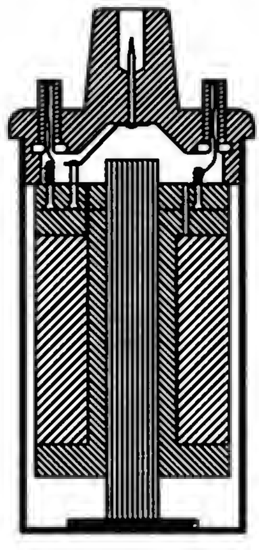
IGNITION COILS AND MAGNETOS IN MINIATURE

BY
Bob Shores

IGNITION COILS AND MAGNETOS IN MINIATURE



HOW THEY WORK AND HOW TO BUILD THEM

BY
Bob Shores

Library of Congress Cataloging in Publication Data:
Shores, B. D.
Ignition Coils and Magnetos in Miniature.

Manufactured in the United States of America
Third Edition

This book is dedicated
to my wife, Mary Margaret.

ABOUT THE AUTHOR.

Bobbie D. Shores was born in Lakeland Florida, the first born of Daniel N. and Jewell T. Shores. He attended Griffin grammar school, Webster avenue school and Lakeland high school. Enlisting in the U. S. Army Air Core, he served in England and Germany. Before retiring from the U.S. Air Force, he married Mary Margaret Mercer of Hosford Florida and fathered three children.

Mr. Shores was then employed by W. R. Grace Co., Bartow Florida and enjoyed a 34 year career in the field of Instrumentation. He attended 18 Technical schools, Polk Community College, Hillsborough Community College and the University of Miami. Specific studies included Computer Programming and Languages, Digital Control, Supervisory Control and Data Acquisition Systems, Programmable Logic Controllers and Management Information Systems.

While employed at Grace, Mr. Shores had a farm, produced vegetables, planted one of the largest vineyards in Florida, raised Black Angus cattle and, for 23 years, owned and operated TeleRay Communications, a Two-Way Radio and pager systems sales and service center. He prepared and presented many technical papers to technical societies and engineering conferences with titles of "Apperception in Instrumentation" 1980, "How Dense is Density" 1981, "Getting Cozy with Computers" 1984, "Getting Cozier with Computers" 1985 and "Samplers, Simple to Super" 1986.

After retiring from W. R. Grace, he was employed by Seimens and worked at the large motor division in Bradenton Florida. He attended the Seimens school of robotics at Peabody Massachusetts. The instrumentation at Seimens included over 1000 computers and PLC's used in robotics, laser cutters, EDM machines, lathes, mills, coil winders, hi-voltage lab, ect..

Leaving Seimens, Mr. Shores worked nation wide as an independent consultant in the disciplines of Electrical, Instrumentation and Control Systems Engineering. He provided design and start-up service to such clients as Badger Engineering, Cambridge MA., Bechtel Engineering, Bristol TN., Union Carbide and Rohn Phlonc, Saint Almands, WV, National Engineering, Portsmouth, NH, Ogden Martin, Fairfield NJ and MTI Engineering, Columbia SC.

Mr. Shores quit consulting work, sold the farm, the cows, the radio business and moved to the quite little town of Ruskin Florida where he now builds small gasoline engines and ignition coils for his enjoyment.

Peter Bianchi

PREFACE TO THE FIRST EDITION

This book is written to share the knowledge of ignition circuitry and the technical aspects of construction of miniature ignition coils and magnetos. The book is primarily for the home shop machinist engaged in the design and/or construction of small internal combustion engines. Other hobbyist, such as model airplane, boat and race car builders may find the book interesting and informative.

Most builders occasionally display their engines to other builders or to the public. The ignition coil is usually out of sight, as it is an automotive or weed trimmer coil and too large to match the engine. Much smaller ignition coils can be built and proudly displayed with the engine. In some cases, the small, beautifully encased coil with a blinking red light will draw more attention than the engine.

Differing views have been published on how an ignition coil operates, some accurate, some not, and many published articles contain errors that are misleading to those lacking a good understanding of electrizzzzity. There are many ways to explain this mysterious phenomenon and its effects, ranging from theoretical physics highlighting quarks, strings and mathematics that only a genius can understand down to the simple and sometimes ridiculous.

The author has chosen the middle ground, omitting most technical terminology, mathematics and circuit analysis in lieu of a comprehensible understanding by those that have led a misspent childhood by not tearing apart ignition coils, capacitors and transformers.

Bob Shores

❖ ❖ ❖ CONTENTS ❖ ❖ ❖

CHAPTER 1
ELECTRICITY

Long ago and quite far away, lived a man by the name of Electricity. It is actually this man that discovered the phenomena when a bolt of lightning hit him in the ass. At the moment that this occurred, his wife screamed 'Electricity'! After that incident,

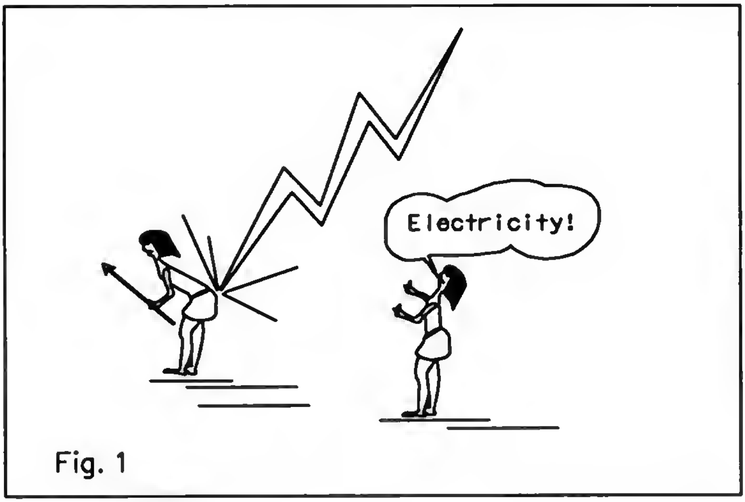


Fig. 1

people would point at lightning flashes in the sky and whisper "electricity".

To this very day, the most knowledgeable scientist will tell you that lightning is electricity. Not only did Electricity discover electricity, he also became the worlds first known conductor. It is true that Electricity did not understand exactly how electricity and conductors work, but he was sure they existed by taking some notice of their effects.

It was many thousands of years later that a round headed Italian with a mustache and spectacles noticed that when he moved a wire through a magnetic field, a current would flow along the wire.

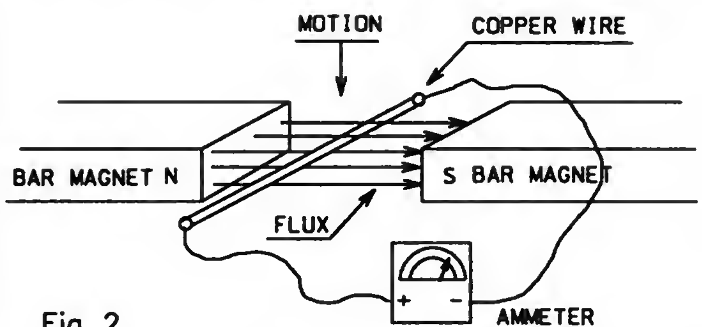


Fig. 2

He was not sure how electrical current, conductors and magnets work, but he was sure they existed by taking note of their effects. Being the son of a wealthy bureaucrat, and not required to work for a living, he spent a lot of time fooling around, some of it with magnets and wires. Years later he found that if he quickly moved the wire through the magnetic field, more current would flow along the wire and he took note of that. In his later years he found that if he quickly moved many turns of wire through the magnetic field, even more current would flow along the wire and he made some more notes.

He published his notes and that really got the wheel rolling. Everyone and his cousin started doing experiments, writing pamphlets and books, drawing sine waves and vectors on paper an using strange sounding terms such as flux density, magnetomotive force, coulombs,joules maxwells and webbers.

Even Benjamin Franklin attempted, in a cautious way, to duplicate the experience of Electricity. Of course electricity knows nothing of sine waves and coulombs as these are terms used by men in an attempt to explain the effects of electricity.

It is said that electricity is invisible. I suppose that it is, as the word is not a noun as claimed by Webster. The word is a descriptive term for the effects produced by the movement of one or many free electrons. We know, in this modern age, that if we place a copper wire across a battery, sparks and a hot wire result. To gain some understand of this effect, we can use two methods,imagination and exaggeration. So let's use both.

Lets take a No.50 AWG (American Wire Gauge) copper wire which is .001" in diameter and 1.090" long, zoom into the end surface and look at it.

We would see that it is composed entirely of copper atoms, each having a nucleus or central cluster, and 29 electrons in orbit around the nucleus.

The nucleus of each atom is composed of 29 small, round purple balls called protons and they look like a cluster of purple grapes. We can also see, in orbit around the nucleus, two yellow objects, each shaped like a football and are called electrons. A little further out from the nucleus is another orbit containing eight electrons, further out, another orbit containing eighteen electrons. The next and outermost orbit contains 1 red electron that resembles a frog. This is a special electron, a free electron. An atom without this free electron is called an ion. The free electron is what electricity is all about. Energy must be applied to make it move. The energy can be from heat, a chemical reaction, or magnetic lines of force. The free electron stores some of the energy applied in the form of a magnetic field surrounding itself. This magnetic field exists around any wire carrying free electrons.

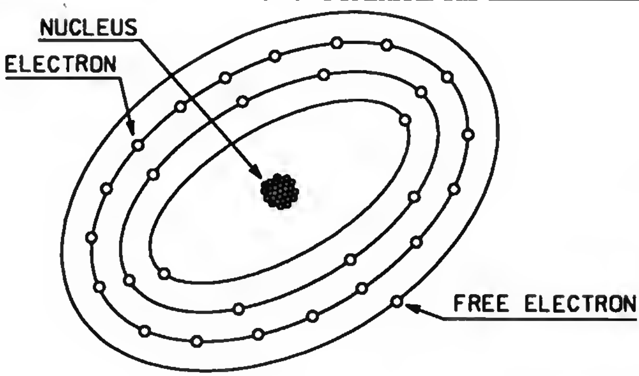


Fig. 3 COPPER ATOM

Looking closely, we see that the outer orbit of each atom touches the outer orbit of all atoms around it and the red electrons can move or jump from the outer orbit of one atom to the outer orbit of another atom, thus bumping a free electron into the next atoms outer orbit.

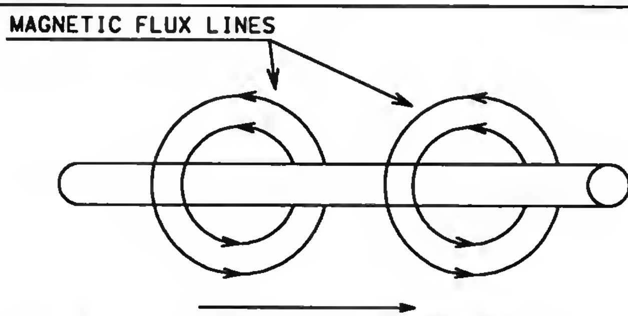


Fig. 4 CURRENT FLOW IN WIRE

The red electrons are constantly in motion, jumping from one atom to another in order to equally distribute themselves throughout the wire. The reason they jump is due to temperature, collisions with other electrons, and attraction or repulsion that exist between other electrons. The free electrons have an overwhelming desire to equally distribute themselves throughout a wire or a circuit. The speed at which they equally distribute themselves is truly phenomenal. The red electrons just jump around, like musical chairs, in one general area and actually go nowhere until energy is applied. Thus they are called "free electrons".

If we reach down to the floor and pick up a free electron and push it in the end of this wire, we notice that a free electron immediately falls out the other end of the wire and hits the floor, (much like a tube filled with marbles, push a marble in one end, and a marble falls out the other end).

If free electrons are pushed into the end of this wire at a rate of 6,242,000,000,000,000,000 per second, there will be a current flow of exactly one ampere.

The word "flow" in this case is redundant, as both "current" and "flow" describe a substance that is moving at a more or less constant rate. The substance in this case being free electrons. The word "current" is commonly applied in discussions of electricity to infer a flow of free electrons along a conductor. In reality, free electrons rarely move at a constant speed.

Free electrons are much like frogs. Both require a certain amount of time to jump from one place to another. Imagine that our No. 50 wire is 186,204 miles long and that we again push a free electron into one end. We would have to wait one second before a free electron falls out the other end. This action is similar to a locomotive "humping" a long string of boxcars.

The locomotive moves only a couple of feet and bumps the first boxcar which bumps the next and so forth on down the line until the caboose is bumped a couple of feet.

It is commonly said that the speed of electricity is 186,204 miles per second. It is more accurate to say that the speed of the EFFECT of electricity moves at 186,204 miles per second. The speed at which the free electrons move (jumping from orbit to orbit) along the wire is very slow. For instance, when ten amperes of current flows along a No. 18 AWG wire, the free electrons are moving along the wire at a speed of 28" per HOUR.

Considering the above, we can understand that the red, frog shaped, free electrons encounter some resistance in jumping from orbit to orbit. The resistance they encounter is similar to mechanical friction. The resistance is due to collisions with other electrons in the copper which converts some of their energy into heat. The resistance encountered by the free electrons is determined by four factors, conductor material, cross-sectional area, length and temperature.

The No.50 copper wire we are using in this example is .001" OD x 1.090" long and has a resistance of exactly one ohm at 68 degrees Fahrenheit.

If the length of this wire is doubled the resistance will change from one ohm to two ohms. On the other hand, if the diameter is doubled the resistance will change from one ohm to one quarter of an ohm. An increase in the temperature of a copper wire will increase it's resistance. If the temperature of the conductor is lowered to absolute zero, it will have no resistance to the movement of free electrons and the conductor will become a superconductor.

In order for electrons to move along a conductor, there must be a circuit. A circuit is an endless loop of one or more conductors, in series or parallel, similar to a railroad that allows a locomotive to run on a large circular track that has no beginning or end. Electrons can be compelled or forced to move through or along a conductor by applying heat, magnetic fields, chemical reactions or mechanical motion.

If one end of an iron wire is welded to one end of a copper wire and the opposite ends are connected to a micro-ammeter as shown in Fig. 5, it will be seen that a current is flowing in the circuit. If heat is applied to the junction of the two wires, the current flow will increase. If the junction is cooled, the current will decrease to zero and then flow in the opposite direction.

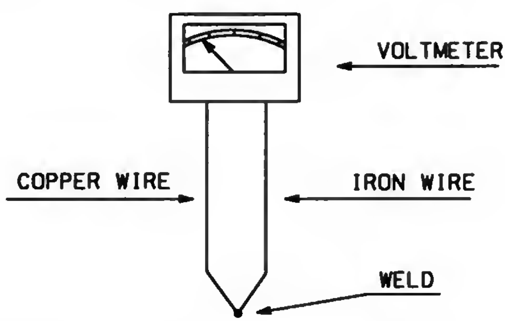


FIG. 5 THERMOCOUPLE

Heat is the force that moves the electrons. Such a circuit is known as a Thermocouple and is used to infer (measure) temperature.

Electrons can be forced to move by chemical reaction. Batteries and fuel cells are examples of chemical reactors. A magnetic field will also force electrons to move in a conductor. Whatever force is used to impart energy to the electron, that energy can be expressed as voltage or volts. A force (or a potential force) of one volt will push one ampere (6.242 quintillion free electrons per second) through a resistance of one ohm. Two volts will push two amps through one ohm of resistance.

So what is a volt ? Lets explain it this way. Suppose that We need to "charge up" the battery we discharged earlier. To do this we simply move free electrons from the positive terminal to the negative terminal of our battery. We do this with an electron pump, loosely called a "battery charger". The amount of energy the charger expends to move electrons from the positive terminal to the negative terminal is the amount of energy you can get from the battery after the charger is disconnected.

Imagine, for a moment, that we set our battery charger to one volt and connect it to two small, identical, rectangular metal plates. The charger will move 6.242 Quintillion free electrons from one plate (+) to the other plate (-) and stop charging. If we disconnect the battery charger and measure the voltage between these two appropriately sized plates, we would measure a difference of one volt (the potential to move 6.242 qfe's, or one ampere of current, from one plate to the other plate). If we now double the area of each plate, we would no longer have a one volt potential, but one half of a volt potential because the electrons are not as compressed on the plates. Free electrons have a strong desire to equally distribute themselves throughout the atoms of a conductor, and they do this with great speed, flowing along the path of least resistance. Voltage is simply a measurement of how compressed the free electrons are.

Electrical voltage is measured with a voltmeter and compressed air is measured with a pressure gauge. Compressing free electrons into a battery or condenser is similar to compressing air into a tank. A pressure gauge will indicate how compressed the air is in the tank in PSI (pounds per square inch). The pressure gauge will not tell you the quantity (cubic feet) of air that is in the tank.

A voltmeter will indicate how compressed the free electrons are in a battery or condenser. The voltmeter will not tell you the quantity (amperes) that exists in the battery or condenser.

A battery (derived from the expression "battery of cells") stores or produces current at the expense of chemical energy.

A condenser is a vessel to be filled with free electrons and is similar to a tank that is to be filled with air or water.

We now have an understanding of what one ampere, one ohm and one volt is and see the interrelationship of the three, which is expressed as $I=E/R$, or, the amperes (I) flowing in a circuit, will be equal to the voltage (E) applied to the circuit, divided by the resistance (R) of the circuit. This law was discovered in 1840 by an Ohm named Georg. Mr. Ohm was awarded a medal from the Royal Society for his mathematical observations. Although it is not actually Mr. Ohms law, one has to admit that the term "Ohms law" is much more convenient than "Gods law No. 14,739,251".

Some explanations of electricity draw a parallel between water and electricity as far as pressure and flow are concerned. Actually, water, air, steam and electrical circuits can be compared. Fig.6 should provide a mental picture of the similarities.

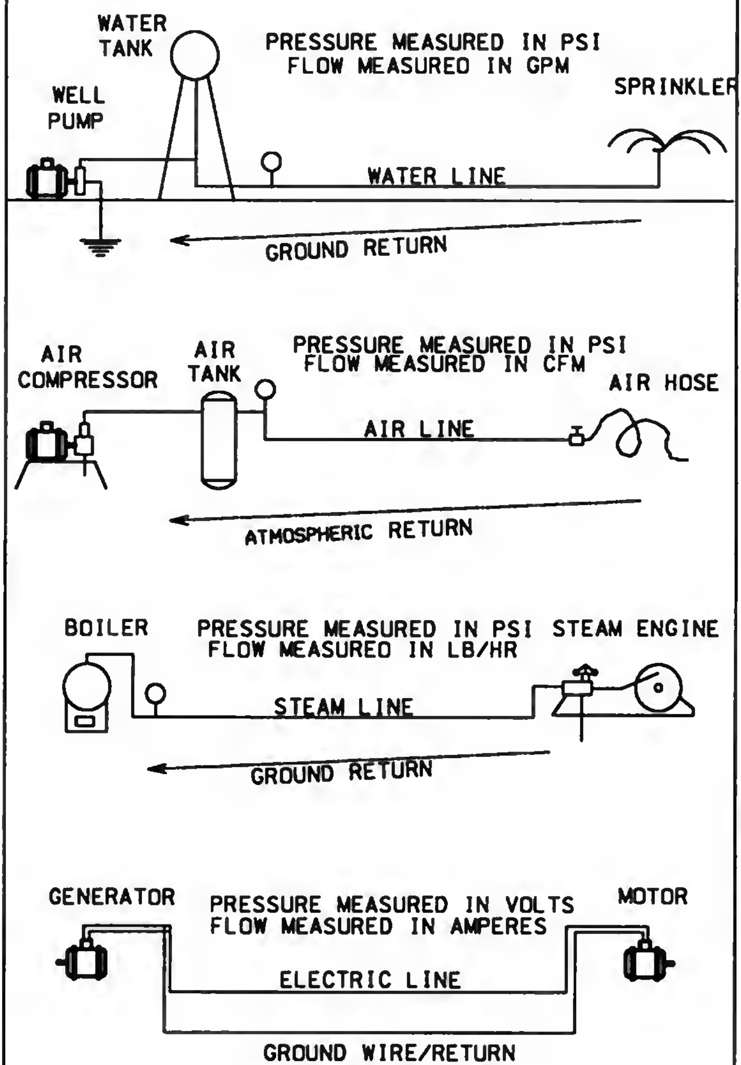

WATER TANK
PRESSURE MEASURED IN PSI
FLOW MEASURED IN GPM
WELL PUMP
SPRINKLER
WATER LINE
GROUND RETURN
AIR COMPRESSOR
AIR TANK
PRESSURE MEASURED IN PSI
FLOW MEASURED IN CFM
AIR HOSE
AIR LINE
ATMOSPHERIC RETURN
BOILER
PRESSURE MEASURED IN PSI
FLOW MEASURED IN LB/HR
STEAM ENGINE
STEAM LINE
GROUND RETURN
GENERATOR
PRESSURE MEASURED IN VOLTS
FLOW MEASURED IN AMPERES
MOTOR
ELECTRIC LINE
GROUND WIRE/RETURN

Fig. 6

If, at this point you understand the terms volts, amperes and ohms and you grasp the relationship between the three (as expressed by Ohms law), you can correctly state that you understand electricity.

I know the electronics guys will be disappointed because I did not use such terms as Coulombs, Joules, Webers, Maxwells, etc. or perform a mesh analysis using Nortons Theorem. The object here is not to teach a course on electrizzzity, but to give a brief and understandable description of the phenomena as it pertains to building ignition coils in the home work shop.

Every reader is encouraged to learn more about electricity, as it is fascinating to learn a little of how "The Great Engineer" designed and built this universe that we live in. It is also interesting to read about the observant men that noticed and recorded physical laws that have existed since matter came into being. A law is not really a law unless it is enforced, which requires an enforcer. Electrical laws are rigidly enforced and a violation can result in personal injury.

The physical laws are enforced and do not change or vary. Our concept and understanding of these laws often change and vary widely. If we violate these laws, we will be hurt or killed. Knowing the laws can make life much easier. Knowledge of these laws also allows us to build houses, automobiles, space shuttles, little engines and,——————miniature ignition coils.

THIS PAGE IS BLANK

but this is not a printing or scanning fault and no content is missing.

CHAPTER 2
MAGNETISM & THE MAGNETIC CIRCUIT

It is claimed that the first natural magnets were discovered in Magnesia, a small country in Asia Minor around 600 B.C.. These natural magnets are a crystalline form of iron oxide called Magnetite. The simplist form of a magnet is a steel bar with it's molecules so arranged that the bar is said to posses a north and south pole. The simplist explanation of magnetism in an iron bar is to consider the atoms of iron. If the orbit of the electrons are circular, the bar is not magnetized, and if the orbits are eccentric the bar is magnetized. The strength of the magnet is determined by the eccentricity of the orbits.

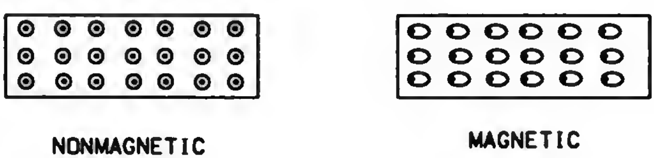


Fig. 7 MAGNETIC POLARIZATION

Soft iron is easily magnetized and looses it's magnetism easily. Hard steel is difficult to magnetize and will retain it's magnetism for a very long time. When an iron bar is magnetized, a field is established around the bar. The field is composed of invisible lines of magnetic force. The lines of force are collectively call flux. The lines leave the north end of the bar, curve outward and back, through the air, in an eccentric path and enter the south end of the bar. The lines of force are endless loops, usually eccentric and expand outward or collapse inward with changes in magnetic strength.

Fig.8 is an attempt to show the magnetic lines graphically.

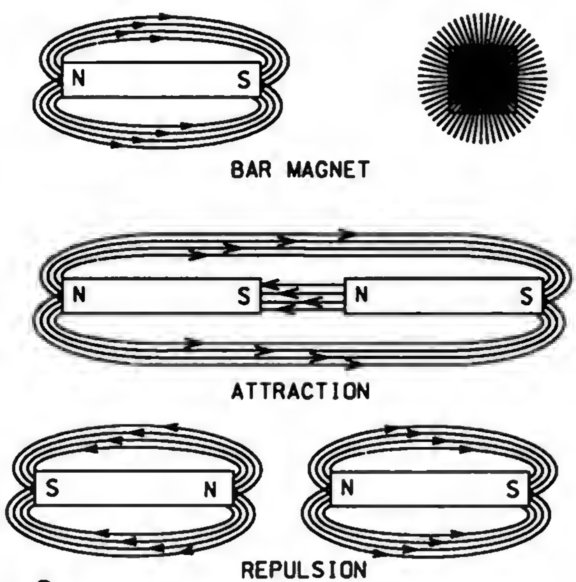


Fig. 8

The lines, or loops, are equally spaced around the bar and extend outward a distance determined by the magnetic strength. The flux density is greatest at the center of the bar as this is the area where one leg of each loop (or line of force) must pass.

When current (electrons) flow along a wire, a magnetic field is established around that wire. The strength of the magnetic field, that is, the number of lines of force or flux, around the wire is determined by the amount of current (amps) flowing in that wire. If a compass is held near any wire that is conducting current, the compass needle will be deflected, not by the current flowing in the wire, but by the magnetic field surrounding the wire.

If the wire is wound into a coil, the flux of each turn of wire is combined to form an expanding field of flux.

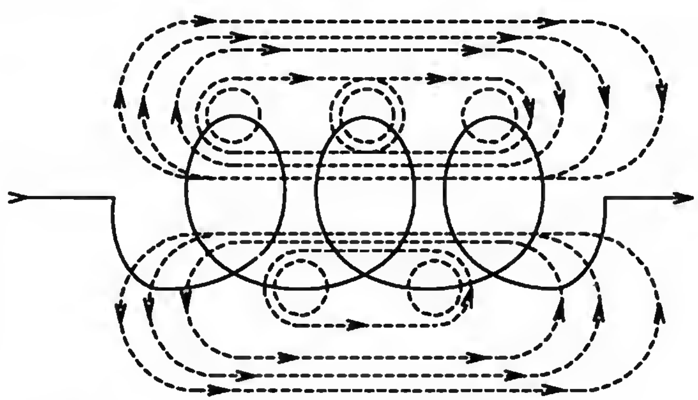


Fig. 9 FLUX FIELD

Fig.9 shows how the individual flux fields around each turn of wire combines into one large flux field. If the wire is wound around a rod, as shown in Fig.10, the individual fields around each wire combine and multiply.

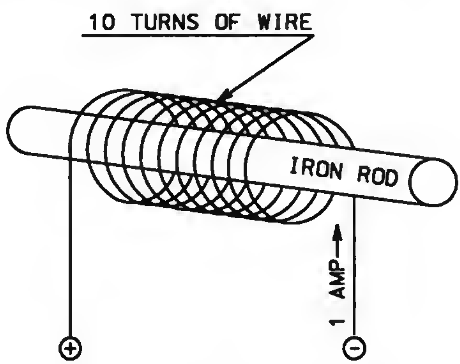


Fig. 10 10 AMPER TURN SOLENOID

The wire is wound in layers, one above the other. When current flows in a straight wire it is stated as Amperes of current flow. When current flows in a coiled wire it is called magnetomotive force and is stated as ampere Turns. The coil of wire is referred to as a solenoid. Ampere turns is the product of the current flowing in the wire multiplied by the number of turns of wire. For instance, if 2 ampere flows through ten turns of wire, the magnetomotive force is 20 ampere turns, and, if 1 ampere flows through 20 turns, the magnetomotive force is again 20 ampere turns.

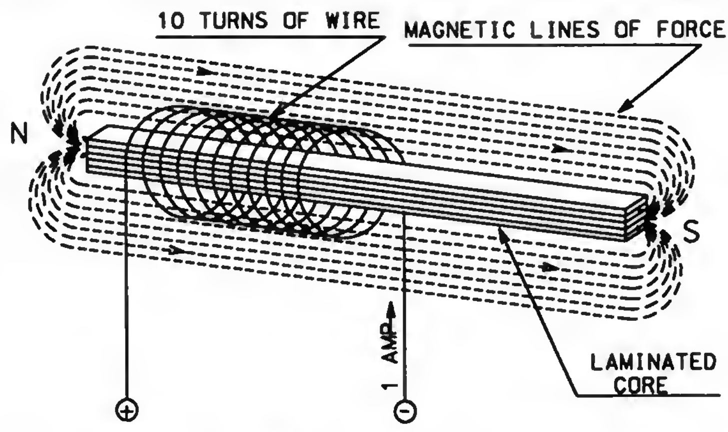


Fig. 11 10 AMPER TURN SOLENOID

Fig.11 shows a 10 ampere turn solenoid and the magnetic field that is established when current flows in the coils of wire. Most materiels including air, are quite reluctant to conduct magnetic lines, or flux. This reluctance of a material to conduct lines of force is called, logically, reluctance and is measured in ohms.

The Flux density (number of lines of force in a given area) is greatest at the geometrical center of the coil as this is the area that all of the elliptical lines of force around the layers of the coil will share. A metallic core offers much less resistance to the flow of flux than air. The metallic core becomes the common pathway shared by each magnetic line of force, as they will travel the path of least resistance, and, the less resistance, the more lines of force that are established. The core does not PRODUCE lines of force, it simply CONDUCTS them. It is extremely important that the core be made of a material that offers low resistance to the flow of magnetic lines of force.

The rod used in Fig.10 can be saturated with lines of force and, forcing more current through the turns of wire will create few, if any, more lines of force. A saturated core is to be avoided in the construction of an ignition coil.

Iron is a good conductor of flux just as copper is a good conductor of free electrons. If the rod is replaced with a cast iron rod, the number of lines of force will increase many hundreds of times with no change being made to the ampere turns.

If the cast iron rod is replaced with one of the many types of laminated magnet steels available today, another large increase in flux will be gained, again, without any change in ampere turns. Fig. 11 shows a laminated iron core.

Placing metal objects in the flux field, such as a metal tube over the coils of wire, will have a pronounced effect upon the flux. Metals such as copper, brass and bronze will reduce the flux whereas a steel or iron tube will increase the flux. A steel tube will provide a path of less resistance than air for the magnetic lines of force to travel in.

Never use a brass tube around a coil as much of the flux will disappear. Plastic, glass, wood, most paints and varnishes have little, if any, effect on the flux.

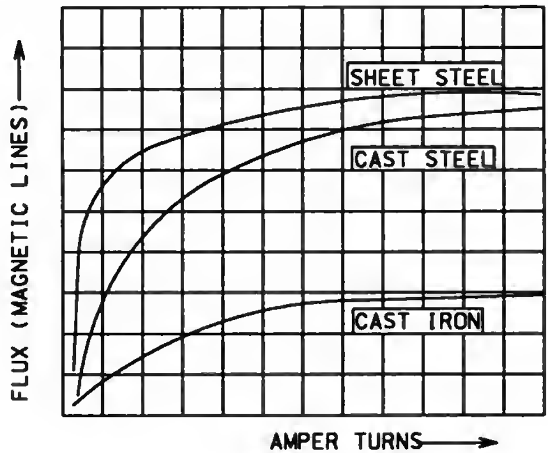


Fig. 12 MAGNETIZATION CURVE

Fig. 12 shows that replacing a solid cast iron core with a laminated sheet steel core will provide much more flux for a given number of ampere turns. In other words, a sheet steel core will be a much stronger magnet than a cast iron core for a given number of ampere turns. An expanded magnetization curve is provided in the appendix.

Fig.12 also shows how each metal becomes saturated and that increasing the ampere turns will result in little increase in flux and a large increase in wasted energy dissipated in the form of heat.

There are many vendors of magnets in the United States, some of which are listed in the appendix. The best catalog, in my opinion, is from Magnet Sales and Manufacturing Co.. The vendors usually require a minimum order. The most commonly used magnet for magneto application is the cast Alnico 5.

Commercial magnets available today are made from a variety of materiels and processes. The more common magnets are the Alnico, Ceramic, Neodymium and Samarium. Except for the regular flexible and ceramic 1 materials, all magnet materials are "oriented". This means that they can only be magnetized through one specific direction. Standard (or "conventional") magnetization is straight through the orientation direction, and produces one North and one South pole. The rare earth magnets are extremely difficult to magnetize in non-standard ways.

ALNICO

Alnico magnets derive their magnetic properties and name from their main constituents, aluminum, nickel and cobalt. They have the widest range of temperature stability of any standard magnetic material. Alnico magnets usually cost more than ceramic magnets. The direction of magnetization for alnico is usually much longer than the other dimensions (parallel to length) for best results.

Cast Alnico is melted and poured into a mould. Once solidified, the material is ground, heat treated and cooled, sometimes in a magnetic field. When treated in the presence of a magnetic field, the magnet is called anisotrophic. This orientates the molecules to take on maximum magnetization and allows a higher gauss level. A cast magnet that is not heat treated in a magnetic field is called isotropic.

Sintered Alnico is made from a powdered mixture of ingredients that are pressed into a die under tons of pressure, sintered in a hydrogen atmosphere and then cooled either within a magnetic field or without (anisotrophic vs. isotropic). The most common grades of Alnico are 5 and 8. Alnico is widely used in Magnetos, motors, generators relays and loudspeakers. Alnico 5 rectangular magnets should have lengths that are long in comparison to their cross sectional dimensions in order to avoid self demagnetization, a ratio of 5 to 1 is best. Sintered Alnico 8 bars are more resistant to demagnetization than the Alnico 5.

CERAMIC

Ceramic, or ferrite magnets, are manufactured by pressing a wet or dry powdered mixture of strontium carbonate and iron oxide. During this pressing process, a magnetic field is applied in the direction of preferred magnetization to orient the molecules and increase the magnet's performance potential. This magnet is considered to be "orientated". If not exposed to a magnetic field at the time of formation, it is called "non-orientated" or isotropic. After the molding process, the material is then sintered at about 2000 F. This process is similar to that of kilning ceramic pottery, thus the name "ceramic" magnet.

Ceramic magnets are magnetized parallel to their thickness. Ceramic magnets are available in grades 1, 5 and 8. Grade 8 is the strongest ceramic material available. Ceramic magnets may contain imperfections such as cracks, porosity, voids, surface finish, etc. as received from the manufacturer. The MMPA standards specifications booklet states that "Chips shall be acceptable if no more than 5% of the pole surface is removed." and that "Cracks shall be acceptable, provided that they do not extend across more than 50% of the pole surface".

Grade 8 is the strongest ceramic material available and is an excellent choice wherever magnet length is at a minimum.

RARE EARTH MAGNETS

The term "rare earth magnets" is used because the elements of neodymium and sumarium are classified as such in the lanthanides section of the Periodic Table of the Elements. The term is also applicable due to the difficulties which were encountered in the separating and refining of the raw elements. The term "rare earth" has been subdivided into two material types: Neodymium Iron Boron and Sumarium Cobalt. Rare earth magnets have from 4 to 10 times the energy product of Alnico or Ceramic materials.

Rare earth magnets are manufactured, generally, by melting the elements together then milling them into a powder. The powder is then pressed to the desired shape in the presence of a magnetic field. The material is then sintered, aged, ground and magnetized.

All rare earth magnets are magnetized through their thickness rather than their length. This presents some problems when applying rare earth magnets to magneto design. Do not grind a rare earth magnet, the risk of fire or explosion of the oxidized grinding dust exists.

NEODYMIUM

Neodymium magnets are the latest development in high-energy magnet technology. Neodymium will rust. Do not subject it to temperatures exceeding 180 F. Neodymium magnets are sold by grade and typically range from grade 27 to 45. Neodymium magnets are expensive but cost less than Samarium Cobalt for the same energy product.

SAMARIUM COBALT

Samarium magnets are the most expensive and lacks the rust problem of Neodymium. Samarium is the better choice for high temperature application than Neodymium and is not as magnetically strong as Neodymium.

A partial table of Magnets and their attributes appears in the appendix. More detailed tables can be found in magnet vendors catalogs.

THIS PAGE IS BLANK

but this is not a printing or scanning fault and no content is missing.

CHAPTER 3
INDUCTORS

An inductor is commonly thought of as a coil of wire. The coil can be a few or many turns of wire. The core can be air or any other material. Ignition coils and transformers are basically inductors. Inductance is a measure of how much a coil will oppose a change in current. Inductance is measured in henries or millihenries. When a voltage is applied across a coil, the current will not immediately jump to the maximum value as determined by ohms law (I=E/R). Some time is required before the current reaches its maximum value. A time constant can be calculated for each inductor. The current can be considered to be maximum after five time constants.

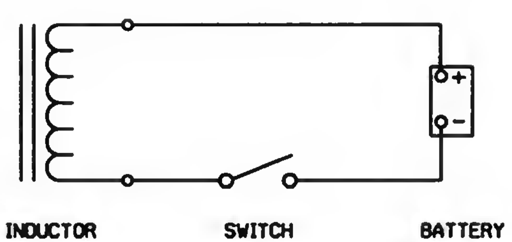


Fig. 13

If the switch in Fig.13 is closed, the voltage across the coil is immediately 12 volts. The current however requires a specific amount of time (five time constants) to reach its maximum value. The delay is shown graphically in Fig.14.

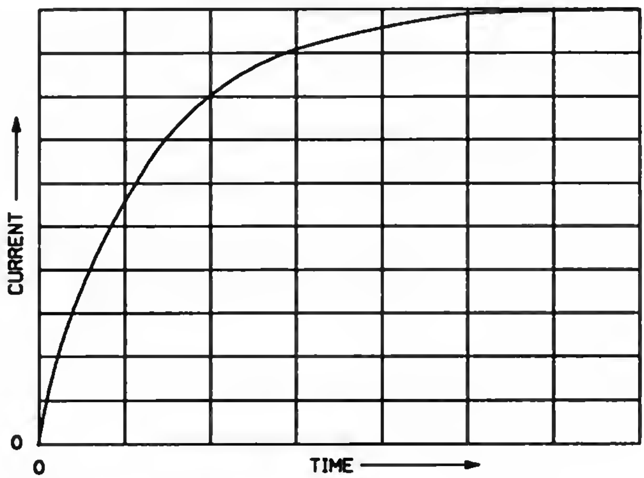


Fig. 14 COIL REACTANCE

If the switch in Fig.13 is then opened, the current will not immediately fall to zero. Again, a period of five time constants are required before the current reaches zero.

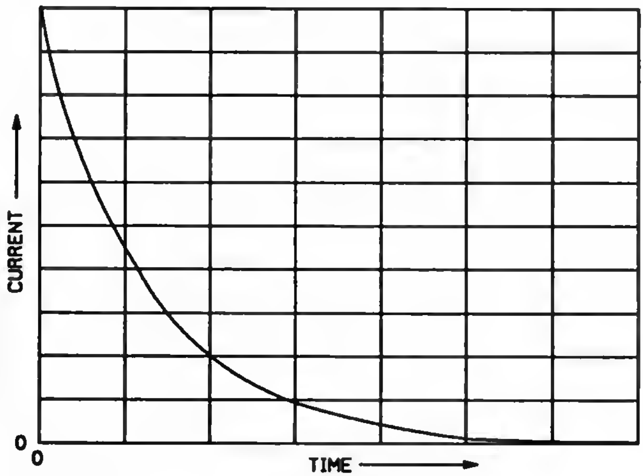


Fig. 15 COIL REACTANCE

Fig.15 traces the current from the moment the switch is opened until the current ceases to flow. The reason for the delay will be dealt with later. The important thing to understand at this point is that the voltage across a coil can change instantly, as when a coil is connected to a battery, but the current through a coil can not change instantly due to inductance. The inductance of a coil is determined by the number of turns of wire, the material in the core, the cross sectional area of the core and the length of the core.

THIS PAGE IS BLANK

but this is not a printing or scanning fault and no content is missing.

CHAPTER 4
LAMINATIONS

Magnetic lamination steels are cold-rolled, low carbon steels intended for low frequency application and are used most frequently as core materiels for small electrical devices. These steels are stamped into E or I shaped sheets called laminations.

Laminations that are used in motors and magnetos are stamped in many different geometries and thickness. Steel sheets manufactured today for use in transformers can be divided roughly into two groups, the Electrical steels and Magnetic Lamination steels. Electrical steels are flat rolled, low carbon, silicon-iron alloys and are applied mainly to low energy loss transformers.

The laminations are most always insulated by the manufacturer. Some types of insulation are:

C-0.......... A natural oxide surface.

C-1.......... Enamel or varnish coating.

C-2.......... A glass like film of MgO.

C-3.......... Varnish, for oil immersed cores.

C-4.......... A phosphatide surface.

C-5.......... Same as C-4 with ceramic fillers.

The steel is laminated in order to reduce electrical loss and heating due to eddy currents in the steel.

The home shop builder of ignition coils and magnetos, usually obtains his laminations from small power supply transformers. The transformers are disassembled, lamination by lamination, using a pocket knife to separate them. The laminations are then cut to the appropriate size using tin snips, hacksaw, file and/or a milling machine.

During this process, the insulation, if it existed, is damaged or lost entirely. This is not a serious concern. The laminations can be used as is or dipped in varnish and clamped together until the varnish dries if the builder wishes to insulate them. The laminations mentioned above are usually about .020" thick. Lamination steel can be purchased in small lots from some supply houses but a cheaper source is the junk pile. Your local TV, radio or electronics repair shop will probably give you a few “junkers”. These junkers are a good source for insulated wire of all colors, switches, etc. and the item you want most, the transformer. Gather unto yourself a few transformers, good or bad, and dismantle them. The laminations are usually E shaped and I shaped.

Hopefully you can find some I shaped laminations that measure .250 wide and about 1.615 long. The .250" wide laminations are quite common so you should have little trouble finding them. Most laminations are .020 thick. If you cannot find suitable I shaped laminations, the E laminations can be cut with a hacksaw. Clamp a dozen of them in the vise and let the top of the vise guide the hacksaw blade. A milling machine will quickly cut then to the .250 width. Keep the end mill close to the top of the vise.

If you are not all that familiar with transformers, dismantling one or two will certainly familiarize you with them. To quickly remove the wire, clamp the transformer in a vise and cut across the wires with a hacksaw. A hammer and screwdriver will do the rest. You will probably need a hammer and screwdriver to remove the first two or three laminations as they will be stuck tightly together. From that point, a pocket knife will separate them.Discard any deformed or scratched laminations. Keep the laminations well oiled or put them in a shallow pan with some oil. The laminations will rust overnight without oil.

THIS PAGE IS BLANK

but this is not a printing or scanning fault and no content is missing.

CHAPTER 5
CONDENSERS

A condenser should not be referred to as a "capacitor". A condenser consist of two parallel plates of a conducting material separated by an insulator. The insulating material can be air, glass, mica, oil or wax saturated paper or one of many other materiels. The capacity of a condenser is rated by the quantity of free electrons it can store when one volt is applied across it's plates. The unit measurement of capacity is the farad, which is the capacity of a condenser whose voltage is raised one volt when one coulomb (6.242 QFE's) of charge is added to it.

A condenser, a fuel tank and an air tank all have a definite capacity. We do not call an air tank a "capacitor" and we should not call a condenser a "capacitor". Technically, a condenser has a storage capacity of one farad if one coulomb of charge is deposited on the plates by one volt (A coulomb is the quantity of free electrons that passes a given point in one second when a current of one ampere is flowing, or 6.242 QFE's. The farad is generally too large a measure of capacitance for most applications, so the microfarad (one millionth of a farad) is more commonly used.

