CHAPTER 7

MAGNETOS AND AUXILIARY DEVICES

Objectives

1. This Chapter has been written with the aim of helping you to satisfy the objectives in the relevant Skills and Knowledge Specifications (SAKS) for the trade in this subject area. When you have studied this Chapter, you will be able to:

a. Explain the basic principles of electro-magnetic induction.

b. Describe a polar induction magneto, its component parts, their purpose and the servicing required, with particular emphasis on the contact breaker and distributor.

c. State how the internal timing of a magneto is achieved and the purpose of the magneto couplings.

d. Explain why variable ignition timing is necessary, the various factors which effect ignition timing and the basic principles of ignition timing.

e. State the purpose of auxiliary ignition devices for engine starting, including impulse starters and ignition coils.

Introduction

2. The purpose of an ignition system is to produce electrical impulses and to convey those impulses to the sparking plugs during the power stroke at regular intervals and in the correct firing order. To achieve this purpose, switches, magnetos, distributors, couplings and ignition harnesses are required. Because of the high safety factor involved, the entire ignition system is duplicated for each engine.

3. Before discussing the components which go to make up an ignition system, the contents of Section 4, Chapter 2 of AP3402, which deals with Electricity and Magnetism, should be fully understood, together with the information in the following paragraphs.

Electro-magnetic Induction

4. When a coil wound around a soft-iron core is carrying a current, then a magnetic field, which will remain as long as a current is flowing, is formed around both the coil and the core. If that current flow is stopped, however, the magnetic field collapses and the lines of force move rapidly in towards the coil, causing a voltage to be induced in any conductor that lies within that field. Similarly, a voltage is induced in such a conductor during the build-up of a current in the coil.

5. Consider two coils wound on an iron core, one above the other and insulated from each other. If a steady current is flowing through one of the coils, a steady magnetic field is formed around both coils and the core. Because there is *no relative movement* between the lines of force and the second coil, a voltage is *not* induced into the second coil. If, however, the current in the energized coil is cut off, the magnetic field immediately collapses and, cutting across the turns of the second coil, induces a voltage into it. This induced voltage causes a current to flow in the second coil for as long as the magnetic field takes to collapse.

6. The magnitude of the voltage so induced into the second coil depends on the ratio between the number of turns in the first and second coils, the speed at which the lines of force collapse across the second coil, and the resistance of the final circuit.

7. Applying this principle to supply a series of sparks to an engine, a relatively small number of turns of stout wire (primary winding) is wound around a core and has a secondary winding of a large number of turns of fine wire superimposed upon it. A low voltage is now applied to the primary winding and by starting and stopping the current in this winding, a series of high voltage electrical impulses is induced into the secondary windings. The low voltage producing the primary current may be supplied by a battery (coil ignition) or by incorporating a simple electrical generator in the unit (a magneto).

The Magneto

8. The purpose of a magneto is to convert mechanical energy into electrical energy which produces and delivers HT voltages to the sparking plugs at regular intervals and in the correct firing order. A magneto must be:

a. Reliable.

b. Built for strength with a minimum weight.

c. Radio screened.

d. Fire proofed.

9. The essential components of a magneto and their purpose are:

a. *A permanent magnet* which provides the magnetic field necessary to be able to generate a low voltage in the primary winding.

b. *The primary and the secondary windings* mounted on a soft iron core. The complete assembly is then known as the *armature*.

c. *A rotating member* that effects a change of magnetism on the armature. The particular basic principle used in the operation of a magneto is governed by this member and is indicated by the type name of the magneto, *eg* rotating armature magneto or rotating magnet magneto (polar inductor).

d. *A contact breaker assembly* which is a mechanically operated switch, timed to break the primary circuit when the *maximum* current is flowing. The contact breaker points are made of tungsten or platinum.

e. *A capacitor (condenser)*, which is connected across the contact breaker points. The action of the capacitor, by reducing arcing at the contact breaker points when the points open, stops the flow of primary current more quickly and brings about a faster collapse of the primary magnetic field. Further, by reducing arcing at the points, excessive burning and erosion of the points is avoided.

f. *The distributor*, which directs the high voltage impulses to the cylinders in turn, as they reach their ignition point.

10. The internal wiring of a magneto can be conveniently divided into two—the primary or low tension circuit, and the secondary or high tension circuit.

a. *The primary circuit*. A simple primary circuit is illustrated at Fig 1.7.1. It consists of a primary coil, wound around a soft-iron core, the coil being connected to a contact breaker, a capacitor and a switch. The switch which earths the magneto, although illustrated at Fig 1.7.1, is not a magneto component, but is included to explain its action. It can be seen that if the switch is closed, the primary circuit is completed and the contact breaker has no effect on the circuit. The magneto is therefore DEAD when the switch contacts are together and ALIVE when the switch contacts are apart, *ie* the REVERSE of a normal switch action.

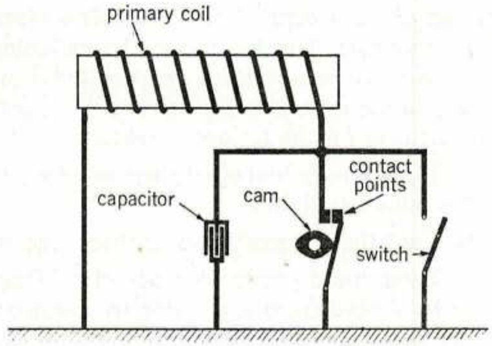

Fig 1.7.1 Primary circuit

b. *The secondary circuit.* The illustration at Fig 1.7.2 shows the secondary circuit superimposed on the primary circuit. The secondary coil is wound around the primary coil, but insulated from it. One end of the winding is in contact with the centre of the rotating arm, or distributor, that leads to the centre electrode of the sparking plug. The other end of the secondary winding is connected via the primary winding to the earth electrode of the sparking plug.

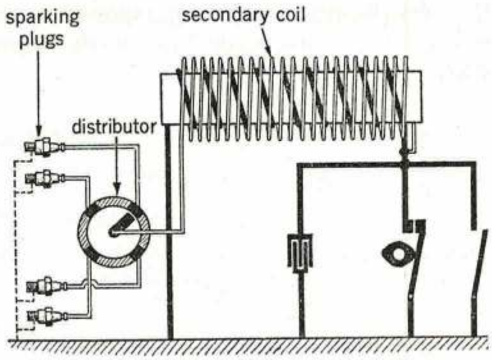

Fig 1.7.2 Complete circuit

11. **Operation of the circuit.** Assuming that a current is flowing in the primary circuit when the contact breaker points are closed, then a magnetic field is also present around the primary and secondary windings, the strength of the field depending upon the strength of the current flow. If the cam is now operated, the contact points are opened, the primary circuit is broken, and primary current ceases to flow. This produces an immediate collapse of the magnetic field, causing the lines of force to move across the secondary winding. Since any movement of lines of force across a conductor induces a voltage into that conductor (para 4), a current will flow in the secondary circuit for the time taken for the field to collapse.

12. The current set up in the secondary circuit is fed to the distributor, the rotor of which is so timed that it is then opposite that segment leading to the sparking plug in the cylinder positioned for firing.

