reach in, and it must be shaped in the casting, a rather tricky process for the amateur. It is best to design this sort of crankcase *a la* K & B engines, making a joint at the top of the transfer passage so that the miller can enter. Alternatively a joint can be made at the base of the cylinder as on the Hornet. Transfer passages affect performance considerably and offer much scope for detail design and experiments. Milling is completely eliminated in a design like the E.D. Racer, and it can be avoided in the Oliver Tiger type of porting by making grooves, using a rotary cutter in an electric drill or by hand in the cylinder liner, instead of the crankcase as on the Javelin. There is also the soldered up tinplate E.D. Comp., Special type and the Elfin layout only requires very careful drilling, aided by using a jig, before the cylinder is drilled and bored.

If you think that milling out ports is going to be too difficult they may be drilled (360° Elfin type) or sawn (K & B or E.D. racer type), and filed out, in which case the cylinder wall will be designed to be as thin as possible to reduce the labour. A drilling jig will have to be made for the Yulon type ports to assist the drill to start on the correct spot on the curved surface.

Milling out between gudgeon pin bosses for lightness is not essential, and if it is felt to be too tedious to set upon the lathe it can either be omitted or effected by drilling small holes, which is not worth the effort anyway. Another system is simply to drill out the inside of the piston to a larger diameter than normal, thus allowing the gudgeon pin end to float, as on K & B motors. Do however, see that the gudgeon pin is strong enough to take the increased bending moment.

Cylinder head finning as on some glo-motors is easily accomplished in the lathe by setting up the head on the cross slide and mounting the cutter in the chuck.

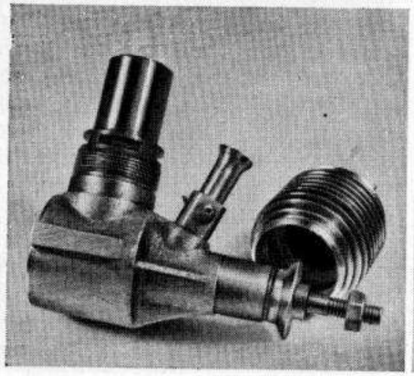
SCREW CUTTING is usually possible since most self-respecting lathes possess a lead screw, but if yours does not, the parts are merely designed to be held together with screws as in the E.D. Racer or K & B 15. Parts which screw together as in the Elfin are usually lighter and are quicker and easier to manufacture and probably more reliable. In certain cases separate screws just have to be employed.

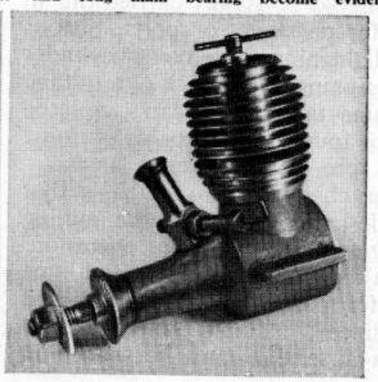
BORING is a normal operation on a lathe but some designs are impossible by direct methods. In the case where crankshaft housing cannot be fully machined directly but must be parted off, turned round and bored from the other side, the difficulty is to get both bores concentric.

Do not design built up crankshafts; these are easily turned from solid bar.

When designing your engine, constantly keep in mind the operations involved in producing each detail. The ensuing chapters, in which the various machining operations will be described, should be of assistance in design. Although you will have your own pet theories on design for high performance some indication of the merits of the various materials required as found by experience is given in the following chapter.

FIRST HOME-BUILT SUGDEN DIESELS had the cylinder retained by the screwed jacket bearing down on to the crankcase. HERE, THE CYLINDER JACKET IS fitted, and the deep finning, long carburettor, and long main bearing become evident.





CHAPTER TWENTY

Materials, Pattern-making and Casting

Materials

THE efficiency with respect to life, power and weight of an engine depends to a large extent upon the choice of materials. All engines depend upon bearing surfaces of one sort or another and the better the bearings the greater the performance. Good plain bearings consist of one very hard surface bearing against another which is tough and malleable. The softer surface then runs in and work hardens to mate perfectly with the opposing part, usually the shaft. This principle, together with other requirements of the parts determines the choice of metal.

CYLINDERS when run in must have a glass-like surface, so that if they cannot be hard chrome plated or case hardened, a work hardening steel, *i.e.*, one containing chromium or nickel, or molybdenum iron must be used. A high tensile steel S82, S96, or such as that used for car half-shafts is very good. With surface or heat treatment a mild steel is the best choice, *i.e.*, S.1, S.15.

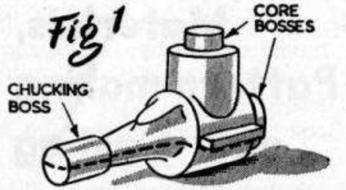
PISTONS are best made from cast iron because its porosity results in it being very difficult to seize and having long-wearing properties, due to the oil and graphite which its surface retains. Meehanite, having a fine grain structure and globular graphite inclusion, is best. Centrifugally cast iron rod is next best since it has a fine uniform crystal structure but plain cast iron is quite good enough.

CRANKSHAFTS must withstand high stresses due to the piston and crash loading and require to be strong and tough. They must be capable of being bent without cracking and must work harden. A high tensile steel is called for, *i.e.*, S.96 or a piece of car half-shaft Case hardening is not recommended because of the uncertainty of the depth of the brittle surface. Hard chrome plating would be advantageous but remember to allow for the thickness of the plate, about .0005 in.

CONNECTING RODS have to be very strong and light and must possess good bearings. Super dural of about 38 tons/in.^{2} is ideal, *i.e.*, DTD 363 or DTD 683. Pure aluminium is useless but ordinary alloy good enough.

CRANKCASES are usually cast from DTD 424, a general purpose casting alloy containing silicon used in foundries. It is rather soft and superior metals are Y alloy or RR 56, *i.e.*, car or aero pistons.

General parts such as the cylinder head, carburettor and driving disc are catered for by ordinary alum. alloy rod but of course the stronger this is the better. The spraybar can be turned from alum. or brass, but since the needle cap is soldered to the needle, brass is used.



LEVEL TO WHICH PATTERN IS EMBEDDED IN THE HALVES OF THE MOULD

Phosphor bronze is a good bearing metal for crankshaft journals and con.-rod big ends, but cast iron is just as good for the former. Ground silver steel is the gudgeon pin material. It is also useful for making special tools when hardened and tempered for work on the softer metals. Magnesium is beautiful to machine but is structurally weak. It requires chromate treatment to render its surface inert to the various corrosive chemicals in fuel. Tufnol is light and strong and is highly resistant to wear, especially where no lubrication can be permitted. It may be used for disc valves.

Pattern Making

This should be relatively straightforward for aeromodellers though there are a few points to note. Any part of the pattern which has to be drawn out of the sand in the moulding operation should possess a slight taper to facilitate this, although on castings of our size this is hardly necessary. It would be appreciated at a foundry where the casting was being made and would indicate which way you wished the pattern to be set in the mould.

Balsa is suitable for patterns but because of its absorbent nature must be given several coats of pigmented dope to harden the surface. Patterns must be capable of withstanding rough treatment as they are liable to be hit during the ramming process of moulding. All lugs and projections should therefore be notched in. Machining is often simplified by the addition of an extra boss which can be gripped in the chuck whilst machining proceeds and which is parted off on completion of the part—see *Fig.* 1.

Coring Out

A pattern made for a cored out casting has bosses attached to the faces into which the cores will enter —see *Fig.* 1. The mould is made in the usual way with the cores arranged to lie on the dividing or parting lines. The cores are made from a special sand mixed with a binding agent such as linseed oil and are baked hard before being placed into the mould in the core prints left by the special bosses. This rather tricky process is best done at a foundry.

One difficulty which comes with using cores is that there is no metal on which to scribe the centre through while the boring and other machining takes place. It may be possible to set the casting up to the outside surface but this will most probably not be true enough for the accuracy of 2 to 3 thou., which is required. Cores are most useful, however, for cutting down machining time and for ensuring a sounder casting, when setting up for machining can be accomplished without difficulty.

Casting

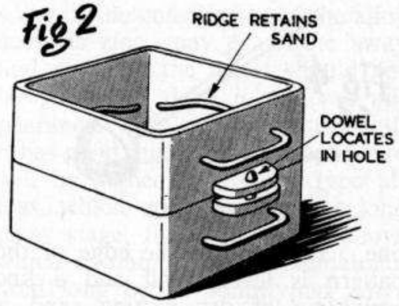
The crankcase and possibly the back cover of a rotary disc induction motor are the only parts usually cast. It is most convenient to take the patterns to the local foundry where the castings will be done cheaply, but making the castings yourself can be interesting.

Causes of Defective Castings. By understanding some of the causes of blow holes and other defects of castings, certain points of moulding and melting will be made readily understood. Uneven cooling of the metal, caused by non-uniform volumes distribution of the casting, results in one portion solidifying before the rest. When this happens the large contraction of aluminium alloy causes cracks or draw-holes at the junction of the regions of unequal volume. Putting cores in a casting brings it to more uniform proportions eliminating the trouble, which is most likely to occur at the junction of the crankshaft housing with the main body of the crankcase.

Blowholes are caused by the inclusion of air that cannot escape due to poor ventilation. The positioning of risers and air vents, made with a knitting needle, is of utmost importance in the production of sound castings and only comes with experience. However, with a bit of imagination the requirements of a small crankcase can easily be catered for.

Porosity may be found in castings made at a foundry due to a cleansing pellet, added to the molten metal for purification purposes, not being allowed to complete its action before pouring.

Arrangement of the Mould. The pattern may be arranged in the mould either with the parting line in the plane of the lugs, as shown in *Figs.* 1 and 3, or along the line of the shaft and up the cylinder, or on an ETA type crankcase across the cylinder. Whichever way is

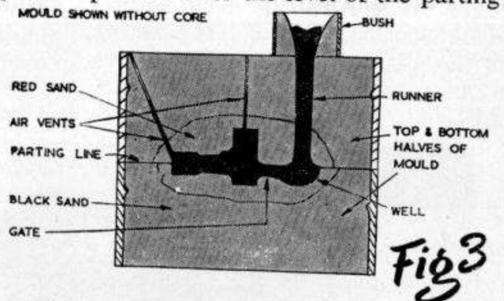


MOULDING BOX

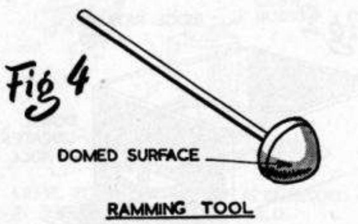
chosen the pattern must be capable of withdrawal from both sides of the mould. Porosity usually occurs in the uppermost regions of aluminium castings which should be arranged to be the part which will be machined away, *i.e.*, where the cylinder fits. The method shown has been found to give the best results.

Moulds may be made from black sand (sand and coal dust moistened with sufficient water to make it bind and feel cool), plaster of paris and steel. Steel dies are only used for mass production of accurate castings and will not be dealt with.

Sand Moulds. One half of the moulding box—*Fig.* 2— is packed level with sand and the pattern is pressed in to the level of the parting



CROSS SECTION THROUGH MOULD WHEN METAL HAS BEEN POURED

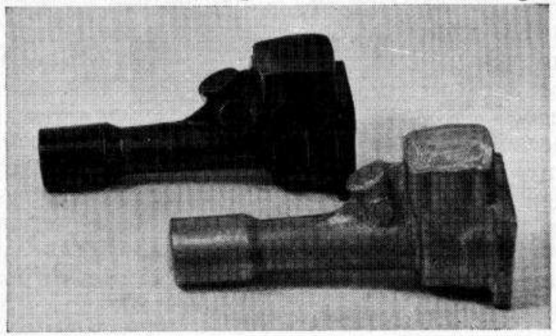


line. The sand at the edge of the pattern is levelled off and a fine sprinkling of dry parting sand is given to prevent the halves of the mould from sticking. This is the odd side which is not used for casting.

The other part of the box is fitted and twisted clockwise to take up any play. Fine red sand containing a little more moisture than the black sand is riddled into the box to cover the pattern and the remaining space is filled with black sand. This is rammed down fairly firmly with a tool of the type shown in *Fig.* 4, a process requiring skill to accomplish correctly. More sand is added and rammed down until the box is levelled off. This part of the mould is lifted off steadily, care being taken to see that it comes away squarely and does not rotate, and inverted. The edges round the pattern are trimmed and any slight faults are touched up.

The pattern is replaced, parting sand applied, the box containing the odd side knocked out, fitted, and the process repeated to produce the other half of the mould. A runner, down which the metal is poured, is made in the top side by withdrawing the sand in a thin metal tube about 1 in. dia. pushed through the sand. In the other side of the mould a well is made to receive the metal from the runner and a passage, known as a gate, is made to connect this to the mould. All corners in this region are rounded to prevent pieces from being washed away and carried into the mould with the rushing metal. The length of the runner is governed to a certain extent by the depth of the box but should be as long as possible to create a good pressure head, to enable the molten metal to flow into all corners, driving out all occluded air.

A bush into which the metal is poured is made by packing sand into a metal ring which is placed on the entrance of the runner. Before the box is finally assembled, not forgetting the clockwise twist, the mould is dusted with graphite to impart a good surface finish to the casting, and all loose particles of sand are blown out. With large castings a heavy weight is rested across the top of the box to prevent the internal gas pressure from separating the mould.



PATTERN FOR THE SUGDEN Special crankcase is carved in balsa, doped and polished. Sand casting obtained from it is in foreground. Similar gravity die-cast crankcases can be bought for 8/- through Aeromodeller Plans Service.

PLASTER OF PARIS MOULDS. A similar procedure to that used with sand is carried out with the exception that an odd side is not required. Runners and venting are similar. The important point is that the mould must be allowed to dry for two or three days and it is best to heat it in the oven to drive out all moisture, otherwise when the metal is poured in, steam is formed which cracks the mould and ruins the casting. These moulds can be used several times and give a good finish.

Melting

The melting point of aluminium alloy is about 550° C. whilst the temperature of red heat is almost 650° C. Red heat should be avoided during melting, because some of the constituents of the alloy such as zinc, may evaporate away and certainly the metal should not be poured if there is any red appearance. The metal is heated until it has good fluidity. The temperature will be higher for forging type alloys, which on cooling have a long pasty stage, than for casting alloys which contain silicon so remaining fluid long before solidifying. After 5 or 10 minutes the casting is extracted. A smooth shiny surface denotes that the metal was too cool, a rough one indicates that it was on the hot side. The latter is preferred since the casting should be sounder.

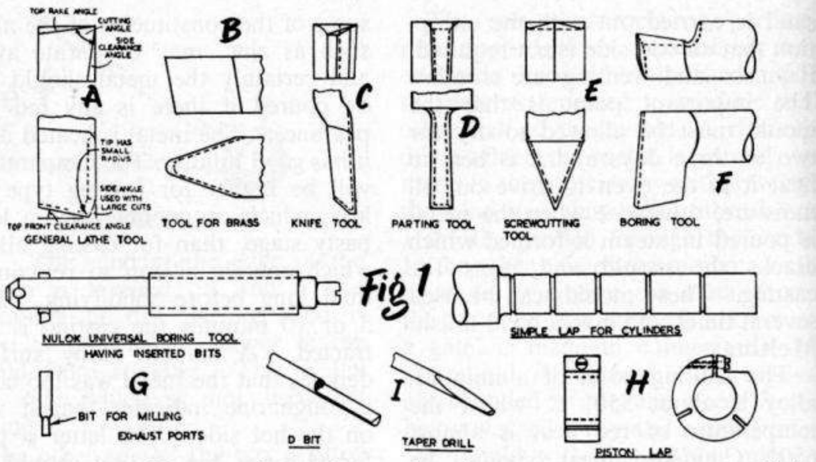
CHAPTER TWENTY-ONE

Tools and Processes in the Lathe

SINCE most of the work is turning, lathe tools will be dealt with first. *Fig.* 1 shows the various types for general work. Each turner has his own pet way of sharpening tools and those shown will merely serve as a guide. A few general rules apply to all lathe tools. Overhang from the tool post must be reduced to a minimum to prevent chatter. Top side and front clearance angles of no less than 3 degrees should be allowed between the finished surface and the tool, so that swarf cannot jam between the tool and the work, thus spoiling the finish. It has been found best to set up a tool at centre height despite what some people may say to the contrary. It is advisable to touch up the tool tip prior to taking a final cut, especially on ferrous metals.

TURNING HIGH TENSILE STEEL (A) The cutting angle should be made fairly large to strengthen the cutting edge and reduce its wear. Because H.T.S. work hardens rapidly the tool must not be allowed to rub and is best operated with a coarse feed at 200 to 400 r.p.m. with as big a depth of cut as allowed by the motor power. Soluble oil and water is a suitable coolant if the work and tool overheat.

CAST IRON. Although C.I. crumbles off when machined, it requires similar treatment to H.T.S. On no account should a cutting fluid



be used as this will cause the tool to rub.

ALUMINIUM. This is easy to machine and any combination of feed, cut and r.p.m. can be used, though for a good finish high r.p.m. is best. Larger rake and clearance angles may be used and, indeed, are essential for some of the softer alloys which tend to build up on the tool tip. Paraffin used as a cutting oil cures this trouble.

BRASS. Being such a soft metal, brass is so easily cut that a tool as shown at (B) with no rake angle plus side angle to prevent digging-in must be used. No lubricant is required. Any combination of feed, r.p.m., and depth of cut is permissible.

PHOSPHOR BRONZE. Although a fairly soft metal, it is very tough and quickly work hardens. It should at all times be treated with respect. A sharp ordinarily-shaped tool will be satisfactory. If difficulty is experienced, cutting fluid may be used to good effect. Any speed with moderate feed and cut is suitable.

Special Tools

KNIFE TOOL. This tool (C) is for cleaning out square corners. It is made either left or right-handed with more rake angle than usual. The point is not robust and will not stand heavy wear. It may be used on any of the various metals above with cutting fluid if necessary, and in general the r.p.m. should be somewhat lower than that used with the ordinary tool.

PARTING TOOL (D). Cutting takes place on the front edge and corners which should therefore be ground true and square to prevent the tool from wandering. A small clearance angle is given to the sides, but adequate metal must be left at the root to take the cutting loads which can be heavy. Even on a good lathe a parting tool tends to chatter and a low speed is often used together with a coarse feel. To stop chatter the feed must be increased. If this does not do the trick, the speed has to be lowered ; 200 r.p.m. is easily possible on dural and also on H.T.S if the tool is good. Always use cutting fluid to prevent chips from jamming.

SCREW CUTTING. A screw cutting tool is ground to the profile of the

thread as shown (E). It may be fed in either perpendicularly or at an angle of 27½ degrees and is set up with the aid of a special template. A 5-thou. depth of cut is suitable and r.p.m. is governed by chatter and the skill of the operator ; bottom speed is best for a start. Choose a thread pitch which divides evenly into the pitch of the lead screw so that the "nut" can be engaged at any position. A screw-cutting dial eases this problem. Having set up the gears, and with a suitable cut, make a run, disengage the "nut" when the tool has run into the groove which should be provided at the end of the thread. Wind out the tool, return it to the beginning, and reset to a new cut. Should anything go wrong, don't panic. Stop the lathe and wind out the tool instantly. Cutting fluid is often useful, as is also a touch of emery cloth to ease the tops of tight threads.

BORING (F). A boring tool should possess properties similar to an ordinary turning tool. The overhang which tends to make the tool chatter should be kept as small as possible. This reduces the whip which makes boring to an accurate parallel diameter a little difficult. Provided that a good finish is obtained the tool may be mounted above centre height so that it does not foul the hole. In general the r.p.m. will be slightly lower than that used for plain turning.

MILLING. The chief difficulty here comes in putting up the job. It is fairly easy to grip it in a machine vice bolted on to a vertical slide which permits 3D motion, but it is considerably more tedious to clamp it on to the cross slide. A vee block with lots of packing including paper is most useful here. The cutter mounted in the chuck will be run at maximum speed and often completes the operation in a couple of minutes. Cutting fluid is useful in preventing clogging.

An end milling cutter will be found to be the most useful for surfacing, cutting transfer passages, lightening pistons, etc. Its size will probably be governed by the radius of the curves. For milling exhaust ports a fly cutter is most convenient This is similar to a boring tool, with the tip ground like a parting tool, mounted in the chuck. The bar part of a Nulok tool with a bit as shown in (G), is admirable.

GRINDING. Means of avoiding grinding and the construction of a small internal grinder were described in Part I. Should you be lucky enough to have a friend who can do grinding for you the following hints may be helpful. Grinding is often done between centres and if at all possible the part should be made with centres for this reason. It will be necessary to leave about 5 thou. on the diameter for grinding. If centres cannot be made and the grinding has to be done in a chuck, a boss suitable for gripping in the jaws must be arranged, and from 10 to 20 thou. left on the diameter to allow for eccentricity of the chuck and setting up. An extra 5 thou should be allowed for distortion if heat treatment is being carried out prior to grinding on parts which are not robust.

LAPPING. This is the process by which the accurate finish and fit of the piston and cylinder is obtained The principle is that of impregnating the surface of a piece of metal with rubbing compound which is then used to "wear" the part down

AN EXPANDING LAP, SHOWING THE GRUB screws used for adjustment.

to the required dimensions. The rate of cutting is dependent on the amount of compound charged into the lap, the coarseness of the grit, and the fit of the lap to the part. A softer material than that being worked upon is used for the lap, so that it will absorb the compound. C.I., copper, aluminium, and brass are the usual materials. Because the lap is made of a soft metal it tends to wear rather rapidly, and if the rate of cut and accuracy of finish are to be maintained the lap must be expandable. For 1-off jobs where little lapping is needed the extra complication of expanding laps is not justified, but on parts which are at all distorted, probably due to heat treatment, they are essential. (H) and the accompanying photograph (above) show the usual types.

A corkscrew type of motion is applied to the part held by hand with the r.p.m. at about 600. Medium grade valve grinding paste has been found to be the most suitable; it then only takes a few minutes to lap out a cylinder from the reamered finish. The surface obtained is fairly smooth, but is rough enough to enable it to run in easily. A dry lap with a little paste gives the best finish. As always, to remove metal quickly, power must be used, and on one occasion when lapping out a case-hardened cylinder which had distorted 5-thou. out of round, a cast iron lap tightly expanded with a liberal amount of paste, employing paraffin for cooling and lubrication, trued the bore track in half an hour. The part was not held by hand as is usual as the torque and temperature were too great. A hone as marketed by Delpena is far superior if your pocket will stand it.

TAPS AND DIES. Taps are made usually in three forms: taper, second, and plug taps which are used to make the initial through to the final cuts. After each half turn the tap should be rotated backwards far enough to free the chips, which on soft metals tends to clog. Cutting oil should always be used except on brass and C.I. It is a good idea to withdraw the tap completely several times to clear the swarf. Large taps are manipulated with a wrench and frequently have a centre hole in the shank which when located by a centre greatly assists a true perpendicular feed. Small taps are best gripped in a drill chuck.

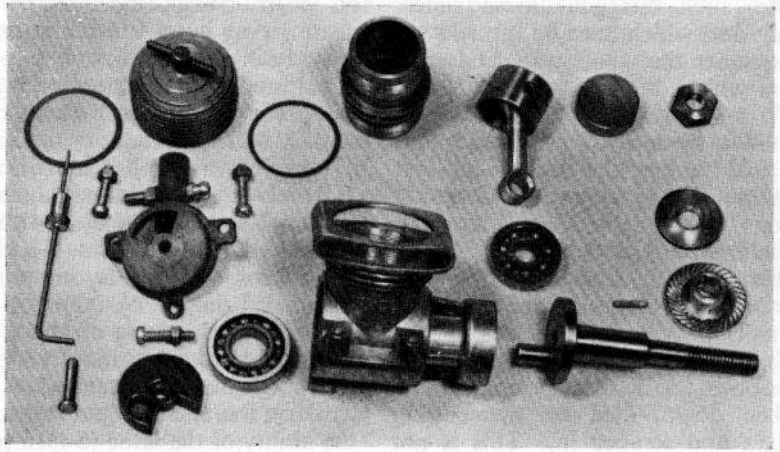
A died thread should always be made after the tapped one since the die is adjustable. The swarf is freed and cutting oil applied as for taps.

DRILLS. Modellers should need little introduction here, though a few hints may be of use. It will be found easiest to drill most holes with at least two drills. The last drill then has a better chance of producing the hole to size since only a small portion of the cutting edges is being employed. It follows the hole already made by the first pilot drill which should therefore be in very good order, or new if possible, to ensure that the drill does not run off centre. Always start the hole

with a centre drill or a good centre pop. Should the drill not be starting on centre before the lands enter the hole, it is possible to pull it back on centre by cutting a groove with a centre pop on the side of the conical depression to which you wish the drill to return. Use cutting fluid to assist swarf removal and cooling and don't use too high r.p.m. with large drills (about 300 r.p.m. for a $\frac{1}{2}$ in. drill in steel) otherwise they may burn out. For small sizes steel wire sharpened to a suitable point is often useful with soft metals.

REAMERS. Reamers are made either to size or expandable. They possess a small taper for the first one-third of their length and so should be able to pass through the hole being finished. Lots of cutting oil and a fastish feed are combined with low r.p.m. to remove only 3 to 4 thou. of metal. A reamer will not produce a good finish if called upon to remove more than this and for sizes where drills increase by $\frac{1}{64}$ in. the hole must be bored out to bring it to a size suitable for the reamer. If the hole cannot be bored and an expanding reamer is not to hand a badly ground drill might be used after a pilot drill to produce a sloppy hole which with luck might to acceptable to the reamer. An accurately ground drill having the corners rounded with an oil stone may be used with a fast feed in soft metal to replace the reamer for finishing the hole. In the smaller sizes, below $\frac{1}{4}$ in., reamers can be replaced by D bits or taper drills (I) made from ground silver steel, hardened and tempered if necessary.

