AIR BOARD

TECHNICAL NOTES

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NOTE.

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ENGINE NOTES.

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PREFACE.

The following notes have been prepared for the use of Officers, N.C.O.'s and men undergoing a course of preliminary instruction in Aero Engines. They have been made as brief as possible consistent with clearness, but care has been taken to include all points of importance in the case of each of the engines dealt with. The descriptive matter has been arranged under headings following in a definite sequence which is adhered to throughout the notes.

The figures for clearances, valve timing, etc., must not be taken as final, for all such figures are liable to modification from time to time as minor changes in design or in the materials used are introduced. With any given design also it is frequently found that the opinions of experts vary as to the clearances and timing that will give best results. In the following pages the figures given agree for the most part with standard practice at an important engine repair depôt overseas. In certain cases, however, the figures given are those recommended by the manufacturers of the engine.

Under present conditions also, several independent manufacturers may be turning out engines of the same name and horse power, a system which results in minor differences in engines which are otherwise identical. In some cases such differences have been referred to in the notes, but the general principle has been to describe the engine of one manufacturer only.

ENGINE NOTES—GENERAL

CLASSIFICATION. Aero Engines may be divided into two main classes, rotary and stationary. Engines of the stationary class may be further sub-divided into the radial, vertical, and vee types, all of which may be either air or water cooled.

RADIAL ENGINES. In comparison with other stationary engines, the radial has the advantage of very low overall length. Engines of this type, however, are at present very little used in the Royal Flying Corps.

VEE ENGINES. The vee type engine is a development of the 4 and 6 cylinder vertical engine, resulting from the demand for increased power. By the introduction of the vee principle, the number of cylinders is doubled without increasing the length of the engine and with but little alteration of its effective width. In practice 6 cylinder vertical aero engines are built in horse powers up to about 200, whilst 12 cylinder vee engines are built to give some 350 H.P.

ROTARY AND STATIONARY ENGINES. In comparing the rotary with the stationary engine it is not possible to lay down hard and fast rules, but broadly speaking it may be said that the field of use of the rotary is in the propulsion of very fast small machines of the Scout type, while the stationary engine is employed nowadays in practically every class of machine, but in particular for machines used in making long flights. The rotary is the lightest type of engine for a given horse power, but it is wasteful in lubricating oil, and is relatively inefficient in fuel consumption. It therefore pays to use this class of engine where flights of short duration only are contemplated so that the advantages of low weight of engine per horse power will not be counterbalanced by the relatively large amount of fuel and oil to be carried. The rotary engine is also regarded as being less reliable than the stationary, and engines of this type require more frequent overhauling. The average rotary engine must be taken down after about 40 hours running whilst most stationary engines can be relied upon to run some 100 hours without overhaul. From this point of view, however, and in the rotary engine in particular, a very great deal depends upon the design of the engine and upon the materials and workmanship employed in its manufacture, as well as upon the skill of the fitters responsible for its overhaul and adjustment. Three out of the four principal rotary engines have steel cylinders without

liners, and the pistons are fitted with obturator rings which in the hands of careless or unskilled mechanics, would prove a source of perpetual trouble.

LUBRICATION. The importance of efficient lubrication in aero engines cannot be over-estimated and none but suitable oil of the very best quality should be used. In engines of the rotary type, a heavy vegetable oil, such as castor oil, is generally used. Under the conditions of use, oils of this type do not mix with petrol of which a certain amount is always present in the crankcase of a rotary engine. Pure castor oil forms an extremely good lubricant but is not the best for use in stationary engines where the oil is in circulation and is passed through the bearings, etc., over and over again. Under such circumstances its lubricating properties are gradually destroyed, the oil becoming gummy and acid. In stationary engines mineral oils are generally used, but a mixture of a large proportion of castor oil, with a small proportion of mineral oil, known as Wakefield's Castrol, is also in use, and pure castor oil is recommended in certain cases. The castor oils in general use are Pharmaceutical Castor Oil and Treated Castor Oil. Castor oil deposits solid fats at low temperatures and should not be stored in cold places. When castor oil is used, the engine oil filter should be examined to detect this deposit. The mineral oils in general use are known as Vacuum "A" and Vacuum "B B," and mixtures of these are also used. In general, oils are prepared in summer and winter qualities.

