FUNDAMENTALS SECTION

ENGINE FUNDAMENTALS

OPERATING PRINCIPLES

The power source for the chain saw does not differ basically from that used to power automobiles, farm or garden tractors, lawn mowers, or many other items of power equipment in use today. All are technically known as "Internal Combustion, Reciprocating Engines."

The source of power is heat formed by the burning of a combustible mixture of petroleum products and air. In a reciprocating engine, this burning takes place in a closed cylinder containing a piston. Expansion resulting from the heat of combustion applies pressure on the piston to turn a shaft by means of a crank and connecting rod.

The fuel mixture may be ignited by means of an electric spark (Otto Cycle Engine) or by the heat of compression (Diesel Cycle). The complete series of events which must take place in order for the engine to run may occur in one revolution of the crankshaft (referred to as Two-Stroke Cycle), or in two revolutions of the crankshaft (Four-Stroke Cycle).

As the two-stroke cycle spark ignition engine is universally used as the power source for chain saws, this will be the only type engine discussed in this section.

OTTO CYCLE. In a spark ignited engine, a series of five events are required in order to provide power. This series of events is called the **Cycle** (or Work Cycle) and is repeated in each cylinder as long as work is done. The series of events which comprise the work cycle are as follows:

1. The mixture of fuel and air is pushed or drawn into the cylinder, by reducing cylinder pressure to less than the outside pressure, or by applying an initial, higher pressure to the fuel charge.

2. The mixture is compressed, or reduced in volume.

3. The mixture is ignited by a timed electric spark.

4. The burning fuel-air mixture expands, forcing the piston down, thus converting the generated chemical energy into mechanical power.

5. The burned gases are exhausted from the cylinder so that a new cycle can begin.

The series of events comprising the work cycle are commonly referred to as INTAKE, COMPRESSION, IGNITION, EXPANSION (POWER), and EXHAUST.

TWO-STROKE CYCLE. In a two-stroke cycle engine, the five events of intake, compression, ignition, power and exhaust must take place in two strokes of the piston; or one revolution of the crankshaft. Thus, a compressed fuel charge is fired each time the piston reaches the top of the cylinder, and each downward stroke is a power stroke. In order to accomplish this, the initial pressure of the incoming fuel-air mixture must be raised to a point somewhat higher than the lowest pressure existing in the cylinder, or a fresh charge of fuel could not be admitted and the engine would not run. This elevation of pressure requires the use of an air pump, or compressor, of approximately the same volume as the cylinder itself. Coincidentally, such an air pump is available with a minimum of additional parts, cost, or friction losses by utilizing the opposite side of the piston and cylinder as the pump. Such engines are called "Crankcase Scavenged," and are universally used in the chain saw industry.

Fig. CS1 shows a schematic view of the crankcase scavenged, reed valve type, two-stroke cycle engine commonly used. The general sequence of events required for operation is as follows: As the piston moves outward from the crankshaft as shown in view "B", the volume of the closed crankcase is enlarged and the pressure lowered, causing air to be drawn through the carburetor (C), where it is mixed with fuel. This mixture is then drawn through the reed valve (R) and into the crankcase. At the same time, a previous charge of fuel is being compressed between head of piston and closed end of cylinder as shown by the darkened area. As the piston approaches top center, a timed spark ignites the compressed fuel charge and the resultant expansion moves the piston downward on the power stroke. The reed valve (R) closes, and downward movement of piston compresses the next fuel charge in the crankcase as shown in view "A". When the piston nears the bottom of its stroke, the crown of piston uncovers the exhaust port (EX) in cylinder wall, allowing the combustion products and remaining pressure to escape as shown by the wavy arrow. Further downward movement of piston opens the transfer port (TP) leading from the crankcase to cylinder; and the then higher crankcase pressure forces the compressed fuel-air mixture through transfer port into the cylinder. The baffle which is built into crown of piston deflects the incoming charge upward, and most of the remaining exhaust gases are driven from the combustion chamber by this fresh charge. Two-stroke cycle, crankcase scavenged engines are sometimes produced with a fuel induction system other than the inlet reed valve. The two induction systems used in chain saw engines in addition to the reed valve are the three-port system illustrated in Fig. CS2 and the rotary valve system illustrated in Fig. CS3.

In the crankcase scavenged engine, most of the friction parts requiring lubrication are located in the fuel intake system. Lubrication is accomplished by mixing the required amount of oil with the fuel, so that a small amount of oil in the form of a fine mist is drawn into the crankcase with each fuel charge. It should be pointed out that the new oil brought into the crankcase can do little more than supplement the losses, therefore it is necessary that the friction parts be well lubricated at the time the engine is started. The use of too much oil in the fuel mixture results in plug fouling, excessive carbon, and poor performance, as well as being wasteful.

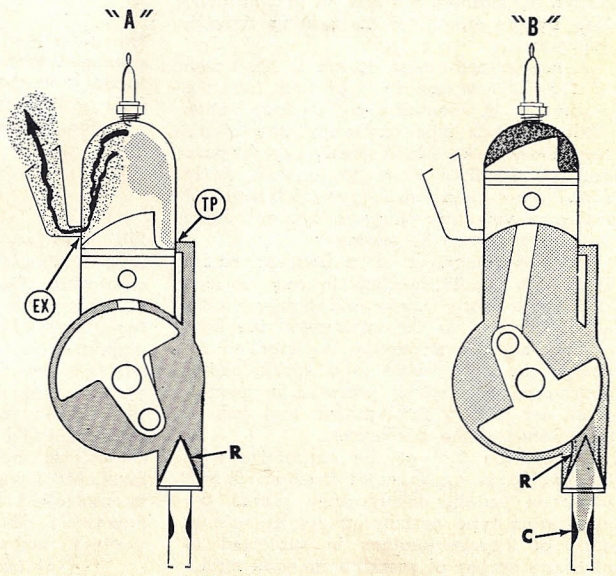


Fig. CS1 — Schematic view of two-stroke cycle, crankcase scavenged engine used in most chain saws. The series of events comprising the Otto cycle takes place in one revolution of the crankshaft by using the crankcase as a scavenging pump.

C. Carburetor
R. Reed valve
TP. Transfer port
EX. Exhaust port

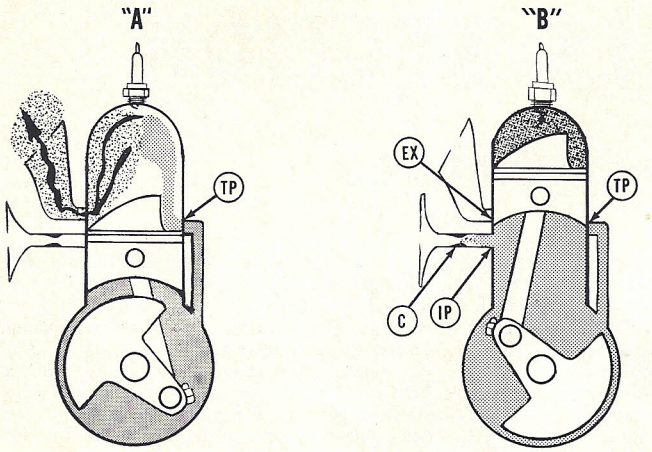


Fig. CS2 — Two cycle, three port engine. Principles are similar to reed valve or rotary valve types except that a third, intake port is located in cylinder wall and opened and closed by the piston skirt.

C. Carburetor
EX. Exhaust port
IP. Intake port
TP. Transfer port

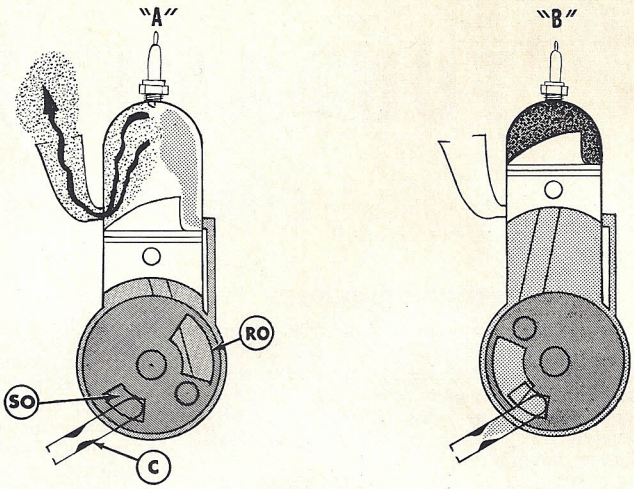


Fig. CS3 — Two cycle, rotary valve engine. The incoming fuel charge is controlled by a rotary valve attached to the crankshaft. The opening in valve (RO) and crankcase (SO) align at the proper time to admit a fresh charge, then close to allow initial crankcase compression.

C. Carburetor
RO. Opening in rotating member
SO. Opening in crankcase wall

CARBURETION

The function of the carburetor is to atomize the fuel and mix it with the air flowing through the carburetor and into the engine. The carburetor must also meter the fuel so that the proper fuel-air ratio for different engine operating conditions is provided. Normal fuel-air ratios are approximately as follows:

	Fuel	Air
For starting in cold weather..	1 lb.	7 lbs.
For idling	1 lb.	11 lbs.
For full load at open throttle.	1 lb.	13 lbs.

Carburetor design is based on the venturi principle which is that a gas or liquid flowing through a necked-down section (venturi) in a passage undergoes an increase in speed and a decrease in pressure as compared to its speed and pressure in the full sized sections of the passage. This principle is illustrated in Fig. CS5. Due to the low pressure at the venturi, fuel is drawn out through the fuel jet and is atomized by the stream of air flowing through the venturi.

A simple carburetor design is illustrated in Fig. CS6 where flow of fuel into the carburetor is controlled by a float valve. With the float type carburetor, the carburetor must be kept in a nearly upright position for the float valve to function. Early chain saws using this type of carburetor had a provision for tilting the bar and chain independently of the engine.

Later development of a floatless carburetor that would function in any position allowed a more simple and lighter design of chain saws. In this carburetor, the flow of fuel into the carburetor is controlled by linking the inlet valve to a spring-loaded diaphragm. The spring pressure is counteracted by suction through the fuel jets at the venturi of the carburetor.

To provide fuel at the carburetor with the engine in an inverted position, a fuel pump is usually incorporated within the diaphragm type carburetor. As the crankcase of 2-cycle engines is subjected to alternate surges of pressure at each stroke of the piston, a diaphragm vented to the crankcase will pulsate at each turn of the engine crankshaft. Thus, the pulsating diaphragm can be used at a fuel pump. See Fig. CS7.

A cross-sectional schematic view of one diaphragm type carburetor with an integral fuel pump is shown in Fig. CS8. The top of the pump diaphragm is vented to the engine crankcase through the channel (8). As the diaphragm pulsates, fuel is drawn into the carburetor through the inlet (1), screen (28) and pump inlet valve (3A). The fuel is then pumped through the outlet valve (3B) into the supply channel (17). Engine suction through the main jet (15) and idle jets (10) is transmitted to the top of the carburetor diaphragm (25) and atmospheric pressure through the vent (23) pushes upward on the diaphragm (25) overcoming spring (20) pressure and unseating the inlet needle (18) allowing fuel to flow into the diaphragm chamber (6).

