CONTINENTAL® IGNITION SYSTEMS

THE AIRCRAFT MAGNETO

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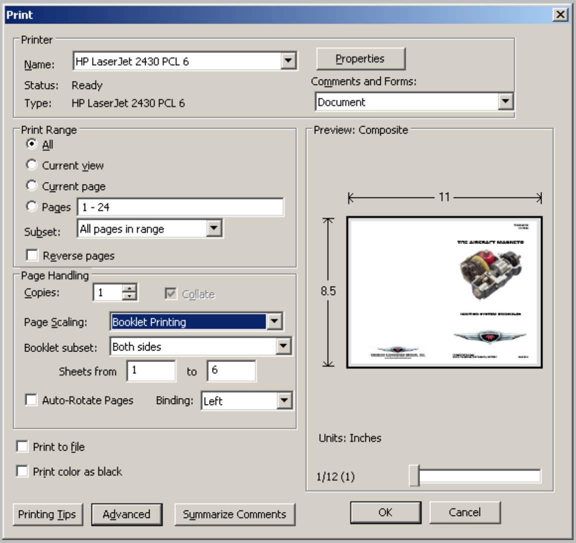

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Continental Motors, Inc.

Publication IGN-51

AUGUST 2011

Supersedure Notice

This manual is a revision of the information contained in Publication Part No. IGN-51, dated 15 March 2010. Previous editions are obsolete upon release of this manual.

Effective Changes for this Manual

0 .... 31 August 2011			

List of Effective Pages

Document Title:The Aircraft Magneto
Publication Number: IGN-51 Initial Publication Date: 31 August 2011

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Published and printed in the U.S.A. by Continental Motors, Inc.

Available exclusively from the publisher: P.O. Box 90, Mobile, AL 36601

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NOTE: Information contained in this publication is for instructional purposes only and shall not to be used for engine troubleshooting or maintenance.

I. Magnets and Flux Lines

Continental Motors aircraft magneto operation is based on the properties of a permanent magnet. A permanent magnet has a magnetic field consisting of many individual paths of invisible magnetic flux commonly known as “lines” of flux. Each flux line extends from the north pole through the intervening air space to the south pole, thereby forming a closed loop, indicated in Figure 1.

The presence of the flux lines can be proven by placing a magnet under a piece of paper on which iron filings are sprinkled. The iron filings will arrange themselves in a defined pattern along the flux lines indicated in Figure 1, which comprise the magnetic field. The flux lines characteristically repel one another. Consequently, they spread over a considerable portion of the air space between the poles.

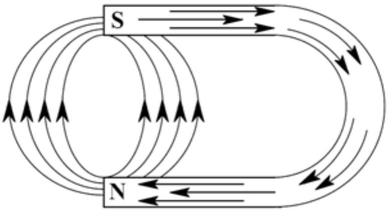

Figure 1. Air Core Magnet

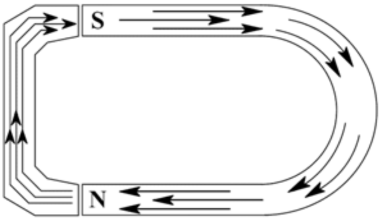

Figure 2. Iron Core Magnet

Flux lines have a natural tendency to seek the path of least resistance between magnetic poles. A laminated soft iron bar is a better conductor than air. For this reason, the lines will crowd together and pass through the bar (Figure 2) when placed near the magnet.

In Figure 2, the flux lines comprising the magnetic field are concentrated in a defined path within the bar instead of occupying a large portion of the air space. Therefore, the density of flux lines within the bar is very high. The application of the laminated soft iron bar to magnetos is explained later in this document.

The direction of flux in the laminated soft iron bar, when placed in a magnetic field, is determined by the polarity of the permanent magnet. The permanent magnet is made of special alloy steel which has the ability to retain a large portion of the magnetism induced in it when it is “charged” by passing flux lines through it from a strong electromagnet. The laminated bar is created from magnetically “soft” iron, which does not retain an appreciable amount of magnetism when magnetic flux lines pass through it. If the magnet in Figure 2 is turned over so the north pole is at the top of the picture, the direction of the flux lines will reverse in the iron bar.

II. Generating an Induced Voltage

Experiments can be performed with a magnet to show how voltage is generated, or induced, in a coil of wire. The coil may be made with a few turns of heavy copper wire and connected, as shown in Figure 3, to an analog (with deflecting needle) voltmeter.

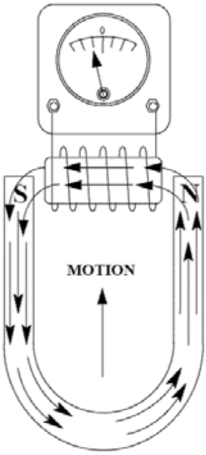

Figure 3. Negative Charge

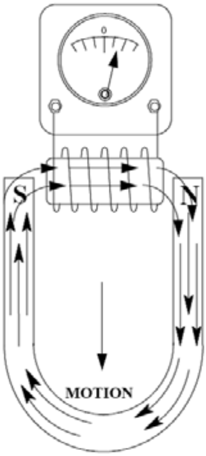

Figure 4. Positive Charge

The magnet flux lines, when in the position illustrated in Figure 3, pass through or “link” the turns of wire in the coil. When one flux line passes through one turn of a coil, it is known as one “flux linkage.” If one flux line passes through six turns of a coil, six “flux linkages” are produced. Accordingly, if six flux lines pass through six turns of a coil, there are thirty-six flux linkages, and so on.

If the magnet is brought up from a remote position to the position shown in Figure 3, the number of flux lines which are linking the coil would be constantly increasing during this motion. In other words, there would be a change in flux linkages as the magnet is moved.

The change in flux linkages, produced by moving the magnet, induces a voltage in the coil of wire. This voltage (or force) is indicated by the deflection of the meter needle. If the magnet is drawn away from the coil, as shown in Figure 4, the flux linkages constantly decrease during this motion, inducing voltage in the coil in the opposite direction, indicated by the meter needle.