The insulating material separating the plates is called a dielectric. For every dielectric there is a voltage that if applied across the dielectric will breakdown the dielectric and allow current to flow. A typical example of breakdown is lightning, which occurs when the voltage between the clouds and the earth is so high that lightning (free electrons) can pass from one to the other through the atmosphere, which acts as the dielectric. A dielectric can be nothing, as in the case of a vacuum condenser. This bit of information is given just in case someone attempts to tell you that the energy in a condenser is stored in the dielectric. A vacuum condenser has no dielectric.

The average dielectric strength of various materials are given in volts/mill (1 mill=.001") for comparison.

Dielectric strength of some dielectric materials.

volts/mill

Dielectric	Strength
Air	75
Ceramic	75
Porcelain	200
Transformer Oil	400
Bakelite	400
Rubber	700
Paper Waxed	1300
Teflon	1500
Glass	3000
Mica	5000

The table is informative. From it we can safely infer that under normal conditions, 75 volts will jump a .001" gap. This factor will vary slightly with changes in temperature, humidity, pressure and geometry. A little multiplication shows that we can reasonably expect 18,750 volts to jump a 1/4" air gap.

Condensers are made in many shapes, sizes and materials. Two types of condensers are commonly used with ignition coils, the paper and the Mylar condenser.

The Mylar condenser is made with interleaving strips of Mylar and aluminum foil. The strips are then folded and rolled, electrodes attached and it is encased in plastic or ceramic. The encasement is usually rectangular.

The type of condenser most commonly associated with ignition coils is the tubular paper condenser encased in metal for protection. It is made by interleaving strips of aluminum foil with strips of wax or oil impregnated paper. The strips are rolled into a tubular form and encased in a metal tube with a mounting lug attached. Fig.16 shows the construction. Both types are sold primarily by their capacity and secondarily by their voltage rating. The voltage rating is the maximum voltage that can be applied across the condenser for long periods of time without breakdown.

The voltage rating also determines the physical size of the condenser as thicker dielectric is required for higher voltages. It is not uncommon to find a 50 or 100 volt mylar condenser in an ignition circuit where it is exposed to hundreds of volts. The reason for selecting the low voltage rating is of course to use a condenser of small physical size.

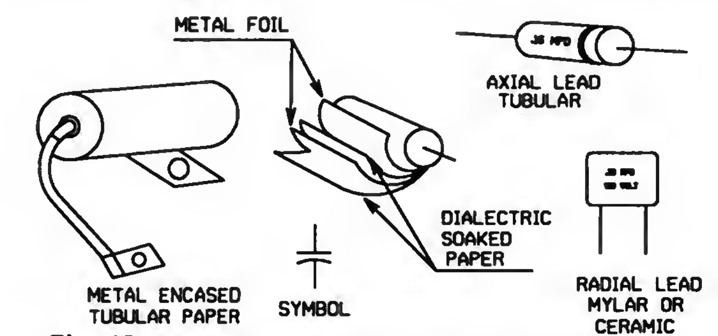


Fig. 16 CONDENSER CONSTRUCTION

Fig.16 also shows the symbol for a condenser. The curved line represents the plate that is usually connected to ground. Electrolytic condensers are not used in ignition circuits as they are polarized and used only in DC circuits. The ideal condenser, like the ideal inductor, and unlike a resistor, does not dissipate the energy supplied to it. The condenser stores the energy in the form of an electric field, whereas the inductor stores the energy in the form of a magnetic field.

The circuit in Fig.17 was designed to charge and discharge the condenser.

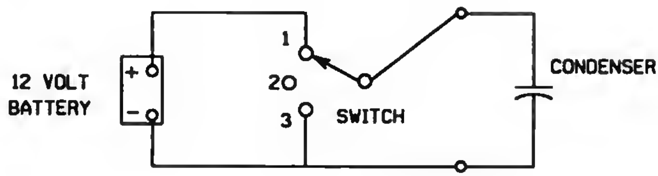


Fig. 17 CHARGE/DISCHARGE CIRCUIT

During the charging phase (switch position 1), electrons are drawn from the top plate and deposited on the bottom plate by the battery, resulting in a net positive charge on the top plate and a negative charge on the bottom plate. The transfer of free electrons continues until the potential across the condenser is exactly the same as the battery. At the instant that switch 1 was closed the current flow was maximum and over a specific period of time, diminished to zero flow.

If the switch is moved to position 2 the condenser will retain the charge of electrons for a length of time determined by its leakage current. For Mylar and paper condensers the charge will be maintained for a long time. If the switch is moved to position 3 the condenser will be shorted. The current flow will be maximum at the moment the switch is closed and the flow will diminish to zero over a period of five time constants.

Fig.18 shows the current flow verses time for switch position 1 and 2.

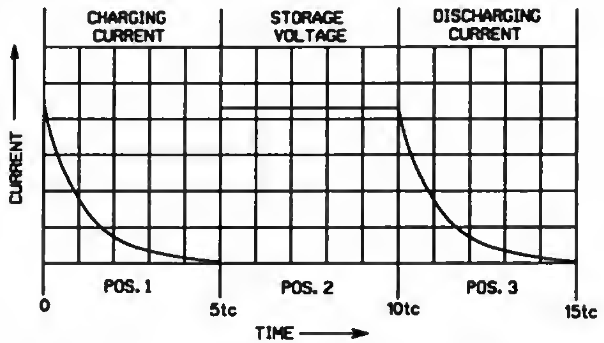


Fig. 18 CAPACITIVE REACTANCE

From all this, we see that a condenser is fully charged with free electrons or fully discharged of free electrons over a specific period (five time constants) of time. Like inductors, a time constant can be calculated for each condenser. The formula used is: $T = R \times C$ sec, where R is the total circuit resistance, C is the capacity of the condenser in microfarads and sec is in microseconds.

Methods to calculate the time constant for inductors and condensers can be found in other books. It is not necessary for the home builder to calculate time constants, but simply to understand that they exist.

Condensers are not a prime suspect when troubleshooting ignition circuits. They can go bad but it is rare. A condenser can be checked with a Simpson model 260 volt-ohm-meter, or compatible. The procedure is to first measure it's resistance, which should be high, that is, in the thousands of ohms or megohms.

When the leads are connected to the condenser, the indicator needle should rise upscale from zero as the condenser is charged by the meter batteries and slowly come to rest at a high resistance reading. A further check is to switch the meter to Milliamps and you should observe a kick of the needle as the condenser discharges through the milliamp meter.

Small metal clad paper condensers are available from your local lawn mower repair shop. When asked, they will usually give you one or two junk weed eaters (string trimmers) from which you can salvage the entire magneto including the coil and condenser.

I have used 50 volt Mylar condensers for years and never had one fail. I prefer the radial lead flat type condenser and locate it at or near the breaker contacts rather than the coil. If the coil is to be encased in a wooden box, The condenser can be located inside the box in order to keep the breaker assembly "clean".

THIS PAGE IS BLANK

but this is not a printing or scanning fault and no content is missing.

CHAPTER 6
WIRE

Wire sizes have been, for many years, indicated in commercial practice almost entirely by gage numbers, especially in America and England. This practice is accompanied by some confusion because numerous gages are in common use.

The most commonly used gage for electrical wires, in America, is the American Wire Gage. The most commonly used for steel wires is the Birmingham Wire Gage. There is no legal standard wire gage in America. A gage for sheets was adopted by congress in 1893. In England there is a legal standard known as the Standard Wire Gage. There is a tendency to abandon gage numbers entirely and specify wire sizes by the diameter in mils (thousandths of an inch). This practice holds particularly in writing specifications and has the great advantages of being both simple and explicit.

The basis of the AWG is a simple mathematical law. The gage is formed by the specification of two diameters and the law that a given number of intermediate diameters are formed by geometrical progression. Thus, the diameter of No. 0000 is defined as 0.4600" and of No. 36 as 0,0050". There are 38 sizes between these two; hence the ratio of any diameter to the diameter of the next greater number is given as the square of the ratio, 1.2610.

The sixth power of the ratio, that is, the ratio of any diameter to the diameter of the sixth greater number, = 2.0050. The fact that this ratio is so nearly 2 is the basis of numerous useful relations or short cuts in wire computations. There are a number of approximate rules applicable to the AWG which are useful to remember.

1. An increase of three gage numbers (for example, from No.44 to 41) doubles the area and weight and consequently halves the d-c resistance.
2. An increase of six gage numbers (for example, from No. 44 to 38) doubles the diameter.

The wire that is commonly used in the fabrication of ignition coils, has for many years been referred to as enameled magnet wire. In recent years, the term has been shortened to magnet wire due to the fact that many new coatings have been developed. These coatings include Polyurethane, Polypropylene, Polyvinylchloride and other various thermoplastics including Nylon.

The home builder need not be overly concerned about coatings as most all Magnet Wire sold today will withstand quite a bit of abuse and is suitable for 270 degree F usage. Wire that can be used at higher temperatures is available. Such wire is not recommended due to cost and the probability that other insulation materiels used in the coil would not withstand that much heat.

Nearly all of the magnet wire produced in the United States is drawn to the American Wire Gauge and all reference to wire size in this book is to AWG. Magnet wire should be purchased in 1 pound or 2 pound spools. The larger size spools are difficult to despool during the winding process due to their inertia and momentum.

A one pound spool of No. 28 AWG contains about 2000 feet of wire and is enough to wind about 40 ignition coils. A two pound spool of No. 44 contains about 30 miles or 160,000 feet of wire and is enough to wind about 32 ignition coils.

Belden Wire and Cable Co. offers a high-temperature, heavy armored, poly-thermaleze magnet wire that is dual coated. It's base coat is a cross-linked, modified polyester. It's top coat is an amide-imide polymer and is rated for 180 degrees centigrade usage.

Belden also offers a magnet wire that combines the excellent characteristics of polyurethane and the known toughness and solvent resistance of a nylon overcoat. Belden's trade name for this wire is Beldsol. A nice feature of this wire is that it can be soldered at 750 degrees without removing the insulation. The Belden part No. is 8054 for a half pound spool of No. 28 that contains 1020 feet of wire.

Belden no longer sells No.44 in small quantities, so you will have to look elsewhere (yellow pages) for a supplier. Do not try to reuse wire from a transformer, or a used automotive coil, it's too much of a risk.

Fig.19 provides wire data for the sizes of wire commonly used to wind ignition coils. Manufactures of magnet wire publish data for their products that include insulation specifications as well as overall diameter.

The resistance of a solid copper wire can easily be found by measuring the diameter and using the mathematical constant for copper, which is, 10.79 (at 75 degrees F). The length of the wire (in feet), is multiplied by the constant and the product is divided by the area in circular mills. For instance, the diameter of No. 36 is 5 mills. The area (diameter squared) is 25 mills. If the wire is 10 foot long, then 10 x 10.79 = 107.9 / 25 = 4.316 ohms. The constant for aluminum is 17.29, for silver 9.84, for iron 63.65, and for platinum 59.02. The table in Fig.19 is based on the constant for copper. The table also appears in the appendix.

Stranded hookup wire used to connect the coil to the battery and breaker contacts should be 18 AWG maximum to 22 AWG minimum.

SIZE AWG	DIAM. INCH	OHMS PER INCH	OHMS PER FOOT	TURNS PER LINEAR INCH
24	.02010	.0022	.0267	46.3
25	.01790	.0028	.0336	51.7
26	.01594	.0035	.0424	58.0
27	.01420	.0044	.0535	64.9
28	.01264	.0056	.0675	72.7
29	.01126	.0070	.0851	81.6
30	.01003	.0089	.1070	90.5
31	.008928	.0112	.1353	101
32	.007950	.0142	.1707	120
33	.007080	.0179	.2152	140
34	.006305	.0226	.2714	164
35	.005615	.0285	.3422	175
36	.005000	.0359	.4316	198
37	.004453	.0453	.5441	225
38	.003965	.0571	.6863	250
39	.003531	.0721	.8654	280
40	.003145	.0909	1.099	320
41	.0028	.1146	1.3762	352
42	.0025	.1438	1.7264	348
43	.00222	.1824	2.1893	365
44	.00198	.2293	2.7522	390
45	.00176	.2902	3.4833	520
46	.00157	.3647	4.3774	565
47	.00140	.4587	5.5051	624
48	.00124	.5847	7.0174	750
49	.00111	.7297	8.7574	825
50	.00099	.9174	11.009	900

Fig. 19 WIRE DATA

THIS PAGE IS BLANK

but this is not a printing or scanning fault and no content is missing.

CHAPTER 7
BOBBINS

Nearly all home shop builders wind their coils on coil forms, sometimes referred to as a bobbin. The material used for the bobbin can be wood, paper, ceramic, plastic, epoxy, metal or a combination of these materiels. The best all around materiel in my experience, and the one that I recommend, is Delrin with Micarta being the second choice.

Micarta is a Westinghouse Electric Corp. trade name for linen phenolic and is manufactured by impregnating sheets of linen with phenolic resin and allowing it to cure under hundreds of tons of pressure. It is then sawn into strips, ground or turned and sold as rod. 1 1/4" OD is the most popular size for coil form use. 1" OD can be used for most coil forms but there will be little allowance. It is tan in color and is one of the strongest materials known to industry.

Micarta's dielectric characteristic makes it a superb insulator and it's maximum operating temperature is 120 degrees. It is easily turned, sawn, filed, drilled and sanded and polishes to a pleasing surface. Micarta is usually sold by plastic dealers in four foot lengths, minimum, at a cost of about 8 dollars per foot. I also use paper phenolic rod because it is available in black color and suitable for the cap.

Paper phenolic is manufactured the same way except that paper rather than linen or cotton is used. It is similar to Bakelite, black in color, but lacks the strength of linen phenolic. Black paper phenolic is excellent for use as the top of an ignition coil. Both materials can be used for distributor rotors and caps, cam followers and insulation blocks.

Micarta is also available with a silicone impregnated woven glass substrate that has a maximum operating temperature of 250 degrees centigrade but, at $250 per foot,,,,,well, we can be mindful to turn the ignition switch off when the engine stops running. Delrin is commonly available and machines nicely.

The bobbin is usually formed by turning round bar stock in the lathe. The center hole in the bobbin is normally drilled 3/8", 1/4" or 3/16". If a square core is to be used, a square file of the above dimensions is driven in and out with a hammer until it passes completely through the Bobbin. The square hole is formed before any machining is done in order to take advantage of diametrical strength. The bobbin is then mounted on a square or round mandrel and turned to outside dimensions. Fig.20 shows a typical bobbin.

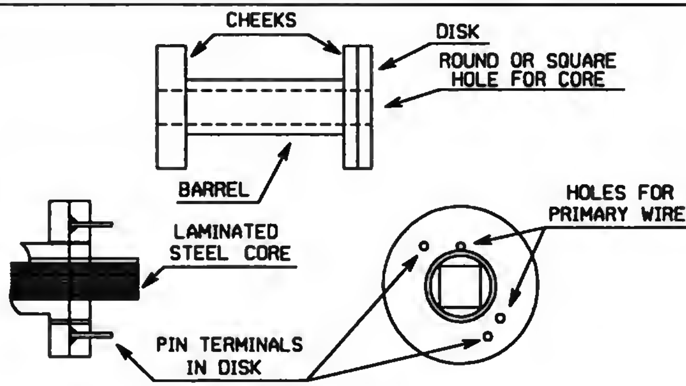


Fig. 20 TYPICAL COIL FORM

The primary winding can be led out of the bobbin through holes in one or both ends of the bobbin, sometimes referred to as flanges or cheeks. The holes must be drilled in the cheek before any winding begins. The bobbin should be kept free from oil, grease and small metal chips during machining and drilling as the Micarta is porous. Porosity should be maintained until the coil is saturated with the desired insulation.

The ends of the primary winding and one end of the secondary winding can be terminated on pins installed in a disc that is glued to one cheek of the bobbin. This is desirable as insulated and stranded wire can then be used from the pin terminals to other parts of the coil.

When the bobbin has been turned to OD, the disc is parted off. The disc should be from .100" to .125" thick. It is then drilled and countersunk for the pins and pinheads. Use a drill the same size as the pins for a tight fit. The pins are started in the holes then Locktite is applied and the pins driven home. Be sure the pinhead is below the surface of the disc. Do not sand the pinheads as this will embed small bits of metal in the disc.

The disc is then coated with a two part epoxy and clamped to the cheek of the bobbin while the square mandrel is in place. After the epoxy has set, the OD of the bobbin can be retouched or trued and the square mandrel driven out. A final pass of the square file through the bobbin should clean things up.

The holes for the wire can then be drilled through the disc and cheek. Use a drill twice the size of the primary wire and locate the holes carefully. The drill bit may have a tendency to wander due to the woven linen construction. Use a shortened drill and make a test drilling in a scrap piece of Micarta.

Delrin, although more expensive than phenolic, is probably the best material for bobbin construction. It machines and drills as well if not better than phenolic and is not brittle, thus eliminating the problem of accidental breaking or cracking of the bobbin.

CHAPTER 8
HOW THEY WORK

Now for step two, how an Ignition Coil operates. First, the term "Ignition Coil" is technically incorrect, so is "Ignition Transformer". The device is properly termed as "Air Gap Autotransformer". For clarity, we will call it an Ignition Coil as most people do.

I have read many published articles by authors attempting to describe the operation of an ignition coil. Most of these articles contain gross technical errors. The reader is attracted to such articles in the hope of understanding how the ignition coil operates but is left confused by inaccurate statements and poor English.

One article states "the (primary) current increases until the core is saturated and cannot produce more field lines". A primary winding with sufficient ampere turns to saturate the core would be inefficient and wasteful of energy. The core CONDUCTS magnetic lines of force, it does not PRODUCE them. The area of the core should be large enough to easily conduct much more flux than the primary winding can produce. Much effort has been expended in a effort to compose steels with low reluctance that easily conducts flux. To design a core that could be saturated and provide much resistance to magnetic flux would not be logical.

One author states that "when the points open, the current stops and the magnetic field collapses". This statement is true but misleading. When the breaker contacts START to open, the current does not stop. The current begins to diminish, over a period of five time constants, to zero flow. This is an important fact when explaining the operation of an ignition coil with respect to the breaker contacts.

To quote another, "The role of the capacitor across the points is to prevent arcing when the points first open. Without the capacitor the flyback voltage pulse would divide between the coil primary winding and the opening points. This would cause an arc (sparking) at the points and would rob the coil of some it's 150 volt flyback pulse". This statement makes no sense at all to me. A condenser has a definite capacity, and a fuel tank has a definite capacity. We do not call a fuel tank a capacitor and we should not call a condenser a capacitor. A condenser has a definite capacity whereas a capacitor has no "condensitivy".

The function of the condenser is not to reduce arcing at the breaker contacts, as will be explained. The terms "pulse", "flyback", "kick", "jump voltage", etc. are delphic and are buzz words used by those with a grasp of television circuits. These words have no place in the description of ignition coils.

There is much about elementary particles that is not known and no man can accurately describe what the mysterious phenomenon of electricity and magnetism is or precisely how they work and interact.

Much is known of their effects and nothing can be gained by arguing different theories. The best explanation of how an ignition coil operates is the one that makes sense, is logical, understandable and applicable. The explanation should contain no buzz words, slang or delphic terminology.

Not everyone will agree with my explanation, however with it you can understand, calculate, design, build, troubleshoot and construct a variety of ignition coils.

A transformer will not work with d-c voltage as it requires a changing current through it's windings, which sets up a changing magnetic flux. D-c current cannot satisfy this requirement. If d-c current is periodically interrupted by some mechanical means, it will then be possible to use an original d-c voltage source with a transformer. This is the principal used in ignition coils. The rising and falling d-c current through the primary induces an a-c voltage in the secondary.

A transformer works very nicely with alternating current (a-c). Alternating current simply means that the current flows in one direction for a period of time and then flows in the opposite direction for a period of time. The two time periods, combined, is usually referred to as one cycle. The standard residential electrical power in the United States is 120 volts alternating at 60 cycles per second, usually written as 120 vac.

Fig.11 shows that if a coil of wire is wound around an iron core and current is passed through the wire, magnetic lines of force are established and, these magnetic lines of force travel in the iron core. Magnetic lines of force seek out and travel along the path of least resistance. In the case of the solenoid, part of their circuitous path is through the iron core, which becomes magnetized. The remainder of the circuitous path is through air. If the iron core is removed and replaced with a rectangular shaped iron core composed of stacked L shaped laminations, most of the magnetic lines of force will travel (partially) in the iron core. The total number of lines of force (flux) that will travel in the core is determined by the number of turns of wire, current in the wire (ampere turns) and the core material and length.

The graphic symbols for transformers as used on schematics and drawings are shown in Fig.21. The step up and step down symbols are applied to shell type and core transformers as well as ignition coils.

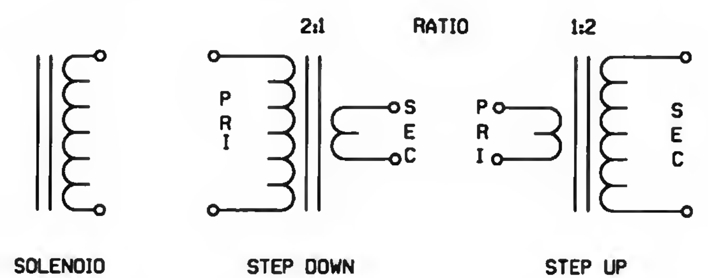


Fig. 21 GRAPHIC SYMBOLS

Fig. 22 is a schematic of an ignition coil.

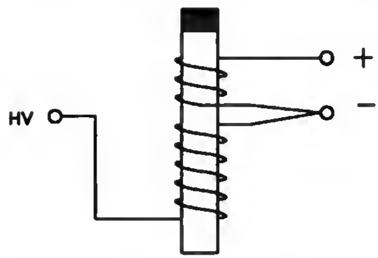


Fig. 22 IGNITION AUTORANSFORMER

The schematic shows that both coils are wound in the same direction around the core and connected in series.

A shell type AC transformer is shown in Fig. 23. The shell type is probably the most common type of AC transformer and is the type that most builders will salvage laminations from.

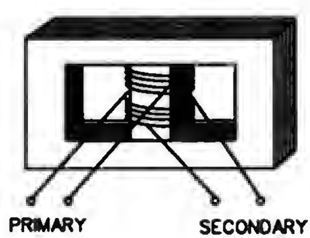


Fig. 23 SHELL TYPE TRANSFORMER

The primary and secondary are wound, one on top of the other. E and I shaped laminations are then assembled around the coil so that the coil is around the center leg of the laminations. This assembly provides three circuitous paths for the flux, two circular paths are through the center of the laminations and the third path is through the air. Air has a high resistance to the establishment or flow of magnetic flux. The iron core provides a low resistance path for the flux, thus a coil with a given number of ampere turns will establish much more flux (magnetic strength) through an iron core than through an air core. Care is taken to use a core large enough to prevent saturation by the flux.

The core type a-c transformer is shown in Fig. 24 and is a good example for discussion.

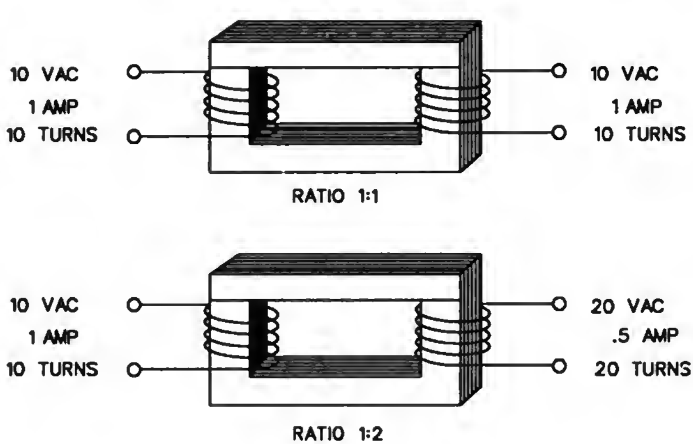


Fig. 24 CORE TYPE TRANSFORMER

The upper transformer is shown to have a 1:1 turns ratio, that is, the secondary winding has the same number of turns of wire as the primary winding. This transformer is usually called an isolation transformer because the secondary provides a circuit that is electrically isolated from the primary circuit.

The lower transformer is shown with a 1:2 turns ratio, therefore the secondary a-c voltage will be twice the primary a-c voltage. There is a small loss, or drop, across the transformer. The ratio of the windings is applied to determine an unknown secondary voltage when the primary voltage is known.

There is another way, somewhat unorthodox, of looking at the transformer if we take a little liberty. Suppose for an instant that one ampere of a-c current is flowing in the primary, thus 10 turns x 1 amp = 10 ampere turns. Let's also suppose that the 10 ampere turn primary generates 5000 magnetic lines of force in the core. The 5000 lines of force traveling through the core, expand and collapse as the current in the primary alternates. The 5000 lines of force cut through the secondary winding and produce a 10 ampere turn secondary. Depending on the number of turns of wire, the secondary can be 5 turns at 2 amp, 10 turns at 1 amp or 100 turns at .1 amp.

The actual number of magnetic lines of force (flux) generated by a 10 ampere turn coil depends on the laminated core material, cross sectional area of the core and the length of the magnetic circuit around the core and through the air.

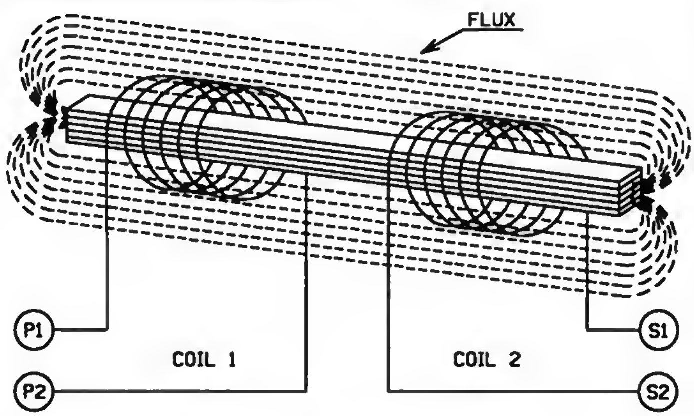


Fig. 25 MUTUAL INDUCTION

A word should be said about induction. Fig. 25 shows a laminated core with two separate coils of wire wound around it. If P1 and P2 are connected to an alternating voltage, the current will cause flux to be established as shown by the dotted lines. The flux will alternate (expand and collapse) in concert with the alternating primary voltage. The alternating flux will cut through the coils of the second winding and induce a voltage to appear across S1 and S2.

If an external circuit is connected across S1 and S2 (such as a resistor), a current (free electrons) will flow in the circuit. The current that is induced in the second coil is said to be produced by induction. The shell type and the core type transformers operate in exactly the same manner. The second coil is usually wound directly on top of the first coil in order to shorten the magnetic circuit (core). This reduces the resistance of the magnetic circuit.

Let's take some more liberty and suppose that the laminations of the core type transformer are cut to form a U shape as shown in Fig.26. Also let's suppose that a magnet has been embedded in an aluminum wheel, with laminated pole pieces, and has been machined to run true on a shaft and that the core laminations have been mounted close to the wheel.

When the magnet/wheel (flywheel) is stopped in the position shown in Fig.26, the laminated core will be magnetized and the maximum flux will exist in the core.

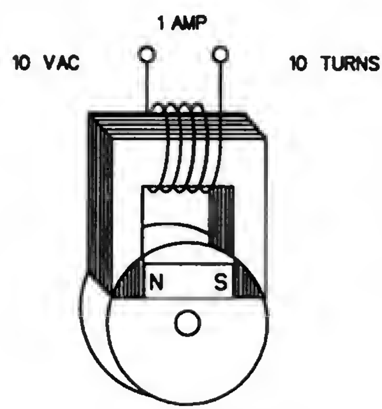


Fig. 26 ALTERNATOR

Let's also assume that the magnet is strong enough to produce 5000 lines of flux in a core that can easily accommodate the flux, and that the coil has 10 turns of wire. Naturally there is no current in the coil as the flux is stationary, that is, the lines of force are not expanding outward or collapsing inward toward the core.

If the flywheel is turned, in either direction, the magnetic field will collapse and induce current to flow in the coil. The amount of current that will flow depends upon the resistance of the wire, number of turns of wire, flux density (number of magnetic lines of force) and how fast the flux collapses.

If the flywheel is turned further to complete one turn, the flux will expand and induce a current to flow in the opposite direction. The current and flux will reach maximum when the magnet poles are again aligned with the core legs as shown in Fig. 26. The flux will collapse, or expand, at a velocity determined by the magnet strength and velocity. If the flywheel is turned slowly, little voltage or current will be generated as the magnetic lines are not cutting across the coils of wire fast enough.

The above is a very brief explanation of a basic generator. The reader at this point should have a basic understanding of an ampere, a volt,an ohm, ampere turns and flux. If not, reread up to this point or turn to other publications on the subject which I am sure will go into much greater detail.

There is one important thing that has not been mentioned up to this point and perhaps this is a good time to go into it. It was pointed out in Chapter 1 that when electrons move along a wire, a magnetic field exists around the wire. It was not explained why. The explanation that I like best, and one that fits my concept of momentum and inertia is this:

When energy is applied to an electron to force it to move, the electron stores some of this energy in the form of a magnetic field or magnetic lines of force, collectively called flux. In fact the electron will not move until it has begun the process of creating a magnetic field. The magnetic field increases as the electron's velocity increases until the electron is moving at a speed determined by the applied force. Thus it can be said that the electron will resist any change in current (by establishing flux, which requires time and energy).

Conversely, the electron will resist a decrease in velocity (or force) by collapsing the magnetic field to gain energy. The diminishing energy is used in an attempt to maintain the electron's velocity. When the energy in the magnetic field has been expended, the electron is at rest without a magnetic field.

Fig.27 is a copy of Fig.11 with a battery and switch added.

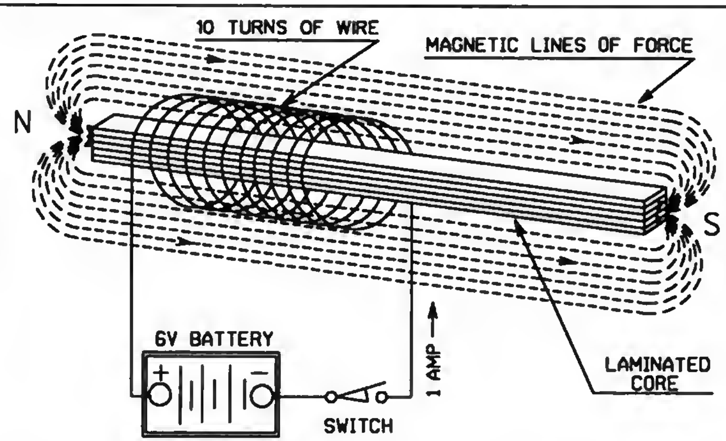


Fig. 27 10 AMPER TURN SOLENOID

With the switch closed, the 6 volt battery will force 6.242 quintillion free electrons per second to move circuitously from the negative terminal of the battery, through the six ohms resistance of the wire, to the positive terminal of the battery. The magnetic fields surrounding each turn of wire are combined to form one large magnetic field (flux) that flows around the coils and partially travel through the iron core which is magnetized and polarized.

We also understand that there was a delay in getting the electrons up to speed. The delay is caused by the inductance of the coil. Inductance is the term used to define a coils resistance to a change in current flow. Inductance is measured in henries or millihenries.

Fig.28 is a graphic representation of the delay, showing the relationship between time and current (or flux). Each coil, or inductor, has a time constant that can be calculated. The graph shows that five time constants are required for the current to reach its "final value" of maximum current.

From the above, we can understand how the electrons resist an increase in battery voltage, or current flow, and that there is a definite time delay required for the current to reach its "final value". For all practical purposes the coil is considered to be a short circuit across the battery after five time constants. If the voltage is suddenly removed from the coil, there is a similar delay before the current drops to zero.

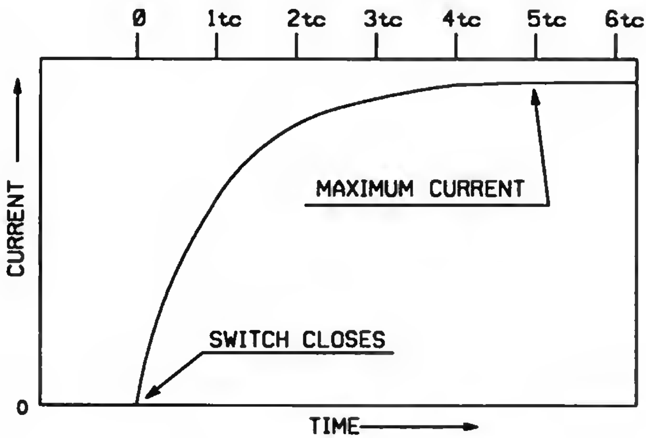


Fig. 28 CURRENT / TIME

Before we open the switch, we again realize that the electrons are happily humming along the wire being pushed by six volts from the battery at a rate of one ampere with energy stored in the form of a magnetic field. How much energy is stored in the field? To determine the exact amount of energy stored involves a long calculation performed with calculus. The formulas and method of calculation can be found other in books on electricity, electronics, radio, etc.

The ideal coil, like the ideal condenser does not dissipate the electrical energy supplied to it. The energy is stored in the form of a magnetic field. Fig.29 is a plot of the voltage, current, and power to the coil during the buildup of the magnetic field surrounding the coils of wire. The energy stored is represented by the hatched area under the power curve.

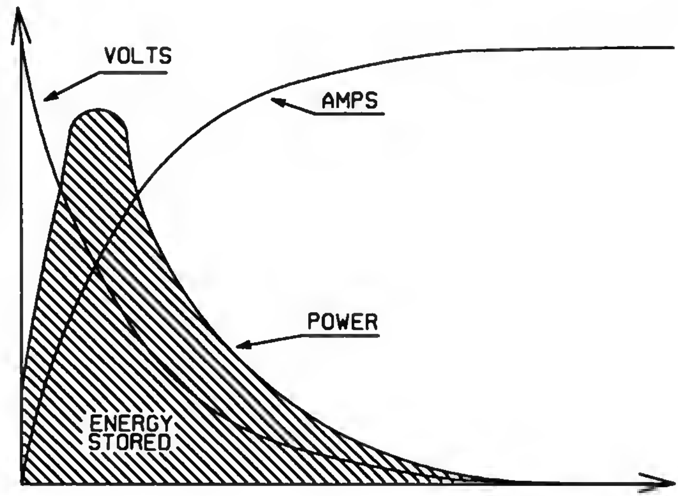


Fig. 29 ENERGY STORED BY COIL

At the instant the switch is opened the electrons go from happy to unhappy, as they do not like any change to their velocity, or current flow. The electrons react by collapsing their magnetic field to obtain energy in an effort to maintain their velocity. This reaction occurs in a straight length of wire as well as a coiled wire, or, for that matter, in a kinked wire. The reaction is called, logically, reactance.

Even though the contacts have separated and the gap is widening, the electrons have sufficient energy to overcome the resistance of the air gap, ionize the air and continue flowing across the gap. This miniature bolt of lightning through the air is called an "Arc".

As the gap widens, and the resistance across the gap increases, the electrons collapse their magnetic field in an effort to gain the energy needed to bridge the gap. A distance between the contacts will be reached where the electrons have insufficient energy to bridge, and the arc is broken, electrons stop flowing, the magnetic field has collapsed and the core looses nearly all of it's magnetism. The small amount of magnetism left in the core is called residual magnetism.

Another way to view this delay is to compare the electrons to a locomotive pushing a long string of boxcars. It requires a lot of energy to accelerate the boxcars to 60 MPH, and to maintain 60 MPH requires a lot less energy. To stop the train instantly would require a tremendous amount of energy as they, like the electrons, have momentum. Simply opening the switch will not instantly stop the train or the electrons.

Now, lets go one more step and copy Fig.27, add a separate winding and label it as Fig.30. The flux lines are not shown for clarity. Since there are now two separate windings around the core, it is semi-logical to call the first winding the primary and the second winding the secondary. The primary is always the winding that is in series with the battery and the breaker contacts.

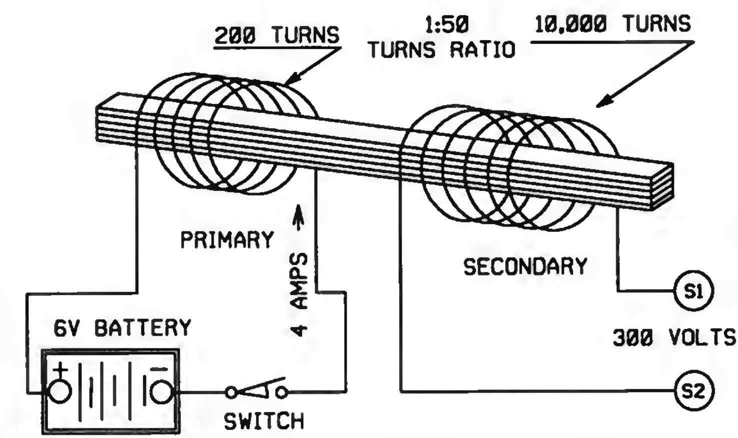


Fig. 30 DC INTERUPTED PRIMARY

If the switch in fig. 30 is closed the expanding flux will induce a voltage in the secondary. After reaching it's maximum value (300 volts), as determined by the battery voltage (6) multiplied by the turns ratio (1:50), the secondary voltage will fall back to zero as the flux is at it's maximum value and stationary. The secondary response occurs very quickly.

If the switch is then opened, a similar voltage, opposite in polarity, is induced into the secondary.

Now, let's go one final step and copy Fig.30, add a condenser (the piano part) and label it as Fig.31. This circuit is commonly referred to as a "capacitor discharge ignition circuit".

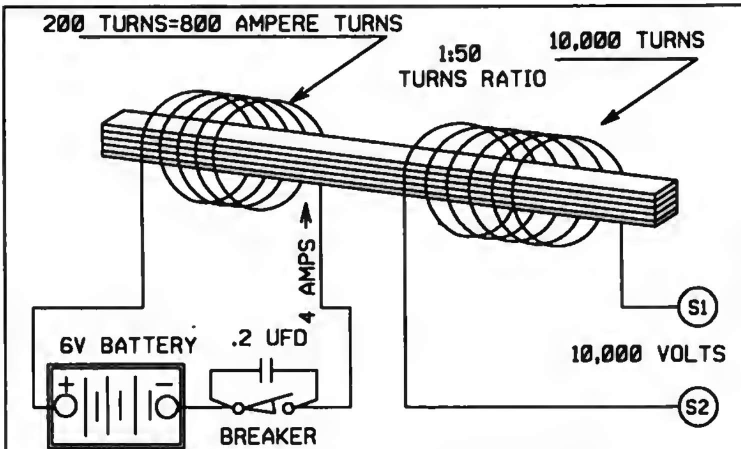


Fig. 31 IGNITION COIL CIRCUIT

If the switch is closed in Fig.31, both sides, or plates, of the condenser will be connected, or shorted, and the same number of electrons will exist on both plates. Once again, one ampere of current will flow from the negative terminal of the 6 volt battery, through the six ohm coil, to the positive terminal of the battery and flux will be established.

If the switch is opened the moving electrons again collapse the flux to gain energy and maintain velocity. Many electrons are forced onto the left hand plate of the condenser. As the gap between the switch contacts increase, a distance will be reached that the electrons can not jump.

At this point, the arc is broken and the moving electrons are forced on to the left hand condenser plate. When the flux has totally collapsed and the electrons stop moving (momentum expended), the condenser is charged to a high potential by the vast number of electrons forced onto one plate.

The charged condenser has stored the energy given up by the magnetic field. At this point, the condenser, if properly chosen, is charged to a potential of hundreds of volts. If the value of the condenser is too small, it will be unable to store all of the charge (high pressure-low quantity) and, if too large, will be undercharged (low pressure-high quantity).

The charged condenser now forces the electrons back through the battery and coil with a potential of hundreds of volts rather than 6 volts and the electrons pile up on the right hand plate of the condenser. During this headlong dash (current flow), the electrons, with a potential of hundreds of volts, create magnetic flux, opposite in polarity, and the core is magnetized with its poles reversed. The condenser is again charged and this oscillating process repeats itself until the electrons are equally distributed across the condenser. Some of the energy is expended as heat due to resistance.

If the temperature of the coil/condenser is dropped to absolute zero, the oscillating current would never stop as there would be no resistance. The alternating current just described can be compared to a clock pendulum swinging back and forth. A properly chosen condenser will absorb the energy given up by the coil and the coil will absorb the energy given up by the condenser. Such an arraignment is called a series resonate circuit.

The concept of resonance is not limited to electrical systems. If mechanical pulses are supplied to a mechanical system at the proper frequency, the system will enter a state of resonance in which sustained vibrations of very large amplitudes will develop. The frequency at which this occurs is called the natural frequency of the system.

A resonate circuit can be demonstrated by holding a hacksaw blade down on the steady rest of a running bench grinder. Clamp the blade with your thumb and forefinger to the steady rest so that about 5" of the blade protrudes from the edge of the steady rest. As you move the blade in or out you will find a length of overhang where the blade vibrates back and forth. If you clamp the blade with a C clamp at the proper length,the blade will oscillate wildly.

The motor supplies the energy and the grinding wheels supply mechanical vibration. The hacksaw blade is mechanically resonate at the speed of the motor which is usually 3600 RPM.

A classical example of resonance was the Tacoma Narrows Bridge built in 1940 over Puget Sound. It had a suspended span of 2800 feet. Four months after the Tacoma Narrows Bridge was completed, a 42 mile per hour pulsating gale set the bridge into oscillations at its natural frequency. The amplitude of the oscillations increased to the point where the main span broke up and fell into the water below. It has since been replaced by the new Tacoma Narrows Bridge, completed in 1950.

A plot of the oscillating voltage across the condenser is shown in Fig.32.

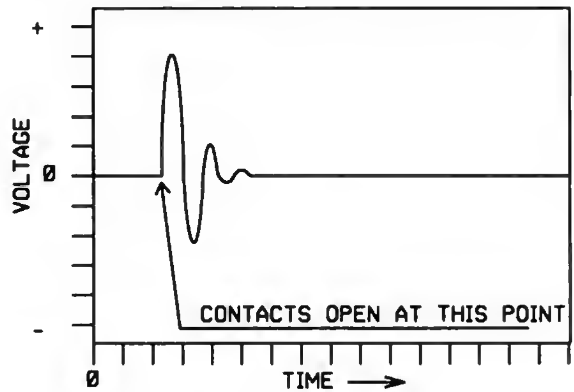


Fig. 32 VOLTAGE ACROSS CONDENSER

It is not at all difficult for an electrical or electronics engineer to determine the resonate frequency of any given coil/condenser combination. The formulas for doing so are easily found in electronics or radio books. The equation is known as the "basic radio equation".

Many writers have erroneously stated that the condenser is placed across the breaker contacts to reduce arcing. Such a statement indicates a lack of understanding. The condenser is placed across the breaker contacts to act as an instantly rechargeable high voltage battery. It is this "hi voltage battery" that drives the primary to induce the high voltage alternating current in the secondary winding. There are methods to reduce excessive arcing at the breaker contacts and will be discussed in a later chapter.

Fig.33 is a graphic diagram for an ignition coil, including the spark plug.