ONE OF THE MOST COMPLEX DIESELS EVER PRODUCED 'en masse' was the Amco 3.5 BB. The alloy crankcase illustrates fine detail involving costly pressure die-casting. Disc valve and crankcase backplate are also castings, otherwise the Amco calls for exactly the same technique of engine manufacture described in these chapters.



CHAPTER TWENTY-TWO

Looking after the Lathe

LIFE is made much more enjoyable if the lathe to be used is in good condition as there is nothing more exasperating than, after having spent half of the evening in turning a part, to have it ruined through no fault of your own as a result of some defect of the machine. Human error is too frequently responsible for the spoiling of a part and it is really worth while to see that the equipment is in the best possible condition. The major difference between working with wood and metal is that if a mistake is made, wood can be stuck back. Metal cannot. Thus every step must be taken with complete certainty that it will be correct. To do this a settled state of mind must prevail which can only be assured if there are as few irritants as possible, such things as loose slides, tight nuts which must be turned with a spanner the whole way, and span ners which don't fit anyway.

It is, therefore, well worth your while to spend two to three evenings in overhauling the equipment and putting it into good order. Common faults with lathes, in fact, all machines, are loose bearings, sloppy slides, end float in spindles, etc. Since this is the case, manufacturers usually provide some means of taking up these slacknesses.

Loose plain bearings must be taken down, filed on the butting edges and scraped in. This is not easy and the aid of a skilled man should be sought. Some lathes like the Myford merely require special 2 thou. packing shims to be removed from beneath the bearing cap to take up the play. Spindles mounted on roller races will have some means of taking up wear which will also remove end play. Although end float has no effect in most ordinary turning work it can be responsible for poor facing or parting off, to say nothing of the havoc it can play with fins or screw-cutting. It should be removed if at all possible.

Slides are easily tightened by means of the screws set into one side which bear on to the adjusting gib plate. It is as well to take slides to pieces to give them a thorough clean out should there be any signs of swarf being embedded underneath. Any burrs which are present must be filed away before the slide is adjusted so that its motion is even along the whole travel whilst being slightly stiff. Slackness in the saddle is taken up by similar means.

Rarely is a lathe found which will turn a constant diameter with the work mounted either in the chuck or between centres. By mounting a piece of 1 in. to $1\frac{1}{2}$ in. mild steel bar with an overhang of about 5 in. in the chuck and without centre, a check on the effectiveness of your work on the bearings and slides, and the ability of the lathe to turn paral-

DESIGNER OF THE HOME-BUILT ENGINE DESCRIBED IN THESE CHAPTERS. Dave Sugden works on the topslide adjuster of his Myford ML7, a favourite lathe with model-makers, amateur and professional.

lel may be made. With a correctly sharpened tool (see Chapter 21) a good $3\frac{1}{2}$ in. lathe should take a $\frac{3}{16}$ in. cut without chattering along the whole length using automatic feed. This is governed by a combination of r.p.m., feed, and shape of tool, and requires much experiment or skill to achieve. It is possible for an unskilled person to turn the last 3 in. without having to drop the r.p.m. below 200. By taking a final cut of a few thou. the amount of taper present can be checked with a good micrometer. One to 2 thou. taper on the 6 in. length can be tolerated for model engines and for anything much above this figure, resulting from further checks, the headstock should be adjusted with the help of your skilled friend. The tailstock is mounted on slides which are perpendicular to the bed to provide adjustment for turning parallel. To check for adjustment for turning parallel the free end of the previous test-piece is centre drilled and the centre inserted. A small cut is taken and the taper measured. To correct this the tailstock is loosened and tapped in a direction across the bed away from the tool if the diameter is larger at the chuck end, and vice versa.

A bent spindle can only be corrected by turning up new back plates for the chucks and facing off the face plate. The former is a rather long job for which you may not have time, but eccentric chucks need not cause trouble provided that in certain cases care in setting up is exercised.

Slackness in belt drives is a common fault which should be rectified to obtain best efficiency. There is nothing so exasperating as to be constantly stopping the machine because the belt drives will not transmit the power.

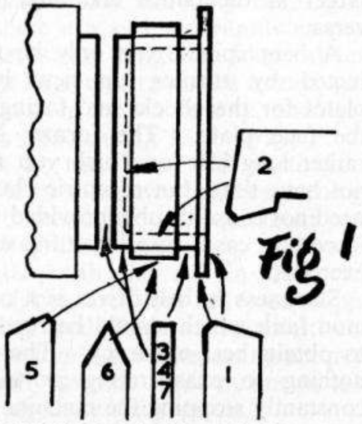
CHAPTER TWENTY-THREE

Work on the Components

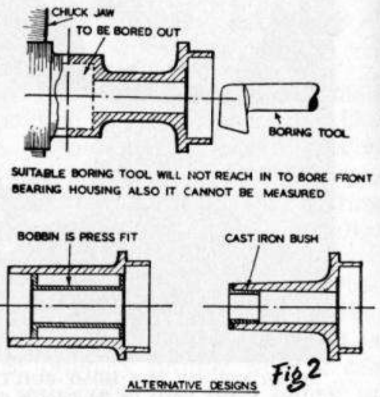
THE components will be dealt with in the order which has been found best in obtaining the most satisfactory mating of parts. A knowledge of the metals and tools to be used will be assumed.

BACK COVER. *Fig.* 1. In order to machine this part without resorting to a jig it must be set up as shown. This means that the threads cannot be tried for fit and so must be made prior to those of the crankcase. The order of machining is not really important, that indicated is as good as any. See that the sealing face is true and has a good finish and that the threads are satisfactory before parting off.

CRANKSHAFT HOUSING. Where a ball race is required, it cannot be machined directly but must be parted off, turned and bored from the other side—*Fig.* 2. The part

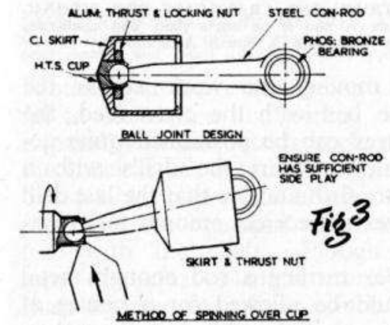


MACHINING BACK COVER



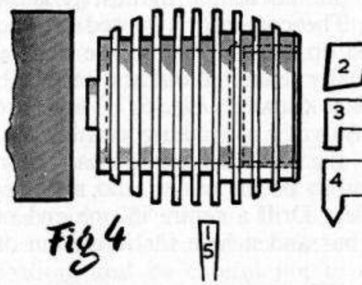
could be shrunk on to a mandrel turned up in the chuck, but if it slipped with subsequent machining the results might be disastrous. It might be possible to use a steady on the outside of the bearing housing so that the boring is concentric with the outside which is true with the rest of the part. A special jig could also be used for the same purpose. These methods are involved and a modification of design as shown surmounts the problem easily. The front ball race could be dispensed with and a plain bearing substituted. Front ball races are hardly worth the extra effort anyway.

BALL JOINT con.-rod-piston assemblies require special spinning equipment for the cup fitting used up inside the piston. Alternative is to use a composite piston as shown in *Fig.* 3, where the piston skirt is secured and soldered to the cup after spinning. The ball end is



turned, filed, and lapped spherical with a piece of copper tubing and grinding paste. A specially ground drill will form the cup contour which is spun round the ball end with a piece of steel, held in the tool post, and well lubricated.

CYLINDER HEAD. *Fig.* 4. This consists usually of simple turning and should present little difficulty. It is easiest to turn the fins before applying the contour. A centre will reduce chatter if this is troublesome. Bore out the inside after completing the fins and do not forget to drill and tap the hole for the compression adjuster before parting off. The order shown is best.

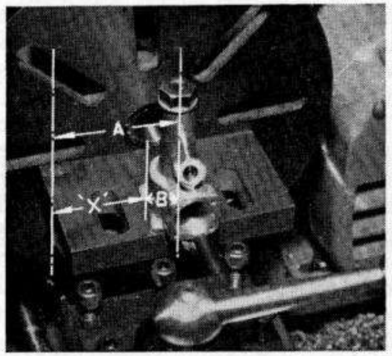


MACHINING CYLINDER HEAD

CRANKCASE, Having gained some experience on easy parts we now turn to something demanding a little more care. By means of the special cast on boss, or at some alternative suitable position, the casting is gripped very firmly, since castings tend to work loose in the chuck. The inside is drilled and bored, the threads are cut and fitted to the back cover and the crankshaft hole and bearing is carefully drilled and reamered. This must have a true finish to permit the crankshaft to run freely, an essential for high power output. A lapped finish on plain bearings where the shaft runs directly in the casting is not recommended due to the difficulty of removing all the grit. Turning out the housing for a ball race on a crankcase of a motor as illustrated has been found to be the most difficult job in the whole engine. It requires a very sharp tool and the utmost skill and patience to obtain the correct fit (see table). It has been found best to use the actual bearing as a plug gauge but be very careful to see that no swarf enters it.

Work on the upper region of the crankcase, where the cylinder fits, can be done next but it is best left until the crankshaft, cylinder, piston and con. rod are finished, so that it can be fitted to the cylinder and ports and be turned down to the height which will give the correct part opening. In this way accumulated errors on the various parts which can completely upset port timing are eliminated.

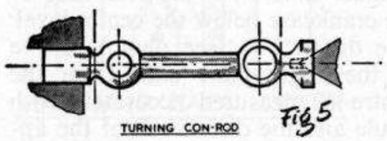
The angle plate is bolted on to the face plate at the distance of the cylinder axis from the rear face of the crankcase below the centre level. The distance A (see photo) of one of the angle plate ends from the centre is measured accurately with a rule and the distance B of the ap-



propriate side of the crankcase from the crankshaft axis is similarly measured. The crankcase is then mounted squarely on to the angle plate at distance X = A-B from the end which puts the cylinder axis true for the subsequent machining which is straightforward.

Do not take heavy cuts since the part may easily be put off centre. It might be convenient to mill out transfer passages or drill the carburettor hole by mounting an electric drill on the cross slide while the job is still set up.

Con Rod. *Fig.* 5. The most difficult part in making this item is in drilling the holes at the correct spacing and ensuring that they are true. Whether the rod is being filed from solid or turned from bar it is best to finish the holes first. With care they can be drilled from centre pops reasonably accurately under a pillar drill, but the most reliable method is to mount the work on a vertical slide, putting the drills in the chuck.



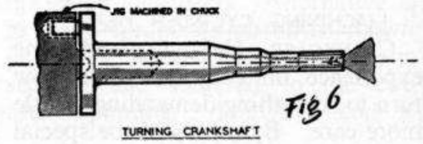
CENTRING THE CRANKCASE FOR BORING, measure A and B on angle plate and crankcase, setting dimension X equals A minus B.

By moving the work across the lathe bed with the cross feed, the centres can be positioned quite accurately. Start the drills with a centre drill and see that the last drill leaves the correct amount for reaming.

For turning a rod enough metal should be allowed for a centre at one end and a boss at the other. The centres for these must be marked out accurately so that the holes will be on the centre line of the rod and be square to it. The boss is nipped to run true in the chuck whilst the other end is supported with the centre. A form tool will assist in shaping the ball ends but a file will produce the required shape without effort. Part off when as much as possible has been turned and finish by hand.

Big End Bushes. These and any other bushes should be of fairly stout proportions, *i.e.*, a wall thickness for one suitable for a $2\frac{1}{2}$ c.c. motor should not be less than 20 thou. When turned and drilled they should be the tightest possible fit. The con. rod is forced on and trued up squarely before the bearing is finally reamered out and sawn off.

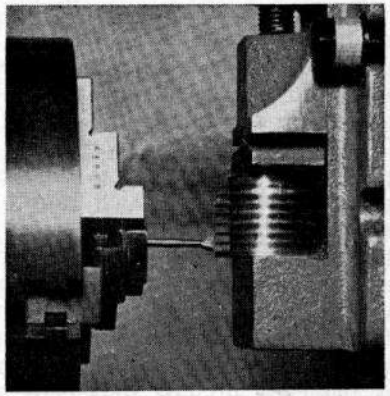
Crankshaft. *Fig.* 6. There are many ways of making crankshafts, but the one described has been found to be the easiest and most reliable. Drill a centre in one end of the bar and a hole for induction or



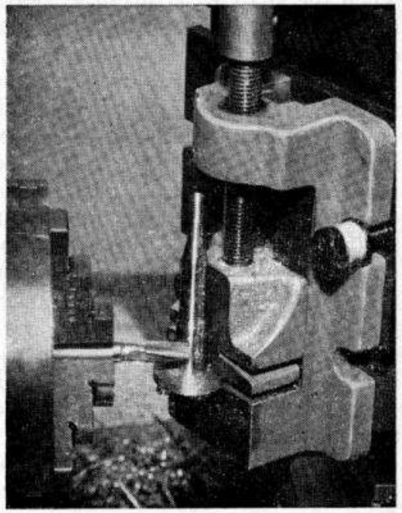
USING A DENTAL BURR TO MILL AWAY fin for holding down nuts on engines such as the early Sugden and Denis Allen 25 (Mk. I version).

lightening in the other, being careful to see that a line joining them is parallel to the outside surface. If the chuck is out of true the bar must be suitably packed to ensure this, otherwise the crankpin will not be true with the shaft. Plough off some of the excess metal round the shaft leaving enough to chuck for turning the crankpin.

By mounting either in a 4-jaw chuck, or in a 3-jaw chuck in which No. 3 jaw has been removed whilst the other two jaws have been wound in, with two or three revolutions of the scroll, before it has been replaced, and using packing if necessary, the bar is set up with the required amount of eccentricity to give the correct stroke. When rotated the throw of the bar is the stroke of crankshaft. This can be measured with a steel rule to 2 or 3 thou. or by winding the tool from a setting with the bar on one side to one when the bar is diametrically opposite, taking readings of the movement from the dial collar. The accuracy of this method depends upon the quality of the screw thread but should be good enough for our purposes. Having mounted the work piece solidly and with as little overhang as possible on it and the tool, turning of the crankpin can proceed at as fast a rate as the lathe and tool will permit. Do not allow the tool to deflect under the impact loading and be careful not to chip it. A sharpened tool will probably be needed to make the finishing cut which should leave 1 thou. on



crankpin diameter. A Swiss file will easily bring the pin nearly to size, leaving a good finish which is quickly polished to an accurate fit with fine emery cloth backed up with a rule. Be careful not to round the corners and use long strokes with the file to reduce the chances of the pin being put out of round. The big end should be a smooth tightish fit and is tried for fit, when thoroughly cleaned.



MILLING THE CRANKSHAFT INDUCTION hole to marks scribed through the throat in the crankcase. Note use of a Myford vertical slide.

To turn the shaft a simple jig is made as illustrated. A hole is drilled off centre and a tapered boss is turned which fits into the hole drilled up the centre of the shaft. To prevent frettage corrosion a piece of soft metal shim is wrapped round the crankpin, which transmits the drive, before it is fitted into the hole in the jig, with the boss acting as a centre at the crankpin end, and the tailstock centre steadying the front end. Use tallow to lubricate this centre if possible. The centre is tightened up just sufficiently to take up any end play but be on the lookout for any chatter, indicating looseness or squeaking, a warning that the centre is burning out. Check the centre occasionally and always before making an important cut. The turning is straightforward and bearings are finished in a similar manner to the crankpin.

The induction hole is milled, sawn and/or drilled and filed to marks scribed on at the internal corners of the carburettor intake, when the shaft is set up in its housing in the correct opening and closing positions.

CYLINDER. This is simple turning work and should present no difficulties. Complete the turning before finishing the bore. A good reamer provides the easiest means of obtaining a suitable finish but failing this—boring will produce the desired result with care. See that the tool is well sharpened and makes the last cut without spring, *i.e.*, continue to make passes along the bore at the same tool setting until it ceases to cut. The bore should then be parallel and true.

The ports come next. It may be found convenient to use the piece nipped in the chuck to grip in the vice whilst filing or milling out the parts, so mark the position of No. 1 jaw before taking the work out of the chuck so that it can be re-chucked accurately for parting off. Milling out of radial ports is easily done with a fly cutter, see page 149. on milling, set to the correct radius. The cylinder is held in a machine vice bolted on to a vertical slide or angle plate mounted on the cross slide. A small drilling jig will be necessary to prevent the drill from running if ports are to be drilled. Much patience is required if they are to be sawn and filed out.

Having finished the ports and parted off the cylinder it may now be heat treated but make it as hefty as possible to minimise distortion when quenching. The last job of all is lapping. To reduce friction it is a good plan to lap cylinders bell-mouthed so that the piston is a loose fit at the bottom of the stroke, where a good compression seal is not necessary, and is a tight fit up the bore where good compression is essential. When mating the piston it is then easy to judge the fit by the distance it will pass up the bore.

GUDGEON PIN. Ground silver steel rod is used here. It can be drilled out for lightness (hole ½ to ⅓ of the outside diameter depending on the general proportions), and dural or brass end pads inserted. However, use a good drill otherwise it may run off centre.

PISTON. The operations here are fairly straightforward except for drilling the gudgeon pin hole. The inside is drilled and bored and as the outside is turned to within 10 thou. when the job is marked and taken out of the chuck. It is then mounted on the vertical slide or clamped by some means on to the cross slide so that drills held in the chuck pass through perpendicularly across the centre line. Alternatively the piston may be mounted on a vee block on a drilling machine or held, on a vee block, on to an angle plate bolted to a lathe face plate. The operation cannot be set up very accurately on a drilling machine which should only be used as a last resort. A vertical slide makes jobs of this sort child's play. The gudgeon pin hole is finally reamered out such that the pin will not quite pass through and requires a light tap to make it fit.

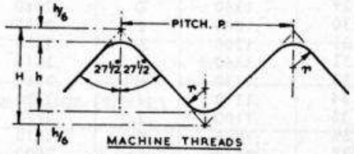
Milling out the inside for lightening demands a similar setting up technique. The slight increase in performance that this gives is not worth the effort involved if you have no vertical slide attachment.

The piston is now returned to the chuck where it is turned down to within 1½ thou. of size, half parted off and lapped to fit the cylinder. This being successfully accomplished it is completely parted off. When fitting pistons to cylinders both parts must be cleaned well to remove grit, enabling an accurate estimate of the interference to be made. Tallow is very useful in preventing the parts from sticking when close fits are being obtained. The correct fit is such that, with tallow the parts will pass fairly freely. They will then feel a little stiff when lubricated with fuel.

CONTRA PISTON. This is easily catered for by allowing some excess length when turning the piston, that is only partially lapped when fitting the latter component. The contra piston is merely parted off at the position which gives the best fit.

JET ASSEMBLY. The screw cap for the needle is made first. The needle is best made from 18 s.w.g. wire finely tapered by careful filing and finished with emery cloth. It is very easy to distort the spraybar when threading and drilling. The hole is finished with a piece of 18 s.w.g. wire sharpened to a point like a screwdriver. Solder the needle very securely to the screw cap. To make the needle a firm fit in the spraybar it can either be bent slightly so that it binds in the spraybar hole, or it can be soldered out of line so that the threads rub a little. There is then no need to go to the trouble of making a saw cut in the screw cap for tightening purposes. 2 s.w.g. wire is suitable for drilling the jet hole on 2½ c.c. engines.

DRIVING DISC. This is simple turning. The taper which fits on to the crankshaft should be done if possible with the same setting on the top slide as was used for turning the crankshaft taper. Serrations are easily applied by winding a boring tool across the driving face.



MACHINE THREADS

TPI	Pitch in.	Standard thread depth. in.	Outside dia.	
			min	max.
40	.025	.0160	⅛	1¼
36	.02778	.0178	⅛	1½
32	.03125	.0200	⅛	1¼
28	.03571	.0229	⅛	1¼
26	.03846	.0246	⅛	3 in.
24	.04167	.0267	⅛	3 in.
20	.050	.0320	¼	3 in.

DATA TABLES

of use to those making their own engines, whether from the Sugden Special design, or their own designs.

DRILL SIZES

Number and Letter Drill dia.			
No.	**Size in.**	**No.**	**Size in.**
1	.2280	52	.0635
2	.2210	53	.0595
3	.2130	54	.0550
4	.2090	55	.0520
5	.2055	56	.0465
6	.2040	57	.0430
7	.2010	58	.0420
8	.1990	59	.0410
9	.1960	60	.0400
10	.1935	61	.0390
11	.1910	62	.0380
12	.1890	63	.0370
13	.1850	64	.0360
14	.1820	65	.0350
15	.1800	66	.0330
16	.1770	67	.0320
17	.1730	68	.0310
18	.1695	69	.0292
19	.1660	70	.0280
20	.1610	71	.0260
21	.1590	72	.0250
22	.1570	73	.0240
23	.1540	74	.0225
24	.1520	75	.0210
25	.1495	**Letter Drills**	
26	.1470	A	.2340
27	.1440	B	.2380
28	.1405	C	.2420
29	.1360	D	.2460
30	.1285	E	.2500
31	.1200	F	.2570
32	.1160	G	.2610
33	.1130	H	.2660
34	.1110	I	.2720
35	.1100	J	.2770
36	.1065	K	.2810
37	.1040	L	.2900
38	.1015	M	.2950
39	.0995	N	.3020
40	.0980	O	.3160
41	.0960	P	.3230
42	.0935	Q	.3320
43	.0890	R	.3390
44	.0860	S	.3480
45	.0820	T	.3580
46	.0810	U	.3680
47	.0785	V	.3770
48	.0760	W	.3860
49	.0730	X	.3970
50	.0700	Y	.4040
51	.0670	Z	.4130

HEAT TREATMENT

Tempering Temperatures		Heat Colours	
Colour	Temp. C.	Colour	Temp. C.
Pale Yellow	222	Dull Red	650- 750
Straw Yellow	238	Cherry Red	780- 800
Brown	254	Bright Red	830- 880
Light Purple	277	Dull Yellow	1050-1150
Dark Blue	306	White	1250-1300

SCREW THREADS

BRITISH ASSOCIATION STANDARD

No.	Diameter	Approx. T.P.I.	Root Dia.	Tapping drill
0	.236	25.4	.189	12
1	.209	28.2	.166	19
2	.185	31.4	.147	25
3	.161	34.8	.127	30
4	.142	38.5	.111	34
5	.126	43.0	.098	40
6	.110	47.9	.085	44
7	.098	53.0	.076	48
8	.087	59.1	.064	51
9	.075	65.1	.056	53

WHITWORTH STANDARD

Size	T.P.I.	Root dia. ins.	Thread depth ins.	Tapping drill
1/16	60	.0412	.0107	58
3/32	48	.0670	.0133	50
1/8	40	.0930	.0160	41
5/32	32	.1162	.0200	31
3/16	24	.1341	.0267	9/64″
7/32	24	.1653	.0267	18
1/4	20	.1860	.0320	11
5/16	18	.2414	.0355	D
3/8	16	.2950	.0400	N
7/16	14	.3460	.0457	S
1/2″	12	.3933	.0534	13/32″
BRITISH STANDARD FINE THREAD				
7/32	28	.1730	.0229	16
1/4	26	.2007	.0246	13/64″
9/32	26	.2320	.0246	15/64″
5/16	22	.2543	.0291	G
3/8	20	.3110	.0320	O
7/16	18	.3664	.0356	3/8″
1/2″	16	.4200	.0400	27/64″

BALL BEARINGS

(Dimensions in inches unless stated otherwise)

Type bore.	Width	Outside dia.	Weight oz.	Limits of shaft	Limits of housing	Abutment dia. shaft	Abutment dia. housing	Manufacturers' Code No.: F.B.C.	Hoffman	R & M	S.K.F.
4 m/m	5 m/m	13 m/m	.166	.1569 .1564	.6305 .6297	.281	.5	R4	104	LJ4	R4
6 m/m	6 m/m	19 m/m	.288	.2356 .2351	.7486 .7478	.375	.625	R6	106	LJ6	R5/6
8 m/m	7 m/m	22 m/m	.432	.3144 .3139	.8667 .8659	.437	.75	R8	108	LJ8	R7/8
¼	7/32	¾	.256	.2495 .2490	.7502 .7495	.40	.62	EE2	S.1	KLNJ¼	EE2
⅜	7/32	⅞	.40	.3745 .3740	.8752 .8745	.53	.75	EE3	S.3	KLNJ⅜	EE3
½	¼	1⅛	.482	.4995 .4990	1.1252 1.1245	.68	1.0	EE4	S.5	KLNJ½	EE4

METALS FOR YOUR ENGINE

Material	Specification	Use	Ultimate Tensile strength tons/sq. in.	Colour Code Identification
Mild steel ...	S.1.	Cylinders when case hardened. General lightly loaded parts.	35	yellow.
Case hardening steel ...	S.15 ... S.82 ...	... Cylinders ... ... Crankshafts	35 75	yellow, brown, yellow. green, red, yellow.
High tensile steel	S.96 ...	... Cylinders and crank-shafts ...	55	black, red, blue.
Aluminium alloy .	DTD 363 ... DTD 364 ...	Con Rods ... ... Con rods or general	38 30	brown, green, brown. green, brown, green.
Aluminium forging alloy ...	DTD 683 RR 77 DTD 130 RR 56	Con rods or general General	31 26	blue, yellow, red. red, black, yellow.
Aluminium casting alloy	DTD 424	Crankcase	10	
Phosphor Bronze .	B.8 ...	... Bearings	11	brown.