PETROL. Petrol tanks should be kept scrupulously clean, and on no account should water be allowed to enter. Petrol of low s.g. ensures easy starting, complete combustion and saving in weight, but the supply of petrol of a lighter s.g. than about ·720 is restricted.

FUEL AND OIL CONSUMPTION. The approximate average petrol consumption for engines of the rotary class is 0·095 gallons per hour per horse power, and the consumption of lubricating oil is about 0·135 pints per hour per horse power, or some 18% of the petrol consumption. In the case of stationary engines, the corresponding figures are 0·08 gallons for petrol and 0·04 pints for oil. The oil consumption being some 6% of the fuel consumption. In both classes of engine some of the lubricating oil is actually consumed in the engine but in the rotary engine the bulk is ejected from the exha valves. In a stationary engine a certain amount is blown through the breathers, etc., but the bulk is returned to sump in gradually diminishing quantities. The oil in sump, having passed repeatedly through the engine, eventu becomes unsuitable for use and must be drained off a replaced by fresh oil.

DIRECTION OF ROTATION. In practically all engi used by the R.F.C. the direction of rotation is coun clockwise as seen from the propeller end. In rotary engin and in all stationary engines where the propeller is dire driven, the direction of rotation of the propeller will of cour be the same as that of the engine, but in most stationa engines fitted with speed reduction gear, the propeller tur in the opposite sense to the engine shaft. The princip exceptions to this rule are as follows :—

Radial Engines—Rotation usually clockwise as seen from the propeller end.

Rolls Royce ——Epicyclic reduction gear is fitted so that propeller rotation is same as engine. Also Rolls Engines are built for either direction of rotation.

MAGNETO SPEEDS. The revolving armature type magneto gives 2 sparks and the revolving shield type 4 spar per revolution. In the 4 stroke engine a spark occurs in ea cylinder every second revolution of the engine, so that a cylinder engine requires 2 sparks and an 8 cylinder engine sparks per revolution. It follows therefore that a revolvi armature magneto for use with a 4 cylinder engine must driven at the same speed as the engine. Also a revolvi shield magneto driven at engine speed is suitable for use wi an 8 cylinder engine. In all other cases the magneto must driven at a speed bearing a relation to the engine spee indicated by the following formula :—

$$\text{R.P.M. of magneto} = \frac{\text{R.P.M. of engine} \times \text{number of cylinders fired by magnet}}{2 \times \text{sparks per revolution of magneto.}}$$

EXAMPLE :—

6 cylinder engine with revolving armature type of magneto giving sparks per revolution.

$$\text{R.P.M. of magneto} = \frac{\text{R.P.M. of engine} \times 6}{2 \times 2} = \text{R.P.M. of engine} \times$$

n this case therefore the magneto must be geared to rotate at $1\frac{1}{2}$ times the speed of the engine.

ORDER OF FIRING. In aero engines, where, from considerations of weight, a flywheel is undesirable, evenness of torque or turning moment is a primary consideration. To obtain the most even turning moment the angle through which the crank, or the engine, moves between any two consecutive explosions must be the same. This angle is found by dividing the number of degrees moved through in any 1 cycle (2 revs.) by the number of cylinders as follows :—

$$\text{Angle between any two consecutive impulses} = \frac{720^\circ}{Nc}$$

Where 720° = number of degrees in 1 cycle (2 revs.) and Nc = number of cylinders.

ROTARY ENGINES. In a 9 cylinder rotary engine, for example, the angle moved through between any two consecutive impulses or explosions will be $\frac{720}{9} = 80^\circ$. In such an engine the cylinders are spaced at angles of 40° so that every other cylinder is fired as it passes the ignition point and with the usual system of numbering the order of firing will be 1, 3, 5, 7, 9, 2, 4, 6, 8. Rotary engines having an even number of cylinders cannot be arranged to give an even turning moment and such engines are not built, excluding the 18 cylinder "2 line" or double rotaries, which, from this point of view, are to be classed as two separate engines. In a rotary engine with 8 cylinders, for example, the correct angle between impulses would be $\frac{720}{8} = 90^\circ$ and the cylinder spacing 45°. The order of firing, 1, 3, 5, 7, gives 90° intervals but a further 90° would bring in No. 1 again, leaving only the possibility of a step of 45° to No. 8, or of 135° to No. 2, neither of which is permissible.

