GASOLINE ENGINE IGNITION

BY

E. J. WILLIAMS

GASOLINE ENGINE IGNITION

BY

E. J. WILLIAMS

CINCINNATI
The Gas Engine Publishing Co.
BLYMYER BUILDING
1906

PREFACE.

From observations made in the marine gasoline engine field, the purchaser of an outfit is usually his own operator, and with him alone rests the responsibility of understanding the different phases attendant with its successful operation. Very few books have been written which render assistance to the marine gasoline engine operator, and those few do not deal pointedly with the ignition system.

Numerous little difficulties are mastered in the general equipment, but occasionally information is wanted regarding the electrical outfit, its installation or principle of operation. With this end in view, the author has endeavored to treat this work in a simple and non-technical manner, basing its contents on the assumption that the reader is a novice in every sense to which the word implies, and trusts its perusal will meet with a favorable reception.

E. J. WILLIAMS.

CONTENTS.

CHAPTER I.

MAGNETISM.

The average person naturally understands nothing regarding electricity, and the only accessory about a gasoline engine in which he has no confidence is this particular part.

A wire, when charged with an electrical current, contains a property adverse to the natural state of the wire when not electrified. When a wire has an electrical current flowing through it, magnetic lines of force surround it to a distance consistent to the strength of the current. If the wire is wound in a circular form, in layers, forming a coil, the magnetic lines of force are increased in strength, and if wound around a bar of soft iron an additional increase is gained.

If a bar of soft iron is wound with several turns of insulated (covered) copper wire, and a current of electricity passed through the wire, either from a dynamo or battery, the bar becomes saturated with a property called magnetism, and is capable of attracting particles of steel as long as the electricity flows through the wire, and ceases immediately, when the wires are disengaged and the current flow stopped. When the bar of iron is magnetized, one end will attract steel while the other end will repel it.

Induction or jump spark coils and any electrically operated mechanism such as dynamos, magnetos, etc., are based on the principles or phenomena of electro magnetism as above stated.

A permanent magnet is a piece of special steel, stored or saturated with magnetism for an indefinite time. It will perfrom the duties of an electro magnet in many instances. Permanent magnets are utilized for the construction of magnetos, and the magnetism contained in the metal lasts generally from 5 to 10 years, according to the grade and work the magneto performs.

In order to first saturate the steel with magnetism, it is necessary to lay it on a direct current dynamo or motor, or rub it on what was originally called a load stone (another permanent magnet). When the magnetism becomes weak the same method of charging is again repeated.

Electric current requires some standard of measurement, therefore it is expressed in volts and amperes. A volt is the unit of pressure or strain, and is similar to the pressure of steam in a boiler, or air in a tank expressed in pounds.

An ampere is the unit rate of flow or amount backing up the volt, and compares with the amount drained from the above referred to boiler or air tank. If a tank or boiler had 100 pounds pressure and discharged the whole contents at once, the rate of flow would correspond to the flow from a battery on short circuit. and to discharge at a low rate for a length of time, would correspond to the drain from a battery through a coil or otherwise.

The drop in pressure during this operation corresponds to the drop in volts when using a battery.

CHAPTER II.

MAKE-AND-BREAK IGNITION.

Electrical ignition for gasoline engines is of two kinds, make-and-break and jump spark.

In mechanical make-and-break ignition a coil is utilized, through which a current of electricity is passed, the coil intensifying the current to such an extent that a very hot spark follows the terminals of the wires if they are separated or the two ends touched together and drawn apart. This action or spark is caused for a short period by the self-inductance or reaction of the current remaining in the circuit after it is broken; that is, when the terminals are separated. This spark occurs only as the wires are separated, after the current or circuit is completed through the coil, and does not occur at the time connection is made or completed.

In making use of this system of ignition in gasoline engines, a means for separating these two ends or break in the circuit is necessary, to throw the spark in the combustion chamber. To this end one electrode is made stationary, the other movable, to touch and complete the circuit and move away from the stationary electrode or terminal. The stationary member is therefore constructed in the form of a plug, insulated from the engine by a mica, or porcelain, bushing, or any non-conducting material. A sectional make-and-break plug or spark pin is shown in Figure 1.

To the point within the cylinder or explosive chamber, A, is affixed a small piece of platinum, iridium or other non-oxidizing composition. Very often steel points are used, but carbonation and oxidation are so rapid that brightening the contact points has to be resorted to very often. B shows the insulation of mica, C the casing or sleeve to screw into the firing chamber, and D the wire terminal or binding post.

It will thus be readily seen that when the plug is screwed into the cylinder, A has no communication metallically, other than with the wire and when the movable electrode comes into action. The other end or

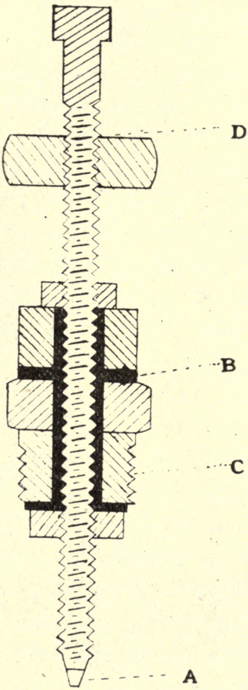


Fig. 1

wire from the battery leads to the ground, as shown in Figure 2. This movable part is mechanically actuated by eccentric, cam, gear, crank, by the movement of the piston within the cylinder or any other means possible.

In a two-cycle engine the mechanical apparatus is arranged to spark every revolution of the fly wheel, and in a four-cycle every other revolution, considering a single-cylinder engine in both instances.

The action of the system as represented in Figure 2 is as follows: The electric current from the batteries, A, is flowing through the intensity or spark coil, B, to the plug, C, in the cylinder head, through the movable electrode, E, if it touches the insulated plug, C, and returning through the ground, D, to the batteries, A, again. As the lever, F, is actuated upward by the rod, the circuit is closed by the movable electrode, E, touching the stationary electrode, C. Separating them again as the rod drops causes a spark to follow the points for a fraction of a second, which ignites the gas in the cylinder, forcing the piston on its downward stroke.

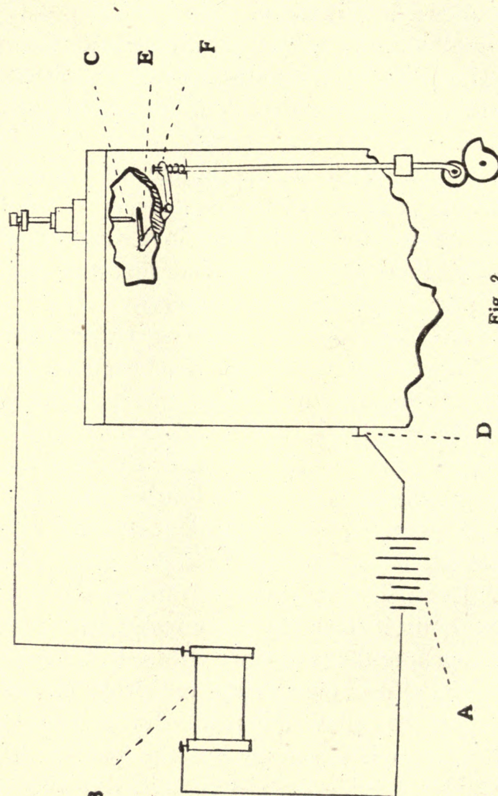


Fig. 2

The spark coil used for this system consists of a single winding of wire, in several layers; in reality, an electro magnet. A bunch of soft iron wires is tightly bound together, and a piece of wood placed over each end, thereby making a sort of spool. On this spool, around the core of soft iron wires, several layers of No. 14 or 16 wire are wound. After finishing the winding process each end of the wire is made fast to a binding post, and the whole mass dipped in molten paraffine wax and left to dry, when it is ready for use.

Different length coils are used and manufactured, varying in size from 10 inches long and 1½ inch in diameter to 4 inches long and 5 inches in diameter. It has often been claimed that the short coil and core gives the better result, because the core becomes magnetized and reacts quicker, giving a quick response to the opening and closing of the circuit, and that the long core coil lags somewhat for high speed. Whether this is ever noticeable is only a matter of conjecture and theory, as no difference can be discovered in the speed of the engine if the short coil is used, and suddenly switched over to a long coil, and when having a tachometer or revolution counter attached.

Figure 3 gives a sectional view of a make-and-break spark or intensity coil. A

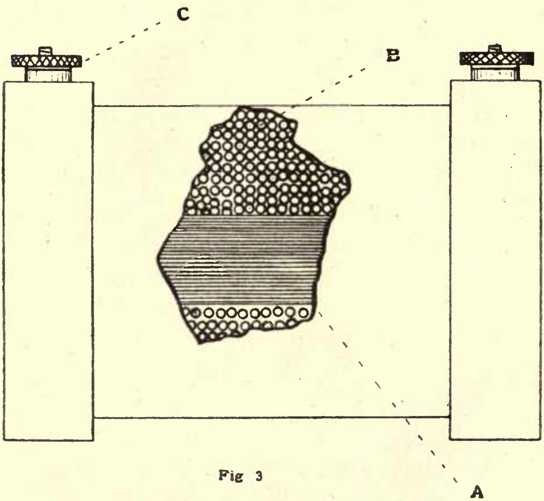


Fig 3

is the core, B the winding and C the binding posts for attaching wires. This form of coil was originally made use of, and is even utilized at the present time for electric gas lighting.

Magnetic primary igniters are now manufactured to screw into the combustion chamber, requiring no mechanical movement or attachment to operate. This form is a compact combination of both electrodes and a spark coil, although by the addition of a make-and-break spark coil into the circuit a larger and hotter spark is realized. The principle of this type is more readily understood by referring to Figure 4.