13. **The distributor.** On a four stroke engine the cylinders need to be fired once in every two revolutions of the engine, in a sequence (the firing order) that produces the least vibration. To do this, high tension leads are connected, in the sequence desired, from segments spaced equally around the distributor block to the sparking plugs. The distributor rotor is driven by the engine *at half speed.* Thus, the rotor passes each segment once every two engine revolutions, coupling individual cylinders to the secondary circuit in the same sequence as the firing order. No matter how many cylinders there are on an engine, the distributor rotor always rotates at half engine speed. Therefore, provided a voltage is induced in the secondary winding whenever the rotor is opposite a segment, the secondary circuit is completed through the correct cylinder sparking plug.

14. We have seen that a voltage is induced in the secondary winding when the current in the primary winding is cut off. However, the question will be asked, 'Where does the current in the

primary circuit come from in the first place?' Clearly, before we can get a current, we must have a voltage. This is achieved by including a small generator known as *a rotating armature type magneto* or *a rotating magnet* (polar inductor) type magneto. Because of the disadvantages of a rotating armature type magneto, its use is strictly limited on aero-engines in the Royal Air Force today for the following reasons:

a. It gives only two sparks per revolution of the armature and, therefore, the magneto speed becomes too high.

b. Centrifugal force tends to throw the windings outwards.

c. There are a greater number of rubbing contacts in the internal circuit. The current has to be passed from a rotating to a stationary contact by means of carbon brushes. Although the carbon brushes used at these points have a low resistance, a fixed contact is more reliable than a rubbing contact.

15. An illustration of the components used in a rotating armature type magneto are shown at Fig 1.7.3 so that a comparison can be made with the polar inductor type magneto considered later.

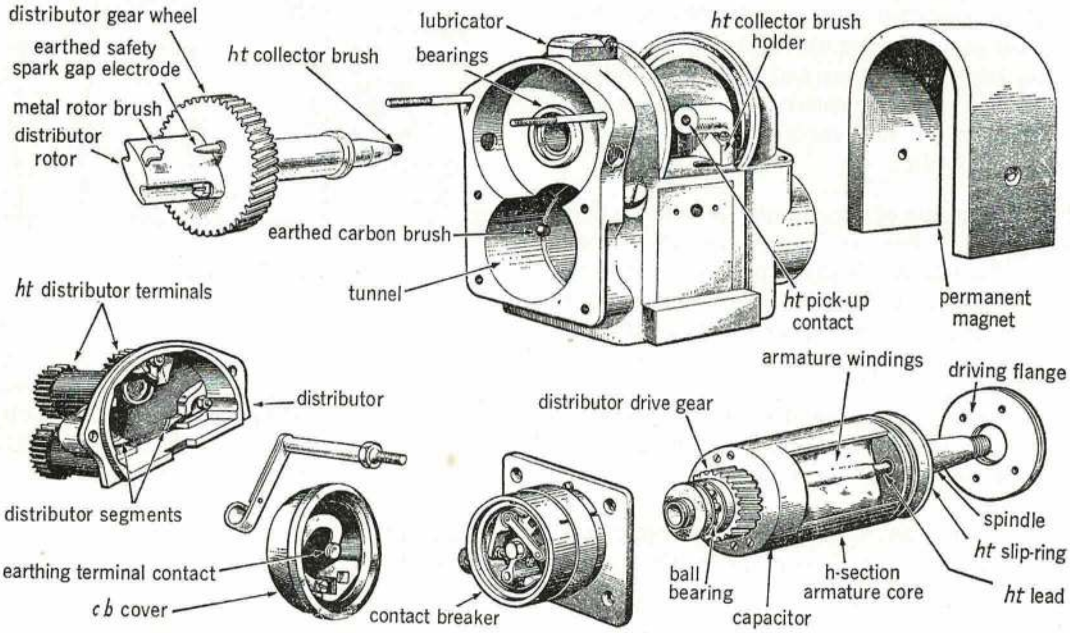

Fig 1.7.3 Components of a rotating armature magneto

A Rotating Magnet Magneto (Polar Inductor)

16. The polar inductor type of magneto normally produces four electrical impulses in the secondary windings (or four sparks) for every revolution of the magneto shaft and is, therefore, more suitable for engines having a large number of cylinders than is a rotating armature magneto. Not only does a polar inductor type run at half the speed of the rotating armature type to produce the same number of sparks, but the coils and switch assembly, being stationary, are free from centrifugal loading. As a consequence, this type of magneto has largely superseded the rotating armature magneto except for those engines with less than six cylinders, where the speed of the magnet at low engine speeds is too slow to generate an effective primary current.

17. The main rotating member of a rotating magnet magneto consists of a non-magnetic steel shaft on which is mounted a tubular magnet, clamped between two-fingered soft iron magnet pole pieces set 90° apart. One end of the tube has a north polarity, the other end is of south polarity and the respective polarity is imparted to the clamping pole pieces. The assembly is rotated in a tunnel formed between the iron extensions of an armature core. This arrangement is illustrated at Fig 1.7.4. The three positions shown cover a quarter revolution of the shaft.

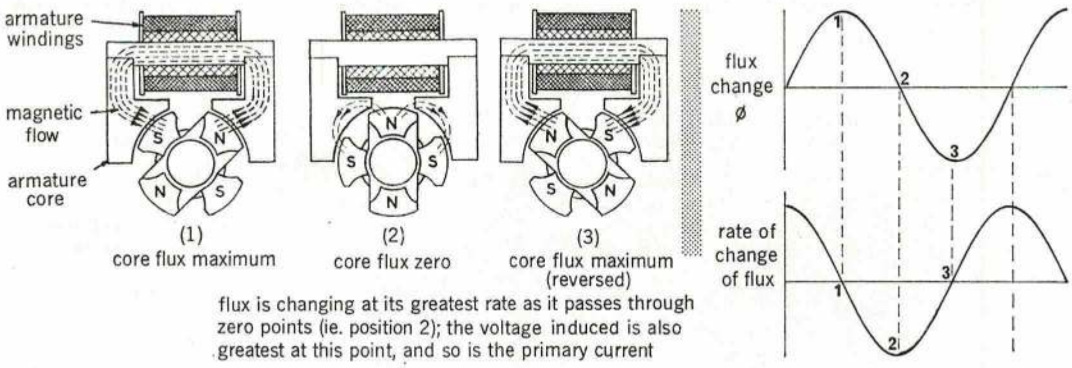

Fig 1.7.4 Rotating magnet and 4-bar polar inductor flux changes

18. Flux changes through the armature core as the magnetic poles revolve produce a change of magnetism around the primary winding of the armature, and the voltage induced in the primary winding reaches a maximum with the poles at position 2 (core flux zero but changing at its greatest rate). The primary current is also at a maximum, and it is at this point that the contact breaker points are opened.

19. The stationary contact breaker assembly is normally housed at the non-driving end of the magneto, so that a four-lobed cam, keyed to the end of the rotating shaft, automatically opens the points when the primary current is at its peak. This arrangement does not apply to radial engines where, as will be explained later, the operating cam and contact breaker are contained within the distributor housing.