The voltage induced in the coil is proportional to the rate of change of flux linkages. The flux linkages can be increased by adding more turns to the coil of wire or by using a stronger magnet having more lines of flux. The rate can also be increased by moving the magnet faster, thus increasing the speed of the flux change. The deflection of the meter needle will indicate the magnitude of the voltage when any of the foregoing experiments increase the rate of change of flux linkages.

No voltage will be induced in the coil of wire if the magnet is held stationary, even though the flux lines link the coil turns because the rate of change in flux linkages is zero. This experiment shows there must be a change in flux linkages to induce voltage.

This is an important principle when applied to a magneto because it indicates the flux lines must be given a magnetic path through the coil and there must be a movement of either the coil or the magnet to produce a change in flux linkages.

It is interesting to note that voltage in the same proportions would be induced in the coil of wire by holding the magnet stationary and moving the coil to provide the necessary relative movement to produce the change in flux linkages. The principle of a moving coil and a stationary magnet was used in some early makes of magnetos. Continental Motors Aircraft Magnetos, however, employ a design with a rotating magnet to produce the change in flux linkages.

III. Current in a Generator Coil

Nearly everyone is familiar with the common electromagnet in which a temporary magnetic field is produced by sending current through a coil of wire. Figure 5 is a sketch of a simple electromagnet in which the energizing voltage is obtained from a dry cell.

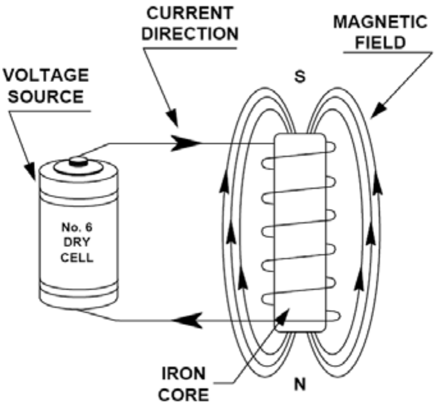

Figure 5. Current Direction

The magnetic field of the electromagnet consists of flux lines and has the same properties as the field of the permanent magnet previously discussed, the only difference being if the battery is disconnected from the electromagnet, the field will disappear. We might say that the iron core becomes a temporary magnet during the time the current is “on” and is just an ordinary iron bar when the current is “off.”

This principle of an electromagnet can be used to further investigate the properties of the coil and magnet, with interesting results. For example, if we short-circuit the terminals of the meter in Figure 3, the voltage induced in the coil of wire will cause current to flow through the circuit. Note that we now have a coil of wire wound on an iron core with a current passing through the wire. This is essentially the same condition that we had with the battery in Figure 5, except that the voltage is now provided by the motion of the magnet instead of the battery.

When a change in flux linkages induces current in a coil, current direction will be in the opposite direction of the motion, or change in flux linkages, which produced the current. This phenomenon is known as Lenz's Law and is of significant importance to magneto operation, explained later in this text.

To clarify, refer to Figure 3. Here we demonstrated the magnetic lines through the coil were increased when the magnet moved toward the coil), the voltage induced was of the opposite direction to that induced when the lines of flux decreased (magnet moving away from the coil).

If we performed the experiment shown in Figure 3, using an ammeter instead of a voltmeter, ensuring the direction in which the coil was wound and the polarity of the magnet were as shown in the picture, we would find when the magnet moved toward the coil, the current would flow up the right hand wire through the ammeter and down the left hand wire.

If we applied the “right hand rule[1]” to this current, we would discover the field which it sets up opposes the field which repels the field of the magnet and tries to push the latter away.

While the magnet moves toward the coil (Figure 3), the normal tendency is to increase the flux through the coil core in the direction from right to left, shown by the arrows. However, as soon as flux

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[1] The “Right Hand Rule” is a convenient means of determining the polarity of a magnetic field when the direction of the current and the direction of the winding of a coil are known. If the fingers of the right hand extend around the coil in the direction of the current, the thumb will always point in the direction of the flux, or the North end of the field.

starts to increase, current flow in the coil reverses, changing direction from left to right. This field opposes the increase of magnetic flux and actually exerts a small mechanical force which tends to push the magnet away from the coil.

When the magnet moves away, shown in Figure 4, the current in the coil will flow up the left hand wire, through the meter, and down the right hand wire. According to the “right hand rule”, the field of the coil is now aiding the field of the magnet. As the magnet moves away from the coil, the flux linkages decrease. Here again, as soon as the flux linkages begin to decrease, current flow in the coil sets up a magnetic field which, in accordance with Lenz's Law, opposes the change. Since the change is now a decrease, the coil field will not, in this case, oppose the magnetic field, but will rather aid it, trying to keep it from dying out or decreasing. Actually, a small mechanical pull is exerted on the magnet by the coil, tending to resist the motion of the magnet away from the coil.

To sum up our understanding of what is happening in these experiments we can consider the magnet and coil as a simple type of generator. If the generator is operated (magnet moved) without a load connected (such as a voltmeter connected across the coil terminals) no current will flow and only voltage will appear across the terminals. If the generator is operated in a short-circuited condition (such as with an ammeter connected across the coil terminals), current will flow but the voltage will be reduced. The lowered output voltage when current increases can be observed on any simple, unregulated generator.

IV. Interrupting Current

Suppose we set up the apparatus shown in Figure 6 with a contact switch connected across the coil, and the spring of the contact switch connected to the magnet with a piece of string. As soon as the magnet moves a slight distance from the coil, the string will pull the switch open.

As the magnet moves away from the coil (Figure 6), the flux through the coil core decreases. This decrease in flux will induce a voltage in the coil. Since the coil ends are connected together through the contact switch, current will flow in the coil. This current causes the coil to act as an electromagnet and tries to prevent the flux in the coil core from decreasing. In other words, the coil will, by its electromagnetic action, keep most of the original amount of flux in the coil core even though the magnet has moved away from the core.