When the timer, C, such as is utilized for jump spark ignition, closes the circuit from the batteries, B, current flows through the electro magnets, A, insulated plug, G, points, E, and to the ground in the engine frame. As soon as the current magnetizes the electro magnets, A, the lever, F, is attracted by the core, D, separating the electrodes or spark points, E, causing a spark to follow their separation. Their separation breaks the circuit, causing the lever, F, to return to G, by the action of the spring, closing the circuit again at the electrodes, E. As soon as connection is made again at E, the same operation is repeated, if the timer is still closing the circuit. This operation is so rapid that a series of rapid

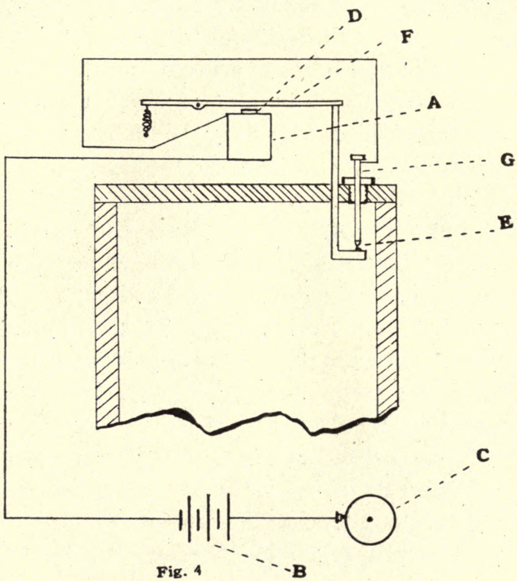


Fig. 4

sparks is made each time the engine timer closes the circuit.

Figure 5 gives a drawing of a primary spark plug in its compact form.

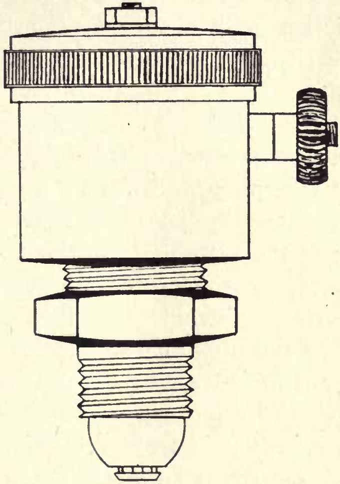


Fig. 5

SPARK ADVANCE.

The advance or retarding of the spark in the cylinder is a convenient method of speeding up or slowing down the engine. Means to advance and retard the spark while the engine is running is not found on all make-and-break spark devices. The meaning of spark advance is the occurring of the spark at an earlier part of the revolution or stroke of the piston. For example, if the spark occurred after the piston had reached its top dead center, and had started on its downward stroke, it would be called a late spark, or negative lead, or that the spark was retarded. If after the engine is running, outside means are available to cause the spark to fire the charge nearer to the piston's top center, or before it reaches its top center, on the compression stroke, it would be called advancing the spark, or that the engine had an early spark, or positive lead, and would cause the engine to speed up proportionately to the distance in the revolution the spark had advanced from its first position.

The spark advancing apparatus in make-and-break ignition is generally operated by a small lever, acting so as to trip the outside device earlier in the stroke after starting. This form is typical of the two-cycle engine with this system. On the four-cycle engine a worm gear on a separate shaft with the ignition device causes the cams, eccentrics or shaft containing this device to twist ahead of the gears thereon.

In jump spark system of ignition the spark is advanced or retarded by the movement of the case, around the cam or arm, which acts on the contacts.

The four-cycle engine behaves better with a negative lead when throttling the mixture to slow down, than the two-cycle engine does. Under such conditions with the latter, crank case or base explosions occur, which will not stop until the spark is advanced.

CHAPTER III.

JUMP SPARK IGNITION.

The jump spark system of ignition is very seldom thoroughly understood, even by persons in daily contact with gasoline engines fitted with this equipment.

If a current of electricity from a battery is passed through a wire, completing the circuit, and another wire is placed near it, without battery connection, forming another circuit, and having no metallic contact with the former, a current of induced nature will occur in the circuit without battery every time the electrified circuit is opened and closed.

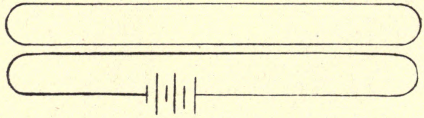


Fig. 6

Figure 6 explains the principle referred to.

To derive a strong current in the induction current, which is called the secondary, the battery circuit or primary circuit is wound in the form of a coil over a soft iron core, thereby making an electro magnet, and over the primary is wound hundreds of turns of very fine wire to make a very strong current emanate from the secondary winding. This form completed thus far is called an induction coil or transformer, the

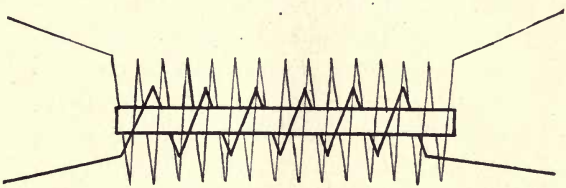


Fig. 7

principle of which is shown in Figure 7. The heavy lines are the primary, the fine lines the secondary and the straight lines from left to right the core.

The jump spark coil is a combination of an induction coil and a condenser, and with or without a vibrator. The proper name for this type of coil is Rhumkorf coil, and before its advent into the gas engine field it was used for multiple gas-lighting apparatus and experimental purposes. Present uses for which it is utilized are for X-rays and wireless telegraphy, but, of course, in very large sizes, at an expenditure of several thousand dollars each.

The only difference in the jump spark ignition coil from the original Rhumkorf coil is in its compact and water-proof arrangement.

As before mentioned, the induced current in the secondary circuit occurs only for an instant as the primary circuit is opened and closed, consequently, to produce a pulsating current in the secondary of any duration, some means must be had to automatically open and close the primary circuit. It is for this reason that a vibrator is used and operated by the magnetism in the iron core of the coil.

Figure 8 represents a vibrator, and shows the contact points for making and opening the circuit.

The principle of jump spark ignition is the jumping of the induced or secondary current across the terminals or ends of the secondary wires, called a spark gap, utilized in the form of a plug, with stationary terminals set about 1-16 inch apart. The plug, as is well known, screws into the combustion chamber of the engine to fire the charge of explosive mixture, by the spark jumping

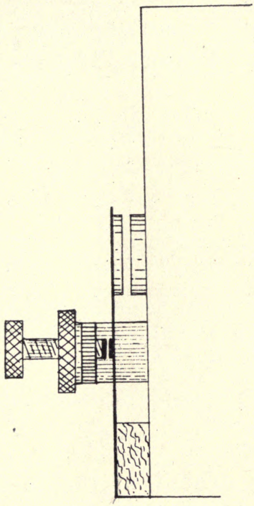


Fig. 8

across the air space between the points.

An electrical condenser, previously referred to, is an apparatus that charges and discharges itself from a galvanic or battery circuit. Without the aid of a condenser no spark would be visible at the secondary terminals. A condenser is constructed of alternate sheets of tin foil and wax paper, every odd number of sheets having a terminal connecting to one side of the vibrator, and every even numbered sheet to the other side of the vibrator. The mass of sheets

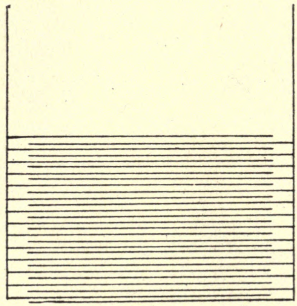


Fig. 9

is generally placed in the bottom of the coil case under the coil.

Figure 9 is a diagrammatical explanation of a condenser's construction. By this method of connecting, as the primary circuit is closed, the condenser is charged, and as the vibrator breaks the circuit, the contents are discharged, forcing the high voltage to jump across the secondary terminals at the spark plug in the form of a flame.

Without the aid of the condenser the current would also intensify through the primary winding, in the same manner as it does through the primary or make-and-break coil, causing a very large hot spark at the vibrator contacts.

Calculations have been made by a number of electrical experts that from 8,000 to 10,000 volts are required to cause the secondary current to jump across an air space of 1-16 inch. In an internal combustion engine, with the gas compressed, thereby further resisting the current, it can be readily seen that a greater voltage will be required under these conditions.

The average voltage emitting from the secondary terminals of the ordinary jump spark coil varies from 20,000 to 30,000, according to the method and care exercised in its manufacture.

Extreme care must be exercised in winding the secondary, in the insulation between primary and secondary, and in calculating the various parts. The iron entering into the construction of the core must contain great permeability and retentive power, because the voltage of the secondary winding is proportional to the amount of magnetism destroyed in the core by the opening of the primary circuit.

The construction of a jump spark coil is as follows: A soft iron core is first made by cutting a lot of No. 16 or 18 gauge iron wire into the desired length. Enough of these wires are cut to fill an iron pipe, the interior of which is the size of the desired core. After filling the pipe, both ends are plugged with clay, and the whole mass placed in a coal fire and allowed to remain there until the fire dies out and the pipe is cold. The wires are then removed from the pipe and each one wiped off to remove the oxide. They are then placed in hot water, wiped dry and each one separately coated with shellac. When thoroughly dry they are again bunched together, bound with a light piece of brass wire and held in place by a drop of solder.

This method of construction is used in the manufacture of the high price coils. In other grades of coils, the wires are bunched together without washing or shellacing, and dipped in molten paraffine wax.

Over the core is slipped a hard rubber tube, or a waxed paper mailing tube, and over the length of the tube is wound two layers of No. 18 B. & S. gauge single cotton covered magnet wire for a primary winding. This primary winding is then given a wax bath and another tube is slipped over this winding. Over this tube is slipped the secondary winding, consisting of from ½ to 1 pound of No. 36 or 38 silk covered magnet wire, in two or more sections, previously wound on a form and soaked in wax until the bubbles ceased to rise to the surface, to hold it intact and thoroughly insulate each layer. The condenser and coil are then placed in the case, the necessary connections made and the box filled with molten paraffine wax.

Cotton-covered magnet wire is often used for the secondary coil, but its insulating properties are inferior to the silk-covered wire.

