SECTION FOUR

EARLY IGNITION SYSTEMS

ENGINE IGNITION REQUIREMENTS

From the very beginning of internal combustion engine design the problem of ignition has been a major item. In comparison with the principles of internal combustion engines, which have undergone comparatively minor changes, the development of electrical ignition systems has been rapid during recent years and has passed through several definite stages of engineering design.

It was realized almost at once that an electric spark system was highly suitable to engine ignition, but a simple means of providing a spark of sufficient intensity in the proper place at exactly the desired time eluded designers. The low tension ignition system was one of the first developments along this line and presents an interesting historical background for modern advances.

LOW TENSION IGNITION SYSTEMS

When a series circuit consisting of a battery and coil is interrupted, a strong spark is produced at the break. The intensity of the spark is the result of self-induction in the coil, the voltage maintaining the spark across the gap being many times greater than that of the battery.

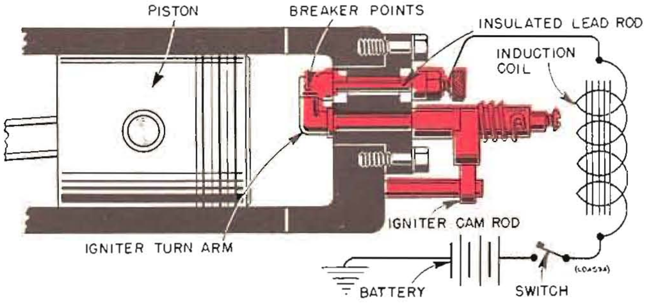

Figure 46—Turn Rod Breaker Points

In order to utilize the low tension spark for ignition purposes in what was known as the "make and break" system, the breaker points themselves had to be placed and operated within the cylinder in a position where the spark could ignite the fuel. To open and close the points several devices and arrangements were used, the most common being a push or turn rod (Figure 46) which operated through a tight bushing in the cylinder head. Another system used extensively provided for the actuation of the breaker points by a pin located on the top of the piston (Figure 47) which, in striking the breaker arm at the top of its stroke, would separate the breaker points

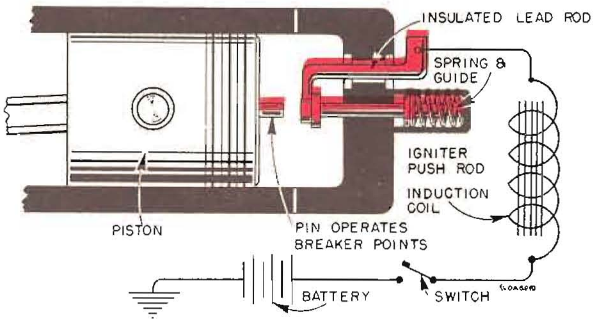

Figure 47—Push Rod Breaker Points

and thereby produce a spark. The chief disadvantages of these systems were the difficulty of maintaining the mechanical actuating linkage and the low voltages of the ignition spark produced. Both of these factors definitely limited the compression and speed of the engines.

LOW TENSION MAGNETO IGNITION

The low tension magneto was developed primarily to replace or supplement the batteries of the original low tension ignition systems. The ignition circuits were not changed in any other way (Figure 48), the same make-and-break arrangements being used to secure an ignition spark at the desired time and place.

Construction of the low tension magneto was very simple, consisting of an assembly in which a single coil armature was rotated in the field of one or more heavy horseshoe magnets. A collector ring on the armature connected the alternating current output to the ignition system wiring.

A somewhat higher system voltage was used with the low tension magneto circuit than when batteries were used.

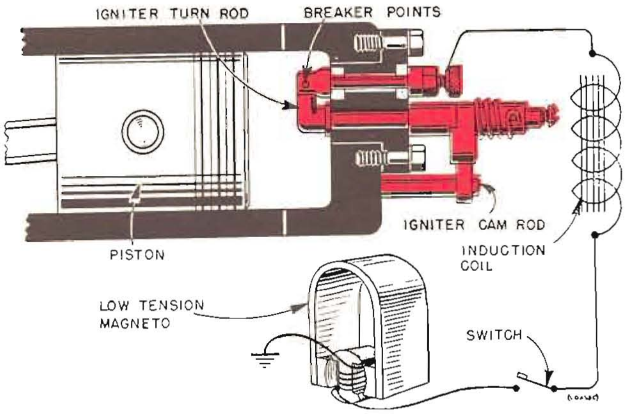

Figure 48—Low Tension Magneto Ignition Circuit

SECTION FIVE

MAGNETO DESIGN & CONSTRUCTION

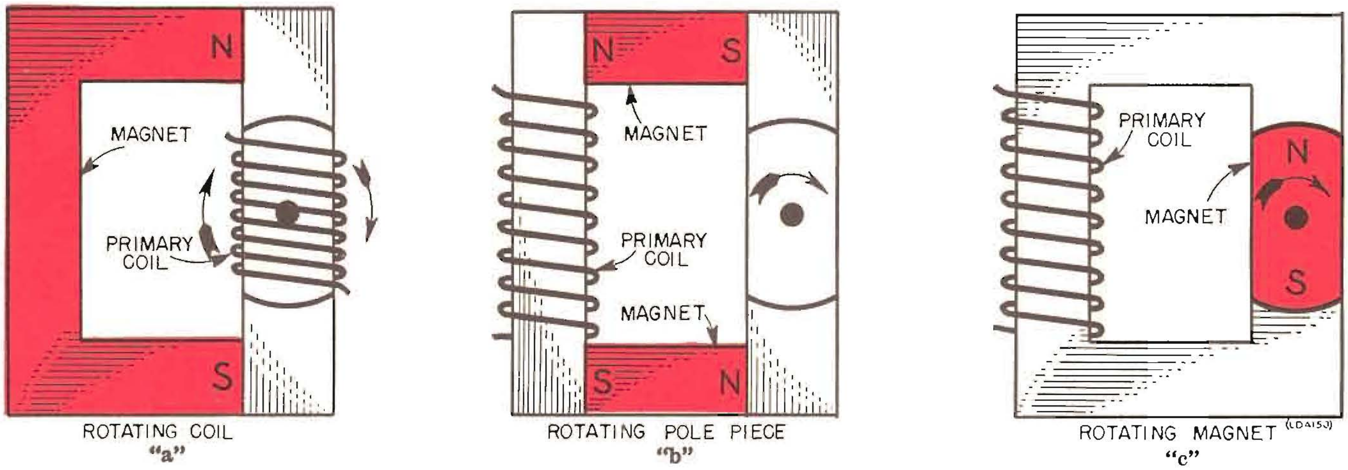

Figure 49—General Classification of Rotary Magneto Designs

GENERAL CLASSIFICATION

Fundamental magneto design is based on the principle of relative movement at right angles between the turns of a primary winding and a magnetic field. Such movement may be in a straight line as in the case of a reciprocating magneto, or along an arc as in the case of a rotary magneto.