When starting an engine, closing the choke disc (16) increases the vacuum in the carburetor throat so that the carburetor will function at the low cranking RPM.

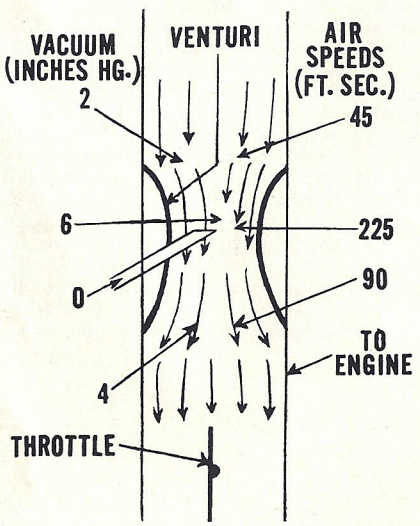


Fig. CS5 — Schematic view of venturi principle. Right hand figures show how air speed is increased by the restriction (venturi) while left hand figures show the accompanying drop in air pressure.

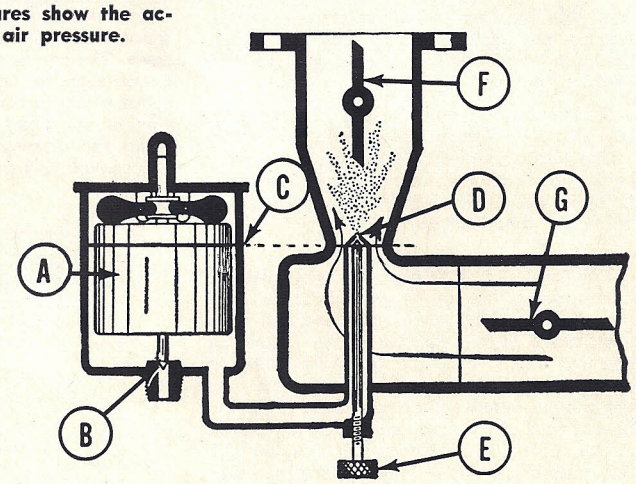


Fig. CS6 — Schematic view of simple float-type carburetor. The buoyancy of float (A) closes the fuel inlet valve (B) to maintain the fuel at a constant level (C). The pressure drop in the venturi causes fuel to flow out nozzle (D) which protrudes just above the fuel level. Maximum fuel flow is controlled by mixture valve (E). Throttle valve is at (F) and choke valve at (G).

When the engine is idling, the throttle disc is almost completely closed and there is not enough air passing through the venturi (14) to create any vacuum on the main jet (15). A vacuum is created at the primary idle jet (10A), however, and the fuel necessary for running the engine is drawn through that jet.

As the throttle disc is opened, enough vacuum is created on the secondary idle jet port (10B) so that fuel is drawn through that port also. At a certain point, the throttle disc is open far enough so that the velocity of air passing through the venturi is sufficient to lower the pressure at the main fuel discharge port (15) so that fuel will flow through this port also. Opening the throttle disc farther results in higher air velocities and lower venturi pressures that increase the flow of fuel out of the discharge ports.

Any vacuum created at the idle discharge ports (10) or the main fuel discharge port (15) is transferred through the metering chamber (6) to the diaphragm (25). Air pressure entering through the atmospheric vent hole (23) pushes against the diaphragm because of the vacuum and overcomes pressure applied by the spring (20) through the control lever (21). This releases the inlet needle valve (18) and allows fuel to enter the metering chamber in a direct relationship to the vacuum created at the fuel discharge ports. The higher the vacuum, the greater the movement of the diaphragm and the larger the opening of the needle valve. Thus, fuel is metered into the carburetor to meet the needs of the engine.

IGNITION SYSTEM

The fundamental principles of the flywheel magneto ignition system in general use on chain saw engines are presented in this section. As the study of magnetism and electricity is an entire scientific field, it is beyond the scope of this manual to fully explore these subjects. However, the information contained in this section should impart a working knowledge of the flywheel type magneto which will be useful when servicing chain saw ignition systems.

BASIC PRINCIPLES. Although the design of different flywheel magnetos varies, all flywheel magnetos operate on the same basic principles of electro-magnetic induction of electricity and formation of magnetic fields by electrical current.

The principle of electro-magnetic induction of electricity is as follows: When a wire (conductor) is moved through a magnetic field so as to cut across lines of magnetic force (flux), a potential voltage (electro-motive force or emf) is induced in the wire. If the wire is a part of a completed electrical circuit, current will flow through the circuit as illustrated in Fig. CS10. It should be noted that the movement is relative; that is, if the lines of force of a moving magnetic field cut across a wire, this will also induce an **emf** in the wire. The direction of the induced current when the wire is a part of a circuit is related to both the direction of magnetic force and the direction of movement of the wire through the magnetic field. The voltage of the induced current is related to the strength of the magnetic field and to the speed at which the wire moves through the lines of magnetic force. Also, if a length of wire is wound into a coil and a section of the coil is moved through a magnetic field so

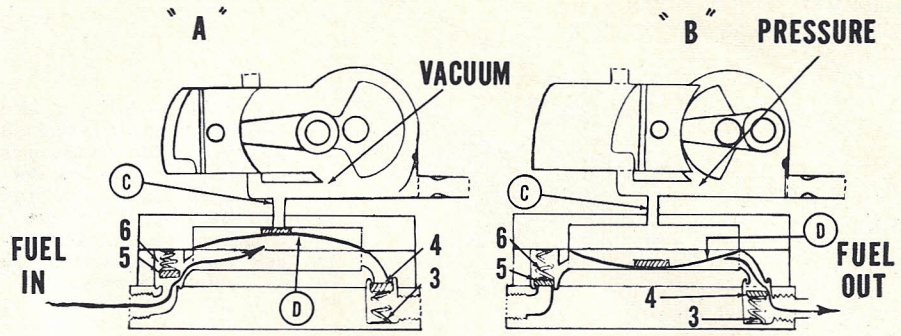


Fig. CS7 — Schematic view of a typical, crankcase operated, diaphragm type fuel pump. Pressure and vacuum pulsations from crankcase pass through connection (C) to rear of diaphragm (D) which induces a pumping action on fuel line as shown.

3. Valve spring
4. Outlet check valve
5. Inlet check valve
6. Valve spring

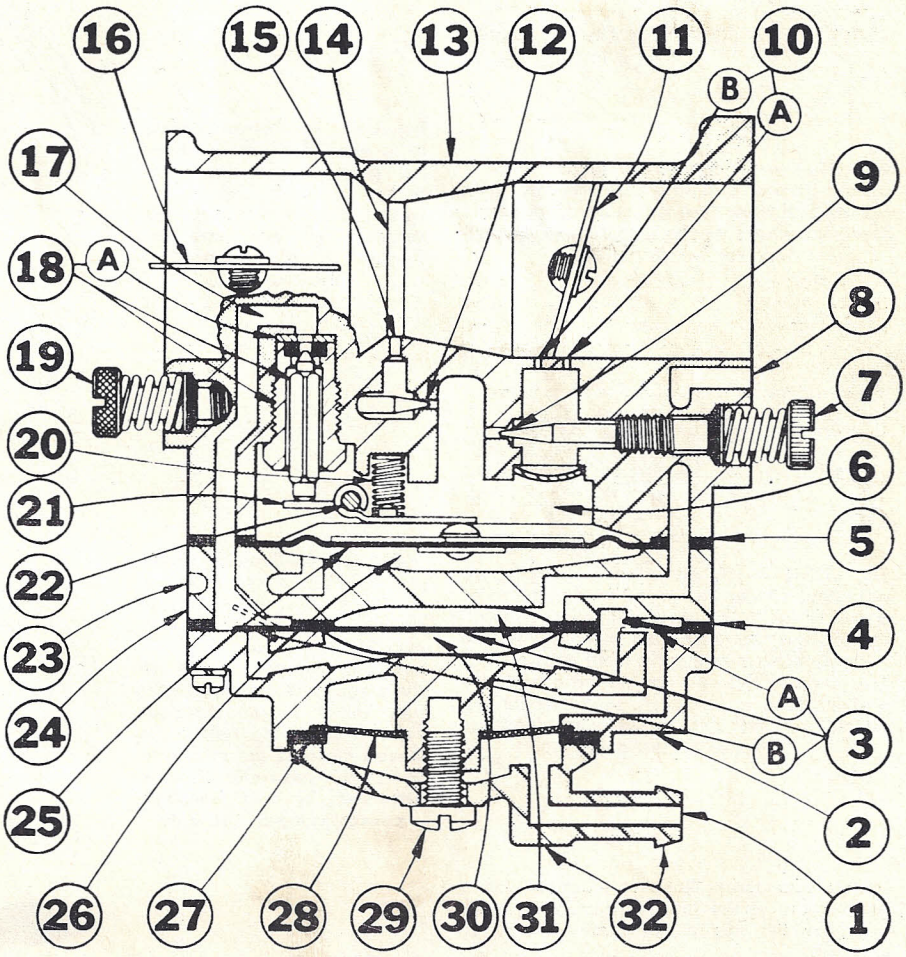


Fig. CS8 — Cross-sectional schematic view of Tillotson series HL diaphragm carburetor.

1. Fuel inlet
2. Pump body
3. Pump diaphragm
3A. Pump inlet valve
3B. Pump outlet valve
4. Gasket
5. Gasket
6. Metering chamber
7. Idle needle
8. Impulse channel
9. Idle fuel orifice
10A. Primary idle port
10B. Secondary Idle port
11. Throttle shutter
12. Main fuel orifice
13. Body
14. Venturi
15. Main fuel port
16. Choke shutter
17. Inlet channel
18. Inlet valve
19. Main needle
20. Spring
21. Diaphragm lever
22. Fulcrum pin
23. Vent hole
24. Cover
25. Diaphragm
26. Atmospheric chamber
27. Gasket
28. Screen
29. Screw
30. Fuel chamber
31. Pulse chamber
32. Strainer cover

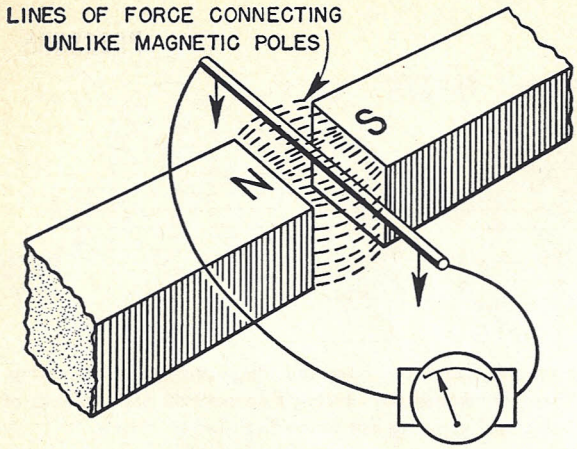


Fig. CS10 — When a wire (conductor) is moved through a magnetic field across lines of magnetic force, an electro-motive force is induced into the wire. If the wire is a part of an electrical circuit, current will flow in the circuit as shown.