By the time the magnet moves far enough to pull on the string, it will be so far away from the coil that it actually contributes very little to the amount of flux in the coil core, most of the core flux being produced by the electromagnetic action of the current in the coil itself.

When the magnet pulls the string, the contacts open. As soon as this happens, current in the coil stops flowing, since the circuit is open. When the current stops, the coil ceases to be an electromagnet and thus the field of flux held in the coil core by the electromagnetic action quickly dissipates, producing a rapid change of flux in the coil core for the duration of time the contacts are open and inducing a voltage which causes an arc at the switch contacts (Figure 7).

Just before the switch opens, the electromagnetic action of the coil retains most of the original field in the coil. As soon as the switch contacts start to separate, current in the coil decreases, thereby allowing the flux to “escape” from the core. The effect of the contact switch and coil is to hold back, or delay the flux change until there is a stress or “stretch” in the flux lines, at which time the opening of the switch releases the flux and allows the change to occur very rapidly.

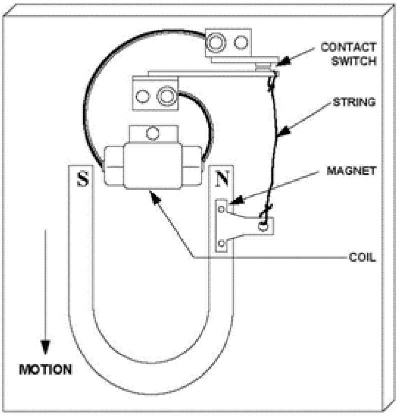

Figure 6. Contacts Closed

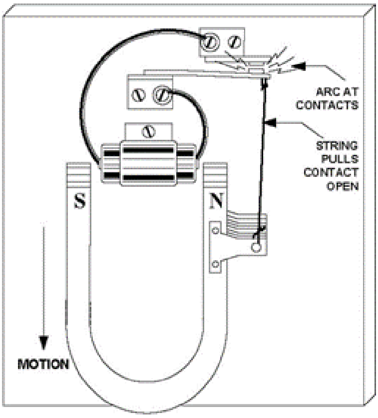

Figure 7. Contacts Open

V. Aircraft Ignition Requirements

The device pictured in Figure 6 and Figure 7 is a form of magneto. Some early stationary gasoline engines employed an ignition system very similar in principle to this simple apparatus. Such engines had the breaker contacts inside the engine cylinder instead of a spark plug, one contact was designed to pivot so it could move away from the other at the instance ignition was desired to occur in the cylinder. The arc at the breaker points would then ignite the gas in the cylinder. Obviously such an arrangement is not practical for aircraft ignition for a variety of reasons, but the principle forms the basis for all types of magnetos, as will be pointed out later in this booklet. It is not too difficult to “draw” an arc between two contacts while they are in the process of separating because the voltage required is quite low.

It is quite a different matter to produce the voltage required to break down a spark plug gap in an engine, since the latter process is not one of “drawing” an arc but rather one of puncturing, or breaking down, the layer of gas between the spark plug electrodes. The voltage required to do this may be as high as 12,000 to 15,000 volts under some conditions of engine and spark plug operation.

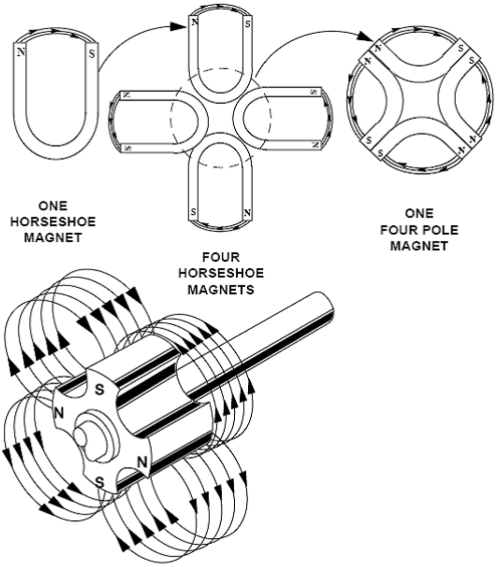

Figure 8. Four Pole Rotating Magnet

To produce the high voltage with a single coil, like the one in Figure 6, would require such a large coil and magnet it would be impractical and would require a great deal of power to move the magnet rapidly enough to produce the required flux linkage rate of change.

Therefore, we must modify the arrangement somewhat to provide a compact and efficient source of high voltage, which is necessary for aircraft ignition. There are two methods to approach this problem, both of which will be discussed in Section VI and Section VI.

VI. Application of Fundamental Principles

The properties of the common horseshoe magnet are present in the rotating magnet of Continental Motors aircraft magnetos. An illustration of a four-pole rotating magnet is shown in Figure 8. The lines of flux of the rotating magnet, when not installed in the magneto, pass from a north pole through the air space to a south pole as indicated. This closely resembles the magnetic field of the horseshoe magnet in Figure 1.

The pole shoes and their extensions are made of soft iron laminations cast in the magneto housing. The coil core, also made of soft iron laminations, is mounted on top of the pole shoe extensions. The pole shoes (D) and their extensions (E), together with the coil core (C) shown in Figure 9, form a magnetic path similar to that made by the coil core illustrated with the common horseshoe magnet in Figure 6. This magnetic path produces a concentration of flux in the coil core when the magnet is in the positions shown in Figure 9. This is known as the “full register” position of the rotating magnet.