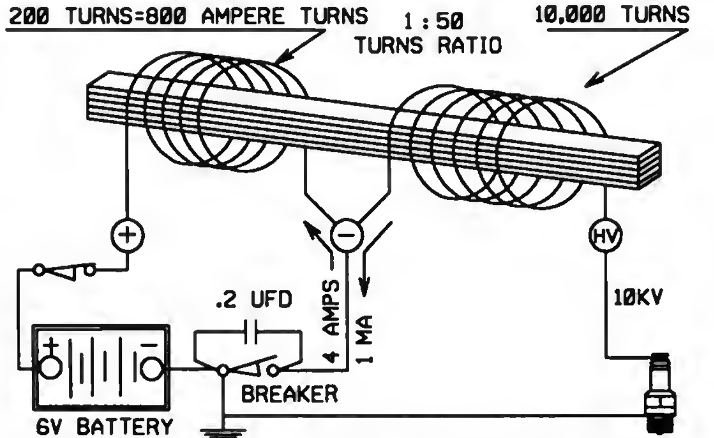


Fig. 33 IGNITION COIL CIRCUIT

The secondary winding in Fig.33 is tied to the primary. If not tied to the primary winding, it is an "isolated" winding and in that case, any point in the secondary may be connected to battery +, battery - or to two spark plugs.

If the breaker contacts shown in Fig.33 are closed, the condenser will be shorted. If the breaker is then opened, the circuit will oscillate as previously described. The magnetic field will expand, collapse, reverse, expand, collapse, reverse at a definite (natural)frequency until the oscillations have stopped and the condenser has an equal number of free electrons on each plate.

During this process, the magnetic lines of force generated by the oscillating current flow in the primary, cut through the secondary winding and force electrons to flow in the secondary circuit. It can be said that the flux produced by the current in the primary induces a voltage in the secondary windings. The voltage that is induced in the secondary depends upon the primary voltage and the number of turns of wire in the primary and secondary.

The air gap transformer, or ignition coil, follows the same rules of transformation that are applied to core type and shell type transformers. The turns ratio, primary to secondary, is the same as the voltage ratio, primary to secondary. Thus,if one knows the peak primary voltage, the peak secondary voltage can be found using the turns ratio.

As an example, suppose that the ignition coil shown in Fig. 33 has a primary consisting of 200 turns and a secondary of 10,000 turns. The turns ratio is 1:50, that is, for each turn of wire on the primary there are fifty turns on the secondary. If the peak voltage across the capacitor is measured to be 200 volts, the turns ratio predicts that a peak secondary voltage of 10,000 volts exists in the secondary.

Applying ohms law to find the peak current in the primary, 200 volts divided by 6 ohms resistance equals 33 amperes peak current in the primary resonate circuit. The peak (maximum value) a-c current exists for a very short time in the primary.

It is not easy for the home builder to measure the peak primary or peak secondary voltage at the moment that the contacts open. If the builder has a good oscilloscope, or access to one, these voltages can be inferred from the scope trace.

The voltages can be calculated. Again this is not easy for the home builder to do. The procedure for calculating resonate circuit voltages is much to lengthy to go into in this book. It is easy to find the formulas and procedure in other books to calculate the permeability of the core, inductance of the coil, the reactive inductance, reactive capacitance, resonate frequency and the short lived voltages generated at the moment that the contacts open.

It is not necessary for the home builder to know, or measure, the exact voltages generated at resonance. It is only important to understand how the high voltage is generated and the importance of selecting the correct capacity of the condenser. The proof of the ignition coil is it's ability to ignite a compressed fuel mixture.

Sufficient measurements can be taken with a volt/ohm meter to determine the condition of an ignition coil. The performance of an ignition coil can be determined, without the risk of causing an internal arc, by using a variable voltage power supply. This method will be explained later.

Never test an ignition coil to determine how far the arc will jump as this is also a test of the insulation between windings. If the insulation fails this test, the coil is ruined by an internal arc.

Fig. 34 shows the classical schematic diagram of an ignition coil and it's accessories properly wired with respect to polarity. Although any point of the primary circuit can be grounded, it is common practice to ground the negative terminal of the battery.

In Fig. 34, one end of the primary and secondary are tied together to form a three terminal device. This configuration can be considered to be an air gap autotransformer.

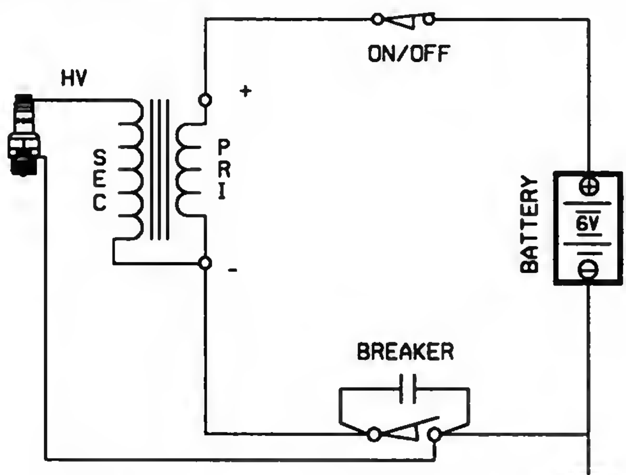


Fig. 34 SCHEMATIC DIAGRAM

If the coils are wound in the same direction, the primary voltage is added to the secondary voltage and, conversely, the primary voltage is subtracted from the secondary voltage. In either case, the amount of secondary voltage is affected very little.

The ignition coil has six components, the coil form, the insulation, primary winding, secondary winding, connection terminals and the iron core. Two circuits are shown in Fig.34, the primary and secondary. The primary circuit consists of the battery, the primary winding of the coil, the breaker contacts and a condenser. The secondary circuit is the secondary winding and a spark plug. One leg of the secondary is normally tied to the negative end of the primary to provide a three terminal device.

All of the components in the primary circuit will rise in temperature due to the current flowing in the primary circuit. Left in this state (as when an engine stops with the breaker contacts closed) the primary circuit will become very hot and probably be irreparably damaged in a few minutes. Always switch the ignition circuit off when the engine stops unless an immediate restart is planned.

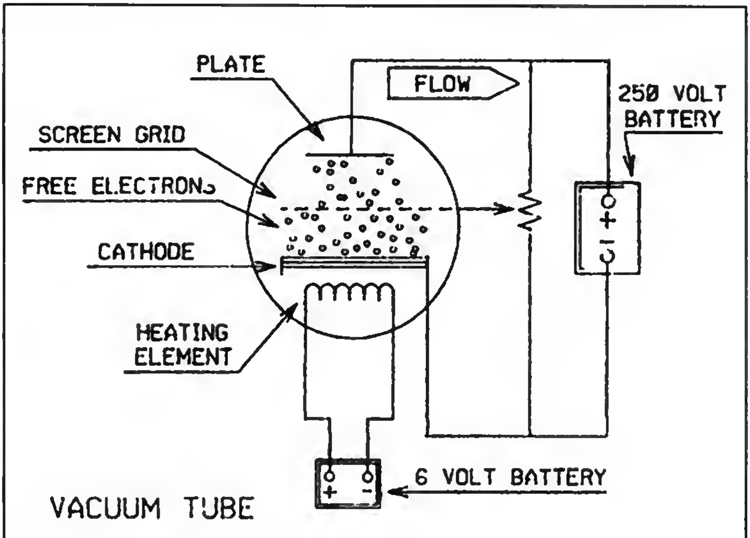
During the winding process, the start of the primary winding is labeled the" +" end and connected to the "+" terminal. The end of the primary winding is labeled the "-" end and connected to the "-" terminal. The start of the secondary winding is normally connected to the "-" terminal of the primary. This is done for convenience and to make a three terminal device rather than a four terminal device.

The end of the secondary winding is labeled the "HV" end and connected to the "HV" terminal. The core can be connected to the battery ground, the - terminal, the + terminal or the HV terminal. It is not at all uncommon to make the core a part of the high voltage circuit. Such a circuit will be shown later in this book.

The above labeling is reflected in Fig.34. The finished coil should have exterior markings for these terminals. If the positive terminal of the battery is connected to the "-" terminal and the breaker contacts and condenser are connected to the "+" terminal the coil will not operate properly.

Another good reason to tie the primary and secondary windings together is to keep the potential difference between the two windings at a minimum. If the two were not tied together there would be a potential difference of 10KV or more between the two windings. If the primary and secondary were not tied together and separated by only two wraps of paper, the high voltage will punch through the paper to get to the primary wires which have a very low resistance to ground. Another consideration is this, supposing the secondary was wound with only two layers of wire. Again the potential difference between the beginning and end of the secondary is 10KV. Since the starting wrap and ending wrap are next to each other, the high voltage would certainly jump this small gap.

Imagine, if you will, a secondary wound spirally with each wrap directly on top of each other similar to a clock spring. The distance between start and end would be quit large and the high voltage would not jump that distance. The coil should be designed with enough secondary layers to prevent a high potential difference between layers. The subject of thermionic emission comes up from time to time and is deserving of a few words. This is the principal of operation used in vacuum tubes in the good old days of radio. The drawing below depicts a vacuum tube.



The circle represents a glass bulb, evacuated, with metal electrodes inside. The positive terminal of a battery is connected to the electrode called the Plate. The negative battery terminal is connected to the electrode called the Cathode. Even with a high voltage (500 volt) battery, few if any free electrons would flow from Cathode to Plate.

By installing a heater to heat the Cathode red hot a significant number of electrons would be liberated from the Cathode to flow to the Plate. The Cathode was also coated with various chemicals to enhance liberation. The flow of electrons could be modulated by varying a small voltage applied to a metallic screen installed between the Cathode and Plate that would act to repel or attract the free electrons. All of these vacuum tubes were basically diodes or rectifiers as current would flow through them in only one direction.

Some have stated that reversing the polarity of the secondary voltage applied to the sparkplug will result in a significant increase in secondary voltage due to the thermionic effect. This statement is true but misleads one to think that he is getting something for nothing. This is not the case due to the "see-saw" effect in the secondary circuit. The see-saw effect can quickly be grasped by using exaggeration. First, realize that the collapsing flux field induces a specific amount of energy in the secondary windings. Imagine that the secondary is an open circuit. When the breaker contacts open, maximum voltage will be measured across the secondary windings,,and,, zero current flow will be measured through the secondary. If the secondary is then shorted and the breaker contacts open, zero voltage would be measured across the secondary ,, and,, maximum current would be measured through the secondary.

From the above, one can see that if the resistance of the sparkplug gap is changed, the secondary voltage will change. This was noted in Fig. 81 as a flat top of the high voltage spike. The energy in the secondary does not change, the voltage and current simply see-saw's. Generally, this misleading statement is accompanied by the claim that the center electrode of the sparkplug is hotter than the side electrode. I tend to disagree.

There are two features of the Champion V2 and V3 sparkplugs that made them outstanding. One is the fact that the side electrode was made of a tapered rod bent into a U shape and welded to the side of the plug body. Both the center and side electrodes were more or less pointed. This allowed electrons to more easily jump the gap. When these plugs were properly installed, the side electrode protruded far into the combustion chamber and the side electrode was certainly hotter than the center electrode. Many times I have shut off a running engine and quickly felt the temperature of the center electrode at the top of the plug. The center electrode has always seemed cooler that the body even though it is encased in a insulator.

A few words should be said here about saturation. A few authors, and many letter writers, have stated that at some point in the operation of an ignition coil, the core is saturated. This is not at all likely using transformer grade laminations, even in a poorly designed core. You can easily and quickly determine if your ignition coil is saturated. If your ignition coil is rated as a 3 volt or 6 volt primary, simply double the primary voltage. If the secondary voltage increases (longer arc) the coil certainly was not saturated at its rated voltage. It is very likely that you can tripple the primary voltage without saturating the core.

To describe how an ignition coil operates, it is entirely correct and proper to say that "opening the breaker contacts causes the primary d-c voltage to be transformed into a high voltage alternating current in the secondary winding". To explain how this occurs is no easy task.

CHAPTER 9
THE SIDEWINDER

Other than the normal tools found in the home shop such as wrenches, pliers, screwdrivers, etc., there are a few tools that make coil winding a lot easier. A lathe, of any size, a drill press, a height gauge, a pin vise, a set of drills from No.60 to 80, a Dremel Minimite model 750, a good soldering iron and a variable d-c voltage power supply plus a coil winder will put you in business.

Coil winders are not easy to obtain and not very difficult to build. The one that I built and use is probably not the best or the worst of designs. The winder should be designed with the following features in mind.

1. Trouble free, reliable and easy to operate.
2. Adaptable to a range of small wire.
3. Ability to turn the lead screw, independently, by hand.
4. Ability to turn the coil form, independently, by hand.
5. Ability to vary the speed of rotation of the coil form from 0 to 300 RPM.
6. Ease of access of the fingers and hand to the coil form.
7. Easy and quick reversal of the lead screw.

When my winder was built, my grandson ask if it was a "Sidewinder" and the name stuck. The Sidewinder was built entirely from parts found in the "junk box". The next several pages are devoted to the drawings for the Sidewinder and I expect each builder will modify the design to accommodate whatever parts are on hand. The drive motor can be a sewing machine motor with a foot operated rheostat, a d-c gearhead motor of spur gears or worm gear drive or a d-c motor with pulleys and belts. A source for the original motor can be found in the appendix. Building the Sidewinder is an interesting and enjoyable project in its self.

The leadscrew threads can be 1/4-32, 1/4-28 or 1/4-20 for use with gears other than those shown or different wire sizes. The 1/2" slots in the side plates allow meshing of gears C and D. It is normally one or both of these gears that are changed to handle wire sizes from No.40 to 46.

The Sidewinder is a small machine as it is intended to wind only the secondary of small ignition coils. The primary is wound in the lathe. The lathe is set to it's slowest speed and the wire is fed onto the bobbin by hand. Wire tension is controlled by letting the wire slip through the hand with more or less ease. The hand is held about six inches from the rotating coil form and slightly behind the leading edge of the winding so that the wire is "close wound".

The spool of primary wire can be impaled on a short rod and clamped vertically or horizontally in the bench vise. Winding the primary in the lathe prevents changing the gear setup for the Sidewinder and the lathe is easily employed to wind less than 300 turns of wire.

There are economical as well as mechanical advantages to choosing one size of secondary wire for all of the coils that are to be built. Nearly all of the secondary's that I wind are wound with No. 44 AWG and I recommend this size. I have used No. 40 in some coils that were designed to operate at elevated temperatures. No.40 has about 1/3 the resistance of No.44. The secondary resistance of ignition coils will increase dramatically at elevated coil temperatures.

The drawings for the Sidewinder are presented for those wishing to build it or a similar machine.

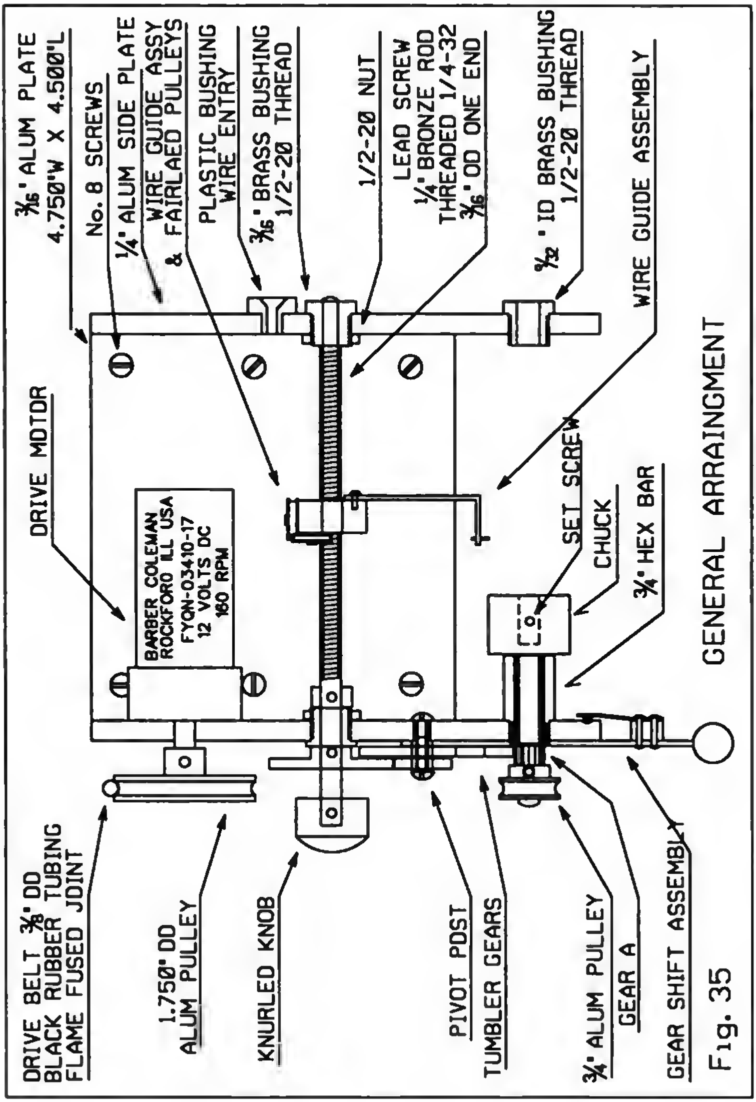
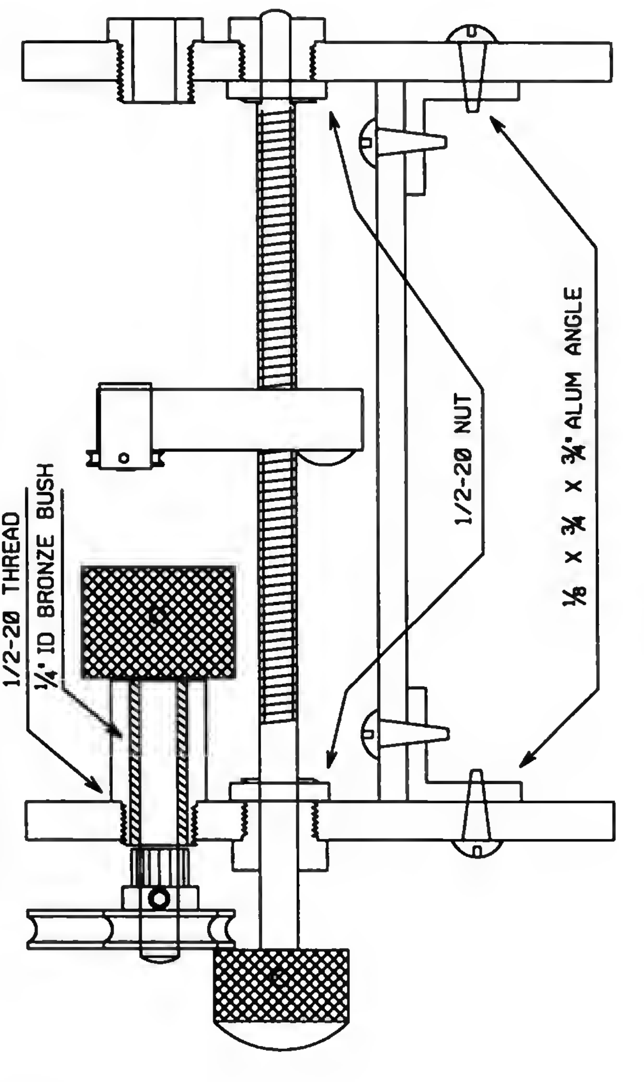


Fig. 35 GENERAL ARRAINGMENT



GENERAL ARRAINGMENT

Fig. 36

The first two drawings, Fig.35 and 36, show the general arraignment of the parts that make up the Sidewinder. The drive motor is a gear head motor salvaged from an industrial temperature controller. It was manufactured by Barber Coleman, Rockford Ill. and the part number is FYQN-03410-17. It is a 12 volt DC motor and turns about 160 RPM at 12 volts. Presently the motor cost $20.00 from C&H Sales Co.

I use a variable voltage power supply to control the speed of the motor by applying 0 to 15 volts d-c. The pulley ratio is about 2.3:1 thus the maximum spindle speed is about 400 RPM. In use, the maximum recommended speed is 300 RPM or less.

The on-off switch on the power supply is not used as there is a chance that the supply can be switched on with the voltage set to some value greater than zero. If this occurred, the wire will probably break and require a fresh start at winding the coil. One should not attempt to splice the wire together, if it breaks, scrap the job and start all over.

The drive belt is made from black rubber tubing cut to a snug fit around the pulley's. To weld the tube together, hold both ends parallel and apply a flame until both ends are ablaze then quickly butt the ends together in a V shaped piece of metal. Trim the joint with a sharp blade. If you have trouble with this procedure, cut two short pieces from the excess tubing and insert them in each end of the tube before setting them ablaze, This will give you a little more material to work with and a slightly stronger joint.

The pulleys can be made from plastic or aluminum as there is little strain on them.

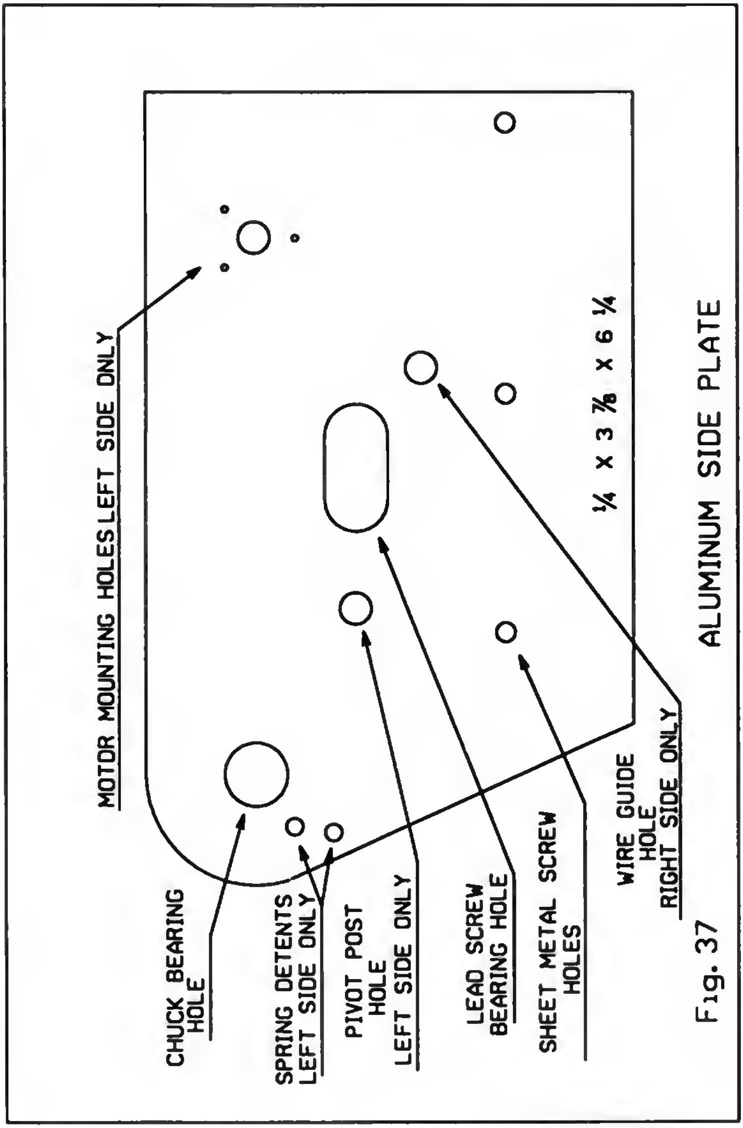
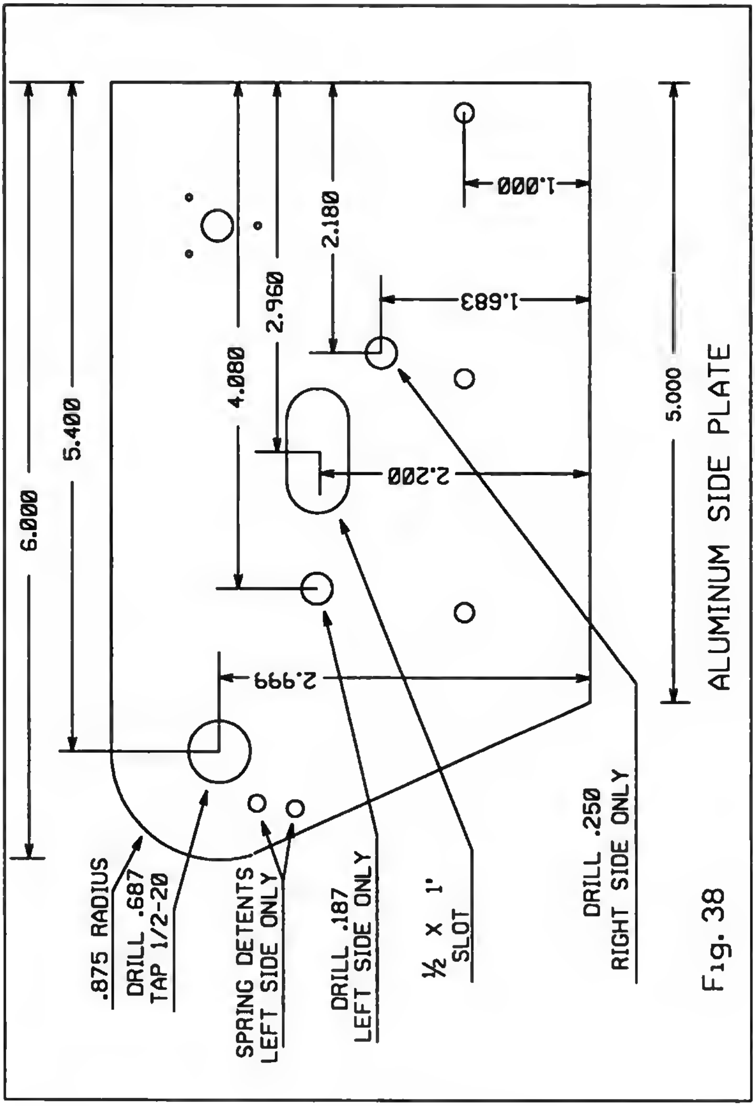


Fig. 37



ALUMINUM SIDE PLATE

Fig. 38

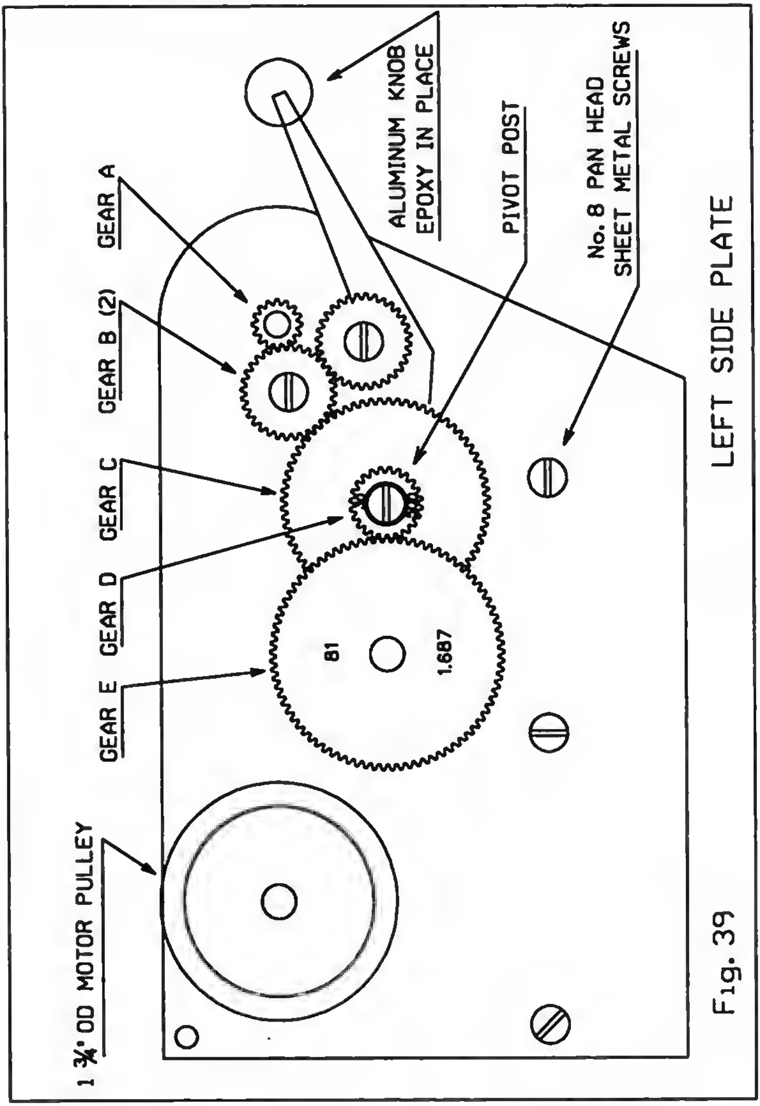
The next two drawings, Fig.37 and 38, show the layout of the side plates. The side plates can be cut from any material that is handy, aluminum, brass or steel and can be 3/16" or 1/4" thick. The plates can be fastened to the angles with sheet metal screws or bolts and nuts.

The spring detent is nothing more than a shallow 1/8" hole on the inside of the left hand plate. The second detent is in the spring. Locate this hole after the gear plate and spring assembly have been fabricated.

The 1/2" x 1" slot for the leadscrew bearings allows for the proper meshing of the lead screw gear, when and if the gear diameter is changed to wind a different size wire. The bearings are turned from 3/4" hex bar and threaded 1/2-20. Thin nuts for the bearings can be found on volume controls and switches used in TV's and radios or they can be turned in the lathe. The left bearing is drilled 1/4" ID and the right bearing is drilled 3/16".

The 1/4" hole in the right hand plate is where the plastic wire guide is pressed in. The dimensions for the wire guide are not critical. The guide serves only to bring the wire into the machine, from any angle, thus it should be chamfered or rounded to prevent damage to the wire insulation. Nylon is the best choice of material for the wire guide.

The 3/16" hole in the left plate is for the pivot post. The pivot post is a short piece of 1/4" brass round bar, drilled and tapped 6-32 through then turned with a spigot of 3/16" OD for a length of .175". The post is secured from the inside of the plate with a short pan head screw.


1 3/4" OD MOTOR PULLEY
GEAR E
GEAR D
GEAR C
GEAR B (2)
GEAR A
81
1.687
ALUMINUM KNOB
EPOXY IN PLACE
PIVOT POST
No. 8 PAN HEAD
SHEET METAL SCREWS
LEFT SIDE PLATE
Fig. 39

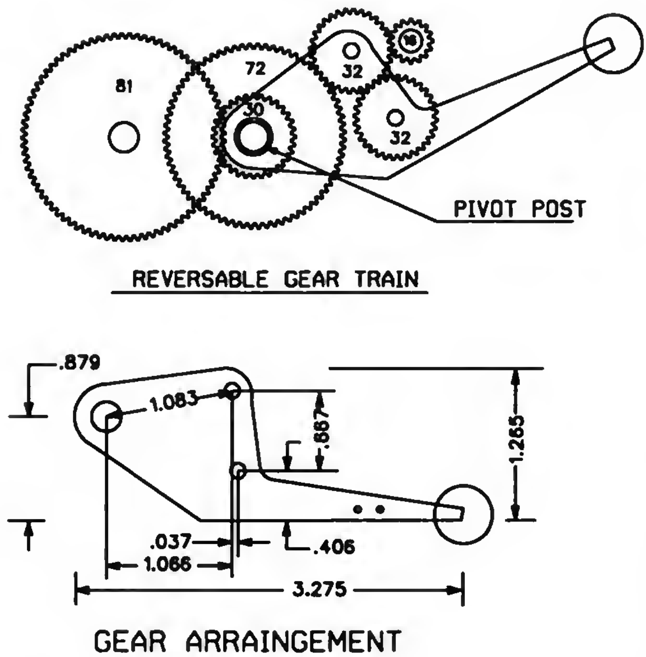


Fig. 40

Fig. 39 shows the layout of the gear train. The gears shown are 48 pitch brass gears setup to wind No.44 enameled wire. If gears E and D are changed to 72 and 34 teeth, respectfully, the Sidewinder will wind No.40 enameled wire.

The gears can be steel, brass, aluminum, fiber or plastic as there is little strain on them. A pitch other than 48 can be used and the lead screw can be threaded 1/4-28 or 1/4-20 to provide a wide range of wire size.

Gears C and D are pushed on a steel bushing, (with locktite to ease disassembly and assembly), and the bushing turns on the pivot post. The shifter plate also pivots around the pivot post. The two tumbler gears, B Gears, are fastened to the shifter plate with shoulder screws and provide for reversing the rotation of the lead screw. The gears can also be shifted to neutral to allow manual rotation of the spindle or lead screw.

Gear A and the 3/4" OD pulley are also pressed on a 1/4"OD x 3/16"ID steel bushing. The pulley hub and bushing are drilled and tapped for setscrews to lock the bushing to the 3/16" section of the spindle shaft. The spindle and shaft are turned from one piece of 1" cold rolled steel. The 1" OD is knurled, drilled and tapped for a setscrew and the end is drilled and reamed 1/4" ID. A 1/4" drill chuck can be used in place of the spindle.

The spindle bearing is turned from 3/4" hex cold rolled steel stock, threaded 1/2-20, drilled and reamed 3/8" for the 3/8" x 1/4" bronze bearing. The length of the bearing is not critical, 1 1/8" length will do just fine. Fig.40 shows dimensions for the shifter plate.

Fig.41 gives the data for the gears used in the original Sidewinder.

Fig. 42 shows the spindle assembly and the guide block layout. The guide block is made from a 3/4" x 3/8" brass bar about 1 3/4" long. The bottom of the bar is drilled for a 1/8" fixed pin and a 1/8" spring loaded pin. The business end of the pins are rounded.

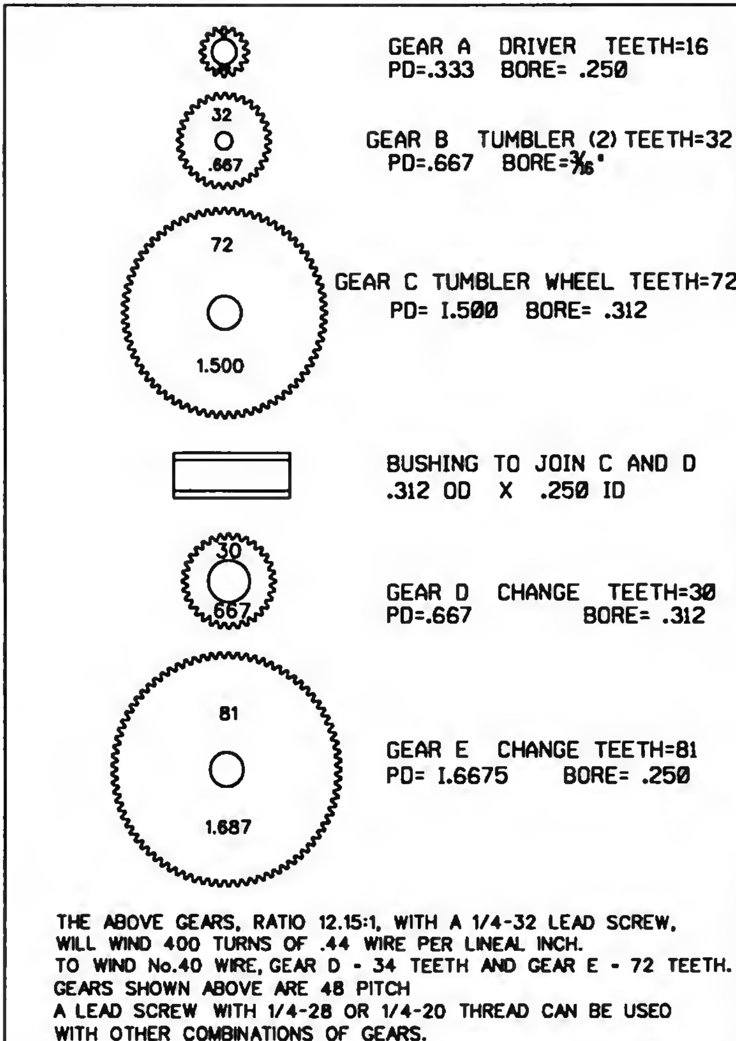


Fig. 41

The guide block is drilled and tapped to match the lead screw thread. Two plastic V pulleys, 1/2" OD x 1/8" thick are bolted to the wire guide with shoulder bolts as shown.

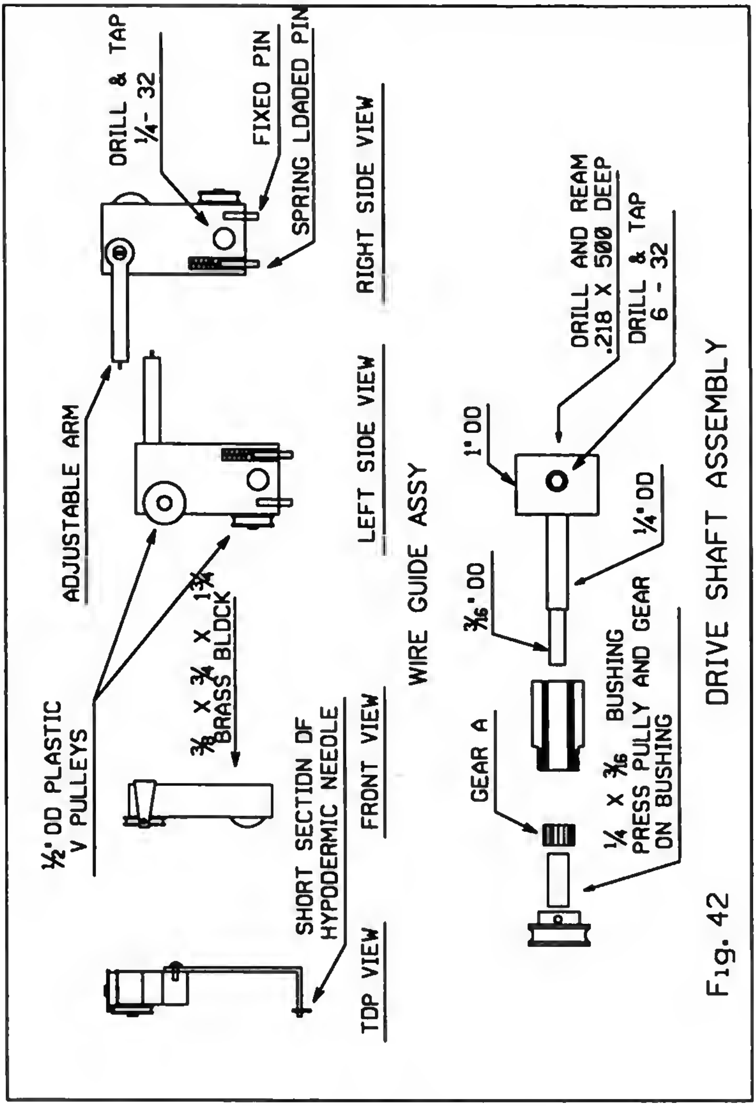

1/2" OD PLASTIC V PULLEYS
ADJUSTABLE ARM
DRILL & TAP 1/4- 32
FIXED PIN
SPRING LOADED PIN
3/8 X 3/4 X 1 3/4 BRASS BLOCK
SHORT SECTION OF HYPODERMIC NEEDLE
TOP VIEW
FRONT VIEW
LEFT SIDE VIEW
RIGHT SIDE VIEW
WIRE GUIDE ASSY
GEAR A
3/16" OD
1" OD
DRILL AND REAM .218 X 500 DEEP
DRILL & TAP 6 - 32
1/4" OD
1/4 X 3/16 BUSHING
PRESS PULLY AND GEAR ON BUSHING
DRIVE SHAFT ASSEMBLY

Fig. 42

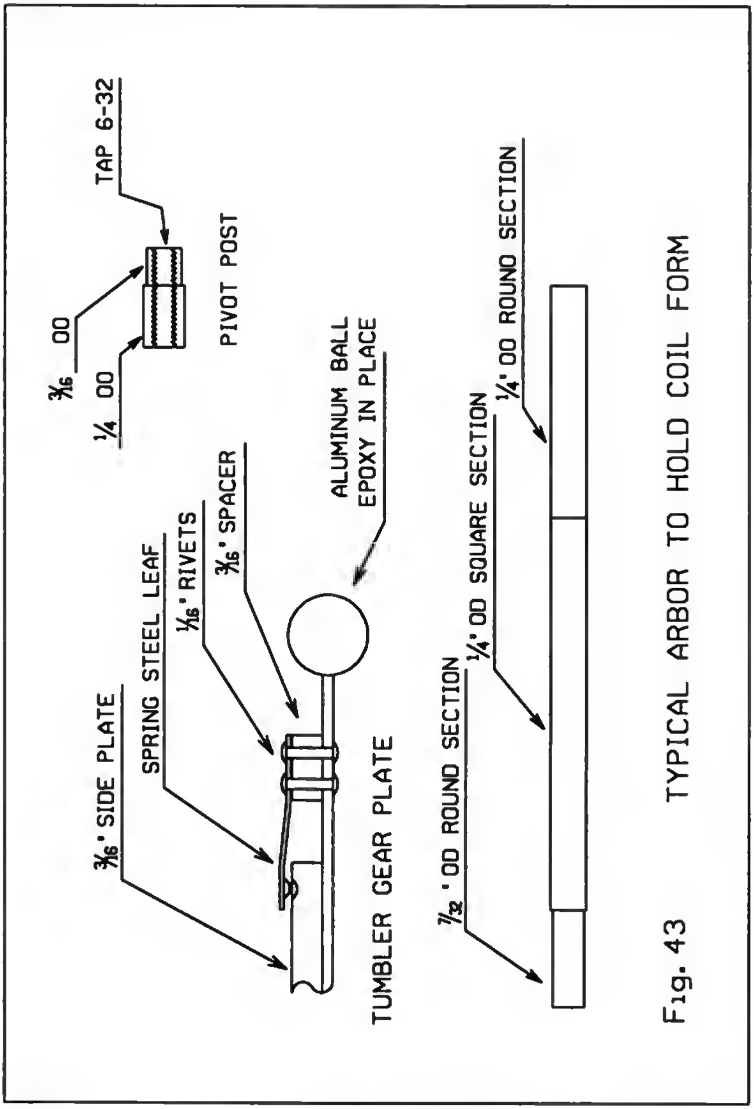


Fig. 43 TYPICAL ARBOR TO HOLD COIL FORM

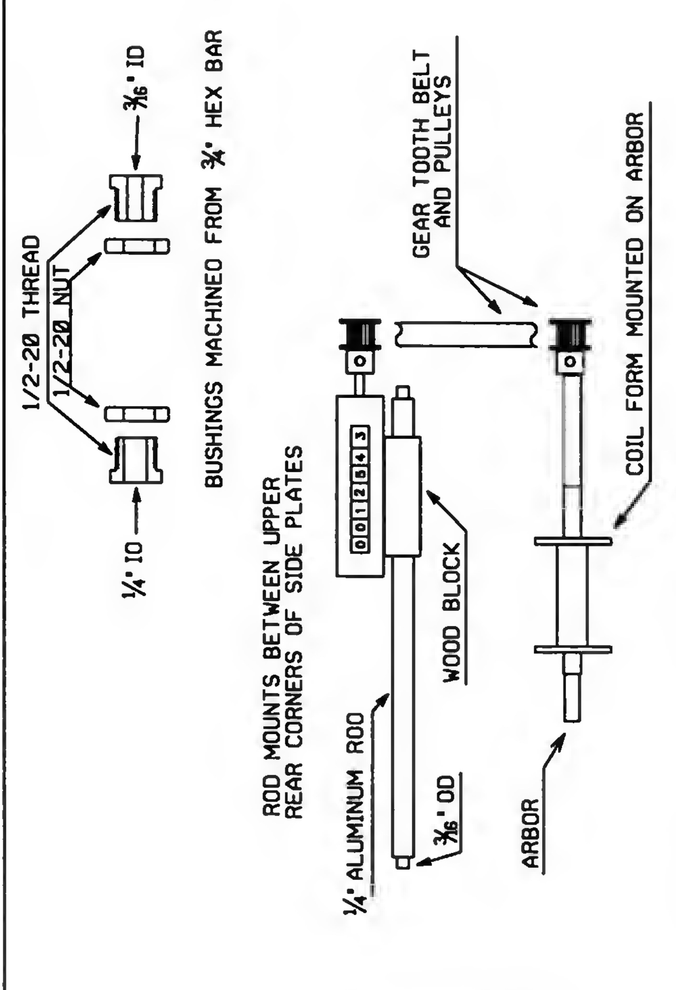
The adjustable (up and down) arm is made from sheet brass. A short section of a hypodermic needle is soldered in place to guide the wire. The hypodermic tube should be free of burrs and chamfered with a small drill. In use, the wire guide may wobble around a bit, but this will not interfere with winding the wire.