When there is a change in the current flowing in a wire, there is a corresponding change in the magnetic field surrounding the wire. If the current ceases to flow, the magnetic field will "collapse." Thus, it can be seen from the illustration in Fig. CS12 that if current in the coiled wire would cease, the collapsing magnetic field would cut a cross adjacent loops of the coil and the resulting induced current would counteract any cease in flow of current through the coil.

FLYWHEEL MAGNETO COMPONENT PARTS. To understand how the flywheel type magneto produces the ignition spark, it is necessary to identify each part of the magneto. The various component parts of the flywheel type magneto are discussed in the following paragraphs.

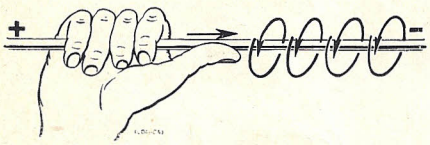


Fig. CS11 — A field of magnetic force is always present around a wire through which current is flowing. The direction of magnetic force is related to the direction of electrical current as shown.

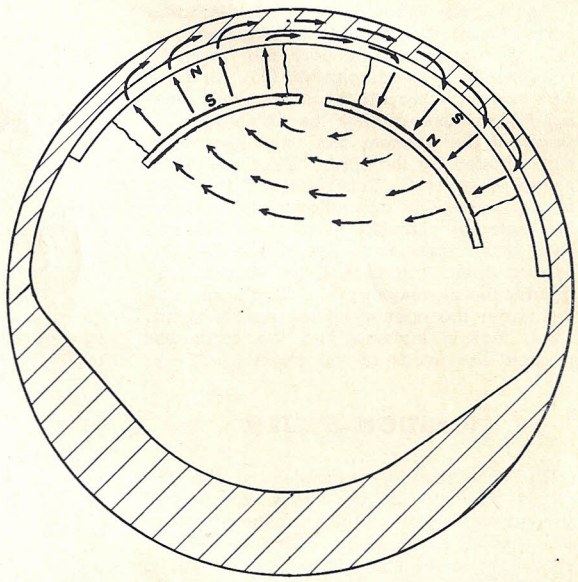


Fig. CS13 — Cut-away view of a typical flywheel showing permanent magnets attached to inside rim of flywheel. In some flywheels, the magnets are cast into the flywheel which is usually a die casting.

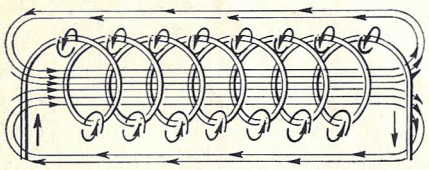


Fig. CS12 — When a wire carrying an electrical current is wound in the shape of a coil or helix, the magnetic field surrounding loops of the wire tend to converge into a single electro-magnetic field as shown. If the loops of the coil are wound closely together, there is very little tendency for the eltctro-magnetic field to surround individual loops of the coil.

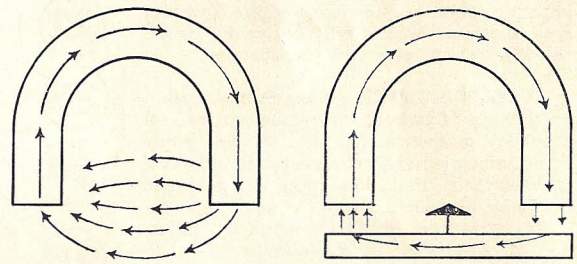


Fig. CS14—Drawing showing function of the magneto armature core. At left, lines of force of permanent magnet are dispersed in the air between the two poles of the magnet. When a soft iron bar, which is an excellent conductor of magnetism, is moved close to the magnetic poles, the magnetic field is attracted by and becomes concentrated in the bar.

that it cuts across lines of magnetic force, the voltage of the induced current is multiplied by the number of turns of wire in the coil.

The second basic principle involved is that when an electrical current is flowing in a wire, a magnetic field is present around the wire as illustrated in Fig. CS11. The direction of force of the magnetic field is related to the direction of current in the wire and the strength of the magnetic field is related to the rate of flow of the electrical current. If the wire is wound in a coil, the magnetic forces around the wire converge to form a stronger single magnetic field as shown in Fig. CS12. If the wire is coiled closely, there is little tendency for the magnetic forces to surround individual loops of the coil.

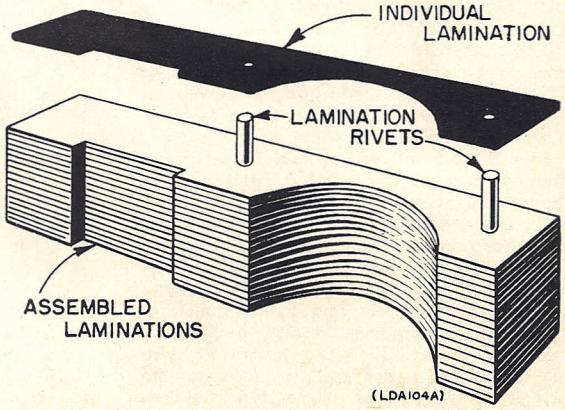


Fig. CS15—To prevent stray electrical currents (eddy currents) from building up within the armature core and creating opposing magnetic fields that would decrease the efficiency of the magneto, the armature core is constructed of thin plates (laminations) that are insulated from each other. (Oxide on surfaces of laminations usually provides sufficient insulation, although laminations in some magnetos are painted or varnished.)

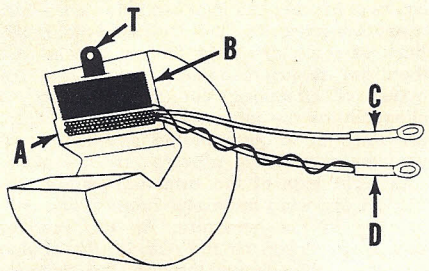


Fig. CS16—Cross-sectional view of a typical high tension coil. Primary windings (A) consists of 100-200 turns of copper wire. Secondary windings consists of about 10,000 turns of very fine wire. Lead (C) is to insulated terminal of breaker points. Lead (D) is to ground. Spark plug (high tension wire) attaches to terminal (T).

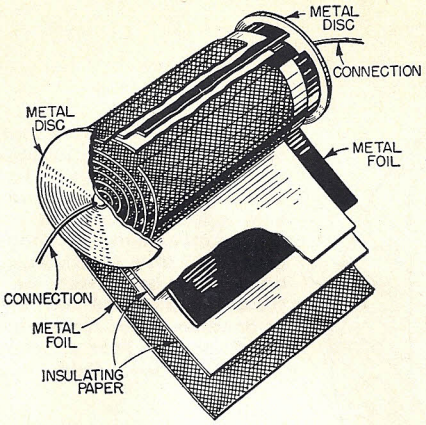
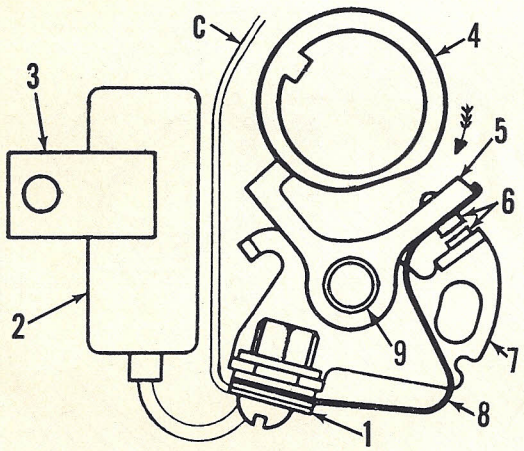


Fig. CS18 — View showing construction of typical condensor. One connection is usually made to the metal housing of the condensor and is grounded to the magneto base plate through the condensor mounting strap (3—Fig. CS17).



C. Lead to primary coil
1. Insulated terminal
2. Condensor
3. Condensor ground (mounting) strap
4. Breaker cam
5. Breaker arm
6. Contact points
7. Breaker base
8. Spring
9. Pivot pin

Fig. CS17 — Drawing of typical flywheel magneto breaker point unit. Cam (4) is driven by keyway in engine crankshaft. Breaker arm (5) is either a non-conductor of electricity or has insulating bushing at pivot pin (9). Breaker arm spring (8) connects contact point on breaker arm to the insulated terminal (1).

FLYWHEEL MAGNETS. Permanent magnets are either attached to the flywheel as shown in Fig. CS13 or imbedded into the flywheel casting. Some magnetos use a single ring shaped flywheel magnet; others use two separate magnets as shown in Fig. CS13.

Alnico, a steel alloy containing aluminum, nickel and cobalt, is used for the flywheel magnet or magnets as Alnico retains strong magnetic properties for very long periods of time.

ARMATURE CORE (LAMINATIONS). As shown in Fig. CS14, a field of magnetic force surrounds the poles of a permanent magnet at all times. If a soft iron bar is moved close to the magnet, the magnetic field will become concentrated in the bar because soft iron is a very good conductor of magnetic flux. Thus, the armature core is used in the flywheel type magneto to concentrate the field strength of the flywheel magnets.

In the operation of the magneto, electrical currents can be induced into the armature core. To prevent these stray currents (eddy currents) from building up in the armature core and creating magnetic forces which would decrease the efficiency of the magneto, the armature core is built up of thin plates (laminations) as shown in Fig. CS15. Thus, the armature core is sometimes called laminations.

HIGH TENSION COIL. Refer to Fig. CS16 for construction of typical high tension coil. The coil assembly consists of a primary coil (A) of about 100-200 turns of wire and a secondary coil (B) of about 10,000 turns of very fine wire. The wire is insulated, usually with a fine coating of enamel, and a paper insulating strip is placed between each layer of wire. The entire coil assembly is then impregnated with an insulating compound and covered with varnished cloth tape or plastic. Refer to wiring diagram in Fig. CS19 for hook-up of coil leads.

BREAKER (CONTACT) POINTS. Refer to the magneto wiring diagram in Fig. CS19. The breaker points are installed between the lead from the primary coil windings and the magneto ground. The breaker points are opened and closed by a cam which is usually located on the engine crankshaft as shown in Fig. CS17.