STATIONARY ENGINES. Vertical aero engines have 6 cylinders and vee engines 4×2, 6×2 or 6×3 cylinders. From considerations relating to balancing, engines having 4 cylinders or 4×2 cylinders have 4 cranks arranged in pairs at 180°, and engines having 6, 6×2 or 6×3 cylinders have 6 cranks arranged in pairs at 120°. *No other arrangement is practicable.* The crankshaft for a 4 cylinder vertical engine or for a 4×2 cylinder vee engine is as shown in fig. 1. The correct angle between consecutive impulses, for a 4 cylinder engine, calculated as above is 180° so that the possible orders of firing are 1, 2, 4, 3, or 1, 3, 4, 2, of which the latter is the more usual. For a 4 × 2 cylinder vee engine the correct angle is $\frac{720}{8} = 90°$, and this is obtained by making the angle of the vee equal to 90°, and treating the 2 sets of cylinders as separate 4 cylinder engines, firing alternately with 180° intervals between impulses. With the cylinders numbered as in fig. 2, the resulting order of firing will be 1, 5, 3, 7, 4, 8, 2, 6. The crankshaft for a 6 cylinder vertical engine and for 6 × 2 or 6 × 3 cylinder vee engine may be as shown in figs. 3 or 4, the latter being the more usual arrangement in aero engines. For a 6 cylinder engine the correct angle between the impulses is $\frac{720}{6} = 120°$, and for normal direction of rotation, with fig. 4 crankshaft, the usual order of firing is 1, 5, 3, 6, 2, 4. With crankshaft as in fig. 3, the corresponding order of firing will be 1, 4, 2, 6, 3, 5. It is usual in 6 cylinder engines to provide 2 carburetters, one supplying cylinders 1, 2, 3 and the other cylinders 4, 5, 6. With the order of firing given it will be seen that each carburetter is drawn upon alternately and at equal time intervals. For a 6 × 2 cylinder vee engine, the correct angle between consecutive impulses is $\frac{720}{12} = 60°$, and this is obtained by making the angle of the vee equal to 60° and treating the two sets of cylinders as separate 6 cylinder engines firing alternately or with 120° between the impulses. With the cylinders numbered as in fig. 5, the order of firing will therefore be 1, 7, 5, 11, 3, 9, 6, 12, 2, 8, 4, 10, with fig. 4 crankshaft, or 1, 7, 4, 10, 2, 8, 6, 12, 3, 9, 5, 11, with shaft as in fig. 3. In a 6 × 3 cylinder vee (or fan) engine, the correct angle between the impulses is $\frac{720}{18} = 40°$. The 3 groups of cylinders are set at 40°, and with the numbering as in fig. 6, the order of firing will be 1, 7, 13, 5, 11, 17, 3, 9, 15, 6, 12, 18, 2, 8, 14, 4, 10, 16, with fig. 4 crankshaft, or 1, 7, 13, 4, 10, 16, 2, 8, 14, 6, 12, 18, 3, 9, 15, 5, 11, 17, with crankshaft as in fig. 3.

The order of firing for vee engines with normal direction of rotation is set out in full above, but it is not suggested that the figures given should be memorised. It is advisable, however, to learn thoroughly the following :—

(1) The types of crankshaft in use.
(2) The corresponding orders of firing for 4 and 6 cylinder engines.
(3) *The system of numbering the cylinders.

The orders of firing for vee engines are then found by setting out the order for the corresponding vertical engine and filling in the numbers for the second row of cylinders in the correct order, which may be conveniently found as follows :—In the case of an 8 cylinder vee add 4 to each of the original numbers and put the new figure down on the right of the original. In the case of the 12 cylinder vee add 6 instead of 4, and proceed in the same way. In the case of the 18 cylinder vee or fan type engine the figures for the 3rd row of cylinders are found by adding 6 to those for the 2nd row and putting the new numbers down on the right as before.

EXAMPLE :—

12 cylinder vee engine having crankshaft as in fig. 3 and normal direction of rotation. The corresponding vertical engine has 6 cylinders, and the order of firing will be

1, 4, 2, 6, 3, 5.

Adding 6 to each figure and putting the new figures on the right we have

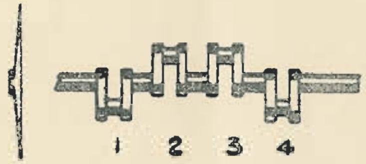
1, 7, **4**, 10, **2**, 8, **6**, 12, **3**, 9, **5**, 11.

which is the order of firing for the vee engine, the heavy figures representing one row of cylinders and the lighter figures the other.