20. Although the primary current is produced in a somewhat different manner to the rotating armature type, the secondary current is set up by an induced voltage in precisely the same way as in the rotating armature type. Thus, when the contact breaker points interrupt the primary current, causing the primary magnetic field to collapse, a voltage is induced in the secondary circuit for the period of time that the lines of force cut across the secondary winding. The magnitude of the voltage so induced depends upon:

a. *The strength of the magnetic field created by the primary current.* This again depends upon the strength of the permanent magnet, the speed of the magneto shaft and the number of turns in the primary winding.

b. *The speed of movement of the collapsing lines of force.* This is related to the time taken for the current flow to stop after the contact breaker points have begun to open. The current does not stop instantaneously; as the points open, current continues to flow, though at a falling rate, until the resistance of the air at the gap becomes too high. In practice, this lag in current shut-off is considerably reduced by the action of the capacitor.

c. *The ratio between the number of turns in the secondary winding to the number of turns in the primary winding.* The greater the ratio, the greater is the relative step-up in the voltage of the secondary circuit to that in the primary.

21. The average voltage in the primary circuit of a magneto running at normal rev/min is in the region of *27 volts*; that of the secondary is between *5000* and *7000 volts*.

22. On engines where it is considered that the speed of a four pole inductor would be too high, more than four poles are formed on the magneto shaft. Where this is so, more flux reversals occur per revolution of the magneto shaft and, given a suitable contact breaker, more than four sparks per revolution are provided. Alternatively, two separate armatures and contact breaker assemblies may be arranged around the tunnel.

23. The main components of a rotating magnet (polar inductor) type of magneto are illustrated at Fig 1.7.5.

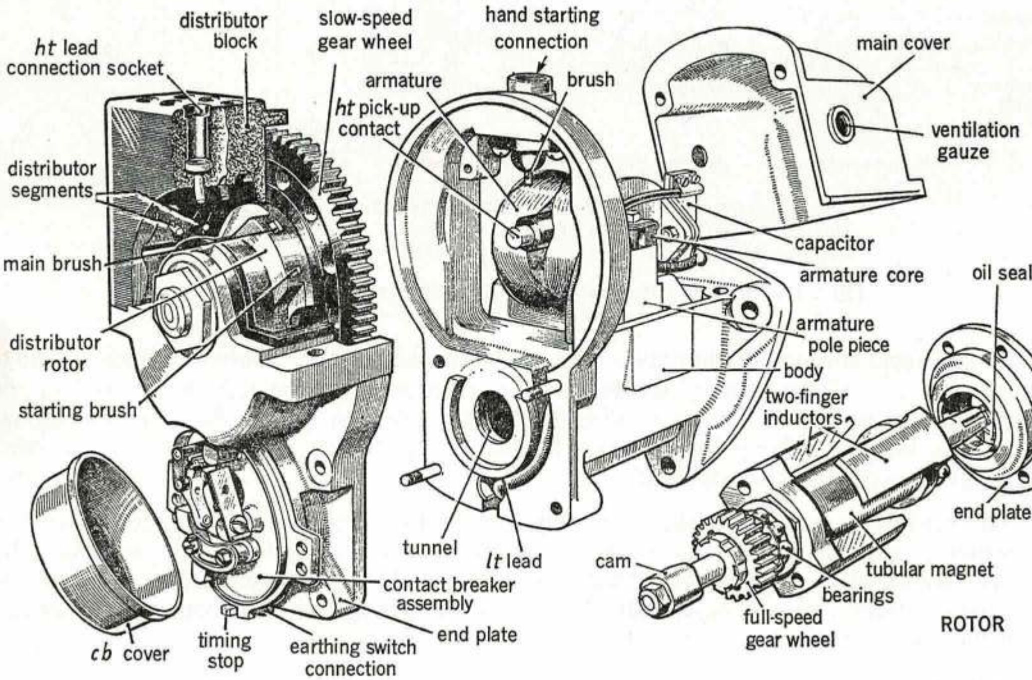

Fig 1.7.5 Components of a polar inductor magneto

Internal Timing of a Magneto

24. To obtain the maximum electrical output from a magneto it is essential that the contact breaker points are opened when the primary circuit flow is at its peak. Further, to be sure that the resulting secondary current flows to a cylinder sparking plug, the distributor rotor must then be opposite a distributor segment. Normally, correct relative positioning (or internal timing) of the magneto pole pieces, the contact breaker cam, and the distributor rotor is done during magneto assembly. In service, however, wear on the contact breaker cam and on the contact breaker points affect the relevant positioning of these components and some adjustment may be necessary to maintain full efficiency.

25. **Magneto speed ratios.** Every cylinder of an engine that works on the four stroke cycle requires one spark every two revolutions of the crankshaft. Consequently, the greater the number of engine cylinders, the faster the magneto needs to be driven to provide the necessary number of sparks.

26. In general, the speed of the magneto relative to the engine speed is calculated as follows:

$$\text{Magneto speed} = \frac{\text{Number of engine cyclinders}}{\text{2 x the number of sparks/rev of the magneto.}}$$

Thus, for a 12 cylinder engine fitted with a rotating magnet type of magneto (4 sparks/rev), the magneto needs to be driven at $\frac{12}{2 \times 4} = 1\frac{1}{2}$ times engine speed.

27. For a four cylinder engine fitted with a rotating armature type of magneto (2 sparks/rev), the magneto speed $= \frac{4}{2 \times 2}$, which is equal to engine speed.

28. Each segment of a distributor is connected to a different cylinder, and each requires one spark every two revolutions of the crankshaft. Therefore, as explained earlier, the distributor rotor, irrespective of the magneto shaft speed, always rotates at half engine crankshaft speed.

Dual Ignition

29. All aero-engines are fitted with dual ignition, *ie* two entirely independent ignition systems. Thus, each cylinder has two sparking plugs, each fed from a different magneto. This is done to:

a. Reduce the possibility of engine failure because of an ignition fault.

b. Increase the engine power output. Power output can be increased on large bore cylinders by igniting the charge at two widely spaced points. This reduces the overall time taken to burn the full charge and so enables peak gas pressure to be reached before the piston has moved very far down its stroke.

The Contact Breaker

30. Though contact breaker assemblies vary widely in detail design, the same basic action is always retained. A typical rotating magnet type contact breaker assembly is illustrated at Fig 1.7.6. The assembly consists of a rocker arm that oscillates on a pivot pin secured to a base plate. One end of the rocker arm is fitted with a fibre heel that is in contact with a four lobed cam which is fitted to the magneto shaft. A movable contact point is mounted at the other end