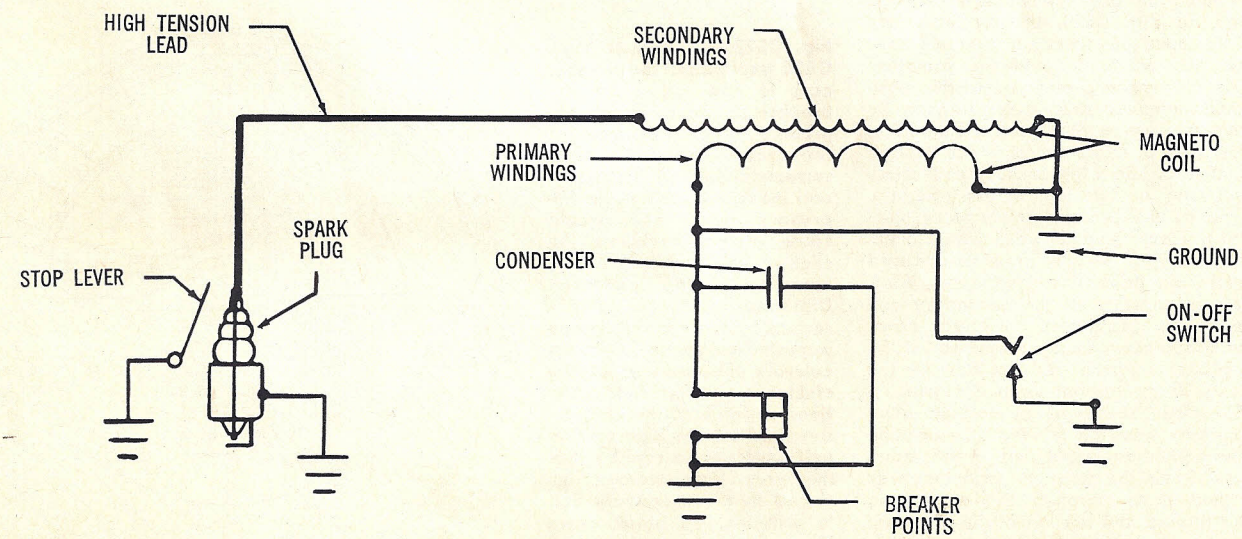


Fig. CS19—Typical wiring diagram for flywheel type magneto. An on-off switch to stop the engine may be attached to the magneto primary circuit to ground out the system, or a stop lever may be used to ground out the center electrode of the spark plug.

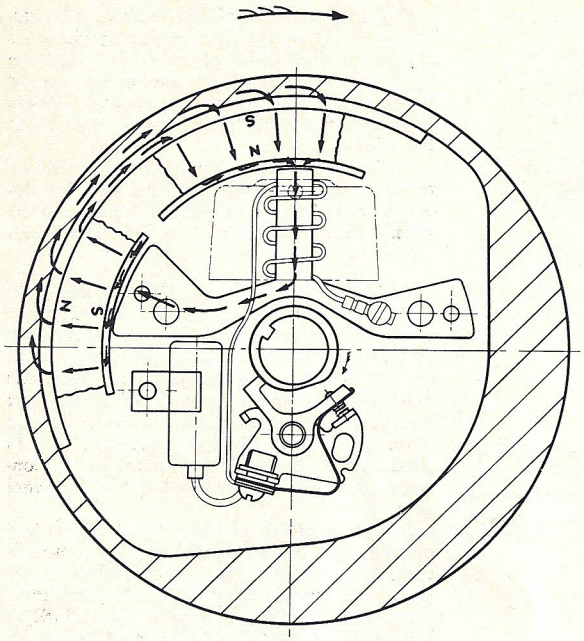


Fig. CS20 — Cut-away view of typical flywheel type magneto at start of cycle. The contact breaker points are held open by the cam on engine crankshaft and magnetic field from the flywheel magnets has been established through center and left leg of armature core. Arrows indicate path of lines of force of magnetic field.

CONDENSOR. Refer to Fig. CS18 for construction of a typical condensor. Usually, the lead from one end of the condensor is connected to the metal covering and is thereby grounded through mounting the condensor. The condensor is connected in parallel with the breaker points as shown in Fig. CS19.

The basic function of the condensor is to absorb the flow of current in the primary ignition circuit to prevent the current from arcing across the opening breaker points.

HOW IGNITION SPARK IS PRODUCED. The following explanation of how the ignition spark is produced is based upon the previous paragraphs in this section. By knowing the basic principles of electro-magnetic induction and electro-magnetic fields, and by being able to identify the component parts of the magneto, magneto operation can be more easily understood.

Figs. CS20, CS21 and CS22 illustrate the operational cycle of a typical flywheel type magneto. In Fig. CS20, the flywheel has turned to move the flywheel magnets over the left and center legs of the armature core. As the magnets moved into this position, their magnetic field was attracted by the armature core as illustrated in Fig. CS14, and the lines of magnetic force cut through the section of the high tension coil windings between the two legs of the armature. However, as the breaker points were open and the primary ignition circuit was broken, no flow of current resulted from the induced voltage in the primary coil windings. Also, the voltage induced in the secondary coil windings was insufficient to break down the resistance between the electrodes of the spark plug, so current did not flow in the secondary (high tension) ignition circuit.

In Fig. CS21, the flywheel magnets have moved away from the left leg to a position over the center and right legs of the armature core. Thus, the magnetic field that was established down through the center leg and out through the left leg of the armature core must cut back through the windings of the high tension coil. This movement of the lines of magnetic force is accelerated by two factors. As the armature core has great attraction for the magnetic field, the lines of force are held for an instant and then are released quickly (much like the action of stretching out and releasing a slingshot) as the magnets move away. Also, the lines of force from the flywheel magnets are now being attracted by the center and right legs of the armature core creating an opposing magnetic force up the center leg of the armature. As the breaker points are closed by the cam on the engine camshaft, the circuit through the primary coil windings is completed and a flow of current is established in the primary ignition circuit by the accelerated movement of the magnetic field through the windings of the high tension coil. Again, the voltage induced in the secondary windings of the coil is not sufficient to break down the resistance between the spark plug electrodes.

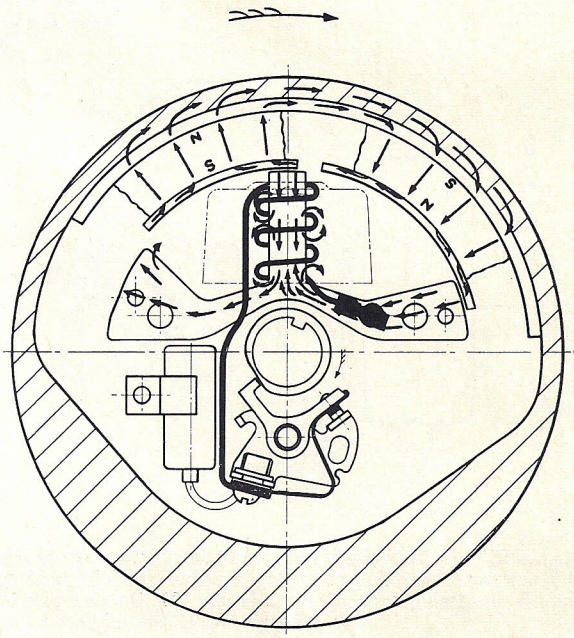


Fig. CS21 — Refer to Fig. CS20. Flywheel has turned moving magnets away from left leg of armature core. Breaker points are closed completing the primary ignition circuit. Magnetic field is being withdrawn from left and center leg circuit of armature core resulting in lines of magentic force cutting across high tension terminal. Thus, a current is induced in the primary circuit (dark line). Field of flywheel magnets is being attracted by center and right leg circuit of armature.

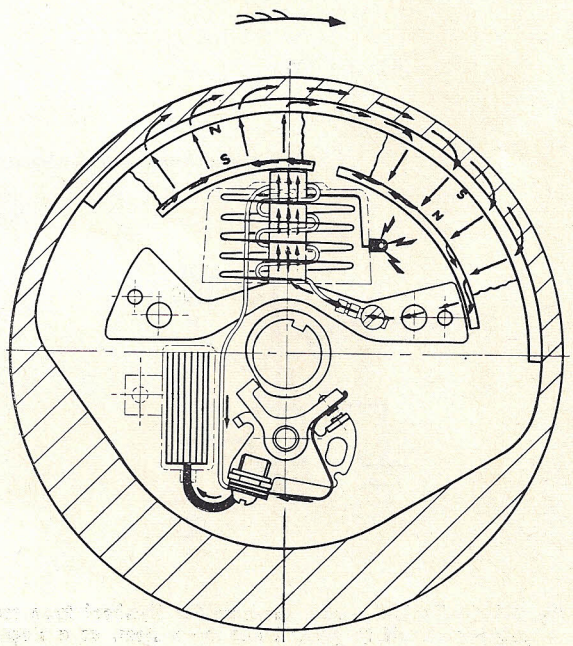


Fig. CS22 — Refer to Figs. CS20 and CS21. The breaker cam is now opening the breaker points to break the primary circuit. Collapse of the electro-magnetic field surrounding the high tension coil induces a voltage in the primary circuit that would cause arcing between the slightly open points, but is absorbed by the condensor. Discharge of the current absorbed by the condensor and opposing magnetic fields accelerate the collapse of the electro-magnetic field. The lines of force of the collapsing field cut the high tension coil windings so rapidly that the very high voltage induced in the secondary coil is sufficient to break down the resistance at the spark plug gap and provide the ignition spark.

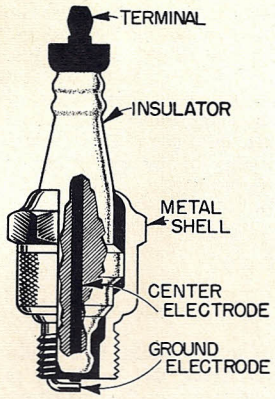


Fig. CS25 — Cross sectional view of spark plug showing construction and nomenclature.

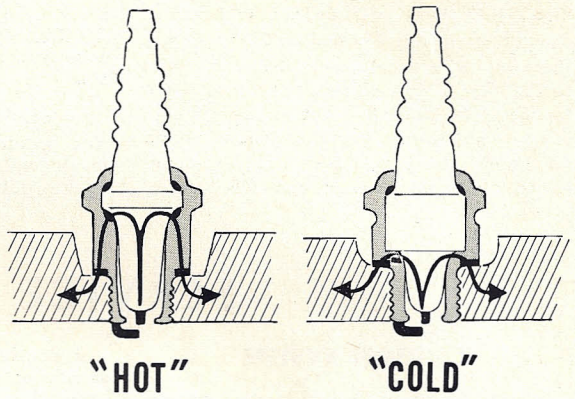


Fig. CS27 — Spark plug tip temperature is controlled by the length of the path heat must travel to reach the cooling surface of the engine cylinder head.

The flow of current induced into the primary coil windings results in an electro-magnetic field being established around the windings of the high tension coil similar to the illustration in Fig. CS12. At the proper instant for ignition of the compressed fuel air mixture in the engine cylinder, the breaker points are opened by the cam on the crankshaft. As the primary ignition circuit is broken, current ceases to flow in the primary coil windings and the electro-magnetic field surrounding the high tension coil must collapse. The lines of force of the collapsing magnetic field cut through the primary windings, inducing a voltage in the primary circuit which would be sufficient to break down the resistance between the slightly open breaker points and cause sparks to arc across the points. However, instead of arcing across the breaker points, this induced current is absorbed for an instant by the condensor. The continued collapse of the electro-magnetic field is then accelerated by two factors. The lines of force of the flywheel magnets being attracted by the center and right legs of the armature core oppose the force of the collapsing magnetic field and the current absorbed by the condensor is discharged back through the windings of the primary coil creating a second electro-magnetic field whose force opposes that of the collapsing electro-magnetic field.