The relative movement between the primary winding and the magnetic field may be accomplished by moving the coil (Figure 49 "a"), moving some component of the magnetic field (Figure 49 "b"), or moving the magnet (Figure 49 "c").

In the earliest magneto designs the primary winding was placed on an armature and rotated between the poles of a horseshoe magnet. Because of the shape of the armature this type magneto is often called the shuttle-wound armature design.

Both the magnet and the coil are mounted in stationary positions in the inductor type magneto, relative movement of the winding and field being secured by breaking and re-establishing the magnetic circuit.

The recent development of permanent magnets of greatly increased strength per unit volume led to the revolving magnet design. In this arrangement the coil, together with a short magnetic circuit, is mounted in a stationary position, while one or more magnets are rotated between the pole pieces.

SHUTTLE-WOUND ARMATURE MAGNETOS

The first high tension magneto designs were of the shuttle-wound armature type, following closely the principles of the earlier low tension units. In its conventional form (Figure 50) the shuttle-wound armature type magneto consisted of a large, stationary horseshoe magnet mounted on a frame in which the pole shoes were locked in place, and of a wound-armature assembly which could be rotated between the pole pieces of the frame.

The wound-armature assembly (Figure 51) was made up of a shuttle-shaped lamination assembly on which both the high and low tension coils were wound, a condenser and the breaker contact points. All connections were made within the armature, only the high tension ignition spark being transferred to the exterior circuit by means of a collector ring and carbon brush.

The principal disadvantages of the shuttle-wound

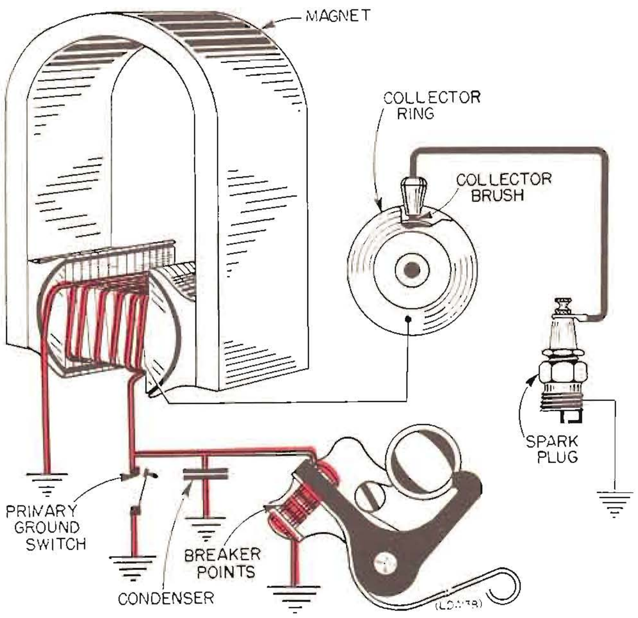

Figure 50—Shuttle-Wound Armature Magneto Circuit

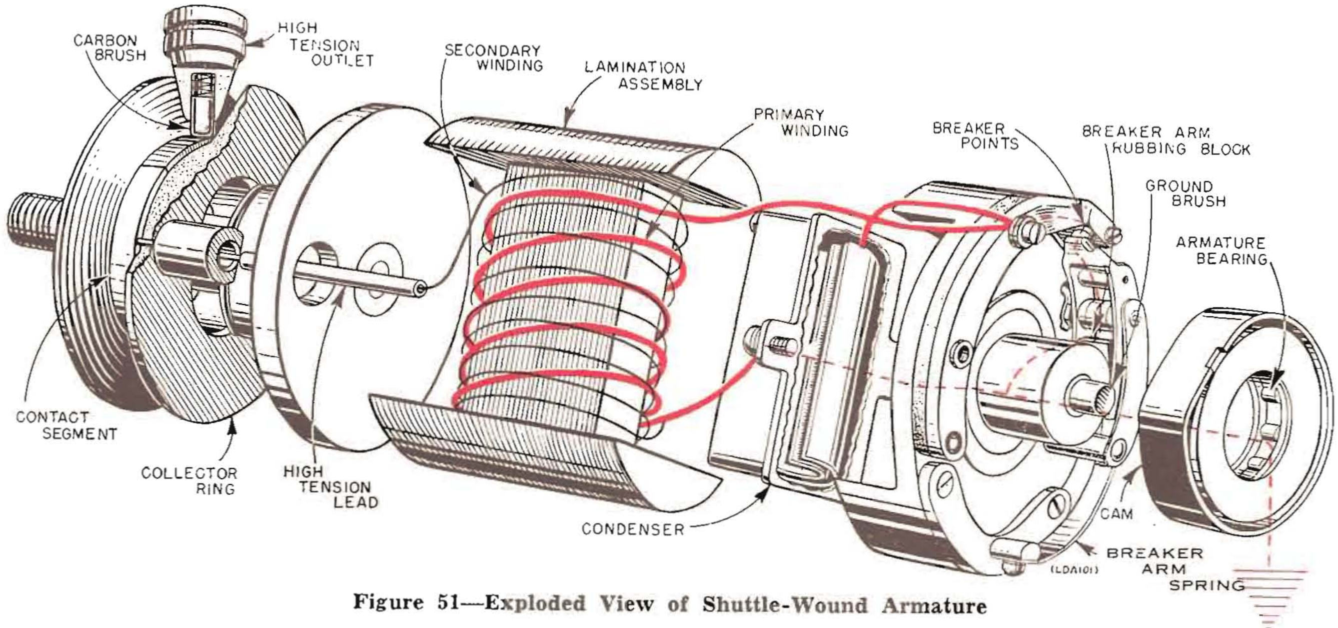

Figure 51—Exploded View of Shuttle-Wound Armature

armature design magneto were its bulkiness, the complexity of the armature assembly and the rotative strain to which the coil, condenser and breaker points were subjected.