In making up the condenser, attention must be given to the grade of tin foil and paper or mica, whichever is used. The

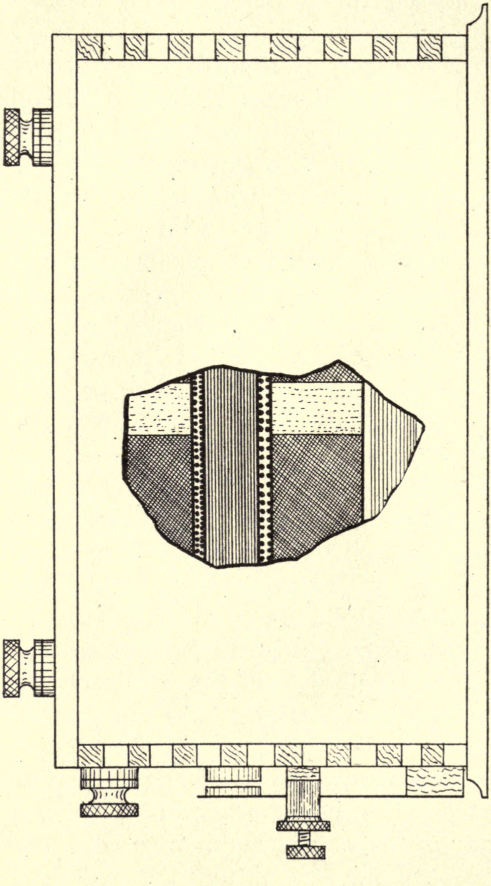


Fig. 10

latter must be free from pin holes, and perfectly dry, and the number and size of sheets of each accurately determined.

Figure 10 shows the general style of vibrating coil in use for ignition purposes, and a sectional view of the interior.

Coils are made vibrating and non-vibrating, the former having a small vibrator attached to the case, with the core of the coil protruding slightly through the end of the case, as shown in Figure 10, and non-vibrating, as its name implies, has no vibrator. Each break of the timer on the engine, when using the latter coil, produces one spark across the spark plug terminals, the same as one vibration of the vibrator on a vibrating coil.

Vibrators are in circuit with the primary winding and battery, and the vibrations per minute can be adjusted by the thumb screw contact.

In operation the action of a jump spark coil is as follows; see Figure 11:

As the primary circuit is closed by the timer, A, the condenser, B, is charged and the core, C, is magnetized, attracting the vibrator, D. When the vibrator, D, moves

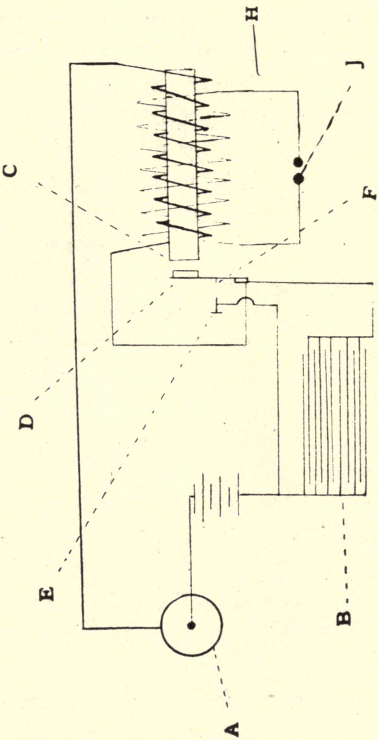


Fig. 11

toward the core, C, the circuit is broken between the thumb screw point, E, and the point, F, on the vibrator. The magnetism in the core ceases when the circuit is broken, the condenser, B, discharges, forcing a high voltage through the secondary, H, and across the points of the gap or plug, J, in the form of a spark. As soon as the circuit is broken at the vibrator, D, demagnetizing the core, C, the vibrator returns to its original position, and closes the circuit again between the contact screw, E, and the vibrator point, F, causing a repetition of the operation. This making and breaking of the circuit is very rapid, causing a series of sparks at the plug terminals as long as the timer keeps the circuit of the primary closed.

Chapter IX gives the scheme for connecting up the various coils.

SPARK PLUGS.

Generally speaking, spark plugs cause the most annoyance of any apparatus in the jump-spark system. The points become clogged with carbon, or the insulation breaks down or cracks.

Figures 12, 13 and 14 show several forms of spark plugs in use. A is a plug with central insulation of porcelain, held in position by a shoulder or enlargement in the center, set up by the gland, G. The ter-

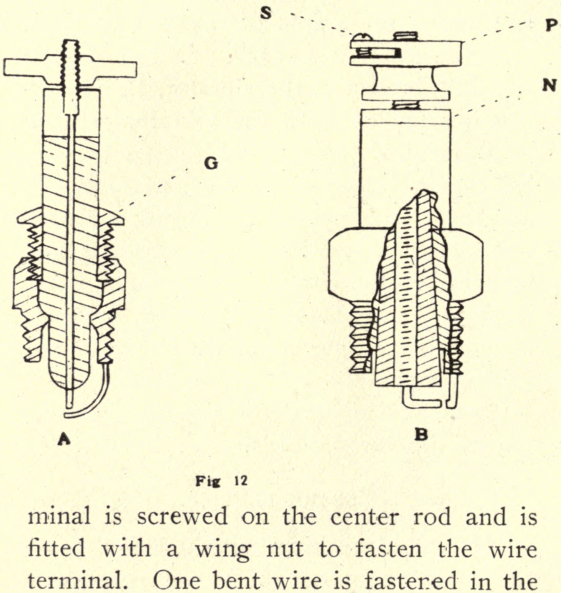


Fig 12

minal is screwed on the center rod and is fitted with a wing nut to fasten the wire terminal. One bent wire is fastened in the threaded portion or ground side, while the other bent wire is an extension of the center insulated rod.

B shows a mica insulated plug, with the mica tapered the whole length, held in place by the thumb screw set nut, N. The thumb screw binding post, P, is vibration-proof against movement by being split lon-

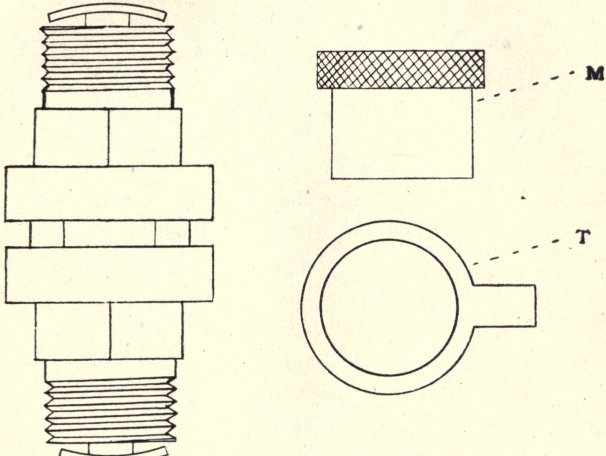


Fig. 13

gitudinally, to be drawn together by the set screw S, binding the threads of the screw head.

Figure 13 shows a mica insulated reversible plug, both ends of which are alike, and either end can be screwed into the cylinder. The end not used in the cylinder is fitted with a metal-threaded cap, M. The spark may be made to jump across both ends at once, the outside end acting as a spark gap. A wire terminal, T, is furnished with

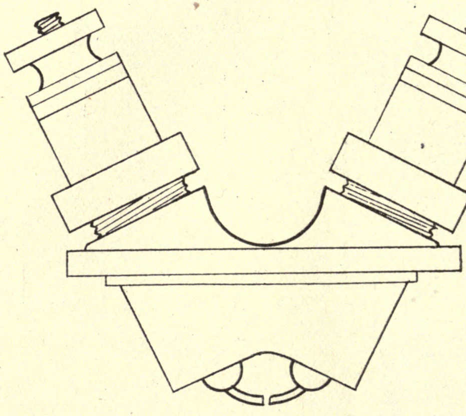


Fig. 14

each plug, and makes the connection by screwing the cap against the terminals.

Figure 14 is a two-terminal plug, and does not utilize a ground. It has a flange set up on the cylinder with bolts, and does not screw into the cylinder in the same manner as an ordinary spark plug. With the two-terminal plug both wires from the secondary of the coil are connected to the plug. With the ordinary plug one wire is grounded on the engine frame.

AUXILIARY SPARK GAPS.

A spark gap, as before mentioned, is the space between the ends or terminals of the secondary circuit. The space between the points of a spark plug is a spark gap. An auxiliary spark gap is another break or gap in the circuit leading to the plug. The auxiliary gap, unless integral with the plug, is arranged with terminals or binding posts for the wire connections. At the present time the utility of the auxiliary spark gap appears to be a matter of question. The reason of its use is the claim of its tendency to break down or prevent a soot bridge between the plug terminals, and also to permit an outside observation of each spark on a secondary wire.

For use in a cabin power boat, the open type would not be altogether exactly safe, should a gasoline leak occur while the engine was running.

Figure 15 shows a spark gap enclosed in a glass tube, which is utilized to a great extent on automobiles. At each end the

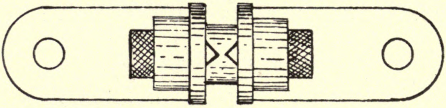


Fig. 15

holes in the case are for screwing to the woodwork at any point, and the thumb screws are for fastening the secondary wires.

TIMERS.

A timer is an apparatus generally used in connection with a jump spark coil, and is connected in the primary circuit to close the latter at the proper point in the cycle to discharge the secondary in the form of a spark across the spark plug terminals in the cylinder. Timers are also called commutators and distributers.