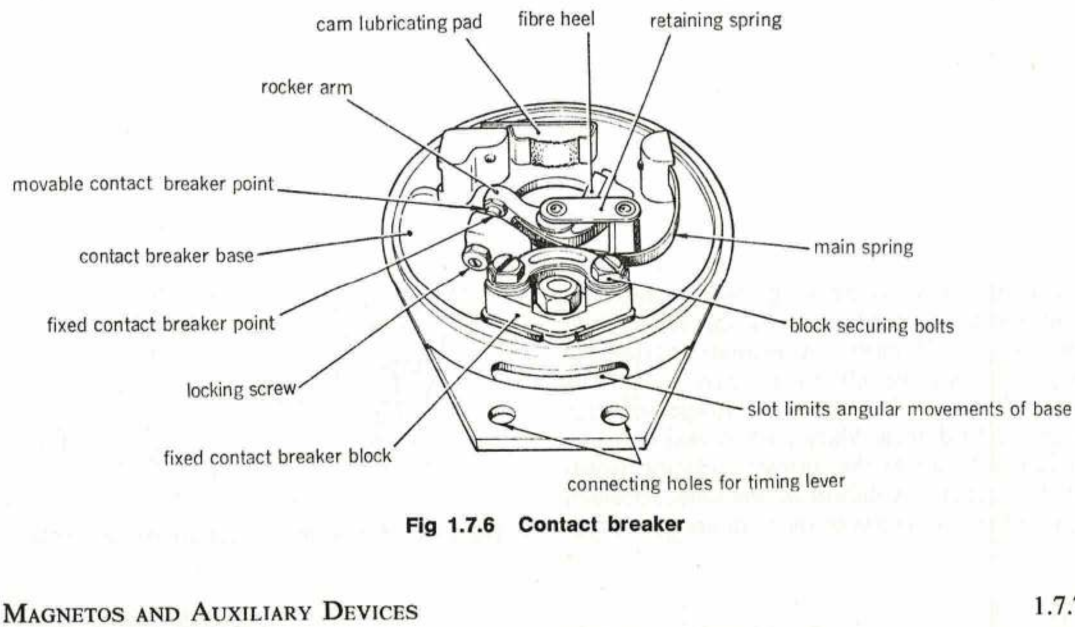

Fig 1.7.6 Contact breaker

of the rocker, a fixed point being secured to the assembly base plate. A leaf spring attached to the rocker arm tends to hold the contacts together.

31. The cam is keyed to such a position on the magneto shaft that when it strikes the fibre heel of the rocker arm, thus opening the points, the primary current flow is at its maximum. The contact breaker spring closes the points when the cam has passed the fibre heel. This cycle occurs four times every revolution of the magneto shaft and consequently both the mechanical and electrical stresses on the assembly are extensive.

32. The mechanical loading on the main spring is very high, especially in the case of multi-cylinder engines. For example, on a radial engine having 18 cylinders running at 2000 rev/min, the contact breaker has to operate 18 000 times in every minute or 300 times each second. The flexing of the spring at this speed raises the temperature of the spring and, in some cases, the spring may lose its efficiency and become weak. Where such overheating can be recognized by a change in colour of the spring, the spring must be replaced.

33. The spring must be of precise strength. If it is weak, the points will remain open for too long so that when they come together again, little time is left in which to build up a strong primary current for the next cycle. If the spring is over-strong, the points close with a hammering effect that produces rapid wear, and any variation in the size of the gap at the points, not only produces a change in the internal timing of the magneto, it also alters the timing of the magneto to the engine.

34. Short reinforcing, or auxiliary springs, are sometimes fitted at each end of the main spring to prevent a concentration of the bending forces at these points. A buffer spring, or a rocker stop, may be secured to the base plate to prevent the rocker arm being thrown too far outwards during high speeds.

35. The contact points of the assembly are tipped with either tungsten or platinum alloy to resist oxidization at the points and to withstand the mechanical hammering. It has already been stated that the primary current may be interrupted as much as 300 times per second and this leads to arcing at the points and erosion of the points.

Double Contact Breaker

36. The high rate of contact breaker mechanical operation on a magneto of a multi-cylinder engine has already been emphasized and, to cut this rate by half, a double contact breaker may be fitted. A double contact breaker has two separate sets of points operated by two rocker arms working on a common cam. Each rocker arm works alternately and either switch can make or break the primary circuit. Such an arrangement is illustrated at Fig 1.7.7 for a fourteen cylinder engine. In this instance the seven lobed cam is driven off the distributor at half engine speed. The wide lobes of the cam should be noted.

37. **Operation.** When points A (Fig 1.7.7) are closed as in the diagram, points B are open. Therefore, when points A open, the primary circuit is broken and a spark is produced at the sparking plug. While points A continue to be held open by the long lobed cam, points B close. A primary current is built up and the circuit is then broken as points B open. The cycle is then repeated with points B held open. Since both A and B points make and break the primary circuit seven times in each revolution of the cam, fourteen sparks per revolution of the cam are produced.

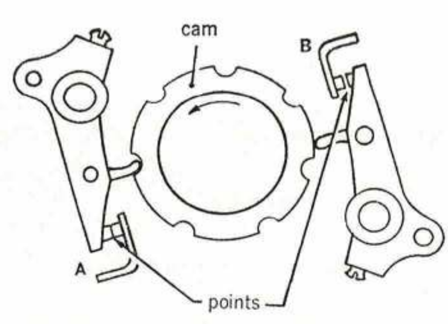

Fig 1.7.7 A double contact breaker assembly

Contact Breaker Servicing

38. The necessity for the efficient operation, both mechanical and electrical, of the contact breaker cannot be too highly stressed. To ensure this, regular and careful servicing is essential. This servicing is detailed in the Servicing Schedule and in Servicing Procedures.

39. **General.** All items comprising the assembly should be examined, particularly for cracks and corrosion. Fixed parts should be examined for insecurity and movable parts for freedom of movement. Cleanliness is absolutely essential.

40. **Contact breaker points.** The electrical resistance at the points must be kept as low as possible so that the primary current builds up freely. For this reason, particular attention must be paid to the points to ensure that they are making a full contact and are free from oil or grease. Examine the points for pitting; any slight irregularities may be removed.

41. **Checking the gap.** Any variation from the designed size of the contact breaker gap has the effect of altering both the internal timing of the magneto and the ignition timing. An incorrect setting produces a weak spark at the wrong time and has a marked effect on engine performance. The gap at the contact breaker is checked when the fibre heel is at the top of the cam lobe. This gap varies and is specified in the leading particulars of the appropriate engine Air Publication Volume 1, but is generally of the order of ·012 in ± ·001 in. Adjustment of the gap size is made through the fixed contact breaker point which is on an adjustable mounting.

42. To check the size of the gap, the contact breaker assembly is firstly rotated to the fully advanced position. The driving spindle is then turned until the fibre heel of the rocker arm is on the peak of the cam lobe (in some instances a particular cam lobe is specified) when the points will be fully open. A feeler gauge is then used to measure the size of the gap.

43. **Adjusting the gap.** Two methods of adjustment are illustrated at Fig 1.7.8.

44. In the first method the fixed contact is mounted on an adjustable contact plate that has elongated holes for the fixing screws. Adjustment is made by loosening the fixing screws and rotating the eccentric to re-position the contact. In the second method the adjustable contact is threaded through a split clamping block and is locked with a locknut and spring washer. Both the clamping screw and the locknut must be slackened off before adjusting the gap.

45. To reset the gap proceed as follows:

a. Unlock the contact plate or the adjustable contact.

b. Fully advance the contact breaker assembly.

c. Turn the driving shaft to position the fibre heel at the top of the cam lobe.

d. Adjust the gap to the specified size, and check.

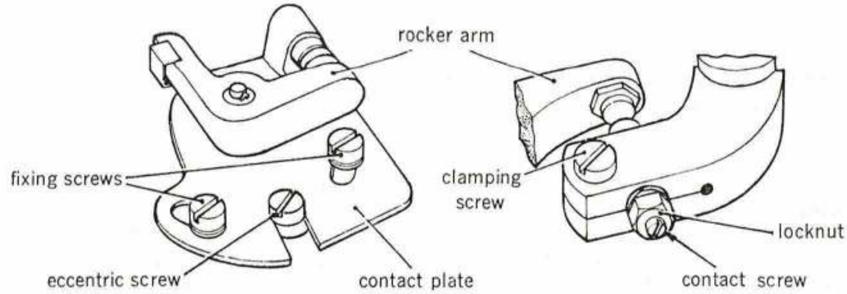

Fig 1.7.8 Two methods of contact breaker adjustment

e. Check the gap on a number of widely spaced lobes (any variation indicates uneven wear of the cam) and, if necessary, re-adjust the gap to a mean setting that brings the gap within the limits on all cam lobes.

f. Re-lock the adjustable contact and re-check the gap size.