ROTATING PRIMARY COIL VARIATION

An interesting variation of the standard shuttle-wound armature magneto was developed in a design (Figure 52) in which only the primary coil is rotated, while the breaker contact points, condenser and secondary coil are mounted in a stationary position. Actually the magneto has two primary windings, one being wound on the armature and connected through a collector ring to another primary winding mounted on a laminated core together with the secondary winding. The primary circuit is completed to ground through the breaker points.

When the armature is rotated a low voltage current is induced in the armature winding which flows through the stationary winding and breaker points to ground in order to complete its circuit. This current establishes a field which links the turns of the secondary winding of the stationary coil. When the primary circuit is abruptly opened by breaker point action, the field established in the coil instantly collapses, with the result that a very high voltage is induced in the secondary winding of the stationary coil. This voltage is strong enough to bridge the gap across the spark plug points to furnish the ignition spark.

ROTARY INDUCTOR MAGNETOS

In the inductor design magneto both the magnet and coil are mounted in a stationary position, a primary current being induced in the coil by rotating one or both legs of the magnetic circuit. When only one leg of the magnetic circuit is broken, the magnetic flux in the coil

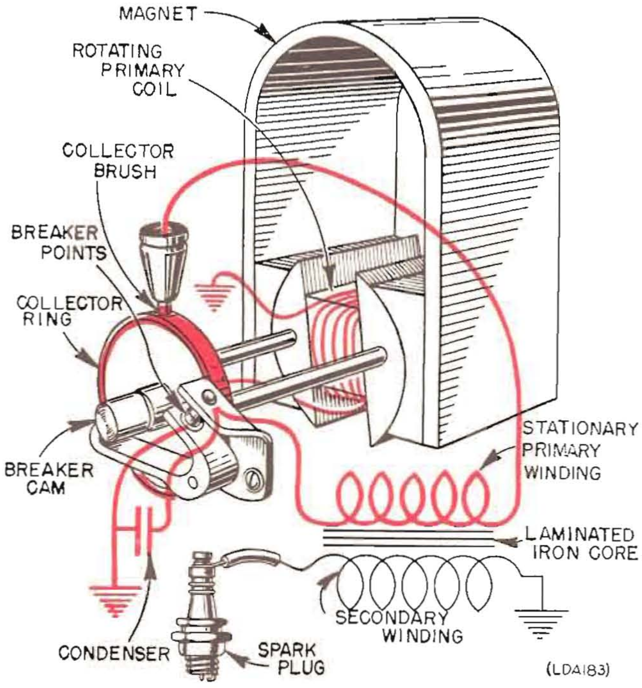

Figure 52—Rotating Primary Coil Variation

alternates from minimum to maximum, but does not undergo complete reversal as in the case where both legs of the magnetic path are interrupted (Figure 53). Reversals of flux in the coil cause corresponding reversals in the primary current with the result that wear due to arcing at the breaker points is evenly distributed between the two contact surfaces.

The construction of the rotary inductor type magneto is similar to that of the rotating magnet design except for its comparatively long magnetic circuit. The original scheme contemplated the use of a large horseshoe magnet as in the case of a shuttle-wound armature magneto,

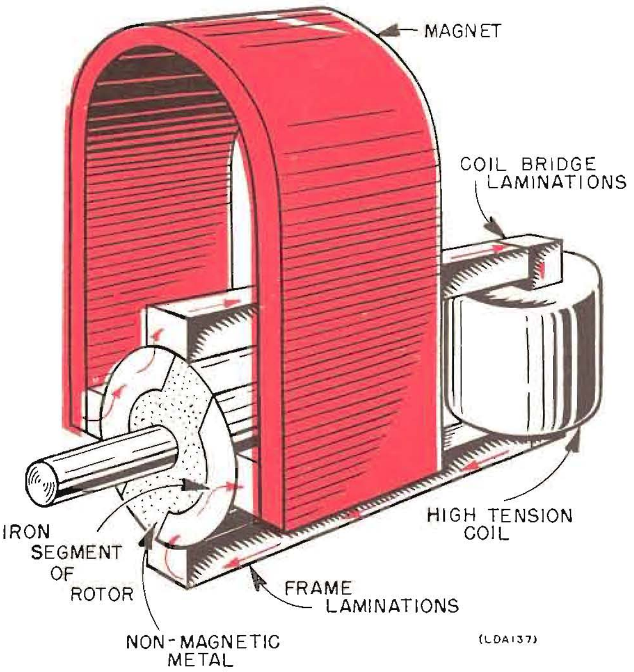

Figure 53—Rotary Inductor Design Magneto

but at the same time secured the advantages of a stationary coil, condenser and breaker point assembly.

Standard design rotary distributor systems are readily adaptable to the rotary inductor type magneto.

RECIPROCATING INDUCTOR MAGNETOS

Reciprocating drive inductor design magnetos (Figure 54) have been adapted with good results to certain slow speed internal combustion engines, usually of the horizontal type. The application is limited to engines of either one or two cylinders.

The mechanical connection (of which there are many variations) between the engine and the magneto consists basically of a push rod arrangement which, working against a spring, trips the actuating lever of the magneto at the instant an ignition spark is desired. As the result of tripping this lever, a second spring snaps the armature away from the coil core laminations, thereby breaking the magnetic circuit and causing the field through the coils to collapse. Since the collapse of this field induces a current in the primary circuit, the opening of the breaker points when the armature has moved about ⅛″ away from the core pieces results in a high voltage current surge in the secondary winding which furnishes the ignition spark in completing its circuit to ground.

THE ROTATING MAGNET MAGNETO

A sweeping change in magneto design and manufacture resulted from introduction of the rotating magnet type magneto. Its advantages are both numerous and outstanding, with performance standards being raised, service being simplified and the original cost being decreased. Present commercial rotary magnetos are nearly all of the rotating magnet design.

Possibly the greatest single advance in this change is the simple, one-piece magnetic rotor which replaces the intricate, wound-armature of former designs. In the rotating magnet design magneto the coil, condenser and breaker points are all mounted in a stationary position with the result that construction is much more substantial, that moving connections are eliminated and that tests and repairs are easily accomplished.