Figure 16 shows a timer used for closing the primary circuit of a four-cylinder jump spark coil. If the engine is a two-cycle, the timer is set on the crank shaft

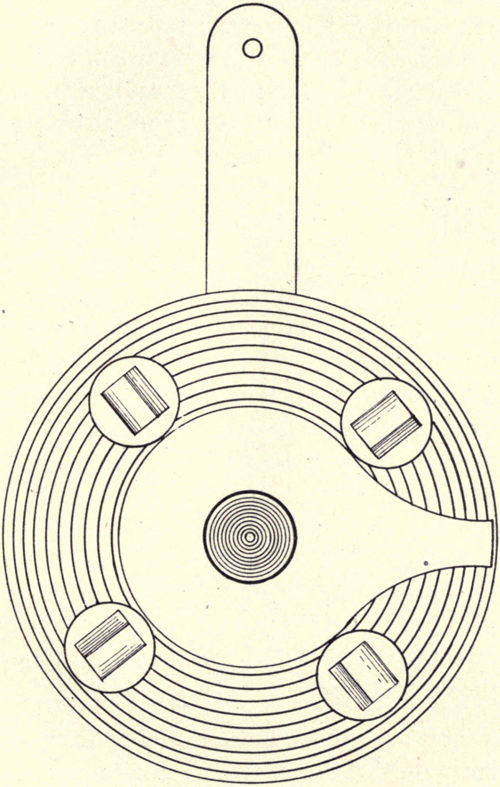


Fig. 16

or a smaller lay shaft, revolving at the same speed as the crank shaft. If the engine is of the four-cycle type, the arm of the timer is keyed on the cam shaft, which is rotated by a 2-to-1 gear; that is, the timer rotates once to the crank shaft's two revolutions.

The arm being fastened to the cam shaft, it revolves with same, touching each contact block during its course. Under each contact block a spring is arranged to allow the block to be forced down in the square socket in the center of the circle or disk, giving a friction contact between the block and rotating arm. The back of each block is metallically connected to a binding post for the primary wire connection to its respective coil. When the arm touches any contact block, a circuit is established to the ground through the arm to the engine frame, to the battery and through the primary winding and vibrator, returning to the contact block.

The arm extending upward from the back of the timer case is attached to the latter and is for attachment to a spark advancing lever, to advance or retard the spark while the engine is in operation.

Several commutators or distributers are now on the market to distribute the secondary current to more than one cylinder at the proper time, by the use of but one coil. With this style the "buzzer" or vibrator is kept in operation all the time. The strain in the coil is greater and the insulation must be perfect for this system.

Another form distributes the secondary and makes a primary contact at the same time, both forms involved in one casing.

CHAPTER IV.

BATTERIES.

There are two sources of electricity for ignition of gas engines, viz., battery and generator.

Batteries are divided into two classes, primary, which generates current by its own chemical action, and secondary, which requires a current of electricity to be turned into it for a given time, and discharges a current for a slightly less time than was occupied in charging.

PRIMARY BATTERIES.

Primary batteries are used to a greater extent than secondary batteries for ignition purposes. The dry battery, sal ammoniac and soda types are all primary, while storage or secondary are mostly made up of lead plates and diluted acid.

Dry batteries are used extensively, because of their convenience, and are practically the sal ammoniac wet battery in paste

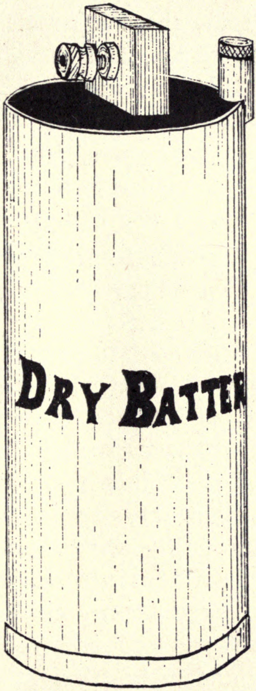


Fig. 17

form. The outside shell is the zinc element and the center connection the carbon. Chemicals are introduced in a paste or by saturating some absorbing material such as blotting paper, etc., and sealed at the top with pitch. The average size, 2½ inches by 7 inches, gives 1.30 to 1.50 volts and from 12 to 15 amperes, and larger sizes give the same voltage, but greater amperage. When a dry battery becomes exhausted it is more economical to discard it than to try some method of reviving or recharging.

SAL AMMONIAC BATTERY.

Sal ammoniac (wet) batteries, consisting of zinc, carbon and a solution of sal ammoniac can be recharged by renewing the liquid, and if zincs are extremely thin or badly eaten away, new ones can be put in. The carbon element should last indefinitely, but should a battery of this type fail to give a satisfactory current after recharging, and connections have been looked over and found to be all right, the carbon element has in all probability become clogged in the pores and requires cleaning. To do this it should be removed from the

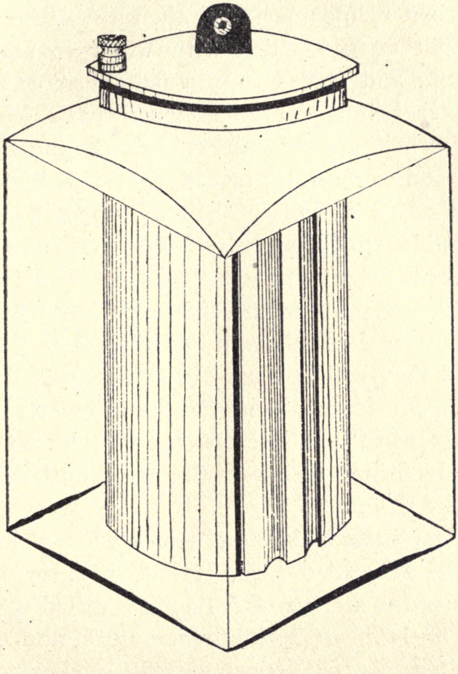


Fig. 18

Sal Ammoniac Battery.

jar, and, if it is a hollow cylinder with a small plug in the top, the contents of granulated carbon should be thrown away. The carbon cylinders should then be placed in a pot or pan, filled with water to cover them, and placed over a fire, keeping the water boiling for an hour or two. After this boiling-out process new granulated carbon should be placed in the cylinder. This will in all probability remedy the trouble, but in case it fails new carbons will have to be purchased.

When purchasing zincs for this type, have the local druggist amalgamate them, and they will be found to last a great deal longer. If salts from the liquid creep over the tops of jars, immerse the tops for about an inch in molten paraffine wax until a deposit is left.

Dry batteries and sal ammoniac wet batteries are called "open circuit" batteries because the work which they are called upon to do is of an intermittent nature, and the voltage is not constant until exhausted. After using for a short period it gradually loses its power, but if left to rest a short time it recuperates again. After running down a number of times it begins to lose its life, and the full power is not derived after recuperation.

Soda batteries are now also extensively used, and appear to give universal satisfaction for marine engine ignition, generally requiring but one charge in a season. The make-up of this type consists of a porcelain or enamel steel jar, a zinc element, a copper oxide element, a solution of soda and a heavy oil. The oil, although playing no part in the chemical action of the elements, is a very essential part. It prevents creeping of salts to the outside of the jar, and prevents evaporation.

This type of battery gives between .07 and .095 volts for ignition purposes. One valuable point of superiority is that it has no local action; that is, the elements are not consumed while not in use. The amperage of this type varies according to size from 50 to 300.

In mixing the soda solution care should be exercised not to get any of the liquid on the skin or clothes, as it is a form of acid and will burn. Very little attention is necessary after setting up, and when run down or exhausted the state of the elements can be easily determined as to whether they are in condition for another charge. Usually they will permit charging a second time, but if the zincs are thin they should be dis-

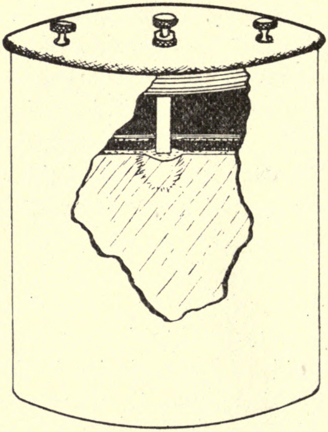


Fig. 19

carded, as it is poor economy to use an inefficient article.

To determine the condition of the copper oxide, pick into the plate with a knife or sharp instrument, and if there is a layer of black in the interior of at least half the thickness of the plate, it will give good service for another charge. If the plate is red throughout, it is entirely exhausted and is useless. Oxide plates should never be allowed to dry outside of the solution, as the result expected after replacing will not be realized on account of artificial oxidation in the air.

When connecting up a set of primary batteries, the zinc of one battery is connected to the carbon of the next until the desired number is in circuit. If batteries are to be used the number of batteries multiplied by the voltage of one battery, or cell, should equal the voltage the coil is intended to work on, or a fraction of a volt more, generally 4 volts for jump spark coils and from 6 to 8 volts for a make-and-break primary coil. Either 7 or 8 soda batteries are always enough for the latter system.

More dry batteries are generally used than figuring the same voltage of the coil, on account of the batteries getting weaker during use; 5 or 6 are generally used for jump spark coils and 8 for make-and-break system.

Two sets are often used, connected to a two-point switch, so that either set can be used. In case one set gets weak the other set can be switched on, and permit the used set to recuperate.

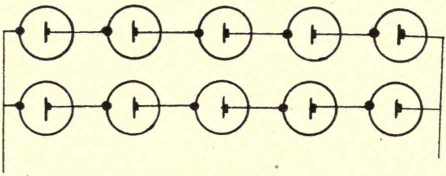


Fig. 20

Although the two sets as above described may be used, if the batteries were

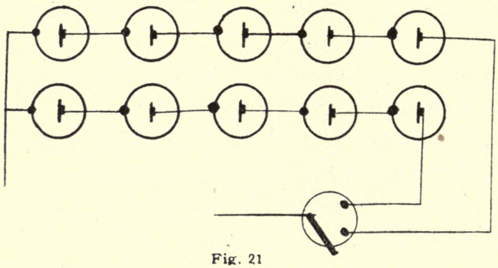


Fig. 21

connected as shown in Fig. 20, more service could be derived than if each set is used separately, as shown in Fig. 21. As peculiar as it may seem, by actual test 12 batteries of 15 amperes, connected as shown in Figure 20, will give longer service than a set of 6 batteries of 30 amperes, or than the 12 connected in two sets as shown in Figure 21. This result is slightly adverse to electrical mathematics, but can be proved with the proper apparatus.