Fig.43 shows a little more detail for the shifter plate. The spring is a 1/4" wide piece of .014" thick blued clock spring steel. To form the detent in the flat spring, first drill a shallow 1/8" hole in a piece of steel. Position the spring over this hole and punch the spring with a 3/32 drill rod with a round end to form the detent.

The spacer shown is 3/16" for use with 3/16" thick side plates. The spacer and spring is riveted to the shifter plate with 1/16" rivets.

Detail for the pivot post show that it is a two step rod, turned from 3/8" welding rod, drilled and tapped 6-32. The 3/16" portion fits in the 3/16" hole in the left side plate and is held in place with a 6-32 pan head screw from the inside. This provides a sturdy mount that is quickly disassembled. A similar screw, on the opposite end of the pivot post, retains the shifter plate and the bushing for gears C and D.

Fig.44 shows a typical arbor to hold the coil form. The arbor can be round or square and the coil form can be held on the arbor with a small amount of Locktite. The arbor can be made long enough to couple a counter, if desired, directly to the end of the arbor or through a timing belt and pulleys.

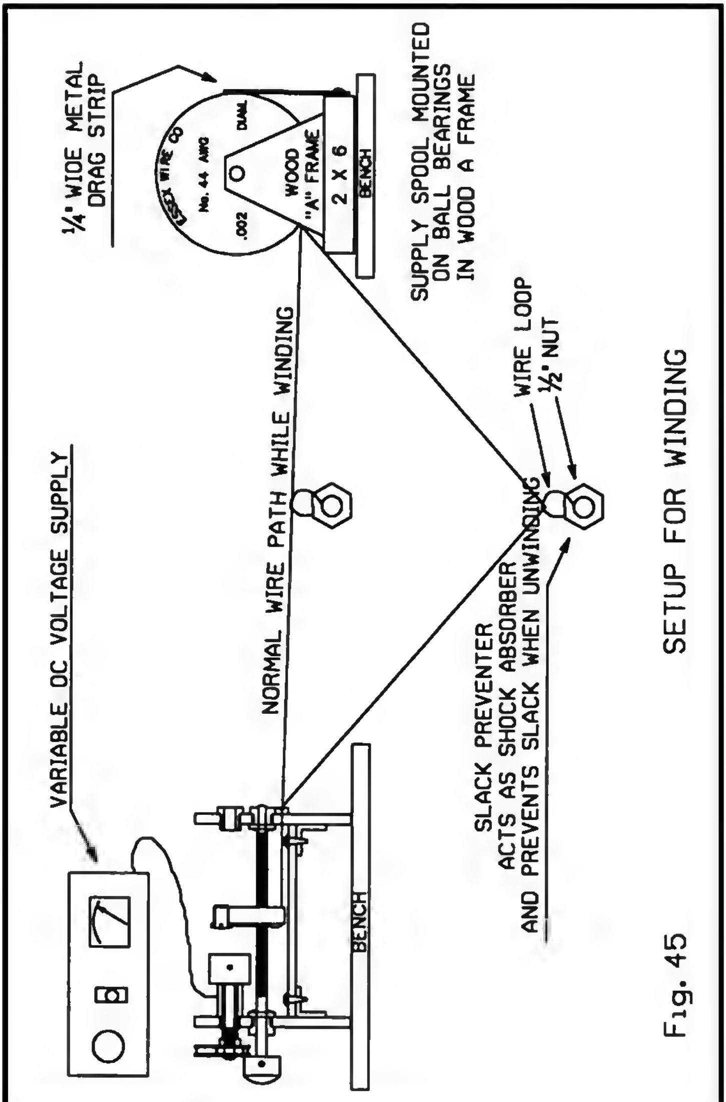


OPTIONAL COUNTER INSTALLATION

Fig.44

The counter is glued to a block of wood that is drilled 1/4" lengthwise and slipped over a 1/4" aluminum rod. the rod is turned 3/16" both ends and mounts between the side plates similar to the pivot post. The assembly is eccentric and, rotating the rod tightens the counter belt as shown in Fig. 44. The counter is driven with a small toothed belt and a pair of gear type pulleys. A counter can be direct coupled to the mandrel with a short rubber tube.

Fig.45 shows a typical setup for winding the coil form. The wire supply spool is mounted on ball bearings, if possible. Usually, a pair of used bearings can be forced in the end of the spool and a rod through the bearings is supported by a wooden “A” frame. The A frame can be slotted rather than drilled for the rod. If the slot is slightly tapered, the rod with bearings and spool can be dropped into the slots. The spool should not touch the sides of the A frame.



SETUP FOR WINDING

Fig. 45

A 1/4" wide strip of aluminum, about 1/16" thick, can be used to provide a little friction to limit the spools momentum when the Sidewinder is stopped.

The slack preventer is simply a weight with a loop, or bail. The bail should be made from 1/8" diameter rod to prevent bending the wire at a sharp angle. The weight should be sufficient to unroll the supply spool about one turn, against the friction of the drag strip, so that the weight hangs about 1 foot below the normal wire path when the Sidewinder is stopped. A key chain snap swivel serves well for the weight.

The slack preventer allows the coil form to be "unwound" in the event that the wire "overlaps", "overwinds" or "back winds". Always start the drive motor at it's slowest speed and gradually increase the speed. When the winding approaches the end of the layer, slow the drive motor prior to stopping it.

Exact dimensions for each part of the Sidewinder are not given as each builder will use whatever is handy or in the Junk box. The only critical factor is how many times the coil form turns in relation to the lead screw rotation.

CHAPTER 10
SL CONSTRUCTION

The first ignition coil presented for construction is the model SL, for lack of a better name. If you have little or no experience with coil winding, this is a good place to start. The SL is easy to construct and will deliver a good hot spark that will jump a 3/8" gap. The SL will operate from 6 to 12 volts. The data shown in Fig.84, column 4, was used to select the design parameters for the SL.

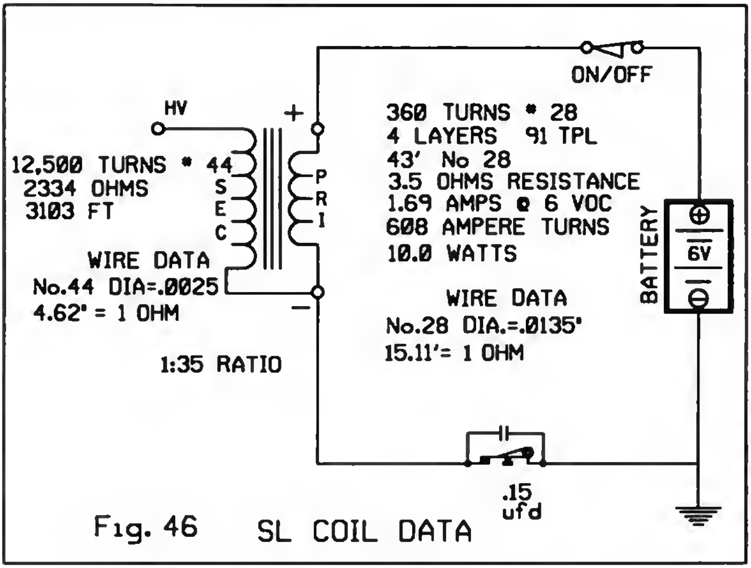


Fig. 46 SL COIL DATA

The SL circuit diagram with the data inserted is shown in Fig. 46.

The exact procedure, step by step, will be given to construct the SL, as this procedure applies to most any coil you would like to build.

Start by fabricating the coil form. The design data determines some of the bobbin dimensions such as, bobbin barrel diameter and length.

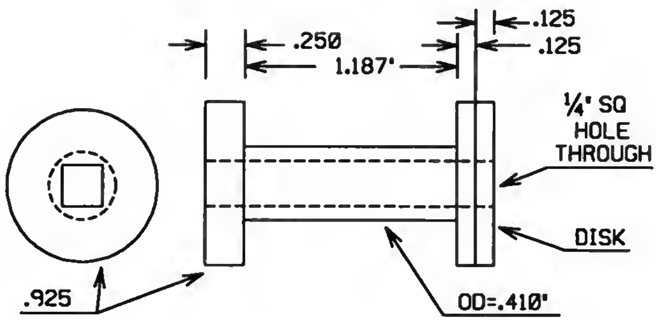


Fig. 47 BOBBIN DIMENSIONS

Fig. 47 shows the bobbin dimensions. The barrel diameter should be a minimum of .410" and the length should be from 1.187 to 1.200". To machine the coil form, Chuck a 1 3/4" long piece of 1" OD Delrin or linen phenolic rod and skim the surface so it will run true. Face the end. Reverse it and do the same. Center drill and drill 1/4" through.

Remove it from the chuck and place it on the jaws of a bench vise. Cut the tang off of a 1/4" square, rough cut file and drive it in the hole. Drive it out. Clean it and repeat this procedure (about 20 times) until the file drives through, leaving a nice square hole. The Phenolic is really tough stuff so do not be afraid to drive the file.

Rechuck the piece and cut off a 1/8" thick disk. The disk will later be reworked to hold the pin terminals. Reface the end of the bobbin.

A mandrel should be made to hold the bobbin. A round, or preferably square, 1/4" bar, center drilled both ends and turned 1/4" round OD for a length of about 5/8" on one end will do nicely.

Impale the bobbin on the mandrel and chuck the round end of the mandrel in the lathe with one turn of paper for protection. Bring up the tailstock center to steady the mandrel and turn the bobbin to the dimensions shown in Fig.48. Try to keep any metal chips and oil away from the bobbin.

Fig.48 shows the layout for drilling the disk to secure the straight pins that are used for the connection terminals. Retail stores offer a wide variety of "straight pins" such as sequin pins, sewing pins and small finishing nails.

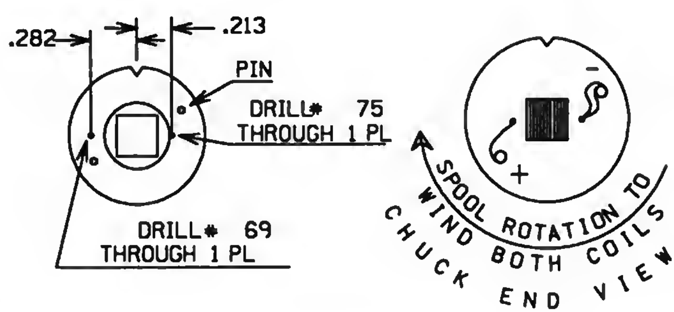


Fig. 48 DRILLING DETAIL

The straight pins normally used measure .030" OD. Use a No. 69 drill to drill the disk. The pinhead diameter can be reduced to about .050" and the head thinned a little. countersink for the heads with a No.55 drill held in a pin vise.

Drive the pins half way in and then clean them and the disk with a spray cleaner that leaves no oil. Apply a small amount of Locktite to the pin shaft and drive the pin home. Be sure the pinhead is below the disk surface. Squeegee off any excess locktite. Cut the pins so they protrude about .150" from the disk. Use diagonal pliers. Do not use a grinding wheel. Let the locktite dry for about 1 hour. Apply epoxy glue to the disk and push it on the mandrel. Clamp it to the spool end and Let it dry overnight. Cyano acrylic glue can be used but epoxy is preferred.

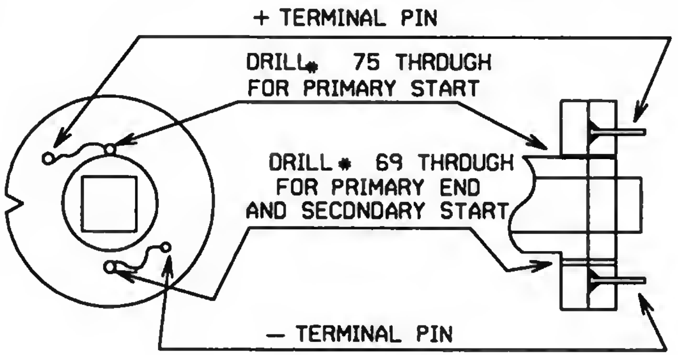


Fig. 49 BOBBIN/DISK DETAIL

Drill the holes for the magnet wire as shown in Fig.49. You may have to steady the small drill bit to start it in the right place as the phenolic varies in density due to it's construction, and the drill may want to jump off center. Ideally the center of the No. 75 drill used for the + terminal should be even with the barrel of the spool. This will allow the wire to lay up against the flange and start the first layer without a bump. Be sure to locate this hole in relation to the square hole for the laminations shown in Fig.47 as the barrel is thicker at this point.

Slip a short length of No.28 magnet wire through the hole for the - terminal, fold it over the flange and disk, twist it and trim it short. This will insure access to this hole later on. File a V shaped notch in the cheek as shown. The high voltage lead will lay in this notch. At this point the coil form is ready for winding the primary.

Set the spool of No. 28 ga. magnet wire over a vertical peg (screwdriver clamped in a vise, etc.). The bottom of the spool should drag on a horizontal surface to provide a little friction to prevent self unwinding. Scrape about 3/8" of enamel from the end of the wire and pass it through the + hole then wrap it tightly around the + pin. Cut off the excess.

Hold the wire in your hand, six to eight inches from the coil form and start rotation of the lathe. My 6" Atlas lathe is equipped with a three speed reversible motor and I run my lathe backgeared, in reverse, at lowest speed, so that the wire is wound over the coil form, not under, from left to right. Wind about three turns and stop rotation. Use a small rectangular wood stick to push the wire up against the left hand flange of the spool. Never touch the wire with a metal object. I keep my left hand on the on-off switch. Apply only a small amount of friction to the wire with your right hand.

Hold your hand slightly to the left and start rotation. The wire should spool onto the form snugly up against the preceding wrap. As the wire approaches the right hand flange, move your hand slightly to the right or 90 degrees to the axis of the coil. When you feel the wire overwrap to start the second layer, move your hand slightly to the right.

Wind four layers of the No. 28. Cut the wire and thread it through the - hole and wrap it around the mandrel several times. Leave the wire loop in the - hole if you can. Do not solder the wire, wait until the secondary has been wound so that you will not have to heat the terminal twice. You will notice that the first two layers went on without trouble. The third and fourth layers probably got a little crooked. Practice will allow you to do a better job. Remove the coil and mandrel from the lathe.

Install the coil and mandrel in the winder. There is no need to place paper around the bobbin before winding the primary and no need for paper in between layers of the primary. Cut a strip of paper, preferably with a paper cutter, about eight inches long. The paper should fit between the cheeks of the bobbin so that it curls up slightly against the cheeks without any wrinkles on the surface.

Place two wraps of common typing paper around the finished primary by inserting the paper from the front of the Sidewinder, under the bobbin, up the back side, and over the top. Glue the edge of the paper to the layer of wire with a white carpenters wood glue. Avoid the use of glue that will damage the wire insulation.

Rotate the bobbin forward two turns and cut the paper with a sharp knife parallel to the bobbin. Tighten the paper by pulling and sliding your finger around the wrap. Glue the end of the paper down. There is no need for concern about manufacturing chemical residue in this paper as the insulation requirement is low.

If you are the type of person that likes to keep records, and you should for the first coil, you probably measured the length of the No.28 wire before you wound the coil, and did some subtraction of leftover to determine the exact length used. If you know the length, you know precisely the resistance of the primary. Some space is provided for a record in Fig.50.

The use, or application of, varnish, shellac or other compounds to the primary are not recommended as this will cause microscopic air pockets and inhibit the impregnation process. The primary winding is finished.

DATA AS BUILT	
NUMBER OF TURNS ON PRIMARY	
TURNS PER LAYER AVG.	
LENGTH OF PRIMARY WIRE	
RESISTANCE OF PRIMARY (FT/15.11)	
NUMBER OF TURNS ON SECONDARY	
RESISTANCE OF SECONDARY	

Fig. 50 AS BUILT DATA

To wind the secondary, set up the Sidewinder as shown in Fig. 45 with a spool of No.44 wire and install a dummy mandrel. Thread the No. 44 through the winder, around the pulleys, through the wire guide, over the top of the dummy mandrel and use a small piece of tape to secure the wire to the mandrel. The chuck should turn clockwise when viewed from the drive pulley end.

Start the winder at slowest speed then increase speed to ascertain that the supply spool drag is set about right, the slack preventer works and that the wire is wound correctly on the dummy mandrel. Stop the winder abruptly and the supply spool should stop turning before the slack preventer reaches the floor. Start the winder again and the slack preventer should rise as the wire tightens and the supply spool begins to unwind.

When you are satisfied that everything is working as it should, remove the dummy and install the mandrel with the bobbin. The terminal pins should be on the left side of the bobbin, next to the chuck. Pull some of the No.44 through the wire guide and remove about half an inch of the insulation from the end. This can be done with fine sandpaper or scraped away with a sharp knife blade. It's very easy to cut the wire, so some practice may be in order.

Untwist, or cut, the No.28 wire loop and unfold it so that the wire presses the paper down and pull the loop through the cheek, from the outside. Thread the No.44 through this hole, from inside the cheek, and wrap it around the - terminal pin. A 1/32" rod about 3" long is very handy to help wrap the wire around the terminal pin. No need to solder the No.44 to the terminal pin at this time.

There should be a 5/32" gap between the cheek and the edge of the winding. Disengage the gears and rotate the lead screw knob to position the wire guide to the right. Rotate the chuck by hand to form a spiral with the wire in order to start the layer 5/32" from the cheek. Use a 5/32" square wood stick about 3" long to gauge the gap.

Rotate the lead screw to bring the wire guide back so that the wire is 90 degrees to the mandrel. Rotate the chuck by hand a few turns to see how things look. The wire should be close wound and the gap between the cheek and coil should be 5/32". Engage the gears to move the wire guide to the right. Rotate the motor pulley a few turns to ensure that the wire will close wind and that the wire guide lags slightly behind the leading edge of the coil.

Start the winder at slowest speed and gradually increase. As the winding approaches the right hand cheek, slow the winder and stop about 5/32" from the cheek. Rotate the motor pulley one way or the other by hand to obtain the 5/32" distance. Leave the gears engaged. Before you do anything else, make a written note that you have completed one layer of the secondary. Each time you complete a layer make note of it. If you are using a counter, make note of the number of turns placed on each layer.

The secondary windings are insulated to prevent internal arcing by wrapping paper over each layer. The common term for this is interleaving. The paper is then impregnated with wax which is an excellent insulating medium. I use a wax paper that is found in most household kitchens. It is made by Reynolds Metals Company, Richmond, Virginia, 23261, and sold under the trade name of Cut-Rite wax paper. The paper measures .0015" thick.

The paper may contain small holes which are filled in the impregnation process. The wax is the insulating medium, not the paper. The wax paper is cut into strips that are about 11" long and to a width that is 1/64" less than the distance between the cheeks of the bobbin to prevent wrinkles and distortion.

If you are using a paper cutter, fold an 11" x 17" sheet of paper to sandwich the wax paper. This makes handling and cutting the wax paper much easier.

In order to make paper handling easy, you will need a temperature controlled iron. The one I prefer is available at Hobby Shops and is used to apply heat shrink coverings to model airplanes. An iron can also be made by modifying your wife's hair curling iron. Machine a conical brass tip then grind a flat on one side of the cone. Smooth the brass tip and polish to a high finish. It will not be temperature controlled but will work just great.

Open a small book or catalog that has no value and place it on the work bench. Melt about seven drops of wax on the book and using the hot iron in a circular motion, make a very shallow pool of wax about two and a half inches in diameter. Use common household wax, a petroleum product, used for home canning.

Lay the strip of paper over this solidified pool of wax, press the hot iron down on top of the paper and pull the paper from under the iron. This will impregnate the paper with wax and leave a little extra wax at the end of the paper. It will soon become obvious that if you pull the paper up, at a steep angle the paper will curl. The curled paper is easier to place around the coil than a flat strip. No need to over wax the paper. The object here is to add a tiny bit of wax in order to make handling easier.

Insert the paper from the front of the Sidewinder, under the bobbin, up the back side, over the top and under the wire from the wire guide.

Touch the hot iron to the center edge of the paper and slide the iron to the left. This will tack the left half of the edge to the coil. Rotate the chuck backwards and then forward. This will reposition the wire so that it winds correctly over the paper. Tack the right half of the edge of the paper.

It is best to avoid touching the wire with the iron. Rotate the chuck to roll up the paper. Hold the end of the paper with one hand and cut the paper parallel to the mandrel with a sharp knife. The paper should wrap around the coil one and a half turns.

It is easy to tighten the paper by sliding your fingers radially around the paper. When tight, seal the edge with the hot iron. Usually the edge of the paper becomes almost invisible after it is sealed.

Have no concern about where the laps occur around the coil. Randomly placed laps usually do not effect concentricity of the coil or cause bumps in the surface. Although not absolutely necessary, I use a sucker stick that measures about 3/8" wide. 1/16" thick and 5" long to remove excess wax from the wax paper as the layer is being wound. The stick is used in the same manner as a gouge for a wood lathe. With the bobbin rotating at moderate speed the square end of the stick is applied ahead of the wire guide to plane off excess wax. I also lightly press the flat side of the stick against the wax paper, ahead of the wire guide to flatten the surface. I believe this helps to make a flat and concentric surface. The paper insertion procedure becomes quick and easy with a little experience. If you break the wire, scrap the secondary job and start all over. It is not a common thing to break the wire. Do not try to splice the secondary wire.

If anything goes wrong, stop the winder and unwind the wire using the motor pulley or disengage the gears and reposition the wire guide with the leadscrew knob. The value of the slack preventer will become very obvious. With a little practice, winding the secondary becomes an easy chore.

The balance of the secondary is wound using the above procedure. Each layer of the secondary should contain about 360 turns of wire on average and 34 layers should provide 12,200 turns. Do not be concerned about placing exactly 12,200 turns on the secondary. 10,000 turns provide ample secondary voltage to operate most single cylinder engines, 12,000 turns provide a little more voltage and 14,000 turns still more secondary voltage.

The secondary voltage should be only high enough to reliably operate your engine. Higher voltage will cause containment problems and flash over at the spark plug.

Record the secondary data in Fig.50. as you will probably want to base a future coil on this data or a variation of it.

To terminate the HV end of the secondary, insert a strip of wax paper, tack the edge and lead the wire over to the center of the bobbin as the chuck is rotated. Wind three layers of wax paper and tack the end down. The No. 44 wire should exit the paper in the center of the bobbin and at the center of the paper.

Remove about 1/4" of the insulation from a small gauge stranded wire. The wire can be quite small as it only needs to be as large as the No.44 enameled wire. Cut a strip of common typing paper and glue the stranded wire to the typing paper as shown in Fig.51.

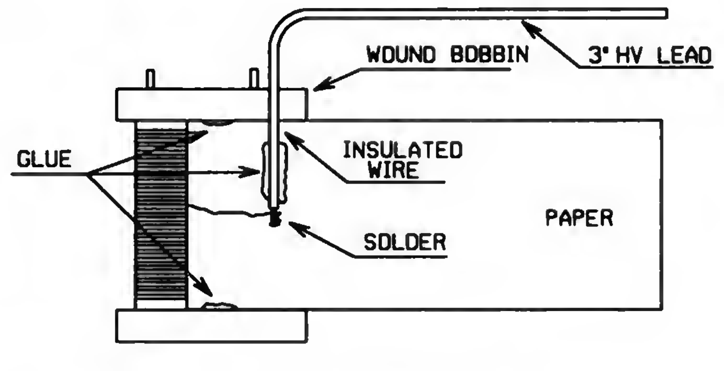


Fig. 51 HV TERMINATION

Wind the paper around a 1/2" diameter rod to form a natural curvature. Lay the paper between the cheeks and spot glue the paper to the cheeks to hold it in place. The stranded wire should be aligned with the notch.

Wrap the No.44 around the exposed stranded wire and solder the two together. If your iron is hot enough, it will melt the insulation on the No.44 wire. Trim the joint and press the joint down onto the paper. Glue this joint to the paper. Try to leave a tiny bit of slack in the No.44 wire for expansion.

Wrap the typing paper two more turns. Cut the paper, glue the end of the paper down and glue the wire into the notch. The coil is wound.

Remove the mandrel from the winder and clamp it vertically in a bench vise. Remove the enamel from the No.28 wire at the negative terminal. Wrap the No.28 over the No.44 on the negative terminal and solder. Wrap the No.28 in the same direction that the No.44 was wrapped. Sling the excess solder from the terminal while it is hot. Be very careful not to break the No.44 wire. Solder the No. 28 at the positive terminal.

Prepare the ends of two lengths of No.26 solid wire (or stranded wire) by removing 1/4" of the insulation. Wrap the ends of the wire around the + and -pin terminals and solder. Cut all three wires so that they are about four inches long.

Resist all temptation to test the coil at this point. Resistance measurements can be taken if desired and recorded in Fig.50.

Keep oil, dirt, moisture and metal chips away from the coil. it's best to store the coil in a plastic film container until the laminations are prepared.

Before the laminations can be prepared they must be obtained. If you have a source, such as a tool and die maker friend, lean on him to stamp some laminations that measure 1/4" wide, 2.125" long and .020" thick. Lacking such a friend, you will probably salvage them from a used, or new, transformer.

If you have a milling machine or a lathe with a milling attachment, a stack of laminations can be easily cut to the required 1/4" width. First make a parallel bar by sitting a 1/4" thick aluminum plate on top of a 1/4" square bar in the mill vise. Cut the top of the plate so that it is .020" above the vise jaws.

Remove the 1/4" square bar and sit 13 or 14 laminations on top of the parallel bar and make the same cut. Deburr the edges of the laminations. You may want to cut quite a few laminations just in case some get bent or to use in future coils.

The laminations should be flat and smooth. Insert the laminations in the bobbin. They may be tight as the primary winding may have compressed the bobbin barrel. Insert the last lamination in the center of the laminations rather than on the side.

The laminations for the SL are a little short, for ascetics, so there is a slight loss in flux density. To obtain maximum flux density, the laminations should tbe 1/2" longer. The laminations should be centered, lengthwise with the coil, not the bobbin.

Small iron rods can be used for the core and, solid cast iron can be used, but these are not recommended. Laminated transformer steel is recommended as it allows much more flux to be established.

THIS PAGE IS BLANK

but this is not a printing or scanning fault and no content is missing.

CHAPTER 11
IMPREGNATION

The home shop builders best choice for insulation is wax or oil. Both substances are easy to work with and wax is the best choice for the SL. An easily obtainable wax that is acceptable is common canning wax and is stocked by the larger food stores.

The impregnation process is best carried out inside a sealed chamber that is heated and evacuated. The temperature should be controlled or at least limited with a thermostat. The pressure inside the chamber should be as low as possible. Under these conditions, all air and moisture can be removed from the coil and replaced with the wax insulation.

The impregnation chamber was made from an automotive air conditioner dryer canister. The dryer was sawn into two pieces. A pair of rings were machined, drilled and taped. The rings were silver soldered to the upper and lower parts of the dryer.

A 1" OD dial thermometer and a 1 1/2" OD vacuum gauge was installed in the top as well as a vacuum line fitting. A rubber gasket was fitted between the two halves and a heating element was installed in the lower half. The temperature inside the chamber is controlled manually by varying the voltage to the heating element.

Fig.52 shows the impregnation chamber that was constructed by the author. The exact dimensions are not given. The chamber measures 3" OD and is 7" overall height. Any chamber that can be heated and evacuated will do nicely.

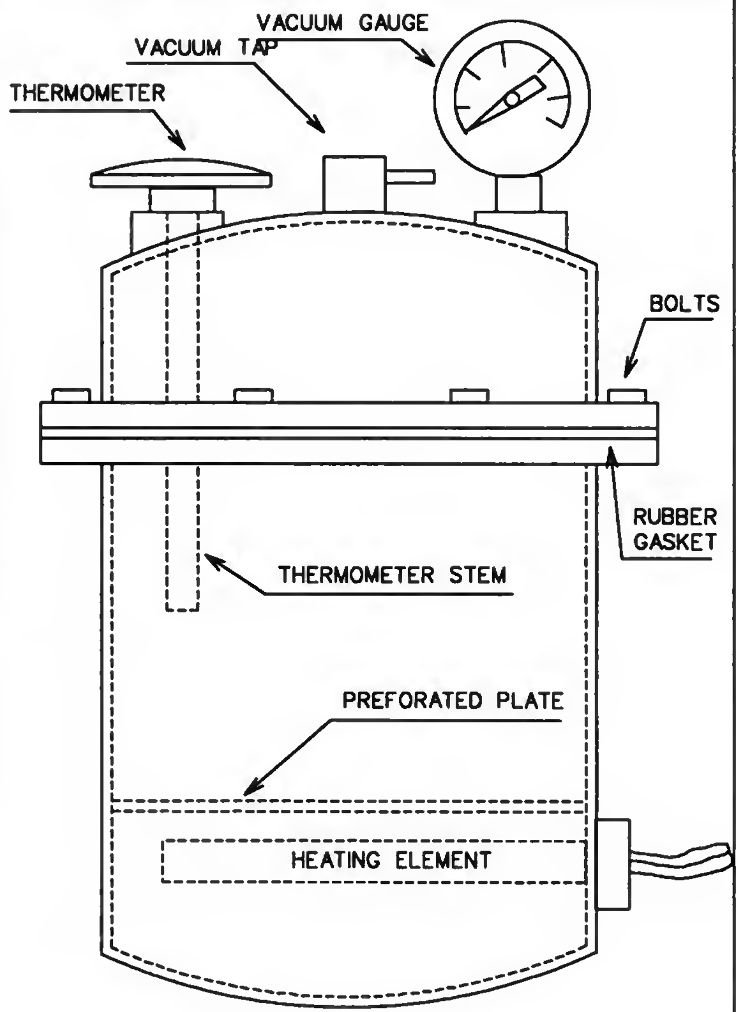


Fig. 52 IMPREGNATION CHAMBER

In use, the coil is placed in the chamber and the chamber is filled with preheated wax. The chamber is bolted together and the internal pressure is reduced as much as possible. The temperature is then increased to the desired value. These conditions are held for about five minutes. The vacuum is released to allow ambient pressure to enter the chamber for a few minutes. The chamber is once again evacuated for two minutes and the vacuum is then removed and the heating element turned off.

The atmospheric pressure that surrounds us at sea level is 14.7 pounds per square inch. When the coil is placed in a sealed chamber and the internal pressure is reduced, the water or moisture in the coil will boil or flash off at a temperature that is much less than 212 degrees Fahrenheit.

Fig.53 shows the temperature at which water will boil at various vacuum gauge readings.

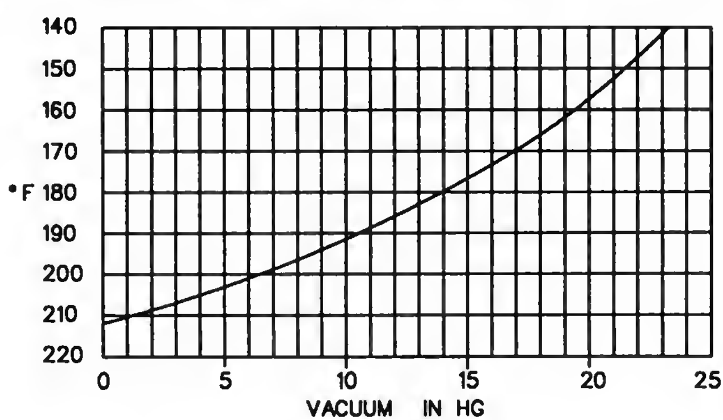


Fig. 53 BOILING POINT OF WATER

The temperature inside the chamber must be high enough to liquefy the wax. Strangely enough, candle wax has no melting point or freezing point, therefore I cannot state a melting point. The transition from solid to liquid usually occurs between 130 and 140 degrees Fahrenheit.

If a vacuum pump is available, it's use is preferable to an aspirator. A vacuum pump will allow a lower temperature to be used inside the chamber. As much vacuum as possible is desired in order to use a lower temperature. When the maximum vacuum is established, refer to Fig.52 to determine the lowest temperature that you should use. Add ten to fifteen degrees to that value just for assurance.

If a vacuum pump is not available, the reader may wish to purchase or construct an aspirator similar to the one shown in Fig.54.

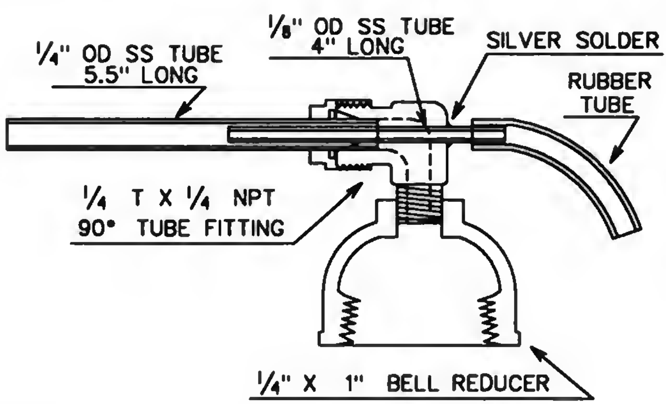


Fig. 54 ASPIRATOR

The aspirator is attached to a water line or water hose and the velocity of water passing over the 1/8" tube forms a low pressure vortex. The vortex creates a vacuum of 20" HG or more within the 1/8" tube.

When using this type of aspirator, be sure to disconnect the vacuum line from the impregnation chamber before turning the water off, else water will be drawn into the chamber.

While the chamber is cooling, the top half is removed. The wax will change from a clear liquid to a white solid at about 135 degrees Fahrenheit. When the wax in the bottom part of the lower chamber is observed to be solidifying, the coil is removed. All air and moisture will be removed from the coil with this process.

If the impregnation chamber and vacuum pump is just too much for you, there is another way. Fig.55 shows an impregnation chamber that can be easily turned in a lathe from 2 3/8" round aluminum bar. Three inches of the bar is bored to 1.500" ID for a depth of 2.600".

The top is bored 1.500" ID for a depth of .600". The top is grooved for an O ring and drilled for a 1/8" brass tube to connect the vacuum line. The top is self sealing when a vacuum is applied and there is no need for bolts, nuts or gaskets.

The top can be shaped to your fancy and the brass tube can be threaded if you like.

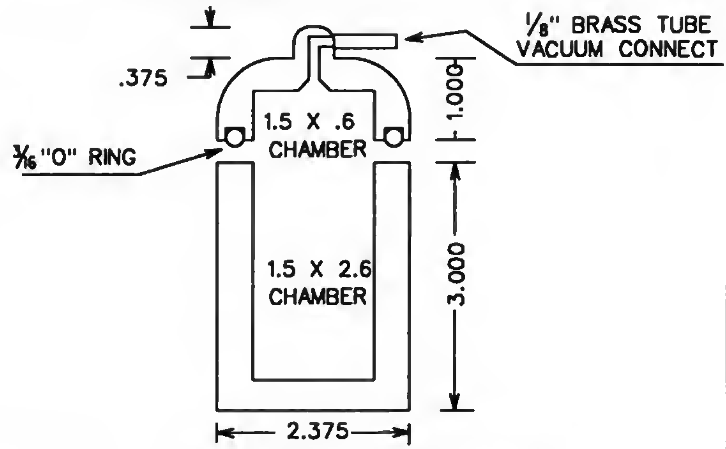


Fig. 55 IMPREGNATION CHAMBER

If you have a coffee brewer such as a Mister Coffee brand of coffee maker, it can be used as a hot plate. The hot plate in the Mister Coffee maker is thermostatically controlled. The thermostat opens at about 220 degrees Fahrenheit and closes at about 180, thus it continuously cycles between these two temperatures.

Partially fill the chamber with wax. When the wax is liquefied, submerge the coil. The coil and laminations should be completely covered with wax and the temperature should not exceed 220 F. Leave the coil in the liquid wax until the air bubbles have ceased then apply a vacuum for about one minute. Remove and reapply the vacuum two or three times. Set the chamber off the hot plate and remove the coil when the wax has partially solidified. Wipe off the excess wax. Be careful to not get metal chips or dirt in the wax.

Chapter 12
ENCASEMENT

The coil is now ready to be encased. At this point you probably can not resist the temptation to test the coil. A word of caution,,, never energize the coil without the proper load on the secondary, that is, a properly grounded spark plug or short the HV terminal to the + or - terminal. Many home built coils are damaged at this point of construction when the builder decides to "test" the coil to determine the maximum distance that the arc will jump. Do not test for maximum arc length.

Although the SL is well insulated, it is never a good idea to test the coil for maximum arc length. If you must test it, use a 1/8" or less gap. The only recommended way to test the coil is to wire it up to an engine and crank the engine or use a variable voltage power supply.

It is best to delay testing until the coil is partially encased as it will be completely submerged in wax at that point.

The SL is encased in a wooden fingerjoint box as shown in Fig.56. The wood can be oak, pine, aromatic cedar, plywood or most any wood of your choice. The wood is 1/8" thick.

One of the many ways to cut the 1/8"notches is to clamp about 6 pieces of wood in the milling machine vise and use a 2 1/2" Dia. x 1/8" thick metal cutting circular saw blade to cut the notches about .130" deep. The lateral distance between the valley of the notches will be the inside dimension of the box. The saw blade is moved down 1/4" for each pass.

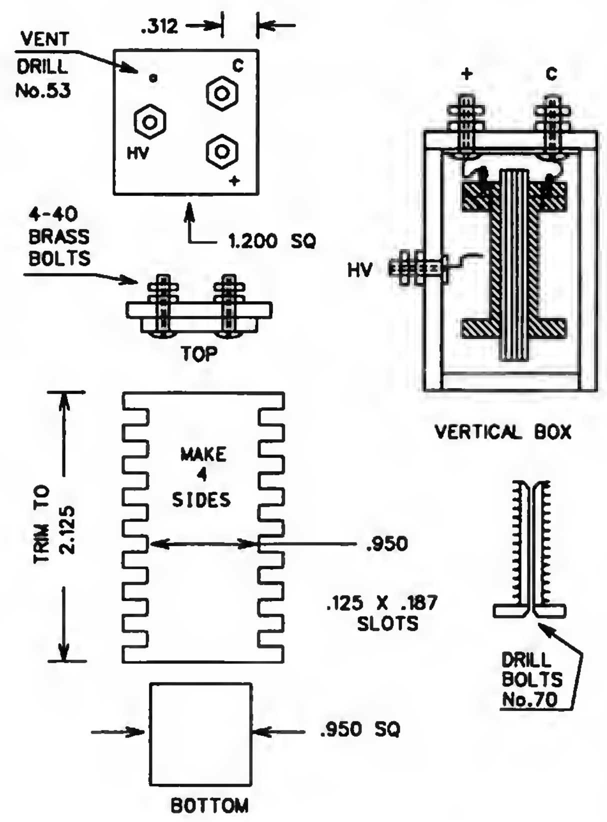


Fig. 56 VERTICAL FINGER JOINT BOX

The box is assembled with glue, the sides are sanded and the ends square cut to length. The top and bottom pieces are cut to size and sanded. The top is drilled and tapped for 4-40 brass bolts and the vent hole is drilled.

The head of the brass bolts are thinned to provide a flat surface and drilled through with a No. 70 drill. Countersink both ends of the hole with a No.60 drill. The bolts are installed in the top with two nuts on each bolt. The bottom is glued in place, all of the wood is given two coats of spar varnish and allowed to completely dry.

The coil/lamination assembly is dropped in and the proper amount of insulation is removed from the wires. Remove only enough insulation to get the wires through the bolts. Heat some wax in a small metal container that has a pouring spout. When the wax reaches about 220 degrees Fahrenheit, pour it into the box until it just covers the upper cheek of the coil. Be careful to not get wax on the upper edge of the box as this will be a glue joint.

Thread the wires through the proper bolts and glue the top to the box. To solder the terminals, Clean the bolts with a spray cleaner then paint the bolt threads with White Out (typewriter correction fluid to prevent solder from running down the threads) and solder the wires to the end of the bolts. Use a hot (800 degree) iron and 1/16" rosin core solder. Do not use a flux that contains acid. Pull the iron tip across a damp rag to clean it, and apply a little solder to the iron tip. Allow the iron to stay on the terminal no more than one second.

Place the solder and soldering iron tip on the wire, up a little distance from the bolt so that solder and flux will run down the wire to the bolt. If you get too much solder on the bolt, invert the case and touch the soldering iron to the wire so that solder will run down the wire to the iron. Try not to overheat and do the job quickly. Trim the wire and file the top of the bolt flat.

To completely fill the box with wax, heat some wax in a metal container to about 220 degrees. Use a small hypodermic syringe with the needle cut off square at the end. submerge the needle and about 3/4" of the syringe in the hot wax to fill the syringe. Inject the wax through the vent in the top of the box.

The coil is now ready for operation. a word of caution. Never test any coil to see how long of an arc it will produce. To do so will force an internal arc, and if possible, will damage the coil. The best test is to wire it to your engine. If the engine cranks easily and runs well when rich, the coil is acceptable.

An excellent way to test the coil is to use a variable voltage power supply. The supply should have the capacity to provide a minimum of 6 Amperes of current. Set the supply for 12 volts, crank the engine and let it warm up. Adjust the carburetor for normal running and slowly reduce the voltage to the coil.

At some point the coil will fail to fire the engine. You will probably find that the SL will run the engine with a fully charged 6 volt battery although the SL is designed for 12 volts. Record the voltage at which the engine fails to fire for future use. To wind the SL for a 6 volt primary, use three layers of No. 28 and for 4.5 volts use two layers of No. 26. Do not apply 12 volts to a 4.5 volt primary.

If the coil does not operate at the voltage you desire to use, reduce or increase the number of turns on the primary of the next coil.

Although it is not well known, a standard 12 volt automotive ignition coil will perform satisfactorily with a 6 volt battery. Using 6 volts rather than 12 volts will cut the current consumption in half and greatly reduce the load through the breaker contacts. Some 12 volt coils will perform satisfactorily with as little as 3 volts.

A few alternative encasements for the SL are in order. The first alternative is to encase the coil in a horizontal box rather than a vertical box. The horizontal configuration is shown in Fig.57.

The procedure is the same as for Fig.56 except that stranded and insulated wire is used from the pin terminals to the bolts, and the last piece to be glued in is the end rather than the top.