The size of the unit is considerably reduced because the stationary coil and breaker point assemblies are more compact, because short, powerful Alnico magnets can be used to full advantage and because parts such as the collector ring and collector brushes have been eliminated.

The simplification of the magneto construction has been a major factor in reducing both its original cost of manufacture and its cost of upkeep.

DESCRIPTION OF OPERATION

Rotation of the magnetic rotor (Figures 55 & 57) sets up an alternating magnetic flux in the magnetic circuit which cuts the primary winding each time it rises and falls. As the result induced electric currents, alternating in direction, flow in the primary circuit during the intervals the breaker points are closed. Since the induced primary current is proportional to the rate of flux linkages, it varies in value, a maximum being reached each time a complete magnetic flux reversal occurs in the magnetic circuit.

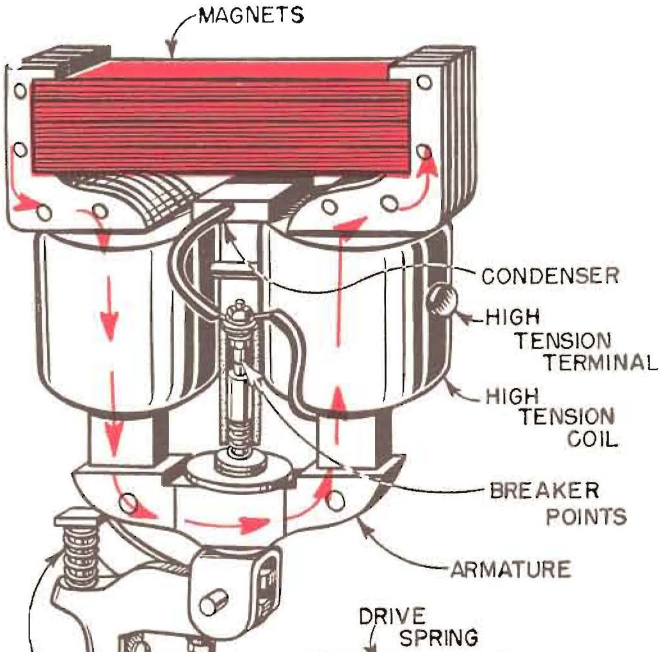

Figure 54—Reciprocating Inductor Design Magneto

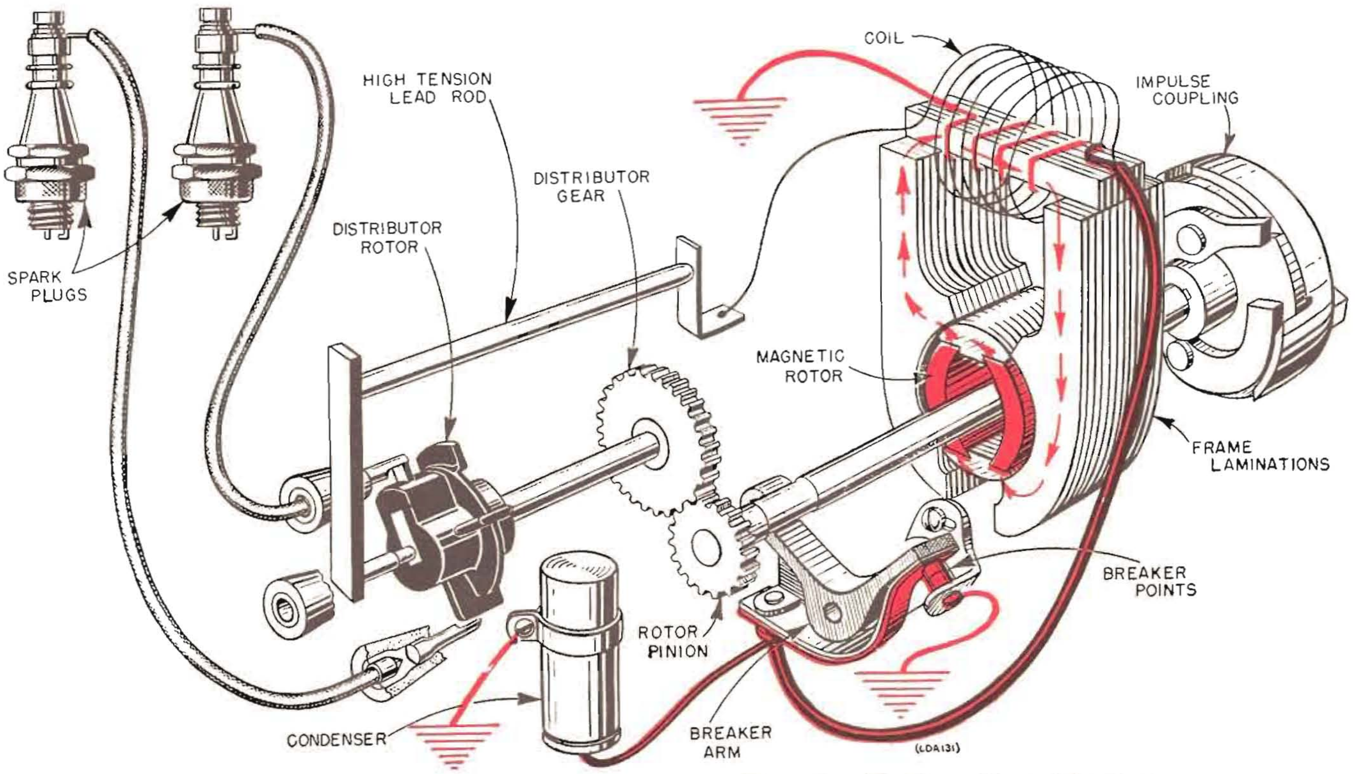

Figure 55—Schematic Diagram of Rotating Magnet Magneto with Jump-Spark Distributor

The current in the primary winding of the coil establishes a magnetic field which interlocks the turns of the coil secondary winding, this field reaching its maximum extent simultaneously with the primary current. Breaker point action at the instant of maximum primary current and field opens the primary circuit with the result that the primary current cannot flow, causing the immediate and complete collapse of the magnetic field existing in the coil.