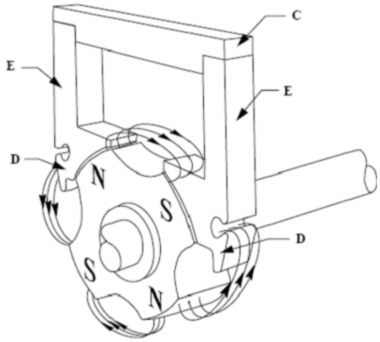

Figure 9. Full Register Position

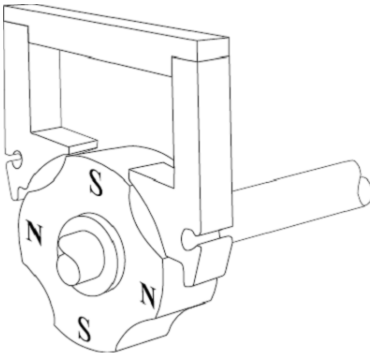

Figure 10. Neutral Position

When the magnet rotates to a position where the poles are centered between the pole shoes in the magneto housing (Figure 10), lines of flux do not pass through the coil core because they are “short-circuited” by the pole shoes. This is known as the rotating magnet “neutral” position.

Please note: no primary or secondary windings are shown on the coil cores in Figure 9 and Figure 10. These have been omitted to permit a clearer description of the magnetic action. By first observing the action without the windings, we can better understand their function in the magneto.

As the magnet in Figure 9 rotates, it passes through four full register positions and four neutral positions during one complete revolution. Each time the magnet is in a full register position, a maximum number of lines of flux pass through the coil core. Each time the magnet is in a neutral position, the magnetic flux through the coil core is zero.

Although the pictures presented up to this point show only a few lines, actually the field of the magnet consists of many thousands of lines of flux. For this reason, it will be simpler to portray the action of the magnetic circuit by means of a graph from this point forward. Figure 11 depicts a number of flux lines plotted against magnet position in degrees. For convenience in visualizing the relation of the magnet to the pole shoes at various angular positions, a series of small sketches of the magnet and pole shoes is shown below the curve.

Figure 11 shows how flux in the coil core changes when the magnet is turned with no windings present. This is called the “Static Flux” curve, because it represents the normal magnetic condition of the circuit. If the magnet is turned with no windings on the coil core, the flux will build up through the coil core, first in one direction and then in the other.

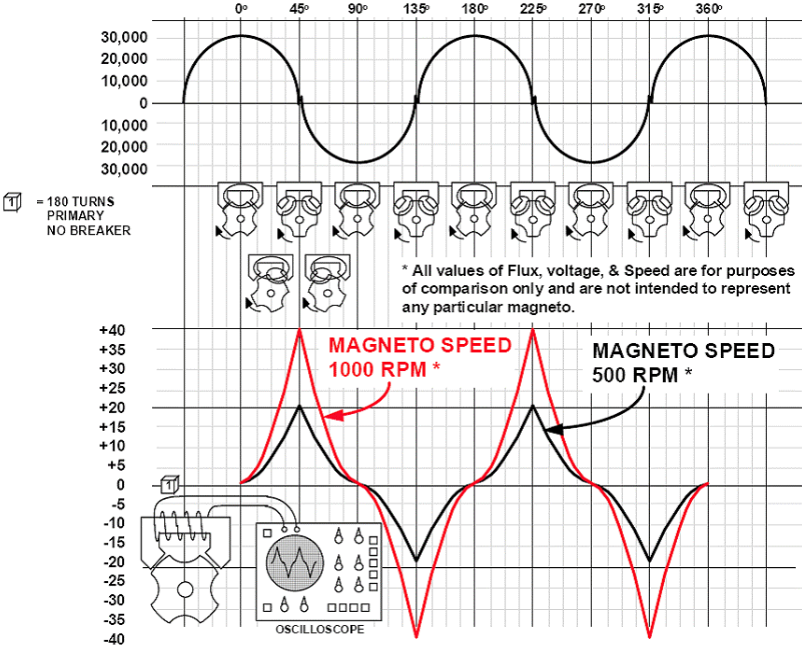

Figure 11. Rotating Four Pole Magneto Flux Curve and Voltages

It is important to realize Figure 11 represents both the direction and the concentration of the flux. When the curve is above the line, the flux is passing through the coil core in one direction. The higher the curve above the line, the greater the number of flux lines in the core. The lower the curve goes below the line the greater the number of lines through the core in the opposite direction (Note arrows on flux lines in sketches). Each time the magnet passes through a neutral position, the flux in the coil core falls to zero and then builds up again in the opposite direction.

The greatest change in flux occurs during the time the magnet passes through the neutral position, indicated by the steep slope of the curve at the points corresponding to the neutral positions of the magnet. For example, suppose there are 32,000 lines of flux passing through the coil core in a direction from left to right (Figure 11) when the magnet is in the full register position indicated by “zero degrees” of the graph.

If we turn the magnet clockwise, the flux value will decrease to zero lines of flux in the coil core at the 45° position, producing a flux change of 32,000 lines in the coil core in 45° of magnet rotation.

If we continue to rotate the magnet, flux lines through the coil core will increase in the opposite direction, from right to left (see Figure 11 with arrow under 90° position). When the magnet reaches 90°, we again have 32,000 lines of flux in the coil core, but this time of the opposite direction. As far as the coil core is concerned, the total change in flux produced by this 90° turn of the magnet is 64,000 lines, since the flux changed from a positive value of 32,000 lines, to zero, and then changed to a negative value of 32,000 lines.

If we continue to turn the magnet in a clockwise direction, the flux value will again reach zero at the 135° position of the magneto. It will then start to increase in a positive direction until a value of 32,000 lines is reached at the 180° position of the magnet. Turning the magnet from its 90° position to its 180° position we again produce a change of 64,000 lines, since we started with a value of 32,000 below the zero axis of the graph, and ended with a value of 32,000 above. In the same way, a flux change of 64,000 lines is produced for the 180° to 270° interval and the 270° to 360° interval of magnet rotation.

From the above description it should be clear that the four pole magnet provides four flux changes for each complete revolution through which it turns, and each of these flux changes has a value of approximately twice the number of flux lines which the magnet is capable of forcing through the coil core.

Having now obtained an elementary understanding of how the static flux curve (Figure 11) is produced, let us see the effect of installing a primary winding on the coil core. We will not connect the breaker points into the circuit just yet, since we first want to observe the open circuit voltage of the primary winding without the breaker installed.