In the case of a 6 cylinder engine, having anti-normal direction of rotation, the order of firing will be 1, 5, 3, 6, 2, 4, if the crankshaft is as fig. 3, or 1, 4, 2, 6, 3, 5, if as in fig. 4. The order of firing for the corresponding vee or fan engine is built up from these figures as in the case of engines having normal direction of rotation.

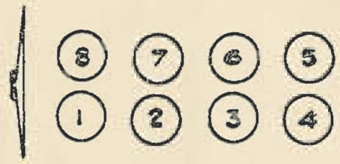
*The system of numbering the cylinders of vertical and vee engines that is used in these notes is quite arbitary, but it is perhaps the simplest and is applicable to all engines of these types. The numbering systems used in practice vary according to the views of individual manufacturers, and can be learnt, if considered desirable, when specialising on any particular engine.

FIG. 1.



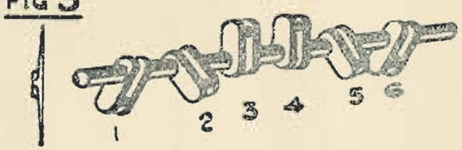
Crankshaft for 4 Cylinder vertical engine or 4×2 cylinder "Vee" engine

FIG 2



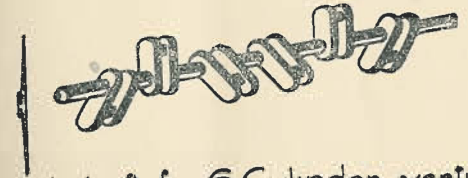
System of numbering cylinders in 4×2 Cylinder "Vee" engine

FIG 3



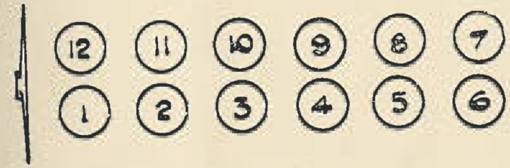
Crankshaft for 6 Cylinder Vertical engine or 6×2 Cylinder "Vee" engine as in 140. H.P. R.A.F.

FIG. 4



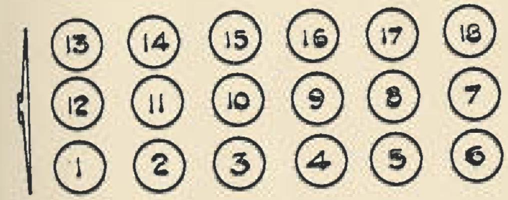
Crankshaft for 6 Cylinder vertical engine or 6×2 Cylinder "Vee" engines as in Beardmore, Rolls, and Sunbeam engines

FIG. 5.



System of numbering cylinders in 6×2 cylinder "Vee" engine

FIG. 6.



System of numbering cylinders in 6×3 cylinder "Vee" or "Fan" engine

ENGINE RUNNING NOTES.

PRELIMINARY. Skill in engine running is mainly a mat of experience, but a very great deal depends upon simple duction and logical reasoning.

Every engine trouble is the result of one or more defin causes and as a rule is accompanied by symptoms from whi the cause may be deduced. In any case a clue is obtain from the manner in which the engine fails. For example, sudden stoppage, unaccompanied by the obvious symptons internal breakage or "seizing up", can only be due to comple failure of fuel supply, or ignition system, and in such a case would be against the dictates of common sense to open up t engine, or even to inspect the sparking plugs.*

In the hands of a capable mechanic an engine in good co dition should start with certainty and ease. When the engi is running, symptoms should be detected, and recognised, befo any trouble fully develops, and in case of failure resulting fro the more common causes, the fault should be located imme iately, or at the most, after a brief inspection of the engine.

STARTING UP. Before starting an engine, turn it ove once or twice, note that the valves are not sticking, and tha the compression is normal. See that there is a sufficient suppl of petrol and oil for the run, and that the oil is of the righ quality and consistency. In winter it may be necessary t warm up the oil, or, in the case of castor oil, to thin it dow with methylated spirit, which may be added in a proportio not exceeding half a pint to the gallon. In water cooled en gines see that the water circulating system is in order, an contains the proper quantity of water. It is usual to allow about 2% for expansion of water when hot.