The ratio of turns in the coil secondary winding to those of the primary is very high and since each line of force of the collapsing primary field must cut the turns of the secondary winding, an exceedingly high rate of flux linkages is obtained. Consequently, the value of the induced voltage in the secondary winding is very high. The secondary circuit is established when this induced high voltage is sufficient to bridge the gap between the spark plug points.

The self-induced voltage occurring in the primary winding as a result of the quick break of the primary circuit is absorbed by the condenser which is shunted across the breaker points. In effect this action promotes a more rapid collapse of the primary field and at the same time reduces contact point burning caused by arcing.

OSCILLOGRAPH ANALYSIS

The operation of a magneto can be analyzed graphically through the use of the cathode-ray oscillograph (Figure 56). Curves are obtained representing the transitory values of the resultant magnetic flux, the primary current or voltage, and the secondary current or voltage.

Typical performance curves (Figure 58) for a two-pole magneto have been reproduced, the resultant magnetic flux curve being superimposed upon the static flux along the upper axis, while on the lower axis the primary current and secondary voltage curves are shown.

The static flux is a basic reference curve usually obtained by measuring the magnetic flux with a fluxmeter at significant intervals through a complete cycle, the

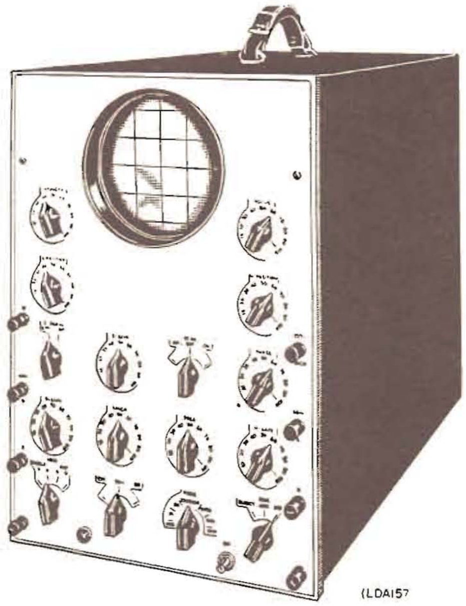

Figure 56—Laboratory Type Cathode-Ray Oscillograph

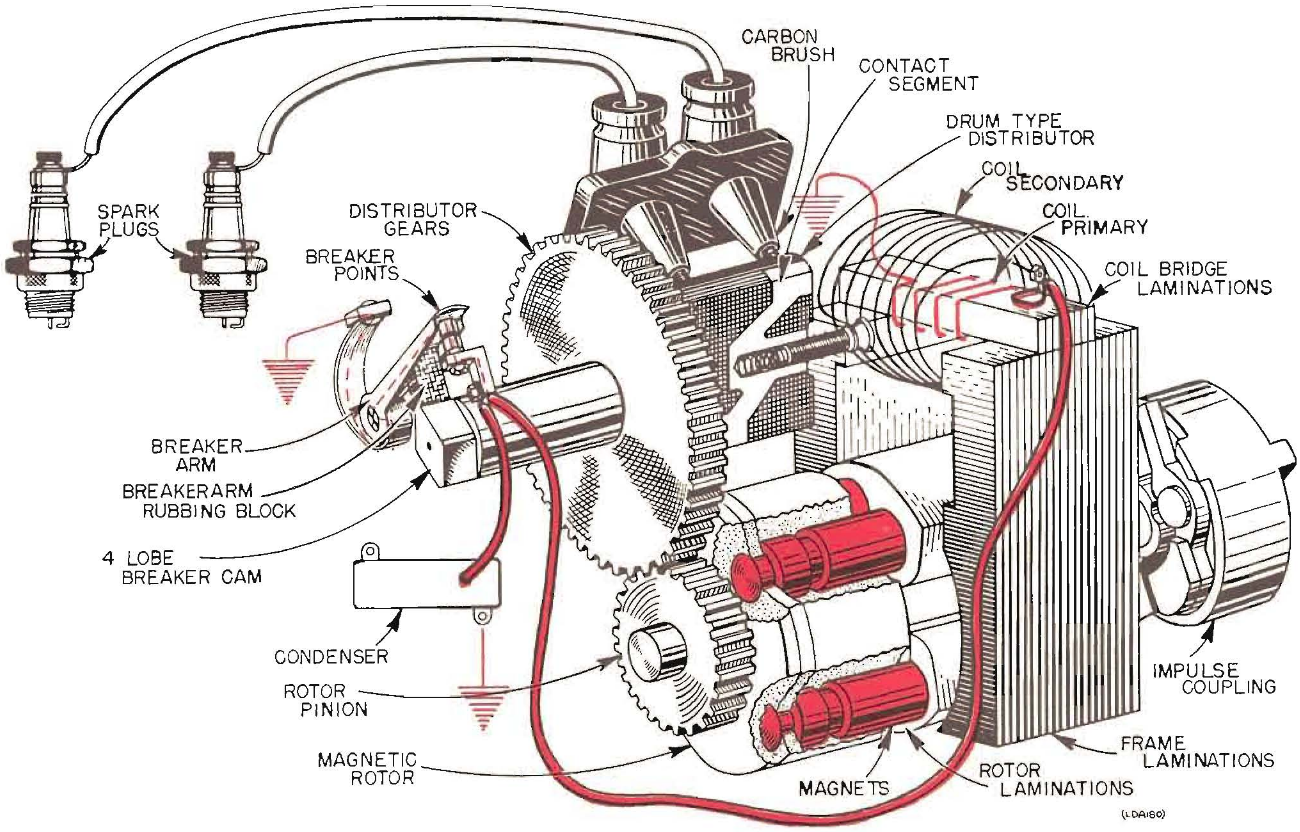

Figure 57—Schematic Diagram of Rotating Magnet Magneto with Carbon Brush Distributor

magnetic rotor being held stationary during each measurement. The curve indicating resultant flux is obtained while the magneto is in normal operation and shows clearly the magnetic flux lag due to rotation and the flux distortion caused by the secondary current discharge.

The steepest portion of the resultant flux curve indicates the greatest flux change in the magnetic circuit and examination of the corresponding primary current curve shows that maximum primary current occurs simultaneously as the result. The sharp break in the primary current comes when the breaker points open the primary circuit and the current immediately falls from its maximum value to zero. This abrupt change in value of the primary current induces the very high voltage in the secondary winding, the secondary circuit being established when the induced voltage is sufficient to bridge the spark plug gap. The voltage necessary to maintain the gap oscillates in value after the original breakdown occurs.