46. **Checking the contact breaker spring.** The strength of a contact breaker spring is bound to deteriorate with extensive use, and so periodic checking of the spring-loading at the contact breaker points is necessary. The spring tension is measured by a spring balance with a special hook that fits under the heel of the rocker arm, as illustrated at Fig 1.7.9. The specified loading varies according to the type of magneto but is generally within the 22-36 oz range. Any main spring that is weaker than the specified bottom limit must be replaced, as too must any spring that has become overheated or corroded.

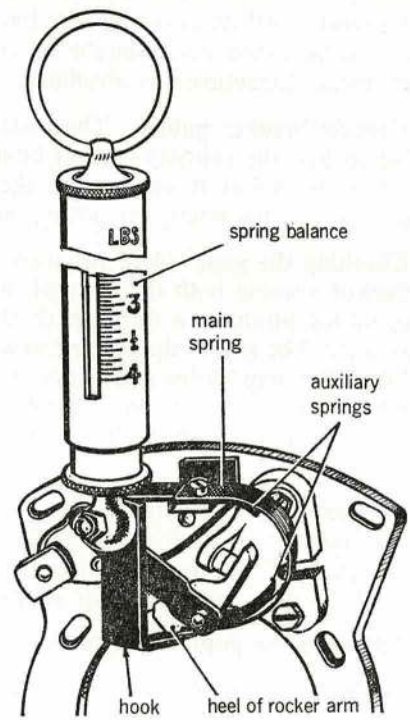

Fig 1.7.9 Testing a contact breaker spring

47. Should it become necessary to replace a spring, attention should be paid to the following points:

a. Only the correct type of spring is to be used.

b. Positive electrical contact must be made at both ends of the spring. It must therefore be free from oil and grease.

c. Auxiliary springs must conform to the normal closed curvature of the spring.

d. There must be no twist in the springs when assembled. This can be checked by operating the mechanism with the finger a few times and noting whether the rocker arm rides up the pivot pin.

e. Check the spring pressure when assembled.

48. **Contact breaker lubrication.** Over-lubrication is a greater hazard than under-lubrication. Not only is clean oil an insulator, but if the oil decomposes with heat, severe arcing at the points occurs and rapid burning and erosion results. As a general precaution some magneto designs have the contact breaker assemblies sealed, and the assembly is never disturbed until diagnosis of an ignition fault points to an assembly. Alternatively, light lubrication of the cam face may be controlled by a grease impregnated pad held in light contact with the cam. The rocker arm pivot may have an oil wick running through its bore that is moistened with oil at *widely spaced periodicities.*

The Distributor

49. As stated earlier in the chapter, the distributor receives high tension voltage impulses from the secondary winding and distributes the impulses to the sparking plugs in the correct sequence. The assembly consists of two main parts—the distributor and the distributor block.

50. The rotor, which is moulded of an insulating material, is attached to the half speed wheel that engages with a gear on the magneto spindle. The rotor head has two electrical conductors passing through the moulding—the main brush and the starting brush. All the voltage induced into the secondary circuit is applied to the main brush via a carbon brush (*see* Fig 1.7.10).

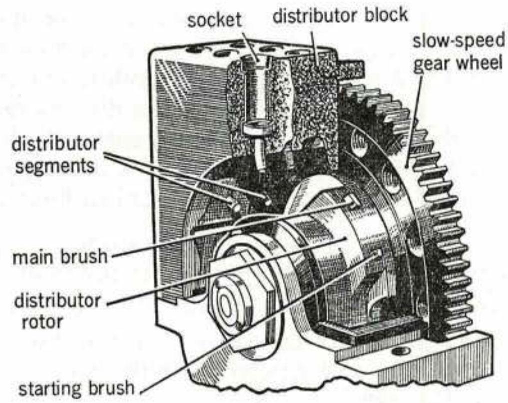

Fig 1.7.10 Distributor assembly

51. The distributor block has as many segments as there are cylinders, spaced equally in its internal bore. The segments are moulded with, but stand proud of, the block. A small clearance exists between the rotor brush and the segments so that as the engine runs, any flow of secondary current causes a small spark to occur between the rotor and the segment. This arcing is preferred to a rubbing contact because it is less likely to cause tracking, *ie* depositing a conductive film that allows an electrical short circuit on the path within the distributor.

52. The segments may be arranged either in a full circle of a single row or two semi-circles in two rows, or three segments in three rows. The rotors in the second and third instances would then have two main brushes and three main brushes respectively. This arrangement is used to simplify the design of screening and ignition harness by grouping the ignition leads into a small area.

53. The starting brush on the rotor is connected to the secondary circuit of the starting ignition system and is in no way connected to the main magneto circuit.

54. Ample ventilation of the distributor is essential to prevent internal corrosion and electrical shorting because of moisture. Also, the continuous sparking within the distributor tends to break down the surrounding air into its chemical components when, not only does the air lose its insulating properties, but the free nitrogen would combine readily with any moisture to form corrosive nitric acid. To prevent this happening, a continual air flow through both the distributor and the contact breaker assembly is provided through flameproof ventilators fitted in the walls of the distributor housing. These ventilators must be kept clean.

55. **Servicing.** The distributor is serviced in accordance with the Servicing Schedule. Periodically, the whole block must be removed and cleaned. If of the unvarnished type, the cleaning consists of washing in lead-free gasoline, wiping dry, washing and rinsing in hot water and finally drying. If the block is varnished it must be wiped only, using a clean dry rag. This cleaning may also be necessary in damp weather to remove all traces of moisture from the interior of the block.

56. The ventilation gauzes must be kept clean and unbroken to minimize risk of fire if the magneto is running in a gasoline-laden atmosphere. Segments and brushes are cleaned by rubbing lightly with fine emery cloth.

57. Moulded components must be examined, particularly for cracking around the metal segments and inserts. Segments and brushes must be examined for burning and erosion.

58. As the gap between the rotor brush and segment cannot be checked directly, it is necessary to check the rotor and the distributor block separately. The rotor may be checked by using a dummy distributor resembling an ordinary distributor complete with segments and of

such a shape that the gap between rotor and segment can be measured by feelers. If the gap exceeds the prescribed limits the rotor must be replaced. The rotor may also be checked against a standard rotor by setting up both rotors and comparing the heights of their brushes by using a Dial Test Indicator (DTI). The distributor block may be checked by a gauge which measures the bore of the segments, or by setting the block up on a special jig and using a DTI on each segment. If the measurements are such that the gap between the segments and the brush of a standard rotor exceeds the prescribed limits, then the block must be replaced.

59. **Carbon brushes.** Carbon brushes, *ie* spring loaded rods of carbon that slide freely in metal guides, are used to conduct electricity from a stationary to a rotary contact because they are good conductors and are self-lubricating. During service, they should be examined for:

a. Full surface contact with the mating face. Contacting areas are indicated by a polished surface. Never interfere with this face once the brush has bedded down except to wipe with a clean rag.

b. Freedom of movement in the guide. Any sticking of a brush in its guide can usually be rectified by cleaning the brush and guide.

c. Spring strength and freedom of movement.