These accelerating forces cause the lines of force of the collapsing magnetic field to cut across the windings of the high tension coil so rapidly that a very high voltage is induced into the secondary coil windings. This voltage (approximately 15,000 volts) is sufficient to break down the resistance between the electrodes of the spark plug and carry the flow of current in the secondary ignition circuit across the spark gap to produce the ignition spark.

From the illustrations of the magneto operational cycle in Figs. CS20, CS21 and CS22, it is seen that the entire cycle has occurred in approximately ⅓ turn of the engine flywheel. In an engine running at 3000 RPM, one turn of the flywheel occurs each 1/50th of a second; thus the operational cycle of the magneto as described in the preceding paragraphs would occur in about 1/150th of a second in an engine running at 3000 RPM.

THE SPARK PLUG. In any spark ignition engine, the spark plug (See Fig. CS25) provides the means for igniting the compressed fuel-air mixture in the cylinder. Before an electric charge can move across an air gap, the intervening air must be charged with electricity, or ionized. If the spark plug is properly gapped and the system is not shorted, not more than 7,000 volts may be required to initiate a spark. Higher voltage is required as the spark plug warms up, or if compression pressures or the distance of the air gap is increased. Compression pressures are highest at full throttle and relatively slow engine speeds, therefore, high voltage requirements or a lack of available secondary voltage most often shows up as a miss during maximum acceleration from a slow engine speed. There are many different types and sizes of spark plugs which are designed for a number of specific requirements.

THREAD SIZE. The threaded, shell portion of the spark plug and the attaching hole in the cylinder are manufactured to meet certain industry established standards. The diameter is referred to as "Thread Size." Those commonly used are: 10 mm, 14 mm, 18 mm, ⅞ inch and ½ inch pipe. The 14 mm plug is almost universal for chain saw engine use.

REACH. The length of thread, and the thread depth in cylinder head or wall are also standardized throughout the industry. This dimension is measured from gasket seat of head to cylinder end of thread. See Fig. CS26. Four different reach plugs commonly used are: ⅜-inch, $\frac{7}{16}$-inch, ½-inch and ¾-inch. The first two mentioned are the ones commonly used in chain saw engines.

HEAT RANGE. During engine operation, part of the heat generated during combustion is transferred to the spark plug, and from the plug to the cylinder through the shell threads and gasket. The operating temperature of the spark plug plays an important part in engine operation. If too much heat is retained by the plug, the fuel-air mixture may be ignited by contact with the heated surface before the ignition spark occurs. If not enough heat is retained, partially burned combustion products (soot, carbon and oil) may build up on the plug tip resulting in "fouling" or shorting out of the plug. If this happens, the secondary current is dissipated uselessly as it is generated instead of bridging the plug gap as a useful spark, and the engine will misfire.

The operating temperature of the plug tip can be controlled, within limits, by altering the length of the path the heat must follow to reach the threads and gasket of the plug.

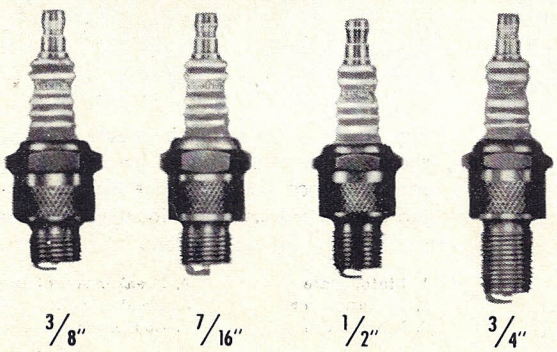


Fig. CS26 — Various "reaches" of plugs available. Chain saw engines normally use a ⅜-inch reach spark plug. A ⅜-inch reach plug measures ⅜-inch from firing end of shell to gasket surface of shell.

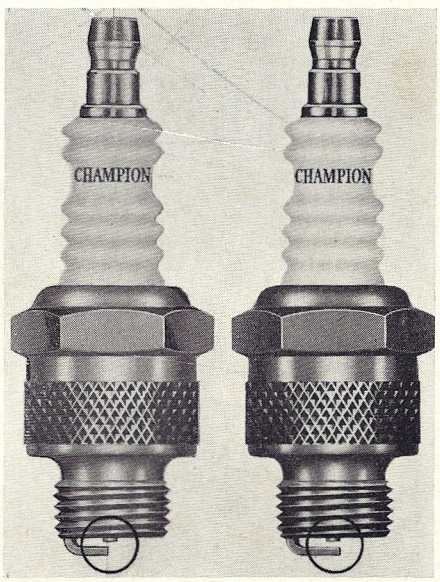


Fig. CS28—The two-cycle spark plug shown at left is almost exclusively used in chain saw engines.

Thus, a plug with a short, stubby insulator around the center electrode will run cooler than one with a long, slim insulator. Refer to Fig. CS27. Most plugs in the more popular sizes are available in a number of heat ranges which are interchangeable within the group. The proper heat range is determined by engine design and the type of service. Refer to SPARK PLUG SERVICING, in SERVICE FUNDAMENTALS section, for additional information on spark plug selection.

SPECIAL TYPES. Sometimes, engine design features or operating conditions call for special plug types designed for a particular purpose. Of special interest when dealing with chain saw engines is the two-cycle spark plug shown in the left hand view, Fig. CS28. In the design of this plug, the ground electrode is shortened so that its end aligns with center of insulated electrode rather than completely overlapping as with the conventional plug. This feature reduces the possibility of the gap bridging over by carbon formations.

SERVICE FUNDAMENTALS

IGNITION SYSTEM

In servicing a chain saw ignition system, the mechanic is concerned with trouble shooting, service adjustments and testing magneto components. The following paragraphs outline the basic steps in servicing a flywheel type magneto. Refer to the appropriate chain saw engine section for adjustment and test specifications for a particular engine.

TROUBLE SHOOTING

If the chain saw engine will not start and malfunction of the ignition system is suspected, make the following checks to find cause of trouble.

Check to be sure that the ignition switch (if chain saw is so equipped) is in the "On" or "Run" position and that the insulation on the wire leading to the ignition switch is in good condition. The switch can be checked with the timing and test light as shown in Fig. CS30. Disconnect the lead from the switch and attach one clip of the test light to the switch terminal and the other clip to the chain saw frame or engine. The light should go on when the switch is in the "Off" or "Stop" position, and should go off when the switch is in the "On" or "Run" position.

Inspect the high tension (spark plug) wire for worn spots in the insulation or breaks in the wire. Frayed or worn insulation can be repaired temporarily with plastic electrician's tape.

If no defects are noted in the ignition switch or ignition wires, remove and inspect the spark plug as outlined in the SPARK PLUG SERVICING section. If the spark plug is fouled or is in questionable condition, connect a spark plug of known quality to the high tension wire, ground the base of the spark plug to engine and turn engine rapidly with the starter. If the spark across the electrode gap of the spark plug is a bright blue, the magneto can be considered in satisfactory condition. NOTE: Some engine manufacturers specify a certain type spark plug and a specific test gap. Refer to appropriate engine service section; if no specific spark plug type or electrode gap is recommended for test purposes, use spark plug type and electrode gap recommended for engine make and model. If the spark across the gap of the test plug is weak or orange colored, or no spark occurs as engine is cranked, magneto should be serviced as outlined in the following paragraphs.

MAGNETO ADJUSTMENTS

BREAKER CONTACT POINTS. Adjustment of the breaker contact points affects both ignition timing and magneto edge gap. Therefore, the breaker contact point gap should be carefully adjusted according to engine manufacturer's specifications. Before adjusting the breaker contact gap, inspect contact points and renew if condition of contact surfaces is questionable. It is sometimes desirable to check the condition of points as follows: Disconnect the condensor and primary coil leads from the breaker point terminal. Attach one clip of a test light (See Fig. CS30) to the breaker point terminal and the other clip of the test light to magneto ground. The light should be out when contact points are open and should go on when the engine is turned to close the breaker contact points. If the light stays on when points are open, insulation of breaker contact arm or condensor is defective. If light does not go on when points are closed, contact surfaces are dirty, oily or are burned.

Adjust breaker point gap as follows unless manufacturer specifies adjusting breaker gap to obtain correct ignition timing. First, turn engine so that points are closed to be sure that the contact surfaces are in alignment and seat squarely. Then, turn engine so that breaker point opening is

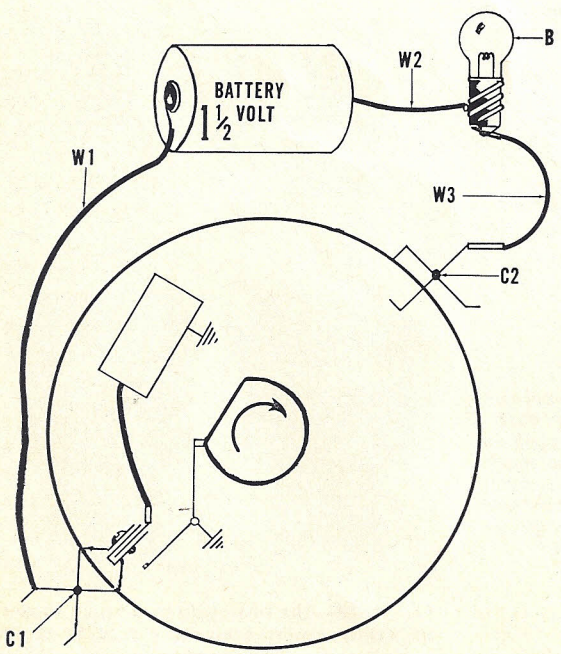


Fig. CS30 — A timing light such as the one shown is a valuable aid in trouble shooting, checking timing and, on some engines, adjusting breaker point gap. The light can be made from a flashlight battery, bulb (B), wire clamps (WC) and short sections of insulated wire.

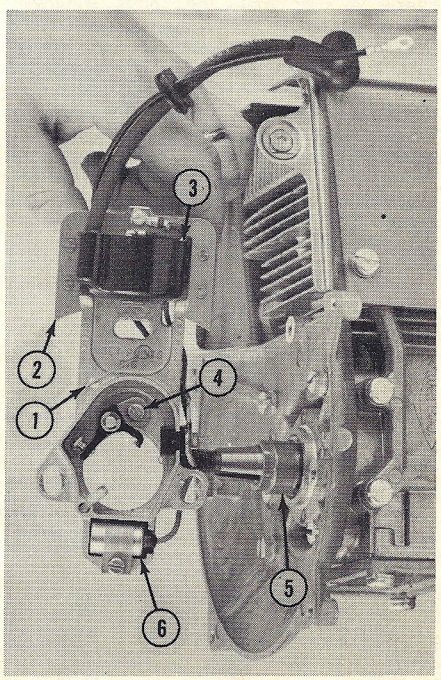


Fig. CS31 — On some chain saw engines, the magneto stator plate mounting holes are slotted as shown so that ignition timing can be adjusted by relocating position of stator plate.