The oscillograph curves are important chiefly in laboratory work connected with original magneto design. The resultant flux curve indicates any possible saturation of the magnetic circuit, while the primary current curve locates the point at which the primary circuit should be broken for greatest secondary voltage. The effect of a condenser shunted across the breaker points is determined by the incline of the primary current curve as it falls from maximum to zero value as the result of breaker point action.

THE MAGNETO HOUSING

The iron laminations through which the magnetic circuit between the coil and the magnet is established are held in place by a main housing assembly, which also provides the mounting for the rotor bearings or bearing plates. Since the laminations are usually shaped to function as the pole pieces adjacent to the armature or magnetic rotor, construction of the housing assembly must provide for the maintenance of a very small and constant air gap when the rotor is turned. As a consequence the construction of the housing must be sturdy and absolutely rigid, the one-piece diecast method of manufacture having been found especially suitable.

THE BREAKER POINT ASSEMBLY

The breaker point assembly is mechanically actuated through the rotation of a breaker cam. This cam may be located on the distributor shaft (Figure 59 "a"), in which case its speed of operation is reduced by the ratio of the gear teeth; or the cam may be located on the magnetic rotor shaft (Figure 59 "b"), where it rotates at the same speed as the rotor. The mechanism must be so adjusted that the contact points open at the exact instant a break in the primary circuit will induce the maximum secondary voltage.

Many factors influence the design of the breaker point assembly with the result that there are hundreds of variations. In general, however, the three types com-

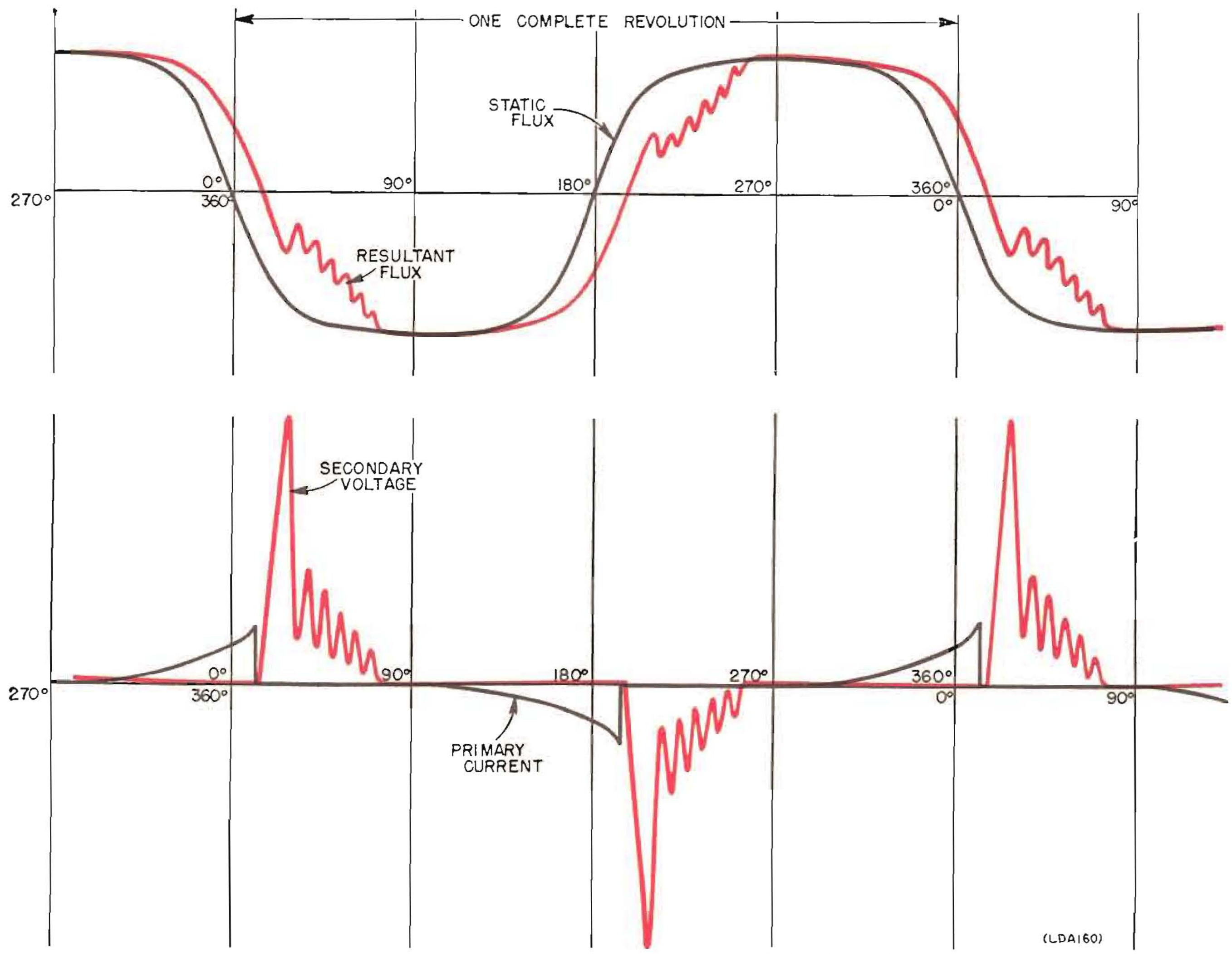

Figure 58—Oscillograph Curves of Operation of 180° Spark Magneto

monly used on commercial rotary magnetos are: (a) the breaker arm with its fulcrum at the end (Figure 60A), (b) the breaker arm with its fulcrum at the center (Figure 60B) and (c) the two-piece, indirect action breaker arm assembly (Figure 60C).