Effect of Radial Engine Articulation

60. The design of the connecting rod assembly of radial engines is such that the angle through which the crankshaft moves between cylinder firing impulses is not always the same. This is because some of the rods do not fit over the crankpin but are attached to the flange of a 'master' rod, with the result that the inner ends of the rods do not follow the exact path of the crankpin. Therefore, to have the correct ignition on each and every cylinder, the contact breaker operating cams must have as many lobes as there are cylinders and the lobes must be machined with a matching angular irregularity.

61. It now becomes imperative that each cylinder is timed to its own cam lobe. Consequently, when timing the magnetos to a radial engine, the actual operation is always carried out on the 'master' lobe of the cam. Such lobes always carry an identifying mark.

Magneto Couplings

62. To obtain the best possible engine performance, the magnetos must be accurately timed to the engine. To be able to do this, some form of magneto drive that provides an angular adjustment between the engine and the magneto is necessary. Many such magneto drive couplings are in use, some employing the Vernier principle to provide a fine adjustment and others which use fine pitched serrations or teeth. One of each type of coupling is described in the following paragraphs.

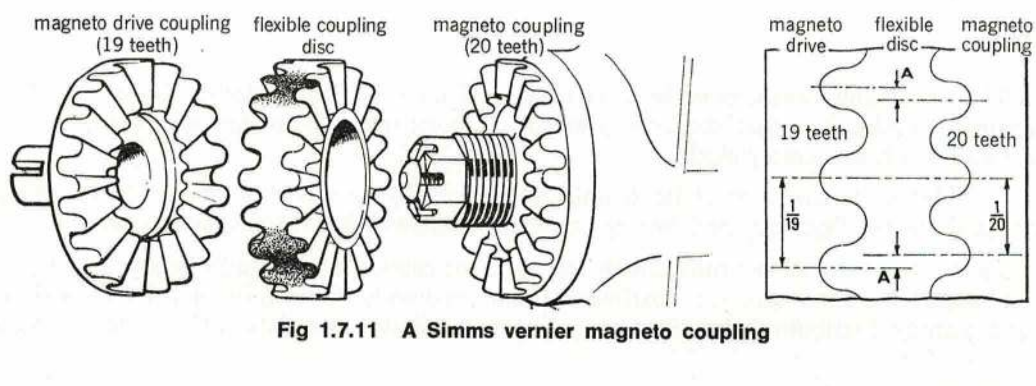

Fig 1.7.11 A Simms vernier magneto coupling

63. **Simms vernier coupling.** This type of coupling, illustrated at Fig 1.7.11, consists of three discs—the magneto drive, the flexible drive, and the magneto coupling. The magneto drive, which is driven by the engine, has 19 teeth and the magneto coupling which is keyed to the magneto shaft has 20 teeth. The intermediate flexible disc has 19 teeth on one side and 20 teeth on the other.

64. It can be seen that the difference in angular movement, which is calculated below, between one tooth on the magneto drive and one tooth on the magneto coupling is equal to A, but one tooth on the magneto drive is equal to $\frac{1}{19}$th part of a revolution and one tooth on the magneto coupling is equal to $\frac{1}{20}$th part of a revolution. Therefore:

$$A = \frac{1}{19} - \frac{1}{20} = \frac{20}{380} - \frac{19}{380} = \frac{1}{380} \text{ rev} = 0{\cdot}95 \text{ degrees.}$$

Thus, if the intermediate flexible disc is disengaged from the outer members, and re-engaged in the next tooth in the same direction of rotation on each side, the angular relationship between the engine and the magneto is altered by 0·95°. Whether this movement advances or retards the magneto depends on the direction of rotation taken by the flexible drive when making the fine adjustment.

65. **BTH couplings.** The BTH coupling consists of a driving and a driven disc, each with 150 serrations on their mating faces. The two discs are held together to form a rigid coupling by two bolts that pass through slots in the discs. Angular adjustment is made by removing the bolts, splitting the coupling and moving the plates one or two serrations before re-assembly. Since there are 150 serrations on the coupling, each serration gives an adjustment of 360° ÷ 150 which equals 2·4°. This adjustment is in terms of magneto movement. To obtain crankshaft movement, the adjustment must be divided by the magneto/engine speed ratio. The magneto half of the coupling is keyed on to the magneto shaft and secured by a nut. It is not a magneto part and must be removed, using an extractor, before returning the magneto to the Equipment Section.

Variable Ignition Timing

66. The peak gas pressure generated within a cylinder should occur just after TDC when the piston is at the start of the power stroke. If peak pressure is reached *before* this point, very little torque is produced, and exceptionally heavy loads are placed on the crankshaft bearings because of the acute angle of the crankweb. If peak pressure is reached *after* this point, not only has gas pressure been lost, because of increase in volume above the piston, but the actual working stroke has been shortened.

67. To ensure that peak pressure always occurs at the same crankshaft position the following factors must be considered:

a. **Engine speed.** The faster an engine runs, the greater is the arc of crankpin travel during the time taken for the charge to burn. Therefore, with an increase in engine speed, the timing needs to be progressively *advanced.* With a reduction in engine speed the timing should be *retarded.*

b. **Manifold air pressure.** The greater the pressure of a gas, the faster it burns. Thus, the cylinder charge of an engine running at high boost burns quicker than a charge at low manifold air pressure. To stop the peak pressure position moving as manifold air pressure is increased, the ignition timing should be progressively *retarded.*

c. **Mixture strength.** A correct mixture burns faster than either a weak or a rich mixture. Any variation from the correct mixture strength requires an *advancement* of ignition timing.

68. There is a tendency for these factors to cancel out (*eg* high engine speed generally means high manifold air pressure and rich mixture), but the cancellation is not exact. On low powered engines, the gain from making slight adjustments to the ignition timing during engine running is usually too small to be considered. On the larger engines, however, where the gain can be appreciable, ignition timing may be varied to suit all three conditions, and this variation can be achieved either by a flexible coupling or by a variable drive. Both of these methods are considered in the following paragraphs.

BTH Automatic Timing Device

69. This magneto driving coupling varies the ignition timing with changes in engine speed (Fig 1.7.12). The driven member is keyed to the magneto driving shaft, and the driving flange is secured to studs in the driving member. Two driving dogs formed on the rear face of the driving flange transmit the drive from the engine.

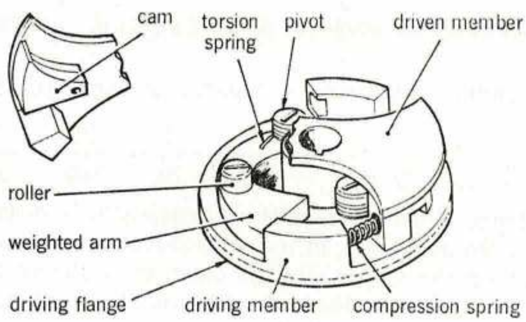

Fig 1.7.12 BTH automatic timing device

70. **Operation.** Automatic *advance* of ignition timing is obtained through two weighted arms inserted between the driving and driven members. The arms are pivoted on the driving member and, when engine speed is increased, they move outwards under centrifugal force. This movement is governed by a roller attached to each arm, each roller following the profile of a cam riveted to the driven member. Thus, outward movement of the arms causes the driven member to rotate *relative to the driving member,* advancing the timing. Reduction in speed lowers the centrifugal force, and outward movement of the arms is opposed by compression springs. The roller moves down the profile of the cam *retarding* the ignition.