1. Stator plate
2. Armature core
3. Ignition coil
4. Breaker point base
5. Breaker cam
6. Condensor

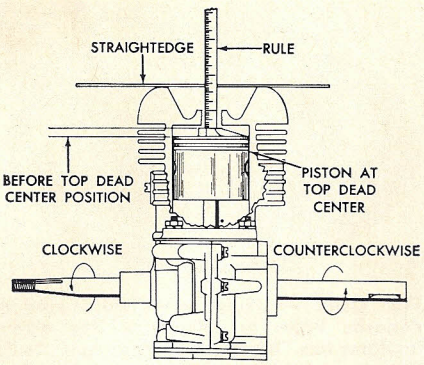


Fig. CS32 — Where timing is specified as measurement of piston travel, measurement can be made as illustrated. Use of a dial indicator instead of ruler will give more exact measurement. Some manufacturers provide a timing gage that can be screwed into spark plug hole or a gage that can be attached to crankshaft.

maximum and adjust breaker gap to manufacturer's specification. A wire type feeler gage is recommended for checking and adjusting the breaker contact gap. Be sure to recheck gap after tightening breaker point base retaining screws.

IGNITION TIMING. On some engines, ignition timing is non-adjustable and a certain breaker point gap is specified. On other engines, timing is adjustable by changing the position of the magneto stator plate (See Fig. CS31) with a specified breaker point gap or by simply varying the breaker point gap to obtain correct timing. Ignition timing is usually specified either in degrees of engine (crankshaft) rotation or in piston travel before the piston reaches top dead center position. In some instances, a specification is given for ignition timing even though the timing may be non-adjustable; if a check reveals timing is incorrect on these engines, it is an indication of incorrect breaker point adjustment or excessive wear of breaker cam. Also, on some engines, it may indicate that a wrong breaker cam has been installed or that the cam has been installed in a reversed position on engine crankshaft.

Some engines may have a timing mark or flywheel locating pin to locate the flywheel at proper position for the ignition spark to occur (breaker points begin to open). If not, it will be necessary to measure piston travel as illustrated in Fig. CS32 or install a degree indicating device on the engine crankshaft.

A timing light as shown in Fig. CS30 is a valuable aid in checking or adjusting engine timing. After disconnecting the ignition coil lead from the breaker point terminal, connect the leads of the timing light as shown. If timing is adjustable by moving the magneto stator plate, be sure that the breaker point gap is adjusted as specified. Then, to check timing, slowly turn engine in normal direction of rotation past the point at which ignition spark should occur. The timing light should be on, then go out (breaker points open) just as the correct timing location is passed. If not, turn engine to proper timing location and adjust timing by relocating the magneto stator plate or varying the breaker contact gap as specified by engine manufacturer. Loosen the screws retaining the stator plate or breaker points and adjust position of stator plate or points so that points are closed (timing light is on). Then, slowly move adjustment until timing light goes out (points open) and tighten the retaining screws. Recheck timing to be sure adjustment is correct.

ARMATURE AIR GAP. To fully concentrate the magnetic field of the flywheel magnets within the armature core, it is necessary that the flywheel magnets pass as closely to the armature core as possible without danger of metal to metal contact. The clearance between the flywheel magnets and the legs of the armature core is called the armature air gap.

On magnetos where the armature and high tension coil are located outside of the flywheel rim, adjustment of the armature air gap is made as follows: Turn the engine so that the flywheel magnets are located directly under the legs of the armature core and check the clearance between the armature core and flywheel magnets. If the measured clearance is not within manufacturers specifications, loosen the armature core mounting screws and place shims of thickness equal to minimum air gap specification between the magnets and armature core (Fig. CS33). The magnets will pull the armature core against the shim stocks. Tighten the armature core mounting screws, remove the shim stock and turn the engine through several revolutions to be sure the flywheel does not contact the armature core.

Where the armature core is located under or behind the flywheel, the following methods may be used to check and adjust armature air gap: On some engines, slots or openings are provided in the flywheel through which the armature air gap can be checked. Some engine manufacturers provide a cut-away flywheel that can be installed temporarily for checking the armature air gap. A test flywheel can be made out of a discarded flywheel (See Fig. CS34), or out of a new flywheel if service volume on a particular engine warrants such expenditure. Another method of checking the armature air gap is to remove the flywheel and place a layer of plastic tape equal to the minimum specified air gap over the legs of the armature core. Reinstall flywheel and turn engine through several revolutions and remove flywheel; no evidence of contact between the flywheel magnets and plastic tape should be noticed. Then cover the legs of the armature core with a layer of tape of thickness equal to the maximum specified air gap; then, reinstall flywheel and turn engine through several revolutions. Indication of the flywheel magnets contacting the plastic tape should be noticed after the flywheel is again removed. If the magnets contact the first thin layer of tape applied to the armature core legs, or if they do not contact the second thicker layer of tape, armature air gap is not within specifications and should be adjusted.

NOTE: Before loosening armature core mounting screws, scribe a mark on mounting plate against edge of armature core so that adjustment of air gap can be gaged.

In some instances, it may be necessary to slightly enlarge the armature core mounting holes before proper air gap adjustment can be made.

MAGNETO EDGE GAP. The point of maximum acceleration of the movement of the flywheel magnetic field through the high tension coil (and therefore, the point of maximum current induced in the primary coil windings) occurs when the trailing edge of the flywheel magnet is slightly past the left hand leg of the armature core as shown in Fig. CS21. The exact point of maximum primary current is determined by using electrical measuring devices, the distance between the trailing edge of the flywheel magnet and the leg of the armature core at this point is measured and becomes a service specification. This distance, which is stated either in thousandths of an inch or in degrees of flywheel rotation, is called the Edge Gap or "E" Gap.

For maximum strength of the ignition spark, the breaker points should just start to open when the flywheel magnets are at the specified edge gap position. Usually, edge gap is non-adjustable and will be maintained at the proper dimension if the contact breaker points are adjusted to the recommended gap and the correct breaker

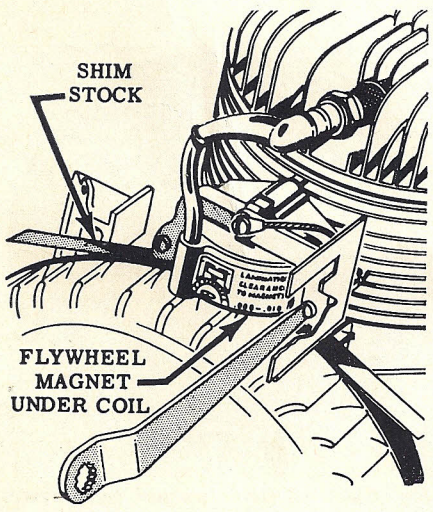


Fig. CS33 — Where armature core and ignition coil are mounted outside of flywheel, armature air gap can be adjusted as shown. Use shim stock of thickness equal to specified air gap. Illustration courtesy of McCulloch Corp.

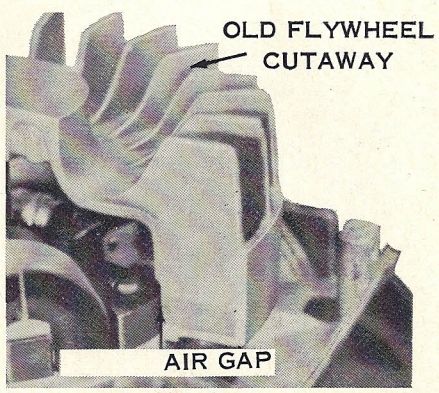


Fig. CS34 — Where armature core and ignition coil are located inside of flywheel, an old discarded flywheel can be cut away as shown to provide air gap adjustment fixture.

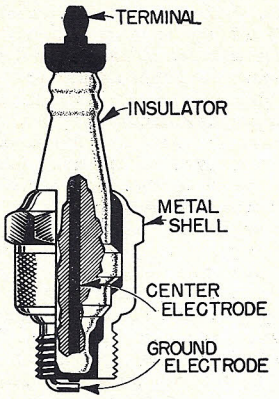


Fig. CS38 — Cross sectional view of spark plug showing construction and nomenclature.

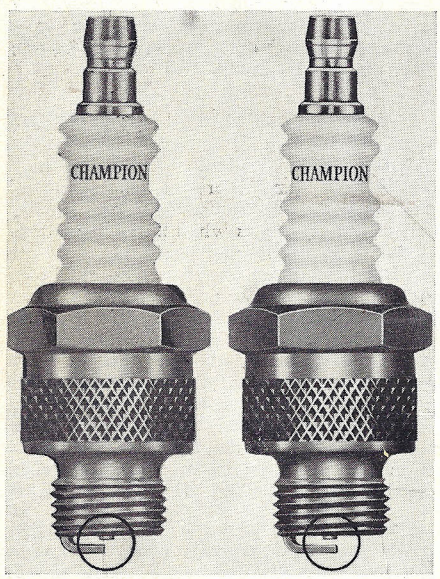


Fig. CS39 — The two-cycle plug (left) differs from conventional plug in that the grounded electrode is shortened to minimize carbon fouling.

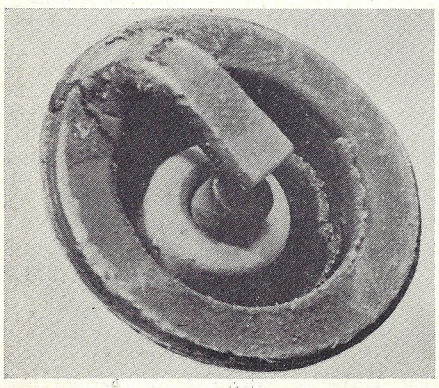


Fig. CS40 — Two cycle engine plug of correct heat range. Insulators light tan to gray with few deposits. Electrodes not burned.

cam is installed. However, magneto edge gap can change (and spark intensity thereby reduced) due to the following:

a. Flywheel drive key sheared
b. Flywheel drive key worn (loose)
c. Keyway in flywheel or crankshaft worn (oversized)
d. Loose flywheel retaining nut which can also cause any above listed difficulty
e. Excessive wear on breaker cam
f. Breaker cam loose on crankshaft
g. Excessive wear on breaker point rubbing block so that points cannot be properly adjusted.

SPARK PLUG SERVICING

ELECTRODE GAP. The spark plug electrode gap (Refer to Fig. CS38) should be adjusted by bending the ground electrode. The recommended gap is listed in the SPARK PLUG paragraph in MAINTENANCE section for the individual motor.

CLEANING AND ELECTRODE CONDITIONING. Spark plugs are most usually cleaned by abrasive action commonly referred to as "sand blasting." Actually, ordinary sand is not used, but a special abrasive which is nonconductive to electricity even when melted, thus the abrasive cannot short out the plug current. Extreme care should be used in cleaning the plugs after sand blasting, however, as any particles of abrasive left on the plug may cause damage to piston rings, piston or cylinder walls.