The primary winding is made up of approximately 180 turns of heavy, insulated copper wire, wound directly around the coil core (Figure 12). Any change in flux in the coil core will cause a change in flux linkages in the winding and induce a voltage in the coil. The voltage induced in the coil depends on how fast the magnet turns because the voltage produced is proportional to the flux linkage rate of change, depicted in Figure 3.

We can prove this by connecting an oscilloscope across the primary winding and measuring its open circuit voltage while the magnet is being rotated. If we turn the magnet at 500 RPM we obtain a voltage curve similar to the black line (labeled Magneto Speed 500 RPM) in Figure 11. If we rotate the magnet at 1000 RPM, the curve will resemble the red line (labeled Magneto Speed 1000 RPM). Since the rate of change of flux linkages has doubled (speed of magnet doubled), the voltage is double that produced at 500 RPM.

As expected, the open circuit voltage curve reaches its maximum value peaks at the neutral positions of the rotating magnet, which represent the positions where the flux rate of change is greatest. While the voltages represented in Figure 11 are not specific to the open circuit primary voltage of any particular magneto, they are never-the-less approximately correct for most magnetos, and serve to show on a comparison basis, that something less than 20 volts is available from the primary winding at low speed. It would require a coil of over 100,000 turns to get 12,000 volts from a coil-and-magnet generator of this type, and even that would require the magnet to turn at 500 RPM or faster. Such a coil would be nearly as big as an entire modern magneto!

Even if we could work out the difficulties of getting proper voltage, it would be impossible to time such a unit to an engine because the slope of the voltage curve shown in flux linkage is quite gradual, and depends on engine speed. As an example, suppose the voltage values shown in flux linkage could be stepped up one thousand times by increasing the number of coil turns. Then 12,000 volts would be obtained at the point on the graph indicated by 12 volts on the voltage scale of Figure 11 but 12 volts is not reached at the same position of the magnet on the 1000 RPM curve as it is on the 500 RPM curve. Since the magnet is driven mechanically from the engine crankshaft, the engine spark timing or firing position would be different for every different speed of the engine. Further, since no two spark plugs fire at exactly the same voltage, engine spark timing would also vary for every spark plug.

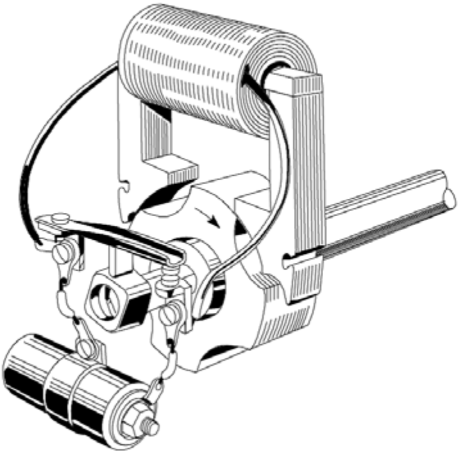

Figure 12. Breaker Points and Condenser

By using a current interrupter similar to the one depicted in Figure 6, we can precisely time the spark with a mechanism of minimum size and weight. Further, we greatly increase the speed of the flux change, so high voltage is obtained with a relatively small coil.

However, you will recall in Figure 6, opening the contacts caused considerable arcing at the contact surfaces. While this arrangement might be acceptable on a stationary engine, the arc is destructive, and will very quickly burn away the contact point surfaces, shortening their useful life. In order to use the interrupter or breaker in an aircraft magneto where long periods of dependable service are required, the arc must be attenuated. This is accomplished by connecting a condenser across the contact points of the breaker, as shown in Figure 12. The condenser prevents the breaker points from arcing, by allowing a “by-pass route” for the current during the time the contacts are separated.

Before the breaker opens, the condenser is completely discharged, since the breaker itself forms a connection across the condenser terminals. During the time the breaker points are separating, current is by-passed around them in the form of charging current in the condenser. During the time the condenser is charging, the breaker point contacts move further apart. By the time the condenser fully charges and stops current flow, the contacts are so far apart that an arc cannot “jump” across them.

The breaker points are electrically connected across the primary coil, and the magneto breaker mechanism is timed to the magnet so the contact points close when the coil core is at maximum flux. The condenser is connected across the breaker point contacts as shown in Figure 12. With the breaker points, cam and condenser added to the circuit shown in Figure 12, the action which takes place when the magnet is turned will be somewhat different from the behavior indicated by Figure 11 for a magnet and coil with no breaker points. The operation of the device shown in Figure 12 is graphically depicted in Figure 13. At the top of Figure 13, the original static flux curve of the magneto is shown for reference, together with degrees of magnet rotation.

Underneath the static flux curve, the sequence of the magneto breaker points opening and closing is shown. The breaker points are timed by means of the breaker cam to close at a position where a maximum amount of flux is passing through the coil core (34° before neutral), and to open at a position 11° after neutral. There are four lobes on the cam, so the breaker will open and close in this same relation to each of the four neutral position of the magnet. Point opening and point closing intervals are approximately equal.