IMPERIAL STANDARD WIRE GAUGE (S.W.G.)

No.	Ins.	No.	Ins.	No.	Ins.	No.	Ins.
0	.3240	13	.0920	26	.0181	39	.0052
1	.3000	14	.0800	27	.0164	40	.0048
2	.2760	15	.0720	28	.0148	41	.0044
3	.2520	16	.0640	29	.0136	42	.0040
4	.2320	17	.0560	30	.0124	43	.0036
5	.2120	18	.0480	31	.0116	44	.0032
6	.1920	19	.0400	32	.0108	45	.0028
7	.1760	20	.0360	33	.0100	46	.0024
8	.1600	21	.0320	34	.0092	47	.0020
9	.1440	22	.0280	35	.0084	48	.0016
10	.1280	23	.0240	36	.0076	49	.0012
11	.1160	24	.0220	37	.0068	50	.0010
12	.1040	25	.0200	38	.0060		

Assembly and Test

CHAPTER TWENTY-FOUR

HAVING at last reached the stage where all constructional obstacles have been overcome, the assembly and test of a new engine must not be rushed, but be carried out with as much care as was put into the construction. Cleanliness is of supreme importance in ensuring that the motor shall have a long working life.

CLEANING. Wash the parts thoroughly in petrol, paying special attention to bearings. Assemble all the parts and check that everything fits together properly. Usually something does not. The con. rod may foul the sides of the crankcase and the piston may touch the top of the back cover. Whatever the trouble, attend to it now. This does, of course, assume that you have designed an engine which *can* be assembled !

Dismantle and select all the ferrous parts (shaft, piston, cylinder, etc.), excepting ball races, which should still be perfectly clean ; put them into a tin containing washing soda, and if this is not available, soap powder and water, and boil for several minutes to remove ingrained grit. The parts are superclean after boiling, and if not oiled will rust rapidly. Lay them out on clean paper and handle as little as possible.

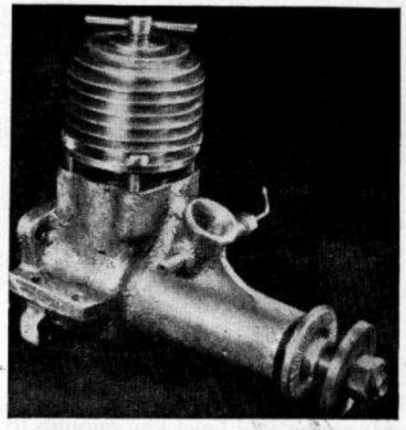
If a ball race has become dirty, it can be cleaned out by carefully spinning it over in a bath of clean petrol. Aluminium parts are cleaned with petrol and a smooth cloth, bearing surfaces being rubbed as vigorously as possible to remove grit. Give them a final dip in petrol to remove fluff.

CRANKSHAFT ASSEMBLY. Assembling an engine having a plain bearing crankshaft is not difficult. Inserting a plain journal bearing is effected by warming the crankcase and pressing home the bush in a vice, using suitable blocks of wood, being careful to avoid any transverse loading which might distort the bearing.

Fitting a ball bearing crankshaft can be decidedly tricky. Using a piece of tube to bear upon the inner race, press the rear ball race on to the crankshaft, using a vice. Warm the front bearing housing over a clean gas flame and insert the race. Tight force with a vice might be needed. There should be a face against which the outer race may seat squarely. It is easy to distort the outer face and excessive force must not be used. If the bearing will not enter or has distorted out of round or does not run freely, it must be removed and the offending part of the housing, usually detected by the score marks, scraped down. A balsa knife makes a good tool for this job. Be careful to remove metal evenly all the way round if the bearing is too tight. To remove the bearing, re-warm and tap out with a drift or with a piece of ground silver steel made to a very tight fit in the inner race.

Having fitted the front bearing

THE PROTOTYPE SUGDEN SPECIAL AS detailed in Chapter 25 was running within moments of its first assembly, due to careful work as prescribed here.

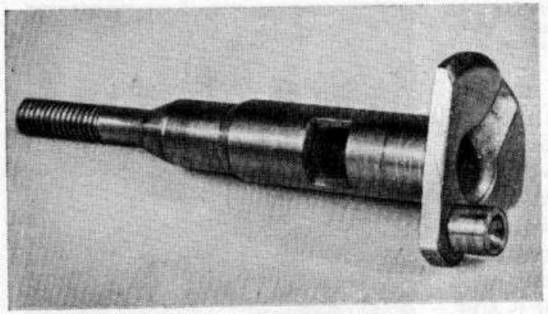


into the crankcase part of the engine and with the rear ball race on the crankshaft the next step is to mate the two assemblies. Warm the rear housing, or the crankcase, and with the front bearing supported on both its outer and inner races press the crankshaft into position with the vice. If it will not fit or is stiff, remove and attend to the trouble. When fitted, a slight tap in the reverse direction relieves stresses set up between the bearings, and the shaft should then spin freely. Slight "lumpiness" may be tolerated on an ordinary engine and it may be found to disappear when the engine warms up.

GENERAL ASSEMBLY. The remainder of the assembly is not difficult. As parts are put together they should be marked so that on re-assembly they can be fitted in the same position. *E.g.*, mark the front of the con. rod and insert the gudgeon pin from the front of the piston. Mark the cylinder. Always tighten opposite screws progressively to ensure that the part—a cylinder head or back cover—is evenly seated.

Gaskets should be used on all joints for the purpose of making absolutely certain that there are no leaks. Many a good engine fails to perform properly due to a leak. A leaky crankcase can make starting tricky which on a new engine can be quite difficult enough with unknown settings. Tough paper is ideal for gaskets.

With everything assembled the engine should turn over rather stiffly. It is a good thing, having mounted the piston and cylinder, to turn over the motor whilst it is immersed in petrol to flush any remaining dirt from the bore. If on tightening up, the piston has become stiff in the bore, either the cylinder is out of line or the con. rod holes are not true. Try the effect of turning the con. rod back to front. If the cylinder is giving the trouble, turn the motor over several times, remove the cylinder and look for rubbing marks which will indicate which way it is out of line, and where the seating should be adjusted. Tightness due to malalignment will loosen up with running as the con. rod bearings wear, but if it is the cylinder that is out of line the motor will never deliver peak power and the con. rod will rapidly wear and may even bend or break. Every effort should be made to assemble the motor free from binding of any sort, as this is the best means of ensuring a long life and high power output. If any parts have to be worked upon they should be recleaned in the manner prior to the commencement of assembly. Lubricate with castor oil.



SCOOPED CRANKWEB AND square cut induction port are aids to high speed running. Shaft is from earlier motor seen opposite.

TESTING AND RUNNING. The motor is at last ready to be run. Bolt it to a suitable mounting and arrange the fuel level low enough to prevent the motor from flooding, but high enough to keep the fuel at the jet. The weight of a plastic prop. eases starting and one should be selected which will not allow the r.p.m. to exceed 8,000 on a plain bearing engine or 11,000 on one fitted with ball races.

A suitable fuel is equal parts of castor oil, Derv or paraffin, with either a 2 per cent addition of amyl nitrite or nitrate. As the motor becomes more free this may be modified to a final mixture as follows: 15 per cent castor oil, 55 per cent Derv, 27 per cent ether and 3 per cent amyl nitrite.

Open the needle so that when choked the fuel is drawn through the tubing at a normal rate for the size of engine. Choke a couple of times and screw down the compression until it feels reasonable. Flick several times and if without success try and prime through the ports. Whilst flicking, turn down the compression until the engine "pops" Further priming should result in a burst and if the engine fails to roar into life, open up the fuel setting. If the motor still does not start and shows no signs of excess fuel, drill out the jet to a slightly larger size. A reasonable design, made with moderate skill, must run, and perseverance will end in success. My first motor took 1½ hours to start; the latest one went on the third flick.

Glowplugs

Glowplugs present no appreciable starting difficulties. Equip with a long reach or warm plug, wind the needle well open, prime through the exhaust port with fuel, say Mercury 5, and with a good glow the motor will run. A reduction of fuel brings it to the best running setting. It is easy as that! The compression ratio is difficult to assess on glow motors because of their deflector head pistons and shaped cylinder heads, but it is easily judged by performance on various fuels and plugs. If on changing to a short reach plug the engine runs as though it is starved of fuel when the correct running setting is approached, compression ratio is too low. On the other hand, if it runs well on all plugs but sounds rough on certain fuels the compression ratio is too high especially for the fuel involved. The best ratio is determined only by checking performances carefully, on the best fuel with the best plug.

When the motor has lost all stiffness in the piston bearing it is virtually run in and small props. can be used. If after a run the piston

TURNING 11,000 R.P.M. ON AN 8 x 6 AND being checked with a vibrating spring steel rev.-reader, this is a plain bearing Sugden engine with screw-over jacket assembly.

feels on the stiff side or looks dry the oil content of the fuel should be raised or a thicker oil used. To prime a new engine with oil before a run is a good thing, making for a long life.

The state of the oil thrown out of the exhaust ports gives a good indication of the conditions within the engine. More nitrite is needed if it contains carbon. If after two or three runs however it has a "polychromatic" look, rapid wear on some part is indicated and the motor should be stripped, examined, and the trouble rectified, before the part —usually the con. rod—is too badly worn. Engines fitted with ringed aluminium pistons are more prone to produce this phenomenon, but it should not be allowed to persist.

A spot of jeweller's rouge or Brasso in the fuel assists a stiff engine to run in more rapidly, where without it the process might take many hours; but it is only recommended where peak power is wanted quickly. It can knock hours off the life of the engine.

The most important instrument for engine testing is a good tachometer. Wire reed indicators are not sufficiently sensitive or reliable. The most convenient method is to run the motor whilst someone compares its note on a piano. If the instrument is in tune you have a fairly accurate check on r.p.m., and anyway it provides a sensitive means of checking small variations in r.p.m. The table gives the r.p.m. indicated by the various notes. R.p.m. are halved if the note is an octave lower and doubled if it is an octave higher!

NOTES OF ENGINE R.P.M.

Note	...	c	d	e	f
R.P.M.	...	7,680	8,640	9,600	10,200
Note	...	g	a	b	Middle c
R.P.M.	...	11,500	12,800	14,400	15,350

CHAPTER TWENTY-FIVE

Making the Sugden Special

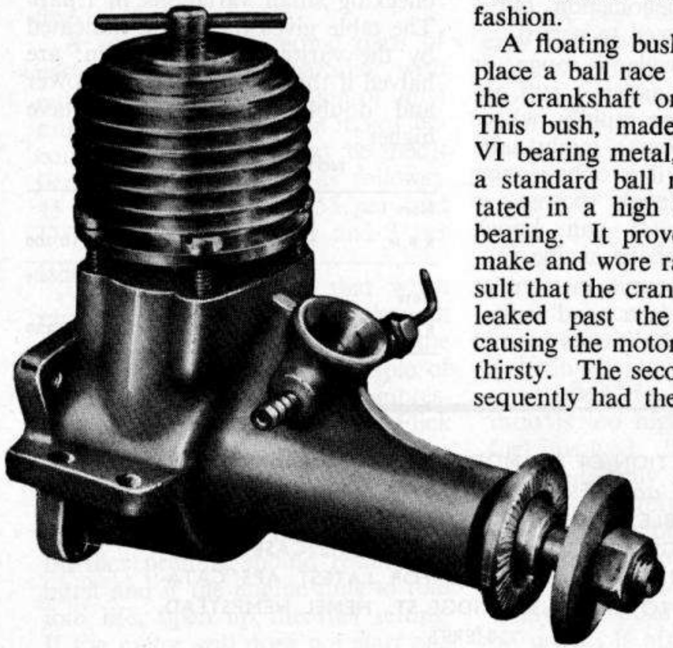
IN designing this engine the requirements were: high power output, low weight and easy construction. The first implies Oliver type porting and low friction crankshaft bearings whilst the others rule out ball races. The effectiveness of the compromises made is indicated by the test results, *i.e.*, the internal shape of the engine is satisfactory, but the output could be raised with ball races for racing purposes.

Design and Development

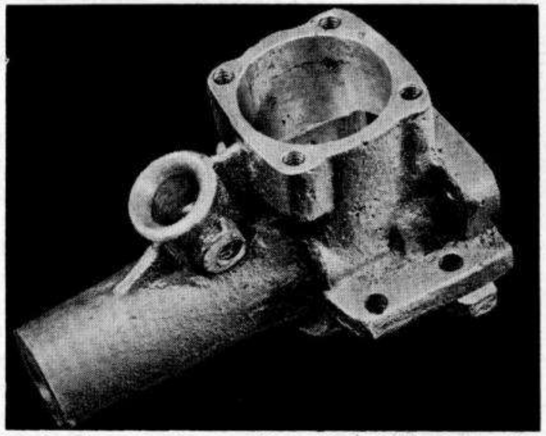
The stroke/bore ratio was chosen small enough to produce a light compact design with docile starting characteristics, but large enough to prevent the internal stresses from being excessive. A value of 1.06 was obtained when a stroke of .6 in. was chosen.

With Oliver transfer ports it is not very practicable to screw in the cylinder, a feature making for lightness, and on the first prototype motor a system of studs was devised which has been superseded by the method shown here. The cylinder is prevented from rotating by the holding-down screws which locate in the grooves between the exhaust ports. The cylinder head then screws on in the normal fashion.

A floating bush was used to replace a ball race at the web end of the crankshaft on the first engine. This bush, made from Immadium VI bearing metal, was the width of a standard ball race and itself rotated in a high tensile steel outer bearing. It proved to be tricky to make and wore rapidly with the result that the crankcase compression leaked past the crankshaft, thus causing the motor to become rather thirsty. The second prototype consequently had the short plain bearing, shown on the drawing, which has proved to be quite satisfactory. A separate inserted front bush used on the first engine was made integral with the crankcase on the later designs since this bearing is lightly loaded.



THE SUGDEN SPECIAL, a remarkable design, already very successful with many home-constructors and capable of high performance. Gravity die cast crankcases ready for machining and full-size drawings complete with instructions are available price 12/6d. the set from Aeromodeller Plans Service.



A GRAVITY DIE-CAST CRANKCASE after all machining operations are completed.

The exhaust ports were reduced from the 80 thou. depth of the first to 60 thou. depth on the second engine and the slightly lower power output of the latter unit could be attributed to this modification. Eighty thou. ports were used on the third and final engine.

The second and third motors had the carburettor intake drilled $\frac{1}{4}$ in. diameter for the simple reason that a suitable smaller size drill was not available. This did not appear to affect starting which is easy on all three engines. Alternative beam mount lugs were provided on the third motor.

Construction

Tolerances are not indicated on the drawing since the design is not intended for mass production. As a matter of principle all dimensions should be produced as accurately as possible and if the order of working as followed below is used, all parts will fit accurately and errors will be eliminated.

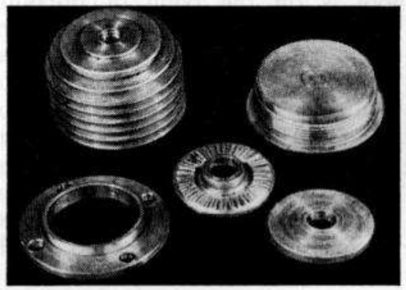
The *pattern* required much care to make and as many parts as possible were turned on a Wolf drill lathe. An additional $\frac{1}{16}$ in. was allowed on the faces to be machined. The local foundry did the casting. Aeromodeller Plans Service can supply quality die castings ready for machining, price 8/- each.

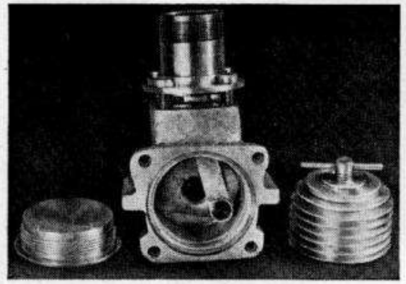
The *back cover* was turned from dural as described earlier.

The *con. rod* was milled from a piece of DTD 610 $\frac{1}{4}$ in. dural plate which despite its rather low strength has proved adequately strong and wear resistant. The holes were drilled and reamered, and the milling on one side completed at one setting up on the vertical slide to ensure good alignment of the rod, which is important. The remainder was easily filed.

The *cylinder head* and *holding down ring* were machined, the finning being completed before the boring and screw cutting were commenced.

SIMPLE TURNED PARTS FOR THE "Special" from Dural.





DISMANTLED, FROM THE REAR, SHOWS cylinder retaining method of flanges for radial mounting, etc.

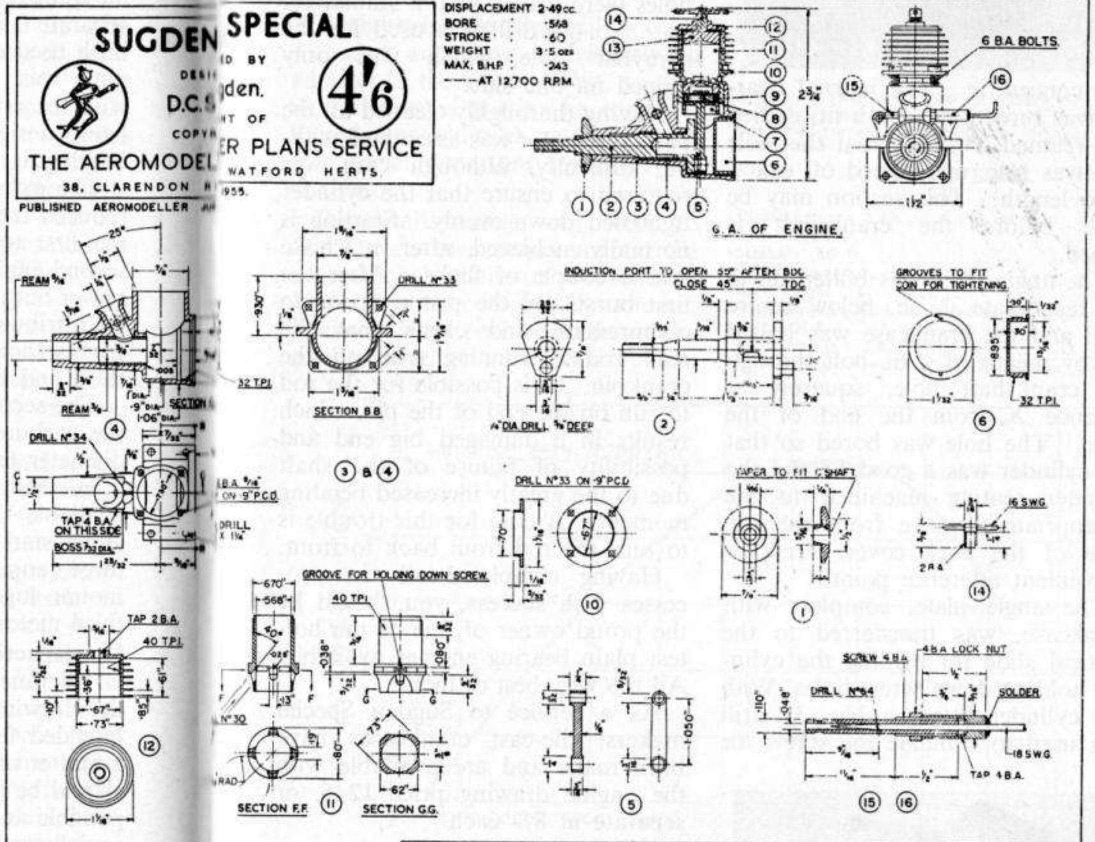
From a piece of S11 stock, sufficiently long to allow 1 in. for chucking, the *cylinder* was machined and drilled ½ in. dia.

Marks are made at 90 degrees intervals round the exhaust ring. The work was marked at No. 1 jaw and transferred to the vice on the vertical slide for milling the transfer grooves. These could be filed out if necessary. A ¼ in. end mill was used although an old drill carefully ground for the purpose would do, and the grooves were located by the 90 degree marks as also was the drilling for the transfer ports. It was not found necessary to use a jig here and with the cylinder set across the lathe bed at 40 degrees, a centre drill and drills No. 40 and 30 completed the hole. This was squared off between the exhaust ports after they had been milled as described in Part V. The milling has been taken to the correct depth when the tool is on the point of breaking through the cylinder bore (½ in. dia.). The work was then returned to the chuck, trued up and bored to 1½ thou. undersize. A half hour of filing remained to complete the porting, after which the liner was parted off. The lap was machined to a tight fit and the cylinder was tapped on for screw cutting the 40 T.P.I. thread. A few minutes lapping with coarse and then fine grinding paste completed the cylinder. It is not recommended that this cylinder design be subjected to the stresses of case hardening.

The *piston* and *contra piston* were made as previously described.

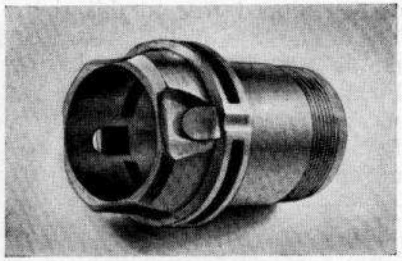
Next the *crankshaft* was machined from a piece of S.11 55 tons H.T. steel. The machined bar was mounted with the correct amount of eccentricity in a 3-jaw chuck which had had No. 3 jaw offset by two or three revolutions of the scroll, using shim packing for the final adjustment. My chuck could not "swallow" the full length of the bar and after checking for alignment with the lathe bed, a ⅛ in. centre drill hole was made. The overhanging end was stabilised with the tailstock centre during subsequent machining of the crankpin. The remainder of the crankshaft machining was carried out as described earlier. The induction port was milled out to port opening and closing lines scribed through the carburettor intake hole as shown in the photograph.

The rear face of the *crankcase* casting was centre popped and the chucking boss was filed until the casting nipped true to this centre. The inside was drilled, bored and the threads cut to fit the back cover. Finally the hole was drilled and reamed to take the crankshaft before parting off. Care was needed to see that these holes were all true



SCHEDULE OF PARTS

PART Nº	NAME	MATERIAL	PART Nº	NAME	MATERIAL
1	DRIVING DISC.	DURAL.	9	END PADS.	DURAL
2	CRANKSHAFT.	HIGH TENSILE STEEL.	10	CYL. HOLDING DOWN RING.	DURAL.
3	CRANKCASE	ALUMINIUM.	11	CYLINDER	H.T.S.
4	CRANKCASE BUSH.	CAST IRON OR PHOSPHOR BRONZE	12	CYLINDER HEAD.	DURAL
5	CON ROD.	DURAL.	13	CONTRA PISTON.	CAST IRON.
6	BACK COVER	DURAL.	14	COMPRESSION SCREW	STEEL.
7	PISTON	CAST IRON.	15	SPRAY BAR.	DURAL.
8	GUDGEON PIN	SILVER STEEL.	16	NEEDLE CAP.	BRASS



FULLY MACHINED CYLINDER ILLUSTRATING the angled transfer ports, and in particular their overlap of the exhaust timing.

and concentric. The journal bearing was turned to a push fit, drilled and reamed, ensuring that this hole also was true, and parted off exactly to length. This section may be done before the crankshaft is turned.

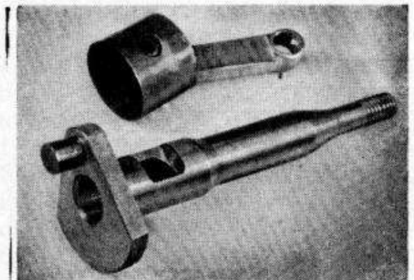
The angle plate was bolted on to the face plate $\frac{9}{16}$ in. below centre level and the crankcase was bolted on, by means of a tie bolt through the crankshaft hole, squarely at distance X from the end of the plate. The hole was bored so that the cylinder was a good fit and the cylinder seating machined to the appropriate distance from the top edge of the back cover recess, a convenient reference point.

The angle plate, complete with crankcase, was transferred to the vertical slide for drilling the cylinder holding down screw holes. With the cylinder fitted, a No. 35 drill was used to simulate the screw for obtaining the correct centres. Holes were drilled in the holding down ring at the same setting by slipping it on to the cylinder in the appropriate position. The carburettoı holes were drilled with a similar set up. No. 34 drill was used for the spraybar hole which was only tapped on one side.

Having thoroughly cleaned all the parts the motor was assembled without difficulty, although care was required to ensure that the cylinder tightened down evenly. Starting is normally achieved after a choke and a couple of flicks. After the first burst, put the piston up on to compression and check that the con. rod is running true on the crankpin. It is possible for the rod to run on the end of the pin, which results in a damaged big end and possibility of failure of the shaft due to the greatly increased bending moment. A cure for this trouble is to turn the rod from back to front.

Having completed all the processes with success, you should be the proud owner of one of the hottest plain bearing engines available. All the very best of luck.

As a service to Sugden Special makers, die-cast crankcases have been made and are available with the engine drawing price 12/6, or separate at 8/- each.



MOST IMPORTANT COMPONENTS, THE shaft and piston assembly require special care.

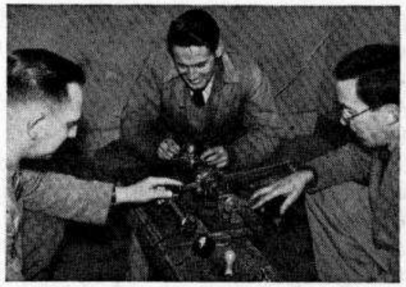
An Opinion on the Special

Initial impression of the "Special" was that it was essentially an aeromodeller's engine, made down to minimum size and with all unnecessary weight removed. Whatever

the claims that a little extra weight may not be important—and perhaps such claims are quite justified—when one thinks of "optimum" aircraft design one automatically links with it minimum weight. In this respect the "Special" rates top marks.