The essential parts of the breaker arm are the rubbing block, the pivot bearing, the actuating spring, the contact point and the contact point connection. The rubbing block is designed to ride smoothly on the surface of the cam, its wear being balanced as nearly as possible with the wear of the contact surfaces. The pivot bearing must

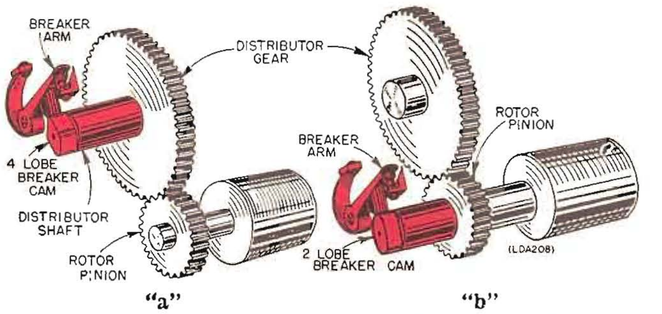

Figure 59—Location of Breaker Point Assembly

function smoothly in order not to cause any appreciable mechanical lag in the breaker arm action. The actuating spring must have the correct tension to maintain rubbing block contact with the cam at the various speeds of operation encountered.

Possibly one of the most important factors in the overall design of the breaker point assembly is the simplicity of contact point adjustment or replacement. Since adjustment is usually accomplished by moving the stationary contact point, arrangements have been made on recent magnetos to mount this point on a semi-fixed bracket controlled by an eccentric head screw. The convenient screwdriver adjustment thus obtained is considered most advantageous, since it permits fine adjustment of the contact point gap as well as providing a positive locking arrangement.

CONTACT POINT MATERIAL

A good deal of research work and field experience has not yielded full, conclusive facts concerning contact point materials. This situation is somewhat further obscured by certain long-held prejudices and preferences.

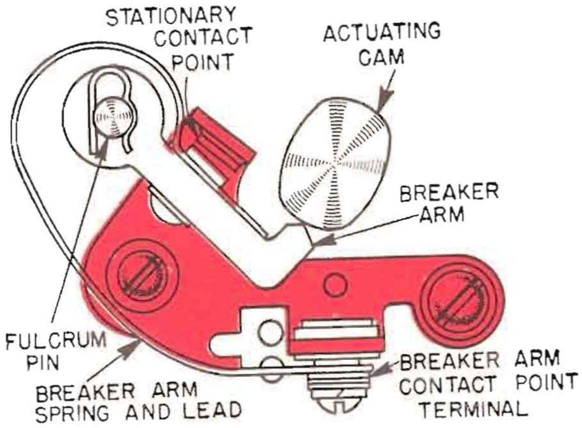

FIGURE 60A – BREAKER ARM WITH END PIVOT

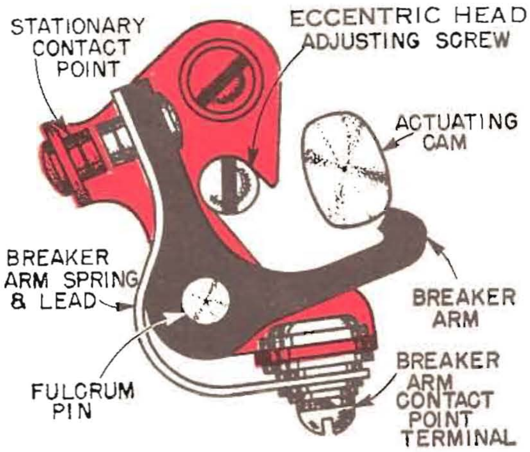

FIGURE 60B–BREAKER ARM WITH CENTER PIVOT

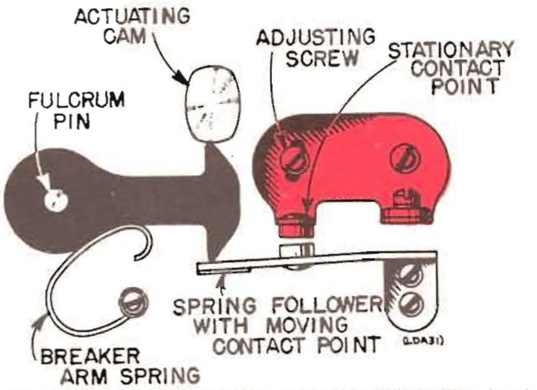

FIGURE 60C–INDIRECT ACTION BREAKER ARM

Two metals, tungsten and platinum, are outstanding in their use as contact points. As might be expected, each has definite advantages as well as disadvantages. In the final analysis the application of the magneto unit is usually the deciding factor in the choice of contact point material.

Since tungsten is one of the hardest metals known, tungsten points will stand continual "pounding" and will give long, efficient service under normal conditions. Tungsten points can be readily reconditioned by resurfacing with a suitable file or stone and can be replaced economically, since their cost is less than a fourth of the cost of platinum points.

Platinum is a comparatively soft metal, but in its use for contact points iridium is added as a hardening agent. Platinum-iridium points are advantageous because of their ability to handle primary current with minimum loss, and as a result are often specified for the shuttle-wound armature design magnetos as well as for some special heavy duty units. Platinum-iridium points are considered essential for aircraft ignition units, but it should be noted that such units are subject to frequent and periodic maintenance and overhaul.

Contact point adjustment has been found to be necessary more often with platinum-iridium points than with tungsten.

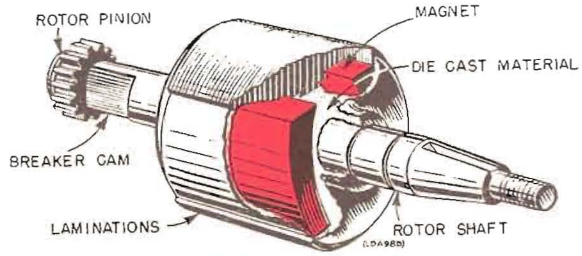

Figure 61—Two-Pole Rotor with Block Magnets

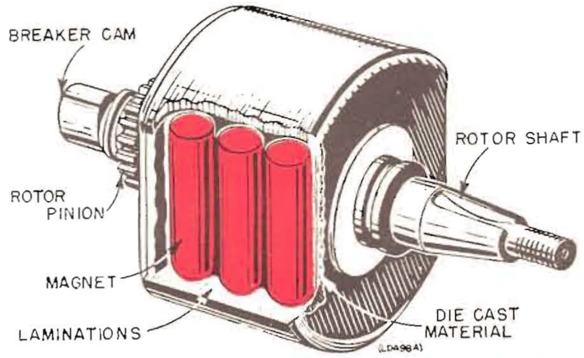

Figure 62—Two-Pole Rotor with Bar Magnets

THE MAGNETIC ROTOR

The magnetic rotor of the rotating magnet design magneto is a solid, one-piece assembly consisting of the magnets, laminations and rotor shaft. The shape and position of the magnets vary widely according to design requirements, the most common arrangement being the two-pole magnetic rotor with either two block magnets (Figure 61) or with multiple bar magnets (Figure 62), the axes of the magnets being set perpendicularly to the