After plug is cleaned by abrasive, and before gap is set, the electrode surfaces between the grounded and insulated electrodes should be cleaned and returned as nearly as possible to original shape by filing with a point file. Failure to properly dress the points can result in high secondary voltage requirements, and misfire of the plugs.

PLUG APPEARANCE DIAGNOSIS. The appearance of a spark plug will be altered by use, and an examination of the plug tip can contribute useful information which may assist in obtaining better spark plug life. It must be remembered that the contributing factors differ in two-cycle and four-cycle engine operation and, although

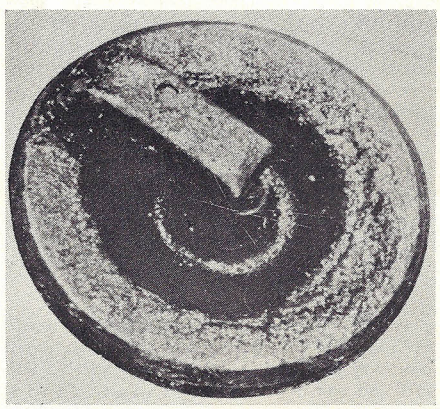


Fig. CS41 — Damp or wet black carbon coating over entire firing end of plug. Could be caused by rich carburetor mixture, too much oil in fuel, or low ignition voltage. Could also be caused by incorrect heat range (too cold) for operating conditions. Correct the defects or install a hotter plug.

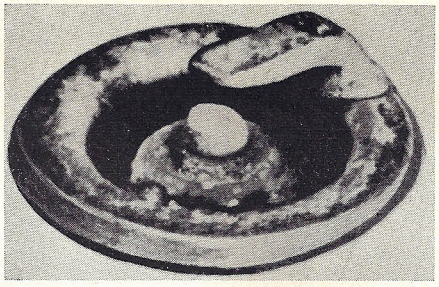


Fig. CS42 — Electrodes badly eroded, deposits white or light gray and gritty, insulator has "blistered" appearance. Could be caused by lean carburetor mixture, fast timing, overloading, or air intake screen and engine cooling fins blocked with sawdust or other debris. Could also be caused by incorrect heat range (too hot) for operating conditions. Check timing, carburetor adjustment, cooling system. If timing, carburetor adjustment, cooling system and engine speed are correct, install a colder plug.

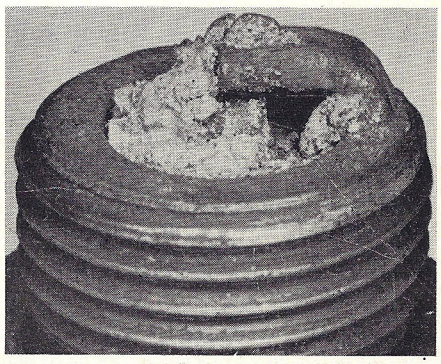


Fig. CS43 — Gray, metallic aluminum deposits on plug. (Seldom encountered). Piston damage due to pre-ignition. Overhaul motor and determine cause of pre-ignition.

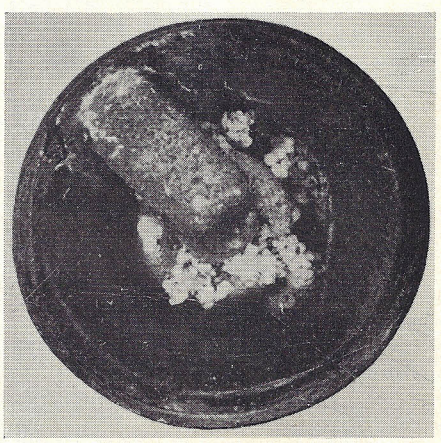


Fig. CS44 — Core bridging from center electrode to shell. Fused deposits sometimes have the appearance of tiny beads or glasslike bubbles. Caused by excessive combustion chamber deposits which in turn could be the result of; excessive carbon from prolonged usage; use of improper oil or incorrect fuel-oil ratio.

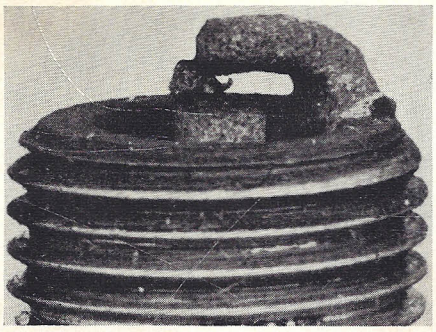


Fig. CS45 — Gap bridging. Usually results from the same causes outlined in Fig. CS44.

the appearance of two spark plugs may be similar, the corrective measures may depend on whether the engine is of two-cycle or four-cycle design. Fig. CS40 to Fig. CS45 are provided by Champion Spark Plug Company to illustrate typical observed conditions in Two-Cycle engines. Listed also are the probable causes and suggested corrective measures.

CARBURETOR SERVICING

The bulk of carburetor service consists of cleaning, inspection and adjustment. After considerable service it may become necessary to overhaul the carburetor and renew worn parts to restore original operating efficiency. Although carburetor condition affects engine operating economy and power, ignition and engine compression must also be considered to determine and correct causes of poor performance.

Before dismantling carburetor for cleaning or overhaul, clean all external surfaces and remove accumulated dirt and grease. Dismantle carburetor and note any discrepancies to assure correction during overhaul. Thoroughly clean all parts and inspect for damage or wear. Wash jets and passages and blow clear with clean, dry compressed air. Do not use a drill or wire to clean jets as the possible enlargement of calibrated holes will disturb operating balance. The measurement of jets to determine the extent of wear is difficult and new parts are usually installed to assure satisfactory results.

Carburetor manufacturers provide for many of their models an assortment of gaskets and other parts usually needed to do a correct job of cleaning and overhaul. These assortments are usually catalogued as Gasket Kits and Overhaul Kits respectively.

Check the fit of throttle and choke valve shafts. Excessive clearance will cause improper valve plate seating and will permit dust or grit to be drawn into the engine. Air leaks at throttle shaft bores due to wear will upset carburetor calibration and contribute to uneven engine operation. Rebush valve shaft holes where necessary and renew dust seals. If rebushing is not possible, renew the body part supporting the shaft. Inspect throttle and choke valve plates for proper installation and condition.

Power or idle adjustment needles must not be worn or grooved. Check condition of needle seal packing or "O" ring and renew packing or "O" ring if necessary.

Reinstall or renew jets, using correct size listed for specific model. Adjust power and idle settings as described for specific carburetors in engine service section of manual.

It is important that the carburetor bore at the idle discharge ports and in the vicinity of the throttle valve be free of deposits. A partially restricted idle port will produce a "flat spot" between idle and mid-range rpm. This is because the restriction makes it necessary to open the throttle wider than the designed opening to obtain proper idle speed. Opening the throttle wider than the design specified amount will uncover more of the port than was intended in the calibration of the carburetor. As a result an insufficient amount of the port will be available as a reserve to cover the transition period (idle to the mid-range rpm) when the high speed system begins to function.

Refer to Figs. CS46 and CS47 for service hints on two different diaphragm type carburetors.

DISASSEMBLY AND ASSEMBLY

Special techniques must be developed in chain saw repair because of the aluminum alloy or magnesium alloy construction. Soft threads in aluminum or magnesium castings are often damaged by carelessness in overtightening fasteners or in attempting to loosen or remove seized fasteners. Manufacturer's recommended torque values for tightening screw fasteners should be followed closely.

A given amount of heat applied to aluminum or magnesium will cause it to expand

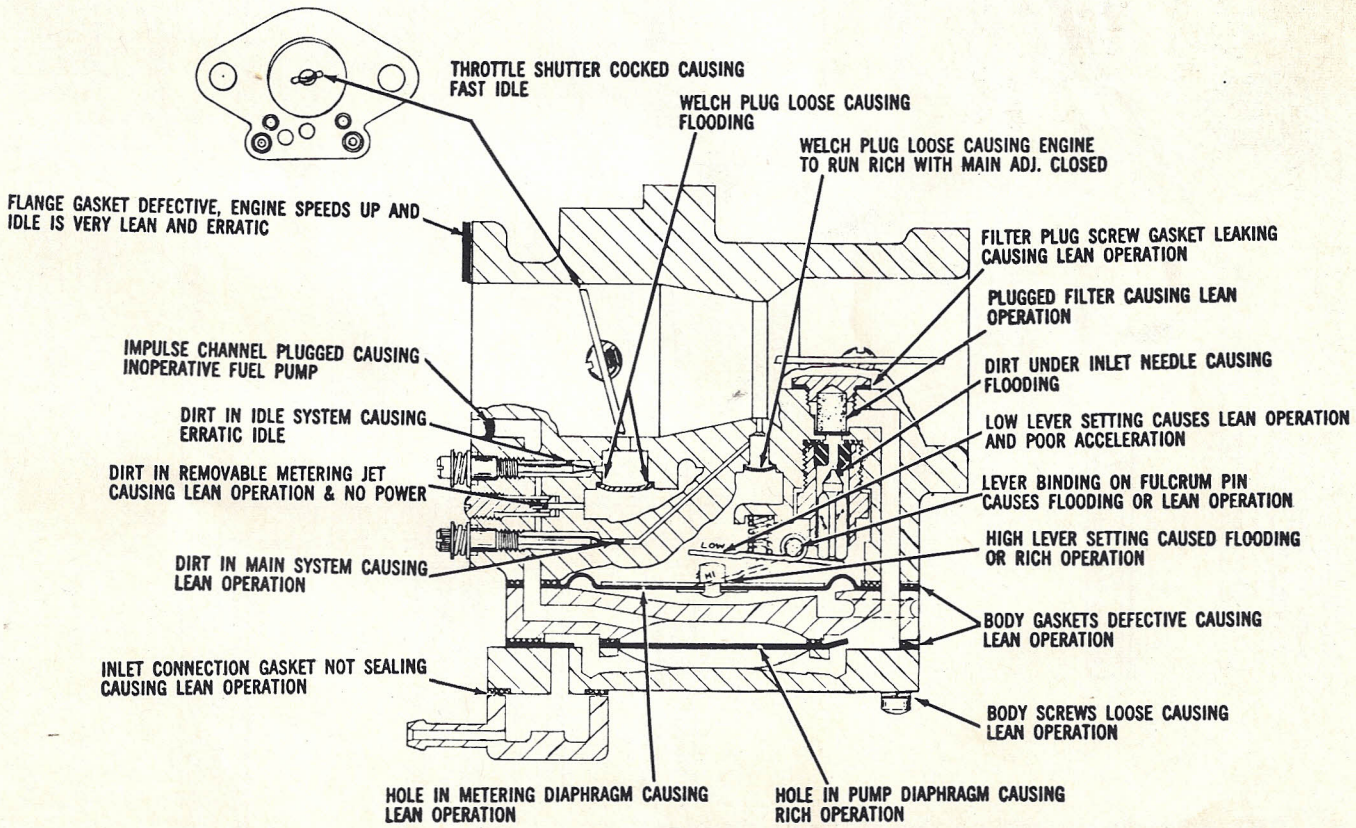


Fig. CS46 — Schematic cross-sectional view of a Brown diaphragm type carburetor showing several possible causes of fuel system malfunction. Refer to chain saw engine service sections for adjustment information on carburetors.