Design-wise the "Special" is quite orthodox and Dave is evidently an admirer of the Oliver stable, as seen in the form of porting he employs, though the cylinder retaining ring is a novel departure from the orthodox.

Being tailor-made, as it were, to suit Dave's own requirements, the test engine had one or two features which the writer would have altered. There was no positive lock on the needle valve, also the contra-piston

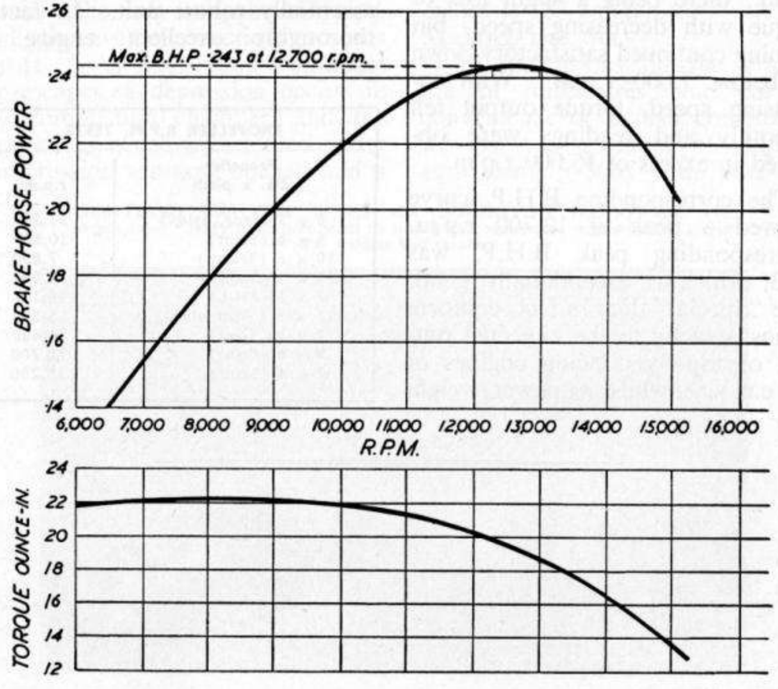


TESTING ONE OF THE SUGDEN SPECIALS are Eric Hook, whose father built the Aeromodeller Eddy-current Dynamometer, designer Dave Sugden and Ron Warring.

SUGDEN SPECIAL

DATA

Displacement : 2.49 c.c. (.152 cu. in.).
Bore : .568 in.
Stroke : .60 in.
Bore/stroke ratio : .93.
Bare weight : $3\frac{1}{2}$ ounces.
Max. torque : 22.2 ounce-inches at 8.500 r.p.m.
Bax. B.H.P. : .243 at 12.700 r.p.m.
Power rating : .0975 B.H.P. per c.c.
Power/weight ratio : .07 B.H.P. per oz.



fit was tighter than most would consider comfortable to handle. But apart from these minor points, everything else had the appearance of being "right".

Starting characteristics appeared quite satisfactory, without being outstanding. Hand-starting with small propellers was typical of a racing engine and the "Special" did appear to like a really generous prime and show a definite preference for the fuel tank being located on an approximate level with the needle valve.

Tests were started with large propeller loads, when it was quickly evident that the torque output was going to be at least as high as any 2.5 c.c. engine yet tested. Maximum torque was generated at 8,500 r.p.m., there being a slight loss of torque with decreasing speed, but running continued satisfactory down to below 7,000 r.p.m. With increasing speed, torque output fell smoothly and readings were obtained in excess of 15,000 r.p.m.

The corresponding B.H.P. curve showed a peak at 12,700 r.p.m. Corresponding peak B.H.P. was .243, which is exceptionally good. The "Special" does in fact, conform almost exactly to the expected output of top-class racing engines of 2.5 c.c. size, whilst its power/weight ratio is appreciably better than average.

Fuel used was quite heavily nitrated, the exact formulation being a matter of conjecture. Basically it started off as 25 per cent Ether, 50 per cent Derv, 22 per cent Castrol XXL, 3 per cent Amyl Nitrate with a *further* proportion of amyl nitrate added to Dave's own ideas. Some separate r.p.m. checks were made with other fuels, all of which showed varying degrees of inferior performance.

Summarising, the "Special" undoubtedly lives up to the requirements of a high-performance 2.5 c.c. engine with no apparent vices, consistent in running with a relatively low vibration level. Particularly commendable is the power/weight ratio achieved whilst retaining an essentially robust unit. In fact, a thoroughly excellent engine all round.

PROPELLER R.P.M. TESTS

Propeller dia. x pitch	r.p.m.
8 x 5 (Frog. nylon)	13,500
9 x 6 (Stant)	10,300
10 x 6 (Trucut)	7,800
11 x 5 (Stant)	7,000
7 x 10 (H-L)	10,100
11 x 8 (Whirlwind)	5,500
9 x 3 (Tiger)	11,400
9 x 4 (Stant)	10,700
7 x 4 (Stant)	15,200

CHAPTER TWENTY-SIX

Making a Pulse Jet

EMIL Brauner of Kladno in Czechoslovakia is a model maker who was forced by circumstances to make his own jet engine. It powers a scale model MiG 15 fighter at 85 m.p.h. We have, therefore, a powerful jet unit and one which can be made by anyone with access to lathe and welding facilities.

First, how it works: Petrol or White Spirit (cigarette lighter fuel) is induced to spray through a metering jet by a fast airflow into the nose cone. The fuel/air mixture passes through flap valves and into the combustion chamber, where it is ignited. Immediately after combustion the burning gases pass through the only exit, the tail pipe, and the resultant reaction provides thrust. As this column of burnt air escapes, a depression occurs in the combustion chamber, and the flap valves which were closed under compression are now opened and a further supply of fuel/air drawn in. So the cycle repeats itself in a series of pulses, each one igniting itself with the heat of the tail pipe which rapidly achieves the state of red heat, as the frequency of explosions is in the region of 200-300 cycles per second.

Because of the fire risk, and the possibility of personal danger, pulse jets are neither to be advised for free-flying nor are they tolerated for such a purpose in Great Britain. They are, however, insurable under a special scheme by the S.M.A.E. for control-line flying and a class exists for Jet Speed, usually flown at the National contests. Current record is 133.3 m.p.h.

Making the Jet

All dimensions on the drawing are in millimetres, and for the convenience of British constructors we provide a table of required equivalents. Start with part 1, a

COMPLETED BRAUNER PULSE JET SERVES TO ILLUSTRATE ITS simple lines. Many have been built as school and apprentice workshop test pieces for welding and turning.

METRIC DIMENSIONS AND DECIMAL EQUIVALENTS

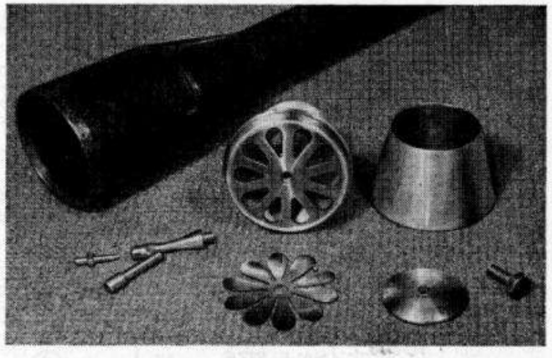
mm.	in.	mm.	in.	mm.	in.
.1	.004	8	.31496	40	1.5748
.15	.006	9	.35433	43	1.69291
.5	.020	10	.3937	44	1.73228
.8	.0314	13	.51181	54	2.12598
.9	.036	14	.55118	55	2.16535
1.0	.03937	15	.59055	56	2.20472
1.1	.04337	16	.62992	60	2.3622
2.0	.07874	17	.66929	64	2.51968
2.5	.0984	18	.70866	65	2.55905
3.0	.11811	19	.74803	86	3.38582
3.2	.12611	22	.86614	129	5.07873
4.0	.15748	24	.94488	134	5.27558
5.0	.19685	30	1.1811	370	14.5669
6.0	.23622	32	1.25984	490	19.2913
7.0	.27559	38	1.49606		

brass turning which serves as an adaptor for the compressed air or car tyre pump air supply during starting. It is brazed at 37° to part 3, the carburettor, which is another brass turning tapped to receive the pilot jet and threaded at the rear end to fit part 6. The pilot jet, part 2, has a 1 mm. orifice. It is advisable to make a set with .9 mm. and .95 mm. alternative jet sizes to determine best diameter for performance. Fuel flows directly from the tank to the pilot jet, thence into the carburettor; and out at 70°-80° through the two .8 mm. oblique holes.

The head—or cone, part 4, is a light metal turning threaded at the rear to fit the collar in the combustion chamber. Care to adhere to the aerodynamic curve, and external relieving to give a wall thickness of 2 mm., will improve performance and save weight. Note that a 3 mm. recess is needed to take part 6 at a later stage. Part 5 is a simple light alloy fairing to blend the carburettor to the valve plate, part 6, and this latter item is turned from the solid in mild steel. There are ten valve holes, each 9 mm. diameter and tapering down to the centre for maximum opening. The valve itself, part 7, is the heart of the jet, and as such is a most critical component. .15 mm. spring steel sheet was used in the original jet; while an alternative, cold drawn sheet, is easier to stamp out and will last for up to 30 starts. Mass production by means of a steel die and hard rubber blanking plate would be one answer to the valve replacement problem. To limit the opening of the valve, part 8 is a backing plate from dural, and here again it is advisable to make alternatives with different curvature to test for optimum performance. Part 9 is merely a standard metric thread bolt to hold the valve assembly together.

Part 6 is peened in place in the head, see detail at 12, and a light alloy nose fairing, 10, riveted as a cone before being "clicked" in place between shoulders. All that remains is the tail pipe, of welded heat-resisting or stainless steel, thickness is not critical between .015 in. and .025 in. made up in three stages to the dimensions in 11. Weld a steel collar in the combustion chamber, and thread to suit the head. Now mount the unit by means of metal collars to a stout board and prepare for first tests.

With fuel in the tank, and a car pump connected to the adaptor, part 1, start pumping with alternate long and short strokes, checking that fuel is drawn through to the carburettor. This done, use the Continental method of ignition by playing a blow-lamp across the jet orifice (not on the tail pipe) and providing a fuel/air mixture is passing through into the combustion chamber, a start is soon effected. There is no such thing as



ALL THERE IS TO THE WORKING parts of a pulse jet! Only really critical component is the flutter valve made from spring steel sheet.

a "misfire" in a pulse jet, either it is going or it is stopped. If the jet appears to show no inclination to keep going, then one should try variations with (*a*) the pilot jet and (*b*) valve backing plate. A low tone indicates a rich mixture and a high note, or short, barking tone, a weak mixture. Hot weather calls for a larger pilot jet, extreme cold a small jet. Having made your own unit, you will soon appreciate these symptoms and their cures.

DIMENSIONED DRAWING APPEARS ON PAGES 176-177

CHAPTER TWENTY-SEVEN

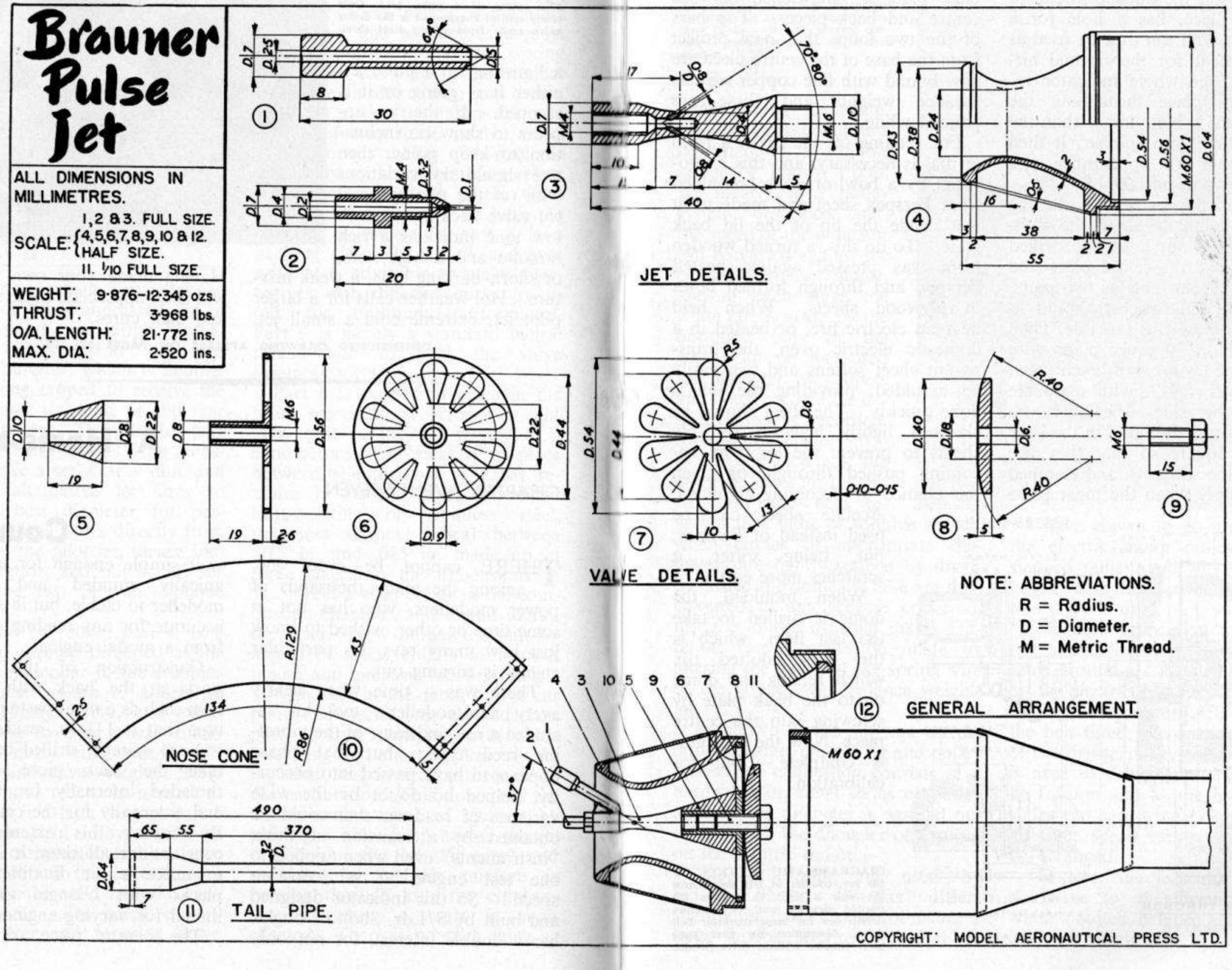
A Home-built Rev Counter

THERE cannot be even one, among the many thousands of power modellers, who has not at some time or other, wished to know just how many revs. his particular engine is turning out.

There was a time when nearly every aeromodeller's tool kit included a rev. indicator of the vibrating reed type; but that phase appears to have passed into obscurity, helped no doubt by the wide variance of readings that could be obtained by a selection of those "instruments" even when applied to one test engine at set constant speed! So this indicator designed and built by S/Ldr. Sholto Douglas has a double interest, for not only is it simple enough for any mechanically minded and equipped modeller to tackle, but it is also very accurate for any reading obtainable from a model engine.

Construction of this indicator starts at the back with a simple item such as a meat paste pot lid (the type that is $1\frac{11}{16}$ in. inside diameter is best) suitably drilled centrally to take the back piece, which is threaded internally for the shaft, and externally for the centre piece. By having this external thread constant for all sizes, it is possible to make a set of different back pieces with changes of internal thread for varying engines.

The centre piece, drilled and



Brauner Pulse Jet
ALL DIMENSIONS IN MILLIMETRES.
SCALE: 1, 2 & 3. FULL SIZE. 4, 5, 6, 7, 8, 9, 10 & 12. HALF SIZE. 11. 1/10 FULL SIZE.
WEIGHT: 9·876–12·345 ozs.
THRUST: 3·968 lbs.
O/A. LENGTH: 21·772 ins.
MAX. DIA: 2·520 ins.
JET DETAILS.
VALVE DETAILS.
NOSE CONE
TAIL PIPE.
GENERAL ARRANGEMENT.
NOTE: ABBREVIATIONS.
R = Radius.
D = Diameter.
M = Metric Thread.
M60 X1
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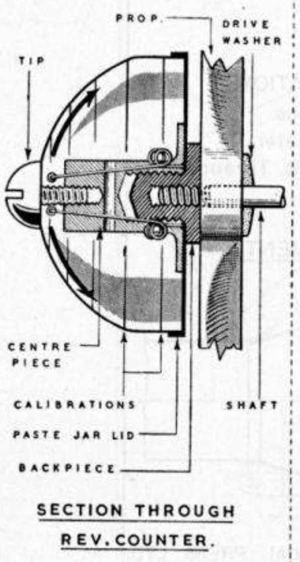
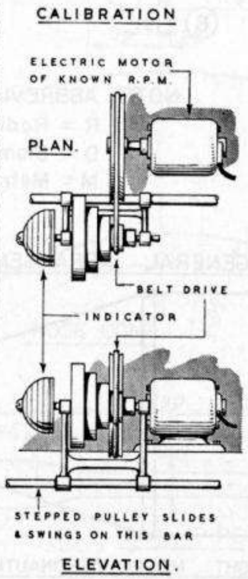
tapped to suit the outside thread of the back piece, has a hole for a tommy bar, and can thus be used as a replacement for the normal airscrew nut, the whole indicator remaining in place throughout the flight. Since it is no larger than the average aluminium spinner, it then doubles both for appearance and indicating r.p.m. at take-off.

Now for the parts that do the work and actually show the revs. per minute. Four holes are drilled in the base of the centre piece and connected by saw cuts as two pairs. Both holes and sawcuts should fit the wire as closely as possible. Then two lengths of 30 gauge piano wire (control-line wire) are each bent into a square "U", with a double coil on either side. The ends are passed through the holes in the base and bent square so that they are locked in the saw cuts, and clamped there securely when the meat paste back plate is sandwiched between centre and back pieces. Top bars of the two loops that now project from the base of the centre piece are now bound with fine copper wire as balance weights and these are painted white.

For reading off the revs., a form of dial is necessary, and this is provided by a bowl or dome, moulded from Perspex sheet and made to fit just inside the lip of the lid back plate. To do this, a turned wooden form was pressed against heated Perspex and through formed holes in plywood sheets. When held near an electric fire, or heated in a domestic electric oven, the transparent sheet softens and can easily be moulded, providing the job is done quickly. The sheet should be clamped lightly between the ply sheets to prevent the lot from becoming pushed through, or given the chance of becoming wrinkled. Acetate sheet can be used instead of Perspex, but, being softer, it scratches more easily.

When moulded, the dome is drilled to take the last item, which is the screw slotted tip, which retains the dome on to the back plate by screwing into the centre piece. Now the indicator is complete — but for calibration.





DIAGRAMMATIC SECTION OF the rev.-counter at left shows how the unit is used to replace the normal airscrew nut. Calibration details are for large diameter belt drive, description on next page gives simpler friction drive details.

MOUNTED ON A FROG 150, the complete unit may be judged for size. Diameter is slightly less than 1⅞ in., and the general contour resembles a transparent spinner.

Calibration

Assembled complete, the indicator should now be fitted to a suitable motor of known r.p.m. By means of a pulley system, described later, the speed of the indicator can be varied against the electric driving motor, and at each stage the white circle made by the out-flung bars of the wires can be measured for diameter by calipers and noted. Once the desired range is recorded, for example, from 5,000 to 12,000 r.p.m., the dome is detached from the unit and held reversed in a lathe or suitable device, when circles of appropriate diameters are lightly scribed by dividers inside the dome. These are then coloured to any scheme preferred, using coloured drawing inks. Different ranges could be made by altering the gauge of the spring wire or the copper wire balance weighting.

As shown in the diagram on the opposite page, the test rig and pulley system for calibration consists of a hardwood or metal series of pulley steps whose diameter is worked out to gear with the diameter of a wheel on the electric motor.

The calibration rig used by S/Ldr. Sholto Douglas differs slightly in that, instead of using a large flexible driving belt such as we have shown to go around both the electric motor pulley and the stepped pulley, and which, is much larger than the Hoover belt, a friction drive is used.

The Hoover belt on the original test and calibration equipment was fitted around a 4 in. diameter pulley on the electric motor. Known revs. of the motor were 1,450 and, with the belt fitted, the outside diameter of the driven pulley was 4⅜ in. This is used to drive the stepped pulley by friction and as the latter pulley slides and can swing to any position, different speed ranges can quickly be arranged.

On test, the indicator gave no doubt as to its efficiency, as the white painted balance weights varied their throw with speed changes.

APPENDIX I

The need for Silencers

INTEREST in the subject of noise from model aircraft and the introduction of a rule making silencers compulsory for all model engines for S.M.A.E. members suggested the need for an investigation into just how much noise different types of models are making. This article describes the result of measurements made at the Nationals in 1964. It compares noise levels of different categories of model flying.

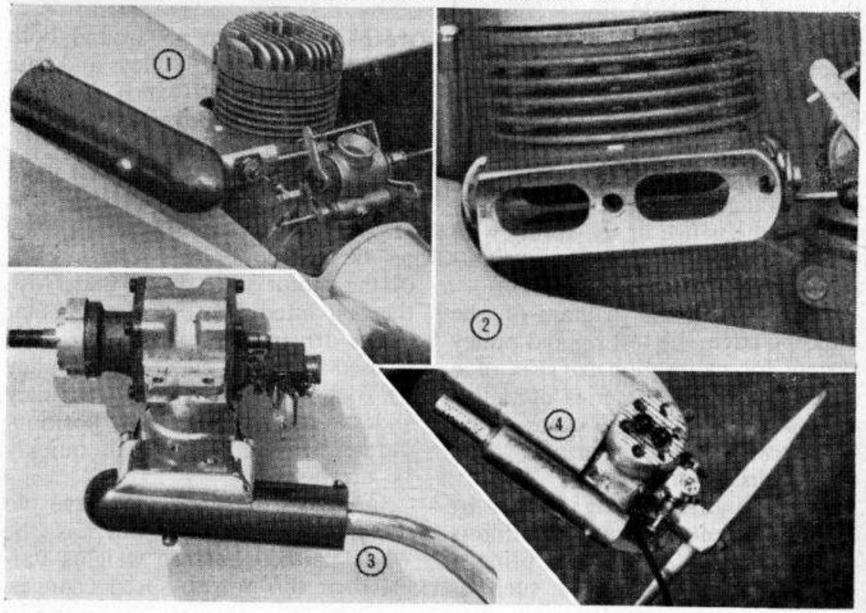
The measurement of sound is a complicated technical procedure with several different units to describe the physical characteristics of the sound such as Sound Intensity and Sound Pressure Level in decibels, and the sensation of loudness produced in the listener in phons and sones. (*Reference* 1). The decibel is a measure of the relative power of two sounds and it only becomes a unit of measurement when an arbitrary reference point is taken. As the loudest sound that we are likely to meet consists of several billion times the energy of the softest, a logarithmic scale is used. This approximates nearer to the response of the human ear than a linear scale. The Overall Sound Pressure Level in decibels is given by the formula:

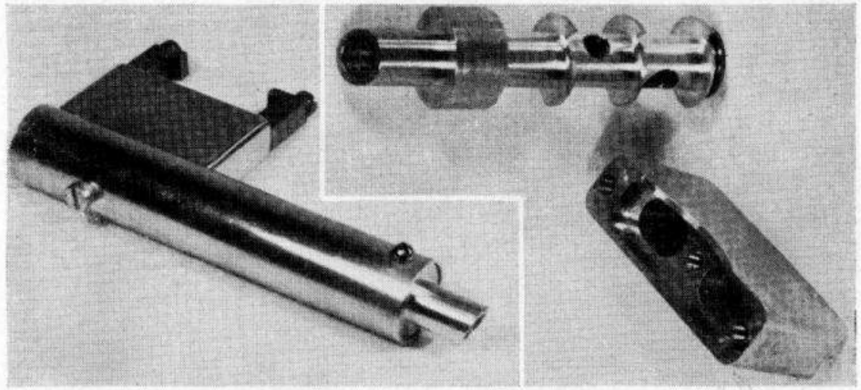
$$\text{O.S.P.L. dB} = 20 \operatorname{Log}_{10} \frac{P}{P_o}$$

Where P = measured sound pressure level and P_o = .0002 dyne/cm². The reference sound pressure.

In practical terms sound meters are

SPINAFLO SILENCER ON A SUPER TIGRE 56 R/C ENGINE WITH THE exhaust baffle incorporated, close up of the mount is in (2) where baffle can be seen. Photo (3) is a McCoy 60 with Johnson carb: and a suspended Spinaflo. Photo (4) is a Rogers-Merco 61, two plugs in the head and Rogers' exhaust silencer.





THE D.A.C. 'Spinaflo' silencer above has an adaptor block according to engine and an internal core with three baffles which rotate the gasflow, hence the name.

built to read directly in decibels and an increase of 6 dB indicates a doubling of the measured sound pressure level.