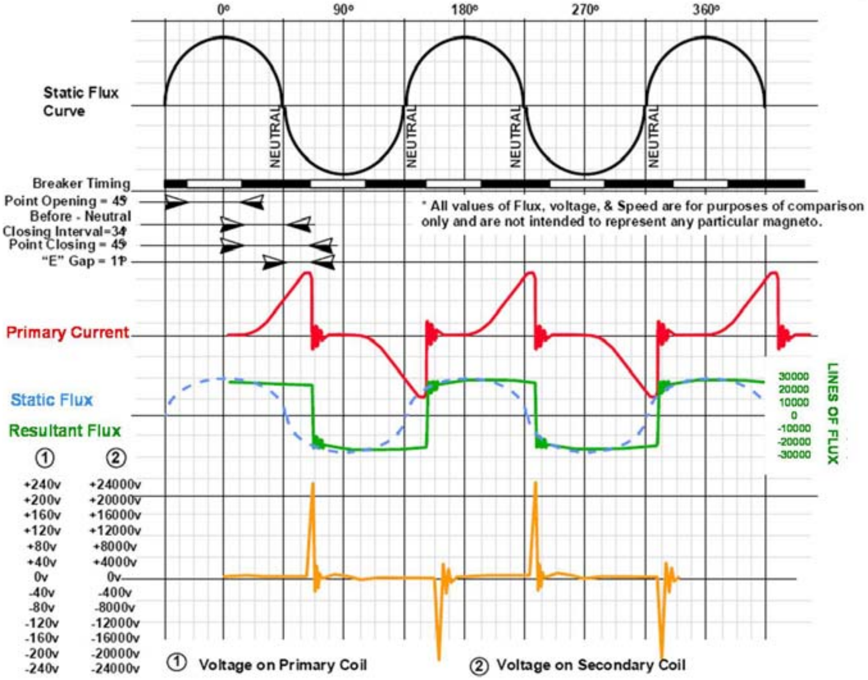

Figure 13. Magneto Operating Circuit Waveform

Starting at the maximum flux position (marked “0°” at the top of Figure 13) the following sequence of events will take place:

As the magnet turns toward the neutral position in Figure 13, the amount of flux through the coil core decreases. This decrease in flux linkages induces a current in the primary winding, depicted by the “Primary Current” curve. As previously stated, a current-carrying coil produces a magnetic field of its own. Accordingly, the current induced in the primary winding sets up a magnetic field of its own.

According to Lenz's Law, the magnetic field set up by this current opposes the change of flux linkages inducing the current. This is shown graphically by the “Resultant Flux” curve in Figure 13. Without current flowing in the primary winding, the flux in the coil core would decrease to zero as the magnet approaches neutral, and then start to increase in the opposite direction, represented by the dotted “Static Flux” curve. However, the electromagnetic action of the primary current prevents the flux from changing, and temporarily holds the field in the coil core instead of allowing it to change, represented by the “Resultant Flux” curve.

As a result of this process, there is great stress in the magnetic circuit by the time the magnet reaches the position where the contact points are about to open, a few degrees past the neutral position. The primary current is maintaining the original field in the coil core where the magnet has already turned past neutral and is now attempting to establish a field through the coil core in the other direction.

The contact points, when open, function with the condenser as described in connection with Figure 12, to interrupt the flow of primary current in the coil, causing an extremely rapid change in flux linkages. In less than a thousandth of a second, the flux linking the coil changes from a positive value of nearly 30,000 lines (“Resultant Flux” curve, Figure 13) to a negative value of nearly 30,000 lines. This change of nearly 60,000 lines, occurring in less than a thousandth of a second, gives a tremendous flux linkage change rate, inducing several hundred volts in the coil. The voltage is shown in graphic form directly underneath the “Resultant Flux” curve in Figure 13. Voltages indicated for this curve are not intended to represent a particular type of magneto, but are for comparison purposes. The same magnet and coil which formerly produced about 20 volts at 500 RPM can produce 12 times as much voltage with a breaker and condenser installed.

The very rapid flux change produced by the use of breaker points and a condenser enable us to obtain the high voltage required for ignition without an extremely large coil. Further, the timing of the rapid flux change is accurately controlled by the breaker. This, together with the very steep nature of the rise of the voltage wave (Figure 13) complies with the requirement for precise timing of the spark in an engine cylinder.

VII. The High Tension Ignition System

The most common method to produce the rapid flux change discussed in connection with Figure 13 and high voltage for firing a spark plug is to remove the coil from the assembly shown in Figure 12 and add a secondary winding of about 18,000 turns of fine wire directly over the 180 turn primary winding already on the coil core. Upon reassembling the unit (Figure 14), we find the secondary winding contains 100 times as many turns as the primary winding. Since the primary winding was capable of producing 240 volts (Figure 13), the secondary winding is capable of producing 24,000 volts. This type of coil is used (with minor variations) in all conventional high tension magnetos.

This secondary winding, containing 100 times as many turns of wire as the primary winding, produces a voltage equal to 100 times that of the primary winding. The open-circuit secondary voltage graph for the new circuit will look exactly like the open circuit primary voltage in Figure 13, except the voltage values are multiplied by 100.

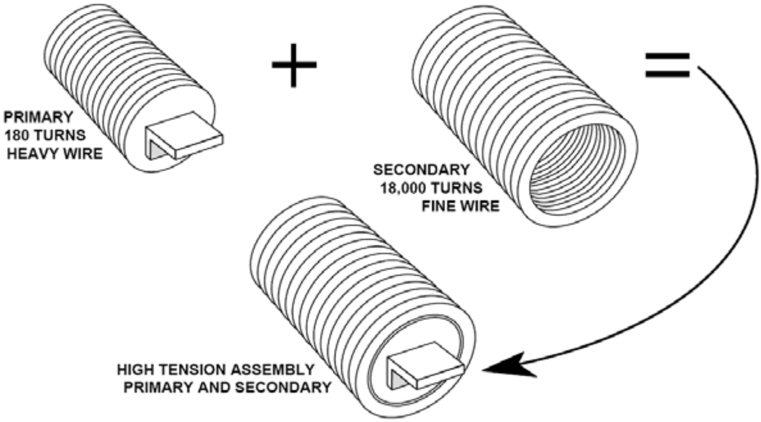

Figure 14. High Tension Magneto Coil Evolution

However, the magneto does not develop its full open-circuit voltage when operating in a normal manner on the engine. In fact, voltage required for a well maintained spark plug is usually less than 5000 volts during engine cruise power operation.

When the magneto secondary voltage rises to the firing or sparking voltage of the spark plug, the plug gap becomes conductive and current flows through the secondary winding of the magneto.

The flow of secondary current to the spark plug alters the shape of the voltage and resultant flux curves considerably due to the electromagnetic effect of current flowing in the secondary coil. As we already pointed out in Section IV, any current carrying coil acts according to Lenz's Law to oppose the flux change which produces the current. As soon as secondary current starts to flow, the rapid flux change will be retarded, or slowed.