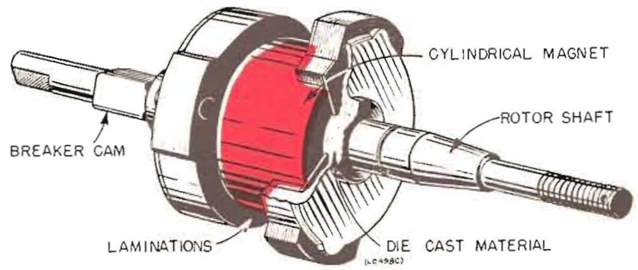

Figure 63—Four-Pole Rotor with Cylindrical Magnet

rotor shaft. The four-pole rotor (Figure 63) has one large cylindrical magnet with its polar axis set parallel to the rotor shaft, the relative position of the rotor laminations providing the four pole sequence. The number of magnets used in a magnetic rotor does not determine the number of effective magnetic poles.

Magnetic rotors used in Fairbanks Morse magnetos are of diecast construction, the one-piece rotor shaft, magnets and laminations being locked together in a single, compact assembly. The size of the rotor depends greatly upon the kind of magnets used. Early models of the rotating magnet design magneto had rotors with chromium steel magnets, the size of such a rotor being several times as large as present type rotors with Alnico magnets.

Remagnetization of the chromium and cobalt steel rotors was occasionally necessary in order to maintain a high output, but the greater original power and retentivity of the Alnico magnets now used has made recharging less essential.

THE HIGH TENSION COIL

A specially designed step-up transformer type coil (Figure 64) is used to convert the low voltage primary current to the high voltage secondary spark discharge. The primary winding of the high tension coil, as it is commonly known, consists of a relatively low number of turns of heavy wire, while the secondary winding has a large number of turns of very fine wire, the ratio of turns varying for different applications, but being on the order of 100 to 1.

The primary coil is formed by winding coated copper wire, in layers, around a laminated iron core. Each layer of wire is insulated by paper inserted between the layers.

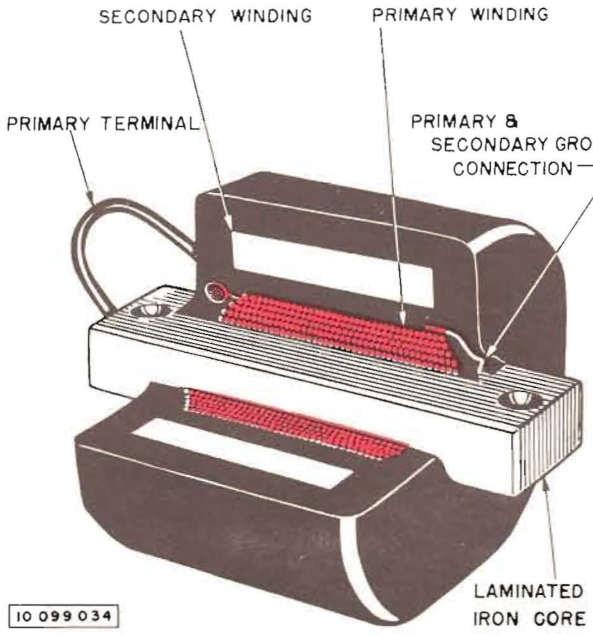

Figure 64—Construction of High Tension Coil

The secondary coil is wound, in the same manner as the primary coil except it is wound on a paper core. The two coils are then assembled and the primary and secondary terminals are soldered in place. The assembled coil is inserted in a mold, coated throughout with liquid plastic and baked in a thermostatically controlled oven.

Since the coil in the rotating magnet and inductor type magnetos is mounted in a stationary position, extremely low resistance connections permit the primary current to reach its true maximum value, a correspondingly greater secondary output thereby being secured. Coils mounted in this manner can also be wound to be sturdier, more compact and more efficient than those used in a rotating armature, and are not subject to the mechanical strains resulting from high speed rotation.

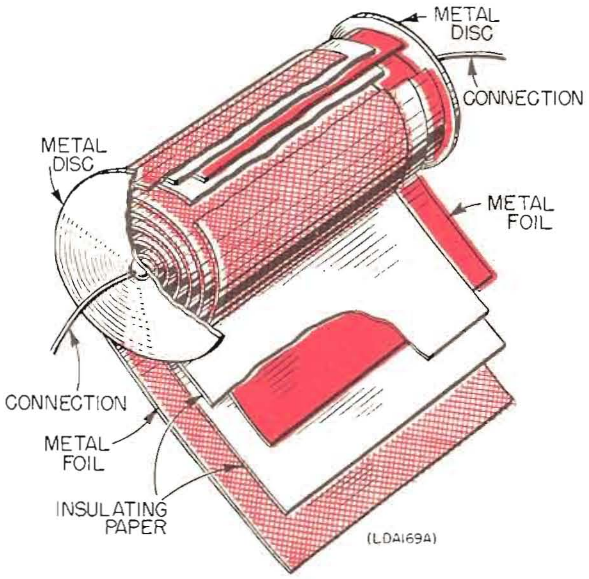

Figure 65—Paper-Wound Condenser

CONDENSERS

Paper-wound condensers have been proven highly satisfactory for ignition circuit applications and are almost universally used. Construction of this type of condenser (Figure 65) is very simple, two separate strips of aluminum foil of predetermined length being wound together with insulating strips of paper into a tight roll. Electrical connections are provided along the edges of the strips in order to obtain a non-inductive condenser. The rolled foil and paper assembly is then wax-impregnated and hermetically-sealed in a metal container.

In certain applications where the condenser is subject to considerable heat, it has been found advisable to use oil-impregnated units, since a breakdown of standard condensers may result if the impregnating wax melts.

The capacitance of the condenser used in a magneto ignition circuit depends upon a number of factors, among which are the voltage, current and type of breaker contact points.