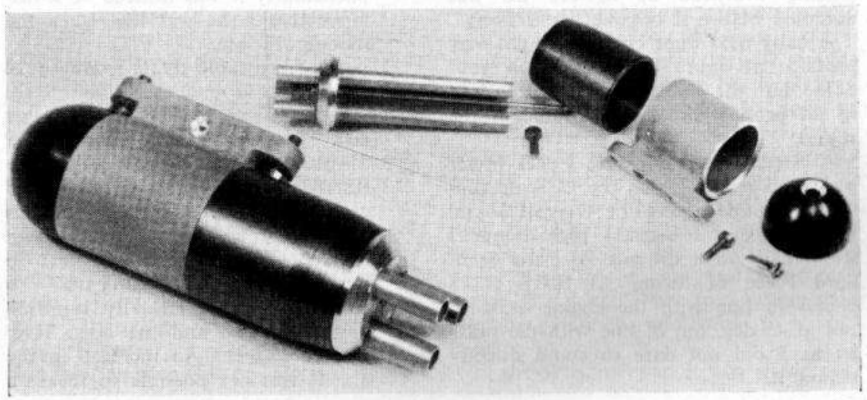
TABLE 1 gives a rough idea of common sounds in decibels:

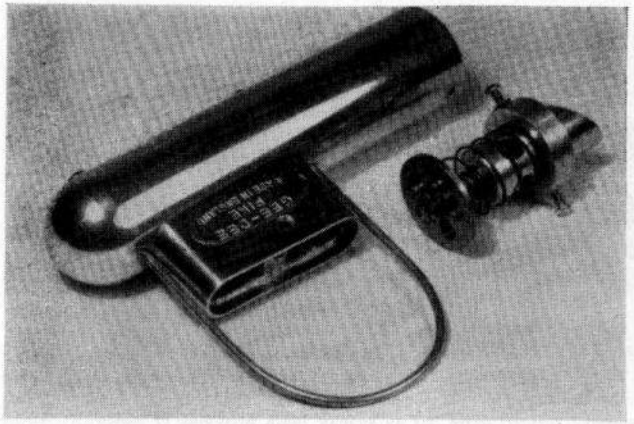
Bird song on a quiet summer evening	40 dB
Normal conversation	60 dB
Underground train	90 dB
Jet airliner take off from outside Control Tower	120 dB

This is by no means the whole picture, however, as sounds occurring in nature are made up of a mixture of frequencies, though one may predominate to give a recognisable "note" to the sound. To measure the sound fully the dB reading for each octave band should be recorded to show how the sound is made up of high and low frequency components. The ear is less sensitive to sounds at either end of the audible range, very roughly, below 100 c.p.s. or above 5,500 c.p.s.

Having now measured the physical characteristics of a noise we are faced with the problem that no two people will hear it exactly the same and that

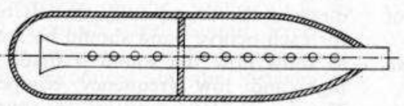
SWISS KOELLIKER SILENCER IS A SIMPLE EXPANSION CHAMBER made up of three pieces plus triple outlet tubes which break down the noise well.

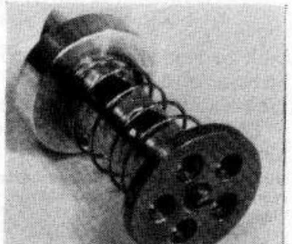




THE GEE DEE PIKE Silencer has an internal spring valve which operates on a resonance with exhaust pressure. See close up. This results in extreme fuel economy and quietness.

THE LINE drawing is a diagram to show what can be done with the plain silencer as originally supplied by O.S. A tube is pushed through from the rear and collects exhaust through holes.





their reaction to it will depend on many different factors. Just two examples quoted in the Wilson Report (*Reference* 2) will show this. A number of people, asked to judge in a controlled experiment, when a motor vehicle was "very noisy" selected 92 dB as the level, but in a similar experiment for aircraft passing overhead up to 115 dB was accepted before it became "very noisy". The baby next door crying at night may produce no more than 40 dB in your home but the annoyance caused is out of all proportion to the volume of the sound.

A Scott Sound Pressure Level Meter was used recording on the C Scale (unweighted) and giving the Overall Sound Pressure Level in decibels. Measurements were made at a distance of "one Standard Piece of String" (1 S.P.S. = 5 paces) in line with the engine exhaust, but at 45 deg. out of line with the pulse jet as I did not dare to stand directly behind it.

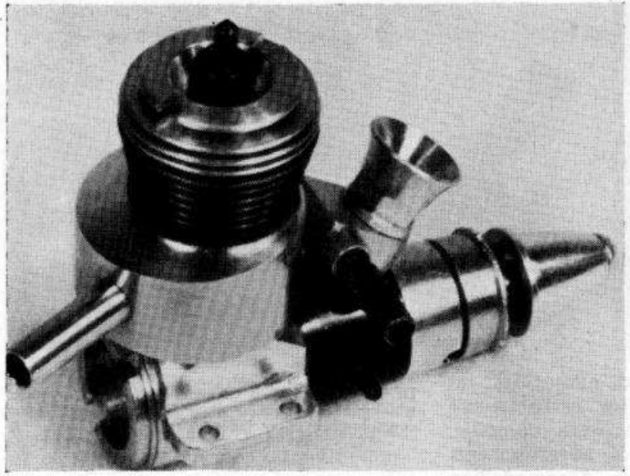
Results

1 Noise from control line flying decreases steadily with distance from the circle, and with stunt models particularly it was noticed at a distance that noise was less when the model was low.

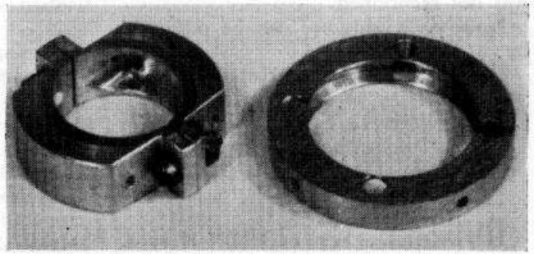
2 Noise from radio flying averaged 70 dB on the ground over about 1 sq. mile and was much harder to get away from than with control line.

3 "Multis" produce little, if any, more dB than a "single" of the same engine type. The apparently anomalous result of a twin being quieter with both engines running was due to loss of power on warming up.

4 Speed models are usually run rich on the ground and the noise level can be expected to increase in the air. It was not possible to measure this increase with the equipment available.



SILENCER AT LEFT for a Cox .049 is by Russell Models, Worksop and Lincoln. Note eccentric manifold chamber which is rotated according to exhaust port position.



THE P. A. MOORE SILENCER for a Cox engine at left is a clamp fit that requires care in installation. At right is the P.A.W. ring for the P.A.W. 2.5, 3.5 and 19 diesels.

5 For a given engine type, noise, as might be expected, increases with an increase of engine speed. The R/C engines seemed noticeably quieter than their C/L equivalent versions.

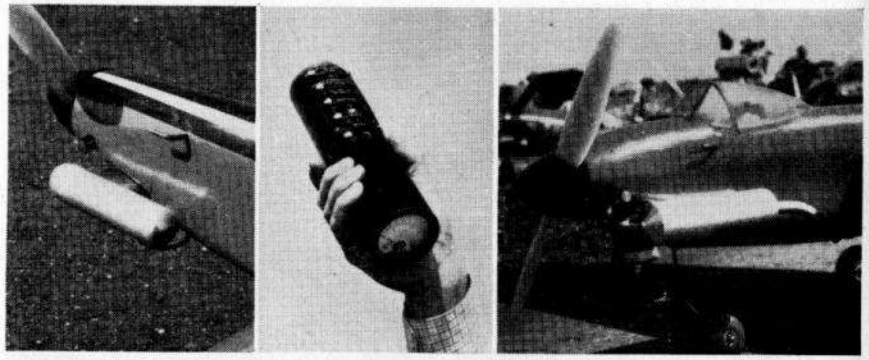
6 In September 1950 the AEROMODELLER reported on the Yulon 49 as unusually noisy. Apart from the Dooling and the pulse jet this still stands.

The dB as measured are no direct measure of potential annoyance. Frequency analysis would have helped as narrow band high frequency noise is more annoying than low frequency noise. However, it is reasonable to expect that, as with full size aircraft, maximum energy is in the frequency band covered by the motor speed in cycles per second, i.e., Stunt 200 c.p.s. and Speed 400 c.p.s. (*Reference* 3).

It seems probable that silencers reduce high frequency noise more than low frequency so that their effectiveness may be even better than suggested by the figures.

The reaction of people to noise is very complex and depends on duration, frequency of exposure and normal background noise as well as the character and sound pressure level of the noise itself. It is worth remembering that old people are more upset by any disturbance than young, and that what may sound like a mild buzz to a young man may be genuinely intolerable to an old lady.

In the Wilson report it was stated that



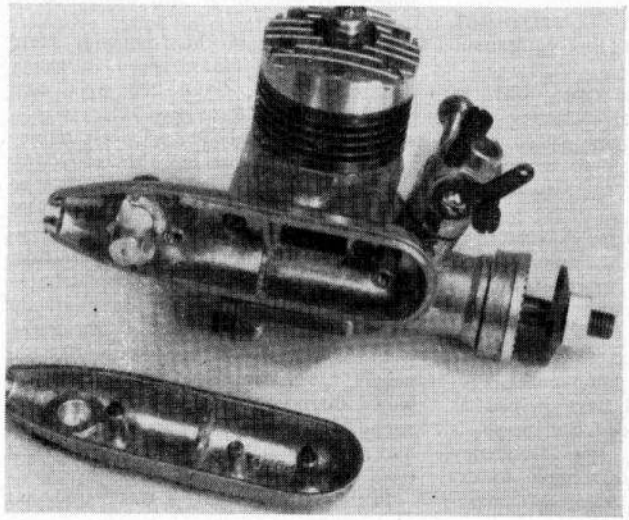
in one year 72 local authorities received 2,350 complaints of noise of which the commonest were domestic, motor vehicles, factories, advertisements and others in that order. Aeromodelling was not mentioned.

Noise as a nuisance can be mitigated by:

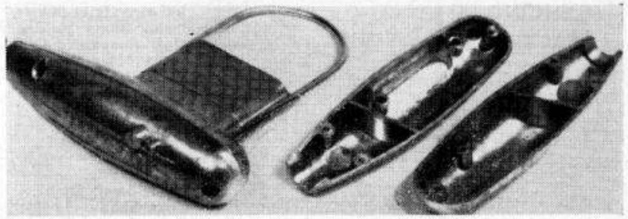
1 *Control at source. Silencers and/or limited flying hours.*
2 *Screening. This does not help with aeromodelling.*
3 *Keeping it at a distance. It is only common sense to fly well away from houses.*
4 **Prohibition.**

THE SCOTT METER AS USED BY AUTHOR Dr. M. F. Hawkins for figures in this Appendix is sandwiched between views of Geoff Higg's home constructed silencer units.

Damage to the ear by permanent loss of hearing can result from exposure to loud noises. Pulse jets produce noise of this level but the exposure of the ground crew is usually remarkably short. However, if ground running of more than four minutes in any one day is contemplated, then some sort of ear protection should be worn. To summarise:



THE O.S. SILENCER with rotary baffle inside connected to the carburettor to aid speed control.



THE MERCO Silencer at right, showing internally cast baffles.

1 Sufficient noise is produced by most forms of model engine to cause a public nuisance and unless action is taken to mitigate the noise, complaints, and therefore loss of flying grounds will increase in the future.
2 Efficient silencers greatly reduce the O.S.P.L. and the annoying character of the noise, but they do not eliminate it altogether and annoyance could still be caused by some forms of "silenced" model.
3 There seems to be little point in fitting a silencer to a "sports" engine of under 1 c.c. as their noise level is well below that of a silenced .35.
4 To quote again from the Wilson Report: "A noise problem must involve people and their feelings and its assessment is a matter rather of human values and environments than precise physical measurement."

REFERENCES

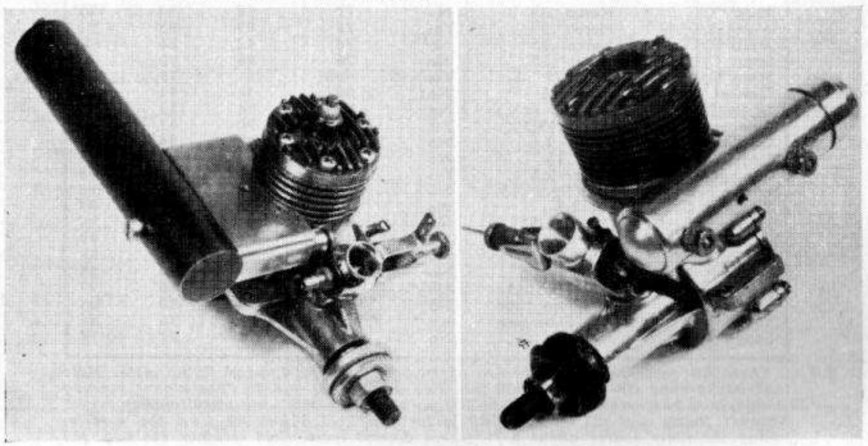
1 *Parrack, H. O. "Effects of Acoustic Energy" in Aerospace Medicine. Ed. Armstrong.* 284-323. *Balliere Tyndall and Cox* 1961.
2 *Final Report of Committee on Noise. Ed. Wilson H.M.S.O.* 1963.
3 *Gasaway, D. C. "Noise Associated with Operation of Military Aircraft". J. Aerospace Medicine.* 35.327. 1964.

Tests with Silencers

Engine	*Type of Silencer*	*Noise Silenced*	*Noise Unsilenced*
Merco 35	Fox	90	94
Merco 35	D.A.C.	80	94
Merco 35	Higgs home-made	80	94*
Merco 35	O.S. Jetstream	82	94*
Johnson 35	O.S. Jetstream	81	94*
Taplin Twin	Manufacturers	80	—

**Estimated*

SPINAFLO SILENCER ON A VECO 19 AND AUSTRALIAN BURFORD silencer on a Taipan 29 R/C. Note the hole for easier priming on the latter at side, and on Spinaflo above adaptor block.



SILENCING FACTS AND FIGURES

RELATIVE LEVELS OF TYPICAL NOISES

NOISE	DECIBELS	TYPICAL EXAMPLES
	120	Threshold of Feeling
Deafening	110	Jet Aircraft at 500 ft. Inside Boiler Making Factory Near Pneumatic Drill Motor Horn at 20 ft.
	100	
Very Loud	90	Inside Tube Train Busy Street Workshop Small Car at 24 ft.
	80	
Loud	70	Noisy Office Inside Small Car Large Shop Radio Set—Full Volume
	60	
Moderate	50	Normal conversation at 3 ft. Urban House Quiet Office Rural House
	40	

Nationals Recordings

All readings in dB. at standard distance from exhaust.

1—**Stunt**
Merco 35 — 96, 94
Fox 35 — 91
Super Tigre 35 — 86
Oliver Tiger — 84
O.S. Max I. 35 — 97
O.S. Max III. 35 — 95

2—**Radio**
Merco 49 — 93, 95

3—**Scale** (Radio)
Merco 35 — 88
Super Tigre 56 — 96
Enya 35 TV — 86
Merco 49 — 92
Frog 500 — 82 (inside cowl)
Enya 29 — 94 (inside cowl)
Rivers 2.5 — 85
A.M. 1.5 — 80 (76 with cowl)
McCoy 60 — 98
Torp 19 x 4 — 88 (all running)

(Control line)
Yulon 49 — 97
E.D. 3.46 x 2 — 82 (83 one running)
(Free flight)
Mills .75 — 76
Mills 1.3 — 70 (very large prop)
A.M. 2.5 — 84
A.M. 1.5 — 80

4—**Free Flight Power**
Torp 19 — 92
Enya 19 — 90
Cox T.D. 15 — 94, 94
Cox T.D. .049 — 89

5—**Team Race**
Eta 29 — 94
Oliver Tiger 1.5 — 82, 84

6—**Combat**
Oliver Tiger 2.5 — 82, 86, 86

7—**Speed**
McCoy 60 — 98
Super Tigre 29 — 96
Johnson 29R — 97
Dooling 61 — 111
O.S. Pulse Jet — **120**

Model type	Engine type	Silenced	Backgound Noise at site	Test dB readings 15 ft.	50 ft.	In air
Multi R/C	Merco .49	No	77	97	94	96
Multi R/C	Merco .35	Yes	78	89	83	91
Multi R/C	Merco .35	No	78	92	86	92
Stunt C/L	Merco .35	No	76	96	90	96
Stunt C/L	O.S. .29	Yes	48	81	79	82
Combat C/L	A.M. 3.5	No	80	98	91	94
Single R/C	O.S. .19	No	78	84	80	90
Combat C/L	PAW .19D	Yes	78	90	83	96
Combat C/L	Oliver 2.5	No	76	92	86	88
Single R/C	O.S. .15	No	78	96	90	94
Combat C/L	Oliver 2.5	Yes	50	81	78	80
Power F/F	Sup. Tigre .15	No	48	98	95	96
T. Racer C/L	Eta 2.5	No	48	93	89	97
T. Racer C/L	Oliver 1.5	No	47	84	82	86
Combat C/L	Cox TD .09	No	48	98	94	99
Sports F/F	A.M. 1.5	No	76	84	80	86
Sports F/F	A.M. 1.0	No	76	83	79	85
Single R/C	Cox TD .049	No	76	97	90	97
Sports F/F	Wen Mac .049	No	76	86	80	83
Sports F/F	Cox Babe Bee	No	76	84	76	86
Sports F/F	Mills .75	No	77	77	77	77

These dB readings were recorded at two well known London flying sites. Note that background dB readings fall into two groups, 40 and 75. The higher reading is due to a busy main road within 100 yards of one site, and simultaneous model aircraft flying. For all tests the dB meter was held downward from the models, facing the noise source about 5 ft. above ground level. Cold weather (40 deg. F.) conditions with slight drizzle prevailed.

APPENDIX 2

R.P.M. TEST FIGURES by TED MARTIN* ON VINTAGE U.S.A. ENGINES STILL IN REGULAR USE

TOPFLITE "POWER PROPS"

ENGINE (.19—.60)	10 x 8	10 x 6	9 x 8	9 x 6	8 x 8	8 x 6	7 x 9
54 Fox 19		11,500		12,000			14,000
Fox 25		12,000		12,800			14,200
Fox 29	11,500	12,400	12,600	13,700	14,050	14,800	14,650
Moir-Fox 29			13,200	14,250	14,600	15,400	15,300
Fox 29R	12,200	13,150	13,500	14,600	15,050	16,100	16,000
Fox 35	11,900	12,750	13,050	14,100	14,500	15,250	15,100
McCoy 29FR	11,400	12,250	12,500	13,600	14,000	14,800	14,500
McCoy 35	12,200	13,000	13,250	14,400	14,700	15,450	15,400
Veco 19		11,400		11,950			13,800
54 Veco 29	11,000	11,900	12,100	13,200	13,400	14,000	13,700
K. & B. 23		11,800		12,400			14,150
K. & B. 35	12,000	12,800	13,200	14,250	14,600	15,400	15,300
Johnson 29	11,100	12,000	12,300	13,400	13,500	14,100	13,800
Forster 29	9,000	10,400	10,600	12,500	12,750	13,700	13,900
Cameron 19		11,000		11,500			13,200
McCoy 60	14,750		16,100		17,050		

ENGINE (.049—.09)	6 x 5	6 x 4	6 x 3	5¼ x 5	5½ x 4	5¼ x 4
Sky Fury 049	10,000	11,000	12,900	12,200	13,200	14,300
Sky Fury De Luxe ...	11,200	12,350	15,000	14,900	16,200	18,100
O.K. 049D	10,500	11,700	14,000	12,800	13,700	15,200
McCoy 049 Glow ...	10,500	11,750	14,250	13,000	14,500	17,000
McCoy 049 Diesel ...	11,200	12,400	14,700	13,750	14,250	14,800
Ohlsson 049 Midget ...	11,800	13,300	15,400	14,100	16,000	17,500
Royal Spitfire 049 ...	9,500	10,500	13,000	13,200	11,500	15,500
Wen Mac 049	9,000	10,400	13,100	11,500	13,350	15,600
Atwood 049	10,500	11,900	14,000	12,500	14,100	16,740
Shriek 049	10,850	12,250	14,400	12,900	14,500	17,200
K. & B 09	13,550	15,000	16,200	14,900		
Cox 049	12,000	13,650	16,400	15,050	18,000	21,200

*Noted British engine designer (Amco 3.5 P.B. & B.B.) currently designing high performance racing car engines.

APPENDIX 3

Torque Absorption Data

A limitation, common to all engine performance test reports to date, is a lack of co-relation between performance in terms of torque output and B.H.P. and performance in terms of r.p.m., with a given size of propeller. Some reports give torque and B.H.P. and no propeller-r.p.m. figures. Others give propeller-r.p.m. figures and no torque or B.H.P. measurements. Our own policy throughout has been to give both, but as a general rule derived under somewhat different test conditions. For that reason, and others which will be discussed, anomalies can appear. Engine "A" which, from the B.H.P. curve is seen to be more powerful than engine "B" does not give a correspondingly higher r.p.m. figure on a quoted size of propeller.

In terms of basic theory the torque absorbed by any particular propeller should be proportional to (r.p.m.)^2, so that the performance of any particular propeller should be capable of being expressed in the form.

Torque $(Q) = K N^2$

where K is a constant (torque coefficient) N = r.p.m.

To be strictly true torque absorbed will also vary with the density of air and so a more accurate equation is

$$Q = Cqo N^2$$

where Cq is the torque coefficient of the propeller, and o is the relative air density.

Now unfortunately Cq is very dependent on the geometry of the propeller. Nominally identical propellers may have quite different values of Cq depending on differences in edge form and thickness, actual blade section, and so on, so there is one possible source of error. The fact that the relative air density may be several per cent different on two different occasions for testing is another.

Other possible sources of error are largely concerned with measurement and adjustment—limits of accuracy of the measuring instrument used and in adjusting the engine itself to optimum settings on a particular load.

Dealing with direct measurement first. Liability to error in r.p.m. measurement can be as high as **plus or minus** 10 per cent with a good reed tachometer and up to twice this with a poor one. That could mean a matter of 1,500 to 3,000 r.p.m. at a nominal 15,000 r.p.m. In general, errors will be smaller than this but, in any case, reed-type counters are not used for our own figures. But either of the alternative standard types—a tachometer or a stroboscope—are still subject to limitations. The former absorbs a certain amount of power to drive and therefore gives a slightly low reading. The latter is subject to drift, possibly as much as 500 r.p.m. **either side** of a nominal value at times.

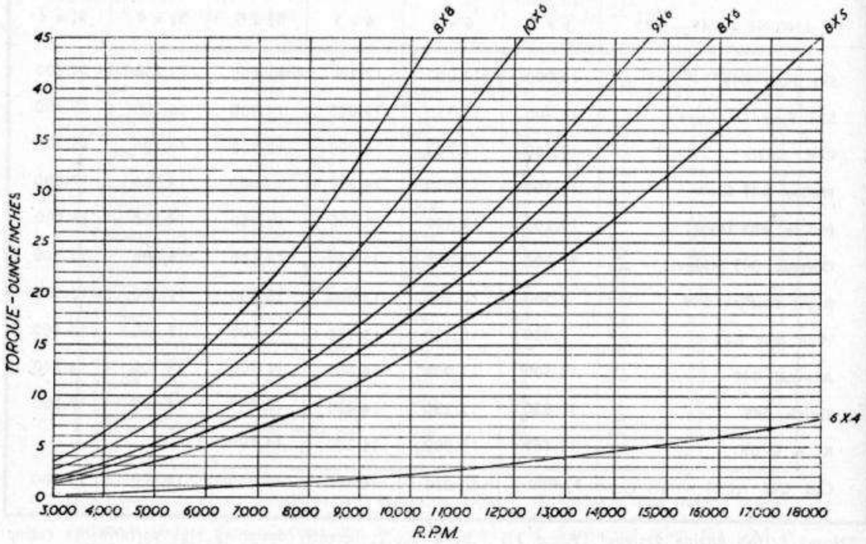
Add to this the fact that engine adjustment also plays a significant part. Also, of course, many engines tend to lose speed on warming up and show a consistent r.p.m. figure lower than might be obtained by measuring straight away after starting.

Try running the same engine with the same propeller on a really rigid mount and then on a fairly flexible mount and again you may get a wide difference in the two r.p.m. readings.

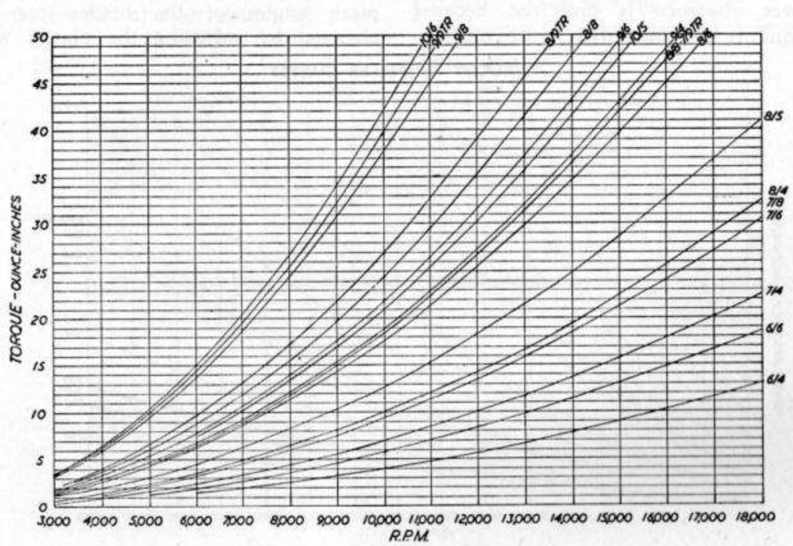
Sooner or later, even taking care to reduce reading and adjustment errors to a minimum, all the "plus" or "minus" errors are going to add up the same way and then you get a big discrepancy, which may well pass unnoticed at the time. Since by far the most difficult part of engine testing is in extracting torque figures corresponding to different speeds, i.e., at different braking loads, one is rather apt to regard the more direct measurement of how fast an engine will drive a particular prop, as more of an afterthought.