Figure 15 graphically depicts the sequence of events which occur in the magneto when running in a normal manner on an engine.

Until the breaker opens, the action of building up a primary current, and of holding back or delaying the flux change are the same as for the open-circuit condition described in connection with Figure 13. The rise of primary and secondary voltage takes place when the breaker points open.

If the magneto is connected to a spark plug which “fires” at 5000 volts, the plug will “break down” and become conductive when the voltage is reached, and current will start to flow, shown graphically in Figure 15. Factors of Resultant Flux, Static Flux, Breaker Timing, Primary Current, Primary and Secondary Voltage are shown plotted in relation to magnet degrees for a magneto in actual operation on an engine.

When the high voltage in the secondary winding discharges, a spark jumps across the spark plug gap to ignite the fuel in the cylinder. Each spark consists of one peak discharge, after which a series of small oscillations occur, indicated by the secondary voltage curve and explanatory notes in Figure 15. During the time it takes to completely discharge spark, current flows in the secondary winding.

As soon as current flows in the secondary winding, a magnetic field is established to oppose the change in flux that produced it. Therefore, the flux change is slowed up, indicated by the tapering portion of the “Resultant Flux” curve.

In spite of the “slowing up” effect of the secondary winding current, the spark discharges completely before the next “closing” of the contact points. That is, the energy or stress in the magnetic circuit is completely dissipated by the time the contacts close for the production of the next spark. In Figure 15, we see the resultant flux curve tapers off to coincide with the static flux curve at the time the contact points close.

In other words, all the electromagnetic action of the coil dissipates, and the magnetic circuit returns to its normal or static condition, ready to begin the build-up of primary current for the next spark, which is produced in the same manner as the first.

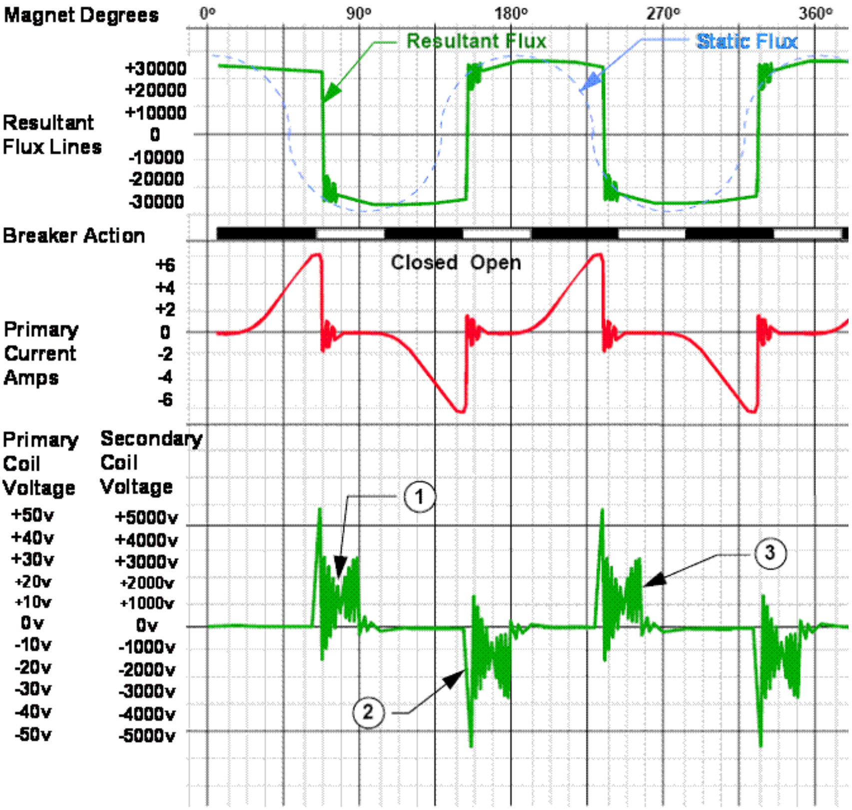

Figure 15. Waveform of Spark Plug Firing in Cylinder

NOTE: All values of flux, current and voltage are for illustration only, and are not intended to apply to a particular magneto.

1. Transition point caused by very low resistance of plug gap when burning gas is present in gap.
2. Initial oscillations due to sudden current load placed on coil when secondary starts to conduct current.
3. "Quench" oscillations caused by the effect of turbulence and pressure on the current flowing across the spark plug gap.

Figure 16 illustrates a complete high tension ignition system consisting of two magnetos, radio shielded harness, spark plugs, ignition switch and a starting vibrator. One end of the primary winding is grounded to the magneto. The other end is connected to the insulated breaker point contact. The other breaker point is grounded. The condenser is connected across the breaker.

The magneto ignition switch terminal is electrically connected to the insulated breaker point contact. A wire connects the switch terminal on each magneto with the ignition switch. When the switch is in the "OFF" position, the wire provides a direct path to ground for the primary current. When the breaker point contacts open, the primary current is not interrupted. This prevents production of high voltage in the secondary winding.