When an engine has been standing, its cylinders will be fille with air or inert gas, and, in order to start up, this must be re placed by an explosive charge. In Stationary engines this is done by turning the engine, with air intakes closed, and petro on, when a rich mixture will be drawn into the cylinders, and the inert gas expelled. In Rotary engines this method alone is not practicable, owing to the large volume of the crank case through which the mixture passes on its way to the cylinders In engines of this class, therefore, it is usual before starting

*A check on the petrol supply at the carburetter, or an inspection and test of the magneto circuits between the switch, the earth con nection and the distributor, would in all probability reveal the source of trouble.

to "dope" or "prime" the cylinders by injecting petrol through the exhaust valves. Some Stationary engines also, e.g.—the Rolls, are fitted with a priming pump, which sprays petrol into the induction pipes, and so facilitates starting up.

Existing engines are started up by one or the other of the following methods :—

(1) Prop swinging (Rotary and low-powered Stationary engines).
(2) Hand driven starting magneto (Beardmore, Green, etc.).
(3) Mechanical hand starting gear (Clerget).
(4) A combination of (2) and (3), (Rolls, Hispano, Salmson).
(5) Compressed air (Sunbeam, 220 H.P. Renault).

Prop Swinging. The usual procedure is as follows :—
The mechanic, before approaching the propeller, calls out "Switch off. Petrol on. Air closed. Suck in."
The Pilot turns the switch knob downwards, turns on the petrol, adjusts the throttle, closes the extra air intakes, and repeats the words of the mechanic.
The mechanic, then gripping the propeller by each blade in turn, pulls the engine over, in its normal running direction, until the cylinders are charged. He then stands clear and calls out "Contact."
The Pilot turns the switch knob upwards and calls out "Contact."
The mechanic then grips the propeller blade and making sure that he has a sound footing, pulls the engine sharply over compression and stands clear.

Hand Driven Starting Magneto. The procedure is as above but after the word "Contact" the mechanic remains standing clear while the pilot starts the engine by vigorously cranking the starting magneto.*

Mechanical Hand Starting Gear. The cylinders are charged by turning the engine with the hand gear. While the engine is being turned over as fast as possible by this means, the switch is put "on" and the starting handle is thrown out of gear.

Mechanical Hand Starting Gear with Starting Magneto. In this case the starting magneto is usually geared to

* The starting magneto should not be left "on" when the engine is running.

the starting handle and is switched "on" when the cylind
have been charged as above.

Compressed Air. Air under high pressure is suppli to a small starting motor or directly to each of the engi cylinders in turn through a distributing valve driven by t camshaft. The air cock is opened and the engine is driven compressed air until the cylinders are charged when t switch is put "on" and the cock closed.

FAILURE TO START. This may be due to:—

(1) Initial impulse lacking in vigour. (3) Incorrect mixture.
(2) Incorrect adjustment of throttle. (4) Engine out of orde

To start an engine it must be swung over compression a reasonable speed. A mechanic exhausted by unsuccess attempts to start a stubborn engine will be unable to p sufficient energy into the swing and should make way f a "fresh" man or take a short rest while looking over t engine to make sure that everything is in order.

Most engines will start best with a particular adjustment the throttle which should be carefully noted. Where t carburetter has a slow running adjustment it is usual to sta with the throttle quite closed. In other cases the throttle set partly open, usually about $\frac{1}{4}$ to $\frac{1}{3}$ but never fully open.

An explosive mixture contains approximately 18 volumes air to 1 of petrol vapour and if the petrol vapour is present a much greater or lesser proportion the mixture will be to strong or too weak and will explode with greatly reduce force or not at all. The vaporisation of petrol is assisted heat and when starting a cold engine, particularly in winte the spirit will be only partially vaporised. This results in weak mixture unless a considerable excess of petrol is pr vided for by flooding the carburetters or "doping" th cylinders or induction pipes. In warm weather and especial when starting with the engine hot it is easy to get too stron a mixture into the cylinders. When an engine fails to sta for this reason, it should be turned over in the anti-norm direction through 2 or more revolutions in order that th mixture may be weakened by the addition of air drawn through the exhaust valves.

In looking over an engine that fails to start ascertain that th ignition system is in working order and that the plugs ar clean, sound and correctly coupled to the distributor. Se that there is no loss of compression through leaky valve plugs, etc., and look for possible air leaks in the inductio pipe joints. As a final measure the timing should be checked

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