Variable Drive

71. Whilst an automatic timing device can vary ignition timing for a change in engine speed, some other way must be used to alter the timing for a change in mixture strength or manifold air pressure. A variable drive is an arrangement where the angular relationship of one shaft to another can be altered without disengaging the drive. A simple arrangement of this magneto drive layout is illustrated at Fig 1.7.13.

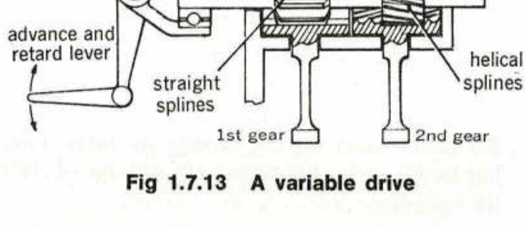

Fig 1.7.13 A variable drive

72. Two internally splined gears of the driving train to the magneto are mounted on the same axis; one has straight splines, and the other has helical splines. A shaft cut with straight splines at one end and helical splines at the other engages with the gears and is free to move axially. A cranked lever linked to one end of the shaft controls its axial position.

73. **Operation.** The drive from the engine passes from the engine drive shaft to the first gear, through the straight splines to the shaft and from the helical splines on the shaft to the second gear and thence to the magneto drive shaft. The splined shaft rotates with the gears.

74. Considering the axial movement of the shaft, if the shaft is moved axially by the cranked lever, the shaft retains its angular position in the first gear because of the straight cut splines, but an axial movement of the helical splines on the shaft must cause the second gear to turn in relation to the shaft and, therefore, to the first gear. Thus the angular relationship of the second and first gears can be varied at will by operation of the cranked lever.

75. This method of varying the ignition timing as the engine is running can be used independently of an automatic timing device. By linking the cranked lever to the throttle lever, variations in timing can be made automatically for changes in manifold air pressure and/or mixture strength.

Ignition Timing

76. When the timing of a magneto is to be carried out, reference must always be made to the appropriate engine Air Publication, Volume 1. The following basic principles apply, however:

a. Position the crankshaft to where the spark should occur for the cylinder to be timed (TDC, compression stroke)—*Set the engine.*

b. Position the magneto drive so that the magneto is in that position in which a spark should be delivered to that cylinder—*Set the magneto.*

c. Engage the magneto to the drive from the engine—*Couple the magneto.*

d. Check and adjust the timing.

77. **Setting the engine.** To position the crankshaft at the ignition point of the timing diagram, a protractor and pointer must be fitted to the engine and set correctly to the TDC of the cylinder to be timed. The protractor plate fitted to the engine is marked in degrees. Its zero position is positioned opposite a pointer secured to the engine casing to correspond to TDC of the cylinder to be timed. The ineffective crank angle of the shaft prevents the accurate positioning of the plate, unless either it is machined to fit a master key on the shaft, or a piston position indicator (PPI) is used. A PPI is a spring-loaded lever pivoted in a plug that screws into the sparking plug insert, as illustrated at Fig 1.7.14. One end of the lever contacts the crown of the piston; the other end registers any piston movement on the plate secured to the plug.

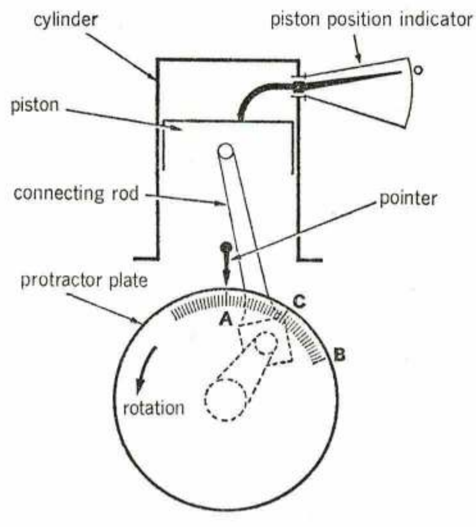

Fig 1.7.14 A timing protractor

78. To position the zero of the protractor correctly to TDC, proceed as follows:

a. Fit the piston position indicator (PPI) to the cylinder to be timed and turn the engine until the pointer of the indicator reaches its lowest point of travel.

b. Fit the protractor pointer to the engine casing.

c. Fit the protractor disc to the crankshaft with the zero opposite the pointer and secure.

d. Turn the engine *against* the normal direction of rotation until the PPI pointer goes off the scale; then slowly turn the engine forward until the pointer registers a short distance up the scale. Using a pencil make a mark opposite the PPI pointer (O) and also on the disc opposite the protractor pointer (A).

e. Turn the engine forward over TDC until the PPI pointer again registers with the pencil mark. Mark the protractor opposite its pointer (B).

f. The two marks on the protractor are both an equal distance from true TDC. Mark the protractor exactly midway between these two points (C), and turn the crankshaft until this central mark is opposite the pointer. The crankshaft is now at TDC. Without moving the crankshaft, adjust the pointer to read TDC. An example of adjustment of the timing protor is also indicated at Fig 1.7.14.

79. **Setting the magneto.** As has been stated earlier in the Chapter, a magneto produces a spark at the sparking plug precisely at the point when the contact breaker points are opened. To determine this point accurately, a lamp and battery (Type A) may be used to give a visual indication. The primary side of the contact breaker points is disconnected or otherwise insulated, and the two leads from the lamp and battery are connected to either side of the contact breaker points so that the contact breaker forms a switch in the lamp and battery circuit. With the contacts closed, the lamp will light and, at the moment of opening, the light will go out. The type 'B' test set gives not only a visual indication but an audible indication as well. Unlike the type 'A' lamp and battery, the light comes on when the contact breaker points *open*, accompanied by a change in pitch of the buzzer. The advantage to be gained from this is that the primary winding need not be disconnected. To set the magneto, proceed as follows:

a. Remove the distributor cover. (This is an important safety precaution and ensures that the engine will not fire if turned.)

b. Check the contact breaker gap. (Refer to engine AP Volume 1.)

c. Fully advance the magneto and lock it in the fully advanced position.

d. Turn the magneto until the distributor rotor is serving the cylinder to be timed and the contact breaker points are on the point of opening.

e. Offer up the magneto to the engine to align the driving dogs, adjust the coupling if necessary and secure the magneto.

80. **Checking the timing.** If two magnetos need to be synchronized, then two type 'B' testers are required. If the type 'A' tester is used, one only is required, as it is fitted with three leads. Check the timing as follows:

a. With the earthing screw removed, connect either the type A or type B synchronizer with one lead to earth and the other to the contact breaker spring retaining screw. DO NOT ATTACH IT TO THE SPRING.

b. Turn the engine *against* the normal direction of rotation and then turn slowly forward until the lamp goes OUT on type A (ON with type B) and check the pointer position. The protractor should show the correct timing.

c. Correct any error by removing the magneto and adjusting on the serrated drive.

d. When the timing is correct, remove the magneto, take out the wedge from the automatic timing device and lock the nuts on the serrated drive.

e. Refit the magneto and recheck the timing.

f. Disconnect the lamp and battery, refit the earthing screw and refit the distributor.

g. Remove the PPI, protractor and pointer and fit the sparking plugs.

h. Connect the HT harness switch lead and starting lead.