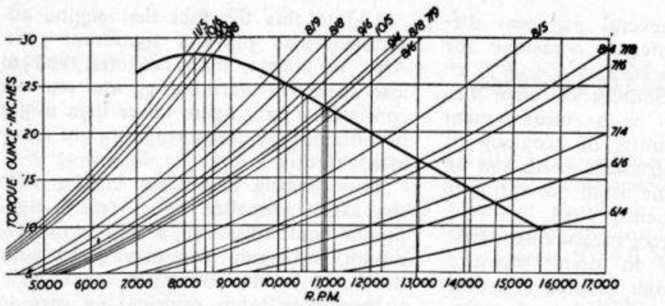
To the engine user, however, the propeller data is probably of more use

TORQUE ABSORPTION : FROG PLASTIC PROPELLERS



STANT PROPELLER CURVES





HOW TO USE the prop. torque charts. This graph shows an overlaid torque curve, taken from an AERO-MODELLER engine analysis, with figures for the Stant prop. range. Reading off estimates, the engine should deliver 14,200 r.p.m. on a 7 x 4, 10,500 r.p.m. on a 9 x 6.

than B.H.P. or torque curves and so for a long time it has been appreciated that a reliable tie-up between the two was necessary. By conforming strictly to the use of a selected batch of propellers only and averaging out results over a large number of engine tests it has, finally, been possible to produce a series of curves which show good co-relation with practical results.

Frog Prop Curves

These curves plot torque absorbed by each propeller against r.p.m. and are based on the simplified equation of torque=torque coefficient **times** (r.p.m.)^2 and assumes that air density is constant. The use of **torque** absorbed instead of **power** absorbed is preferred because torque is the **measured** figure on test.

The corresponding horse-power absorbed is found by

$$\text{horse-power} = \frac{\text{torque (oz.-in.)} \times \text{r.p.m.}}{1{,}008{,}000}$$

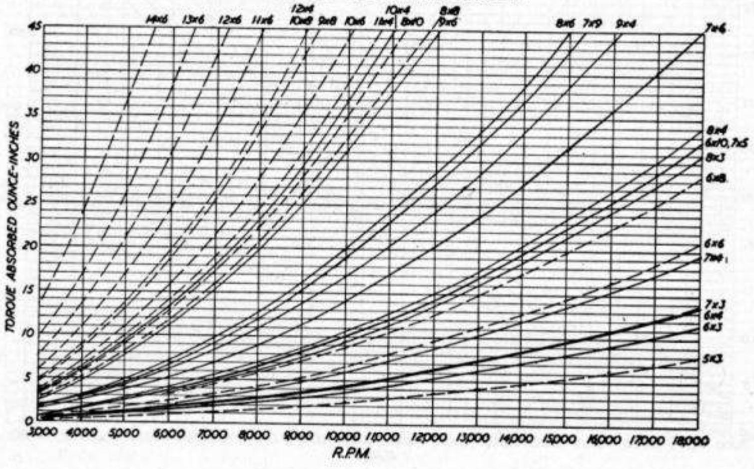
or with sufficient accuracy for most purposes.

H.P.=torque (oz.-in.) x r.p.m. **divided** by 1,000,000.

Thus thinking in terms of power, original errors are **multiplied** by r.p.m. and so exaggerated.

The Frog range of plastic propellers is actually moulded in high impact Polystyrene, Acetate and Nylon AF, the former in colours (mainly red) and the latter only in natural (translucent creamy-white). Both materials are thermoplastic which means that the pitch angles of the blades can be changed by softening the plastic with

TRUCUT PROPELLER CURVES



gentle heat and twisting. This is an advantage in many practical cases. For example, the standard propeller for the Frog "50" is the 6 x 4 which is a little too small for optimum performance on a control line model. A marked improvement can generally be realised by resetting the blades to a slightly coarser pitch angle (5 to 6 inches pitch) and, if necessary, trimming the blade diameter slightly. Such treatment provides an "intermediate" propeller size to fill the gap at present existing between the 6 x 4 and the next smallest size in the range (8 x 5).

The fact that the materials used are thermoplastic is also a disadvantage in that the pitch as moulded may be subjected to change on ageing. In fact the final pitch on any moulded propeller is largely dependent on the temperature of the product when initially removed from the mould. Thus individual examples do show differences in performance in practice, the main offender in the range being the 8 x 5 which has a somewhat thick blade section.

Data on Torque Absorption for the Wooden Prop Ranges

From the readers' point of view these should be of value in estimating probable r.p.m. figures with standard commercial propellers against an engine performance curve—subject to a rather wide range of tolerance and the fact that discrepancies may well show up related back to some individual test reports because of the different conditions under which some of these figures were obtained.

Table below gives comparison of figures measured from graph and actual readings taken on test bench from engine, discrepancies of up to 200 r.p.m. are insignificant.

Propeller	R.P.M. from graph	R.P.M. as measured
11 x 5	8,000	8,000
10 x 6	8,250	8,200
10 x 6	8,250	8,200
9 x 9	8,450	8,400
9 x 8	8,650	8,600
8 x 9	10,200	9,600*
9 x 6	10,500	Not tested
10 x 5	10,650	10,500
9 x 4	10,950	11,000
8 x 8	11,050	10,900
7 x 9	11,050	11,000
8 x 6	11,250	11,200
8 x 5	12,350	12,250
8 x 9	13,050	13,000
7 x 4	14,200	Not tested
6 x 6	14,700	Not tested
6 x 4	15,750	Not tested

* Test report reads . . . "motor was not happy with this prop".

APPENDIX 4

World's Model Engines

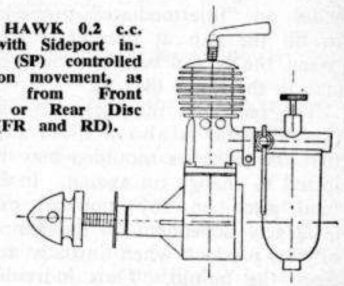
The old scheme of classifying engine utility against its capacity used to serve as a standard yardstick — until engine design unfolded new techniques, new power levels. For example, there are some 1.5 c.c. diesels equal in usefulness to others of 2.5 capacity. Conversely there are 2.5 c.c. engines with "slogging" power at lower, revs per minute, that equal much larger engines for use in a sport model, yet fall below requirements for 2.5 c.c. when employed for a contest model.

Grading the world's engines so that due allowance be made for differences in characteristics and power output has meant that no less than fourteen classes are used to segregate the vast range from .15 to 26 c.c. The classes are lettered from **A** to **O** and to find the grading for your particular engine, just follow the line against its name until you reach the "power coding" column.

Propeller Selection

Against each engine there are three sizes of propeller. These are basic dimensions derived from practice in the field, contest flying, sports flying and designer's advice. Use the size given if you have any doubt on your own selection — and remember — large airframes (72 in. for 2.5 c.c.) require an extra inch in prop diameter, keeping advised pitch, and smaller airframes (48 in. for 2.5 c.c.) can be cut by as much as half an inch on diameter.

KEMP HAWK 0.2 c.c. diesel with Sideport induction (SP) controlled by piston movement, as distinct from Front Rotary or Rear Disc valves (FR and RD).

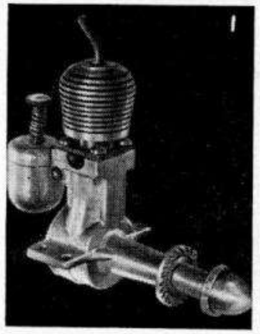


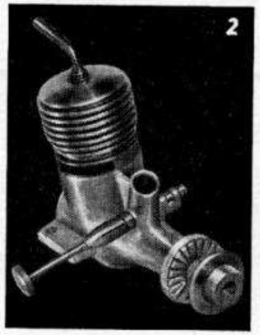
Gear the pitch of your prop against the rate of climb and engine r.p.m. (4 in. pitch for a fast climbing contest model and 12,000-13,000 r.p.m. engine) or step up the pitch for slower sports models (6 in. pitch for 7,000-9,000 r.p.m.). A good tip is to fit the prop back to front for first test flights when full thrust is not advisable.

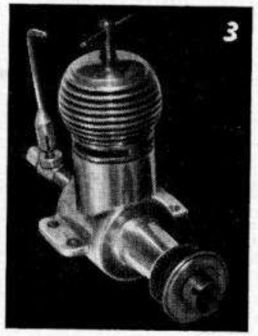
Above all: mount your engine firmly, and treat it with the respect it deserves.

ABOVE LETTER POWER CODING SYSTEM IS APPLIED TO ALL POWER DESIGNS IN THE AEROMODELLER PLANS SERVICE.

THREE DIFFERENT INDUCTION SYSTEMS are typified below. (1) is Sideport (SP); (2) is Front Rotary via the crankshaft valve (FR); and (3) is Rear Disc valve (RD).







WORLD'S MODEL ENGINES (excluding Soviet Products)

ENGINE	DISPLACEMENT cc.	DISPLACEMENT cu. ins.	Cylinder Bore	Cylinder Stroke	WEIGHT (ozs)	Useful RPM RANGE	RECOMMENDED PROPELLER Sport	Contest	C/L	MOUNTING*	• Induction	POWER GROUP
BRITISH												
Allbon Bambi ...	.15	.009	.21	.25	.75	10–14000	4x2	—	—	R or B 9/16	FR	A
Kalper	.32	.019	.251	.402	.875	9–11000	5x3	—	—	B 11/16	SP	B
E.D. Baby	.47	.028	.312	.375	1.4	10–12000	5x3	6x3	6x3	B 3/4	FR	B
Frog 50	.49	.030	.343	.33	1.25	11–13000	6x3	6x3	6x4	B 3/8	FR	B
Allbon Dart ...	.55	.036	.35	.35	1.25	9–14000	7x4	6x3	6x4	R or B 11/16	FR	C
Elfin .5	.536	.0327	.329	.385	1.5	10–12000	6x4	6x4	6x4	R	FR	B
A.S. 55	.566	.034	.350	.356	1.5	6–16000	7x4	5x6	6x4	B 11/16	FR	C
Cobra 049	.798	.0487	.406	.376	1 3/8	8–16000	6x4	6x3	6x4	B 3/4	RR	C
A-M 049	.83	.0506	.421	.364	1.75	9–18000	6x4	6x3	6x4	B	FR	C
D.C. Bantam ...	.762	.0465	.410	.352	1.5	10–18000	6x3	5x3	6x4	B 11/16	FR	C
Frog 049	.808	.0492	.400	.392	1.8	8–15000	6x4	6x3	6x4	B	FR	C
Frog 80 Mk II ...	.80	.049	.400	.392	1.9	7–14000	7x4	6x4	6x6	B	FR	C
Mills P 75	.75	.047	.335	.516	2	6 12000	8x4	7x4	6x6	B 7/8	SP	C
Albon Merlin ...	.76	.047	.375	.420	1.75	9–14000	8x4	7x4	6x6	R or B 13/16	FR	C
Amco .87	.87	.053	.375	.5	1.75	7–9000	8x4	8x4	7x6	B 13/16	SP	C
Allbon Spitfire ...	.975	.059	.425	.42	3	9–12000	9x4	8x4	7x6	R or B 7/8	FR	D
E.D. Bee	.98	.059	.437	.420	2.75	8–11000	9x4	8x4	7x6	B 7/8	RD	D
Frog 100 Mk. II ...	1.02	.062	.416	.460	3	6–14000	8x5	8x4	7x5	B 7/8	FR	E
A.M. 10	1.0	.061	.426	.430	3	11–14000	8x4	7x4	7x6	B 7/8	FR	E
M.E. Heron ...	.97	.059	.424	.420	2.4	7–14000	8x4	7x6	7x6	B 7/8	FR	D
Frog Viper	1.48	.09	.500	.460	4 1/8	8–16000	9x4	7x4	8x4	B 1 1/16	RD	F
Frog Venom ...	1.48	.09	.500	.460	3.75	8–12000	8x4	7x4	7x6	B 1 1/16	RD	D
P.A.W. 1.49	1.473	.09	.494	.469	3.5	7–18000	9x4	7x4	7x6	B 7/8	FR	F
Oliver Tiger Cub II	1.46	.089	.4659	.523	4 1/8	7–17000	9x4	8x4	8x4	B	FR	F
E.D. Super Fury ...	1.49	.092	.500	.462	3.75	8–17000	9x4	7x4	7x6	B 7/8	RD	F
Mills 1.3	1.33	.081	.406	.625	3.25	5–8000	9x5	9x4	8x6	B 1 1/8	SP	E
E.D. Hornet ...	1.45	.085	.531	.4	3.25	9–13000	9x5	8x4	8x6	B 7/8	RD	E
E.D. Fury	1.5	.090	.5	.468	3 5/8	8–14000	9x5	8x4	8x6	B 7/8	RR	E
A.M. 15	1.48	.089	.517	.430	3	7–15000	9x5	8x4	7x6	B 7/8	FR	F
J.B. Atom	1.47	.09	.536	.397	3.12	8–10000	8x4	7x4	7x6	R or B 15/16	FR	D
Frog 149 & 150 ...	1.49	.091	.5	.46	3.25	11–14000	9x5	8x4	8x6	R or B 7/8	FR, RR	F
Elfin 1.49	1.49	.091	.503	.466	2.6	11–14000	9x6	8x4	8x6	B 7/8	FR	F
Elfin 1.49 BB ...	1.49	091	.503	.46	4	10–15000	9x6	8x4	8x6	B 7/8	RR	F
AllbonJavelin&Sabre	1.49	.091	.525	.42	3	10–12000	8x6	8x4	8x6	B 7/8	FR	E
Elfin 1.8 PB	1.8	.110	.505	.562	3.25	8–12000	10x6	9x4	8x6	R	FR	F
Elfin 1.8 BB	1.8	.110	.503	.562	4.1	8–14000	10x6	8x4	8x6	B	RD	F
E.D. Comp. Special	2.0	.122	.5	.625	5.75	6–8000	10x6	8x6	8x8	B 1 1/2	SP	E
Allen-Mercury 25	2.4	.147	.57	.562	4	10–13000	10x6	8x4	9x6	B 1"	FR	G
E.D. Racer	2.46	.15	.59	.55	5.4	10–15000	10x6	9x4	9x6	B 1 1/8	RD	G
D.C. Allbon Rapier	2.46	.15	.578	.570	5	8–13000	9x6	8x4	9x6	B 1 1/16	RD	G
Elfin 2.49 PB & BB...	2.48	.15	.554	.625	3.4	9–13000	10x6	8x4	8x6	B or R	FR, RR	G
Frog 249	2.49	.151	.58	.568	6	8–16000	11x6	10x4	9x6	B 1 1/16	FR	G
Rivers Sil. Streak II	2.49	.152	.578	.578		8–17000	10x6	9x4	9x6	B	FR	G
P.A.W. 2.49 III ...	2.46	15	.592	.532	5	8–17000	10x6	8x4	9x6	B	FR	G
Oliver Tiger III ...	2.424	1479	.551	.620	5.5	8–16000	9x6	8x4	8x6	B	FR	G
ETA 15	2.48	.15	.558	.620	5.75	8–18000	9x6	8x4	9x6	B 1/18"	RD	G
P.A.W. 19D	3.128	.1912	.642	.590	5.5	7–16000	10x4	8x4	8x6	B	FR	H
Rivers Sil. Arrw 3.5	3.46	.211	.607	.642	7 1/8	8–17000	10x6	8x5	9x6	B 1 1/8"	FR	H
Frog 3.49	3.43	.209	.666	.600	6.5	8–14000	10x4	9x6	9x6	B 1 1/8"	RD	G
ETA 19 Mk 2 ...	3.254	.1985	.640	.617	4.5	9–18000	9x6	8x4	8x6	B	RD	H
D.C. Tornado ...	4.972	.303	.567	.585	10	8–14000	11x4	9x6	9x8	R		J
Amco 3.5 PB ...	3.42	.209	.687	.562	4.25	10–12000	11x6	10x4	10x6	R or B 1	FR	H
Amco 3.5 BB ...	3.42	.209	.687	.562	5.5	10–13000	11x6	10x4	10x6	B 1 1/8	RD	H
Allen-Mercury 35 ..	3.42	209	.687	.562	4.5	10–14000	11x5	9x4	9x6	B 1	FR	H
D.C. Manxman ..	3.43	.209	.687	.562	5.5	8–11000	11x6	10x6	10x8	B 1 1/8	FR	H
E.D. Hunter ...	3.46	.211	.656	.625	6.5	8–11000	12x6	10x5	10x6	B 1 1/2	RD	H
Miles Special ...	4.92	.3	.781	.625	10	8–14000	12x6	10x4	10x6	B 1 5/16	RD	J
ETA 29 (glow) ...	4.95	.3	.75	.672	6.5	10–14000	10x6	9x5	9x6	B 1 1/2	RD	J
Frog 500 (glow) ...	4.95	.3	.75	.68	7.75	7–11000	11x6	10x4	9x6	R or B 1 1/4	FR	J
Merco 35	5.794	.353	.800	.703	7.5	8–16000	11x6	10x4	10x6	B 1 5/16	FR	L
Taplin Twin... ...	6.920	.420	.656	.621	15	6–10000	10x8	—	10x8	B 1 1/4	FR	J
NORWEGIAN												
David Anderson ..	2.46	15	.551	.630	5 3/4	6–12000	11x6	9x4	9x6	B	FR	
AUSTRALIAN												
Taipan 1.5	1.500	091	.511	.453	3 3/16	7–16000	8x4	7x4	7x6	B 7/8"	FR	E
Burford Sabre 15 ..	1.42	091	.503	.466	3	8–12000	9x6	8x4	7x6	R	FR	E
Sabre 250	2 46	15	.55	.620	4 1/4	8–14000	10x6	9x4	8x6	B 1" or R	FR	G
Taipan 2.5 BR ...	2.506	1529	.576	.587	5 1/2	8–16000	9x4	8x4	8x6	B 1 1/16"	FR	G
Glo-Chief 19 ...	3.30	.1994	.640	.620	6 1/8	8–16000	9x6	9x4	9x6	B	FR	H
Glo-Chief 29 ..	4.92	30	.739	.700	7 3/8	8–17000	11x4	9x6	10x6	B 1 1/4"	FR	J
Burford Sabre 19 ...	3.27	19	64	.620	6	9–14000	10x6	9x6	9x8	B	FR	H
Sabre 49 ..	8.2	49	.89	79	8	9–13000	11x8	10x6	10x6	B	FR	L

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WORLD'S MODEL ENGINES (excluding Soviet Products)

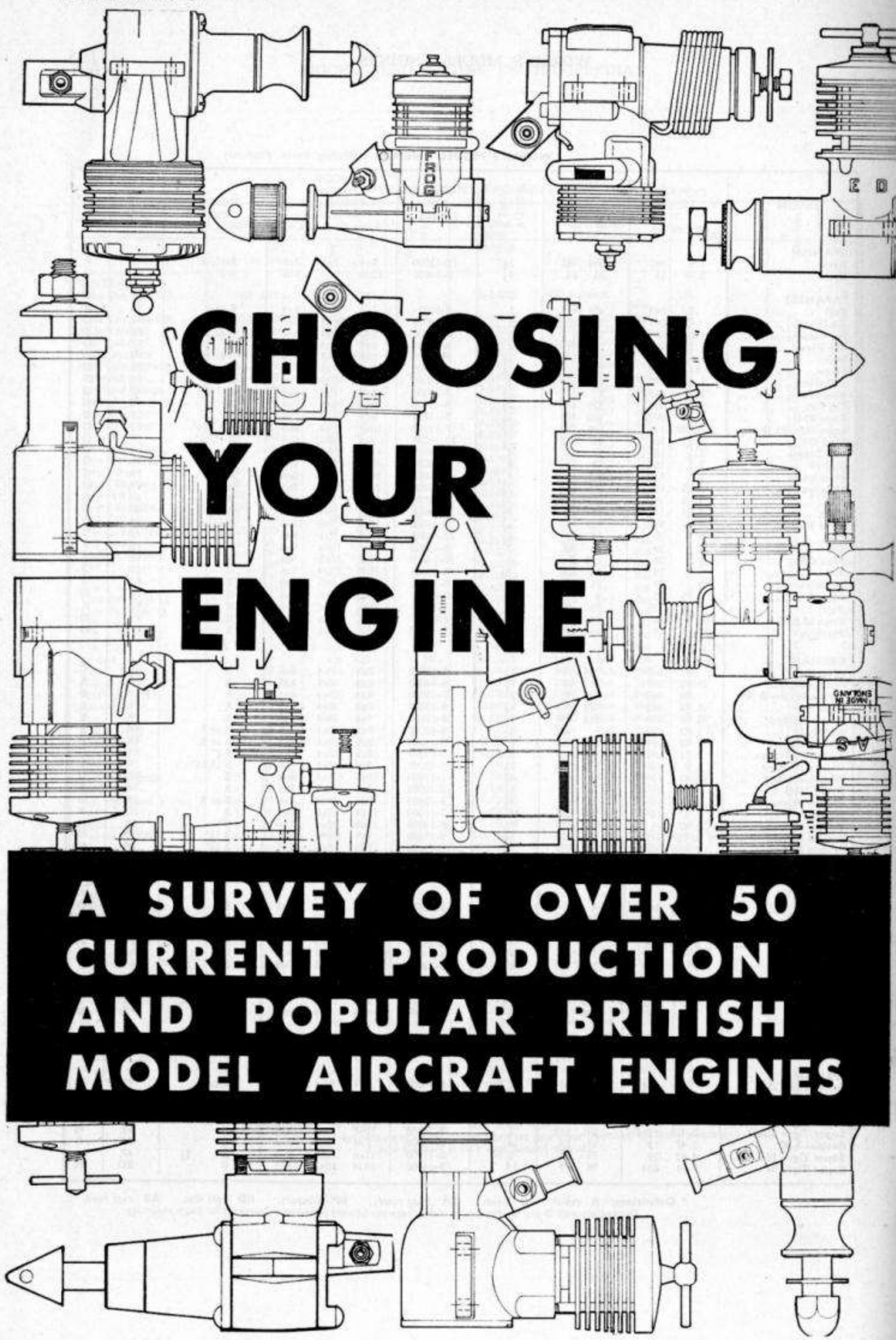
ENGINE	DISPLACEMENT cc.	DISPLACEMENT cu. ins.	Cylinder Bore	Cylinder Stroke	WEIGHT (ozs)	Useful RPM RANGE	RECOMMENDED PROPELLER Sport	Contest	C/L	MOUNTING*	* Induction	POWER GROUP
AMERICAN												
Cox Tee Dee 010 ...	.163	.010	.237	.226	¼	16–34000	3½" supplied. Cox 3¼" x 2¼" three			R	FR	B
Cox Tee Dee 020 ...	.327	.0199	.300	.282	.85	13–23000	Blade or Cox 4"x2½"			R	FR	B
K & B Infant ...	.327	.020	.281	.331	1	12–15000	5x2	5x2	—	R	FR	A
OK Cub	.6	.039	.39	.336	1½	11–16000	5½x4	5½x4	5½x4	R	FR	B
Baby Spitfire ...	.72	.045	.375	.406	1	10–13000	6x4	6x3	6x3	R	FR	C
OK Cub (glow & D)	.8	.049	.420	.36	1¼	9–14000	6x4	5x4	5x4	B ⅞" or R	FR	C
Atwood	.8	.049	.420	.36	1½	9–14000	6x4	5½x3	5½x3	R	FR	C
Holland Wasp ...	.8	.049	.420	.36	1½	9–14000	6x4	5½x3	5½3x	R	FR	C
Holland Hornet ...	.795	.048	.422	.35	2	8–15000	6x4	5½x3	5½x3	R	FR	C
K & B Torpedo ...	.8	.049	.396	.406	1¼	10–15000	5x3	5x3	5x3	R	FR	C
McCoy Diesel ...	.8	.049	.405	.386	1¼	7–15000	7x6	6x4	6x6	R	FR	C
Wen-Mac	.8	.049	.42	.37	1¼	9–16000	6x3	5x3	5x3	B ⅞" or R	FR	C
Cox Babe Bee ...	.81	.0494	.406	.382	1½	12–16000	6x4	6x4	6x4	R	RR	C
Cox Golden Bee ...	.81	.0494	.406	.382	1⅛	10–17000	6x4	6x3	6x4	R	RR	C
Royal Baby ...	.8	.049	.396	.406	1½	10–15000	6x4	6x3	6x3	B	FR	C
Allyn Skyfury ...	.8	.049	.420	.36	1½	9–14000	6x4	5½x3	5½x3	R	FR	C
Atwood	.83	.051	.420	.37	1¼	9–14000	6x4	5½x3	5½x3	R	FR	C
Royal Spitfire ...	1.06	.065	.44	.420	1¾	8–12000	7x4	6x4	6x6	B	FR	D
OK Cub	1.21	.074	.479	.415	1¾	10–13000	7x4	6x4	6x4	B ⅞" or R	FR	D
OK Cub (Diesel) ...	1.23	.075	.48	.415	2	7–12000	8x4	7x3	7x6	B ¾" or R	FR	E
OK Cub	1.6	.09	.51	.5	2	8–13000	8x4	7x3	7x6	B 1" or R	FR	D
McCoy Diesel ...	1.61	.09	.5	.5	2.6	7–12000	9x5	8x4	8x6	B 5/16"	FR	E
Fox 09	1.639	.099	.530	.453	3	8–16000	7x4	6x4	6x6	R or B	SP	D
Fox 15	2.415	.147	.593	.537	4	9–16000	9x4	8x4	8x6	B 1"	FR	G
K & B 15R	2.485	.1516	.599	.537	4.9	10–18000	9x3	8x4	8x6	B 1⅛"	FR	G
Cox Olympic 15 ...	2.423	.1478	.585	.55	4	10–19000	9x4	8x3	8x6	B 1"	RR	G
Cox Tee Dee 15 ...	2.449	.1494	.585	.556	4	10–18000	9x4	8x4	8x6	B 15/16	FR	G
OK Cub	2.45	.14	.6	.530	2.75	9–15000	9x3	8x3½	7x6	B 1⅛" or R	FR	F
K & B Torpedo ...	2.43	.15	.595	.535	3.75	10–14000	9x3	8x3½	7x6	B 1" or R	FR	G
OK Cub	3.25	.19	.655	.59	3	11–13000	9x6	8x4	8x6	B 1¼" or R	FR	G
Arden	3.25	.19	.635	.625	4.16	8–12000	10x4	8x4	8x6	R	FR	H
Veco	3.25	.19	.635	.63	6	11–14000	11x6	9x6	9x8	B	FR	J
K & B Torpedo ...	3.25	.19	.64	.62	5¼	11–14000	11x6	9x6	9x8	B 1¼"	FR	J
McCoy	3.25	.19	.625	.630	4	10–14000	11x5	8x4	8x6	B	FR	H
Cameron	3.25	.19	.64	.62	5	6–14000	10x6	9x4	9x6	B 1¼"	FR	H
Fox	3.25	.19	.65	.6	4½	11–12000	10x6	9x6	10x6	B 1¼"	FR	J
K & B	3.75	.23	.68	.62	5.6	11–14000	11x6	9x6	9x8	B 1 3/16"	FR	J
Ohlsson	3.75	.23	.687	.625	5	6–12000	11x5	9x4	8x8	B 1¼"	FR	H
Fox	4.09	.25	.738	.6	4¾	8–14000	11x6	10x4	9x6	B	FR	J
Ohlsson	4.9	.29	.76	.660	5	7–11000	11x5	10x4	9x6	B	FR	H
K & B Torpedo ...	4.9	.29	.725	.724	7½	8–13000	11x5	10x4	10x6	B 1¼"	FR	J
McCoy	4.9	.29	.75	.672	6	11–14000	10x8	9x6	9x8	B	RD	J
OK Hothead ...	4.9	.29	.76	.660	7½	6–10000	11x6	10x9	9x8	B	FR	H
Forster	4.9	.29	.75	.67	6¼	8–13000	12x6	10x6	10x6	B 1 5/16"	FR	J
Veco	4.9	.29	.725	.724	7½	11–14000	10x8	9x6	10x6	B 1¼"	FR	J
Fox 29 & 29X ...	4.9	.29	.738	.7	5¾	10–14000	12x6	10x6	10x6	B 1 3/16"	FR	J
Dooling	4.9	.29	.8	.594	6¼	10–16000	10x6	10x4	7x9	B	RD	K
De Long	4.9	.30	.748	.680	8¼	8–12000	11x6	10x5	9x6	B	RD	J
Forster	5	.305	.760	.672	6¼	8–13000	12x6	10x6	10x6	B 1 5/16"	FR	J
Ohlsson	5.4	.33	.687	.687	5	9–14000	12x6	10x6	10x6	B 1¼"	FR	J
Fox	5.75	.35	.8	.7	5¾	10–14000	12x6	10x6	10x6	B 1 3/16"	FR	K
Veco	5.75	.35	.78	.725	6¾	10–14000	12x6	10x6	10x6	B 1¼"	FR	K
K & B	5.75	.35	.79	.72	7¼	11–15000	11x6	10x6	10x6	B 1¼"	FR	K
Veco 35C	5.743	.3502	.785	.725	7¾	9–15000	10x6	9x6	10x6	B 1 5/16"	FR	K
K & B 35 (61) ...	5.78	.3574	.790	.719	8¼	9–17000	11x4	9x6	10x6	B 1 5/16"	FR	K
McCoy 35	5.362	.327	.775	.743	7½	8–15000	12x4	10x4	10x6	B 1⅜"	FR	K
Fox 40	6.495	.3961	.800	.788	7⅜	8–16000	11x4	9x6	10x6	B 1¼"	FR	L
Atwood Triumph ...	8	.49	.89 •	.79	8¼	9–13000	14x6	12x6	11x6	B	FR	L
Pal Twin	9	.55	2x.72	.6	10	6–10000	14x6	12x6	11x8	B	SP	K
Fox	9.75	.59	.937	.860	9¼	10–16000	14x6	12x6	11x8	B	RD†	N
Ohlsson	9.9	.604	.937	.875	9	6–12000	14x6	12x6	11x8	B	SP†	M
McCoy	10.0	.607	.940	.875	14	12–16000	12x8	11x6	11x6	B	RD	N
Dooling 61	10.0	.607	1.015	.75	14	11–18000	12x8	10x6	9x11	B	RD	N
Super Cyclone ...	9.9	.604	.906	.937	9¼	6–11000	14x6	12x6	11x8	B	FR	M
Anderson Spitfire	10.6	.64	.937	.937	12	8–14000	14x6	12x8	12x8	B	FR	N
Forster 99	16.4	.997	1.062	1.125	14	3–8000	16x8	14x6	14x8	B	SP	O
OK Twin	20	1.208	2x9	.95	22	6–8000	16x8	14x6	14x8	B	RR	O
Avion Mercury ...	26.25	1.609	1.25	1.312	20	4–6000	16x8	14x6	14x8	B	SP	O