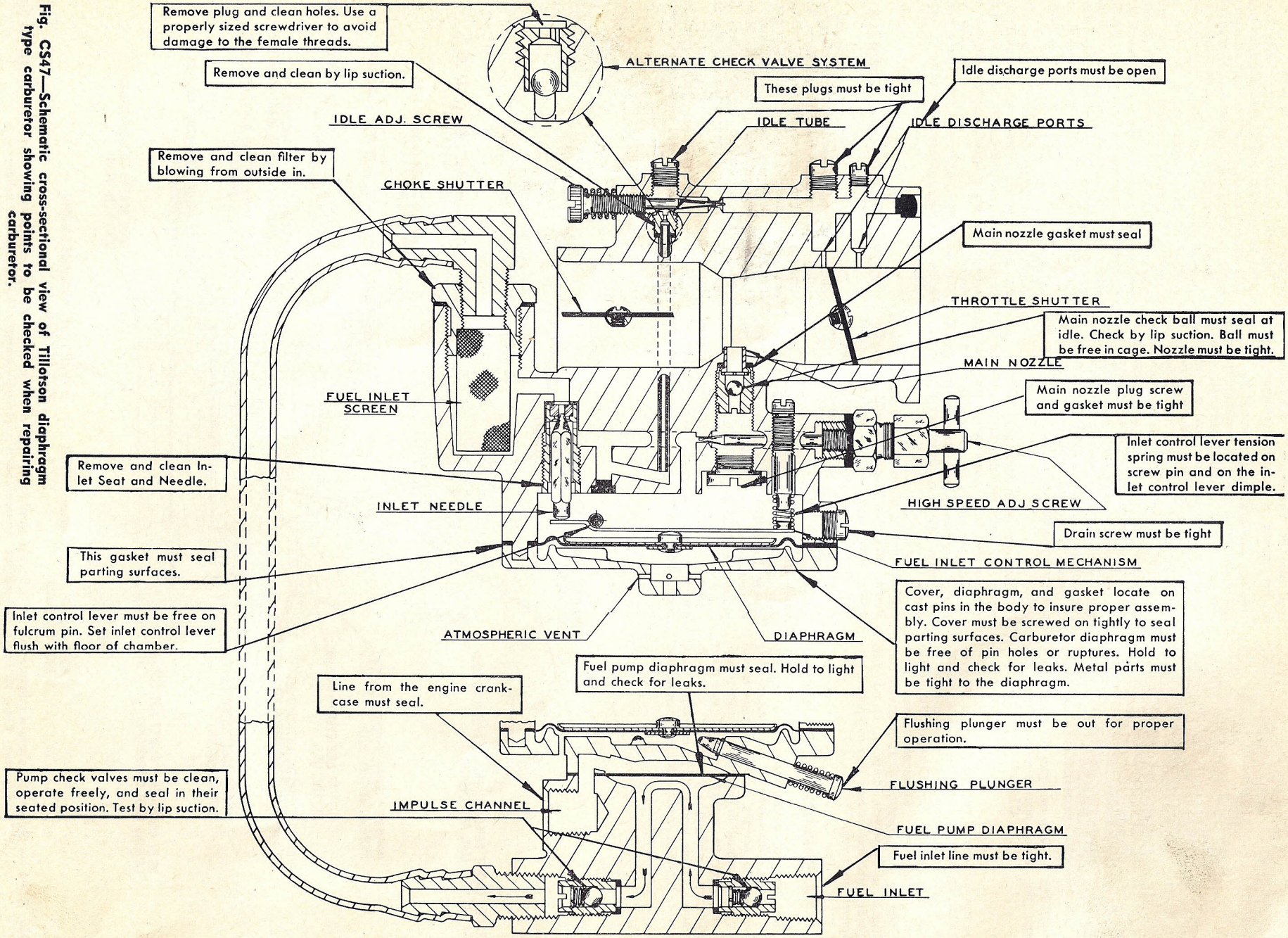


Fig. CS47—Schematic cross-sectional view of Tillotson diaphragm type carburetor showing points to be checked when repairing carburetor.

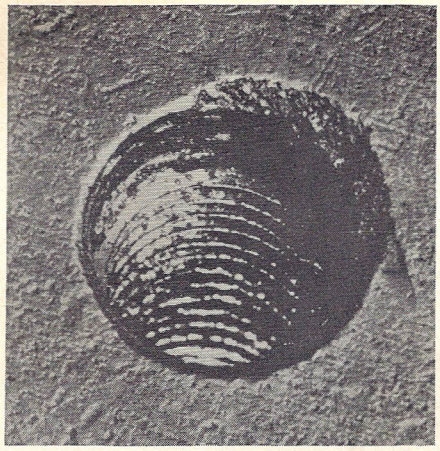


Fig. CS50 — Damaged threads in aluminum casting before repair. (Series provided by Heli-Coil Corp., Danbury, Connecticut).

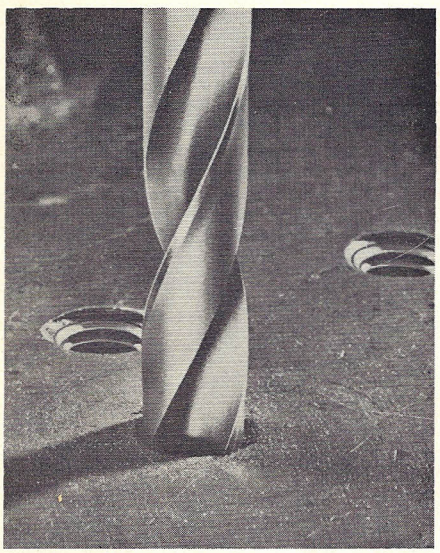


Fig. CS51 — Drill out the old threads or broken stud, using drill size recommended in instruction sheet which comes with kit. Drill all the way through an open hole or all the way to bottom of a blind hole, making sure hole is straight and that centerline is not moved in drilling process.

a greater amount than will steel under similar conditions. Because of the different expansion characteristics, heat is usually recommended for easy installation of bearings, pins, etc., in aluminum or magnesium castings. Sometimes, heat can be used to free parts that are seized or where an interference fit is used. Heat, therefore, becomes a service tool and the application of heat one of the required service techniques. An open flame is not usually advised because it destroys the paint and other protective coatings and because a uniform and controlled temperature with open flame is difficult to obtain. Methods commonly used are heating in oil or water, with a heat lamp or in an oven or kiln. The use of water or oil gives a fairly accurate temperature control but is somewhat limited as to the size and type of part that can be handled. Thermal crayons are available which can be used to determine the temperature of a heated part. These crayons melt when the part reaches a specified temperature, and a number of crayons for different temperatures are available. Temperature indicating crayons are usually available at welding equipment supply houses.

The crankcase and combustion chambers of a two-cycle engine must be sealed against pressure and vacuum. To assure a perfect seal, nicks, scratches and warpage are to be avoided. Slight imperfections can be removed by using a fine-grit sandpaper. Flat surfaces can be lapped by using a surface plate or a smooth piece of plate glass, and a sheet of 120-grit sandpaper or lapping compound. Use a figure-eight motion with minimum pressure, and remove only enough metal to eliminate the imperfection. Bearing clearances, if any, must not be lessened by removing metal from the joint.

Use only the specified gaskets when reassembling, and use an approved gasket cement or sealing compound unless the contrary is stated. Seal all exposed threads and repaint or retouch with an approved paint.

Damaged threads in castings can be renewed by use of thread repair kits which are recommended by a number of chain saw and chain saw engine manufacturers. Use of thread repair kits is not difficult, but instructions must be carefully followed. Refer to Figs. CS50 to CS53 which illustrate the use of Heli-Coil thread repair kits that are manufactured by the Heli-Coil Corporation, Danbury, Connecticut.

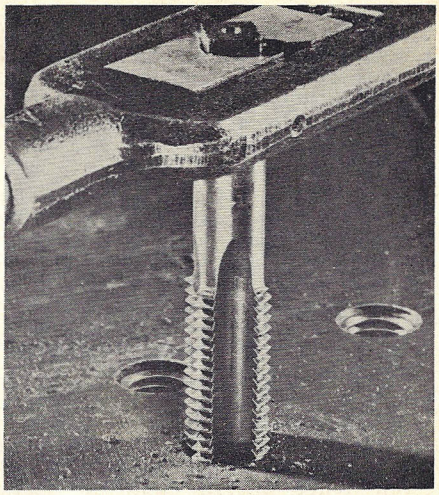


Fig. CS52 — Special drill taps are provided which are the correct size for OUTSIDE of the insert. A standard size tap cannot be substituted.

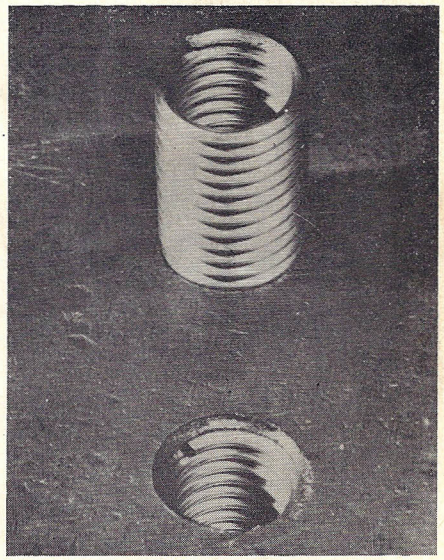


Fig. CS53 — Shown is the insert and a completed repair. Special tools are provided in kit for installation, together with the necessary instructions.

SAW CHAIN MAINTENANCE

This section on saw chain maintenance has been prepared to give information that will enable the small engine mechanic to service the cutting chain as well as the engine of the chain saw. Information for trouble-shooting saw chain problems is also given in this section.

SAW CHAIN TYPES. Saw chains now in popular use can be classified into three types as:

1. Chipper Tooth Chain or "curved L router."
2. Chisel Tooth Chain or "square L router."
3. Scratcher Chain or "crosscut."

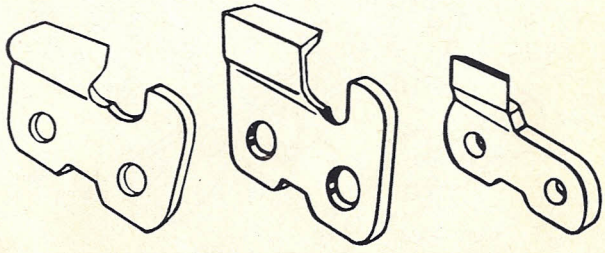


Fig. 1—Cutting links from each of the three types of saw chains.