SECONDARY BATTERIES.

Secondary batteries are commonly called storage batteries, or accumulators. The make-up of this type consists of a hard rubber or non-breakable jar, lead plates and a solution of diluted sulphuric acid. The plates of the positive side are connected to one binding post or lug, and the negative plates to another lug, the plates being separated in the solution by a very thin piece of corrugated hard rubber.

After charging, the positive plates are of a brown color, and the negative plates of a gray color. The reason of this is because in their construction the positive plate only is covered with peroxide of lead, and during discharge causes the pure lead (negative) plate to partially oxidize through the chemical action from the positive plate.

In connecting up two or more accumulators one lug of each battery will be found to be marked with a + for positive and a — for negative. The positive of one battery is therefore connected to the negative of the next, until the number required is in circuit. From 2 to 4 are generally required for ignition purposes, dependent upon the system used. A storage battery of course has to be charged from some source of electricity, consequently a dynamo is utilized for this purpose, which gives a voltage in excess of the voltage of the set when charged. Each storage battery gives from 2 to 2½ volts and amperage consistent with size and weight of plates.

Storage batteries should be kept clean, and to reach this end the portable enclosed type is mostly in use. If any acid accidentally spills or evaporates, a solution of very weak sulphuric acid should be added to bring the liquid to a proper level and test.

CHAPTER V.

DYNAMOS—GENERATORS.

A dynamo is a generator of electric current, and requires a power to rotate its armature. The essentials of a dynamo are a rotating member called an armature, electro magnets called fields, an armature winding of insulated copper wire, a field winding of the same material, a commutator and brushes. The principle involved in producing an electric current from a generator is the rapid revolving of a number of turns of copper wire, called an armature, between the magnetic fields or poles of a magnet. The poles of a magnet, as before referred to, are the ends of a magnet, either electro or permanent.

A dynamo has a positive and negative wire; that is, the current from this type has a direction of flow the same as an electric battery. By having a direction of flow it is called direct current, and this current can be used to store accumulators, furnish current for jump spark coils, either vibrating or non-vibrating, or make-and-break spark coils.

Figure 22 gives an outline of the principle

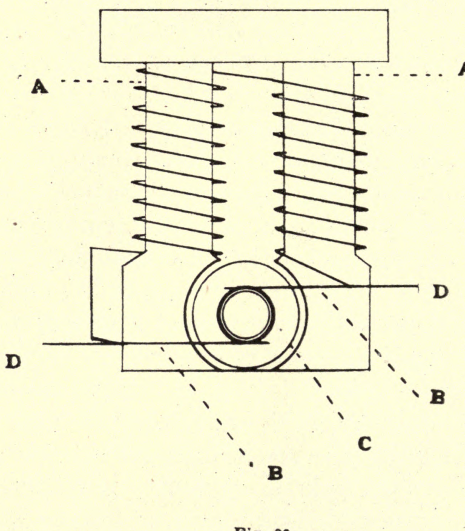


Fig. 22

ple of the type of generator used for gas engine purposes.

A A, field cores, constructed of iron, over which field wire is wound; B B, brushes resting on commutator; C, the armature; D D, the line wires.

As shown in Figure 23, the commutator is made up of a number of segments of brass or copper, forming a circle, each segment separated from its neighbor by either mica or hard rubber insulation, and is set on the end of the armature shaft. Each end of each winding of wire on the arma-

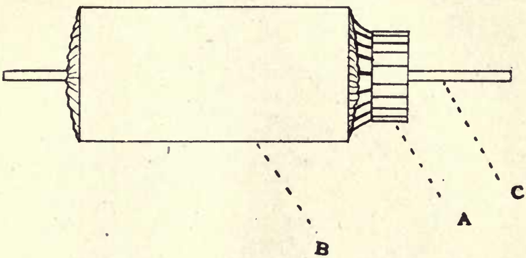


Fig. 23

ture is soldered to its respective segment on the commutator, and the current generated is taken from the commutator through the brushes as the armature revolves.

A, commutator; B, armature winding; C, armature shaft.

By both wires leading from the fields being connected to each brush, part of the current generated by the armature goes

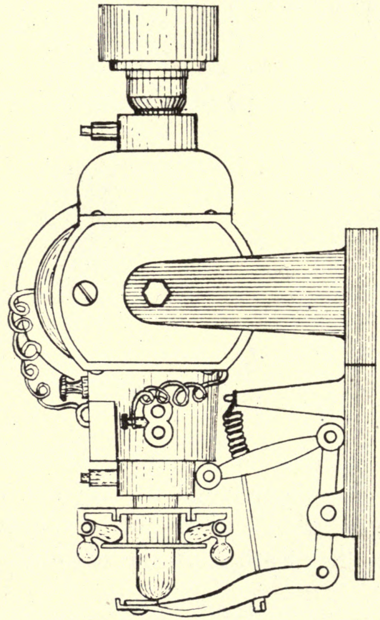


Fig. 24

Improved Speed Regulating Dynamo.

through the fields to magnetize the field cores and make magnetic poles for the armature to revolve upon.

MAGNETOS.

A magneto is also a generator of electricity, but instead of having wire wound on the field cores, utilizes what is known as permanent magnets of the horseshoe type. This gives a permanent magnetic field for the armature to revolve in.

There are several different types of this machine, and they vary in construction to produce practically the same result, although the principle is the same. For ignition purposes one type produces alternating current of from 8 to 10 volts, another direct current of the same voltage and another furnishes a high voltage in connection with a coil made and placed within the magneto case.

The direct current magneto, although having an output of about 10 volts, has a very low capacity of less than one ampere. Its principle of operation is similar to that of the ignition dynamo. It can be utilized to furnish current to a make-and-break spark coil or the magnetic primary plug, but is not adapted for furnishing current to a jump spark coil direct, owing to its low output of amperage. The only means of utilizing it for this kind of ignition is through the medium of a storage battery set, for the following reason: While a storage battery or accumulator set furnishes the proper amount of amperes to operate a jump spark coil, the drain therefrom is only intermittent; that is, there is more actual space or time between connection through the timer on the engine than there is in contact. As the direct current magneto furnishes a smaller amount of amperes than is used from the accumulators, the supply is constant, and enables the batteries to be kept fully stored.

By using the accumulators in connection with a direct current magneto, either vibrating or non-vibrating coils can be used.

The alternating current magneto is very much like the direct current magneto in appearance, and is used more extensively for mechanical make-and-break ignition spark coils. The difference between the two types of magneto is only in the manner in which the armature winding is arranged. In the alternating current magneto there is no direction of flow of the

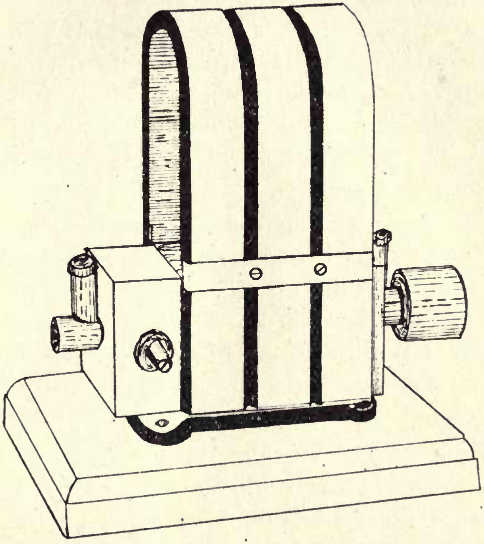


Fig. 25

Magneto.

current produced. It alternates from one binding post or brush to the other many thousand times in a minute.

Alternating current is therefore unlike a direct or battery current, because it has no positive or negative wire. It will not ring an ordinary electric bell or magnetize an electro magnet. For make-and-break ignition, magnetism is not utilized for the operation of this system, other than for the type of magnetic primary igniters before mentioned. When used in conjunction with a make-and-break spark coil, very good results have been given.

This form of magneto has also been utilized to some extent with jump spark coils without a vibrator, the alternations producing a series of sparks as the circuit is closed by the engine timer, corresponding to the action of a jump spark coil with vibrator, when used with battery or dynamo. An alternating current magneto will not operate a vibrating jump spark coil because the core requires to be magnetized on the same principle as an electro magnet, to attract the vibrator of the coil. Magnetic primary igniters will not operate with alternating current for the same reason.

High tension or voltage magnetos are now manufactured which require no outside coil, and are operated through the ordinary jump spark plug.

The magneto is so well known in appearance that a further description is not necessary.

Magnetos are now made without what appear to be brushes. One side of the current from the armature coil is grounded in the armature, and the magneto frame metallically connected to the engine frame. The other wire is connected to a sleeve around the shaft or to the shaft itself, which is insulated from the armature, the shaft or sleeve pressing against a spring, the end of which is made fast to a binding post insulated from the magneto frame. This method gives the appearance of no brushes to the magneto, but one is theoretically there.

The one wire leading from the insulated binding post is connected to the spark coil binding post, and another wire from the coil to a switch, thence to the insulated plug of the engine, where, upon contact, the current flows through the engine frame, returning to the magneto and armature winding.

CHAPTER VI.

TESTING FOR TROUBLE.

One of the principal causes of trouble in the electrical equipment of a marine gasoline engine, especially when used on salt water, is the corrosion of copper wires, caused by being in close proximity to metals of opposite polarity, both of which may be situated in a damp place, either in the bilge of the boat or where continual spray is thrown when under way.

A broken wire is a very perplexing problem to locate to the novice. If a broken wire is suspected between one battery and another, it can be easily proved or located by connecting a piece of wire to the zinc binding post at the end of the set and rubbing the other end of the wire on the carbon plate on the battery at the other end of the set, but not on the binding post. If the connections between each battery are all right, a small arc or flame will occur between the wire and the carbon each time they come in contact, but if an open circuit prevails, or the batteries have become exhausted, no spark will appear.