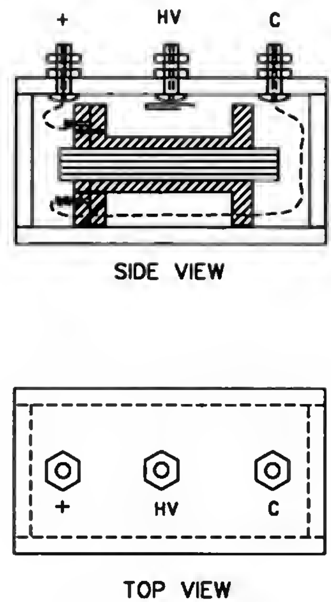


Fig. 57 HORIZONTAL FINGER JOINT BOX

The horizontal configuration also allows the secondary to be terminated with a "flag". The flag is a narrow strip of .004" brass shim stock bent in a semicircle to contact the HV bolt when the coil and lamination assembly is inserted into the box. There is less chance of high voltage leakage using a flag rather than insulated wire. The coil should not be able to rotate inside the box.

Another alternative is to encase the condenser. Use a .15, .2 or .47 Microfarad, 100 volt, rectangular Mylar condenser. The box will require two more bolts as shown in Fig.58.

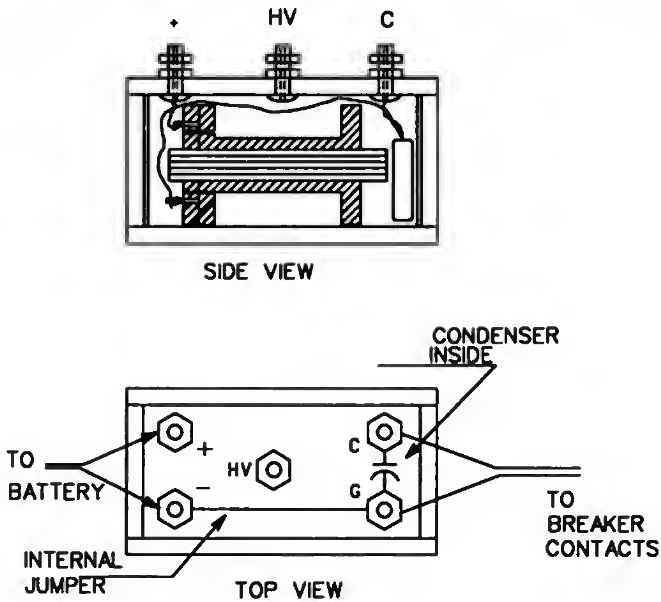


Fig. 58 HORIZONTAL FINGER JOINT BOX

This configuration keeps the condenser out of harms way as well as out of sight. It is unlikely that this condenser will ever go bad. If your engine already has a condenser installed, leave it there and use both condensers.

This configuration also allows one pair of wires to the battery (+ and -) and one pair to the engine (breaker contact and engine ground). This makes a neat installation and the coil box can be glued to almost any surface. Still another nice configuration is to add a red light to the box that will blink when the plug fires. The red light configuration is shown in Fig.59.

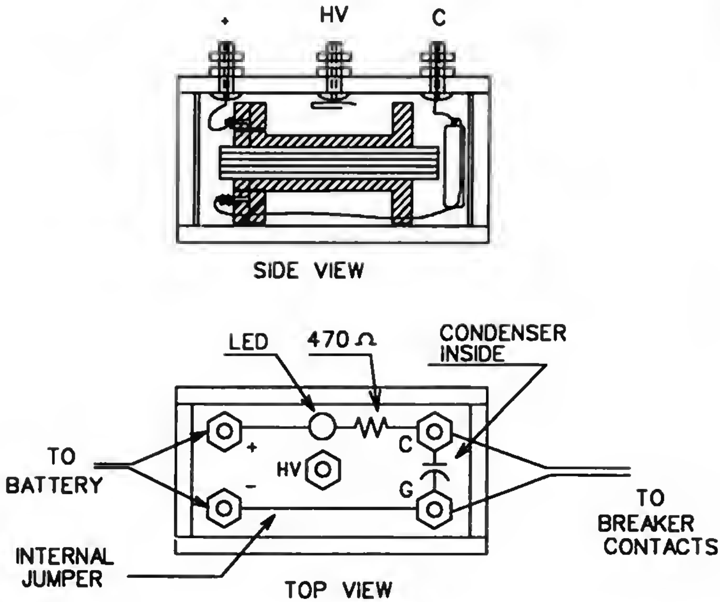


Fig. 59 HORIZONTAL FINGER JOINT BOX

Actually the red light is a red LED (Light Emitting Diode). The LED is inexpensive and can be had in green, yellow, blue and clear as well as red. The LED requires a 470 Ohm resistor in series to limit current. The LED will be damaged if subjected to a temperature greater than 180F.

The Led is very handy for timing the ignition circuit. The plug fires at the instant that the LED turns off. The LED will also give a visual warning, when the engine is not running, that the ignition switch is on, that the breaker contacts are closed and the coil is getting very hot. It will also indicate correct battery polarity. The complete schematic diagram for the SL including the LED and wire data is shown in Fig.60.

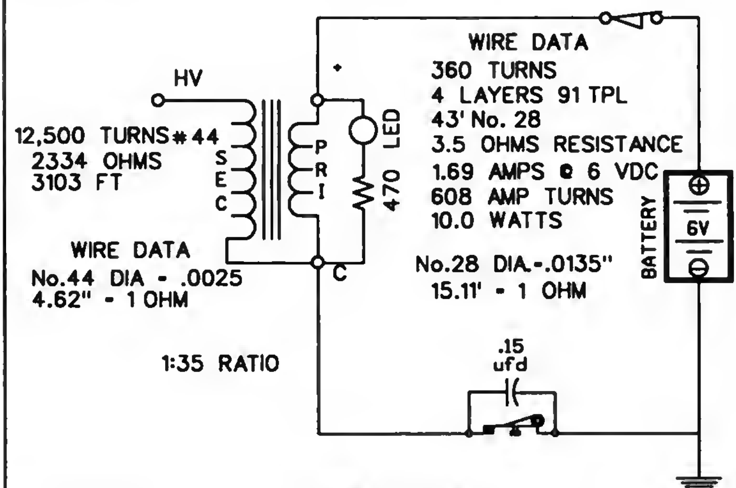


Fig. 60 SL COIL DATA

CHAPTER 13
SM CONSTRUCTION

The SM is a miniaturization of the standard automotive ignition coil. It is identical to the SL coil except for dimensions and encasement. The general arrangement is shown in Fig.61.

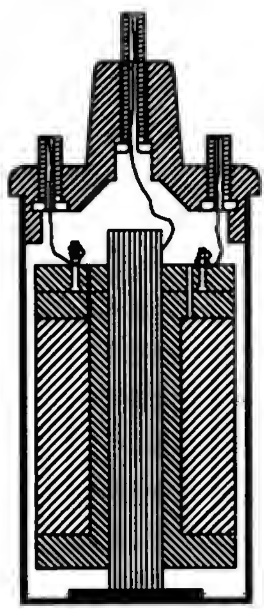


Fig. 61 SM CROSSECTIONAL VIEW

The SM coil is encased in a 1.000" OD steel tube that is 1.990" long. Stainless steel can be used for the case but mild steel is recommended. Do not use brass, bronze or copper as these metals will distort the magnetic flux.

The bobbin is prepared exactly as the SL except that a 3/16" square file is used to form the square hole through the bobbin. The bobbin is turned to an OD that will fit easily inside the tubing, usually about .900". The bobbin is mounted on a mandrel so that the barrel OD is concentric with the square hole. The barrel is turned to .340 OD.

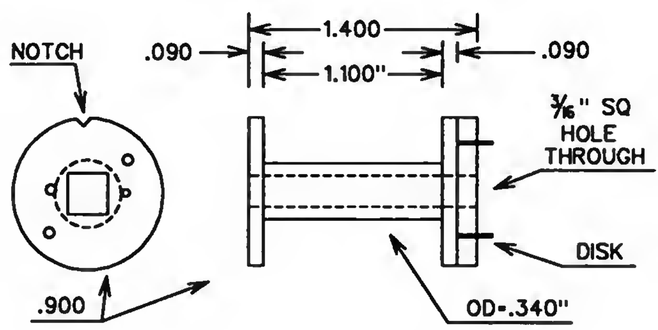


Fig. 62 SM BOBBIN DIMENSIONS

Fig.62 shows the bobbin dimensions. Prepare the disk and pins. Drill the cheek the same as for the SL. Install a loop of N0.28 wire in the - hole and wind four layers of No.28 wire. Wrap with two layers of typing paper and wind 12,000 turns of No.44.

If you can only get 10,000 turns on the bobbin, the coil will work but 12,000 turns gives a little more secondary voltage.

Considering that this coil is encased in metal and the secondary is close to the metal, it is good practice to wrap about four turns of typing paper over the finished winding. This paper needs to fit snugly between the cheeks.

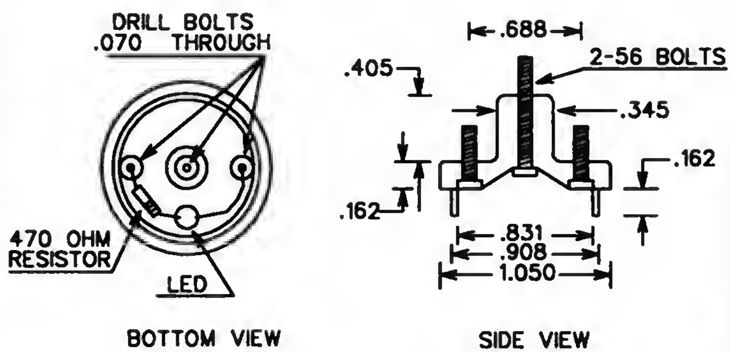


Fig. 63 SM INSULATED CAP

Fig.63 shows the detail for the top. The top is machined from black paper phenolic rod. Change any dimension to fit the size tubing that you use. Drill the 2-56 bolts and lead the coil wires through the bolts. Any color LED can be used in the top. Wire it in series with a 470 ohm, 1/8 or 1/16 watt resistor. Remember that the LED is polarity sensitive, so install it accordingly. Do not forget to drill a No.70 vent hole in the top of the cap. Glue the LED in place with crazy glue (cyano acrylic glue).

Solder the bottom in the case. The bottom is nothing more than a metal disk. If you opt for the LED, drill the cap and glue the LED in place. Solder one resistor lead to one LED lead. Cut the remaining two wires short and solder a No. 28 bare wire to them, The No. 28 is much easier to thread through the hole in the 2-56 bolts. The positive wire of the LED must go to the Positive wire of the coil and the positive terminal in the cap.

To fill the case/coil with wax, it is best to submerge the case and coil in liquid wax at no more than 220 degrees. When most of the bubbling action ceases, apply a vacuum. A higher temperature than 150 may damage the LED, therefore, install the cap after the coil has been impregnated and the case filled with wax.

Lead the coil wires through the drilled 2-56 bolts. Press the cap into the case. The cap should be a press fit. Install two nuts on each bolt then solder the wires to the top of the bolts. Trim the excess wire. I have built several of the SM coils and used common 10 weight motor oil in place of wax. Motor oil expands quite a bit with heat and wax is probably the best choice of insulation. If you have space, place extra paper between the insulated wire and the case to prevent an arc at this point.

The coil can be mounted with a spring clip or the bottom can be made with a stem that is threaded 6-32 or 8-32. The bottom disk and threaded stem should be made from one piece of cold rolled steel to prevent two soldering jobs. This type of mounting will conduct a significant amount of heat from the coil. The SL and SM are both designed to operate on 12 volts DC and probably will fire your engine satisfactorily using a fully charged 6 volt battery. Lower voltage performance can be improved by using only 2 layers of No.26 AWG.

THIS PAGE IS BLANK

but this is not a printing or scanning fault and no content is missing.

CHAPTER 14
SS CONSTRUCTION

The SS is a unique ignition coil. It is very small, operates on 6 volts and has an outward appearance of a standard automotive ignition coil in miniature. Actually it is a 1/3 scale reproduction of an automotive ignition coil with a chromed case. It will greatly enhance the appearance of any small gas engine. If you build the SS, I am sure that it will be your pride and joy. The SS is shown on the cover of this book. The schematic diagram with data is shown in Fig.64.

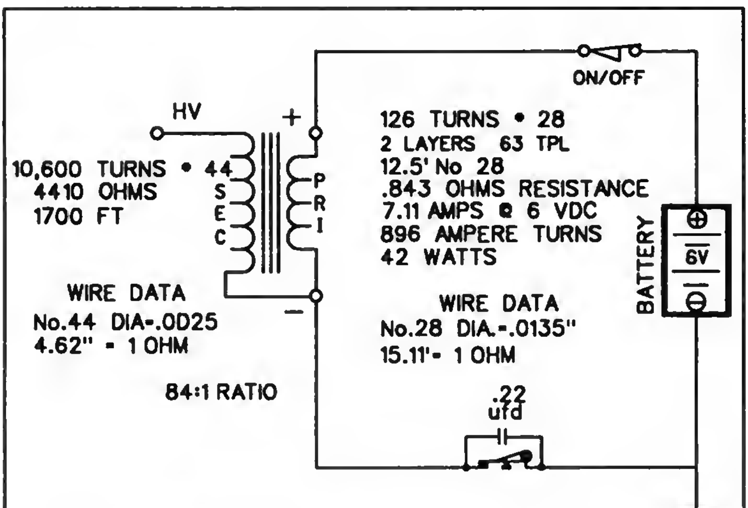


Fig. 64 SS COIL DATA

Due to the fact that the laminations are shorter than good design calls for, there is a loss of some of the flux cutting the primary winding at 90 degrees. In order to compensate for this loss, the primary current is increased by using two layers of No. 28 AWG wire, wound from cheek to cheek. This places a limitation on the use of the coil.

If the SS is applied to a Hit-or-miss engine with ignition contacts on the rocker arm which fires the plug only when the governor calls for speed, about every 10 turns of the flywheel, the coil can be operated continuously for hours with little concern for overheating.

If the SS is applied to a single cylinder engine with a long dwell or a multicylinder engine or a high speed engine, the coil will overheat after a specific period of continuous operating time. To determine the safe period of continuous operating time, monitor the temperature of the case with your thumb and forefinger. When the case gets very warm the primary is very hot and the engine should be stopped. Another indication of overheating is when the wax liquefies, expands in volume and overflows through the vent hole.

The length of safe operating time will vary with each engine. Most builders demonstrate their engines by running them for only a few minutes at the time and, in this case, overheating is not a problem. If the engine happens to stop with the breaker contact closed, be very quick to turn the ignition switch off or the coil will certainly over heat and may be damaged beyond repair. The SS operates at 6 volts and a plug gap of .020. The SS can be operated at a maximum of 8 volts for short periods of time. Apply no more than 8 volts.

To construct the SS, first salvage the case of a size "C" Nicad battery. Keep the case as long as possible. It should measure approximately .860" OD x 1.440" long. The ID should be about .840". It should be a one piece magnetic steel case.

Machine the bobbin from linen phenolic with a 3/16" square hole through the center. The barrel is .340" OD and .950" between cheeks. The cheeks are .100" thick and .834" OD. Drill the holes for the primary wire through one cheek. File or saw a V notch in the periphery of the same cheek that is about .040" wide and deep. The notch is to accommodate a small insulated stranded wire that connects the secondary end to the center terminal of the cap. The notch should be cut at an angle to prevent the cap from pinching the wire when the cap is pressed into the case.

To wind the primary and secondary, follow the procedure given for the SL construction. Wind two layers of No.28 on the bobbin, check to check. Usually this is done in the lathe at slowest speed. Cut the two ends of the primary winding so that they are about two inches long. Install a loop of No. 28 AWG wire in the - hole and twist the ends together. Transfer the mandrel and bobbin to the Sidewinder.

Install one and a half wrap of typing paper around the primary. The paper should fit snugly up against the cheeks with a very slight fold against the cheeks. Use white carpenters glue to glue the paper to the wire and then to it's self.

Start about 1/4" from the outside of the cheek and carefully remove the insulation from the - wire of the primary. Remove the wire loop and thread the No.44 through the Sidewinder and through the - hole.

Wrap the No.44 around the - end of the primary wire in a long spiral, and solder the No.44 to the No.28 - end of the primary. No need to remove the insulation from the No.44 as a hot soldering iron will melt it. Keep the soldering iron on the underside of the joint to minimize the amount of solder on the joint. Leave no excess solder on these two wires as they must pass through the terminal bolts. These two wires are tied together for no other reason than to make a three terminal device.

Use a tiny dab of glue to glue the No.44 to the paper, about 3/32" from the cheek. Leave a little slack in the No.44 between the glue joint and the solder joint for flexibility. Make every effort not to bend the No.28 back and forth as the copper may fatigue and break at the cheek.

If you have a doubt about soldering the wires, practice it a few times beforehand. Remember that you must have some slack in the No.44 to prevent breaking it if the No.28 is accidentally bent at a sharp angle.

Start the secondary winding .085" from the inside of the cheek and finish the first layer .085" from the opposite cheek. Use a thin wood stick of that width to gauge. Install one and one quarter wrap of wax paper. Continue the winding process, interleaving each layer with wax paper, until 10,000 turns of No.44 has been wound on. This will normally require 36 layers.

Glue the end of a 1" wide strip of typing paper to the last layer of wire and to each cheek. When dry, rotate the bobbin to wind the paper around the coil. Lead the No.44 to the center of the bobbin as two wraps of paper are wound on. Glue the end of the paper down. The No.44 should exit from under the paper in the center of the bobbin.

Remove 1/8" of the insulation from a 4" length of very small insulated, stranded wire. Wrap the No.44 around this wire and solder. Glue the insulated wire to the paper, leaving a little slack in the No.44. The insulated wire should lay in the .040" slot in the cheek. Wrap a couple more turns of typing paper or as many wraps as you can without exceeding the OD of the cheeks and glue the end down.

The laminations should be .187" wide and 1.330" long. Using care, install the laminations so that they protrude an equal distance from the outside of each cheek. Do not force them as the cheeks will break or the barrel will split. If necessary, pass the square file through the bobbin just in case the wire has compressed the barrel. Slip the assembly into the case.

Cut a thin strip of Teflon, about 1/4" wide and about 5/8" long and slide it between the insulated wire and the case to provide a little more insulation at this point. The Teflon should extend about 1/16" past the end of the case so that it is bent over when the cap is pressed in.

At this point of construction, measure the resistance from the HV wire to either one of the primary wires. The resistance should be about 4,470 Ohms. If the resistance is OK, impregnate the assembly with wax.

Machine the top from black paper phenolic In the 3 jaw, turn the overall OD to about .950" then turn the large spigot to be a firm press fit in the case. Drill and bore the cap for clearance of the iron core. Drill through and tap 2-56 for the HV terminal bolt. Drop back toward the chuck and machine the small spigot that will be the high voltage tower and cut off. In the drill press, drill, tap and countersink for the + and - terminal bolts. Drill and countersink for the LED if used.

In the 3 jaw, thin the head of the 2-56 bolts with a file, leaving a shallow screwdriver slot. Center drill and drill through with a No. 70 drill. Prepare the LED/ resistor combination as shown in Fig. 61. Glue the LED in place and thread the bare wires through the + and - terminal bolts. Remove most of the insulation from the stranded wire. Leave enough insulation to reach the HV bolt head when the stranded wire is threaded through the HV bolt and the cap is pressed on.

Drop the entire assembly, top up, in the impregnation chamber. Keep the wax temperature at, or below, 212 degrees F.. Let the assembly soak for ten minutes in the liquid wax.

You will probably notice a steady stream of bubbles exiting the windings. When the bubbling abates, place the top on the impregnation chamber and apply maximum vacuum for a few minutes. Break the vacuum and reapply several times.

Remove the chamber top and if no bubbles can be seen exiting the vent, the assembly is properly impregnated. Pour some of the wax out of the case to leave space to press the cap in. Let the wax cool to the point of solidification. Install two nuts on each bolt and thread the wires through the proper bolts. Press the cap in place.

Cut the wires about 1/2" from the bolt ends. Be certain that all the insulation has been removed from the wires. With the wires horizontal, solder them to the bolt ends. Keep the soldering iron on the wire and apply solder so that it runs to the bolt. Point the wire down and apply the iron to remove excess solder. Trim the wires flush with the bolt ends. The coil is now ready for use.

Test the coil by wiring it up to an engine and running it. When operating the coil, remember to monitor the case temperature with your fingers until you are familiar with it's thermal characteristics.

A bolt can be soldered to the bottom for mounting and heat dissipation. The resistance of the secondary, at 75 degrees fahrenheit, will be about 4,230 ohms. At 212 degrees fahrenheit, it will be about 5,620 ohms. A 34 % change in resistance for a 137 degree change in temperature. The square hole through the bobbin and the lamination width can be increased to .197" to provide a little more iron

If, during operation, the coil gets hot enough to boil some of the wax out of the vent, it can be replaced with a small hypodermic syringe. First cut the needle square to remove the sharp point. Load the syringe by submerging the needle and about half of the syringe in hot wax. Inject the hot wax through the vent in the cap. Record all the data for this coil as you will want to base the next coil on this data.

CHAPTER 15
VARIATIONS

You now have three coils, beautiful, unique and one-of-a-kind. I am sure you have a few ideas about construction, encasement and mounting.

After accumulating this much experience, you may wish to design your own ignition coils. Start by making up a table similar to Fig.84. Base the table on any parameter that you like, such as bobbin diameter, bobbin barrel length, lamination size, etc.. You should have from 150 to 300 turns on the primary, 600 to 1100 ampere turns and the wattage should be as low as possible as heat is the No.1 enemy of any ignition coil.

The coil can be designed so that the laminations are soldered to a flat head bolt. The flat head would be the bottom of the case and the case is thus bolted to a metal surface. This arrangement will conduct much heat from the coil. Do not use silver solder.

The secondary can be wound first and the primary wound last. Such an arraignment is called an "outside primary" coil. This arraignment allows a greater number of secondary turns with less resistance as the coils have a smaller diameter. The start of the secondary is often soldered to a brass grommet or pin that contacts the laminations. The laminations are insulated from the case and become the high voltage terminal. A spring in the top contacts the laminations and conducts the high voltage to the spark plug wire.

The end of the secondary is connected to the start end of the primary and is the "-" terminal. The end of the primary is, of course, the "+" terminal. The primary wire in this case can be a larger size as it's diameter and length will be greater. The best design is to improve on the last successful coil built.

I have tabulated the data on the coils (ignition and magneto) that I have information on. Each parameter was then averaged. The following average parameters were obtained. Core area = 3/8", Primary wire size = No.24, Primary turns = 201, Secondary wire size = No.46 Secondary turns = 14,000.

CHAPTER 16
IGNITION CIRCUITS

There are two distinct systems to ignite the explosive mixture of fuel in a combustion chamber. In days past, they were refereed to as the Touch Spark system and the Jump Spark system.

The Touch Spark system was sometimes called the Contact Spark, the Make and Break Spark,the Hammer Spark or the Wipe Spark system. The Touch Spark system was used on many early farm type stationary engines of the hit-or-miss variety such as the New Holland Engines.

The spark is produced by interrupting battery current flowing through an inductance. The breaker contacts are located inside the combustion chamber. The stationary contact is located on the inside surface of the head. The moving contact is located at the end a short arm that is fixed to a shaft. The shaft extends through the head in a insulated bushing and is partially rotated, first in one direction then in the other, by mechanical linkage to the cam shaft.

The inductance consists of about 300 turns of No.24 wire wound around an iron core. There are two outstanding advantages with this system. First, of course, is simplicity. The second is the fact that an engine using the Touch System will run outdoors in a pouring rain as water has no effect on this ignition system — there is no high voltage involved.

The only disadvantage is that usually the head must be removed to clean the contacts. Fig.65 shows this circuit in detail.

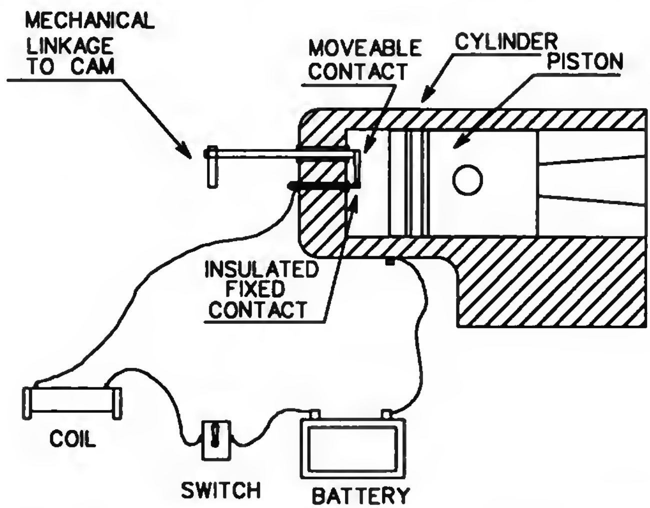


Fig. 65 LOW VOLTAGE IGNITION SYSTEM

The breaker contacts for a single cylinder, four cycle engine may be located on the crankshaft or the camshaft. Consider for a moment, that the breaker contact is located on the crankshaft, the plug fires every revolution of the crankshaft and the battery last one hour. If the breaker is relocated to the camshaft, the plug will fire every other revolution of the crankshaft and the battery will last two hours.

If the engine is a hit or miss type, locating the breaker contact on the exhaust valve rocker arm will allow the plug to fire only when the governor calls for speed or about every ten to fifteen turns of the crank. The battery will last from 10 to 15 hours.

A rocker arm activated switch in series with the crankshaft or camshaft mounted breaker will give the same result. Such a switch wired in series with the breaker contacts is called a "battery saver" switch.

Battery life is also determined by dwell. Dwell is the amount of crankshaft rotation that can occur (forward or backward) while the breaker contacts are closed. Dwell is stated in degrees of crankshaft rotation. Dwell can be stated as time if the crankshaft speed in RPM is given.

Fig.14 showed that a specific amount of time is required for the current to reach maximum in the primary circuit after the breaker contacts close. An average time for most ignition coil primaries to reach maximum current after the breaker contacts have closed is 1.20 milliseconds or .0012 seconds. This value will vary with the inductance of the primary.

It is also true that the breaker contacts must remain open for a similar amount of time, or longer, in order for the condenser to become fully charged with electrons by the collapsing magnetic flux.

The maximum secondary voltage is equal to the maximum primary (condenser) voltage multiplied by the turns ratio.

A period of five time constants are required to charge the condenser. If the contacts are closed for a shorter period of time, the coil will perform poorly, usually producing a weak spark because insufficient time was allowed to establish maximum flux in the iron core and/or maximum charging of the condenser. The contacts should be closed long enough for the current to reach maximum value through the ignition coil primary when the engine is running at maximum speed.

If the contacts are closed for a period longer than five time constants, the battery is supplying energy that is not required to operate the coil. The excess energy will heat the coil, contacts and prematurely discharge the battery.

More importantly, although usually not a concern, is the fact that the breaker contacts must be open long enough for the condenser to be fully charged. The time required to fully charge the condenser is five time constants. If the contacts are open for less than five time constants or if the value of the condenser is too small or too large, the secondary voltage will be reduced accordingly.

If the condenser is removed from the circuit, the secondary voltage will fall drastically as the secondary voltage is then determined as battery voltage multiplied by the turns ratio. With the condenser in the circuit, the secondary voltage is determined as maximum condenser voltage multiplied by the turns ratio.

A 10 degree dwell simply means that the breaker contacts are closed for 10 degrees of crankshaft rotation. The breaker contacts will be closed for about .0012 seconds on an engine running at 1,400 rpm with a ten degree dwell. In order to reliably run the engine faster than 1,400 rpm, the dwell must be increased.

Fig.66 provides a graph that shows the recommended dwell for engine maximum speed.

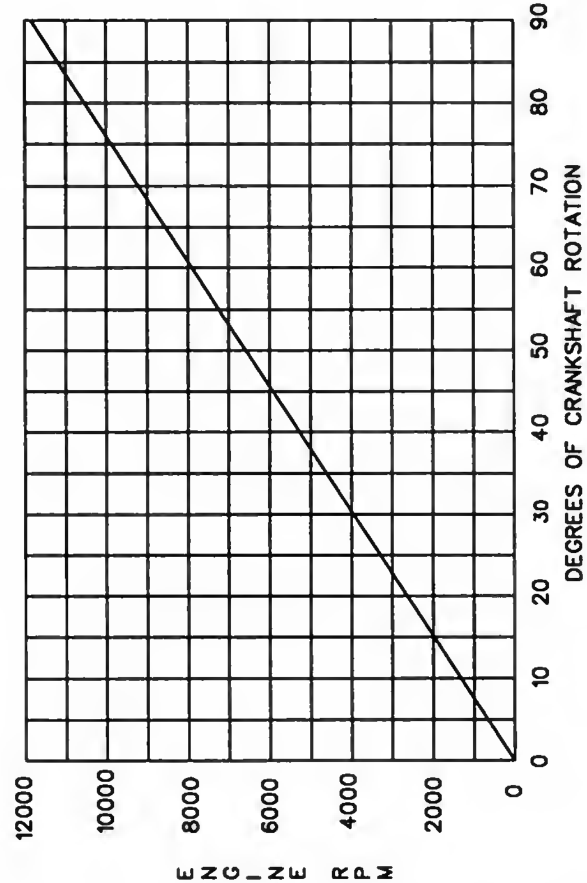


Fig. 66 RECOMMENDED DWELL FOR MAXIMUM ENGINE SPEED

Even if your engine is not in a model airplane, boat or car and it is run on a bench with an automotive battery as a source of power, the dwell should be near minimum to prevent overheating the coil.

The design of the Cam and breaker contacts determine dwell. It is common practice to design the breaker assembly with an adjustment to set the "gap" between the contacts. Actually, the gap is unimportant so long as the gap is wide enough to break the arc. What is important is the ability to vary the dwell.

For single cylinder engines the dwell can be more or less fixed with cam design as shown in Fig.67.

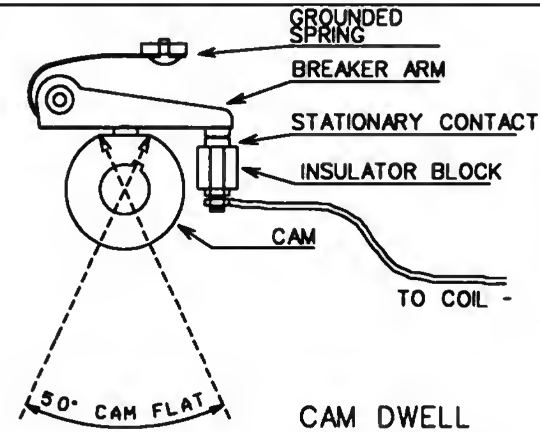


Fig. 67 CAM DWELL

The standard automobile ignition coil consists of a primary and secondary winding mounted on a common magnetic circuit (laminated core) with an air gap. In a conventional 12 volt breaker point ignition system, the characteristics of the coil are as follows: primary resistance 3.5 to 7 ohms (including about 1.8 ohms external resistance to reduce contact arcing and coil heating), primary inductance 8 to 20 millihenries. The primary to secondary turns ratio is usually 1:50 to 1:100, the secondary having 12,000 to 30,000 turns of No. 40 to No. 44 AWG magnet wire.

The distributor breaker cam usually has as many lobes as there are engine cylinders, and in four cycle engines the cam is driven by the engine at one-half of engine speed.

Whenever a spark is to be produced, the cam separates two normally closed contacts (breaker contacts) which are held together by a spring, and the sudden decay of the flux in the magnetic circuit of the ignition coil charges the condenser to a high voltage. The condenser voltage is transformed by the turns ratio to the secondary winding of the coil, and is then carried through the rotor and thence distributed to the proper spark plug.

The breaker contacts are made of pure tungsten, and a condenser of .15 to .47 uf is connected across them. On a six lobe cam for a six cylinder engine the breaker contacts are closed for about .004 seconds each time they close at a vehicle speed of 60 miles per hour. The coil is usually filled with transformer oil and mounted with a wide metal strap for heat conduction. The coil usually draws 8 amperes (100 watts) from the 12 volt battery.

Quite a few automobile manufacturers now use a 6 volt coil in a circuit that applies 12 volts to the coil during cranking and 6 volts when the engine is running. Such a circuit is shown in fig.68.

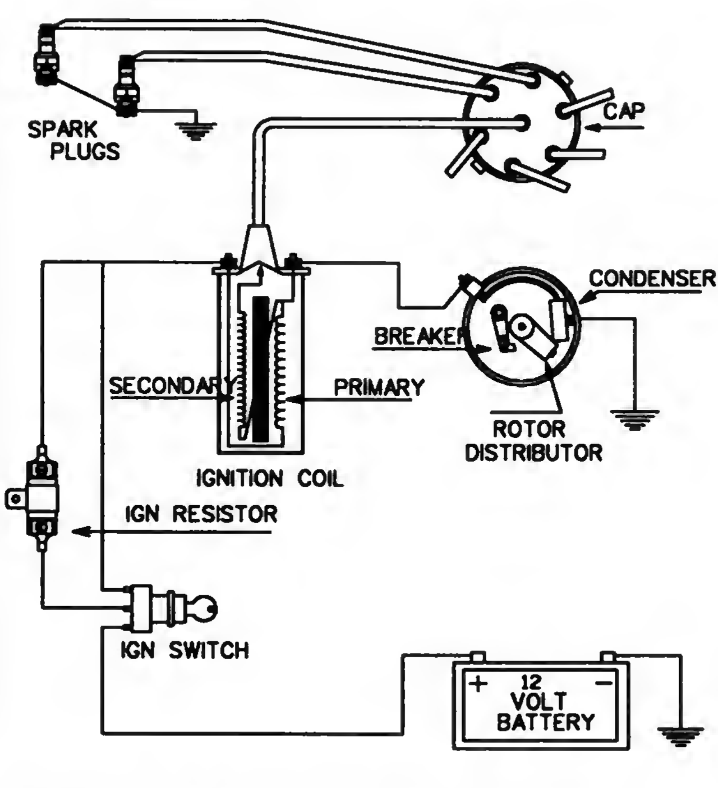


Fig. 68 TYPICAL SIX CYLINDER IGNITION CIRCUIT

If your auto is equipped with this circuit and your engine starts missing after driving through a puddle of water, it may be possible to move the ignition switch to a position just before the starter is energized to apply 12 volts to the ignition coil. The engine will immediately stop missing and sputtering and perk up. Usually, engine heat will evaporate the moisture in a few seconds and the switch can be returned to the run position. This little trick has saved my day many times.

Quite a few engine owners/operators notice excessive arcing at the breaker contacts and, in some cases, will observe sparks flying out from the breaker contacts for a distance of as much as one inch. This condition indicates that the contacts are made of some material other than tungsten and/or that too much current is flowing in the primary circuit. Excess current is the result of applying excess voltage such as, using a 12 volt battery with a 6 volt coil. The arcing cannot be eliminated but it can be reduced, usually by reducing the primary current or by adding resistance in series with the primary winding.

It is common practice in the automotive industry to provide some series resistance in the primary circuit to reduce arcing at the breaker contacts. The series resistance is usually a few turns of resistance wire located inside the metal case of the ignition coil.

One method for the home shop builder to add resistance is to install an automobile tail light bulb between the battery positive terminal and the coil positive terminal. With the engine running, the filament should have a faint red glow. If the filament is brighter that this, add a second or third bulb in parallel with the first one.

The first bulb should be visible and the second (or third) should be hidden below the engine. Should the engine stop with the breaker closed, the bulbs will glow brightly and indicate that the flywheel should be turned slightly or the ignition circuit turned off to prevent overheating the coil.

The arc between the breaker contacts should appear normal, that is, it should resemble a small ball of bluish white light. There is no excuse for making contacts from anything except tungsten rivets and to do otherwise invites a lot of trouble.

One of the most popular ignition coils for model airplane engines is the Modelectric 3 volt coil. I purchased one in the late 40's to fire my Super Cyclone 60. Both have been in constant use to this day. I have applied the Modelectric in 3 volt, 4.5 volt and 6 volt circuits. I will admit that the coil got hot enough to loose a little wax in the 6 volt circuits. The Modelectric is an excellent coil for model airplane gas engines. The coil is not as popular among home shop engine builders as they prefer to use standard 6 and 12 volt batteries, chargers and circuit components.

If you disassemble the Modelectric 3 volt coil, as many of us have, the following data (approx.) will be found. The core is .187" square by 2.5" long and consists of 13 laminations. A three piece bobbin is used, the barrel is simply paper wound around the core to an OD of .285. The two bakelite cheeks are .043" thick and .900" OD. The cheeks are spaced 1.000" apart ID. The primary is wound with No.28 AWG in three layers. The first layer contains 45 turns, the second 56 turns and the third contains 54 turns for a total of 155 turns. The length of the primary wire is 151", has a resistance of .833 Ohms and draws 3.6 amps at 3 volts.

The 560 ampere turn primary (at 3.0 volts) dissipates 11 watts. The secondary consists of 11,600 turns of No. 44 AWG. There are 35 layers with 333 turns per layer. Each layer of wire is .750" wide. The resistance of the secondary is 4,960 ohms and the turns ratio, primary to secondary is 1:75. The coil is covered by a phenolic tube that is .968" OD by 1.250" long. This coil lends itself nicely to a dual voltage circuit as shown in Fig.68.

Modelectric Products Corp. was founded in 1938 by Charles Nadler and is currently owned by Stanley Nadler. Modelectric produces a wide variety of miniature high voltage devices used for triggering photo-flash systems, stroboscopes, geiger counters, lasers, igniters, optical systems, medical systems and devices that have made the trip to the moon via NASA shuttles.

Of interest to the reader is the wide variety of miniature ignition coils available from Modelectric such as;

The Precision coil, weight 1 1/2 oz,

The Master coil, weight 1 3/8 oz,

The Deluxe coil, weight 1 7/8 oz,

The Racer coil, weight 1 3/4 oz,

The Two-spark coil, weight 2 3/4 oz,

The Two-spark coil (isolated secondary), is for use with two cylinder engines or single cylinder engines equipped with two sparkplugs. This coil features a built-in safety spark gap. The Modelectric coils are highly recommended as their design, workmanship and materiels are second to none.

Another alternate two-spark coil can be purchased at your local motorcycle shop. These coils are designed to operate from a 12 volt battery and draw only 4 amps from the battery. The standard automotive coil draws 8 amps from the 12 volt battery. The two-spark can be used as a single spark by grounding one of the sparkplug wires.

The motorcycle coil is a good choice if you plan to mount your engine on a box, for display purposes, and put the ignition system and battery inside the box. The motorcycle coil is smaller than the automotive coil and larger than the model coil. It generally has a longer and larger (1/2" square) core which reduces concern about heat build up in a closed space.

The motorcycle coil and a 12 volt lead acid battery is also an excellent choice for your start-up box.

A transistor driver circuit for the Modelectric (or similar small) coils, submitted by Bruce Satra, is shown in Fig.69. This circuit is recommended for use with multi-cylinder engines using a miniature distributor. A condenser is not required with this circuit.

The inductance consists of about 300 turns of No.24 wire wound around an iron core. There are two outstanding advantages with this system. First, of course, is simplicity. The second is the fact that an engine using the Touch System will run outdoors in a pouring rain as water has no effect on this ignition system — there is no high voltage involved.

The only disadvantage is that usually the head must be removed to clean the contacts. Fig.65 shows this circuit in detail.

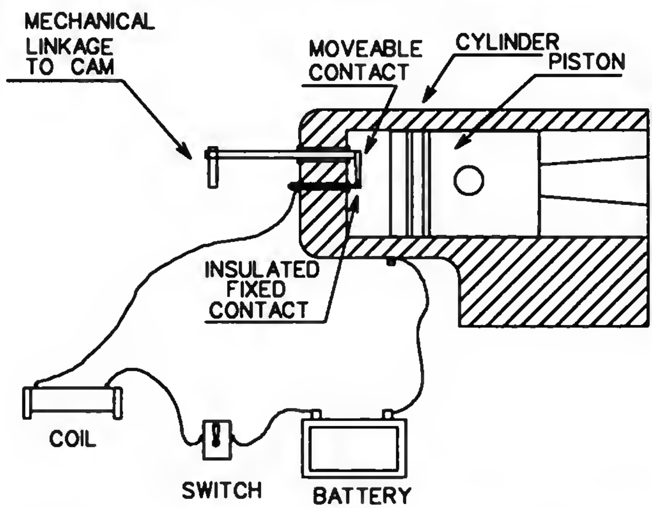


Fig. 65 LOW VOLTAGE IGNITION SYSTEM

In a typical condenser discharge circuit, quite a bit of energy is wasted in the arc that forms across the ever widening breaker contacts. Sufficient energy remains to charge the condenser and pulse the primary. In the solid state circuit, the breaker contacts switch a very small amount of current (no arc) that flips the SCR (transistor) on or off.

The SCR opens the primary circuit instantly and cleanly with no arc inside the SCR. This allows the established magnetic field to collapse from it's maximum value, with no waste, inducing high voltage and current to flow in the secondary.

There are at least three different "Jump Spark" ignition circuits for 2 cylinder engines. The most common circuit was shown in Fig.68.

An alternate circuit, for two cylinder four cycle engines is to use two ignition coils, two capacitors, one battery and a single lobe cam located on the camshaft. For two cylinder, two cycle engines the cam is located on the crankshaft. This arraignment prevents the use of a distributor. The circuit for this arraignment is shown in Fig.70.

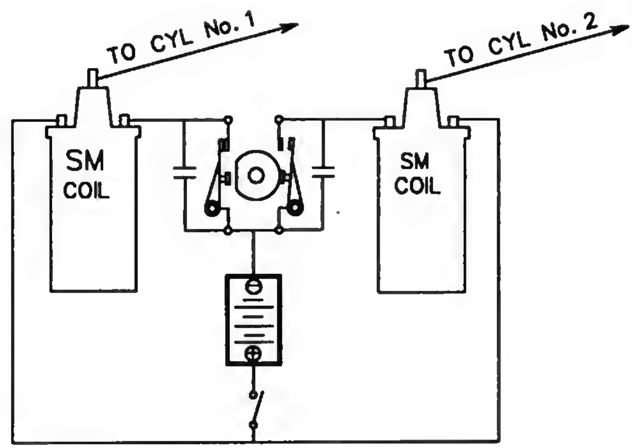


Fig. 70 TWIN COILS

An interesting circuit is shown in Fig.71 for two cylinder, or pairs of cylinders in multi cylinder engines, that are opposed in timing. A single ignition coil, battery, condenser and single lobe cam is used to eliminate the distributor.

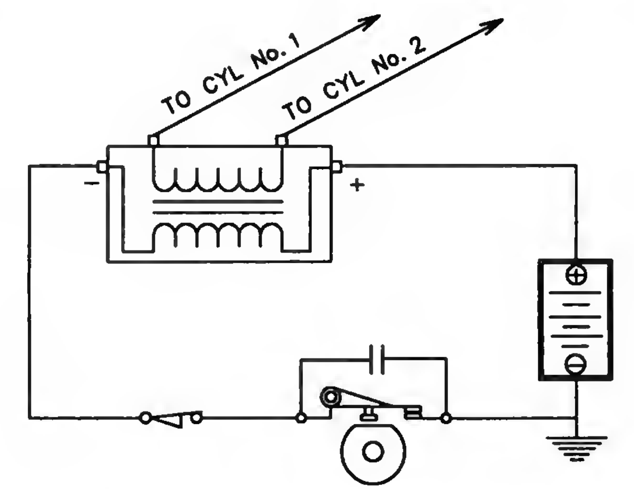


Fig. 71 TWO SPARK COIL

The ignition coil fires both sparkplugs when the contacts open. One spark provides ignition while the other occurs in the cylinder that is at the end of its exhaust stroke. This arraignment uses the least number of parts. The coil is different from the common coil only in that the secondary is not tied to the primary. Both ends of the secondary are terminated to provide two HV terminals. This type of coil is refereed to as a "Two-Spark coil".