Auxiliary Ignition Devices for Engine Starting

81. When starting a piston aero-engine it seldom happens that the engine is turned over fast enough for the magneto to operate, and some other means of providing the initial sparking becomes necessary. In general, the method used is decided by the size of the engine—low

powered engines use impulse starters, whilst high powered engines use some form of booster coil.

82. **Impulse starter.** The impulse starter, which is illustrated at Fig 1.7.15, is used on low powered engines and on light aircraft where the engine is started by hand swinging the propeller. The unit is a spring-loaded coupling through which the engine drives one of the main magnetos. The drive passes from the engine half of the coupling through a strong spiral spring to the magneto half of the coupling.

83. **Operation.** When turning the engine to start, the magneto turns with the engine until just before the magneto contact breaker points are about to open. At this point a pawl falls against a stop on the magneto end plate and prevents further magneto rotation. Continued engine turning winds up the spiral spring until, just after TDC, a cam on the engine coupling releases the pawl. The spring then unwinds rapidly and flicks the magneto round fast enough to produce a spark, which is so far retarded that there is no danger of a 'kick-back' of the propeller. The pawls are so mass balanced that centrifugal force holds them out of engagement during normal engine running.

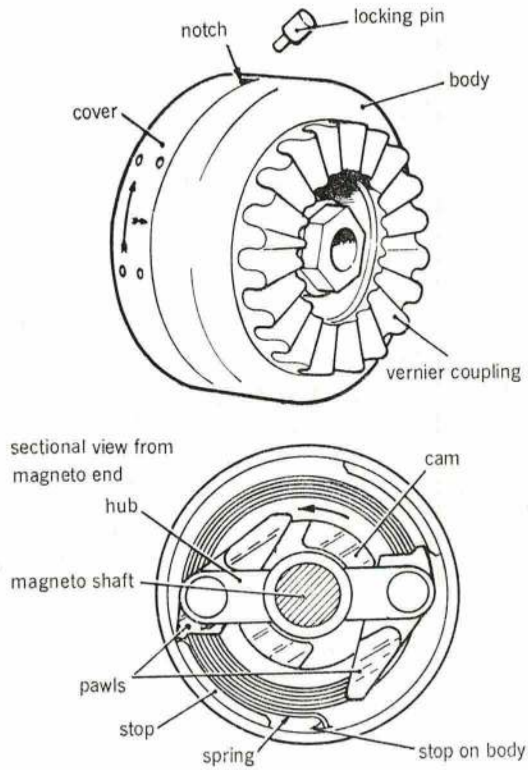

Fig 1.7.15 An impulse starter

84. **High tension booster coil.** High tension booster coils, one of which is illustrated at Fig 1.7.16, are also used for engine starting. The unit supplies a continual stream of high tension electrical impulses, each capable of producing a spark at the sparking plug. These impulses are directed to the cylinders in the correct firing order through an additional trailing brush on the engine magneto distributor rotor.

85. The HT booster coil consists of an armature and an electrically operated switch. The armature, as in the magneto, has a soft iron core on which are wound primary and secondary windings. The electrically operated switch controls the primary circuit and the movable contact of the switch is secured to a leaf spring which tends to hold the contacts closed. The hook of a flexible steel plate, upon which is mounted a soft iron pad, is caught under the leaf spring.

86. **Operation.** The primary contacts are normally closed so that, when the primary circuit is energized from the external power, the iron core becomes magnetized. The magnetized core immediately attracts the iron

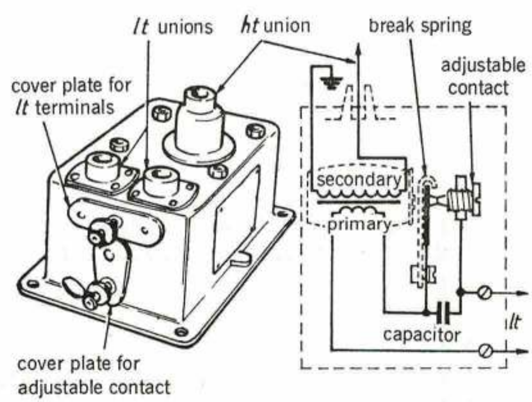

Fig 1.7.16 A HT booster coil

pad, causing the hook to open the contact points and break the primary circuit. This causes:

a. The magnetic field to collapse across the secondary winding and to induce a high tension electrical impulse that is fed to the trailing brush of the engine magneto distributor rotor.

b. The armature to lose its magnetism, thus allowing the leaf spring to close the contact points.

87. The moment the contact points close, the primary circuit is again energized and the cycle is repeated and continues to be repeated until the external power is switched off. Thus an endless stream of high tension impulses is fed to the distributor of the main magneto and on to the sparking plugs.

88. As on a magneto, a capacitor is fitted across the contact points to reduce arcing at the points and to:

a. Increase the speed of the collapse of the primary current and magnetic field.

b. Reduce burning and erosion at the contact points.

89. **Low tension booster coil.** This type of booster coil, the circuit of which is illustrated at Fig 1.7.17, is used where normal timing is retarded sufficiently for starting purposes. The operation of the unit is basically the same as the HT booster coil, but a separate starter brush on the magneto distributor rotor is not required. This removes any chance of 'flash-over' at altitude and consequent engine misfiring.

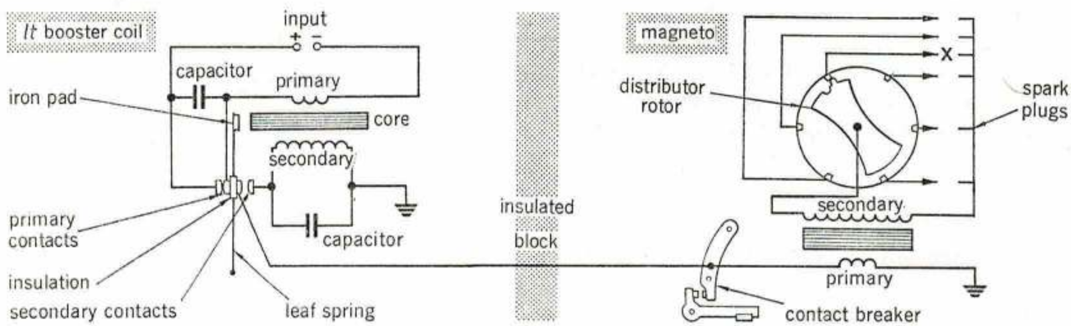

Fig 1.7.17 A LT booster coil circuit

90. The unit consists of primary and secondary windings on a soft iron core, primary and secondary contact points and a capacitor in each circuit.

91. **Operation.** The primary contacts are normally closed so that, when the primary circuit is energized from the external power, the iron core becomes magnetized, attracts the iron pad, and breaks the circuit. The resultant collapse of the magnetic field induces a voltage into the secondary winding that charges the second capacitor. The movement made by the iron pad and leaf spring when breaking the primary circuit also closes the secondary contacts. The energy in the secondary capacitor then discharges into the primary circuit of the magneto. Such a primary current flow, as in normal magneto operation, causes a high tension voltage to be induced into the secondary windings of the magneto and a spark is produced at the sparking plug.

Conclusion

92. Now that we have discussed the basic principles of electro-magnetic induction and the purpose of a magneto (which was to convert mechanical energy into electrical energy), we shall continue in Chapter 8 with a description of how the HT voltages are conveyed to the sparking plugs and how the components are serviced.