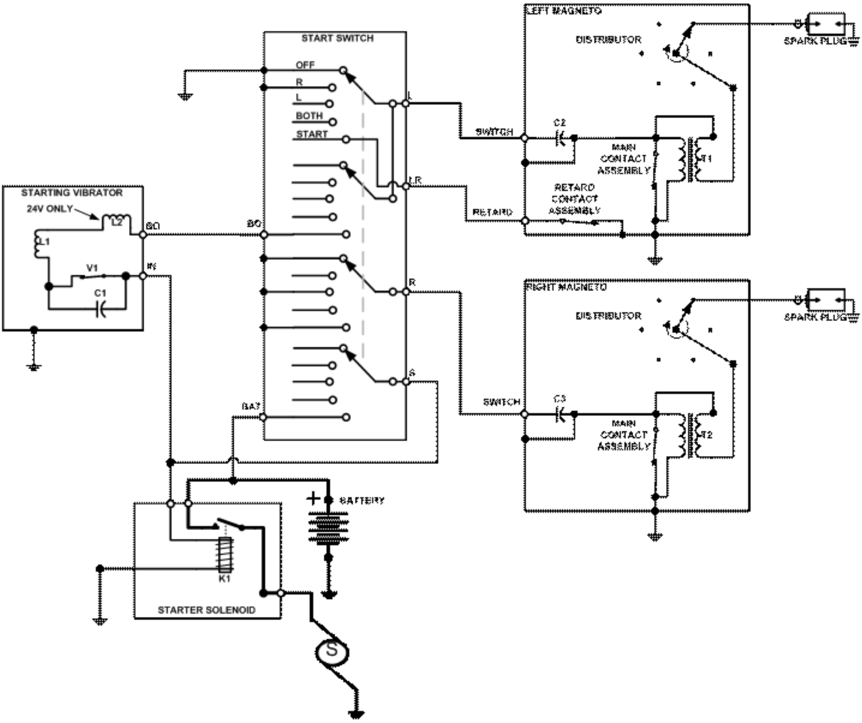

Figure 16. Magneto Circuit with Starting Vibrator

One end of the secondary winding is grounded to the magneto. The other end terminates at the high tension insert on the coil. The high tension current produced in the secondary winding is conducted to the central insert of the distributor finger by means of a carbon brush. From here, it is conducted to the high tension segment of the distributor finger and across a small air gap to the distributor block electrodes. High tension cables in the distributor block carry it to the spark plugs where discharge occurs.

The distributor finger is secured to the large distributor gear which is driven by a smaller gear located on the drive shaft of the rotating magnet. The ratio between these two gears is always such that the distributor finger rotates at one-half engine crankshaft speed. The gear ratio ensures proper distribution of the high tension current to the spark plugs according to the particular engine firing order.

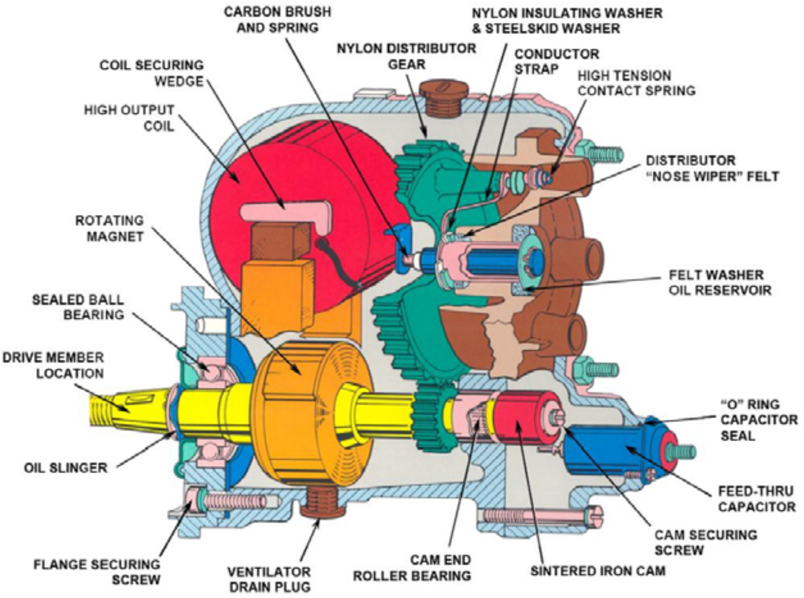

Figure 17. Cutaway View of Magneto

The majority of piston aircraft engines operate on the four stroke principle. Consequently, the number of sparks required for each complete engine revolution is equal to one-half the number of engine cylinders. The number of sparks produced by each revolution of the rotating magnet is equal to the number of its poles. Therefore, the ratio of the speed at which the rotating magnet is driven to that of the engine crankshaft is usually half the number of cylinders on the engine divided by the number of poles on the rotating magnet.

The numbers on the distributor block denote the magneto firing order rather than engine cylinder numbers. Therefore, the distributor block position marked "1" must be connected to No. 1 cylinder, distributor block position marked "2" to the second cylinder to fire, and the distributor block position marked “3” to the third cylinder to fire, and so on.

Sparks are not produced until the rotating magnet turns at or above a specified number of revolutions per minute at which speed the rate of change in flux linkages is sufficiently high to induce the required primary current and resultant high tension output. This speed varies for different types of magnetos but the average is 150 RPM, known as the “coming-in” speed of the magneto.

When conditions make it impossible to rotate the engine crankshaft fast enough to produce the magneto “coming-in” speed, magneto timing must be altered and input energy boosted for starting purposes. This may be accomplished with an integral impulse coupling or an external battery-powered starting vibrator. In the former, flyweight pawls on a spring-loaded cam catch stop pins until tripped by rotation of the body, thus storing and rapidly releasing mechanical energy and retarding timing. In the latter case, the vibrator points in the starting vibrator serve to supply an interrupted or pulsating current to the ignition system primary winding. Grounded until the retard contacts open, this pulsating current is stepped up by transformer action in the magneto coil to provide the required voltage for firing the spark plug.

Inasmuch as a magneto is a form of high frequency generator, radiation emanating from it during operation will cause interference with airplane radio reception if the ignition system is not shielded. A radio transmitter radiates waves of a controlled frequency; oscillations produced in the magneto during operation are uncontrolled, covering a wide range of frequencies.

If the high tension cables and switch wire of the magneto are unshielded, they can act as antennas from which these uncontrolled frequencies are radiated. Since the airplane receiving antennas are relatively close to the ignition wiring, the uncontrolled frequencies will be picked up by the antennas along with the controlled frequencies from the radio station, causing interference which may be heard over the airplane radio receiver.

To prevent radio frequency interference, the ignition system is enclosed in a special metallic covering known as “radio shielding.” Various parts of the shielding are bonded together and grounded to the engine and the airframe to prevent the undesirable noise from reaching the receiving antennas.

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