The SL is easily adapted to this configuration by using 4 layers of No.28 (for 12 volts) or 2 layers of No.26 (for 6 volts) and 20,000 turns of No.44. The finished OD will be slightly larger and it can be encased in a horizontal fingerjoint box as shown in Fig. 72.

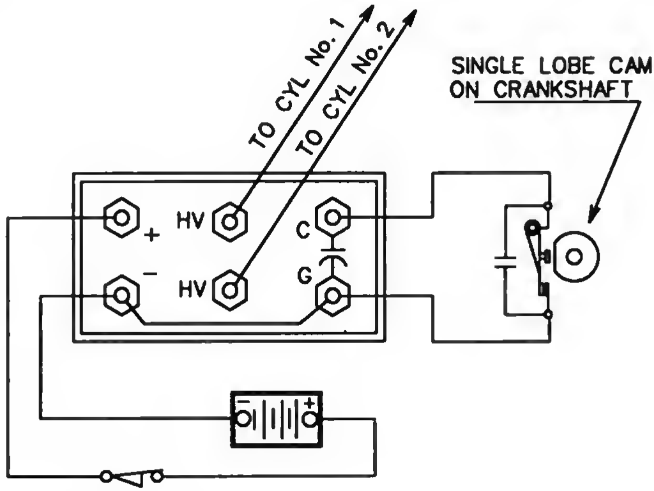


Fig. 72 ISOLATED SECONDARY

The condenser can be installed inside the fingerjoint box. The internal connections are as shown in Fig. 58. An LED can also be installed in the box as shown in Fig. 60. The spark plug gap may need to be reduced as the arc must jump both gaps.

An alternative Two Spark coil can be had at your local motorcycle shop. These coils have the distinct advantage that they work with a 12 volt battery and draw only 4 amperes from the battery. The 12 volt automotive coil draws 8 amperes from the battery. The Two Spark can be used as a single spark coil by grounding one of the HV wires.

Without a proper load, the secondary voltage may be high enough to jump inside the coil. When an arc occurs through air, the molecules of air are ionized and provides a low resistance path for the arc.

When an arc occurs across a material such as plastic, ceramic or wood, the arc leaves a trail of carbon atoms. This trail of carbon atoms is more or less permanent and provides a low resistance path for the next arc. Subsequent arcing will add to the carbon trail and a permanent short will eventually result.If you incorporate a safety spark gap in your coil, be sure the arc occurs through air and not over some type of material.

The "Buzz Coil" has been around for many years. It was standard equipment on Ford automobiles in the 1920's. The coil is so named because it vibrates or chatters. The first question to ask is why anyone would choose to use a Buzz Coil. Here are some reasons:

The engine is a slow running engine.
The engine is hand cranked.
The engine uses dirty fuel (Oil, Diesel, Kerosene, etc.) As a novelty.

The buzz coil provides many successive sparks when the breaker contacts close. At higher speeds, the buzz coil will provide only one spark due to the momentum of the leaf switch (moving contact) and limit engine speed unless radical methods are provided to advance the timing.

A miniature model T buzz box (trembler coil) is not too difficult to build by putting the SL coil in a finger joint oak box, filled with wax, or tar, and a leaf switch on top that is deflected by the magnetic circuit flowing in the core. The mass, that is, the thickness, width, length and shape of the leaf switch will determine the frequency that the contacts make and break. The flexibility also plays a large part in how fast the leaf switch vibrates.

The condenser is installed inside the box and is wired across the leaf switch. The plug fires, continuously, in this case, when the breaker contacts are closed. The arrangement is shown in Fig.73. Select a condenser value, .1, .2 or .4 microfarad that gives the highest secondary voltage or that fires your engine best.

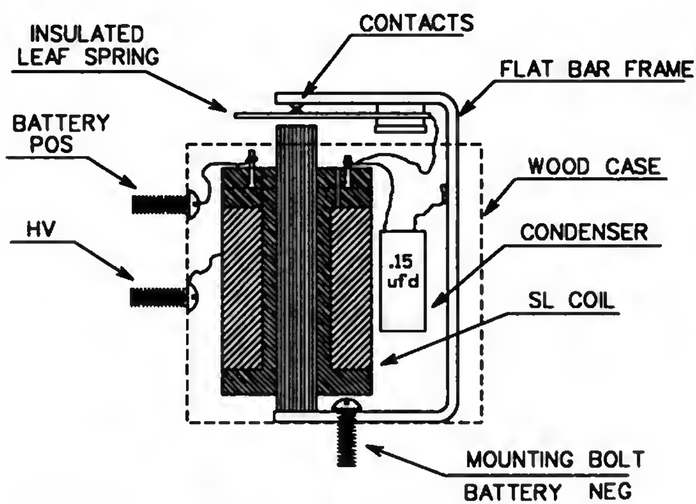


Fig. 73 TREMBLER COIL

If you do not intend to wind your own coils or if you desire an ignition coil with capabilities somewhere between the SS and the standard automotive coil, one can easily be obtained. Your local lawn mower repair shop will sell, or give you a junk weed-eater or gas powered string trimmer. The magneto can usually be salvaged and modified.

Fig. 74 shows the modification of a typical magneto coil.

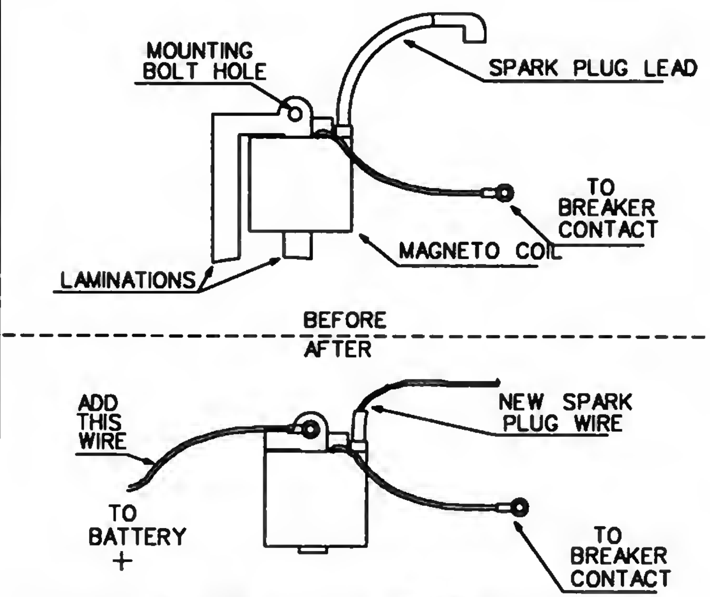


Fig. 74 MAGNETO COIL MODIFICATION

The coil is usually mounted with a nonconductive strap around the circumference of the epoxy encasement. The modified magneto coil will work with a 6 volt battery and will stand 12 volts for short periods of time. The modified coil is a good choice for the "start-up box" mentioned later in this book.

The magneto coil must be taken from a weed-eater that uses a condenser and breaker contacts. If the weed-eater is labeled "Solid State Ignition" or if it does not use a condenser and breaker contacts the coil cannot be modified. A portion of the laminations can be removed with a hacksaw, a smaller sparkplug lead is spliced on and a wire is added. One end of the primary winding is connected internally to the laminations, therefore the laminations become the + terminal and must be isolated form ground. The added wire is attached to the laminations with a bolt through the (former) mounting bolt hole and is connected to battery + terminal.

Engine eers and coil makers often speculate about the conditions inside the combustion chamber at the instant the plug fires. Some have attempted to simulate these conditions in order to test sparkplugs and coils.

A vessel pressurized with air is a far cry from combustion chamber conditions. The pressure and temperature inside the combustion chamber, changes rapidly. An increase in temperature, increases the resistance across the sparkplug electrodes. Any oil in the fuel also increases this resistance as oil is an excellent insulator.

In addition to the normal gases found in the air coming through the carburetor, plus the fuel and it's additives of lead, detergents, rust inhibitors, etc., there is residual carbon monoxide, and carbon particles as well as cast iron and aluminum particles in the combustion environment.

I can not offer a device or fixture to simulate these conditions, but I can offer a method to determine the equivalent conditions. The equivalent being in ambient air. Fabricate an adjustable air gap as shown in Fig. 75.

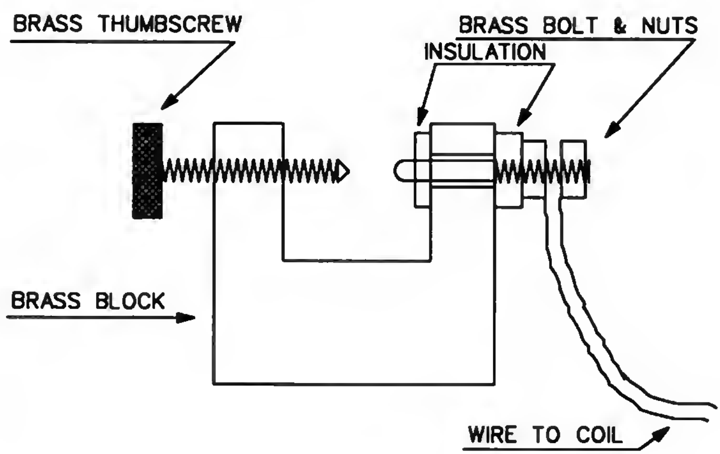


Fig. 75 ADJUSTABLE AIR GAP

Install the air gap in parallel with the spark plug of a running engine as shown in Fig. 76.

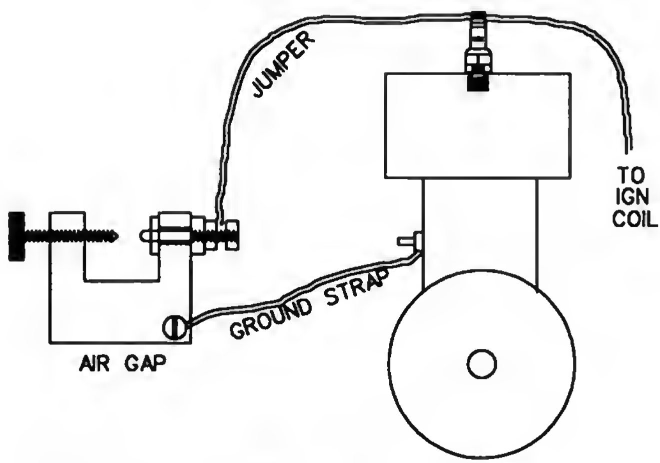


Fig. 76 AIR GAP ENGINE

With the engine running, slowly reduce the gap of the adjustable air gap. At some point the arc will intermittently occur across the air gap. Careful adjustment will allow a setting where the engine misses every other firing. The reason that the engine misfires every other arc should be explained.

You may have noticed when observing the arc across a sparkplug's electrodes that the arc tends to "dance around" on the electrodes. If you pull the lead off of a sparkplug of your car and hold it close to the engine block you will notice, in addition to the fact that the arc is long, blue and noisy, that it also "dances around" and does it's best to avoid hitting the same spot every time.

When an arc occurs between two metal objects, the atoms in the metal are instantly heated to a high temperature. Although the heat is quickly dissipated, it last long enough to increase the resistance of the metal. Electricity, and magnetic lines of force, seek the path of least resistance. The succeeding arc therefore avoids the hot atoms and seeks a cooler spot of less resistance

When the arc alternates between the sparkplug and the air gap, the conditions between both gaps are identical, as you have established a parallel electric circuit, as shown in Fig. 77.

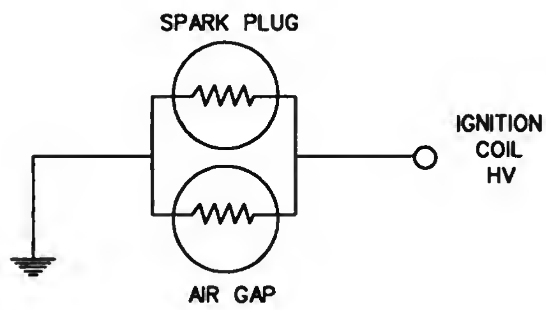


Fig. 77 PARALLEL CIRCUIT

Both legs of the circuit are of equal resistance. Therefore AG=SG, the resistance across the air gap, AG, equals the resistance across the sparkplug gap, SG. Before you set this up, measure the sparkplug gap and mentally determine what you expect the air gap to be. I am sure you will be surprised.

Choosing the ignition circuit for your particular engine should be determined by ease of starting and running the engine. This is followed by ease of construction (coils, breakers, mounting brackets, batteries, chargers, cams, switches, etc.), ease of maintenance and appearance.

Nicad batteries are great for portable devices such as telephones, model airplane electric systems and other applications where weight is the prime consideration rather than voltage or capacity. Normally, these batteries are connected to a trickle charger when not in actual use. Nicads are rated in milliampere hours.

Gel cell batteries are great for computers and stationary applications requiring a bit more power (emergency or back-up) and again these batteries are normally connected to a trickle charger when not in service. Both types are sensitive to, and can be damaged by, charging and discharging.

Nicad, Alkaline, Carbon and Gel cell batteries should be avoided unless there is a specific requirement for their use.

Sealed lead-acid batteries, either 6 or 12 volt, should be used whenever possible for one outstanding reason, and that is, to reduce the problems and aggravation in your life. Six volt, 4.5 amp hour, sealed lead-acid batteries that measure 1 3/4" by 2 3/4" by 4" high are readily available for about $10.00. This type battery is not sensitive to charging, discharging, load or position. Lead acid batteries are rated in ampere hours rather that milliampere hours.

The most reliable system uses the least number of components. This fact makes a well designed, built and applied set of mechanical breaker contacts very hard to beat. If the breaker is not well designed built and maintained, a TIM (Transistor Ignition Module) can be used to correct the faulty breaker. The use of a TIM circuit adds more components and treats the effect, not the cause.

The Hall effect system is useful when applied to very small engines to eliminate the cam and breaker system, thus reducing friction. It is also used when converting glow fuel engines to gasoline.

Every engine builder eagerly awaits the day when the engine is first started. This can be an enjoyable or frustrating experience. The majority of problems are found in the ignition or fuel systems. To lessen the frustration, bewilderment, speculation and foul language, a "start-up box" is recommended.

The start-up box consists of nothing more than a standard 12 volt automotive or motorcycle ignition coil with it's condenser, an on-off switch and a 6 volt lead acid battery. Three wires should exit the box and be connected to the engine. A wire to engine frame (ground), a wire to the breaker and a wire to the spark plug.

After the engine is running, the ignition timing is set, the valve timing is set, the carburetor adjusted and the engine broken in, then use the ignition system of your choice.

A typical 3 volt model airplane ignition coil that consumes about 15 watts from a 3 volt battery can not be compared to a 12 volt coil that consumes 100 watts from a 12 volt battery. The secondary of the later contains 10 times the energy to ignite the fuel mixture. Miniature ignition coils, like miniature engines, cannot be expected to produce the same power as the full sized ones.

If you do some test or comparisons of different ignition systems (TIM circuits, Hall effect circuits, 3 volt coils, 6 volt coils, 12 volt coils, magnetos, plug gap and different condensers) using one particular engine, you will find an amazing difference in engine performance.

Check this out using one of your engines that has many hours of running time. At idle speed apply an increasing load (torque) until the engine stops. Change the ignition system to a 12 volt automobile coil and 6 volt lead acid battery and run the same test. I am sure you will find that the engine will run slower and at twice the load. The value of the condenser will usually have an effect on maximum rpm.

Fuel also effects ignition. Oil is an excellent insulator and adding it to the fuel increases the resistance across the plug gap. Carbon deposits are left in the combustion chamber by hydrocarbon fuels. Carbon is conductive and lumps of it get caught between the valves and seats requiring head removal and cleaning.

The fuel I have used for years keeps carbon washed out of the combustion chamber. A mixture of 90% Coleman lantern fuel and 10% WD-40 dramatically reduces friction and washes the carbon out the exhaust. This fuel virtually eliminates carbon build up on valves and sparkplugs. For hit-or-miss engines, the number of turns that the flywheel makes during the "miss" period will increase 10 to 15% with this fuel.

The fuel for your engine should be the one that is compatible with the engine and causes least problems.

CHAPTER 17
IGNITION COIL ANALYSIS

For those that like all the details, the SS coil was analyzed with an oscilloscope. The waveforms shown in Fig. 78 through 82 are typical of all ignition coils. The voltage, current and frequency will vary from coil to coil. If you carefully scope most any coil, you will see these waveforms. A primary voltage of 6.0 volts was chosen for SS coil analysis.

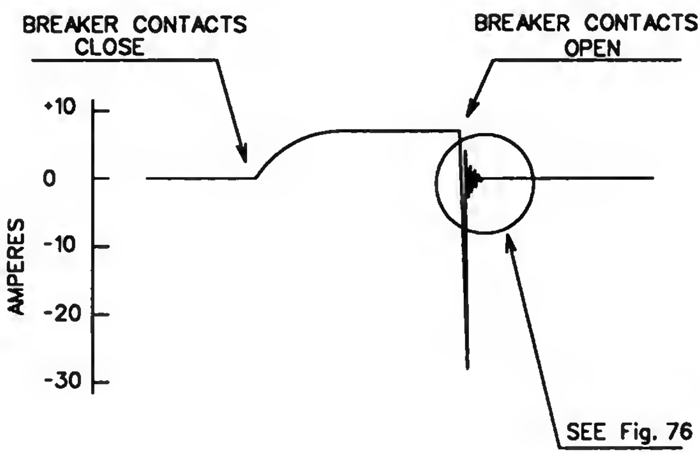


Fig. 78 PRIMARY CURRENT WAVEFORM

Fig.78 is a trace of the primary current as the breaker contacts close and then open. As the trace moves from left to right, the current is seen to rise, at a rate of 5 time constants, from 0 to 7 amperes after the contacts close. The current remains at 7 amperes until the contacts open. At the instant that the contacts open, the current goes very quickly from plus 7 amperes to minus 36 amperes and induces a 150 volt potential across the condenser. The current very quickly returns to zero, oscillating a bit at 45 kilohertz as the electrons seek equilibrium across the condenser.

Fig.79 is a magnification of the encircled area in FIG. 78.

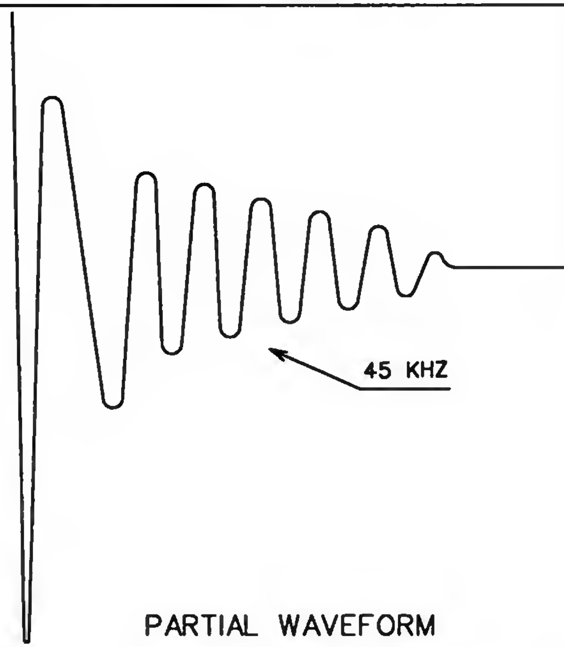


Fig. 79 PARTIAL WAVEFORM

Fig.79 shows the current alternating between the plates of the condenser at a frequency of 45 kilohertz. The current quickly diminishes to zero when an equal number of electrons rests on each plate of the condenser.

To look at things from the standpoint of the secondary, Fig.80 shows the Trace of secondary voltage with the SS coil applied to an engine running at 1200 rpm and the breaker contacts located on the camshaft.

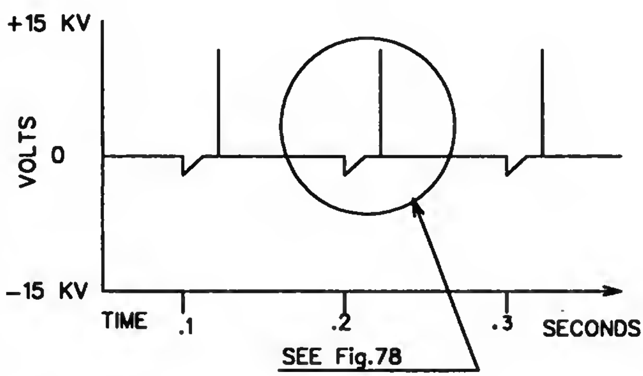


Fig. 80 SECONDARY VOLTAGE WAVEFORM

The area inside the circle is amplified for clarity in Fig. 81.

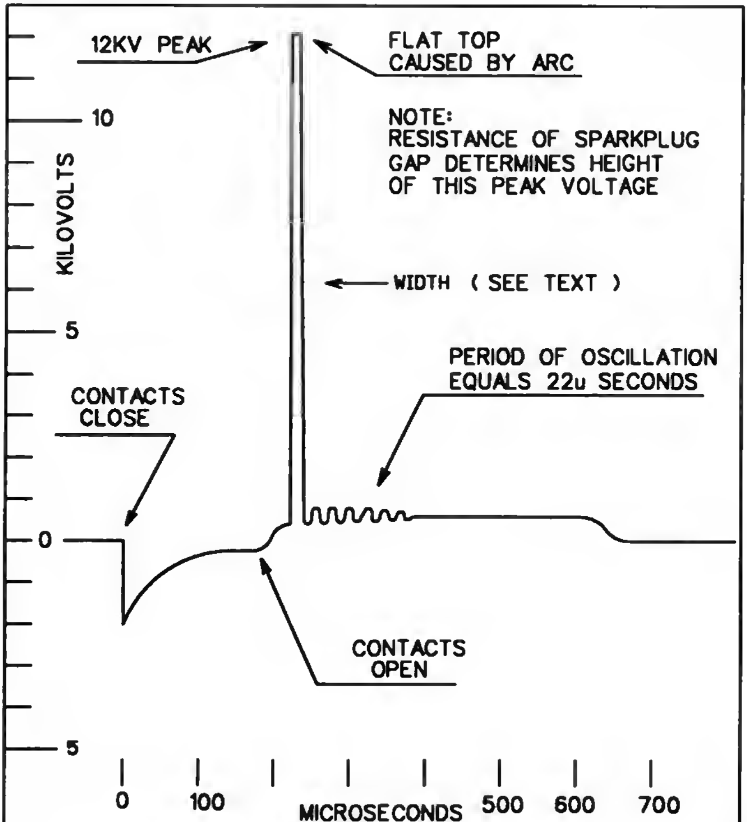


Fig. 81 SECONDARY VOLTAGE WAVEFORM

This trace shows that about 2,000 volts is being induced into the secondary when the contacts close. This is due to the primary current creating the magnetic field.

The secondary voltage trace contains a reflection of the 5 time constant curve of the primary current as it goes from zero to maximum value. The secondary voltage diminishes to zero over a period of 5 time constants because the magnetic field is stationary and, although it is at maximum, it is not cutting across the windings of the secondary. For as long as the contacts remain closed, there will be little, if any, voltage induced in the secondary.

The trace shows that when the breaker contacts open, a 12,000 volt potential is induced into the secondary. The trace shows that this a-c voltage quickly diminishes to zero over a period of 8 cycles. Each cycle has a time period of 22 microseconds.

It was interesting to see that the width of the 12,000 volt "spike" was proportional to the spark plug gap. Increasing the spark plug gap increases the width of the spike. I believe this is due to the ionization of the gas molecules across the plug gap. An adjustable air gap was substituted for the spark plug to determine that the width of The spike is directly proportional to the gap. The top of the spike is flat as this is the point that the arc jumps the plug electrodes.

I expected to see the "spike" swing to a large negative value, it did not happen.

To satisfy another curiosity, the scope leads were placed across the condenser to obtain a trace of the condenser voltage. The trace is shown in Fig. 82 as accurately as I can draw it. I am not a graphics artist and being too cheap to hire one, I will have to bear some criticism of my drawings.

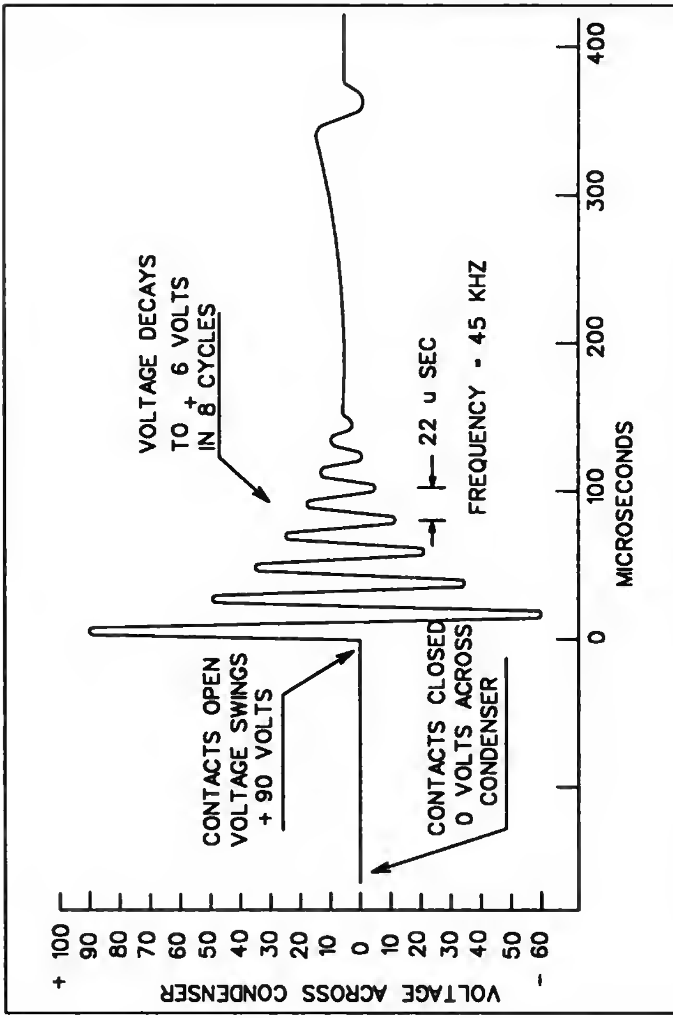


Fig. 82 VOLTAGE ACROSS CONDENSER

The trace shows that the condenser is charged to + 90 volts when the breaker contacts open and the collapsing magnetic field forces free electrons to be compacted on the + condenser plate. When the magnetic field has completely collapsed, nearly all of the electrons quickly migrate through the .843 ohm primary winding to the - condenser plate in an attempt to equally distribute themselves across the plates. When the migration subsides, the condenser is charged to –60 volts. This 150 volt change (current flow) produces flux in the core that induces the 12,000 volts in the secondary windings.

The electrons migrate, or oscillate, back and forth until an equal number of electrons have settled on each plate. This action is similar to dropping an object into an open vessel filled with water. The molecules of water splash, or slosh, or migrate, or oscillate until they are equally distributed and the surface is once again flat.

The scope trace indicated that each cycle of migration required 22 microseconds to complete. This equates to a frequency of 45 kilohertz. The same frequency was observed in the secondary. In order to determine the credibility of the scope, the inductance of the primary and secondary was promptly measured. The SS coil primary winding measured 66 microhenries and the secondary measured 5.25 henries. Using the "basic radio equation", the resonate frequency calculated to be about 45 kilohertz. Replacing the .22uf with a .47uf condenser resulted in a 28% loss of all of the above voltages. This emphasizes the importance of condenser selection.

To view these waveforms, use a high quality scope with the appropriate high voltage probes and filters to screen out intermodulation and harmonics. An adjustable air gap (load), a selection of condensers and precision resistors should be on hand.

I wish to thank Mr. Tim Beeche for his assistance with the analysis.

CHAPTER 18
HOW TO DESIGN YOUR COILS

Before construction of an ignition coil begins, one should have more than a concept of how an ignition coil works, wire sizes, coil form construction, materiels and a coil winding machine. Design criteria for an ignition coil includes these parameters;

1. Secondary voltage
2. Primary voltage
3. Primary current
4. Primary wattage
5. Turns ratio
6. Wire size
7. Operating temperature
8. Size. diameter and length
9. Core size. area and length
10. Core type and material
11. Insulation
12. Termination
13. Encasement

Quite a list of parameters. Usually the design hinges on the selection of a few, being three, as the Good Book states "and there came a few wise men, being three". The first Is, naturally, the secondary voltage as it must ignite a compressed fuel mixture. The second is usually the physical size of the finished ignition coil and the third is usually the primary voltage, 3, 6 or 12 volts.

Fig.83 is provided to give a mental picture of the interrelationship of the parameters.

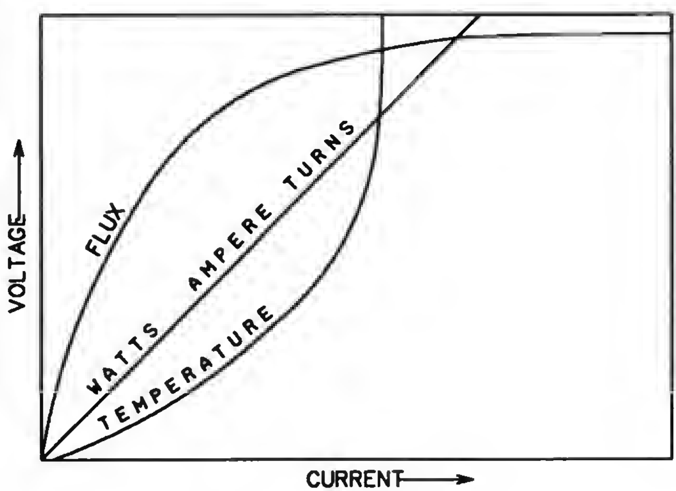


Fig.83 VARIABLES

It can be seen from Fig.83 that changing one parameter will change most, if not all, of the other parameters. Having selected three parameters, the others can be calculated or logically selected. The final design parameters can then be chosen from a list of the data calculated. The data can be compiled into a table for quick visual review, consideration and selection.

Probably the best procedure for most is to design the next coil on the basis of the last coil constructed, and this is where taking notes really pay off.

Fig.84 is a data table for a 6 or 12 volt coil using No.28 AWG wire for the primary winding. The table can be expanded to show data for 3 volt and 24 volt primaries. Similar tables can be compiled for other wire sizes.

The secondary data is not shown on the table for several reasons. One reason is that the core data is not shown. Another is that the secondary voltage and current are difficult to calculate as they result from the flux generated in the core by the primary. Also the value of the condenser has a large effect on the secondary voltage. The secondary turns are normally chosen as a ratio of the primary turns. The ratio should range from 1:50 to 1:100.

	LAYER 1	LAYER 2	LAYER 3	LAYER 4	LAYER 5	LAYER 6
PRIMARY OIA.	.420	.440	.464	.486	.560	.586
CIRCUMFERENCE	1.319	1.395	1.457	1.527	1.759	1.840
LENGTH IN/FT	120/10	244/20.3	376/31.3	512/42.6	158/13.1	165/13.8
TURNS	91	180	271	360	450	540
RESISTANCE	.834	1.69	2.61	3.55	4.58	5.67
AMPS AT 6 VOLTS	7.19	3.55	2.29	1.69	1.31	1.058
AMPS AT 12 VOLTS	14.3	7.10	4.59	3.38	2.62	2.11
AMPER TURNS 6V	654	639	620	608	590	571
AMPER TURNS 12V	1301	1278	1243	1216	1180	1142
WATTS 6/12	43/171	21/85	14/55	10/40	7.8/31	6.3/25

PRIMARY WINDING DESIGN DATA

Fig. 84 FOR No.28 AWG MAGNET WIRE

The table is very useful to quickly set additional parameters. If one desires the coil to dissipate no more than 10 watts of power, the table shows that 43 feet of No. 28 is required to supply the resistance, and that length of wire will require 360 turns in four layers. Keep the turns ratio in mind and limit the primary turns to about 200 turns.

The most important parameter shown in the table is the Ampere turns. From experience, we know that the ampere turns should be no less than 600 and no more that 1100. Notice that the ampere turns do not vary much across the table while the current and wattage varies considerably. The table shows that two 6 volt coils can be built using No.28 wire, one consumes 21 watts from the battery and the other consumes 6 watts.

The 6 watt coil will require more turns on the secondary than the 21 watt coil due to turns ratio. Keep the turns ratio between 1:50 and 1:100.

THIS PAGE IS BLANK

but this is not a printing or scanning fault and no content is missing.

CHAPTER 19
THE PLUG LEAD

A coil is not complete without a hi voltage lead. A very nice spark plug leadwire is easily made as shown in Fig.85.

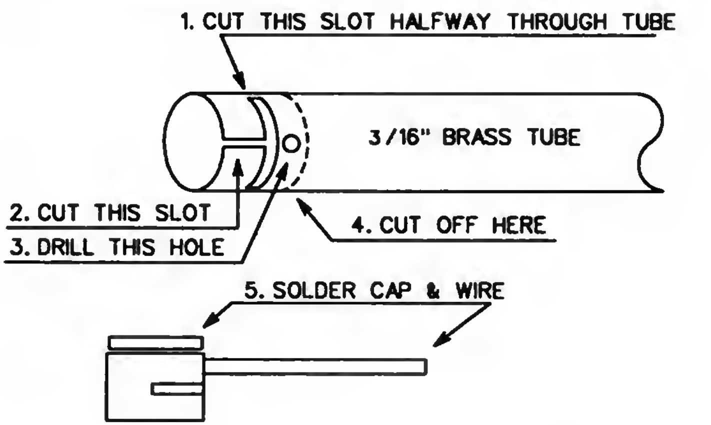


Fig. 85 SPARK PLUG CONNECTOR

A Dremel tool is handy here, but if you do not have one, a fine tooth metal saw will work just as well. Cut the end of a 3/16" OD brass tube square. Drop back about 1/16" and cut the tube 3/4 of the way through, vertically. Cut this thin section horizontally so that it will act as a spring clamp to grip the top of the spark plug. Drill a No. 60 hole as shown. Drop back about .107 and cut this section off.

Machine a brass cap to fit in the tube as shown. Remove about 1/8" of insulation from the end of a wire and insert it in the drilled hole. Lay a heavy object on the wire to hold it still. Lay the cap, inverted on the work bench, fit the tube, with the gap up, over the cap. Hold the tube in place with a knife blade.

Drop a couple of pieces of 1/16" OD rosin core solder in the tube. Each piece should be about 1/16" long. Bring up a hot, tined soldering iron and touch the side of the cap. The solder should melt and bond the wire, tube and cap.

To give the assembly a professional look, bend the end of the tube for a snug fit on the plug, so that it will push on and pull off, yet grip the plug terminal snugly. Wrap a few turn of sewing thread around the wire about 1/2" from the tube. Push the tube over a short length of 5/32 rod and dip the assembly in Plastidip or a similar product sold in hardware stores.

Plastidip is a thick liquid used to apply a thick coat of plastic to tool handles. Plastidip is available in different colors and dries quickly.

Chapter 20
BREAKER CONTACTS

Let no man deceive you. A properly built set of breaker contacts will give little or no trouble for many hundreds of hours of service. Multiple millions of them have been manufactured and installed on engines used in more applications than I can name. Many thousands of people have staked their lives on the reliability of mechanical breaker contacts by flying, or riding on, airplanes during the past 50 years.

Many people have said some bad things about mechanical breaker contacts. The reasons for these derogatory statements can be attributed to one or more of the following;

1. Poor design of the breaker.
2. Bad choice of materiels.
3. Improper application.

Any man that builds the contacts from silver solder, brass, bronze, cold rolled steel, drill rod, hacksaw blades or alloyed socket head screws is asking for trouble. Relay contacts (coin silver) is not the best choice. Pure Tungsten is the preferred metal, usually Tungsten rivets. The rivets are fabricated with a thin disk of pure Tungsten welded to a soft metal base for easy rivetting. A source for these rivets can be found in the Appendix.

The breaker spring must exert sufficient force to bring the contacts together firmly, without "bounce" or vibration, otherwise they will fail in a dirty environment. Tungsten contacts with a healthy spring will function very well when SUBMERGED in dirty, filthy oil and grease.

Never exceed the current rating of the breaker. Do not use a 4 ampere breaker (common in model engines) in an 8 ampere circuit (common in automobiles). To do so is similar to taking a double dose of laxative when a single dose is called for and, the results are about the same.

Over current will result in excessive "sparking" or arcing at the contacts and will heat the breaker components. Some parts of the breaker, such as the spring, breaker arm and stationary contacts with threaded screws are not good conductors of current and will easily become very hot with excessive current as they are the high resistance portion of the circuit.

The spring should be protected from excessive current by placing a strip of copper In parallel with the spring. The copper will conduct most of the current and prevent the spring from getting hot and being annealed.

If you must use an automotive coil with a miniature breaker, do not use a 12 volt battery. Use a 6 volt battery as this will halve the current. Most magneto coils salvaged from weed eaters or small engines will operate on as little as 3 volts.

Make every effort to keep the primary current as low as possible. External resistance, such as a lamp is helpful. The lamp acts as a variable resistor. The lamp filament has a low resistance until it gets hot, and at operating temperature, the resistance is high. The lamp allows a high current for a very short period then, when the filament gets hot, it will limit the current. The lamp (or lamps in parallel) is selected so that at normal engine speed the lamp filament is seen to be just barely red in color.

A review of ignition circuits would not be complete without presenting at least one example of how to build a reliable breaker, in miniature.

Fig.86 shows the general arrangement of the breaker. The breaker assembly can be made smaller or larger by scaling most of the dimensions shown. If the breaker is made smaller, care must be taken to insure that the spring exerts sufficient contact pressure. If the contact pressure is adequate the breaker will function well in dirty and oily conditions.

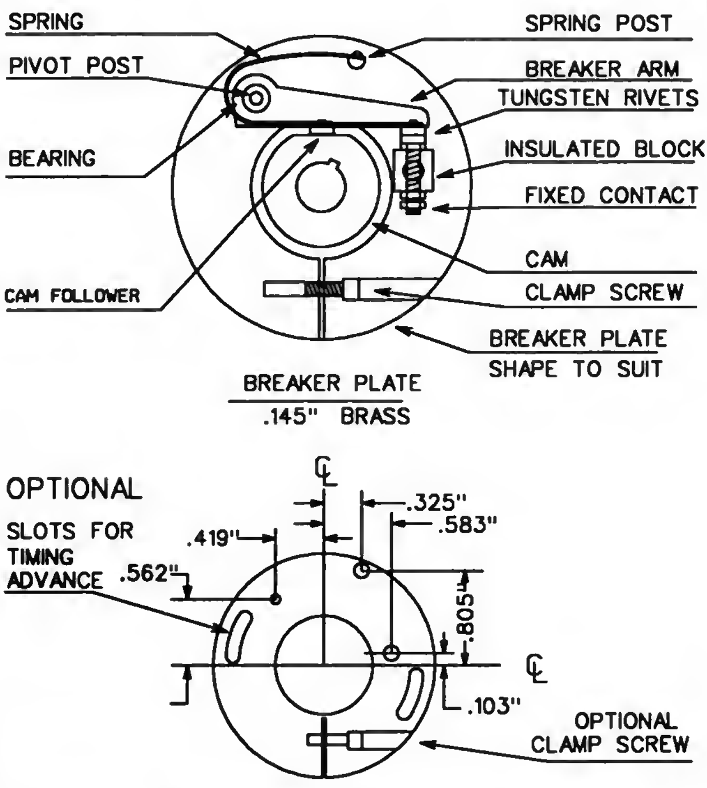


Fig.86 MINIATURE CONTACT BREAKER

The breaker plate shown was sliced from a 2" round brass bar and is about 1/8" thick. The breaker plate for your application may be of a different metal and shape. The pivot post and the spring post may be soldered into the plate rather than pressed in. The plate may be mounted with the optional slot as shown in order to advance or retard the timing, or it may be mounted around a hub or spigot with a clamp screw.

For a very small breaker, 1" in diameter or less, use a common safety pin for the spring. The sharp tip and the clasp are cut off and the coiled portion is placed around the pivot post. A loop can be formed in one end of the wire then flattened with a hammer. The cam follower extends through the loop and is rivetted to hold the spring to the breaker arm. This will provide a very strong spring in a small area.

You will need two tools to build the breaker arm, a steel bar 9/64" thick, 1/2" wide and 1 1/2" long, and an aluminum bar of the same dimensions. The arm can be made of Stainless Steel, or brass. Shim stock is a good source and it should be .010 to .012" thick. Cut the shim stock to be one 1" wide and 1 1/2" long.

Use a smooth jaw vise to bend a 90 degree angle lengthwise. Tap the bend with a hammer and a piece of lead or aluminum to make the bend exactly 90 degrees. Lay the steel bar in the bend and clamp it widthwise in the vise. Fold the stock again to form a square U shape. Replace the steel bar with the aluminum bar.

Drill the hole for the bearing, going through the stock and aluminum bar. Install a bolt and washers to clamp the stock to the aluminum. Using a metal cutting band saw or a vise, hacksaw and files, shape the arm as shown in Fig.87. Drill the holes for the contacts and remove the aluminum bar.

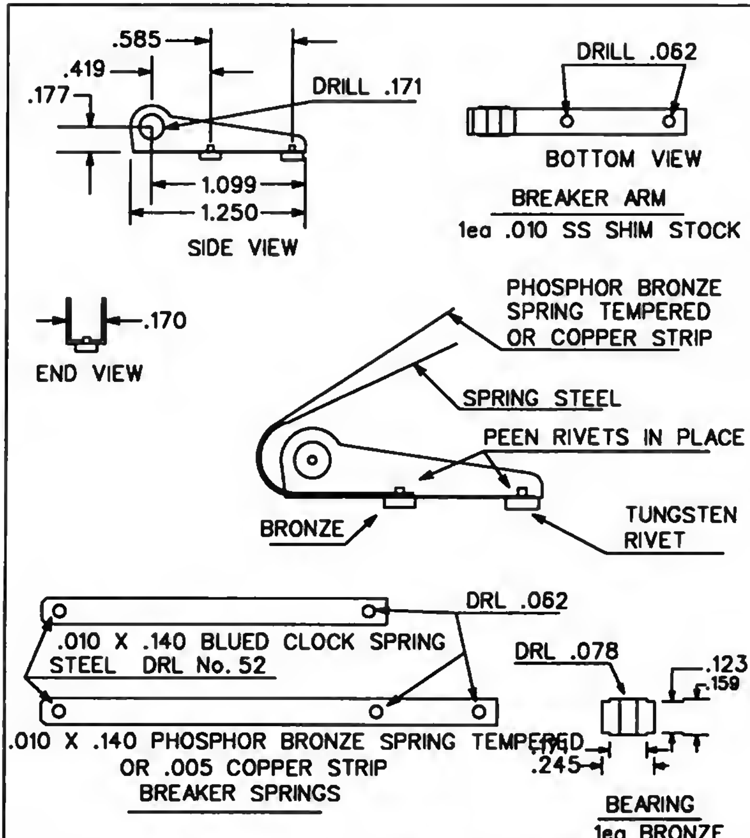


Fig.87 MINIATURE BREAKER ARM

The spring steel is easy to cut if you clamp it in the top of a smooth jaw vise and use a Dremmel Mototool with an abrasive disk. The portion you want to keep is in the vise jaws to minimize heat. Keep the head of the bolt that holds the disk on the Mototool in contact with the top of the vise jaw to ensure a straight cut. Cut slowly and run the Mototool at low speed. To drill the holes in the spring, you need three dental burrs. The small ball, large ball and the tapered shaft coated with diamond dust. When asked, my dentist gave me a handful of used burrs.