Before placing the wire on the zinc binding post, remove the permanent wire therefrom and open the switch, so that there can be no ground at any point in the outside wires, and through the battery box in any unforseen manner. By going over each binding post very often a loose connection with the wires and binding posts will be found as the cause. If the binding posts are making a good connection, with the piece of wire still fastened at the zinc binding post, making a perfect metallic connection, touch the carbon of the battery next nearest the end where the zinc and wire are connected and continue thus with each battery toward the zinc connection until a spark is seen on the carbon. As soon as it sparks, the trouble is between that battery and the one next to it which would not spark.

Should the batteries appear to be in perfect condition, and in case the engine should fail to start, if the equipment is make-and-break system of ignition, remove the wire from the insulated electrode or plug and wipe it across any bright or polished part of the engine, after closing the switch.

If a spark occurs, following the wire each time, turn over the fly wheel until contact is made by the movable and stationary electrode inside of the cylinder. This point occurs just before the device on the outside of the cylinder trips or snaps, which separates the electrodes. Now, wipe the wire across the insulated plug electrode, and if a spark occurs, turn the fly wheel still further until the device snaps to separate the electrodes, and try the same thing again. If no flame is perceptible, the spark is occurring inside of the cylinder. The trip separating the electrodes should occur barely before the piston reaches its top center, generally marked by a cut in the flywheel rim to alleviate matters.

A puzzling stage to many is when, after all these tests, no spark has shown itself, and the batteries are all right. The trouble may be a broken wire, bad connection at switch connections or contacts, switch binding posts, coil binding posts or ground binding posts on the engine frame. Referring to Figure 26, a make-and-break system of connection is shown.

Proceed to locate the trouble by turning the engine fly wheel so as to make connection between the electrodes. See that the

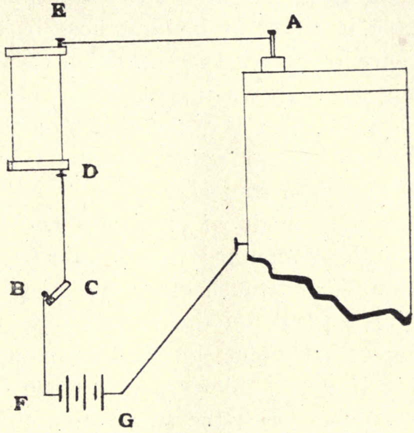


Fig. 26

switch is closed, and with a piece of wire, place one end at G on the batteries and wipe the other end across the top of the insulated electrode or plug, A. If a spark shows, the trouble is either in the ground wire, where it is connected to the battery, or the engine frame, or between the two electrodes possibly by a bad connection of sparking points.

If no spark appears, with one end still at G, repeat the same operation at the coil binding post, E. If a spark appears, the trouble is either at binding post E, or in the wire, or at A, on the insulated electrode. If no spark shows itself, trouble is either at D of coil, C or B of the switch or battery connection, F, or poor connection in the knife switch or contact.

The next mode of procedure will be to fasten the temporary wire at battery connection F, and touch other end of wire to binding post B, on the switch, first of all trying switch points by sand-papering and noting if spark follows points when opening switch. With the supposition that an open circuit still prevails, by no spark showing when touching temporary wire to B, touch next to C of switch, and then to D. When a spark is noticed the trouble lies between where spark occurred and the last point it failed to show.

There may be such a thing that after a period unused the whole installation may be defective. If no spark can be determined at all, this can be ascertained by fastening temporary wire at F and D, and with another piece of wire, fastened to G, touch the binding post E, of the coil. A spark should now show itself, as this cuts out the engine and switch and all the wiring, and should be convincing enough to show the necessity for new wires.

Although appearing to be a rather intricate method, any person can soon learn the why and wherefore.

For jump spark ignition remove the plug from the cylinder and lay it on a bright metallic part of the engine, with the wire attached to it, being sure that only the portion of the side metal containing the screw threads make the connection, the same as if screwed into the cylinder. Turn over the engine until contact is made at the timer or commutator. If the trembler or vibrator of the coil does not operate, adjust by turning the thumb screw in either direction until it does. If it fails, pass a fine piece of sand paper between the point on the trembler and the thumb screw adjuster. If it operates now, observe the size of spark at the spark plug.

Jump spark coils are invariably situated near the engine and batteries, and are very convenient for locating trouble. If a good-sized wire is used when installing, a failure of the vibrator to work can be located by seeing that good contact is made at timer, switch points are clean, binding posts tight; in the event of which all are in good condition, the same test for trouble in the batteries as before mentioned can be used. When batteries are suspected of causing the trouble, new batteries are not always at hand to put in their place to save testing out.

With jump spark ignition, very often after putting in new batteries, a very hot spark occurs at the vibrator and a weak spark at the plug. This is caused by a poor connection between the condenser and the wires leading to the vibrator inside of the coil case. The best thing to do in this case is to send the coil to the manufacturer or discard it, unless the operator has the ingenuity to repair it and understands its principle and theory.

Do not use small gauge wires, as they are too readily subjected to injury. No. 14, and, better yet, No. 12, safety wire will carry the current better and stand harder usage. Always wind several turns on a pencil before fastening an end to a binding post, so that, should a break occur at the fastening, enough will be left for another connection.

If imperative to run wires along the bilge in a damp place, use lead-covered wire. Run all wires in the lockers if possible, or under the edge of the coaming. Never fasten two wires under one staple, or a short circuit may be caused by cutting through the insulation of the wires and each point touching the metal. Do not drive staples home, as they are liable to cut the insulation and break the wire.

Single or double pole, double throw, knife switches for two sets of batteries or magneto and battery, or single-throw knife switches, or electric light snap switches, give better results than the ordinary electric bell or automobile switch, for the reason that the former have a rub pressure contact attendant with closing.

When installing a double-throw knife switch, set it up horizontally, so that it will not close by its own gravity. Single-throw switches should be set up vertically, so that in opening, the lever is pulled down, for the same reason.

Place all dry batteries in a dry place. If the whole set is not sealed up in pitch, and if inconvenient to procure any, connect the set together, soldering all connections, and place them in a box to just nicely contain them. Put binding posts on the end of the box or extend the wires through the holes in the box, and fill the case with pitch or asphalt. This will keep the set water-proof under all circumstances. Those who desire to keep dry batteries from absorbing moisture, and do not care to use pitch, can place the set in a box, filling same to the top with sawdust. When this absorbing material becomes damp, renew.

All dry batteries should be set right side up, unless water-proofed with pitch, else the pitch in the top of the cans will run on warm days and permit the contents to evaporate.

When putting screws or nails in a battery box to hold it in position, be sure to see that a nail or screw has not misdirected and touches one of the batteries and a wire.

Brighten all contacts and ends of wires when fastening to binding posts, screws, etc., and solder and tape over any splice made in the wire.

When the novice installs his own jump-spark electrical equipment, it is a common occurrence to find ordinary electric light wire leading from the coil to the spark plug on the engine. Very few explosions are gotten from the engine before trouble occurs. Notwithstanding the use of ordinary wire when there is more than one cylinder to the engine, these wires are bunched together and taped.

Remember that it is most imperative that wire with a heavy insulation of rubber is necessary for this secondary current to carry to the plug, on account of the high voltage and liability to jump through the insulation of ordinary wire. If unable to procure the heavy insulated wire, use the

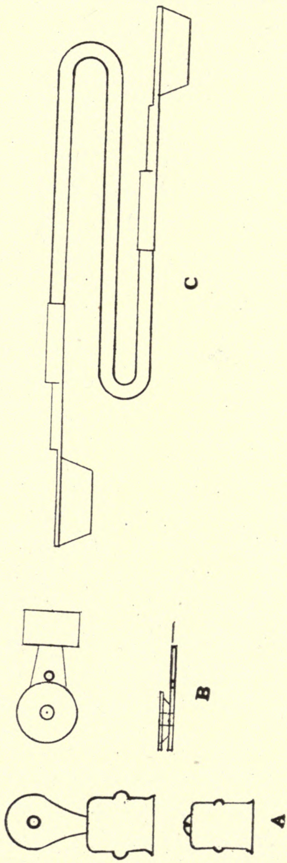


Fig. 27

ordinary wire, but procure a piece of pure rubber tube or circular loom, such as electric light wires are run through, and slide this over the wires.

Wire terminals are now manufactured which facilitate a good metallic connection, and also prevent the wire from breaking at the point of connection. Figure 27 shows two forms of spark plug wire connectors, A and B, and a form of battery terminals, C.

Water-proof plug protectors are being utilized to great advantage in protecting the plug and wire terminal from corrosion and short circuits caused by spray. These are a boon to the open power boat.

CHAPTER VII.

KINKS IN THE POWER INSTALLATION.

Difficulties are encountered other than in the ignition system of a marine engine. Poor water circulation or chronic trouble in starting the water flow through a gear or rotary pump, foreign substances in the gasoline, affecting carburation, trim or motion of the boat acting on the gasoline level in the fuel tank, leaks in the gasoline pipe or connections, sticking of the check valves in the water supply, etc., are troubles very often traced directly to the manner in which installation was put in.

Unless a rotary or gear pump is placed at a point below the water line in a boat, there is no suction to start the water to flow, and priming with water has to be resorted to, and, even though they work satisfactorily when new, they soon require the priming process, as all the water escapes from the cylinder jacket through the pump when not in operation. The best remedy for this is to place a check valve between pump and entrance of pipe through the hull. This will insure the pump remaining filled with water, by the check closing when the pump stops and remaining wide open while running.

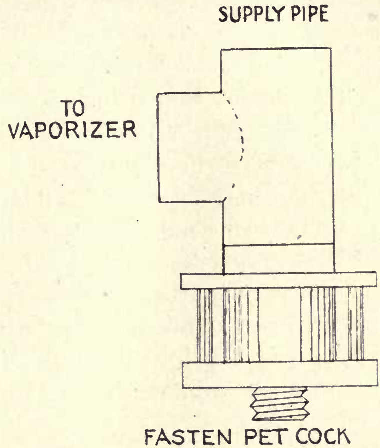


Fig 28

Any foreign matter in the fuel can be readily drained from the pipe by the use of a T connection with a sight glass fitted with a pet cock at its lowest point, as shown in Figure 28.