* **Definitions: R** radial. **B** beam. **FR** front rotary. **SP** sideport. **RD** rear disc. **RR** rear reed.
Dimensions with B are for distance in inches between bearers (crankcase clearance) for Beam mounting.
† Also available in FR (Front Rotary) versions.

WORLD'S MODEL ENGINES (excluding Soviet Products)

ENGINE	DISPLACEMENT cc.	DISPLACEMENT cu. ins.	Cylinder Bore	Cylinder Stroke	WEIGHT (ozs)	Useful RPM RANGE	RECOMMENDED PROPELLER Sport	Contest	C/L	MOUNTING*	* Induction	POWER GROUP
SPANISH												
Byra	1.5	.091	.494	.455	3¾	10–13000	9x4	7x4	7x6	B 15/16"	RD	F
Byra	2.47	.15	.56	.64	4½	8–14000	10x6	9x4	8x6	B 1"	RD	G
JAPANESE												
Fuji	.8	.049	.402	.4	1	8–9000	6x4	5½x3	6x4	B or R	FR	B
Ko Diesel ...	.8	.049	.420	.36	2	9–14000	6x4	5½x3	6x5	R	FR	C
Ko Diesel ...	1.6	.099	.51	.5	3	9–14000	8x4	6x4	6x6	R or B	FR	E
OS Diesel ...	1.5	.095	.5	.49	3	8–12000	8x4	6x4	6x6	B	RD	D
Fuji	1.6	.099	.5	.5	2½	9–12000	8x4	7x3	7x6	R or B	FR	D
Hope	.16	.099	.5	.5	1¾	8–14000	8x4	7x3	7x6	B	FR	D
KO Glow ...	1.6	.099	.49	.51	2	10–14000	8x4	7x3	7x6	B	FR	D
Mamiya	1.6	.099	.5	.5	1¾	8–14000	8x4	7x3	7x6	B	FR	D
OS Pet	1.61	.098	.529	.448	2¼	8–15000	8x4	8x3	7x6	B	FR	E
Enya 09-II ...	1.60	.0978	.500	.498	3¼	7–15000	8x4	7x4	7x6	B	FR	E
Enya 15D Mk II ...	2.448	.149	.589	.547	6½	7–17000	10x6	8x4	8x6	B 1 3/16"	FR	G
Max OS	2.5	.15	.597	.540	3¼	10–16000	9x4	8x3½	8x6	B 15/16"	FR	G
KO Diesel ...	2.5	.15	.59	.55	4	8–14000	10x6	9x6	9x6	B	FR	G
Fuji 15	2.5	.15	.59	.55	4	8–14000	10x5	8x4	8x6	B	FR	G
Mamiya 15 ...	2.5	.15	.577	.56	4	8–14000	10x5	8x4	8x6	B	FR	G
Mamiya	3.25	.19	.625	.630	3½	9–15000	10x5	9x4	9x6	B	FR	G
KO	3.25	.19	.625	.630	3¼	9–15000	10x5	9x4	9x6	B	FR	G
Enya	3.25	.19	.63	.63	4¼	12–16000	10x5	9x4	9x6	B or R	FR	G
Enya 29-3B ...	4.94	.3012	.735	.710	6¾	9–16000	10x6	9x6	10x6	B 15/16"	FR	J
Fuji	5	.29	.75	.67	6¼	12–14000	10x6	9x5	9x6	B	FR	J
OS	5	.29	.74	.68	7	8–13000	11x6	10x4	9x6	B	FR	J
Max OS	5	.29	.738	.7	6	10–14000	11x6	10x5	9x6	B	FR	J
KO	5	.29	.74	.68	5¼	8–15000	10x6	10x4	9x6	B	FR	J
Mamiya	5	.29	.75	.67	6	8–15000	10x6	9x5	9x6	B	RD	J
Max OS	5.75	.35	.8	.7	7	10–14000	12x6	10x6	10x6	B	FR	K
Fuji	5.75	.35	.75	.75	6	13–15000	12x6	10x6	10x6	B	FR	K
Enya 60 & 63 ...	10	.60	.94	.875	14	10–16000	4x6	12x6	12x8	B	FR	N
Mamiya	10	.60	.94	.875	16	10–16000	4x6	12x6	9x12	B	RD	N
GERMAN												
Wilo Boy	.71	.043	.394	.354	1½	6–12000	8x4	7x4	6x6	R	FR	C
Webra Piccolo ...	.78	.049	.41	.35	1½	8–14000	8x4	7x4	6x6	R	FR	C
Taifun Hobby & RS	.99	.060	.424	.43	2	7–13000	8x4	7x4	6x4	B	FR, RR	D
Wilo Fox	1.36	.082	.472	.472	2½	8–13000	9x6	8x4	7x6	R	FR	E
Taifun Record ...	1.49	.090	.512	.441	3¼	8–12000	9x6	8x4	7x6	B	FR	E
BWM 150	1.49	.090	.5	.461	3½	8–12000	9x6	8x4	7x6	B or R	FR	E
Webra Record ...	1.48	.099	.512	.453	3	8–12000	9x6	8x4	8x6	B or R	FR	F
Taifun Hurrikan ...	1.51	.092	.507	.457	3.8	10–14000	8x5	7x4	7x6	B ¾"	RR	F
Webra 1.7 glow ...	1.7	.10	.513	.515	2¾	9–13000	8x4	7x4	7x6	B 15/16"	FR	E
Webra Mach. I ...	2.47	.15	.61	.51	4½	11–14000	10x6	8x4	8x8	B	RD	G
BWM 250D	2.47	.15	.56	.64	5¼	8–10000	11x4	10x4	9x6	B	FR	F
Webra Winner ...	2.46	.15	.56	.64	3¾	8–12000	10x6	9x4	9x6	B or R	FR	G
Jaguar	2.47	.15	.59	.55	5¼	7–10000	11x4	9x6	9x6	B	FR	F
Taifun Tornado ...	2.47	.15	.59	.55	5¼	8–14000	10x6	8x4	9x6	B	FR	G
Webra Komet ...	2.454	.175	.551	.627	5½	9–15000	9x4	8x6	8x6	B 1¼"	FR	G
Webra Bully ...	3.416	.208	.650	.627	5½	8–13000	9x6	9x6	9x6	B 1¼"	FR	G
Taifun Bison ...	3.629	.2214	.631	.703	6	8–15000	9x6	9x4	8x6	B	FR	H
Taifun 3.5	3.44	.210	.65	.61	6½	9–13000	11x6	10x6	9x8	B	FR	H
FRENCH												
Micron	.8	.04	.4	.4	2	5–10000	8x4	7x4	6x6	B	SP	D
Meteore	2.47	.15	.59	.551	4	9–14000	10x6	9x4	9x6	B 1"	FR	G
REA	4.79	.29	.74	.66	6	8–12000	10x6	10x4	9x6	B	FR	H
Micron 28	5	.305	.74	.68	7	9–14000	10x6	10x4	9x6	B	FR	H
Micron 29	5	.305	.74	.68	7½	11–14000	10x5	9x5	9x6	B	RD	J
Micron 10	10	.60	.95	.86	8	9–13000	11x6	10x6	10x8	B	FR	K
HUNGARIAN												
Alag X-4	1.517	.0925	.512	.044	2½	8–16000	8x4	7x4	7x6	B ⅞"	FR	E
Moki S-2	2.465	.1503	.590	.550	5	10–19000	9x4	8x4	8x6	B 1¼"	FR	G
DUTCH												
Typhoon R250 ...	2.47	15	.59	.55	4.75	8–13000	11x6	8x4	9x6	B 1"	FR	G
ITALIAN												
Super Tigre 25 ...	.95	.059	.43	.40	2.5	8–14000	8x4	6x4	6x6	B or R	FR	D
Barbini B.38... ...	.99	.061	.4	.48	2	10–13000	9x4	8x4	6x6	B	FR	D
Super Tigre 26 ...	1.49	.091	.52	.43	3	8–14000	9x6	8x4	8x6	B or R	FR	E
Super Tigre 20 & 23	2.46	.15	.59	.55	4	8–14000	9x5	8x3½	7x6	B 1"	FR	G
Super Tigre G20D...	2.482	.1514	.591	.552	6	8–16000	10x4	8x4	8x6	B	FR	G
Barbini B.40... ...	2.47	.15	.57	.59	4	8–12000	9x4	8x3½	8x6	B	FR	G
Super Tigre 19 & 21	4.82	.29	.75	.67	8.5	8–12000	11x6	10x4	9x6	B 1¼	FR	J
Super Tigre 24 ...	9.81	.604	.98	.79	14	9–16000	14x4	10x6	11x8	B	RD	N

* **Definitions: R** radial. **B** beam. **FR** front rotary. **SP** sideport. **RD** rear disc. **RR** rear reed.
Dimensions with **B** are for distance in inches between bearers (crankcase clearance) for Beam mounting.



1965/6 PRODUCTION SUMMARY

A complete listing of British engines in current production with pertinent facts and prices. Basic price is for the benefit of overseas readers who are not liable to Purchase Tax. "D" means Diesel, "G" means Glowplug

Engine	Ignition	Displacement		Cylinder		Weight	May 1965	British price
		c.c.	cu.ins.	Bore	Stroke	(oz)	basic price	with p.t.
A-M								
10	D	1·00	·061	·462	·430	3·0	51/8d	60/10d
10 R/C	D	1.00	·061	·462	·430	3·25	62/8d	74/0d
15	D	1·48	·09	·517	·430	3·00	53/4d	62/10d
15 R/C	D	1·48	·09	·517	·430	3·25	64/2d	75/9d
25	D	2·4	·147	·57	·562	4·00	60/0d	70/9d
35	D	3·42	·209	·687	·562	4·5	61/8d	72/9d
E.D.								
Cadet	D	·98	·061	·437	·400	3·9	24/6d	29/6d
Hawk	D	1·48	·093	·513	·452	3·3	24/6d	29/6d
2·46 Racer	D	2·46	·15	·59	·55	5·4	70/5d	85/0d
2·46 Racer (tuned)	D	2·46	·15	·59	·55	5·4	89/1d	107/6d
2·46 Racer R/C	D	2·46	·15	·59	·55	6·00	89/1d	107/6d.
ETA								
15 Mk III	D	2·48	·15	·558	·620	6·25	125/0d	148/6d
29 Mk VIc	G	4·95	·30	·750	·672	6·5	129/6d	153/10d
FROG								
80 Mk III	D	·80	·049	·400	·392	1·9	46/3d	54/6d
100 Mk III	D	1·02	·062	·416	·460	3·00	48/3d	57/0d
150 Mk III	D	1·49	·091	·500	·460	3·25	50/4d	59/6d
249 BB	D	2·49	·151	·580	·568	6·0	67/4d	79/6d
349 BB	D	3·49	·208	·666	·600	6·7	74/4d	87/6d
349 BB R/C	D	3·49	·208	·666	·600	6·7	88/8d	105/0d
MAROWN								
M.E. Heron	D	·97	·06	·424	·420	2·4	50/10d	60/6d
M.E. Snipe	D	1·48	·09	·505	·455	4·1	56/3d	67/0d
M.E. Snipe R/C	D	1·48	·09	·505	·455	4·25	64/4d	76/6d
MERCO								
·29	G	4·75	·29	·734	·703	7·5	101/3d	119/6d
·29 R/C	G	4·75	·29	·734	·703	8·25	129/0d	152/6d
·35	G	5·79	·35	·800	·703	7·5	101/3d	119/6d
·35 R/C	G	5·79	·35	·800	·703	8·25	129/0d	152/6d
·49	G	8·00	·49	·880	·805	12·5	169/0d	199/6d
·49 R/C	G	8·00	·49	·880	·805	13·00	200/0d	236/8d
·61 R/C	G	10·00	·61	·938	·875	13·00	217/6d	256/9d
P.A.W.								
1·49	D	1·48	·09	·494	·469	3·5	72/10d	86/0d
2·49 Mk III	D	2·49	·151	·592	·532	5·00	83/0d	98/0d
19 D Mk II	D	3·128	·1912	·642	·590	5·5	88/6d	104/6d
19-BR	D	3·128	·1912	·642	·590	6·0	106/9d	126/0d
TAPLIN								
Twin Mk II	D	8·00	·49	·705	·625	17·00	158/4d	190/0d
OLIVER								
Tiger Cub Mk II/S	D	1·46	·089	·470	·523	4·13	108/4d	130/0d
Tiger Cub Mk II(sports)	D	1·46	·089	·470	·523	4·13	125/0d	150/0d
Tiger Mk III/S	D	2·424	·148	·551	·620	5·5	115/10d	139/0d
Tiger Mk III (sports)	D	2·424	·148	·551	·620	5·5	132/6d	152/6d
Tiger Mk III R/C	D	2·424	·148	·551	·620	5·5	145/10d	175/0d
Tiger Major/S	D	3·47	·212	·620	·705	6·00	129/2d	155/0d
Tiger Major (sports)	D	3·47	·212	·620	·705	6·00	145/10d	175/0d
Tiger Major R/C	D	3·47	·212	·620	·705	6·00	160/5d	192/6d
D.C. Quickstart								
Dart	D	·55	·036	·35	·35	1·25	63/9d	75/0d
Bantam	G	·76	·047	·410	·352	1·5	38/3d	45/0d
Bantam de luxe	G	·76	·047	·410	·352	1·5	49/4d	58/0d
Merlin	D	·76	·047	·375	·420	1·75	50/7d	59/6d
Super Merlin	D	·76	·047	·375	·420	1·8	55/3d	65/0d
Spitfire	D	·97	·059	·425	·420	3·00	54/4d	71/0d
Sabre	D	1·49	·091	·525	·420	3·00	63/9d	75/0d

From the smallest . . .

This survey of current production and recent British engines is offered as a buying and identity guide

Made under licence from **Wen Mac** the **A.M. .049** glow engine is no longer in production. This was the first British engine to have a fully enclosed starter called "Rotomatic" in the U.S.A. Front rotary induction with a plain bearing shaft and integral air intake made this a very light-weight engine. For beam or radial mounting the lugs were slotted and not drilled as in the normal manner. Space bearers $\frac{3}{4}$ in. apart. Sadly the **A.S. 55** also went out of production. This was a pity as it was a really nice easy starting and smooth running little engine. Bearers are spaced $\frac{11}{16}$ in. apart for beam mounting. A lively little engine is the red headed **D.C. Quickstart Dart** .5 c.c. diesel. It was one of the first "performance" front rotary induction miniature engines with the air intake cast into the crankcase and now has a coil spring and cam rewind starter with a transparent fuel tank as standard items. Beam mount only with bearers spaced $\frac{11}{16}$ in. apart. The **D.C. Quickstart Merlin** comes in both standard and de luxe versions (called the **Super Merlin**) the extras including a rear bolt-on transparent fuel tank and a red spinner nut and cylinder, front rotary shaft induction via integral air intake. They are easy starters, cheap to run and can be fitted by radial or beam mounting with bearers spaced $\frac{15}{16}$ in. apart. The **D.C. Quickstart Bantam** is also produced as a de luxe version, this including radial mounting rear tank as an extra. It has front rotary shaft induction with the air intake cast into the crankcase. Beam mounting can be used with bearers spaced $\frac{11}{16}$ in. apart. Out of production but still widely used, the **E.D. .46 Baby** is known for its docile handling and ability to run on practically any sort of fuel. Beam mount with the bearers spaced $\frac{3}{4}$ in. apart. Also no longer in production the **Frog 50** diesel was another with front rotary shaft induction and a turned metal tank. With a screw-in cylinder liner and head it proved very popular for small F/F models of up to 35 in. span. Beam mount only bearers spaced $\frac{5}{8}$ in. apart. The current production **Frog 80** incorporates a coil spring cam starter and can be used for all sport models. With a deeply finned steel cylinder, large but shallow exhaust stacks and built in nylon compression screw lock, it has much to commend it. Having front rotary shaft induction with integral air intake it is suited to 30-44 in. F/F or 30 in. R/C and 12-25 in. C/Liners. A glow plug version known as the **Frog .049** was once produced with an unfinned head and knurled spinner nut for pulley starting. Beam mount only on bearers spaced $\frac{11}{16}$ in. apart. The **Mills .75** must surely enjoy a hallowed place in many modellers' hearts for its ability to run for many years without needing any attention, easy starting and slogging power on large props. With side port induction that has the air intake screwed to the rear of the cylinder and a suspended clear plastic fuel tank it is easily distinguishable with its black crackle finish cranckcase and small diameter shaft housing. Beam mount only with the bearers spaced $\frac{1}{8}$ in. apart. Regrettably the Mills .75 is no longer produced. Also out of production the **Keil Kraft Cobra .049** was a rear reed valve induction glow plug engine with a neat rear mounted needle valve. Beam mount on bearers spaced $\frac{3}{4}$ in. apart. Alphabetically last of the small capacity group is the **Z.A. .92** a zippy little engine that starts and runs well. It went out of production only recently. Front rotary induction is arranged via an integral air intake that forms a square block in front of the cylinder. Beam mount only with bearers spaced $\frac{13}{16}$ in. apart. *All the engines in this group should use* $\frac{1}{4}$ *in.* x $\frac{3}{8}$ *in. hardwood bearers for beam mounting.*

17 Years of AEROMODELLER ENGINE ANALYSES

PEAK B.H.P. and R.P.M. FIGURES FOR 212 TESTS

1948

E.D. Comp. Special	May	·109 @ 7,000
Frog 100	June	·058 @ 8,100
Mills Mk. II 1·3	July	·078 @ 7,250
AMCO Mk. 1·87	August	·046 @ 8,900
Eta '5' Diesel	September	·181 @ 6,250
Jagra Dyne 3	October	·103 @ 6,300
Kalper ·3 cc	November	·010 @ 10,250
Allbon 2·8	December	·144 @ 6,500

1949

'K' Vulture 5 cc	January	·246 @ 8,900
2·8 cc Masco Buzzard	February	·108 @ 7,300
Nordec R.G. 10	March	·480 @ 11,200
E.D. Mk. II	April	·128 @ 7,800
Mills Mk. III	May	·167 @ 9,900
Weston 3·5 cc	June	·204 @ 7,500
Elfin 1·8 cc	July	·114 @ 12,100
Frog 160	August	·081 @ 10,850
Eta 29 Mk I	September	·370 @ 11,600
E.D. Mk I Bee	October	·062 @ 10,600
Yulon '30'	November	·310 @ 12,300
AMCO 3·5 cc PB	December	·260 @ 11,600

1950

Allbon Arrow 1·5 Glow	January	·051 @ 11,500
E.D. Mk. IV 3·46 Hunter	March	·265 @ 13,300
Wildcat Mk. III 5 cc	April	·340 @ 10,000
Frog '500'	May	·381 @ 13,300
Elfin 1·49	June	·100 @ 13,700
Javelin 1·49	July	·099 @ 12,000
Fox 35	August	·623 @ 15,000
Forster G-29	August	·580 @ 16,200
Yulon 49	September	·820 @ 12,900
Frog 100 Mk. II	October	·071 @ 8,000
D.C. 350	November	·270 @ 11,000

1951

Allbon Dart	January	·045 @ 13,300
E.P.C. Moth	February	·042 @ 9,700
Reeves, H.18	March	·104 @ 11,700
Super Tigre G.19	April	·485 @ 13,300
Super Tigre G.20	April	·240 @ 14,400
Sabre 2·50 cc	May	·225 @ 13,300
Elfin 2·49	June	·231 @ 12,300
Frog 250	July	·192 @ 10,700
E.D. 2·46 Racer	August	·260 @ 14,100
Frog 150	September	·121 @ 12,900
Atwood Wasp ·8 cc	October	·100 @ 15,400
REA 5 cc	November	·360 @ 10,900
Hot Top Super Hurricane	December	·279 @ 11,600

1952

D.C. 350 (G)	January	·262 @ 11,100
D.C. 350 (D)	January	·281 @ 11,300
Frog 500 Glow	February	·420 @ 13,200
Metro 52	March	·225 @ 12,600
Typhoon 2·47	April	·241 @ 13,500
Mills P.75	May	·059 @ 11,350
E.D. ·46 Baby	June	·028 @ 11,000
Frog 50	August	·030 @ 12,300
Moteurs Micron 28	October	·225 @ 11,000
Super Tigre G. 20. S.	November	·260 @ 14,000
Oliver Tiger Mk. II	December	·305 @ 14,000