Twist a sharp pointed scribe into the spot for the hole. Lightly center punch. Use a ball shaped dental burr in a slow running Mototool. Stop the chuck with your fingers to place the ball in the punch mark. Slowly release the chuck and let the ball cut. Enlarge the hole with A tapered diamond dental burr. A copper strip or .003 brass shim stock is placed in juxtaposition with the spring to prevent electrical current from heating the spring and drawing the temper. One end of the flat spring is held to the arm by the movable contact rivet. One end of the copper strip is riveted with the flat spring to the arm by the cam rider.

Never use copper, brass, bronze, silver solder, etc. for contacts, use pure tungsten rivets. A fixed contact is available that consists of a tungsten rivet or disk welded to a 2-56 bolt. The bolt is generally too short for most applications therefore an alternate fixed contact is shown in Fig.88. The tungsten rivet is pressed in the end of a threaded rod made from 3/16" hex brass stock for the adjustable contact.

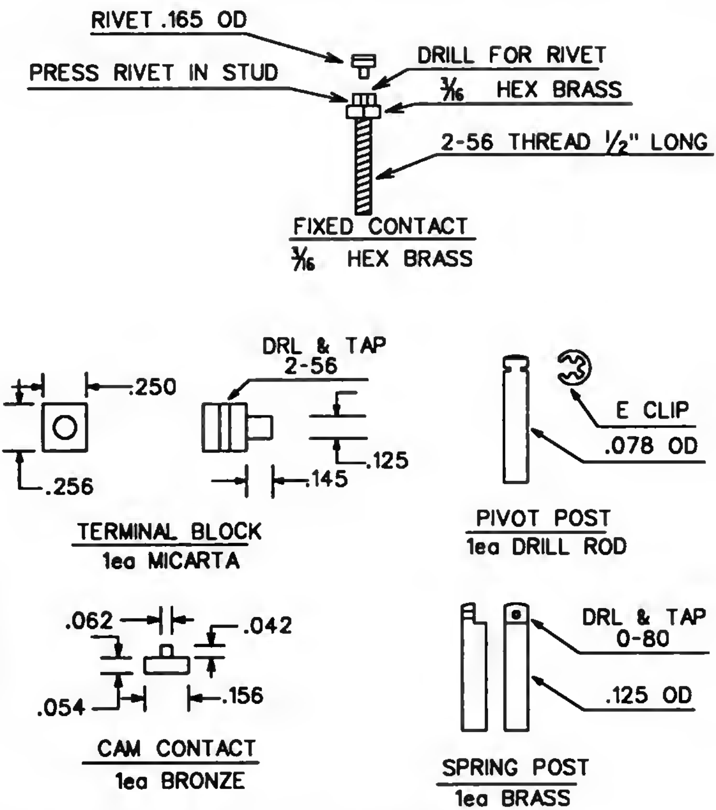


Fig. 88 FIXED CONTACT

The linen phenolic (Micarta) terminal block is pressed in the breaker plate with Locktite. Install a rectangular shaped, .15 uf, 100 volt Mylar condenser on the breaker plate. This hides the condenser, keeps it from harm and permits only one wire from the ignition coil -terminal to the breaker and one wire from the engine frame to the battery - terminal.

The bronze bushing should be soldered into the arm. Very little solder is required. The contacts should come together squarely, with all the pressure that the spring can exert. The current through the contacts should be limited to four amperes or less.

THIS PAGE IS BLANK
but this is not a printing or scanning
fault and no content is missing.

CHAPTER 21
THE MAGNETO

The miniature magneto is not a new thing or even recent. It seems to me that nearly all of the original patentable ideas occurred before 1915. The idea of using electricity to illuminate a house, of putting an engine in a vehicle all occurred prior to that date. Since then, nearly all patents have been issued due to design engineering.

The earliest mention of a successful miniature magneto, that I can find, appeared in the September 1926 issue of The Model Engineer. This magneto was a scaled down copy of the Villers full sized magneto that was popular at that time. Over the years the miniature magneto has undergone many design changes. Improvements in magnets, magnetic materiels. wire and insulation products have affected the basic design.

The heart of the magneto is, of course, the magnet. All other components are designed around the strength of the magnet as it alone produces the magnetic flux. The side poles and core simply CONDUCT the flux so that it cuts across the windings and compel free electrons to flow.

The electrical circuit for the magneto is identical to the ignition coil circuit with the exception that the battery is removed. The magnetic circuit differs in that the core of the magneto is a laminated U shape, or a type of C shape. A permanent magnet is aligned with the ends of the core to establish maximum flux.

The only purpose for the battery in the ignition coil circuit is to magnetize the core, or more accurately, to create flux that flows in the core.

In the magneto circuit, the flux of a permanent magnet flows through the core when the magnet is aligned with the core ends. The high voltage in the secondary is produced when the magnet is removed or reversed, thus collapsing the flux field. A timed contact is separated to place a condenser in the primary circuit shortly after the field begins to collapse.

In both circuits, as the breaker contacts open, the collapsing flux field charges a condenser. The flux field surrounding the ignition coil collapses at a rate of 5 time constants. In the case of the magneto, the rate of collapse is determined by the rotational speed of the magnet.

Remember that the voltage generated in the coils of wire, and across the condenser, is not only determined by the flux density (magnet strength) but also by how quickly the flux collapses. A slowly collapsing flux will not force many electrons to flow on to the condenser plates.

A flywheel magneto, typically, has a magnet and two laminated pole pieces cast into a flywheel. The flywheel is then machined and the magnet is remagnetized. This type of basic magneto arraignment with its electric and magnetic circuits, along with a typical ignition coil circuit for comparison, is shown in Fig. 89.

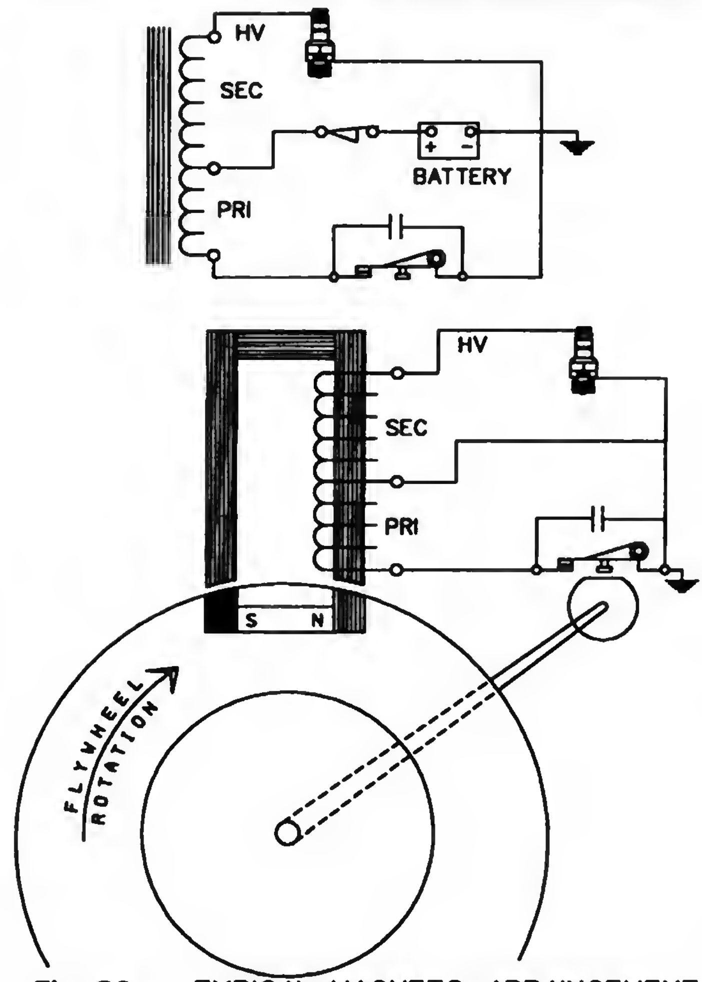


Fig. 89 TYPICAL MAGNETO ARRAINGEMENT

The common complaint of the magneto circuit in Fig. 89 is that it fails to produce sufficient high voltage at low speed. This shortcoming can be corrected to some extent by rearranging the electrical or magnetic circuit.

A two conductor, normally closed jack can be installed that allows a battery to be inserted between the breaker contacts and the coil primary. The battery can be plugged in to start the engine or for low speed running. This is a risky circuit as the battery voltage can demagnetize the permanent magnet. The circuit is shown in Fig.90.

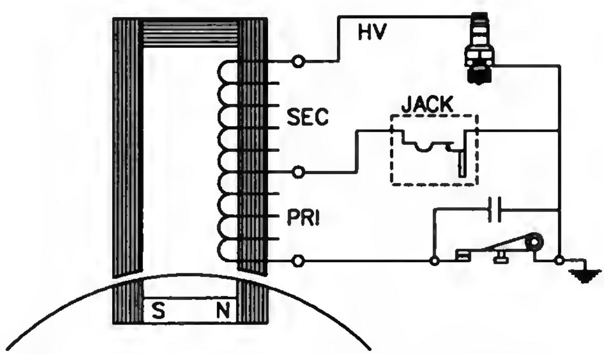


Fig. 90 BATTERY JACK ADDITION

The magnetic circuit can be modified to use two magnets, in a three pole configuration as shown in Fig.91. This arraignment provides a more rapid collapse of the flux at low engine speed.

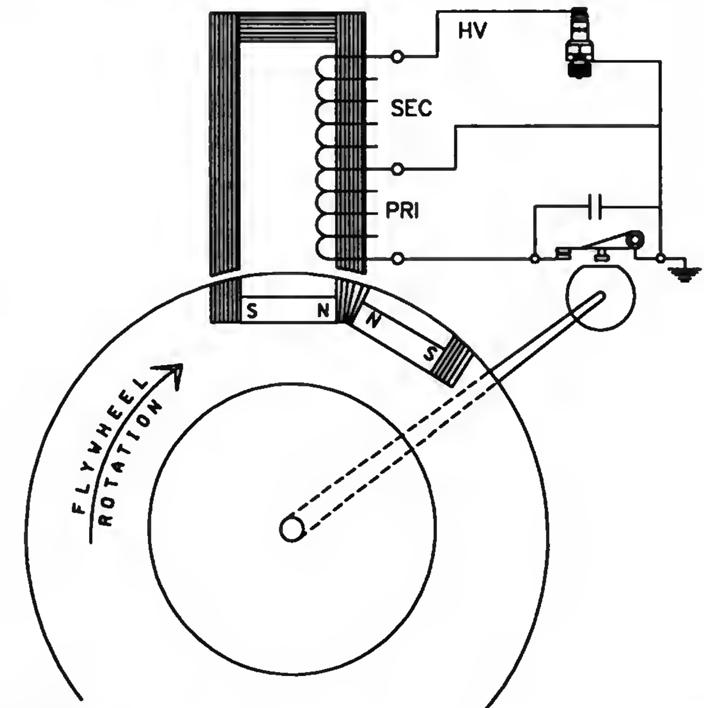


Fig. 91
TWO MAGNETS CONFIGURED WITH 3 POLES

The breaker contacts are adjusted to open just after the second magnet pole pieces have past alignment with the core legs as this is the point where the maximum flux starts to collapse.

Magnetos have been built with many different mechanical configurations. The most popular, and successful, is the stationary coil/rotating magnet arrangement. The stationary magnet/wound rotor type is more difficult to build and miniaturize.

Quite a few of our fraternity have asked for an explanation of the so called "Solid State Ignition" circuit as applied to small magnetos. The system in question has been in use for the past 18 or so years and is commonly found on small single cylinder internal combustion engines as applied to weed-eaters (string trimmers), snow blowers, lawn edgers, chain saws, portable skill saws, etc..

The Solid State Ignition Module consist of an assortment of electrical components contained within a short, cylindrical case of molded PVC. There are no external components such as breaker contacts or condenser. Only one wire comes from the module and carries high voltage to the sparkplug. In applications where a "kill switch" is desired, a second wire is brought out of the module and led to a manually operated switch that is used to stop the engine.

The module has a square hole through its center so that it can be slipped over a stack of ferromagnetic laminations that serve as an iron core. The module produces high voltage for the sparkplug when it is excited by passing a magnet across the poles of the ferromagnetic core. Fig. 92 shows an outline of the solid state module.

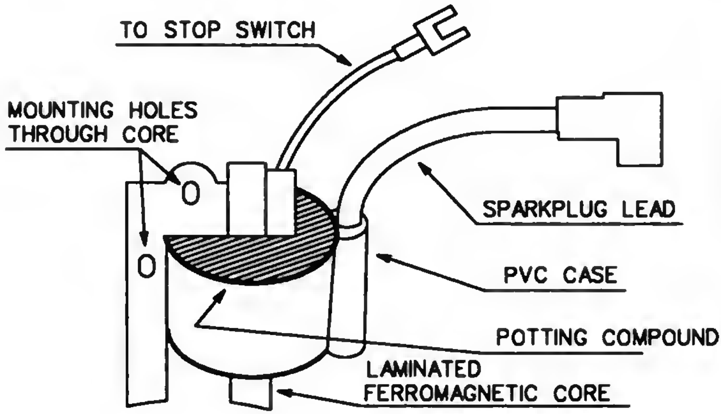


Fig. 92
SOLID STATE IGNITION MODULE OUTLINE

This is a great little device as, excluding the ferromagnetic core and magnet, there is only one component, the solid state module, to fool around with. It has only one wire to connect, to the sparkplug, and one (if provided) to a stop switch. No breaker contacts, no springs, no condenser, no batteries, no cam, no adjustment screws.

The Condenser Discharge Circuit has been around for a hundred years or more. Numerous variations of the basic circuit have been devised by many different men. A search of patent records will reveal more than twenty different men that have patented a variation of the basic circuit for use with internal combustion engines.

The Solid State Ignition Module uses two of the more modern devices to charge and discharge the condenser. The Diode and the Silicon Controlled Rectifier that was developed in the late 50's by Bell Labs.

The component layout for the Solid State Module is shown in Fig.93. There are three windings, or coils, around the core, A charging winding, a primary winding and a secondary winding.

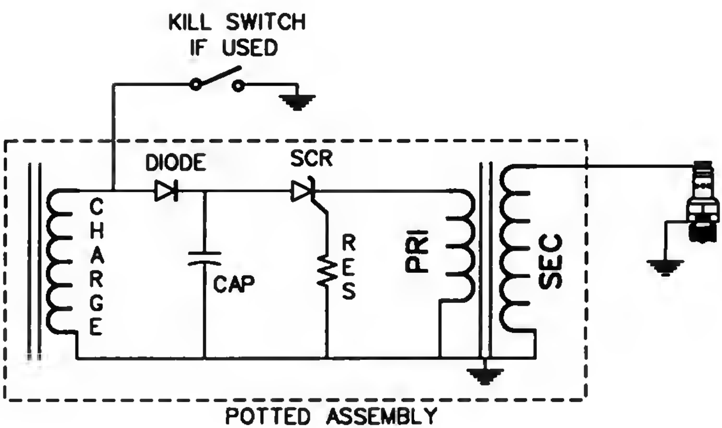


Fig. 93
SOLID STATE MAGNETO COMPONENT LAYOUT

A three pole ferromagnetic core operating with a single magnet in orbit is shown in Fig.94.

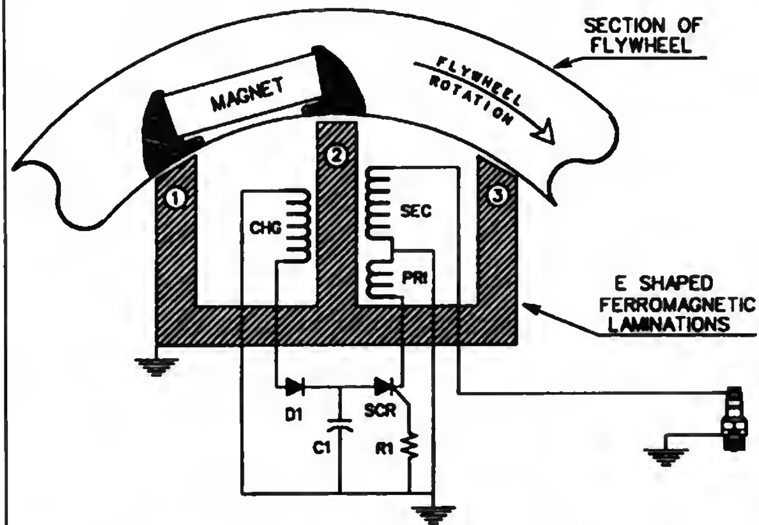


Fig. 94 SINGLE MAGNET/3 POLE STATOR

When the magnet approaches alignment with core poles 1 and 2, an expanding flux field travels in the core and forces free electrons to move from the lower condenser plate through the charging coil and through the Diode to the top condenser plate. Many electrons are compressed on the top plate (similar to a balloon that is inflated almost to the bursting point). The poled diode and the SCR prevent electrons from leaving the condenser plate. The potential (for many electrons to move quickly) is measured across the condenser as voltage. The voltage that is developed depends on the magnet strength, magnetic circuit resistance, number of turns of wire for the charging coil and the electrical circuit resistance.

As the magnet moves away from alignment with poles 1 and 2 and approaches alignment with poles 2 and 3, the magnetic flux collapses and induces electrons to flow in the opposite direction. This flow is prevented in the charging coil circuit by the poled Diode and the SCR, thus trapping the charge on the condenser plate.

The collapsing magnetic flux also forces electrons to flow in the primary and secondary coils. When this flow through the primary and bias resistor reaches a certain point, the SCR is switched from nonconducting to conducting. This allows the charge on the top capacitor plate to suddenly flow (without an arc) through the SCR and primary winding to the lower plate. In other words, the capacitor discharges through the primary winding via the SCR and induces high voltage in the secondary. The voltage induced in the secondary depends on the primary current, primary resistance, core resistance and the primary to secondary turns ratio. The secondary voltage is calculated as condenser voltage multiplied by the turns ratio.

Fig. 95 shows a 2 magnet, 2 pole version of the Solid State Module. This is probably the most popular arraignment and functions as described above.

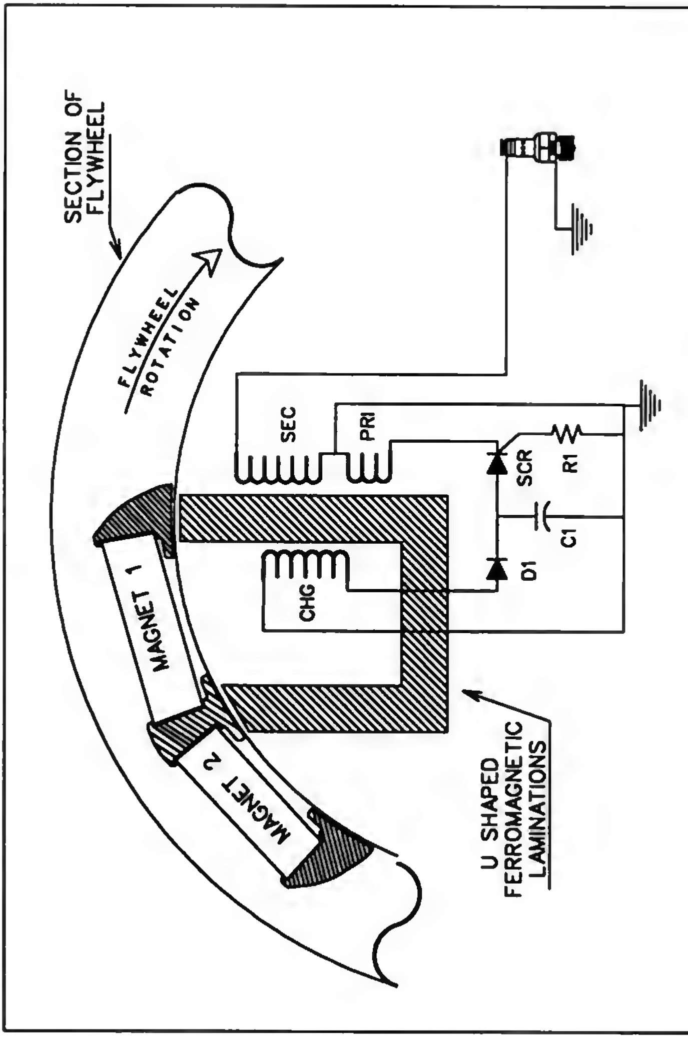


Fig. 95 2 MAGNET / 2 POLE STATOR

Component values can now be inserted into the electrical schematic. The logical way to determine the values of a particular Solid State Module is to "de-pot" it. The module case is molded from black PVC. During manufacture, the various components are placed inside the case and impregnated with a red colored resin. This resin can be dissolved with Acetone, available at most hardware stores.

The module is submerged in a jar of Acetone for 24 hours then, using a toothbrush, some of the resin can be brushed away and the module is submerged for another 24 hours. The procedure is repeated until enough resin is removed to allow cutting the case with a pair of side cutting diagonal pliers. Some of the case is then peeled away with the pliers.

Repeat the preceding procedures until the components are de-potted. Normally, the Acetone will not damage the color code bands on the resistors or the numbers on the Diode and SCR. At this point you can size the wire, count turns, identify components and draw a schematic. Typical values are shown in Fig.96.

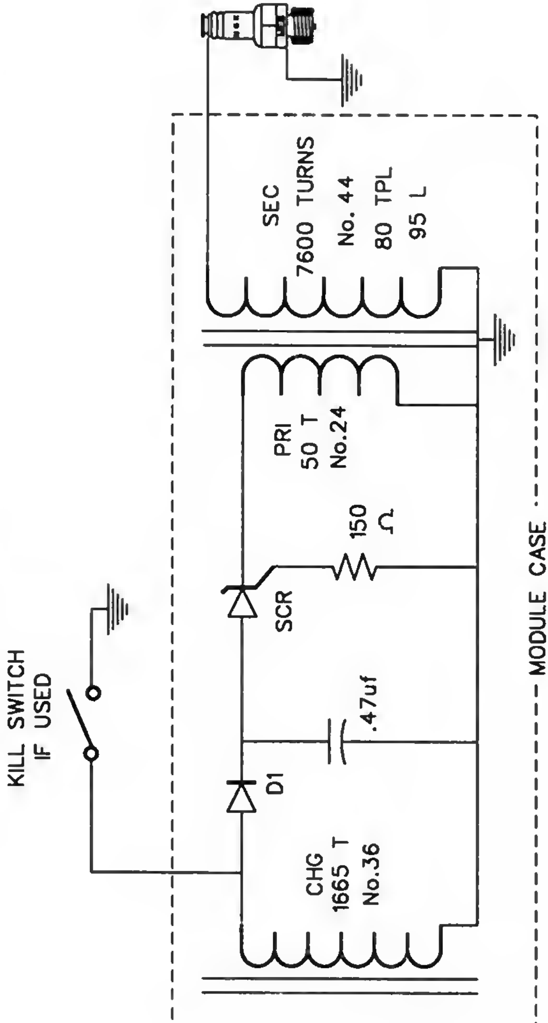


Fig. 96 SOLID STATTE MODULE ELECTRICAL SCHEMATIC

Over the years, the miniature magneto has evolved, due to improvements in metallurgy, wire and insulation products and is again becoming quite popular. Presently the accepted basic design configuration is shown in Fig. 97.

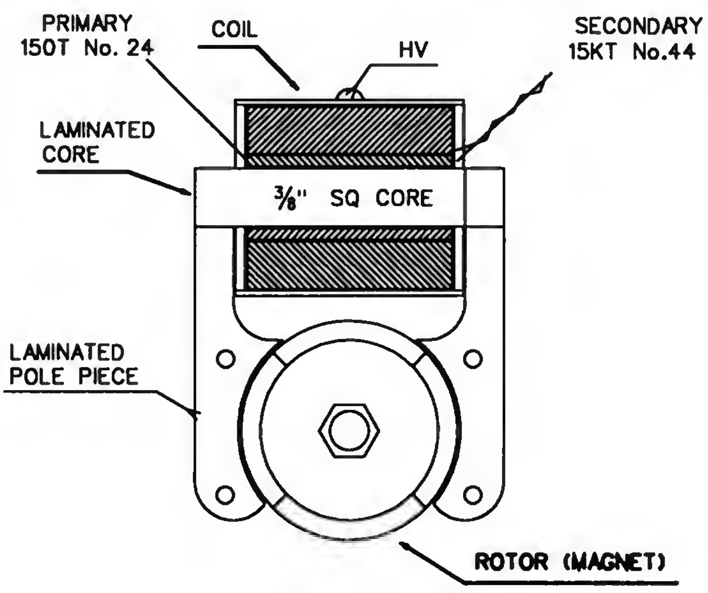


Fig. 97

BASIC MINIATURE MAGNETO CONFIGURATION

There are a few variations in rotor (magnet) design. One variation is shown in Fig. 98.

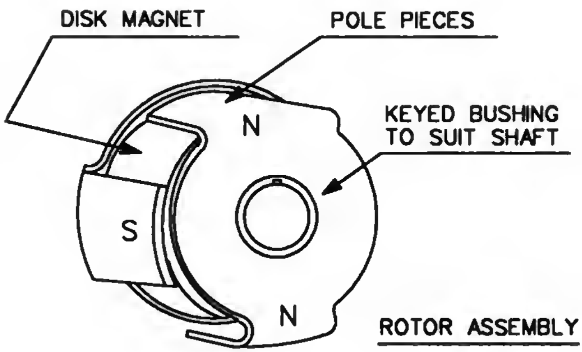


Fig. 98

VARIATION OF ROTOR CONSTRUCTION

A ring magnet is fitted with a bushing and two plates that are formed to produce 4 magnetic poles, two north poles and two south poles.

Another variation is to use a salient magnet. A few magnet vendors offer 4 and 6 pole salient magnets as shown in Fig. 99

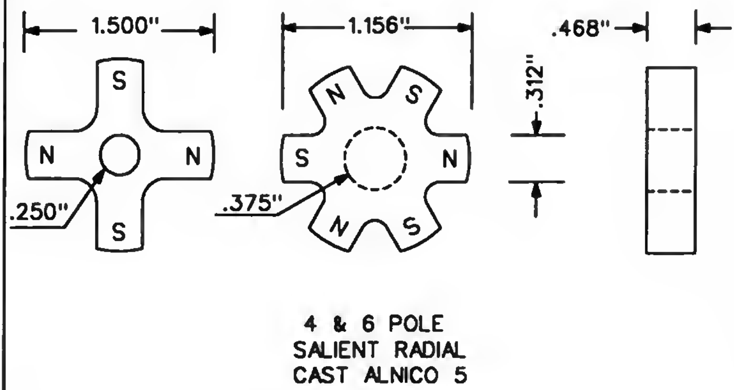


Fig. 99 SALIENT MAGNETS

I believe that two of the 4 pole salients could be ganged on a common shaft to produce as many as 4 sparks per revolution if the cam has four lobes. If the cam has 1 lobe, only one spark is produced per revolution. The one spark occurs during one quarter of the magnet rotation. A possible configuration is shown in Fig. 100.

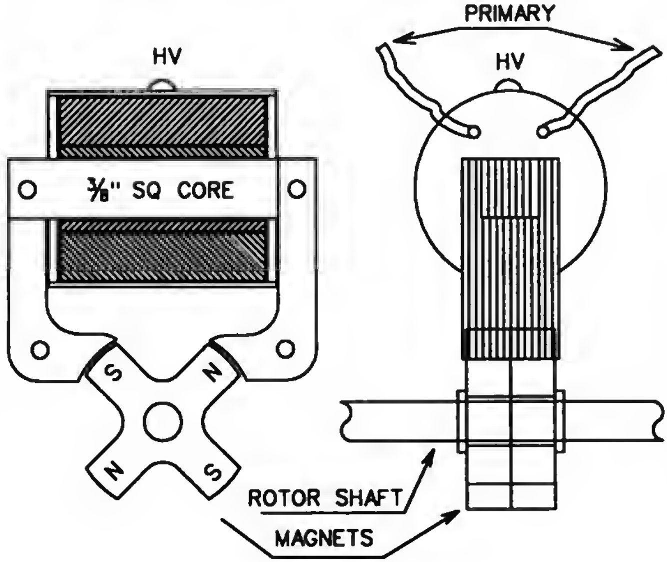


Fig. 100 4 POLE SALIENT MAGNETS

Other rotor variations, and a wealth of construction information, is available as reprints from articles that have appeared in Model Engineer, a British publication.

Without a doubt, the best miniature magneto that is commercially produced, in my opinion, is the Minimag, produced by Jim Shelley of Walsall England. A outline of the basic design is shown in Fig. 101 as an end view and in Fig.102 as a side view.

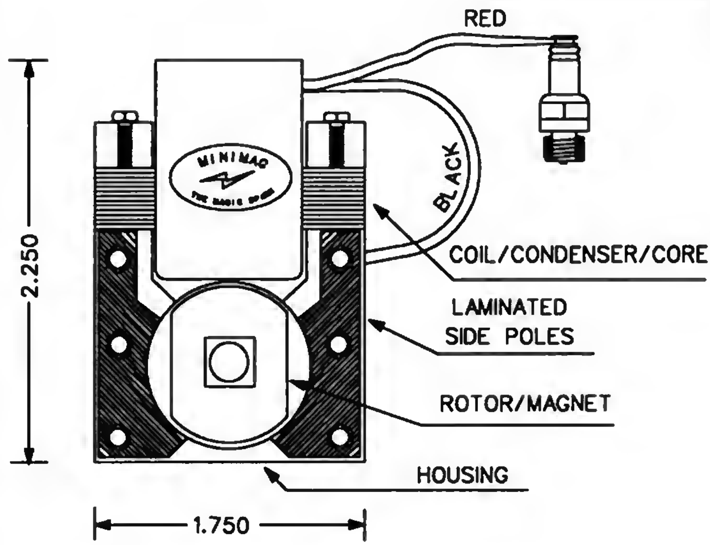


Fig. 101 **FRONT VIEW OF MINIMAG MAGNETO**

The magneto is sold as an engineers kit that contains all of the essentials to build it. Jim has elaborate coil winding and potting machines to produce the coil, condenser and 3/8" core as one moulded unit. I do not know the capacity of the condenser, wire sizes or turns ratio. Each side pole consists of 36 laminations.

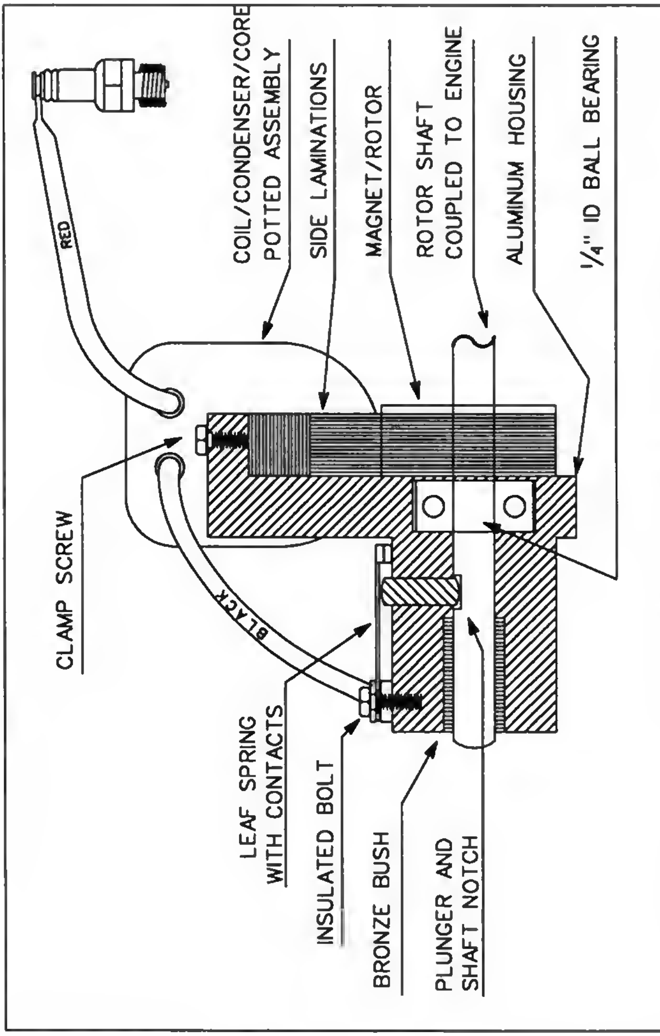


Fig. 102 SIDE VIEW OF MINIMAG MAGNETO

The magnet used for the rotor is an Alcomax IV magnet ground to 1.007" OD. The magnet is .625" long and has a .317" diameter center hole concentrically ground through the center. All the necessary hardware is supplied to construct the magneto including the tungsten rivets for the breaker contacts. Jim also sells the Minimag coil as a separate item labeled Spark Demon Coil. This is nice for those wishing to use a miniature factory built ignition coil that will operate from a 2 to 6 volt battery with the condenser built in. A brochure is available from the address given in the Appendix.

For those interested, the magneto circuit is shown in Fig. 103.

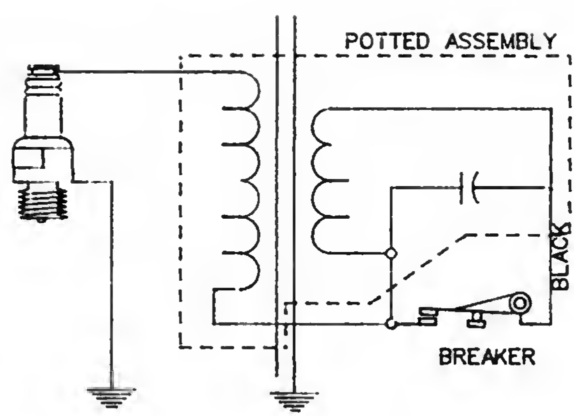


Fig. 103 MAGNETO CIRCUIT DIAGRAM

The difficulty in building a miniature magneto is to produce the shaped laminations. It is not likely that you will find suitable laminations that can be salvaged and used "as is" from a small electrical motor or transformer. The laminations will have to be stamped out or machined.

To stamp the laminations, a tool is needed. The tool is a "die" and "punch", arraigned as an assembly called a "die set".

A hydraulic press is required to press the punch into the die. The amount of pressure required depends on the thickness of the lamination and the shape.

One of the die sets that I have made and used to stamp laminations is shown in Fig. 104.

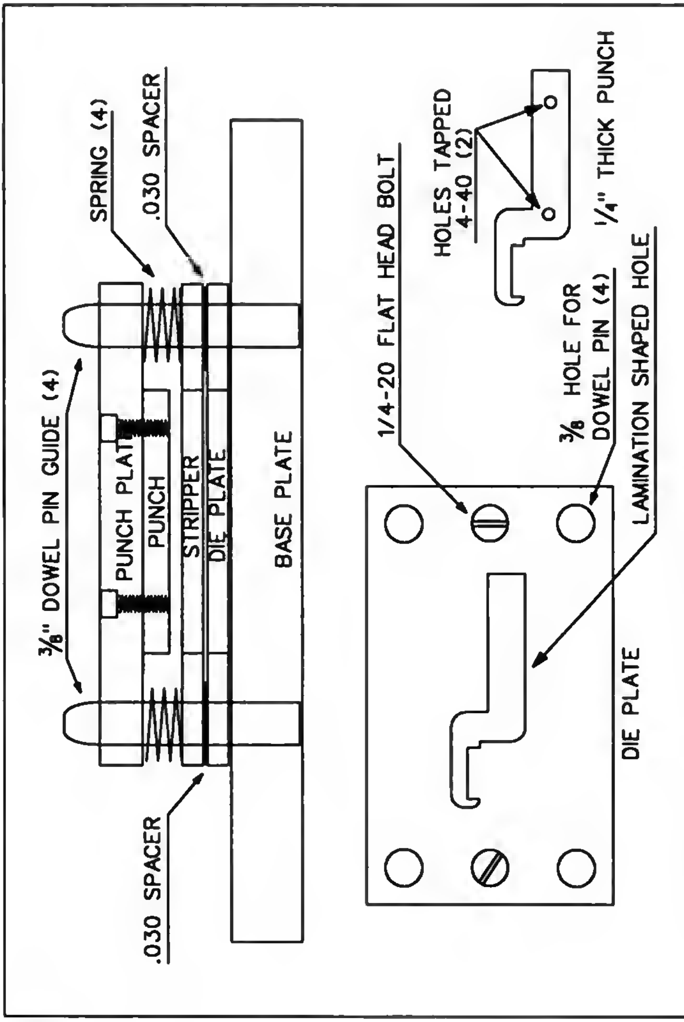


Fig. 104 DIE SET GENERAL ARAINGMENT

The die is made from oil hardening precision ground flat stock, 3/16" thick, 2 1/2" wide and 5" long. The four 3/8" guide holes are drilled and reamed and the two 1/4" holes are drilled and countersunk. The plate is then hardened to Rockwell C-60. Actually, I made two of these plates and bolted them together. The second plate acts as the stripper plate.

For a fee of $100.00, my local machine shop cut the lamination shaped hole in the two die plates with a wire type EDM (electrical discharge machine).

The punch was fabricated from 1/4" flat stock by first drilling and taping the two holes for 4/40 bolts and then hardening to Rockwell C-60. The machine shop, for another $100.00, cut the male punch with the EDM machine to fit inside the die with a few thousandths clearance all around.

The base, die plate, spacers, stripper plate (second die plate), punch and springs are assembled into a die set.

A sheet of magnetic lamination steel is inserted into the die set, between the spacers (between the die plate and the stripper plate) and a hydraulic ram is used to press the punch through the steel sheet and into the die, or almost into the die. About 4 tons of pressure is required to punch .014" thick lamination steel. A thickness of .020" is much easier to assemble and work with but will require 8 to 10 tons of pressure to stamp, depending on the shape of the lamination.

The die and punch can be fabricated using the milling machine and files if the shape of the lamination is not complex. The laminations themselves can be cut using the milling machine, drills and files but this is difficult as the magnetic steel is thin and soft, or should be.

Many have asked why the rare earth magnets are not commonly used in miniature magnetos. There are several reasons. They are expensive, do not tolerate high temperatures and are magnetized through their width, or thickness, rather than their length.

The ring magnet shown in Fig.98 is also available in Sumarium Cobalt with an OD of 1.550", ID of .312" and thickness of .350". The price of the Sumarium ring, at this writing, is $350.00.

Although I have not built a rotor using rare earth magnets, I see no reason why one could not be constructed using two segmented “shells” to encase a ring type rare earth magnet as shown in Fig.98.

Suggested coil data; 150 to 200 turns for the primary and 12,000 to 18,000 turns for the secondary. Primary wire should be no smaller than No. 30 and the secondary wire no larger than No.44.

You may have questioned the shape of the laminations cut by the die set shown in Fig.104. The laminations were used to construct a small impulse magneto, similar in appearance to the Wico type EK magneto. The magneto has been named the BOSH magneto. The Bosh measures 2 3/8" wide, 3 3/8" high (overall) and is 1 3/8" thick. When applied to a half scale Witte hit-or-miss farm type engine or other similar sized low speed engines, the Bosh looks and performs well.

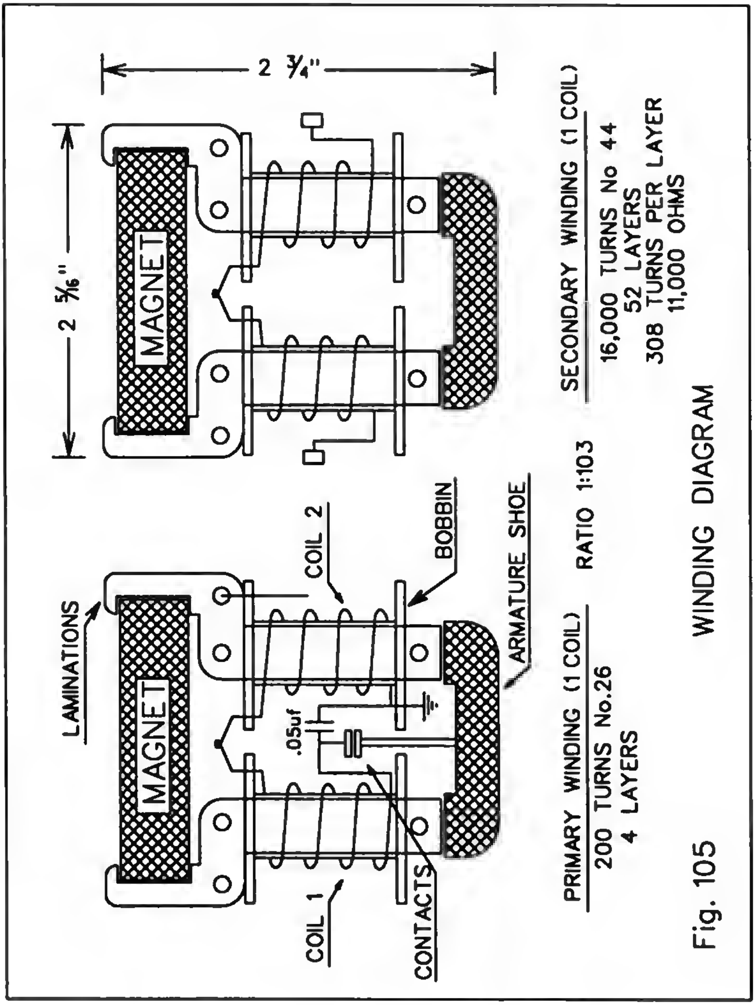
The Bosh magneto generates high voltage (spark) when the armature is abruptly pulled away from the laminated cores, thus collapsing the magnetic field that surrounds the two cores. The primary breaker contacts open shortly after the flux begins to collapse and brings the condenser into the circuit to be charged. Due to the fact that so much stray capacitance exists in the design, the condenser can be omitted, however, a little hotter arc can be obtained by using a .047 or a .5 uf condenser. The armature is moved by a spring (for abruptness) which is part of the mechanical linkage to the camshaft.

I do not wish to dishearten anyone that desires to build this magneto but,in all fairness, I should warn that to construct the Bosh is no easy task as it requires time, patience and some expense. On the other hand, it is a satisfying project for the home shop machinist with an interest in coil winding.

Each coil has four layers of No.26, wound cheek to cheek, for the primary winding of 200 turns. The fourth layer is spiral wound rather than close wound in order to reduce the number of turns on the fourth layer. The secondary of each coil has about 16,000 turns of No.44 wound in the same direction as the primary. As many turns as possible should be placed on the secondary. There are about 310 turns per layer, 50 layers. Both coils are identical. Both are wound and terminated alike.

When the armature contacts the laminations, the flux field that normally surrounds the magnet finds a path of low resistance through the laminations rather than through the air and the flux field expands through the coils. When the armature is pulled away from the laminations the path of least resistance is through the air and the flux collapses through the coils. This "switching" of the magnetic field causes the flux to cut through the windings and induce voltage in the primary. Fig.105 provides a diagram of both windings, showing how they are wound.

From the above, one can understand that the geometry and thickness of the laminations is of paramount importance.