Water is the most annoying substance in the fuel, but with this form of filter or separator, its presence can be detected, as well as any sediment, etc., as it will settle to the bottom of the gasoline by its own gravity. The gasoline enters the tip, going out the side of the T to the vaporizer. Sediment in the gasoline pipe is often traced to the use of a galvanized iron tank. Annealed copper tanks, tinned inside, are the most satisfactory and only safe tank to install in a boat. No matter what the tank is constructed of, it should rest in a pan, fitted with outboard scuppers and separated from the boat proper by a bulk-head, making an air-tight compartment.

In case of leaks developing in the tank, the contents will run into the pan and be directed outboard, and not enter the hull, to cause fire.

Leaks in the gasoline tank are very dangerous, and should be repaired at once. The pipe should be in one piece, either lead or annealed copper, and all connections made fast with soft solder. When setting up threaded ends of gasoline pipe, they should be sweated in or set up with brown shellac, and nothing else. Gasoline often escapes from the vaporizer or carbureter and lodges in the bilge of the boat, endangering a fire. The only safe method in such instances is to arrange a pan, or length of pipe like a U, under the vaporizer.

The motion or roll of the boat may cause the mouth of the gasoline pipe in the tank to occasionally be uncovered. Cylindrical and V-shaped tanks overcome this difficulty. When equipped with a square tank, and trouble of this sort prevails, arrange the piping as shown in Figure 29, with an outlet from both sides.

Check valves in the water inlet pipe often placed near the cylinder jacket, cause annoyance by rust backing up to the check, forming a deposit on the valve seat, affecting the water circulation. Checks should always be kept clean, and occasionally smeared with vaseline or oil on the seat.

When a new engine has been installed by a novice, very often the engine will stop after a few minutes' run, with apparently no reason for doing so, and after a thorough examination of every part shows nothing amiss. The cause of this is often due to the absence of a vent in the gasoline tank, which can be remedied in a small equipment by drilling or punching a very small hole in the filling cap of the tank. In larger equipments it is better to solder a ⅛-inch copper pipe to the top of the tank, leading

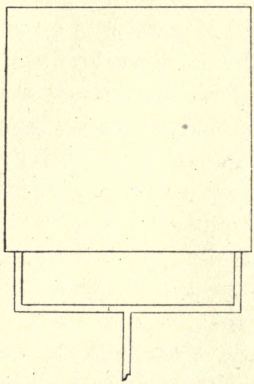


Fig. 29

same to a point well toward or at the stern, over deck.

One of the safest methods of installing a gasoline tank in a power boat is to insert a brass pipe in the top of the tank, of sufficient size to be convenient for filling, set up on the inside and outside of the tank with lock nuts, soldered fast. The top of the brass pipe should be long enough to extend through the deck far enough for a collar to screw on and fasten to the deck, and a cap to cover the open end and set up against the collar. In the event of any gasoline spilling during the fitting of the tank, it can not enter the boat, and must go overboard.

Never place any rubber gaskets, hose, etc., in connection with any pipe, part of the tank, carbureter, etc., where either gasoline or its vapor is liable to come in contact with same. Rubber is soluble in gasoline, and may cause a disastrous leak at any time if used.

Never place a stop cock in the water overflow pipe leading from engine outboard or into exhaust pipe. It will sooner or later be found closed, after the pump has broken or the water jacket cracked.

CHAPTER VIII.

HORSEPOWER.

One of the most peculiar phases confronting the intending purchaser of a marine engine is how to estimate the horsepower of any engine under consideration. The suspicion of overrating invariably presents itself, especially when two styles of different speed, weight and size claim the same power.

Irrespective of manufacturer's rating, the feeling exists to know the exact rating and what a horsepower constitutes.

An American or English horsepower represents the equivalent of 33,000 pounds raised to a height of 1 foot during a period of 1 minute, or 1,000 pounds 33 feet in 1 minute, or 550 pounds per second, or any proportional combination of these figures. This represents the value of an American or English horsepower, and not a French horsepower.

The French people utilize two kinds of horsepower, cheval vapeur and poncelet.

The former is the value of 32,550 pounds raised 1 foot in 1 minute, or 542.5 pounds per second, which is .9863 that of the English horsepower. Poncelet equals the value of 43,400 pounds raised 1 foot in 1 minute, or 1-3 more than cheval vapeur. Poncelet is used for laboratory tests, while internal combustion engines are rated by the cheval vapeur.

In French measurements the English horsepower represents 76.04 kilogram meters per second; cheval vapeur, 75 kilogram meters per second, and poncelet, 100 kilogram meters per second. It will thus be seen that there is a difference of about 2 per cent between the horsepower of a French engine and one of Amrican manufacture. An American engine would, therefore, figure less power, dimensions for dimensions, than one of French manufacture.

It must be taken into consideration that different compression space dimensions, design, workmanship and material, may be the cause of different power ratings for the same dimensions and speed. There are several rules for approximately figuring the horsepower of an internal combustion engine.

1905

AMERICAN POWER BOAT ASSOCIATION RULE.

Area of piston, multiplied by the number of cylinders, times the revolutions per minute, divided by 1,000 for a 4-cycle and 750 for a 2-cycle engine.

Designated by:

$$\frac{D^2 \times .7854 \times N \times R}{1000} = \text{H P. 4-cycle.}$$

$$\frac{D^2 \times .7854 \times N \times R}{750} = \text{H. P. 2-cycle.}$$

D equals diameter, N equals number of cylinder, R equals revolutions per minute.

A rule used by several manufacturers is to square the diameter of the cylinder, multiply by the stroke, then by the revolutions per minute, and number of cylinders, dividing this result by 17,000 for a 4-cycle and by 13,000 for a 2-cycle engine.

$$\frac{D^2 \times L \times R \times N}{17{,}000} = \text{H P. 4-cycle.}$$

$$\frac{D^2 \times L \times R \times N}{13{,}000} = \text{H. P. 2-cycle.}$$

D equals diameter piston, L equals length stroke, R equals revolutions per minute, N equals number of cylinders.

Another rule is to figure 10 cubic inches piston displacement per horsepower for high-speed 4-cycle engines, and 8 cubic inches for a high-speed 2-cycle.

Which is:

$$\frac{D^2 \times .7854 \times L \times N}{10} = \text{H. P. 4-cycle.}$$

$$\frac{D^2 \times .7854 \times L \times N}{8} = \text{H. P. 2-cycle.}$$

The rule for high-speed engines refers to those rated at from 950 to 1,500 revolutions per minute.

This high speed is not utilized to any advantage over 1,000 revolutions per minute in a power boat, and if a speed of 800 to 900 is realized it can be more practically utilized.

If the engine is rated at 1,600 revolutions, the power development will be about one-half at 800, and if rated at 1,200 revolutions, two-thirds the power derivation will be realized at 800.

By noting the American Power Boat Association's rating of various engines in comparison to the manufacturers' rating, and especially those of foreign rating, a difference will be noticeable.

On account of the demand created by the high speed development of the automobile, high-speed marine engines are in demand, notwithstanding their short length of life. Unless the craft is strictly a speed boat, a lightly constructed engine is wholly out of place.

The following tables of dimensions are the engine ratings of prominent manufacturers. Various sizes of engines are produced by multi-cylinder of 2, 3, 4, 6 and 8 combinations. The horsepower is for a single cylinder engine in the following:

2-cycle, 2-ported type.

H.P.	R.P.M.	Bore.	Stroke.
1½	500	3½	3½
2	500	3¾	4
3½	550	4½	5
7½	425	5½	6½
10	350	7	7½

2-cycle, 3-ported type.

H.P.	R.P.M.	Bore.	Stoke.	Weight.
1	700	3	2½	38
2	950	3	3	75
3	500	4	4	150
4	900	3½	3⅝	125
5	600	4½	5	180

4-cycle.

H.P.	R.P.M.	Bore.	Stoke.
1	750	2½	4
2½	600	3½	5
3	950	3½	3½
3½	600	4½	5
4	900	4	4½
5	500	5	6
7	800	4¾	5
7½	450	6¼	7
7½	450	6¼	7
8	800	5	5
10	750	5½	6
15	800	6½	6½

CHAPTER IX.

WIRING DIAGRAMS.

In making use of the various wiring diagrams on the following pages, it will be well to remember that the order of firing the cylinders in a multi-cylinder engine has not been set forth. This order of firing, for jump spark ignition, in a four-cycle engine can be located by the positions of the cams on the cam shaft for the exhaust valve lifts. Before wiring to the commutator or timer, the fly wheel can be turned over until the exhaust valve cam of the cylinder nearest the front of the engine starts to open the valve. This indicates that this same cylinder was the last to ignite, consequently the last to close the primary circuit at the timer.

By locating the binding post on the timer which is then the one just passed contract, with the timer retarded for a late spark, in other words, the timer cover or case carrying the binding posts or connections, moved as far as practical in the same direction as that which the timer shaft rotates. When this binding post is located, the primary wire of coil number one is fastened to same, and the secondary wire of coil number one made fast to the plug on cylinder number one. The flywheel can then be turned over until the next cam comes into action for locating the next connection, or can be found by looking along the cam shaft until the next cam to come into action is located or figured out.

Although a four-cylinder engine may fire, 1, 2, 4, 3, the secondary wires should be led to the plug direct without crossing, as, coil 1 to cylinder, 1, 2 to 2, 3 to 3, 4 to 4, and the changes for order of firing arranged at the timer by the primary connections thereto. Each primary wire from the coil to the timer, is for the secondary or plug wire directly over the former on the coil. Multi-cylinder coils are made up of single cylinder coils.

When wiring a two-cycle multi-cylinder engine, the order of firing can be located by noting which crank revolves next in order from number one cylinder.

For make-and-break ignition, the sparking mechanism on the outside of each cylinder generally takes care of the firing of each cylinder correctly.