1953

Allbon Javelin	January	·130 @ 11,000
E.D. 1·46	February	·150 @ 10,500
Typhoon 5 cc	March	·430 @ 13,000
Allbon Dart Mk. II	April	·042 @ 11,000
AMCO BB 3·5 cc I	May	·320 @ 13,000
Allbon Spitfire	June	·085 @ 11,000
O.K. Cub 2·5 cc	July	·195 @ 12,500
Super Tigre G.22	August	·095 @ 12,600
Typhoon R. 250	September	·290 @ 13,500
McCoy ·049	October	·080 @ 12,000

1954

K & B Torpedo ·15	June	·142 @ 13,600
Oliver Tiger 1·5 Cub	July	·120 @ 12,500
Allbon Bambi	August	·007 @ 12,500
Webra 2·5 Mach 1	September	·218 @ 16,700
Webra 2·5 Winner	September	·162 @ 11,300
Allen Mercury 25	October	·181 @ 12,200
E.D. 2·46 Racer	November	·196 @ 14,650
Allbon Merlin	December	·058 @ 13,000

1955

Elfin 1·49 BB	January	·158 @ 13,600
Webra 1·48	February	·133 @ 13,800
Miles 5 cc	March	·435 @ 13,500
Taifun 1 cc Hobby	April	·100 @ 13,400
Tornado 2·5 cc	April	·192 @ 14,000
Miles Special	July	·365 @ 13,000
Webra ·8 Piccolo	August	·058 @ 12,800
1 cc E.D. Bee Series 2	September	·068 @ 10,900
Jaguar 2·5 cc	October	·199 @ 12,750
Allen Mercury 35	November	·260 @ 11,400
Byra 2·5	December	·196 @ 12,000

1956

Frog 249 BB	January	·206 @ 13,700
Frog 150	February	·108 @ 12,400
Allbon Sabre	February	·104 @ 13,300
Mamiya 15	March	·160 @ 12,800
Super Tigre G.20	March	·174 @ 13,400
J.B. Atom 1·5 cc	April	·090 @ 10,700
Carter 5 cc	May	·595 @ 18,300
E.D. 2·46 Racer (Buskell)	June	·271 @ 14,700
Frog 149 Vibramatic (D)	July	·122 @ 12,750
Frog 149 Vibramatic (G)	July	·078 @ 14,000
Allen Mercury 10	August	·113 @ 14,200
Schlosser 2·5 cc	September	·215 @ 14,000
Daru	September	·154 @ 11,000
OS MAX-15	October	·237 @ 14,650
Elfin 2·49 BR	November	·202 @ 13,200
Eta 29	December	·600 @ 17,200

1957

Taifun Hurrikan 1·48	January	·154 @ 14,500
D.C. Manxman	February	·257 @ 10,700
Frog 80	March	·051 @ 11,000
Byra 1·5	April	·114 @ 12,000
Webra 1·7 cc	April	·090 @ 13,000
Barbini 1 cc	May	·104 @ 15,500
OS 29	June	·480 @ 14,800
D.C. Rapier	July	·213 @ 13,800
Barbini B. 40 T.N.	August	·189 @ 14,000
Spitfire Mk. II	September	·073 @ 12,400
Veco 19	October	·316 @ 15,000
Enya 15D	November	·252 @ 14,200
PAW Special	December	·249 @ 14,000

1958

Alag X-3	January	·185 @ 12,700
Webra 2·5R Glo.	January	·202 @ 13,200
Frog 2·49 Modified BB	February	·253 @ 14,800
Taifun Hobby RS.	March	·071 @ 12,000
Fuji 29	April	·400 @ 12,400
Fox 29X	May	·465 @ 14,000
Fox 29R	May	·625 @ 17,500
E.D. 1·49 Fury	June	·132 @ 14,000
A.M. 15	July	·152 @ 14,000
O.S. Pet 1·6 cc	August	·133 @ 14,400
Super Tigre G-32	September	·097 @ 15,000
Frog 100 Mk. II	October	·103 @ 15,500
Kometa M.D. 5	November	·234 @ 13,000

1959

Taifun Blizzard	January	·242 @ 13,000
Taipan 1·5	February	·110 @ 12,000
Alag X-4	March	·123 @ 13,000
Rivers Silver Streak	April	·277 @ 15,800
Taplin Twin	May	·290 @ 9,000
Glo-Chief 29	June	·495 @ 14,600
Fox 15	July	·218 @ 13,500
Webra Komet	August	·235 @ 13,000
Webra Bully	August	·200 @ 9,500
E.T.A. ·19	September	·300 @ 16,800
Enya 29-3b	October	·590 @ 14,000
Cox 15 Olympic	November	·287 @ 16,500
Frog 3·49	December	·303 @ 12,200

1960

A.M. ·049	January	·052 @ 14,000
D.C. Bantam	January	·053 @ 15,000
Frog ·049	January	·046 @ 12,000
Merco 35	February	·550 @ 13,400
P.A.W. 1·49	March	·176 @ 17,000
A-S 55	April	·052 @ 12,000
McCoy "35"	May	·455 @ 12,000
E.D. Super Fury	June	·162 @ 14,000
Rivers Silver Arrow	July	·382 @ 15,500
M.E. Heron	August	·072 @ 9,500
D.C. Tornado	September	·397 @ 12,200
Cobra ·049	October	·052 @ 15,000
Enya 09	November	·115 @ 12,800
O.S. Pet 09	November	·119 @ 11,000
ETA 15 Mk I	December	·345 @ 16,600

1961

Fox ·09	January	·084 @ 14,000
Rivers Silver Streak 11	January	·296 @ 16,000
P.A.W. 2·49 111	February	·318 @ 15,000
Enya 15D Mk II	March	·332 @ 15,000
Frog Venom	April	·075 @ 10,000
Frog Viper	April	·161 @ 14,800
Cox Babe Bee	May	·056 @ 13,000
Cox Golden Bee	May	·063 @ 14,000
Taifun Bison	June	·304 @ 13,300
Veco 19 R/C	June	·395 @ 14,000
Super Tigre G20D	July	·322 @ 15,000
Glo-Chief 19	July	·310 @ 13,800
Oliver Tiger III	August	·330 @ 15,100
Oliver Tiger Cub	August	·170 @ 14,000
P.A.W. 19D	September	·347 @ 15,000
Cox Tee Dee 010	October	·028 @ 32,000
Frog 80 Mk II	November	·057 @ 11,000
Fox 40	December	·596 @ 14,000

1962

Cox Tee Dee ·15	January	·455 @ 18,000
Veco 35C	February	·538 @ 15,000
Moki S-2	March	·320 @ 18,000
K. and B. 15R	April	·480 @ 19,250
Taipan 2·5B	May	·245 @ 14,000
K. and B. 35 Series 61	June	·560 @ 14,000
Cox Dee Tee ·020	July	·031 @ 20,500
D.C. Bantam De Luxe	August	·053 @ 14,500
Marown Snipe 1·5	September	·138 @ 14,000
Merco 49 R/C	October	·720 @ 12,200
Cox Tee Dee ·049	November	·105 @ 22,000
Taifun Zyklon 2·5	December	·210 @ 12,500

1963

O.S. ·49 R/C	January	·550 @ 12,200
Enya ·45 R/C	January	·550 @ 12,400
Cox Special ·15	February	·460 @ 18,000
Moki M-3	March	·530 @ 13,800
M.V.V.S. -1D	March	·132 @ 15,400
Rossi ·60	April	no B.H.P. reading taken
Taplin Twin Mk. II	April	·363 @ 9,500
Cox T.D. ·09	May	·235 @ 19,000
Cox Medallion ·09	May	·162 @ 16,500
E.D. Cadet	June	·028 @ 6,400
Rythm 2·5	July	·250 @ 14,400
E.T.A. ·15 Mk II	August	·350 @ 16,400
Webra Piccolo	September	·062 @ 13,500
Webra Record R/C	September	·134 @ 13,000
Taifun Orkan	October	·328 @ 16,400
Fox ·40 B.B.	November	·760 @ 15,600
Aero 35	December	·400 @ 12,800

1964

Z.A. ·92	January	·082 @ 11,800
Taipan 1·5 cc	February	·101 @ 11,000
Jena 2 cc	March	·283 @ 13,800
Oliver Tiger Major	April	·386 @ 13,200
Moki S-4	May	·600 @ 17,800
O.S. Max ·19 R/C	June	·254 @ 13,300
Fox ·15 R/C	July	·220 @ 13,000
McCoy ·35 R/C	August	·438 @ 12,700
Enya ·09 R/C	September	·118 @ 12,750
Merco ·61 R/C	November	·860 @ 11,800
K & B ·19 R/C	December	·317 @ 13,400

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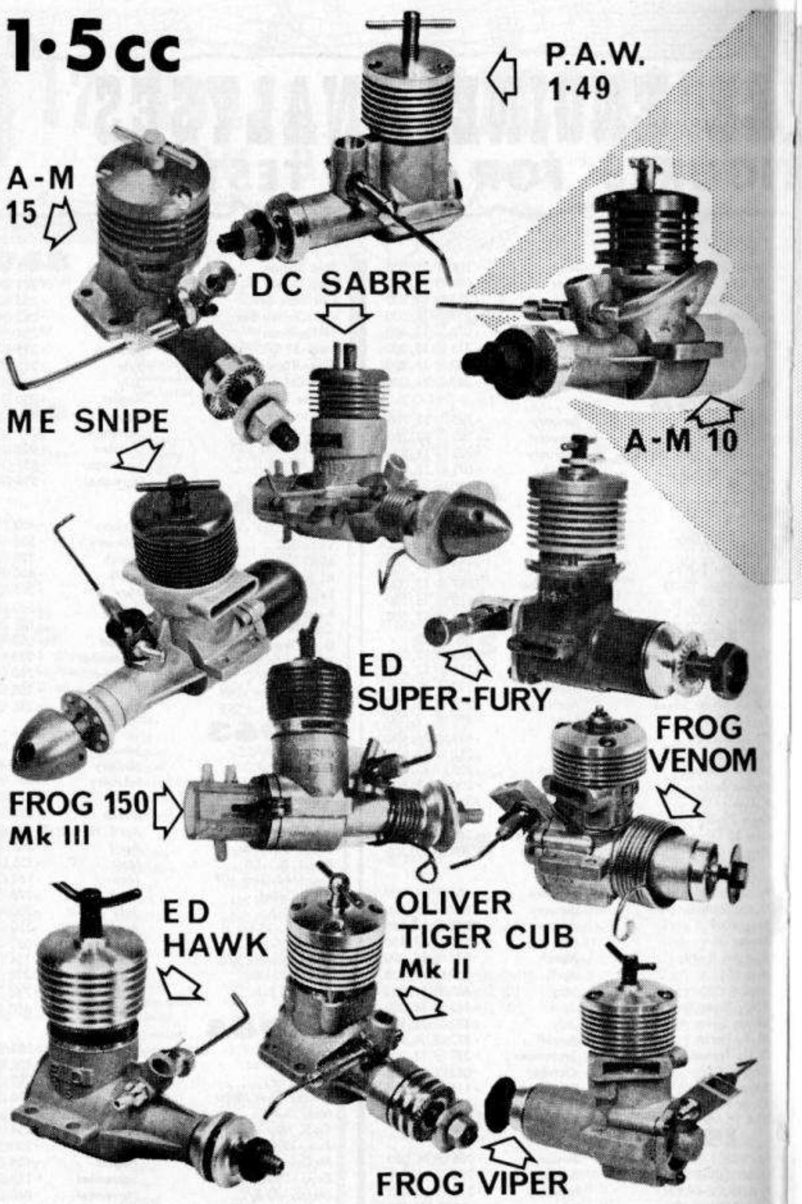

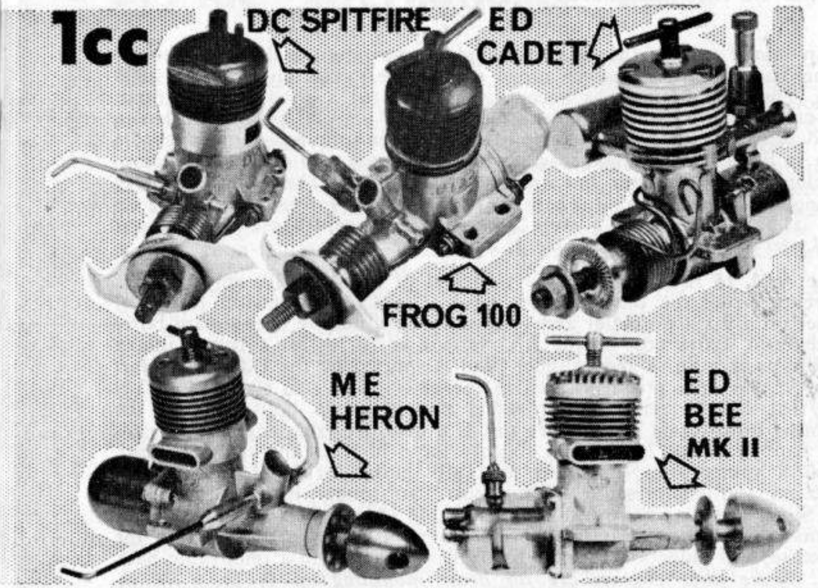

. . . the popular 1 cc to 1.5 cc

The **A.M. 10** is a universal purpose engine and was exceptional for its specific power output when introduced in 1956. Green anodising on the cylinder head distinguishes it from the blue headed A.M. 15, each sharing the same front rotary shaft induction via an integral cast intake in crankcase, also the same rear bolt-on nylon tank. A radio control version with a simple rotating barrel throttle is available at 12/5d. above the basic cost and with slight increase in weight. The A.M. 10 will slog at 6,000 or equally happily at 14,000 r.p.m. Developed over many years the **D.C. Quickstart Spitfire** is a very docile sports and beginners engine. Featuring a coil spring and cam recoil starter, with a blue cylinder head (it was once red) and transparent fuel tank bolted onto the mounting lugs it is robust and prang proof. A screw-in cylinder head retains the otherwise loose fit cylinder and the needle valve is swept back for greater propeller clearance. Tank mounting bolts can be used if a radial mount is preferred. Although no longer in production the **E.D. Bee** is still a favourite and there are thousands to whom this was a first engine. Featuring rear disc induction with the air intake running through the tank. **E.D. Cadet** was introduced as a replacement incorporating a coil spring recoil starter and silencer as standard items. The back plate mounted tank is turned from alloy and the rest of the engine is basically similar to the E.D. Bee with modification to side-port induction and solid cylinder head. Starting, with silencer proved to be less predictable. Mounting details are as for the Bee. A most forgiving engine for beginners, the **Frog 100 Mk. III** is recognisable by its red cylinder head and spring cam starter. It has front rotary shaft induction

(continued)

1 c.c. to 1.5 c.c. *(continued)*

via an intake cast on the crankcase and a transparent fuel tank is bolted to the backplate. The power range extends very usefully over 6-14,000 r.p.m. The **M.E. Heron** has become renowned for a good power output. The crankshaft is exceptionally strong and is unusual in that it has a honed bearing, making for longer life and better running. A raked needle valve is fitted to the intake cast on the crankcase and the Heron comes complete with a spinner nut and metal fuel tank. This is a very easy starting and reliable engine. *These 1 c.c. engines are for beam mounting on ¼ in. x ⅜ in. hardwood bearers spaced ⅞ in. except the Frog* 100 *and Quickstart Spitfire which require 15/16 in.*

The **A.M. 15** is a bored out development of the A.M. 10, only external difference being the blue cylinder head. The 15 R/C version is a real slogger on a 9 x 4 propeller and vibration is low despite over-square bore/stroke ratio. Extra cost of the R/C version is 12/7d. for a rotary intake choke type throttle. A red cylinder head is sported by the **D.C. Quickstart Sabre** (it was once green) as well as the coil spring cam starter and fuel tank that can be removed for radial mounting via bolts through the mounting lugs. Again over square this is a good slogging engine that runs most happily at 10-12,000 r.p.m. With a loose fit liner and screw-in head, it has a spinner nut, integrally cast air intake for front rotary shaft induction and compression finding post. No longer in production the **E.D. Super Fury** is a very fast engine suitable for all sport or contest work on small propellers. Shaft is supported in twin ballraces pressed into the crankcase, and induction by rear rotary disc attached to a removable back plate. *These three engines are for beam mounting on 5/16 in.* x *7/16 in. bearers spaced ⅞ in. apart.*

Originally a Webra engine with front rotary shaft induction via cast intake and screw-in cylinder liner the **E.D. Hawk** runs most happily at 8-10,000 r.p.m. Easy starting and robust construction made this a good first engine. Both of 1.5 c.c. capacity the **Frog Venom and Viper** use the same major parts except for the alterations required to make the Venom for Glow Plug ignition and the Viper as a diesel motor. No longer in production they are both unusual with rear drum induction, a twin ballrace supported shaft and rearward slanting exhaust ports cast into the crankcase unit. The Venom was equipped with a spring starter. Another unusual recognition feature was the use of deep cooling fins on the bottom of the crankcase. Developed over many years the **Frog 150 Mk. III** has a bright blue cylinder head and front rotary shaft induction via an intake cast into the crankcase. A coil spring and cam starter is fitted together with a transparent plastic bolt-on fuel tank. Essentially a sport engine we have also seen many perform creditably in ½A T/R and speed. *These four engines are beam mounted on hardwood bearers 5/16 in.* x *7/16 in. spaced 1⅝ in. apart.*

A very "hot" 1.5 c.c. engine is the **P.A.W. 1.49** distinguished by its tall upright air intake situated close to the cylinder head. Front rotary induction and plain bearing shaft of rugged proportions make this engine suitable for all types of flying and contest work, where high revs are desired, space mounts ⅞ in. apart. Last but by no means least of the 1.5 c.c. engines comes the **Oliver Tiger Cub Mk. II** with a twin ballrace supported shaft and front rotary induction, racing porting and performance to match. This engine is the standard for ½A T/R flying. Performance outclasses some 2.5 c.c. engines. Long life and low fuel consumption make this an outstanding product for which one must pay extra. Beam mount on ⅜ in. x ½ in. hardwood bearers spaced 1 in. apart.

. . . the 'international' class

In production for many years and still firm favourites the **A.M. 25** and **A.M. 35** are easy to start, reliable moderate power output engines for general purpose use. They have also achieved many contest successes, especially for open power duration models. The A.M. 25 with black cylinder head was the first to be produced and the A.M. 35 came as a bored development recognisable by its red head. Both are front rotary shaft induction with the air intake cast into the crankcase, and screw-in back plates. Useful r.p.m. range is 10-14,000. Both are for beam mounting on at least ½ in. x ⅜ in. hardwood bearers spaced 1 in. apart. Now back in production the **E.D. 2.46 Racer** is available in three versions. Standard model is rear rotary disc induction with the air intake cast into the back plate assembly. Shaft is supported in twin ballraces and a hollow bolt is used to retain the propeller. The radio control version is identical with addition of a butterfly throttle. A tuned version with a higher power output is also available. Beam mount on hardwood bearers ½ in. x ⅜ in. spaced 1⅛ in. apart. Designed for F.A.I. team racing the **Eta 15 Mk. III** has a twin ballrace supported shaft, rear disc induction and special porting for speed and fuel economy. This is a good starter for the novice or expert and has a specially cast cylinder. Beam mount on ⅜ in. x ½ in. hardwood bearers (preferably faced with ⅛ in. steel) spaced 1⅛ in. apart, or alternatively a cast metal pan. No longer in production the **Eta 19 Mk. II** is a lightweight racing glow motor with rear disc induction and a twin ballrace supported shaft. An unusual feature of this engine was the use of an integrally cast rear air intake with the front housing removable. Peak power is realised at high r.p.m. with small propellers. Beam mount on ⅜ in. x ½ in. hardwood bearers spaced at 1 3/16 in. Recognisable by its square front rotary shaft intake and red cylinder with head fins is the **Frog 2.49 BB.** A pace setter in its day, this engine is suited to combat or similar hard work. The twin ballrace supported shaft is set up very free so a plastic seal is used around the front housing to keep out foreign matter. Beam mount onto hard-wood bearers ½ in. x ⅜ in. spaced 1 1/16 in. apart Produced in a radio and standard version the **Frog 3.49 BB** is a rear drum induction, ballrace supported shaft motor with ability to slog at heavy loads without complaint. An unusual feature of this engine is the side stack exhaust port which was one of the first designed to accept a silencer. Firmly beam mount to absorb vibration on hardwood bearers ½ in. x ⅜ in. spaced 1⅜ in. apart. A much respected name the world over is that of the Oliver Tiger. It is true to say that over the years they have won more team races and combat finals in their class than all the other makes put together. The **Oliver Tiger Mk. III** is a twin ballrace supported shaft, front rotary induction contest motor with a screw-in air intake just in front of the cylinder. This engine has both high and low speed capabilities. Latest addition to the range is the **3.5 c.c. Oliver Tiger Major.** Similar to the Tiger in layout this engine provides extra power for combat and peaks at a lower r.p.m. It is also ported for radio control use and for a silencer. Both of these engines are available in several versions these being the **/S** machined to accept a silencer, the **Sport** ready silenced and the **R/C** version complete with a barrel throttle and silencer. Mount both engines on ½ in. x ⅜ in. hardwood bearers, spaced 1⅛ in. apart for the Tiger and 1¼ for Tiger Major. **P.A.W. 2.49 Mk. II** is also a contest engine and has a single ballrace supported shaft with front rotary shaft intake via an air intake cast in the crankcase. Very robust and tough throughout, this engine has been used and progressively modified with success in combat and team racing. Beam mount on ½ in. x ⅜ in. hardwood bearers spaced 1 in. apart. A development of this led to the **P.A.W. 19 D Mk. II** and **19 D BR** being produced to meet a demand for a larger engine. The same layout is used

in each but the 19D is plain bearing. Each delivers quite extraordinary power for weight. Beam mount on ½ in. x ⅜ in. hardwood bearers spaced 1 in. apart. No longer in production but still to be seen in considerable use are the Rivers engines. Aimed at the contest modeller the **River Silver Streak Mk. II** was unique in having a roller bearing supported shaft. A front rotary shaft valve induction engine with the air intake cast onto the crankcase and tapped shaft for bolt-on propeller fitting, it is tough but had a habit of breaking connecting rods. The 3.5 c.c. **Rivers Silver Arrow** also used the roller race supported crankshaft and was of the same layout with the exception of a general beefing up and extended air intake for combat flying and stunt models. Mount both engines on hardwood bearers at least ½ in. x ⅜ in.

and the 'Big Stuff' up to 10 cc

Only surviving British racing .29 glow engine is the **Eta .29 VIc.** Developed over many marks this engine enjoys the classic racing glow ignition layout originated in the U.S.A. during the late 40's. A twin ball-race supported shaft with an extension collar is used in a detachable front housing. It is of rear disc induction, the air intake being cast onto the removable rear backplate. The large transfer passage and exhaust stack together with its black finned cylinder head are easily distinguishable features. A feature unique to the Eta is the use of a thick asbestos fibre gasket under the cylinder head. Decidedly happier at higher r.p.m., this is mainly a contest modellers' engine for F/F, speed and "B" T/R. Mount on hardwood bearers at least ½ in. x ½ in. spaced 1¼ in. apart. Out of production for some months but a leader in its time the **Frog 500 RG** has a closely finned cylinder head, and light crankcase with a bolt-on metal fuel tank and long exhaust stack. Employing front rotary induction via an air intake cast into the crankcase, it originated as a coil/spark ignition engine. Beam or radial mount, on ½ in. x ½ in. hardwood bearers spaced 1¼ in. apart.

The Merco range of large capacity engines started with the **Merco 29** and **Merco 35** using similar components. Front rotary shaft induction with the shaft supported in a plain bearing and a one piece crankcase incorporating the air intake, these engines are robust and suitable for all forms of aeromodelling, the 35 being the standard British choice for control line stunt flying for several years. Radio control "Multispeed" versions of both engines are available using a rotating barrel carb: with air bleed adjustment and a linked exhaust chopper. Beam mount on ½ in. x ½ in. hardwood bearers spaced 1¼ in. apart. The **Merco 49** and **61** also use the same crankcase, the 61 having a bored out liner. Construction is more complex than the smaller sizes with the shaft supported in twin ballraces and front rotary shaft induction air intake cast into the crankcase which only extends as far up as the top of the transfer passage. The liner has a light alloy cooling fin jacket and a finned cylinder head. The piston has two rings and extra ports cut in the side to match those in the liner to aid gas transfer. Standard version is available of the 49 for C/L stunt. The 61 is for radio control only and uses the same carb/chopper as the 49. The carb: is a progressive barrel type with air bleed adjustment via a small screw and is linked to a centrally pivoted exhaust chopper which is removed when a silencer is fitted. Mark II versions of both engines have honed bronze bushed piston bearings and connecting rod as well as two glow plugs. Although many twin cylinder engines have been produced in the U.S.A., Germany and in Great Britain, the Taplin is the only one to have proved continually popular and to have retained a fairly low price level. Current model is the **Taplin Twin Mk. II** of 8 c.c.

capacity, an in-line alternate firing twin with built up shaft supported in front by one roller race and by one ballrace at the rear. Induction is side port via a single screw-in adjustable throttle that offers remarkable speed range control. Exhaust is collected in a common manifold. With symmetrical timing the engine runs usefully in either direction. Heavy at 17½ oz. it comes into its own on large (14 in. dia.) propellers and peaks on an 11 x 4. Reliability and very low idle speed are two of its virtues for large sport models. Beam mounting only on ½ in. x ½ in. hardwood bearers spaced 1¼ in. apart.