2 ¾"
2 5⁄16"
MAGNET
MAGNET
LAMINATIONS
COIL 2
BOBBIN
ARMATURE SHOE
.05uf
COIL 1
CONTACTS
PRIMARY WINDING (1 COIL)
200 TURNS No.26
4 LAYERS
RATIO 1:103
SECONDARY WINDING (1 COIL)
16,000 TURNS No 44
52 LAYERS
308 TURNS PER LAYER
11,000 OHMS
WINDING DIAGRAM
Fig. 105

The isolated secondary winding of each coil begins at the small stranded wire and ends at the punch formed copper button. When installed on the laminations, the secondary is properly phased by connecting the two stranded wires together. The buttons make contact with the brass case that covers the magneto. One side of the case grounds the button while the other side connects the sparkplug lead wire to that button. The case can be rotated to provide right or left hand sparkplug lead wire. Fig.106 shows the electrical connections to properly phase the two coils.

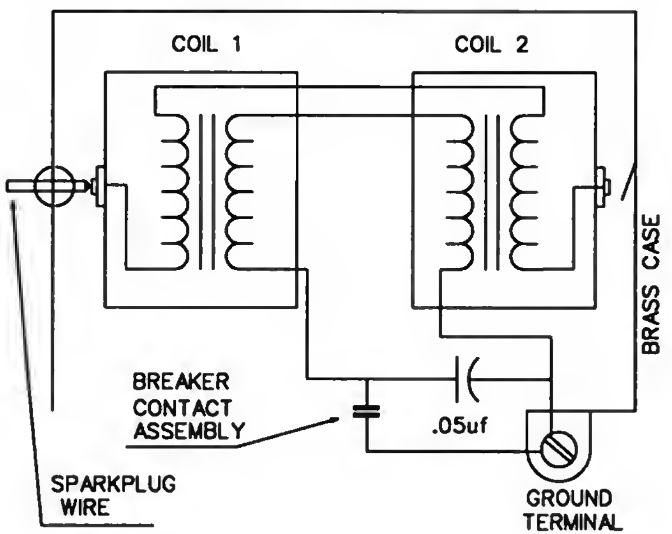


Fig. 106 ELECTRICAL DIAGRAM

The Bosh uses a single bar magnet, an Alnico 5 magnet that measures 1/2" x 1" x 2" and is not expensive, costing about $12.00, depending on where you purchase it.

Construction normally begins by fabricating the laminations as this is the difficult part. Thin (.014") laminations, require about 4 tons of pressure to stamp. Thicker laminations are much easier to work with and can be as much as .025" thick. To stamp this thickness, about 10 tons of pressure will be required. Two versions of the laminations are required, one version is the complete lamination as shown in Fig.107.

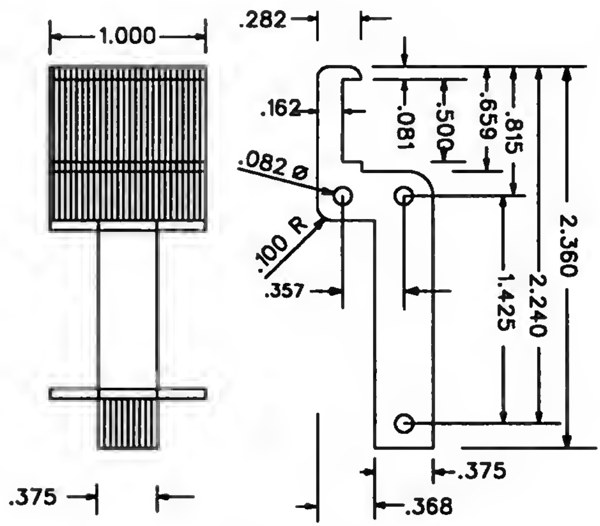


Fig. 107 LAMINATION DIAGRAM

The second version consists of only the “head” of the question mark shaped lamination. Only the Head can be stamped by inserting the proper width of sheet in the die set or the “tail” can be cut off of the first version.

The mounting holes must be punched in the laminations which requires a second, third and fourth "station" or operation. A thicker sheet of brass can be stamped with the die set, fixed down and used to precisely locate each lamination under the .082" OD hole punch by placing the lamination inside the brass cutout.

Dimensions for the frame are shown in Fig.108. The location of the bolt holes in the laminations will probably be determined by whoever punches the laminations. Therefore the dimensions shown in Fig. 108 may be off.

To locate the holes in the base plate to accept the 2-56 lamination clamp screws, assemble the laminations inside the empty bobbins. Install the magnet between the laminated pole pieces and lay the assembly on the frame.

Spot through the holes with a N0.46 drill then drill No.50 and tap 2-56.

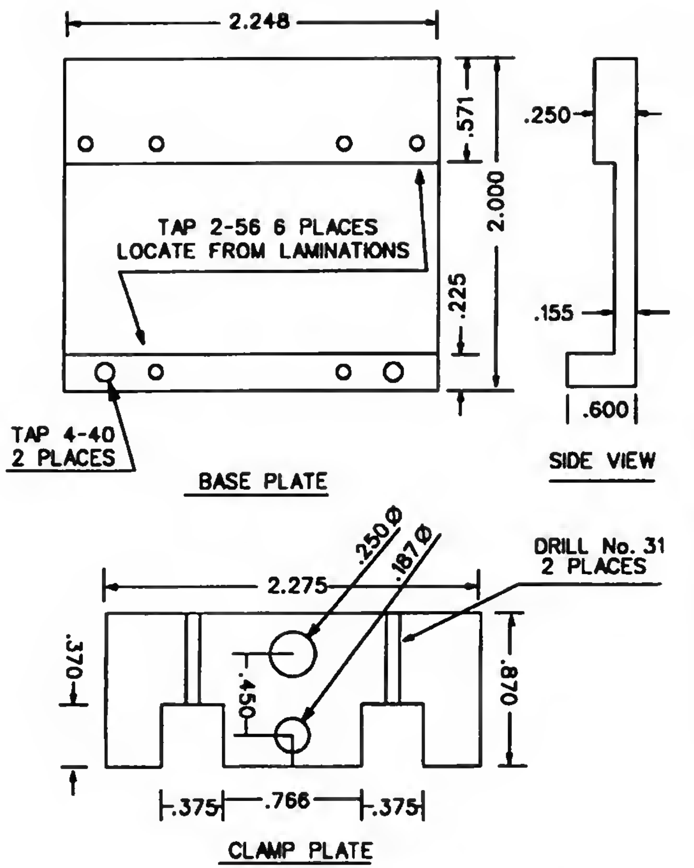


Fig. 108 FRAME DIAMENSIONS

The bar that clamps the laminations into the frame and supports the guide pin is shown in Fig.109. The guide pin for the armature assembly is pressed squarely into the bar. The guide pin must be square with the laminations to ensure that the armature pulls away from both legs simultaneously. The bar is also drilled and reamed to accept the 1/4" brass tube that holds the plunger and contacts.

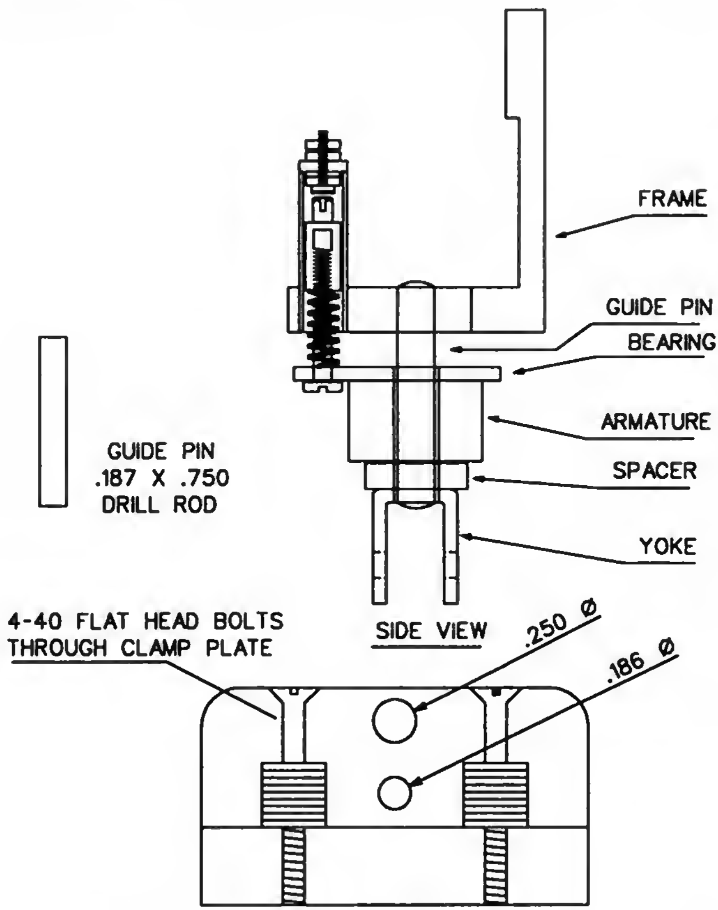


Fig. 109

The breaker contacts are built around a short length of 1/4" brass tube. A small disc is soldered into the end of the tube then drilled to accept the two insulating washers. A slot is cut across the tube for easy cleaning and visual adjustment of the contacts.

The plunger is machined from cold rolled steel for an easy sliding fit within the brass tube. A tungsten rivet is pressed in the end of the plunger to mate with a similar rivet pressed into the head of a 4/40 bolt. The bolt serves as the fixed isolated contact and terminal post.

A spring is employed to hold the contacts firmly together until the armature has moved the required distance (about 1/8") before separating the contacts.

Fig.110 shows the general assembly.

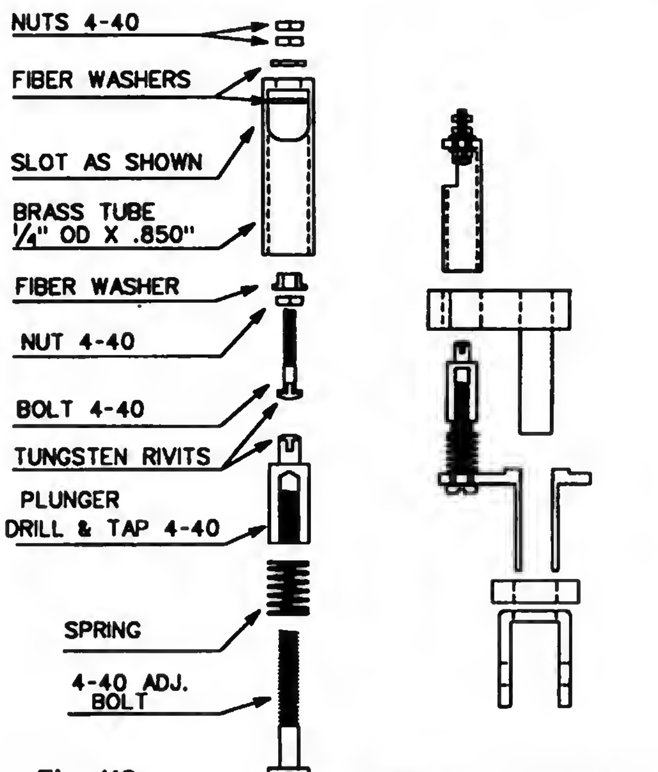


Fig. 110 BREAKER CONTACTS

The armature, spacer and yoke are assembled on the armature bearing and the end of the bearing is swaged to retain the parts.The dimensions are shown in Fig.111. All parts are machined from cold rolled steel except the armature. The armature can be machined from cast iron rather than laminated, with little loss of flux.

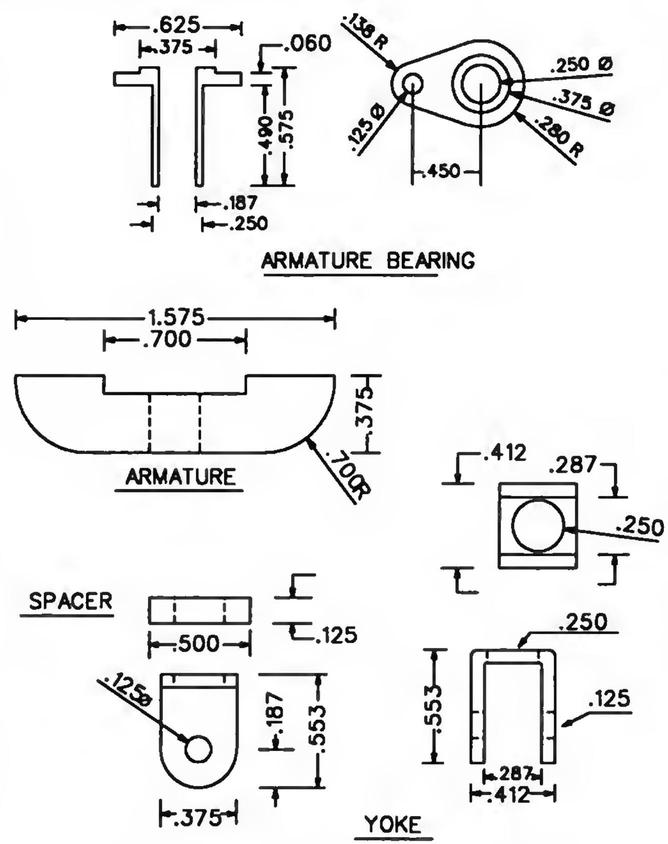


Fig. 111 ARMATURE COMPONENTS

Fig.112 shows bobbin detail. The bobbins are machined from Delrin.

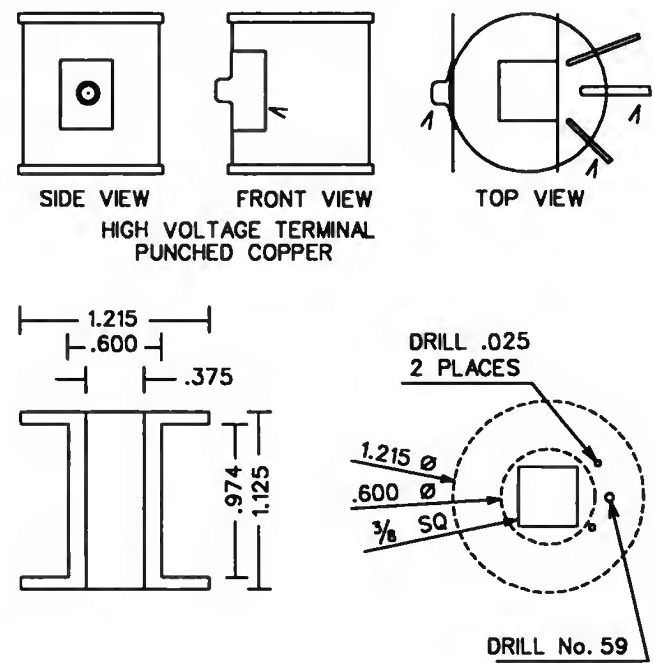


Fig. 112 DELRIN BOBBIN

Three holes are drilled in one cheek as shown to bring out the primary wires and the stranded wire that is the start of the secondary. The coil is finished with two or three wraps of paper, bringing the No.44 to the center, then up through a hole in the copper terminal.

The terminal is glued to the paper then one and a quarter turn of thin adhesive tape is placed on each side of the terminal. The No. 44 is soldered (with slack inside the terminal) and trimmed. Cut a hole in a strip of tape to fit over the copper button. The length of this third piece of tape should be one and a half turns.

Glue the ends of the tape with cyano acrylic glue so that the tape will not come loose during the impregnation process. Impregnate the coils with wax as described in chapter 11.

To ensure that the primary windings are properly phased, connect a milliampmeter to one wire of each coil. Temporarily connect the remaining two coil wires together. Move the armature away from the laminations and observe how far the indicating pointer on the meter moves. Reverse the wires of one coil and make another observation. The connection that provides maximum pointer deflection is the correct connection.

Anyone attempting to build this magneto should obtain or borrow a full sized Wico EK type magneto and examine it closely. Also, familiarize yourself with the different mechanical methods of actuating the magneto. There is at least one small book available on the Wico that shows the mechanical setup. This type magneto should be tripped with a spring for fast separation of the armature and cores.

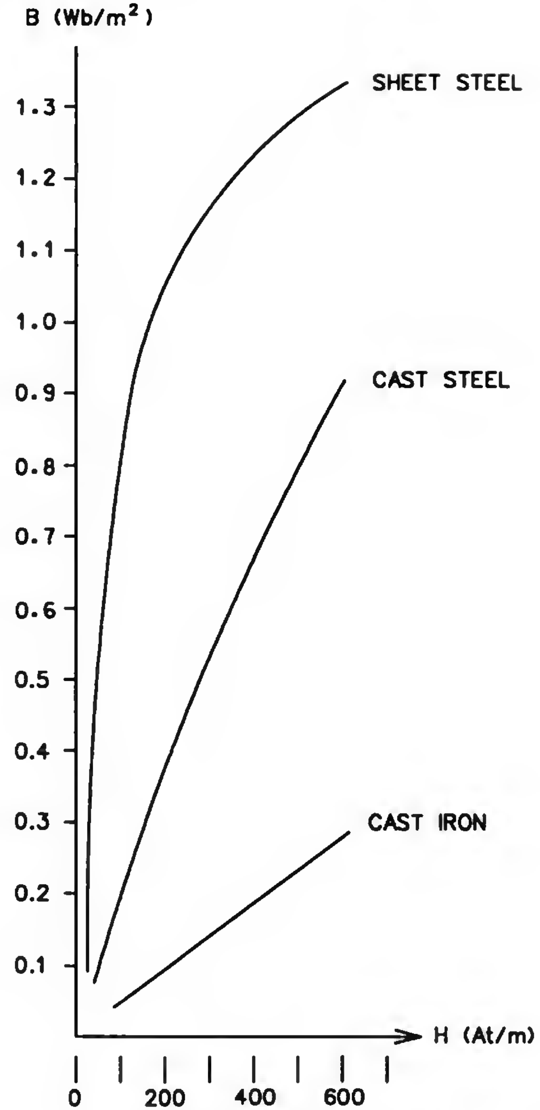
The impulse magneto is not known to produce a good hot spark similar to an ignition coil, therefore the plug gap may be reduced. The Bosh will produce a spark that is about 3/16" long.

A variation in construction is to install the socket head capscrews from the back side of the base plate. In this case the holes are counter drilled from the back side and the clamp bars are threaded.

Vary the number of short laminations on the back side to shim the assembly true to the base.

THIS PAGE IS BLANK

but this is not a printing or scanning fault and no content is missing.



NORMAL MAGNETIZATION CURVE

MAGNET MATERIAL	MAXIMUM ENERGY PRODUCT	RESIDUAL INDUCTION BR	MAXIMUM OPERATING TEMPERATURE	RELATIVE COST
	BH (MAX)	GAUSS	°F	SCALE 1-10
CERAMIC MATERIAL				
CERAMIC 1	1.0	2300	842	1.5
CERAMIC 5	3.4	3800	842	1.5
CERAMIC 8	3.5	3850	842	1.5
ANISOTROPIC ALNICO				
ALNICO 5	3.9	10900	975	3.75
ALNICO 8	4.0	7400	1020	3.75
ALNICO 8 (CAST)	5.3	8200	1020	3.75
ALNICO 5 (CAST)	5.5	12800	975	3.75
RARE EARTH MATERIAL				
SmCo 18	18.0	8700	500	9.5
SmCo 20	20.0	9000	842	9.5
SmCo 24	24.0	10200	572	9.5
SmCo 26	26.0	10500	660	9.5
NEODYMIUM 27	27.0	10800	212	7.0
NEODYMIUM 27H	27.0	10800	212	7.0
NEODYMIUM 30	30.0	11000	212	7.0
NEODYMIUM 30H	30.0	11000	212	7.0
NEODYMIUM 35	35.0	12300	212	7.0
NEODYMIUM 40	40.0	12300	302	7.0
NEODYMIUM 42H	42.0	13300	240	10
NEODYMIUM 45	45.0	13500	250	9.5

SIZE AWG	DIAM. INCH	OHMS PER INCH	OHMS PER FOOT	TURNS PER LINEAR INCH
24	.02010	.0022	.0267	46.3
25	.01790	.0028	.0336	51.7
26	.01594	.0035	.0424	58.0
27	.01420	.0044	.0535	64.9
28	.01264	.0056	.0675	72.7
29	.01126	.0070	.0851	81.6
30	.01003	.0089	.0172	90.5
31	.008928	.0112	.1353	101
32	.007950	.0142	.1707	120
33	.007080	.0179	.2152	140
34	.006305	.0226	.2714	164
35	.005615	.0285	.3422	175
36	.005000	.0359	.4316	198
37	.004453	.0453	.5441	225
38	.003965	.0571	.6863	250
39	.003531	.0721	.8654	280
40	.003145	.0909	1.099	320
41	.0028	.1146	1.3762	352
42	.0025	.1438	1.7264	348
43	.00222	.1824	2.1893	365
44	.00198	.2293	2.7522	390
45	.00176	.2902	3.4833	520
46	.00157	.3647	4.3774	565
47	.00140	.4587	5.5051	624
48	.00124	.5847	7.0174	750
49	.00111	.7297	8.7574	825
50	.00099	.9174	11.009	900

WIRE DATA

USEFUL INFORMATION

Amperes X turns = Ampere Turns
Amperes X Resistance = Voltage
Area = 3.1416 X Radius squared
Area = Diameter squared X .7854
Centi = hundredth
Centigrade X 1.8 plus 32 = Fahrenheit
Centimeters X .3937 = Inches
Centimeters divided by 2.554 = Inches
Circumference = Diameter X 3.1416
Cubic inches X .061 = Cubic Centimeters
Current = Voltage/Resistance
Current X Resistance = Voltage
Current X Voltage = Watts
Current = Watts/Voltage
Deca = ten
Deci = tenth
Fahrenheit - 32 divided by 1.8 = Centigrade
Grams per square centimeter X .03613 = PSI
Grams X .0022 = Pounds ecto = hundred P = Watts/746
Inches X 2.54 = Centimeters
Inches X 25.4 = Millimeters
Kilo = thousand
Kilograms X 2.2046 = Pounds
Kilograms X 35.3 = ounces
Milli = thousandth Millimeters X .03937 = Inches
Millimeters divided by 25.4 = Inches
Myria = ten thousand
Pounds X 453.6 = Grams
Pounds X .4536 = Kilograms
PSI divided by .03613 = Grams per square Centimeter
Resistance = Voltage/Current
Voltage = Current X Resistance
Voltage divided by Resistance = Current
Volts X Amperes = Watts

• • • SOURCES OF SUPPLY • • •

ADAMS MAGNETIC PRODUCTS.........................Magnets
155 Matta Way, Suite 105
San Marcos, Ca. 92069 1-800-521-4773

AERO ELECTRIC....................................Tungsten rivets
3706 N 33rd
Galesburg, MI 49053
616-665-9693

ARGO-USA.............................Spark plugs, Ignition Coils,
Condensers. Request Catalog.
3229 Dianora Drive,
Palos Verdes Peninsula
Ca.,90275, 310-377-6186

BUNTING MAGNETICS COMPANY.....Magnets
Min. order 40.00
1150 Howard St.
Elk Grove Village, Il. 60007
1-800-284-5012

C and H SALES COMPANY ....Coil winder motor.
Stock No.DCMTG8401
2176 Colorado Blvd.
Pasadena, CA 91107-9988
213-681-4925

COLES POWER MODELS.....Casting kits (Steam & Gas),
tools, metal, plugs.
Request catalog.
Box 788,
Ventura Ca. 93001
805-643-7065

• • • SOURCES OF SUPPLY • • •

DABURN ELECTRONICS and CABLE CO................Small quantities of magnet wire.

224 Pegasus Ave.
Northvale, NJ 07647
201-768-5400

DIGI-KEY CORPORATION..................Condensers, LED's, Wire, Resistors, Lamps

701 Brooks Ave. S.,
Thief River Falls,MN 56701
1-800-344-4539

MAGNET SALES & MANUFACTURING INC. ....Magnets Nice Catalog

11248 Playa Court
Culver City, Ca 90230-6162
1-800-4421-6692

MAIMI MAGNET COMPANY (preferred vendor) Magnets Min. Order $30.00

6073 N.W. 167th St. Suite C-26
Miami, Fl. 33015-4330
1-800-222-0641

MINIMAG CO...............................Miniature magneto kit, Alcomax magnet ground and magnetized, Spark Demon ignition coil.

358 Birmingham Rd,
Walsall, West Midlands,
WS5 3NX, England.

• • • SOURCES OF SUPPLY • • •

MODELECTRIC..Ignition coils.
23 Cindy Lane
Asbury Park, NJ 07712
908-493-8585

POWER MODEL SUPPLY CO. ....Steam-Gas castings & supplies.
Rt.1 Box 177
De Soto Mo. 63020

SMALL PARTS INC................................Tools, Hardware, Supplies, Etc,.
Request Catalog.(352 pages)
Excellent catalog and service.
13980 N.W. 58th Court,
P.O. Box 4650,
Miami Lakes Fl. 33014-0650
1-800-220-4242

W. M. BERG INC....................Gears-precision mechanical components.
499 Ocean Ave.,
East Rockaway, NY, 11518
516-596-1700

AC

Alternating Current. A flow of charge that is continually changing in magnitude and direction. A current that continuously reverses its direction during a specific period of time. Also infers an alternating voltage.

AIR GAP TRANSFORMER,

A transformer in which the core is not a continuous circular metallic path.

AMMETER,

An electrical instrument that displays the amount of amperes flowing in a circuit.

AMPS,

An abbreviation for amperes.

AMPERE,

The movement of a specific amount of charge or free electrons. The flow of 6.242 x 10 18 free electrons, at a uniform velocity, in one second, past a given point in a circuit.

AMPERE TURNS,

Ampere turns is the product of the number of turns and the current in amperes, used to describe the relative magnitude of the magnetomotive force in a magnetic circuit. The magnetomotive force, or mmf (corresponding to emf in electric circuits), is proportional to the magnitude of the current, I, and to the number of turns, N, in the coil. The mmf remains the same for the coils of the same physical size regardless of the current value, if the product of I X N remains constant. Thus F = I X N. There are 1.257 gilberts per ampere turn. (A gilbert is the magnetic force between two points I cm apart in a unit magnetic field.)

ANISOTROPIC,

Orientated. The material has a preferred direction of magnetic orientation.

ARC,

The flow of electrons, or current, across a gap between two conductors.

ATOM,

A tiny particle. The smallest part of an element that can exist alone or in combination.

AWG,

American Wire Gauge. A system of wire sizes.

BATTERY,

A single cell that furnishes electrical current. A battery of such cells.

BOBBIN,

A small round device similar to a cylinder, spindle or reel on which wire or thread is wound.

BREAKER,

A set of electrical contacts arraigned to close or open an electrical circuit. A pair of metallic contacts arraigned to quickly interrupt the flow of current by automatic, manual or mechanical operation.

BREAKER CONTACTS,

The electrical contact points used in a breaker.

CAPACITOR,

An improper name for a condenser. Vulgar terminology.

CAPACITY,

The unit of capacity, for condensers, is the Farad, which is the capacity of a condenser whose voltage is raised one volt when one coulomb of electricity is added to it. Because the Farad is a very large unit the microfarad, mfd., (one millionth of a farad), and the micro-microfarad, mmf., (one million millionth farad) is used.

CAPACITANCE,

The property of an electric nonconductor that permits the storage of energy (free electrons) as a result of electric displacement when opposite surfaces of the nonconductor are maintained at a difference of potential. The quantity of charge (Q) of a condenser is equal to the capacity (C) in farads, multiplied by the applied voltage (E). Q denotes coulombs. One ampere is a current flow of one coulomb per second. A coulomb is the electric charge of 6.25 X 10 18 electrons. Another formula, rarely used in practice, to determine the charge of a condenser is W = 1/2 C E2. In this formula the energy, W, is expressed in joules. This unit is rarely found in practice; it is defined as the energy expended in passing one coulomb through one ohm of resistance. If one coulomb per second passes through one ohm, this fact can be stated by saying that one ampere passes through one ohm, which is one watt (I2R), or by saying that one joule per second is the power (power equals energy-units per second). This shows that one watt equals one joule per second. It follows that one watthour equals 3600 joules. The formula could also be written as W = 1/2 Q E; this shows, as might be expected, that the energy is proportional to the quantity of charge, and to the pressure or voltage at which it is stored.

CHARGE,

A quantity of free electrons. Usually a vast number of free electrons that have been forced onto or into a small space or area.

CHEEK,

The flanged end of a cylinder. The thin, large diameter cylinder, at each end of a cylinder.

CIRCUIT,

A metallic path that conducts the flow of free electrons.

COERCIVE FORCE,

The demagnetizing force, in orsteds, required to reduce the residual induction, Br, of a fully magnetized magnet to zero.

COIL,

Wire that has been wound around a mandrel or form to produce a spiral. A coil can be one or many such wraps of wire.

CONDENSER,

A device consisting of two or more plates or foils separated by a thin layer of insulation. The plates are used to temporarily store a charge of electrons.

CONDUCTIVITY,

The conductivity of a material is defined as the ratio of current per unit cross-section (amperes per square centimeter) to the emf per unit length which produces the current. It is the reciprocal of resistivity. Experiments have shown that silver has the highest conductivity of any substance; that is, if the same voltage is applied to two conductors having identical dimensions, one of silver and the other of any substance, more current will flow in the silver one. Six common conductors, in order of conductance are; silver, copper, gold, aluminum, zinc and platinum.

CONDUCTOR,

Materiels that permit a generous flow of free electrons with very little electromotive force applied. Copper is the standard. Aluminum has 61% of the conductivity of copper. The resistance of a Conductor is influenced by four main factors; cross- sectional area, length, material and temperature. If the diameter of a conductor is doubled, the resistance will become one quarter of the original value. The resistance of a conductor varies inversely with the cross-sectional area of the conductor. Thus, any increase in the area will decrease the resistance. However, the area varies as the square of the diameter. If the diameter is doubled, the area will be increased by four times. Since the area is four times greater, then the resistance is now four times less, or equal to one-quarter of the original value.

CONTACTS,

Two or more spherically shaped pieces of metal that are mechanically arraigned to come together and permit the flow of current or to move apart and cease the flow of current.

COPPER ATOM,

The smallest piece of a common reddish metallic element that is ductile and malleable and one of the best conductors of electricity and heat.

CORE,

A mass of iron serving to concentrate and intensify the magnetic field resulting from the current in a surrounding coil. The center part. Typically composed of stacked laminations.

COULOMB,

A measurement of quantity. A coulomb is the charge of electricity which passes a given point in one second when a current of one ampere is flowing.

CURRENT,

The flow of free electrons along a conductor.

DC,

Direct current. A current that flows in one direction only.

DIELECTRIC,

A nonconductor of electric current.

EDDY CURRENT,

A current which is induced in the body of a conducting mass by a variation of magnetic flux.

ELECTRIC CURRENT,

This term is also expressed as "electron flow", "electron drift" and "amperage" is sometimes used. The term "current flow" is not particularly definite as to the direction of the flow or to the polarity of the charges in motion. So-called "conventional current" assumes positive charges to be in motion and the direction, externally of the generator, is from + to -. On the other hand, the terms "electron flow" or "electron drift" are quite definite. In this case, the moving particles are negative charges and the direction, externally of the generator, is from - to +. "Electron flow" is applied most correctly in such cases as vacuum tubes, while the term "electron drift" would more aptly describe the motion of electrons in a solid conductor.

ELECTRICITY,

The movement or potential movement of free electrons from a point of excess (charged(high voltage)) to a point of deficiency (discharged(low voltage))

ELECTRON,

An electron is a minute subdivision of matter having the smallest known unit of a negative electric charge. Electrons are ordinarily found as an essential part of the structure of the atom; they are about 1/2000 as massive as the smallest atom. Electrons, having like charges, repel each other.

ENERGY,

The capacity to do work.

FARAD.

A unit of measurement of electrical capacity. One farad is the capacity which will store one coulomb (6.25 X 10 18 free electrons) of electricity when one volt appears across it. The farad is too large a unit for practical use, and the microfarad, mf., (one millionth of a farad) is commonly used.

FIELD INTENSITY,

The formula for the field intensity of a solenoid is H = 0.4 X 3.14 X N X I divided by L. Where H equals field strength in orsteds, N equals number of turns, I equals current, and L equals length of solenoid.

FREE ELECTRON,

In any substance, the outer ring of electrons of an atom of that substance determines its electrical characteristics. If the outer ring is lightly bound to the atom, it is possible that one or more electrons in the outer ring will leave the atom without much urging from an external source. Such an electron is called a "free" or conduction electron. If many of these electrons are present within a substance, their movement under an applied emf constitutes an electric current, and the substance is then a good conductor. On the other hand, if there are very few of these free electrons, the current will be extremely small; in such a case, the substance is called an insulator or nonconductor.

FREQUENCY,

The number of vibrations or oscillations that occur in a specific period of time. FLANGE, A thin circular disk at the end of a cylinder.

FLUX,

Invisible magnetic lines of force that exist around a magnet. Magnetic lines of force established by passing a current through a coil of wire.

FLUX DENSITY,

The number of magnetic lines of force that exists in a defined area. GAUSS, Unit of measure of magnetic induction, B, or flux density.

GAUSS,

Unit of measure of magnetic induction, B, or flux density.

HENRY,

A unit of measure of inductance. A Henry is defined as the amount of inductance across which one volt of counter emf will be developed if the current through it is changing at the rate of one ampere per second. A millihenry equals one-thousandth of a henry and a microhenry equals one-millionth of a henry.

HYSTERESIS,

Magnetic hysteresis is a property of magnetic material by virtue of which the magnetic flux density corresponding to a given magnetizing force (gilberts, ampere-turns) depends on the previous conditions of magnetization. The effect of hysteresis, when the field is alternating, is an energy loss appearing as heat in the material.

IGNITION,

To establish a fire. To initiate the process of combustion.

IGNITION COIL,

An air gap transformer operated with an interrupted DC primary winding that induces a short burst of high voltage a-c in its secondary winding. Used to ignite the fuel mixture in gasoline engines.

IGNITION TRANSFORMER,

Typically, a transformer with a 120/240 vac primary and a 20kva-c secondary that is used to ignite fuel in a burner or furnace. I

INDUCTOR,

A coil that is wound to have a specific amount of inductance.

INDUCTANCE,

Inductance is the property which tends to resist a change of the current flowing in a wire or coil. The resistance is due to a counter voltage developed by the changing current. When the current is increasing, the increasing magnetic field induces a voltage in the conductor or coils, opposed to the applied voltage, which tends to decrease the current. When the current decreases, the opposite effect occurs. The induced voltage, which opposes the applied voltage, is called the counter-electromotive force (cemf). The unit of inductance is the henry. One millihenry is one-thousandth of a henry and one microhenry is one-millionth of a henry.

INSULATOR,

A material that has very few free electrons, high stability and density, and low mobility.

INSULATION,

A material that is used to separate or isolate electrical conductors or components.

INTERLEAVING,

Alternate layering of different materiels.

INTRINSIC COERCIVE FORCE,

A measurement, in orsteds, of the materials inherent ability to resist self demagnetization. ION, An ion is an atom or a chemical group of atoms, having either an excess or a deficiency of electrons. Ions are commonly thought of as being positive in an electric circuit. Here it is usually a case of an atom being struck be a moving electron, the impact liberating one or more of the free electrons from the atom. This leaves the atom with a net positive charge and it is then called a positive ion. There are also negative ions, which are atoms containing an excess number of electrons. These negative ions are more commonly found in electrolyte solutions.

ISOTROPIC,

Non-orientated. The material has no preferred direction of magnetic orientation, which allows magnetization in any direction. JOULES, An absolute unit of work or energy.

LAMINATION,

A thin plate or sheet.

LED,

Light Emitting Diode. A low power lamp available in red, yellow, green, blue and clear colors. Luck, When preparation meets opportunity.

MAGNET,

A body having the property of attracting iron and producing a magnetic field external to itself. A mass of iron, steel or alloy that has this property artificially imparted.

MAGNET WIRE,

Copper wire that has a very thin coating of varnish or other similar insulation.

MAGNETIC CIRCUIT,
An arrangement of metals or alloys that will conduct magnetic lines of force.

MAGNETIC FIELD,
The portion of space near a magnetic body or a current carrying body in which the forces due to the body can be detected. An area filled with invisible magnetic lines of force.

MAGNETIC INDUCTION,
Symbol B. Flux per unit area of a section normal to the direction of the magnetic path. Measured in gauss.

MAGNETIZED,
A mass of iron, steel or alloy that has been subjected to a very strong magnetic field and has retained the properties of a magnet.

MAGNETO,
An alternator with permanent magnets used to generate current for the ignition of an internal combustion engine.

MAGNETOMOTIVE FORCE,
A force that is the cause of a flux or magnetic induction. Expressed as ampere-turns. Abbreviated as mmf.

MAXWELLS,
A unit measurement of magnetic flux that is equal to the flux per square centimeter of normal cross section in a region where the magnetic induction is one gauss.

MICROFARAD,
One millionth of a farad.

MICRO-MICROFARAD,
One million millionth of a farad.

MOLECULE,

The smallest particle of a substance that retains the properties of that substance and is composed of one or more atoms.

NEGATIVE,

Denoting the absence of something. Of, or related to, or charged with electricity of which the electron is the elementary unit.

NORTH POLE,

The north geographical pole of the earth is actually the magnetic south pole. Therefore, the needle of a compass which points toward the north geographical pole is a north magnetic pole. The magnetic lines of force within a coil are parallel to the axis of the coil. The compass needle is itself a bar magnet and will become aligned with the magnetic lines of force, pointing to the north pole of the coil. If the compass were held outside of the coil the needle would point to the south pole of the coil.

NUCLEUS,

The positively charged central portion of an atom that comprises nearly all of its atomic mass and that consist of protons and neutrons.

OSCILLATE,

To vibrate or move back and forth.

OHM,

A specific amount of resistance. The resistance through which one volt will force one ampere of current to flow. The resistance of a circuit, in Ohms, is found by dividing the voltage by the current.

OHMS LAW,

A mathematical expression based upon: Effect = Cause/ Opposition. A formula used to determine any one of three electrical variables when two are known. $I=E/R$ $E=IxR$ $R=E/I$

PEAK VOLTAGE,
The highest voltage or charge.

PERMEABILITY,
Permeability is the ratio of magnetic flux density in a substance to the field strength which produces it.

POSITIVE,
Charged with electricity of which the proton is the elementary unit.

POTENTIAL,
Something that can develop or become actual.

POTENTIAL DIFFERENCE,
The voltage difference between two points that represents the work involved or the energy released in the transfer of a unit quantity of free electrons from one point to the other.

POWER,
The time rate at which work is done or energy emitted or transferred.

PRIMARY,
The first in the order of development.

PRIMARY COIL,
The coil in which the inducing current passes in an induction coil or transformer.

PROTON,
An elementary particle that carries a positive charge.

RELUCTANCE,
The opposition offered by a magnetic substance to magnetic flux. The ratio of the magnetic potential difference to the corresponding flux.

RESIDUAL INDUCTION,

Symbol Br. Flux density, measured in gauss, of a magnetic materialGlossaryGlossary after being fully magnetized in a closed circuit.

RESIDUAL MAGNETISM,

The magnetic force which remains in a substance after the original magnetizing force has been removed. The ability of metal (particularly iron and steel) to have residual magnetism is called "retentivity". Soft iron has low retentivity or relatively weak residual magnetic force. On the other hand, certain hard steels have very high retentivity or relatively strong residual fields.

RESISTANCE,

The opposition to the flow of free electrons in a conductor or circuit. The opposition is due to collisions between electrons and between electrons and other atoms in the conductors which converts electrical energy into heat. See Ohms.

RESONANCE,

Vibrations of large amplitude in a mechanical or electrical system caused by a relatively small periodic stimulus of the same or nearly the same period as the natural vibration of the system.

RHEOSTAT,

A variable resistance for varying the flow of current.

SATURATE,

To fill completely. To furnish or charge to the point where no more can be absorbed.

SECONDARY,

Immediately derived from something original or primary. Relating to the induced current, or its circuit in an induction coil or transformer.

SINE WAVE,

A graphic representation of time/event. A drawing or scope trace that represents periodic oscillations in which the amplitude of displacement at each point is proportional to the sine of the phase angle of the displacement and that is visualized as a sine curve. A graphic drawing of the rotation of machinery or the oscillation of current flow.

SOLENOID,

A coil of wire commonly in the form of a long cylinder that when carrying a current resembles a bar magnet so that a movable core is drawn into the energized coil.

SPARKS,

A luminous disruptive discharge of very short duration between two conductors. Sometimes followed by smoke.

SWITCH,

Two or more contacts mechanically arraigned to come together (On position) or to move apart (Off position).

TERMINAL,

A common point, connection or junction point in a circuit.

TIME CONSTANT,

The time constant, for condensers is the length of time (in seconds) required for the condenser to attain a voltage across its terminals equal to 63.2% of the applied voltage. The time constant may also be defined as the time required for a condenser to discharge 63.2% of the original condenser charge. (The remaining charge at the end of one time constant is therefore 36.8%.) In each succeeding time constant, the charge in the condenser will again change (charge or discharge) by 63.2%. For all practical purposes, a condenser is considered fully charged or discharged in five time constants. The time constant T = R X C sec, where R is the resistance in ohms , C is the capacity in farads, and T is the time in microseconds.

TRANSFORMER,

A device employing the principal of mutual induction to convert variations of current in a primary circuit into variations of voltage and current in a secondary circuit. Typically, two or more windings of wire around an iron core. A transformer requires a changing current through its windings, which sets up changing magnetic flux. D-c current cannot satisfy this requirement. If d-c current is periodically interrupted by some mechanical means, such as a vibrator, commutator or contacts, it will then be possible to use an original d-c voltage source with a transformer. This is the principle used in ignition coils. The rising and falling current through the primary induces an a-c voltage in the secondary of the transformer.

TURNS RATIO,

The number of turns of wire on the secondary divided be the number of turns on the primary.

VOLT,

A specific amount of pressure, charge or Accumulation of free electrons. A potential difference between two points. A difference of 1 volt will exist between two points if 1 joule of energy is expended moving 1 coulomb of charge between the two points.The amount of electrical pressure or potential that will force one ampere through a resistance of one Ohm.

VOLTAGE,

Electrical pressure that will force current through a conductor. Other common expressions are: electromotive force, difference of potential, voltage drop, IR drop. The terms “voltage” and “electromotive force” usually apply to a source of electrical energy: e.g., the terms “generator voltage or emf” and “battery voltage or emf.” On the other hand, the terms “IR drop” and “voltage drop” usually apply to a circuit or portion of a circuit to which the voltage is applied. The voltage applied to a circuit can be found by multiplying the current (in amperes) by the resistance (in Ohms).

WATT,

A unit of electrical power. One watt is the amount of energy dissipated due to a current of one ampere flowing through a resistance of one ohm. One watt equals one joule per second. One watthour equals 3600 joules. 750 watts equal one horsepower.

WEBERS,

A unit of magnetic flux equal to that flux which in linking a circuit of one turn produces in it an electromotive force of one volt as the flux is reduced to zero at a uniform rate of one ampere per second.

WIRE,

Metal in the form of a thread or slender rod.

I sincerely hope this book has been of some benefit to you an that it is a welcome addition to your library.

The prospect of producing an expanded fourth version of this book is being entertained, therefore, comments, criticism, contributions and any suggestions concerning this work are not only welcome, but also encouraged.

I would be interested in corresponding with anyone that has built a miniature ignition coil or magneto. If you would like to contribute text, drawings, reprints, data, helpful hints, techniques or sources of supply, to be shared by other readers, credit will certainly be given if desired.

Please address all correspondence to:

Bob Shores
108 Carmelina St
Ruskin FL 33570
813-645-8322