Each of the following diagrams is arranged for two sets of batteries, to use each set at will, through the medium of a two-point or double-throw switch. If a generator is to be used, with one set of batteries for starting, the arrangement is made in the same manner in the circuit as if one set of the two represented in the diagrams was removed, and the generator inserted in its place.

The diagram key is: P. plug, S. switch, T. timer, ═ ground.

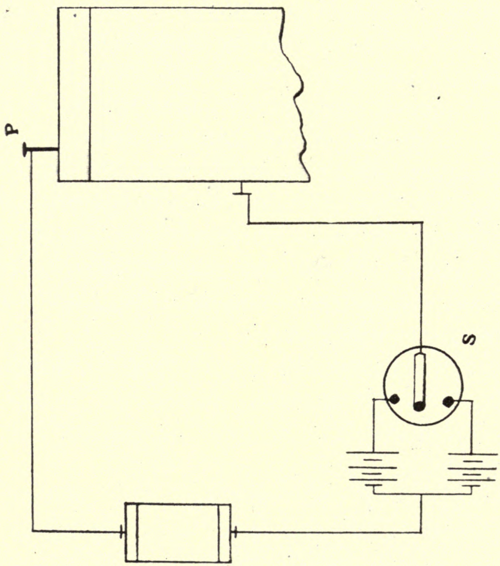


Fig. 30

Single Cylinder. 2 Sets Batteries. Make-and Break.

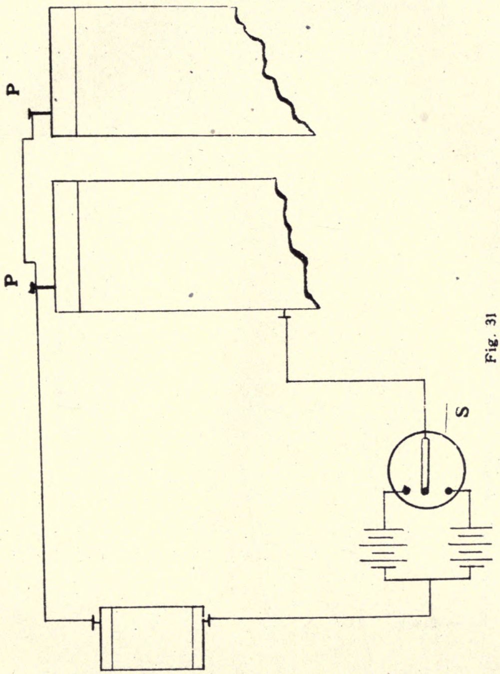


Fig. 31

Two-Cylinder, Make-and-Break, 2 Sets Batteries.

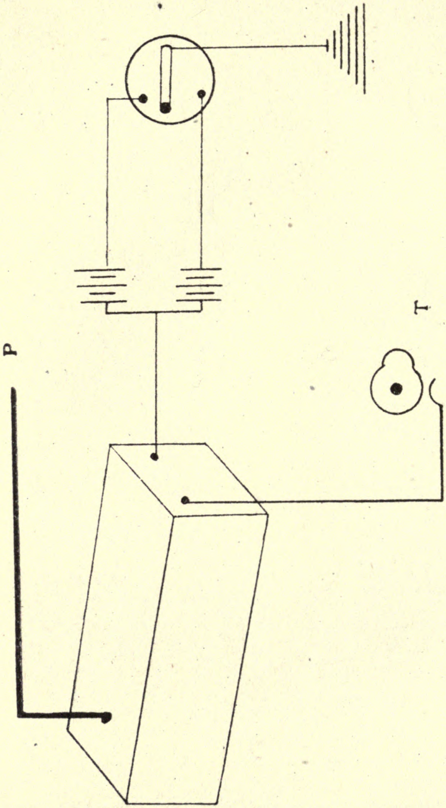


Fig 32

Single-Cylinder, 3 Terminal Coil, 2 Sets Batteries, Jump Spark.

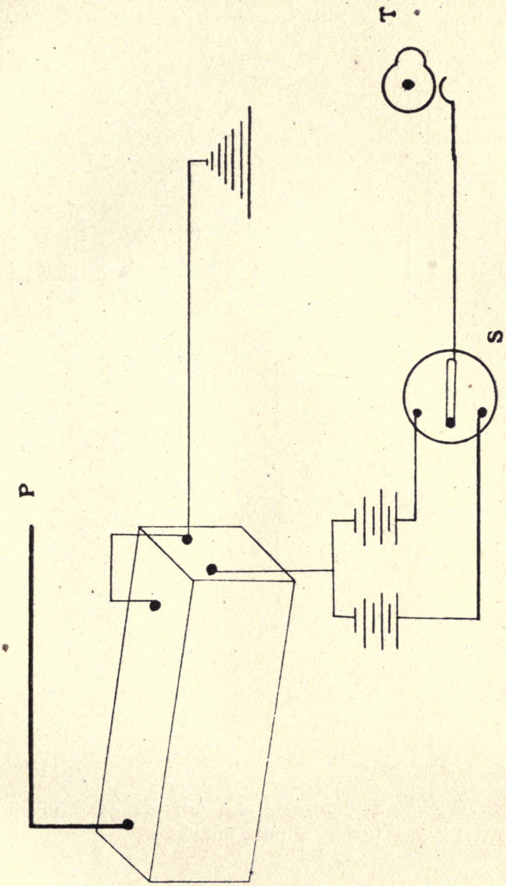


Fig. 33

Single Cylinder, 4 Terminal Coil, 2 Sets Batteries. Jump Spark.

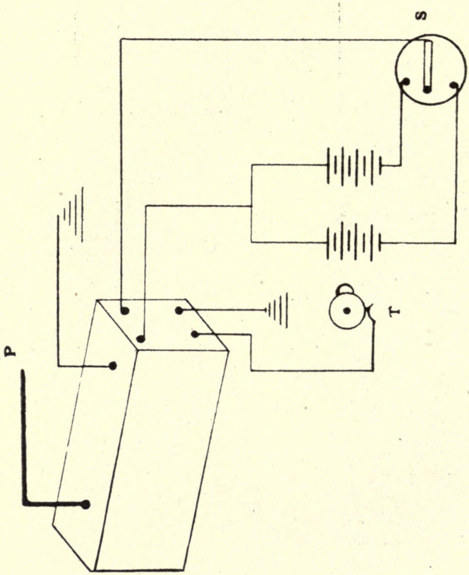


Fig 34

Single Cylinder. 6 Terminal Coil. 2 Sets Batteries. Jump Spark.

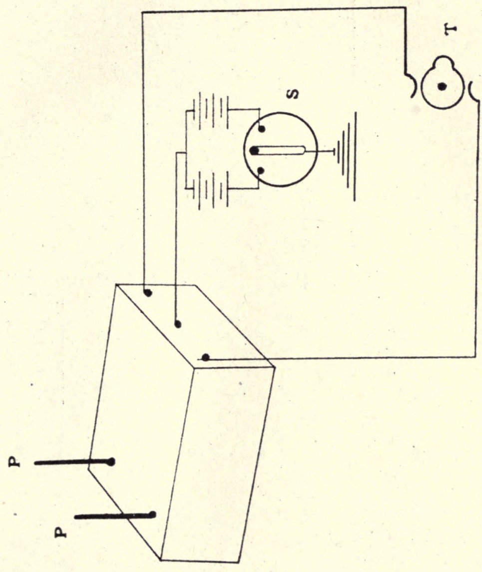
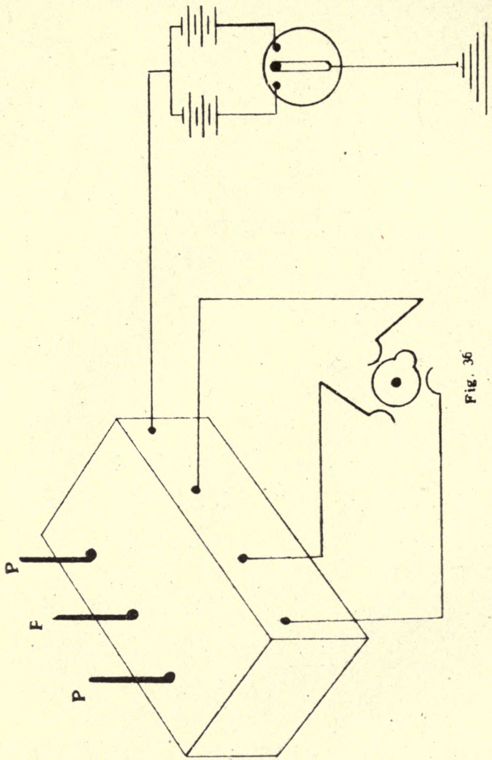


Fig. 35

Two-Cylinder, 5 Terminal Coil, 2 Sets Batteries, Jump Spark.



Three-Cylinder. 7 Terminal Coil. 2 Sets Batteries. Jump Spark.

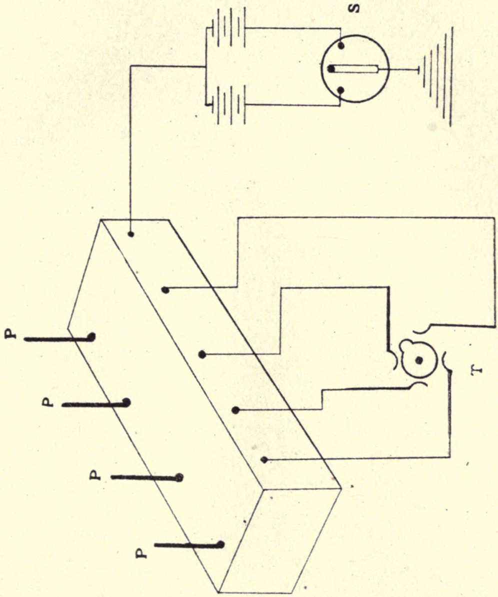


Fig. 37

Four-Cylinder, 9 Terminal Coil, 2 Sets Batteries, Jump Spark.

INDEX.